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# CHEMICAL PROCESS INFLUENCING THE COMPOSITION SPECIFICATION OF ENVIRONMENTAL CHEMISTRY

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**Abstract**

The need for environmental education, both formal and non-formal, was keenly felt at the national level. The objective of environmental education is to enlighten the public about the importance of protection and conservation of our environment and about the needs to restrain human activities that lead to indiscriminate release of pollutants into the environment. At present, many environmental issues exist that have grown in size and complexity day by day, threatening the survival of mankind on earth. The various incidences of such environmental issues include London smog of 1952—killing about 4000 people, the Mediterranean sea turning into Dead Sea in the 1950s—unable to support aquatic life, death of a number of Japanese people because of eating fish from the Minamata Bay in the 1960s, historical monuments and statues in Greece and Italy getting damaged by the effect of rainwater, white marble of Taj Mahal in India becoming yellow by the action of sulphur dioxide fumes, leakage of methyl isocyanate (MIC) vapours at Bhopal in India in 1984, and the hazardous effects of nuclear weapons and radiations on the people of Hiroshima and Nagasaki. Pollution of river water in India, use of plutonium or other isotopic fuel-based breeder/nuclear reactors for energy production, use of dangerous artificial food additives, and ozone hole in the Antarctic and Arctic regions are some typical chemical issues that need to be resolved critically. This research paper to be discussed "**Chemical Process Influencing the Composition of Environmental Chemistry**"

**Keywords:** Hydrocarbons, Greenhouse Effect, Particulate Pollutants, Photochemical start, Nitrogen oxides, Ozone hole Organic base.

## Introduction

### Statement of the Problem

**"The Earth does not belongs to us. We belongs to the Earth"**

**Chief Seattle**

Environmental chemistry is the study of the chemical and biochemical phenomena that occur in nature. It involves the understanding of how the uncontaminated environment works, and which naturally occurring chemicals are present, in what concentrations and with what effects. Without this it would be impossible to study accurately the effects that humans exert on the environment through the release of chemical species. It is a multi-disciplinary science that, in addition to chemistry, involves physics, life science, agriculture, material science, public health, sanitary engineering, and so on. More or less, it is the study of the sources, reactions, transport, effects, and fate of chemical species in the air, water, and land, and the effect of human activities upon the various environmental segments, such as atmosphere, hydrosphere, lithosphere, and biosphere.

There are four environmental segments: atmosphere, hydrosphere, lithosphere consisting of abiotic or physical environment, and biosphere— the fourth segment of environment that consists of flora and fauna. Abiotic and biotic components together constitute the biome environment. Atmosphere is a protective blanket of gases surrounding the earth, which supports life and protects it from the hostile environment of outer space. Atmosphere absorbs most of the cosmic rays from outer space and a major portion of the electromagnetic radiation from the sun, and also maintains the heat balance of the earth. It transmits only near-ultraviolet, visible, near-infrared (IR) (300–2500 nm), and radio waves (0.14–40 m), and absorbs energy re-emitted from the earth in the form of IR radiation. It serves as an insulator against heat loss from the surface of the earth, and stabilizes weather and climate owing to the heat capacity of the air. The major gases of the atmosphere are nitrogen and oxygen, while the minor gases are argon, carbon dioxide, and some trace gases. Atmosphere is the source of oxygen and carbon dioxide. Several cycles that relate to the movement of matter between an organism and its environment are also present in the atmosphere—hydrological cycle, carbon cycle, nitrogen cycle, phosphorus cycle, and many others. It also supplies nitrogen, which is used by nitrogen-fixing bacteria and ammonia manufacturing plants to yield chemically bound nitrogen that is essential for life. The atmosphere can be divided into the following five concentric layers, depending on the temperature variations:

