



## Air Pollution and Its Types

\*Naveen, N. and S. Anu Rajan

College of Agriculture, Vellayani, India

\*Corresponding Author's email: [naveennatarajan2025@gmail.com](mailto:naveennatarajan2025@gmail.com)

Air Pollution refers to the contamination of the atmosphere and the environment due to harmful substances that affect human health, ecosystems and the climate. Air Pollution appears in the form of gases, solid particles and the combination of both. Air pollution is one of the most serious forms of environmental pollution all over the world. The World Health Organization (WHO) estimates that air pollution causes close to seven million deaths worldwide each year.

### Types of air pollution

There are various types of air contaminants that originate from different sources and have different impacts on human health and the environment. Air pollutants are broadly classified into two categories which are primary and secondary pollutants.

### What are primary air pollutants?

Primary air pollutants are substances that are released directly into the atmosphere from an identifiable source. They retain their original chemical form once emitted. These are the pollutants, it can be trace straight back to a smokestack, exhaust pipe, or burning field. They come directly from the source; they are generally easier to monitor and regulate compared to secondary pollutants. Here are the most significant primary air pollutants:

- Carbon monoxide (CO)
- Sulphur dioxide (SO<sub>2</sub>)
- Nitrogen oxides (NO<sub>x</sub>)
- Volatile organic compounds (VOCs)
- Particulate matter (PM)
- Lead (Pb)

### Carbon monoxide (CO)

Carbon monoxide is a colorless, odorless, and highly toxic gas. It forms when carbon-based fuels such as gasoline, coal, natural gas, or wood which do not burn completely. In urban areas, automobile exhaust can account up to 95% of all CO emissions. Other industrial processes, residential heating, and wildfires. Once inhaled, CO reduces the blood's ability to carry oxygen to organs and tissues, dangerous for people with cardiovascular conditions.

### Sulfur dioxide (SO<sub>2</sub>)

Sulfur dioxide is a pungent, reactive gas produced primarily when sulfur-containing fossil fuels like coal and crude oil are burned. Power plants burning coal are the single largest source, contributing about 73% of SO<sub>2</sub> emissions. Industrial facilities such as metal smelters and refineries also release significant amounts. SO<sub>2</sub> is harmful to the respiratory system and is a key precursor to acid rain and secondary particulate formation

### Nitrogen oxides (NO<sub>x</sub>)

Nitrogen oxides, primarily nitric oxide (NO) and nitrogen dioxide (NO<sub>2</sub>) form when nitrogen and oxygen in the air react at the high temperatures found inside combustion engines and power plants. The main sources are vehicle engines, electrical utilities, and industrial. NO<sub>2</sub> in

particular is a reddish-brown gas that contributes to smog formation and acid rain. It also plays a central role in generating secondary pollutants like ground-level ozone.

#### **Volatile organic compounds (VOCs)**

VOCs are carbon containing chemicals that evaporate easily at room temperature. vehicle fuel combustion, industrial solvents, paints, cleaning products, and even everyday household items are the sources. Gasoline and natural gas are major sources, as VOCs are released during the combustion process. In Outdoors environmental conditions VOCs are critical because they react with nitrogen oxides in sunlight to form ground-level ozone. Then coming to the Indoors conditions VOC concentrations can be up to ten times higher than outdoor levels, contributing to poor indoor air quality.

#### **Particulate matter (PM)**

Particulate matter refers to tiny solid particles and liquid droplets suspended in the air. It is categorized by size: PM<sub>10</sub> (particles smaller than 10 micrometers) and PM<sub>2.5</sub> (particles smaller than 2.5 micrometers). Primary sources like vehicle exhaust, construction sites, power plants, and wood-burning stoves. Fine particles (PM<sub>2.5</sub>) it can penetrate deep into the lungs and even enter the bloodstream, leading to cardiovascular and respiratory diseases. The WHO classifies particulate matter as a known cause of lung cancer.

#### **Lead (Pb)**

Lead enters the atmosphere through ore processing, metal manufacturing, and historically through the burning of leaded gasoline. Control measures - Regulatory action to remove lead from on-road vehicle fuel in the United States led to a 98% decrease in airborne lead levels between 1980 and 2014. Despite this progress, lead remains a concern near industrial facilities and in countries where leaded fuels are still in use. Even the low level exposure is hazardous, especially for children, affecting brain development and nervous system function.

### **What are secondary air pollutants?**

Secondary air pollutants are not emitted directly from any source. Instead, they form in the atmosphere when primary pollutants undergo chemical reactions with each other or with naturally occurring atmospheric components like water vapor and sunlight.

