Concept of Pollution

Definition of Pollution

Pollution is an undesirable change in the physical, chemical or biological characteristics of our air, land, and water that may or will harmfully affect human life or that of desirable species, our industrial processes, living conditions, and cultural assets (**Odum**, 1971).

Correlation between Human Population and Pollution

Some authors (such as **Southwick**, 1976), associate the human population explosion with the pollution problem. They point out that with more people there is more sewage, more solid wastes, more fuel being burned, more fertilizers and insecticides being used to produce more food for hungry mouths. But, there are certain writers who have pointed out that in underdeveloped countries, pollution is not the severe problem as it is in technologically developed countries and yet the populations may be very dense. They feel that it is the wasteful aspects of our technology which strive always to produce more convenient products ("disposable" items) which pollute our environment.

Definition of Pollutants

Every human society, be it rural, urban, industrial and most technologically advanced society, dispose of certain kinds of byproducts and waste products which when are injected into the biosphere in quantities so great that they affect the normal functioning of ecosystems and have an adverse effect on plants, animals, and man are collectively called **pollutants** (**Smith**, 1977). A pollutant is a constituent in the wrong amount, at the wrong place or at the wrong time.

Types of Pollutants

Pollutants primarily are grouped into the following two types:

1. Natural pollutants. Certain pollutants such as carbon dioxide, carbon monoxide, sulphur dioxide, lead, mercury and other trace elements are the consequence of life processes being produced through respiration, faeces, urine and body decomposition. With an increase in human population, the pollutants are increasing with alarming rate.

2. Synthetic, man-made, anthropogenic or xenobiotic pollutants. A vast array of synthetic pollutants are increasing continuously with urbanization and industrial growth. They include pesticides, detergents, pharmaceuticals, cosmetic products, organic acids, aerosols, and metals, etc. Several of these compounds are extremely stable and persist in the environment for a considerable period posing serious environmental hazards.

From the ecosystem viewpoint, these pollutants can be classified into two basic types:

Non-biodegradable pollutants and biodegradable pollutants (**Odum**, 1971). The materials and poisons, such as aluminium cans, mercurial salts, long-chain phenolic chemicals and DDT that either do not degrade or degrade only very slowly in the natural environment, are called **non-biodegradable pollutants**. Such non-biodegradable pollutants not only accumulate but are often "biologically magnified" as they move in biogeochemical cycles and along food chains. Also they frequently combine with other compounds in the environment to produce additional toxins. **The biodegradable pollutants** include domestic sewage, heat, etc. The domestic sewage can be rapidly decomposed by natural processes or in engineered systems (such as a municipal sewage treatment plant) that enhance nature's great capacity to decompose and recycle. Problems arise with the biodegradable pollutants when their input into the environment exceeds the decomposition or dispersal capacity.

Air Pollution

Air pollution is the presence in the atmosphere, or injection into it, of substances that are not present naturally, or present naturally but is in much smaller concentrations, and that may harm living organisms directly or indirectly (**Allaby** 1995).

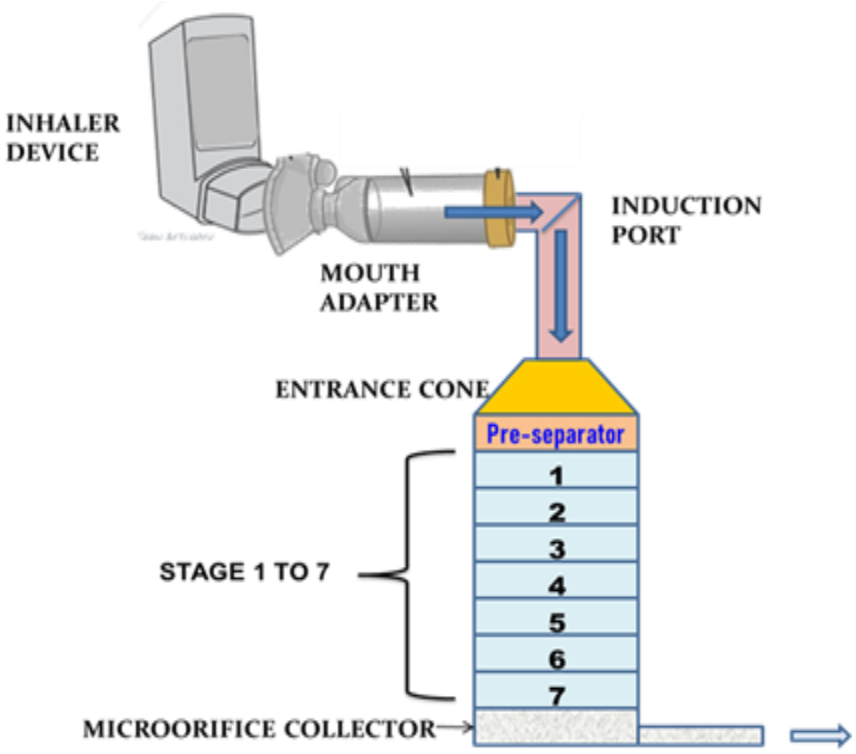
Methods of Detection and Measurement of Air Pollution