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**Troposphere:** In this layer, humans and other organisms live.
**Stratosphere:** In this layer, the temperature is very low, because of which there are no clouds, dust, or water vapours.
**Mesosphere:** In this layer, the temperature drops to about −95°C. The principal chemical species in the mesosphere are $N_2$, $O_2$, $O_2^+$, and $NO^+$.
**Thermosphere or ionosphere:** In this layer, most of the gaseous components are ionized under the influence of radiant energy and so ionosphere contains electrically charged particles such as $O^+$, $O_2^+$, and $NO^+$. Radio messages can be transmitted through this layer round the curve of the earth.
**Exosphere:** In this layer, the temperature is very high due to solar radiation. This region lacks atoms except hydrogen and helium. Human beings, on the one hand, are enjoying all the advantages of the development in science and technology and, on the other hand, have been dumping waste materials into the atmosphere and producing a large number of pollutants, which are threatening the survival of mankind itself on earth.

**Hydrosphere**

Hydrosphere, which covers more than 75% of the earth's surface, includes all types of water resources—oceans, sea, rivers, lakes, streams, reservoir, glaciers, polar ice caps, and groundwater (that is, water below the earth's surface). About 97% of the total water available on earth is in the form of oceans, which cannot be used for human consumption owing to its high salt content. About 2% of the water resources are locked in the polar ice caps and glaciers, while only 1% is available as freshwater (surface water—river, lakes, streams, and groundwater) for human consumption and other uses. Freshwater is also available in the form of rains, snow, dew, and so on.

Among all liquid substances, water possesses the highest heat of fusion and evaporation at ordinary temperature. These properties of water moderate the temperature of the biosphere. The history of ancient civilization—growth and decline—is intimately linked with the quantum of the water supply. The major uses of water are for irrigation (30%) and thermal power plants (50%), while other uses include domestic (7%) and industrial consumption (about 12%). Water is also a buoyant medium. Organisms can survive in it without specialized supportive structures. Surface water gets contaminated by pesticides and fertilizers from agricultural run-off water, human and animal wastes in sewage, and industrial wastes. Salinity in water is one such example. Salinity of marine water is about 3–3.5%.

**Lithosphere**

This is the outer mantle of the solid earth, consisting of minerals occurring in the earth crust and the soil. The earth is a cold, spherical solid planet of the solar system, which spins on its axis and revolves around the sun, maintaining a certain constant distance. It comprises a complex mixture of minerals, organic matter, air, and water.

Lithosphere mainly consists of three layers: crust, mantle, and outer and inner core. The surface of the crust is covered with soil, which is the most important part of lithosphere. Soil is a mixture of organic as well as weathered rock and materials necessary for the growth of plants. It is a storehouse of minerals, a reservoir of water, a conserver of soil fertility, a producer of vegetative crops, and a home of wildlife and livestock.

**Biosphere**

Biosphere denotes the realm of living organisms and their interaction with the environment, that is, atmosphere, hydrosphere, and lithosphere. Both the biosphere and the environment are influenced by each other considerably. Thus, the levels of oxygen and carbon dioxide in the atmosphere depend entirely on the plant kingdom. As a matter of fact, green plants alone are responsible for the accumulation of oxygen in the atmosphere, through photosynthesis and decay; the original atmosphere was devoid of oxygen. The biological world, in general, is intimately related to the energy flow in the environment and water chemistry. The interactions among organisms are symbiotic (living together for mutual benefits) and antagonistic (living together, but at least one is harmed). Biosphere as a whole supply us with food, and there exists a cycling of materials through expiration, excretion, and extinction of the form.

**TOXIC CHEMICALS IN THE ENVIRONMENT**

The chemicals present in the environment are toxic as well as non-toxic in nature. The toxic chemicals that are discharged by industries into air, water, and soil get into the human food chain from the environment. Once these chemicals enter the biological system, they perturb the natural biochemical processes, causing adverse effects.

