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Air Pollution – Sources and Classification

Akshey Bhargav[1]*, Swati Bhargava[2], Richa Singhal[3] and Twinkle Ahuja[4]

[1] *Senior Professor, CEPT University, India*

[2] *Masters in 'Sustainable Environmental Design (SED) AA School of Architecture, London, UK,*

[3] *MSc Energy & Sustainable Building Design, De Montfort University Leicester UK,*

[4] *Natural Resource Management, Guru Go bind Singh Indrapratha Uuniversity, New Delhi, India*

*Corresponding author: Akshey Bhargav, Senior Professor, Ex. CEPT University, India

Abstract

The present paper deals with types of air pollution along with sources, classification, and definition of air pollution. It covers general aspects including knowledge base for the students and others to understand the emerging issues related to air pollution.

Definition

Air pollution may be defined as the presence of one or more contaminants or combinations thereof in the air in such quantities and of such duration as may be or tend to be injurious to human, animal and plant life, or property, or which unreasonably interferes with the comfort and well-being of life or property. An air pollutant can be solid (large or sub-molecular), liquid or gas and could be present in the air temporarily or permanently. These air pollutants adversely impact the environment by interfering with the health, comfort, or by interfering with the food chain to be consumed by the people [1].

Air pollution can also be defined as the presence of toxic chemicals or compounds (including those of biological origin) in the air, at levels that pose a health risk. In an even broader sense, air pollution means the presence of chemicals or compounds in the air which are usually not present and which lower the quality of the air or cause detrimental changes to the quality of life (such as the damaging of the ozone layer or causing global warming).

Types of Air Pollutants

Air pollutant is known as a substance in the air which can cause harm to humans and the environment and can be in the form of solid particles, liquid droplets, or gases. Besides, they may be natural or man-made and can also be classified as either primary or secondary pollutants. Primary air pollutants are substances directly emitted from a process and are present in the atmosphere with the same composition as they are emitted, such as ash from a volcanic eruption, the carbon monoxide gas from vehicular emissions or sulphur dioxide released from industries. Secondary pollutants are not emitted directly into atmosphere but when primary pollutants react or interact, they form or transform into another compound in the atmosphere like ground-level ozone and photochemical smog.

Primary Air Pollutants

The primary pollutants are "directly" emitted from the processes such as fossil fuel consumption, volcanic eruption and industries thereby releasing pollutants in the form of oxides of Sulphur, oxides of Nitrogen, oxides of carbon, particulate matter, Methane, Ammonia, Chloro-fluorocarbons, toxic metals, etc. The description of these primary air pollutants are as under:

Oxides of Sulphur

Sulphur Oxides are generally a product of the volcanoes, industrial processes, coal, and petroleum because most of them have Sulphur in their composition. The Sulphur Dioxide in the presence of a catalyst such as NOx causes acid rain due to the formation of Sulphuric acid. The Indian coal is though low in sulphur content coal consumption in large quantities poses a major danger of acid rain because of the coal-based power plants.

Oxides of Nitrogen

Nitrogen Oxides are produced due to high-temperature combustion and the most important toxic gas is Nitrogen dioxide which is brown in color and hasa sharp odor. The brown haze dome observed above the cities is mostly because of the Nitrogen Oxides.

Carbon Monoxide

Carbon Monoxide (CO) is colorless, odorless, tasteless and non-irritating but very poisonous gas which is the product of incomplete combustion of the natural gas, coal or wood. The vehicle exhaust is the major source of CO which is formed during the incomplete combustion of carbon-containing compounds. The chemical reactions and formation of CO under different operating conditions are given hereunder:

$$2C + O_2 = 2CO \quad \ldots (1)$$

It is also produced in large amounts during the reaction between carbon-containing materials at high temperatures as in

blast furnaces.

$$CO_2 + C = 2CO \ldots (2)$$

Besides, Carbon monoxide is also produced during the dissociation of CO2 at high temperature.

$$CO_2 + C = 2CO \ldots (3)$$

The carbon monoxide enters the bloodstream through the lungs where it reacts with hemoglobin (Hb) to convert oxy-hemoglobin (O2Hb) to carboxy-hemoglobin (COHb) as per following equation.

$$O2Hb + CO = COHb + O_2 \ldots (4)$$

Carbon monoxide has a much greater affinity for hemoglobin as compared to oxygen thereby it reduces the oxygen-carrying capacity of the blood and affects the brain function resulting in elevated heart rate.

Carbon Dioxide

The Carbon Dioxide is associated with the ocean acidification and is emitted from combustion, industries, and respiration of living organisms. We have also primary pollutants such as Volatile Organic Compounds or VOCs like methane (CH_4) and non-methane (NMVOCs). Methane is a GHG which contributes to global warming, while the NMVOCs include the aromatic compounds such as Benzene, Toluene,and Xylene which are proved or suspected carcinogens. Another dangerous compound is the 1,3-butadiene, often associated with industrial uses.