Air pollution is usually measured by sampling of air by *thermal* and by *electrostatic precipitation, Sonkin impactor* and *electrostatic dust collectors.* The particulate pollution is measured by the instrument called *deposit gauge* or by *Owen's dust counter.* The thickness of the smoke is measured by *Liegean sphere* and by *Ringelmann chart.* The rough estimation of SO2 in air can be made by chemical analysis of the dust collected in a deposit gauge or by a *bubbler method.* Fluorides are estimated by colour reactions.

Ringelmann 0	0% opacity – clear	
Ringelmann 1	20% opacity – barely visible	
Ringelmann 2	40% opacity – clearly visible	
Ringelmann 3	60% opacity – somewhat transparent	
Ringelmann 4	80% opacity – barely transparent	
Ringelmann 5	100% opacity – black	

Figure 2: The Ringelmann scale

Electrostatic Dust Collector



Sources of Air Pollution

1. Air Pollution by Natural Means

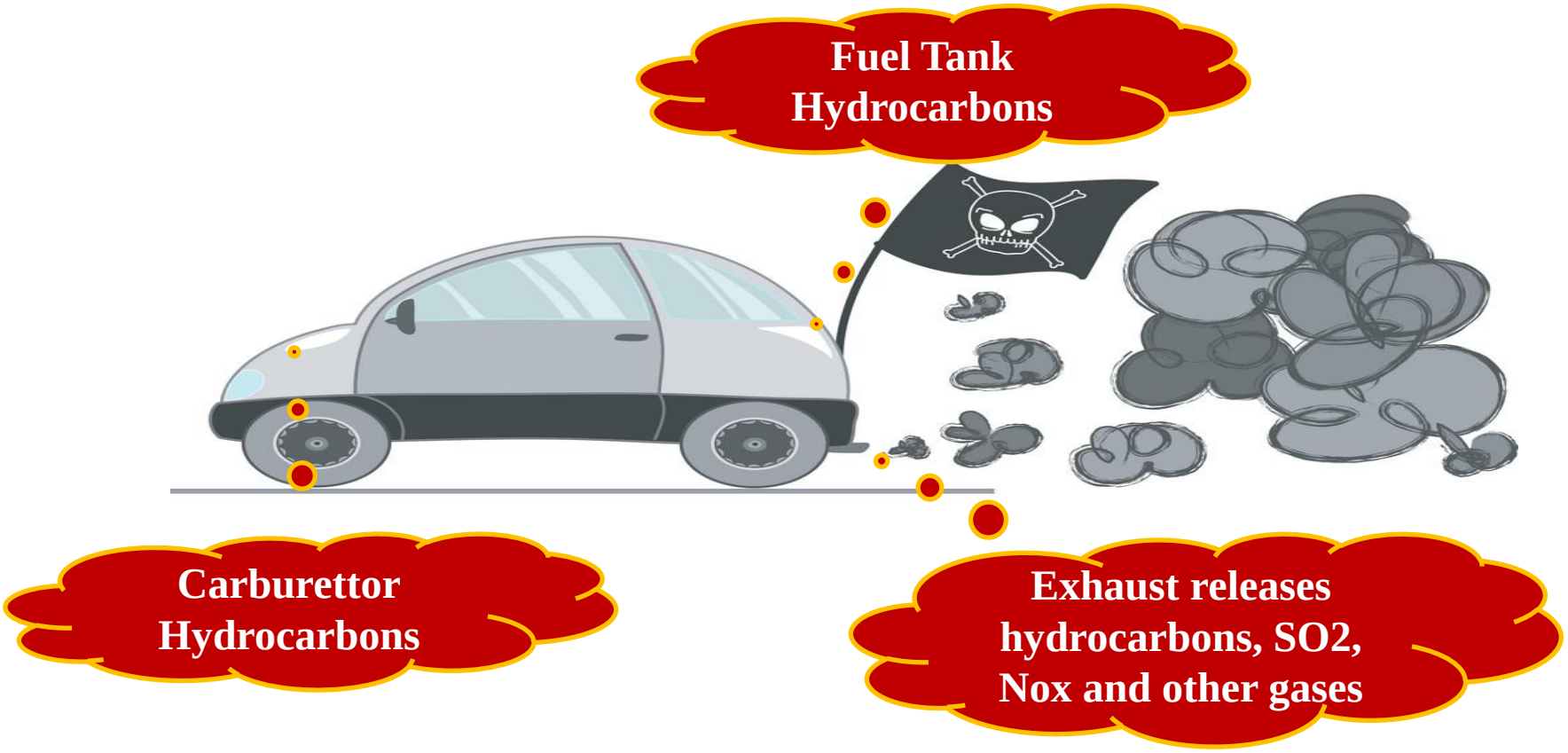
Nature adds few natural pollutants such as pollen, hydrocarbons released by vegetation, dusts from deserts, storms, and volcanic activity. Thus, **volcanic eruptions** may eject large amounts of gases and particulate matter. Settling volcanic ash can kill vegetation by coating leaves and preventing photosynthesis and transpiration *(e.g.*, following the 1980 eruption of Mt. St. Helens, USA). Fine particles, mainly of sulphates, may penetrate the stratosphere, spread widely and reflect significant amounts of solar radiation, leading to climatic cooling *(e.g.*, the 1991 eruption of Mt. Pinatubo, Phillippines). Likewise, **dust storms** sometimes carry fine sand for thousands of kilometers and favourable weather conditions stimulate the release of pollen, affecting people sensitive to it.