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Toxic chemicals are huge in number; however, toxicity levels of many compounds are still unknown. Some useful chemicals are being controlled rigorously as their non-toxicity has not yet been proved. Many metals that are known to cause environmental hazards are essential dietary trace metals required for normal growth and development of animals and human beings. These elements are Al, Sb, As, Ba, Be, Cd, Co, Cu, Ce, In, Pb, Hg, Mo, Ag, Te, Tl, Sn, Ti, W, U, and Zn (Table 1). For instance, As, Pb, and Cd—which are well-known toxic metals—are required in trace quantities for the growth of animals.

Schwartz used the term "concentration window" to draw the arbitrary lines of demarcation:

(i) "Essential" at the trace level for sustenance of life processes
(ii) "Deficient" at lower level than (a), causing metabolic disorder
(iii) "Toxic" at higher level than (a), causing adverse effects

According to the "International Register of Potentially Toxic Chemicals" of the United Nations Environment Programme, 4 million known chemicals exist in the world today and another 30,000 new compounds are added to the list every year. Among these, 60,000–70,000 chemicals are commonly used. Apart from their benefits to increasing production, living standards, and health, many of them are potentially toxic.

**Classification of Toxic Matters**

Toxic matters may be classified according to their function and effects, such as mutagens, carcinogens, and pesticides; food additives, preservatives, and so on; or heavy metals, metal carbonyls, organochlorine compounds, radioactive chemicals, and so on.

**Mutagens**

In reference to the field of genetics, a mutagen is a physical or chemical agent that changes the genetic material, usually DNA. A large number of chemicals may interact directly with DNA. However, many chemicals such as PAHs (polycyclic aromatic hydrocarbons), aromatic amines, and benzenes are not necessarily mutagenic by themselves, but produce mutagenic compounds through metabolic processes in cells.

Other chemical species are reactive oxygen species, which include superoxide, hydroxyl radicals, and hydrogen peroxide. A large number of these highly reactive species are generated by normal cellular processes, for example, as by-products of mitochondrial electron transport or lipid peroxidation. Deaminating agents such as nitrous acid, aromatic amines (2-acetylaminofluorene), alkaloids, sodium azide, bromine and its compounds, and alkylating agents such as ethyl nitrosourea, which transfer methyl or ethyl group to bases or the backbone phosphate groups, also react with DNA. Guanine when alkylated may be mispaired with thiamine. Some may cause DNA crosslinking and breakages. Nitrosoamines are an important group of mutagens found in tobacco; other alkylating agents include mustard gas and vinyl chloride.

**Carcinogens**

A carcinogen is a substance that is capable of causing cancer in humans and animals. If a substance is known to promote or aggravate cancer, but not necessarily cause cancer, it may also be called a carcinogen. A number of substances have been identified as being carcinogenic. Some commonly known carcinogens include asbestos, radon and other radioactive isotopes, certain pesticides, arsenic and other heavy metals, and tobacco smoke. In addition to chemical substances, ultraviolet ray is also known to cause a variety of cancers that affect the skin.

**Pesticides**

Pesticides are the chemicals used to protect the crops and fodders from insects and pests, including rodents and weeds. Biochemical processes constitute the major mechanism by which pesticides in the environment are degraded and detoxified. One good example of such pesticides is DDT, whose biological action on the environment has been studied most extensively. Like many other insecticides, DDT targets the central nervous system. DDT dissolves in lipid (fat) tissue and accumulates in the fatty membrane surrounding nerve cells. This is likely to interfere with the transmission of nerve cells. The net result is disruption of the central nervous system, killing the target insect. While DDT is fairly stable and persists in the environment, the other groups—organophosphates and carbamates—degrade quite rapidly. The latter react with $O_2$ and $H_2O$, undergoing decomposition within a few days in the environment.

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**Food additives**

Food additives are chemical substances that are added voluntarily to food to preserve its flavour or enhance its taste and appearance. Some additives have been used for centuries, for example, for preserving food by pickling with vinegar, salting, preserving sweets, or using $SO_2$ gas as in some wines. Food additives are of both natural and artificial origins.