Our atmosphere significantly consists of nitrogen, oxygen, other gases, and particles whereas carbon dioxide is a relatively insignificant non-pollutant gas (present level 356ppm) in the atmosphere. However, increasing concentration of carbon dioxide along with methane, chloro fluorohydrocarbons, nitrous oxide, water vapor in the atmosphere is of serious environmental concern. Methane and carbon dioxide mainly contribute to global warming and the relative contribution of gases is shown in the following Table 1.

Table 1: Contribution of Gases in Global Warming.

Active gas	% Contribution to temperature rise
CO_2	50
CH_4	19
CFC	17
O_3	8
N_2O	4
H_2O	2

Particulate Matter

The particulate matters are the fine particles which may be either solid or liquid, suspended or respirable available in an air-polluting gas. They are different from aerosols in various ways. Aerosols are particles and gas referred together. The aerosols which are created by the human activities are anthropogenic aerosols and account for around 10% of the total aerosols in the atmosphere.

Other Primary Pollutants

Another category of the primary air pollutants is toxic metals such as Cadmium, Lead, and Copper which are emitted from the industrial processes. Moreover, the Chlorofluorocarbons (CFCs) are proved to be harmful to the ozone layer and are emitted from products currently banned from use. Besides, Ammonia is emitted from an agricultural process, fertilizer industries, ice factories, etc. and is characterized bya pungent odor.

Secondary Air Pollutants

The secondary pollutants are not emitted directly; rather they form when the primary pollutants react with themselves or other components of the atmosphere. Most important secondary level Air Pollutants are Ground Level Ozone, Smog, and POPs (Persistent Organic Pollutants). The description of these secondary air pollutants are as under:

Ground Level Ozone

The most important secondary pollutant is the ground level Ozone or Tropospheric Ozone. The emissions from industrial facilities and electric utilities, motor vehicle exhaust, gasoline vapors, and chemical solvents are some of the major sources of NOx and VOC. Ground-level Ozone forms due to reactions of the NOx, Carbon Monoxide and VOCs in the presence of sunlight.

Tropospheric ozone to some extent arises from the natural transport of ozone from the stratosphere where it is formed by the action of energetic UV rays from the sun but the rest is produced in the troposphere by the photochemical ozone formation. The photochemical ozone or ground-level ozone formation can proceed through the following four steps:

i. The reaction between VOCs or CO and OH to form peroxy radicals, ROO.
ii. The peroxy radicals oxidize NO to NO_2.
iii. NO_2 is split by sunlight with the formation of NO and release of oxygen atoms.
iv. Oxygen atoms react with molecular oxygen, O_2, to form ozone.

Smog

"Smog" is a term originally formed by the combination of the words "smoke" and "fog". The burning of large amounts of coal results in the emission of smoke and sulphur dioxide which, along with vehicular and industrial emissions in the presence of fog causes smog. The primary emissions released from the vehicles and industries into the atmosphereereact with ultraviolet light from the sun to form secondary pollutants in the form of photochemical smog. Though there are thousands of reactions taking place in the atmosphere on a smoggy day there are some which help in understanding the formation of photochemical smog. Six sequential reactions are given hereunder for brief understanding.

In the first reaction, the Nitric Oxide (NO) which is emitted from various combustion processes combines with oxygen in the atmosphere to form nitrogen dioxide (NO2) and further breaks into single oxygen radicals (O) in the presence of UV rays of sunlight, which triggers many subsequent reactions of photochemical smog.

$$NO + O_2 \text{--->} NO_2 + U.V. \text{--->} O + NO$$

The second reaction is about the formation of ozone from the single oxygen radical under the presence of various catalysts

$$O + O_2 \text{--->} O_3$$

The third reaction is a scavenging reaction and usually occurs in the evening where conversion from ozone to oxygen takes place thereby dropping the ozone concentration during the evening.

$$O_3 + NO \rightarrow O_2 + NO_2$$

The fourth reaction is related to the hydrocarbons (represented here as RC) combining with the oxygen-free radicals to form RCO which represents a variety of Aldehydes and ketones whereas some of these constituents can combine with oxygen to form

Peroxide radicals (RCO_3).

$$RC + O \rightarrow RCO + O_2 \rightarrow RCO_3$$

The fifth reaction demonstrates the importance of these peroxide radicals (RCO3) where they accelerate the formation of ozone.

$$O_2 + RCO_3 \rightarrow O_3 + RCO_2$$

The last reaction shows the role of the peroxide radicals which accelerate the formation of nitrogen dioxide which subsequently will go on to form more ozone [2].

$$NO + RCO_3 \rightarrow NO_2 + RCO_2$$

Sources of Air Pollution

There are two main types of air pollution sources, namely, manmade sources and natural sources, the details of which are described hereunder and as reflected in **Figure 1.**