- Ground-level ozone (O<sub>3</sub>)
- Sulfuric acid (H<sub>2</sub>SO<sub>4</sub>) and acid rain
- Peroxyacetyl nitrates (PANs)
- Secondary organic aerosols (SOAs)
- How photochemical smog forms

#### **Ground-level ozone (O<sub>3</sub>)**

Ground-level ozone is one of the harmful secondary pollutants. It should not be confused with the protective ozone layer high up in the stratosphere. At ground level, ozone is a component of smog and a serious health hazard. It forms when nitrogen oxides (NO<sub>x</sub>) emitted from vehicles and industrial facilities react with volatile organic compounds (VOCs) in the presence of sunlight. This is why ozone levels tend to spike on hot, sunny afternoons in urban areas. Exposure can cause chest pain, coughing, throat irritation, and worsened asthma symptoms.

#### **Sulfuric acid (H<sub>2</sub>SO<sub>4</sub>) and acid rain**

When sulfur dioxide released from power plants and industrial processes reacts with water vapour and oxygen in the atmosphere, it forms sulfuric acid. Nitrogen oxides can react to produce nitric acid. These acids mix with water droplets to form acid rain, which damages forests, acidifies lakes and rivers, corrodes buildings, and harms aquatic ecosystems.

#### **Peroxyacetyl nitrates (PANs)**

PANs are another group of secondary pollutants formed through photochemical reactions involving nitrogen oxides and VOCs. They are a key component of photochemical smog the brownish haze frequently visible over cities with heavy traffic and intense sunlight. PANs are strong eye and respiratory irritants and can also damage vegetation and crops.

### Secondary organic aerosols (SOAs)

When VOCs undergo chemical transformations in the atmosphere, they can form tiny particles known as secondary organic aerosols. These contribute to fine particulate matter (PM<sub>2.5</sub>), reduce visibility, and pose respiratory health risks. SOAs also play a role in cloud formation and can influence regional climate patterns.

### How photochemical smog forms

It typically forms in cities where vehicle and industrial emissions are high and sunlight is abundant. The process begins when nitrogen dioxide absorbs solar radiation and breaks apart, eventually producing ozone and other oxidants. VOCs participate by reacting with nitrogen compounds, preventing the natural removal of ozone and allowing concentrations to build. Temperature inversions where a layer of warm air traps cooler air near the ground can worsen smog by preventing pollutants from dispersing upward

## Major Sources of Air Pollution in India

### Transport Sector

Growing vehicle population with poor emission standards. Cities with metro systems face issues due to weak last-mile connectivity.

### Policy Gaps:

Inconsistent enforcement of age limits on commercial vehicles. Slow EV adoption due to inadequate infrastructure and weak incentives. Weak public transport leads to pushes reliance on private vehicles.

### Industrial Sector

Heavy use of coal, biomass, and unapproved fuels in MSMEs and Ineffective operation of installed air pollution control devices.

### Municipal Waste Management

Open burning of waste and frequent landfill fires. And Lacking of waste segregation and treatment infrastructure.

### Re-Suspended Dust

Dust from unpaved roads, construction sites, and barren lands elevates PM<sub>10</sub> levels.

### Agriculture

#### Stubble Burning:

Major winter pollution trigger in Delhi-NCR. **Excessive Fertilizer Use:** Produces ammonia emissions. Ammonia (NH<sub>3</sub>), a pungent gas primarily found in fertilizers and livestock waste, is one of the most important agricultural pollutants. Once released, ammonia can react with other atmospheric compounds to form secondary particulate matter (PM<sub>2.5</sub>). Burning of crop residues still common in many parts of South and Southeast Asia also releases large amounts of CO, PM, and VOCs.

#### Rural Emissions

Mainly depend on biomass for cooking/heating. Rural emissions often travel into urban airsheds, worsening city air quality.

## Natural sources for Air pollution

### Wildfires

Increasing frequently and severe due to climate change results in release of massive quantities of fine particulate matter, carbon monoxide, and VOCs. Research shows wildfires cause large spikes in gaseous pollutants including CO, NO<sub>2</sub>, and formaldehyde.

### Volcanic eruptions

It releases sulphur dioxide, carbon dioxide, hydrogen sulphide, and ash into the atmosphere. Of the gases volcanoes emit, sulphur dioxide poses the most immediate risk to public health, causing respiratory and eye irritation.

**Dust storms** are a major source of coarse particulate matter, especially in arid and semi-arid regions.

Strong winds lift fine soil particles that can travel thousands of kilometers — Saharan dust, for example, regularly crosses the Atlantic Ocean. Effects- visibility, agriculture, and respiratory health in populations far from the original source.