**Types of food additives**

The different types of food additives, their uses, and examples include the following:

- **Anti-caking agents**—prevent ingredients from becoming lumpy, for example, calcium polyphosphate and potassium aluminium silicate
- **Antioxidants**—prevent foods from being oxidized or going rancid, for example, disodium EDTA, oxystearin, and vitamin C
- **Artificial sweeteners**—increase the sweetness, for example, saccharin, aspartame, and cyclamates
- **Emulsifiers**—prevent fats from clotting together, for example, dimethyl polysiloxane
- **Food acids**—maintain the right acid level in the food, for example, sodium or potassium fumarate and 1,4-heptonolactone
- **Colours**—enhance or add colour to food, for example, niacin, nicotinamide, tartrazine, riboflavin, and turmeric
- **Humectants**—keep foods moist, for example, maltitol, lactitol, xylitol, and triacetin
- **Flavours**—add flavour to food
- **Flavour enhancers**—increase the power of a flavour added to food, for example, monopotassium glutamate, MSG, and zinc acetate
- **Foaming agents**—maintain uniform aeration of gases in foods
- **Mineral salts**—enhance texture and flavour of food, for example, aluminium sodium sulphate, calcium hydroxide, and magnesium hydroxide
- **Preservatives**—prevent microbes from multiplying and spoiling the food, for example, lysozyme, isopropyl citrate, and sodium benzoate
- **Thickeners and vegetable gums**—enhance texture and consistency of food
- **Stabilizers and firming agents**—maintain even food dispersion, for example, sodium or potassium gluconate
- **Flour treatment**—improves baking quality
- **Glazing agents**—improve appearance of food and can protect it
- **Gelling agents**—alter the texture of foods through gel formation, for example, agar, alginic acid, and carrageenan
- **Propellants**—help propel food from a container
- **Raising agents**—increase the volume of food through the use of gases
- **Bulking agents**—increase the volume of food without major changes to its available energy, for example, starch, mannitol, pectin, and polydextrose

**Reactions due to food additives**

A number of food additives are more likely than others to cause various hypersensitive reactions in people, which include:

- **Digestive disorders**—diarrhoea and colicky pains
- **Nervous disorders**—hyperactivity, insomnia, and irritability
- **Respiratory problems**—asthma, rhinitis, and sinusitis
- **Skin problems**—hives, itching, rashes, and swelling

**Water pollution**

Out of all natural resources, water is the most essential for the existence of living beings. Water sustains life on the earth. Unfortunately, civilization has perished it and is responsible for its pollution. Water pollution may be defined as the deterioration in the physical, chemical, and biological properties of water, brought about mainly by anthropogenic activities. It can also be caused by natural weathering of the product of rocks, minerals, soil sediments, nutrients, as well as organic matters of soil (decomposed animals, microorganisms, and vegetable materials) that are transported by erosion. This deterioration in quality of water body (both surface and ground) has increased during the past few decades mainly by enhanced human activities in industrial and agricultural sectors.

In recent years, there has been an increasing concern around the world regarding the widespread distribution of the pollutants stemming from human activities and the potential harmful effects of these pollutants on human or the ecological systems. Some environmental problems such as contaminated water have arisen from poorly controlled discharges of industrial effluents into the water bodies, while others such as air pollution have arisen from poor emission control on the energy generation industry and motor vehicles.

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**parameters of pollution**

The following parameters determine the nature and extent of pollution in water:

(i) **Physical parameters** — colour, odour, turbidity, density, temperature, and so on

(ii) **Chemical parameters**—pH, total dissolved solids (TDS) and their ionic composition, suspended solids, dissolved oxygen (DO), residual chorine, COD, biochemical oxygen demand (BOD), redox potential, radioactive substances, organic materials, metallic ions (including heavy metals), oxides, by-products of industries, and so on

(iii) **Biological parameters**—different types of microorganisms, bacteria, algae, small animals such as protozoa and crustaceans, and so on.