2. Air Pollution by Human Activities

(a) Industrial chimney wastes. There are a number of industries which are potent sources of air pollution. **Petroleum refineries** are the major sources of gaseous pollutants *(e.g.*, SO2, NOx, etc.) Mathura-based petroleum refinery has been accused to aggravate the pollution-related decay of Taj Mahal in Agra and other historical monuments of Fatehpur Sikri Complex. **Industrial processors** such as metallurgical plants and smelters, chemical plants, petroleum refineries, pulp and paper mills, sugar mills, cotton mills, and synthetic rubber manufacturing plants are responsible for about one fifth of the air pollution. **Cement factories** emit plenty of dust, which is potential health hazard. Stone crushers and hot mix plants also create a menace. The SPM levels in such stone crushing areas are found to be five time the industrial safety limits. **Chemical manufacturing industries** emit acid vapours in air.

(b) Thermal power stations. The coal consumption of thermal power produce chief pollutants of coal burning are fly ash, SO2' and other gases (CO, NO2), aldehydes and hydrocarbons (**Chaudhuri,** 1982).

(c) Automobiles. At the global level, there are over 300 million cars, trucks and buses and their number is increasing rapidly. India too has millions of vehicles, of which more than 65% are two wheelers operating on petrol.



Types of air pollutants

1. **Carbon compounds** *(e.g.,* CO_2, CO)
2. **Sulphur compounds** *(e.g.,* SO_2, H_2S and H_2SO_4)
3. **Nitrogen oxides (*e.g.*, NO, NO_2 and HNO_3)**
4. **Ozone (O_3)**
5. **Flurocarbons;**
6. **Hydrocarbons *(e.g.*, benzene, benzypyrene, etc.)**
7. **Metals *(e.g.*, lead, nickel, arsenic, beryllium, tin, vanadium, titanium, cadmium, etc.)**
8. **Photochemical products *(e.g.*, olefins, aldehydes, photochemical smog, PAN, PB2N, etc.)**
9. **Particulate matter *(e.g.*, fly ash, dust, grit and SPM); and**
10. **Toxicants**.

Table 14-1. **Common air pollutants, their sources and pathological effects on man (Source: Southwick, 1976)**

Pollutants	Where they come from (source)	Pathological effect on man
1. Aldehydes	Thermal decomposition of fats, oil, or glycerol.	Irritate nasal and respiratory tracts.
2. Ammonias	Chemical processes—dye-making; explosives, lacquer; fertilizer.	Inflame upper respiratory passages.
3. Arsines	Processes involving metals or acids containing arsenic soldering.	Break down red cells in blood, damage kidneys; cause jaundice.
4. Carbon monoxides	Gasoline motor exhausts; burning of coal.	Reduce oxygen-carrying capacity of blood.
5. Chlorines	Bleaching cotton and flour; many other chemical processes.	Attack entire respiratory tract and mucous membranes of eyes; cause pulmonary edema.
6. Hydrogen cyanides	Fumigation; blast furnaces, chemical manufacturing; metal plating.	Interfere with nerve cells; produce dry throat, indistinct vision, headache.
7. Hydrogen fluorides	Petroleum refining; glass etching; aluminium and fertilizer production.	Irritate and corrode all body passages.
8. Hydrogen sulphides	Refineries and chemical industries; bituminous fuels.	Smell like rotten eggs; cause nausea; irritate eyes and throat.
9. Nitrogen oxides	Motor vehicle exhausts; soft coal.	Inhibit cilia action so that soot and dust penetrate far into the lungs.
10. Phosgenes (carbonyl chloride, $COCl_2$)	Chemical and dye manufacturing.	Induce coughing, irritation, and sometimes fatal pulmonary edema.
11. Sulphur	Coal and oil combustion.	Cause chest constriction, headache, vomiting, and death from respiratory ailments.
12. Suspended particles (ash, soot, smoke)	Incinerators; almost any type of manufacturing.	Cause emphysema, eye irritations and possibly cancer.