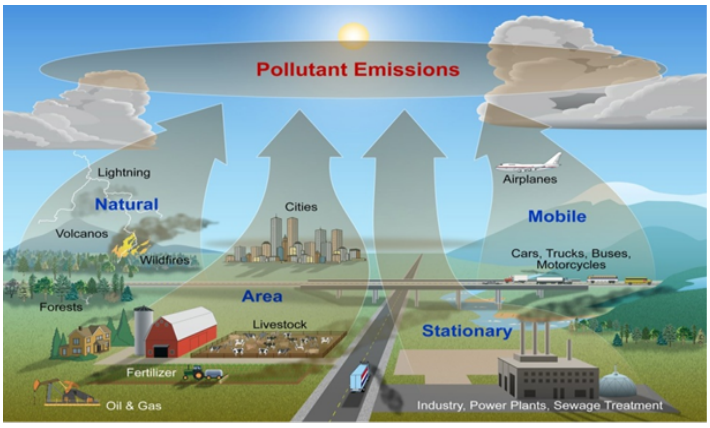

Figure 1: Showing sources of air pollution.

Manmade Sources

Manmade sources are further classified under following categories:

a. Mobile sources in the form of cars, buses, trucks, scooters, autos, planes, and trains

b. Stationary sources, such as power plants, oil refineries, industrial facilities, and factories

c. Area sources such as agricultural areas, cities, and wood-burning fireplaces, mining, etc.

Natural sources

Natural sources are in the form of forest fires, volcanic eruptions, dust storms, etc.

Manmade sources

The manmade sources can further be divided into the following:

a. Particulate matter and gas

b. Elevated and ground

c. The point, area, and mobile

d. Indoor and outdoor

There are two types of emissions:

a. Point source emissions: channeled through a pipe such as a chimney stack or vent.

b. Non-point source (diffuse or fugitive) emissions: caused by direct contact between volatile substances or particulate matter into the environment. These emissions may originate from field sources (tanks, pools, mounds, etc) or leaks from equipment (valves, taps, couplings, etc.)

Sources of Energy Generation

This is where CO_2 and SO_2 and water vapor are released in the atmosphere as large amount of coal, oil, L.P/ natural gas, gasoline and biofuels are used in combustion.

Transport: This is mobile and most leading source of CO. Combustion in engines is mainly fueled by gas, petrol, diesel, and kerosene. Jet engines of sub-sonic long-range and air crafts are major sources of NOx. The vehicular traffic on road is considered as non-point or line source. Additionally, the turbine engines of huge ships also emit tons of greenhouse gases and toxic particles in the air.

Industry: Most of the industries directly or indirectly depend on fossil fuels, as they produce CO and CO_2, sulphur hexafluoride and particle matters. Particularly, the cement industry releases large amounts of particle matters in the environment. There is an array of hazardous volatile compounds that are released from paints, electronics, dry cleaning products, and decreasing agents. Furthermore, utilization of HFC, oxides of Nitrogen, PFC and SF_6 produce pollutants.

Households: Carbon and soot emission during cooking with the use of fossil fuels can be considered here. The volatile toxicants such as Permethrine compounds from insecticides could contaminate the air or even food resulting in intoxication.

Agricultural practices: Agricultural activities such as the use of natural fertilizers release greenhouse gases. Pesticides release persistent organic pollutants (POP). Enteric fermentation in cattle ranching produces greenhouse gases like methane. The toxic chemicals found in pesticides and weedicides also reduce the quality of air inhaled.

Land mining, earthmoving activity, and quarrying: The process of mining large mineral deposits in the earth is often accompanied bythe emission of dust and other chemicals. Further, blasting, quarrying limestone or cement manufacturing processes produce dust particles.

Construction and repair work: Drilling, blasting, transportation, loading and unloading activities often cause dust generation. In addition, there are several nonpoint anthropogenic sources related to dust generation such as welding, painting, automobile repairing, etc.

Burning of Wastes and Incinerators

This is a more severe threat to the environment as it contaminates the atmosphere with persistent organic pollutants (POP) such as dioxins, furans probably major sources are plastics

and electronic wastes. In addition, normal combustion emits carbon as oxides and soot. Wastes are in a vast array such as plastic, electronic wastes, cement dust, industrial chemicals, paper, glass, steel and various derivatives of soil minerals, biological and medicinal wastes, drugs and other chemicals. Incinerators destroy the hazardous effect of any gas or particle and the remaining dust emission could be as smalls as PM10-PM2.5 or lesser. Unless the right particle filters are used, it will end up with adverse results [3].

Natural Sources

These include the compounds released from volcanic activities such as black smoke, ash, metals, SO_2, CO_2,and release of methane from thawing of permafrost regions in the Northern hemisphere, wetlands, sanitary landfills. Forest fires and bush fires, dust storm, sea spray and conversion of land use and release of isoprenes and terpenes by forest (precursors of low-level ozone).

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*Corresponding author: Akshey Bhargav, Email: draksheyb@gmail.com

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