**Water pollutants**

Nature and concentration of the pollutants depend upon their sources, physical and chemical conditions, and reactivity with the surrounding environment. The large number of water pollutants may broadly be classified under the following categories:

(i) **Organic pollutants—**These include degradable and non-degradable products, as well as disease-causing agents, plant nutrients, sewage, synthetic organic compounds, and oil. DO is an essential requirement for aquatic life. Its level in the water body should be 4–6 ppm. Decrease in this value is an indication of pollution mainly caused by organic matter, for example, sewage, industrial wastes, and run-off from agricultural lands

(ii) **Inorganic pollutants—**These pollutants consist of inorganic salts, finely divided metal or metal compounds, trace elements, complexes of metal with organic moiety mineral acid, and so on

(iii) **Sediments—**Sediments are insoluble soil particles of unknown composition that enter water bodies by soil erosion. In fact, sediments are the most extensive pollutants of surface water. It has roughly been estimated that suspended solids loading reaching natural waters are about 700 times as large as the solids loading from sewage discharge. Several factors such as agricultural practices, construction activities, and strip-mining activities have great influences on solid erosion rates in the given area.

(iv) **Radioactive substances—**Radioactive pollution is the worst pollution among all and it is detrimental to health. Sources of environmental radioisotopes may broadly be grouped as natural and artificial. Natural radioisotopes produced by cosmic rays find their way into soil and water courses through precipitation (rainfall and snow) and run-off, whereas those occurring on the surface of the earth and below enter the water-bearing formulations through weathering. On the other hand, man-made radioisotopes enter the environment mainly through nuclear installations and research organizations. Some of the radioisotopes such as K-40; Ra-222, Ra-226, and Ra-228; Pb-210; and C-14 are incorporated into the human body through different pathways.

(v) **Thermal pollutants—**Coal-fired or nuclear fuels used by steam power plants are among the most important sources of thermal pollutants, as only a fraction of the heat generated using these fuels is successfully converted to work and the remaining is wasted. Even in the modern coal-fired plants, the efficiency does not exceed 40%. The condensers used in these plants utilize water from nearby river or lake or municipal sources and discharge the wastewater back to the water body, with its temperature being raised by about 10°C in the process. This decreases the DO level of water and adversely affects the aquatic life.

**Main Sources of pollutants**

Water pollution is caused by one or more of the following sources:

1. **Point sources:** Sources that are readily identifiable at a single location, such as the following:
   - (a) Industrial waste disposal
   - (b) Water treatment plant
   - (c) Municipal sewage leakage
   - (d) Combined sewer overflows
   - (e) Raw sewage disposal
   - (f) Leaching residue tips
   - (g) Sanitary landfills
   - (h) Aerial fallout
   - (i) Industrial effluent seepage

2. **Non-point sources:** Sources whose location cannot be identified, such as the following:

(a) **Pollution due to industrial chemicals:** With the increase in global population, industrial activities have also increased. The effects of population growth have been recorded not only on industrial areas, but also on global commons such as Antarctic, the Arctic, and remote natural reserves. In addition, increasing concentrations of chemical substances originating from industrial sources and other human activities have been detected in water, air, and soil. Such elevated concentrations and consequent bioaccumulation of some substances have given rise to environmental and ecotoxicological effects. Over 11 million chemical substances are known, of which 60,000–70,000 are in regular use. Data on environmental and ecotoxicological effects of these chemicals are sparse;

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however, many cases have been reported about the heavy metals and metalloids, pesticides, fertilizer, aromatic polychlorinated compounds, flame- retardant chemicals, wood preservatives, washing powders and detergents, polymeric resins, and so on poisoning the water bodies.