**Biological sources** also contribute.

Vegetation emits VOCs such as isoprene and terpenes, which can react with human-made pollutants to form ozone and secondary aerosols. Decomposing organic matter in soils and wetlands releases methane, and ocean spray contributes sea salt aerosols to the atmosphere.

### **Air Pollution in India Severity**

India is ranked as one of the most polluted countries all over the world, with high levels of particulate matter. (PM<sub>2.5</sub>). In 2021, about 97% of the population will have been exposed to PM<sub>2.5</sub> levels exceeding WHO's air quality guidelines, putting people at risk for severe health problems. Urban cities like Delhi and other metropolitan cities have constantly failed to meet the air quality standards. Small towns and medium sized cities also victim to rising levels of pollution. Apart from the particulate matter, pollutants such as nitrogen oxides, sulfur dioxide and toxic compounds are contributing to the crisis

### **Air Pollution Effects**

**Health Impacts:** Causes respiratory diseases like asthma, bronchitis, and chronic obstructive pulmonary disease (COPD). Increases the risk of cardiovascular problems and premature deaths. According to the Health Effects Institute (2018), annual deaths from air pollution in India are projected to rise from 1.1 million in 2015 to 1.7 million in 2030.

**Environmental Impacts:** Pollutants contaminate soil and water bodies, harming ecosystems and biodiversity. High emissions of sulfur dioxide and nitrogen oxides cause acid rain, which damages crops, forests, and aquatic systems. Greenhouse gases such as carbon dioxide and methane exacerbate global warming and climate change.

**Economic Impacts:** Declines agricultural productivity by degrading soil quality and crop health. Raises healthcare costs due to increased disease burden. Reduces labour productivity owing to illness related absenteeism. The annual economic cost of air pollution in India is estimated at over \$150 billion.

### **Conclusion**

Air pollution is a complex and growing environmental problem with serious implications for human health, ecosystems, and economic development. The increasing levels of pollutants due to rapid urbanization, industrialization, and unsustainable practices highlight the urgent need for effective control measures. Strengthening environmental policies, adopting cleaner technologies, and promoting public awareness are essential to mitigate air pollution. A coordinated effort at local, national, and global levels is crucial to ensure cleaner air and a sustainable future.

### **References**

1. World Health Organization (2023). Types of pollutants. <https://www.who.int/teams/environment-climate-change-and-health/air-quality-and-health/health-impacts/types-of-pollutants>. 10 December, 2023.
2. Arizona Department of Environmental Quality (2022). Air pollutants defined. <https://azdeq.gov/air-pollutants-defined>. 15 March, 2023.
3. Chemistry Libre Texts. Outdoor air pollution. [https://chem.libretexts.org/Courses/Maryville\\_College/Essential\\_Chemistry\\_for\\_Poisons\\_Potions\\_and\\_Pharmaceuticals/07:\\_Air/7.03:\\_Outdoor\\_Air\\_Pollution](https://chem.libretexts.org/Courses/Maryville_College/Essential_Chemistry_for_Poisons_Potions_and_Pharmaceuticals/07:_Air/7.03:_Outdoor_Air_Pollution). 22 November, 2023.
4. National Institute of Environmental Health Sciences (2024). Air pollution. <https://www.niehs.nih.gov/health/topics/agents/air-pollution>. 05 January, 2025.
5. UCAR Center for Science Education (2023). Air pollution. <https://scied.ucar.edu/learning-zone/air-quality/air-pollution>. 18 October, 2023.
6. University of California Riverside (2022). Primary vs secondary air pollutants. <https://pollution.ucr.edu/primary-vs-secondary>. 09 April, 2023.

7. Institute for Environmental Research and Education (2021). What are secondary air pollutants. <https://iere.org/what-are-secondary-air-pollutants/>. 12 August, 2022.
8. ScienceDirect (2023). Photochemical smog. <https://www.sciencedirect.com/topics/engineering/photochemical-smog>. 27 September, 2023.
9. Breeze Technologies (2023). Major air pollutants: their impact and sources. <https://www.breeze-technologies.de/blog/major-air-pollutants-their-impact-and-sources/>. 14 December, 2023.
10. United Nations Office for Disaster Risk Reduction (2022). Hazard and risk terminology. <https://www.undrr.org/understanding-disaster-risk/terminology/hips/en0102>. 21 February, 2023.
11. Clarity Movement Co (2023). Natural sources of air pollution. <https://www.clarity.io/blog/natural-sources-of-air-pollution>. 03 November, 2023.