**(b) Pollution due to agricultural activities:** The key role of fertilizers in increasing the crop production is now well established. Fertilizer consumption in India has registered a spectacular growth during the last four decades. In addition to chemical fertilizers, large quantities of organic manures and pesticides are also being used for increasing crop production. Unfortunately, increasing use of the above-mentioned inputs for achieving the planned agricultural growth is creating environmental problems. Reports say that, in India, the efficiency of nitrogen fertilizers is about 30–40% for paddy and about 50–60% for wheat. For potassium and phosphate fertilizers, the efficiency values are around 50% and 15–20%, respectively. This shows that a huge amount of applied fertilizers not used by plants is available for leaching into groundwater, which can cause water pollution. Micronutrients added as fertilizers may be toxic if they get into groundwater. Nutrients can flow into groundwater at many points. It should be recognized that only a small portion of the nitrogen load comes from the agricultural land surface, while the major portion comes from the air and the domestic and industrial wastes of the cities.

**(c) Oil pollution:** Besides the problems of dwindling petroleum reserves and global oil pollution, the use of fossil fuels contributes to the increase in greenhouse gas (GHG) and change in global

- **Arsenic, cadmium, lead, nickel, manganese, and molybdenum:** These metals are potentially harmful to human life as they are bioaccumulative and can seriously affect health even in relatively small dosages. Also, with the addition of copper and chromium, all these metals become very detrimental to aquatic life.
- **Zinc, lead, aluminium, boron, and iron:** These metals may rapidly become available either in acid soils or as salts precipitated by neutralizing acid solutions. They are all, to a greater or lesser extent, toxic to plant growth.
- **Mercury:** Mercury is highly toxic as a liquid, a vapour, and organic complexes. It is bioaccumulative and is, therefore, a major health risk to workers who are handling it. Its detrimental effects on animals and humans are irreversible. Mercury can be absorbed through the skin, inhaled as a vapour, or taken in by eating contaminated fish and drinking contaminated water. Mercury is used extensively by small mines in some developing countries; these mine workers should be educated about the health hazards associated with mercury and how to handle it safely.

  Mercury can also cause major environmental damage to all types of animals and plants. Residual mercury should be carefully collected and returned to the supplier. In addition, all purchases and uses of the mercury should be recorded.
- **Copper:** Copper is commonly toxic to most aquatic vegetation. Therefore, care must always be taken not to allow copper to enter drainage systems where there may be aquatic life.

**(d) Pesticides:** Pesticides are the chemicals used to protect the crops and fodders from insects and pest including rodents and weeds. Biochemical processes constitute the major mechanism by which pesticides in the environment are degraded and detoxified. One good example of such a pesticide is DDT, whose biological action on the environment has been studied most extensively. Like many other insecticides, DDT targets the central nervous system. DDT dissolves in lipid (fat) tissue and accumulates in the fatty membrane surrounding nerve cells. This is likely to interfere with the transmission of nerve cells. The net result is disruption of the central nervous system, killing the target insect. While DDT is fairly stable and persists in the environment, the other groups— organophosphates and carbamates—degrade quite rapidly. The latter react with $O_2$ and $H_2O$, undergoing decomposition within a few days in the environment.

**(e) Radioactive waste:** Radioactive wastes are derived from the mining and processing of uranium ores. Other sources of radioactive waste climate. Petroleum hydrocarbons enter freshwater environment in a variety of ways, including land run-off, airborne contaminants, shoreline facilities, and leaks and spills from vessels, pipelines and underground storage tanks.

**(f) Eutrophication:** The word eutrophication literally means "the process of becoming well fed"; it can also be referred to as excessive fertilization of lakes, reservoirs, slow-flowing rivers, and certain marine coastal waters by nutrients, which result in the nuisance growth of aquatic plant materials such as algae and macrophytes. This in turn leads to deterioration of water quality and taste, odour problems, oxygen depletion, reduced transparency, declines of fisheries, possible fish kill, and toxic effects on animals and human beings.

**(g) Consequences of eutrophication:** Eutrophication of lakes, reservoirs, impoundments, rivers, and coastal waters is related to the impairment of recreation for bathers, health concern from contact dermatitis, and ingestion of toxin-producing algae. In addition to these factors, eutrophication also causes impairment of fisheries and consumption of contaminated shell fish, adverse effects on livestock, drinking of toxicologically contaminated water, macrophyte-impaired navigation, and increased habitat for some disease vectors such as schistosomiasis or bilharzias.

**(h) Control of eutrophication:** Eutrophication can be controlled effectively by drastic reduction in the total nutrient load in an overloaded water system. An integrated approach based on water body nutrient mass balance, taking into consideration specific geographical, climatological, and ecological conditions, can be effective.

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(i) **Heavy metals:** When heavy metals on a site, which either may have been produced by mining operation or occur naturally, are mobilized, these cause potential health and environmental problems in the overburden in soil and water. When acid mine drainage is detected, there is a high probability that heavy metals are present in abundance. Sulphuric acid derived from the oxidation of sulphides normally carries many heavy metals usually in fairly high quantities. The management of acid mine drainage, which contains these metals, includes neutralization and pH increase of the solution to precipitate most of these metals, most commonly as metallic salts. These salts would then become soluble and may enter the local water regime.

It is, therefore, necessary to review the heavy metals that are detrimental to humans, animals, plants, and fish life.

**Effects of photochemical smog on human**

(i) Photochemical smog is characterized by a yellowish grey haze in the atmosphere. This smog along with ozone may irritate the eyes and nose, affect lung function, degrade physical performance of humans, and exacerbate asthma.
(ii) Symptoms such as nasal block and discharge, sneezing, hacking cough, and airway obstruction may persist in highly vehicular areas.
(iii) Studies have also revealed prevalence of chest problem and upper airway morbidity in the area with higher levels of oxidants, such as Mumbai and Delhi.
(iv) Occurrence of cold, cough, and sputum and breathlessness are closely related to peaking of vehicular pollution.
(v) Photochemical smog leads to respiratory problem, reduces visibility, alters various blood parameters, and aggravates diseases such as headache and bronchitis.

**Effect of photochemical smog on plants**

(i) Photochemical smog is reported to cause injuries to petunia, lettuce, pinto bean, citrus, salad crops, and coniferous trees even at a very low concentration of 0.001 ppm.
(ii) PAN causes injury in beets, celery, pepper, and aster. It causes silvering of leaves and death of forest tree.
(iii) PAN inhibits important Hill reactions of photosynthesis.
(iv) Photochemical smog is believed to cause early maturity in plants.
(v) Exposure of 4 ppb of PAN for 4 h is known to create visible damage in plants. Vegetation damage may take several forms, such as chlorosis, leaf abscission, and curling.
(vi) Photochemical smog alone or in conjunction with $O_3$, PAN, and $NO_X$ causes damage to forest, agriculture, and other materials such as rubber, paints, fibres, and polymers.

**Control Methodologies for Sulphur Oxides**

Sulphur dioxide emissions from fossil fuel-fired combustion sources can be reduced by five techniques. Fuel treatment and FGD are the most common techniques being used to comply with the Clean Air Act requirements.

(i) **Low sulphur fuel firing:** One of the most straightforward ways to reduce $SO_2$ emissions from combustion sources is by burning a low-sulphur-containing fuel. The coal-fired boilers use low-sulphur coal, low-sulphur fuel oil, or natural gas, instead of a high-sulphur coal. The use of low-sulphur coal can reduce $SO_2$ by more than 80%. Low-sulphur coal usually contains between 0.4% and 1% of sulphur, whereas high-sulphur coal contains sulphur between 1% and 5%.
(ii) **Flue gas desulphurization (FGD):** FGD is the most common technology used for controlling emissions of sulphur oxides from combustion sources. FGD technology is also used to reduce $SO_2$ emissions from copper smelters. In this method, $SO_2$ gaseous emissions are usually removed by a post-combustion absorption process. FGD scrubbing processes can be "wet" or "dry". Wet scrubbing processes use a liquid absorbent to absorb the $SO_2$ gases.
(iii) **Dry scrubbing:** Dry scrubbing is basically a two-step chemical process. In the first step, the flue gas leaving the boiler or incinerator is scrubbed with a stream of alkali, usually calcium hydroxide. In the second step, the reaction products are collected in a high-efficiency particulate matter control device, such as a pulse jet bag house, a reverse air bag house, or an electrostatic precipitator. There are two types of dry scrubbers: spray dryer absorption and dry injection absorption.
(iv) **Fluidized-bed combustion:** A fluidized-bed boiler using an alkali such as limestone can reduce emissions of sulphur oxides. In this type of boiler, a grid supports the bed of coal and limestone (or dolomite) in the firebox of the boiler. Combustion air is forced upwards through the grid, suspending the coal and limestone bed in a fluid-like motion. Natural gas is used to ignite the pulverized coal. Once the coal is ignited, the gas is turned off. The sulphur in the coal is oxidized to $SO_2$ and consequently combined with limestone to form calcium sulphate ($CaSO_4$). The $CaSO_4$ and fly ash particulate matter are usually collected in a bag house or in an electrostatic precipitator. Fluidized-bed boilers usually require a calcium-to-sulphur stoichiometric ratio

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of 2.0:1.0 to 4.0:1.0 because of the limited amount of calcium oxide surface area available.

**(v) Fuel treatment**

- **Coal gasification:** Over 70 different processes have been developed for producing a combustible gas from coal. Three basic steps are common to all coal gasification processes: pretreatment, gasification, and gas cleaning. Coal pretreatment involves coal pulverizing and washing. The pulverized coal is gasified in a reactor with limited oxygen, producing a gas with a low, medium, or high heating value by applying heat and pressure or by using a catalyst to break down the components of the coal. The gas produced contains carbon monoxide, hydrogen, carbon dioxide, water, methane, and contaminants, such as hydrogen sulphide and char. During gasification, the sulphur content in the coal is converted to $H_2S$, which is then converted to elemental sulphur by partial oxidation and catalytic conversion. The synthetic gas produced is free of sulphur and can be burnt without releasing harmful pollutants.
- **Coal liquefaction:** A process for changing coal into synthetic oil is called coal liquefaction. It is similar to coal gasification. Two basic approaches are used for liquefaction. One approach uses gasifiers to convert coal to carbon monoxide, hydrogen, and methane, followed by condensation to convert the gases to oils. The other approach uses a solvent or a slurry to liquefy pulverized coal and then converts this liquid into a heavy fuel oil. Some processes produce both a synthetic gas and a synthetic oil. Hydrogen is used to convert sulphur present in the coal to hydrogen sulphide gas, which is partially oxidized to form elemental sulphur and water. More than 85% of the sulphur can be removed from coal by liquefaction.

**Summing Up**

There are two types of coal cleaning processes: physical and chemical. Physical coal cleaning is used to remove the inorganic (mainly pyritic) sulphur compounds present in the coal, whereas chemical coal cleaning is used to reduce organic sulphur compounds. Physical coal cleaning is a well- established technology that has been used for more than 50 years to reduce the sulphur and ash content of high-sulphur coal supplies. Physical coal cleaning uses the differences in density of both the coal and the sulphur-bearing impurities in the coal. The coal is crushed, washed, and then separated by settling processes, using cyclones, air classifiers, or magnetic separators. Approximately 40–90% of the pyrite sulphurcontent can be removed by physical coal cleaning. Its effectiveness depends on the size of pyritic sulphur particles and the amount of pyritic sulphur contained in the coal Chemical coal cleaning methods that reduce the organically bound sulphur are currently under development. In microwavedesulphurization, the coal is crushed and then heated for 30–60 s by exposure to microwaves. Mineral sulphur selectively absorbs this radiation, forming $H_2S$ gas, which is reduced to elemental sulphur by the Claus process. In another microwave process, calcium hydroxide [$Ca(OH)_2$] is added to crushed coal. The organic sulphur present in coal converts to $CaSO_3$ when exposed to this radiation. The coal is washed with water to remove the $CaSO_3$ and other impurities. As much as 70% of the sulphur can be removed by the microwave process.

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