Ecology of Air Pollution

A. Gaseous Pollutants

1. Sulphur oxides and hydrogen sulphide. These gaseous pollutants are naturally released by the biological decomposition and from volcanic eruptions. They are also released artificially due to human activities such as smelting of sulphide-containing ores, combustion of sulphur containing fuels such as coal and oil, petroleum refining and obtaining of geothermal energy. Lichens are particularly sensitive to SO2 and in polluted regions one does not find lichens growing on the tree trunks. Thus, lower quantities of sulphur dioxide suppresses the overall vegetative as well as reproductive growth and yield. Its high atmospheric concentrations produce various injuries to leaves such as inter-veinal and blade damage, necrosis of leaves and cellular collapse. However, moderate SO2 pollution results in chlorosis of leaves without cellular collapse. Further, in the atmosphere, SO2 does not remain in the gaseous state for long time, but very soon it reacts with moisture to form sulphuric acid or H2SO4. Sulphuric acid causes many respiratory diseases in man and also produces **acid rainfalls** over parts of the earth.

2. Carbon monoxide. It is released chiefly from gasoline engines and burning of coal in the defective furnaces. In man, CO produces headache, dizziness, inability to distinguish time intervals, nausea, ringing in the ears, heart palpitation, pressure in chest and difficulty in breathing. This gas combines with haemoglobin of blood to form carboxy-heamog-lobin in RBC which reduces its oxygen carrying capacity to all parts of body and, thus, causing asphyxia. The higher concentrations of carbon monoxide (CO) may be even fatal.

3. Nitrogen oxides. The natural sources of this pollutant are anaerobic bacterial breakdown of nitrogenous compounds, forest fires and lightning. Nitrogen dioxide (NO_2), a pungent gas that produces a brownish haze, causes nose and eye irritations and pulmonary discomfort in man. It also produces general and pulmonary oedema and hemorrhage. In plants, NO_2 brings about bifacial necrosis leading to collapse of leaves, enhancement of green colour followed by chlorosis and extensive leaf drop.

Photochemical smog. In the atmosphere nitrogen dioxide is reduced by ultraviolet light to nitrogen monoxide and atomic oxygen :

$NO_2 \rightarrow NO + O$ Atomic oxygen reacts with oxygen to form ozone.

$O_2 + O \rightarrow O_3$ Ozone reacts with nitrogen monoxide to form nitrogen dioxide and oxygen, thus, closing the cycle : $NO + O_3 \rightarrow NO_2 + O_2$

In the presence of sun light, atomic oxygen from the photochemical reduction of NO_2 also reacts with a number of reactive hydrocarbons (such as methane, ethane, toluene, etc., all of which originate from burning of fossil fuels or directly from plants) to form reactive intermediates called **radicals.** These radicals then take part in a series of reactions to form still more radicals that combine with oxygen, hydrocarbons, and NO_2. As a result nitrogen dioxide is regenerated, nitric oxide disappears, ozone accumulates and a number of secondary pollutants are formed such as formaldehyde, aldehydes and peroxyacetyl nitrate or PAN ($C_2H_3O_5N$). All of these collectively form **photochemical smog**.

4. Ozone. Levels of ozone (O3) may rise in atmosphere due to human activities. formed by NO2 under UV-radiations effect. Minor amounts of ozone are also added to the atmosphere by electric discharges such as lightning flashes, by vertical flux of stratospheric ozone and by tropospheric storms. Ozone near the earth's surface in the troposphere creates pollution problem. Increase in O3 concentration near earth's surface is toxic to plants reducing crop yields significantly. It also has adverse effects on human health. Thus, while higher levels of O3 in the atmosphere protects us, it is harmful when it comes in direct contact with us and plants at earth's surface.

Table 14-2. **Effects of ozone (O3) on human health.**

Concentration (ppm)	Effects observed
0.2	No ill effects
0.3	Nose and throat irritation
1.0–3.0	Extreme fatigue after 2 hrs.
9.0	Severe pulmonary oedema

5. Fluorocarbons (Hydrogen fluoride). Natural sources of fluorides in the atmosphere are active volcanoes. Their man-made or artificial sources are petroleum refining, aluminum, steel and electrochemical reduction plants, blast furnaces, brick-kilns, and tile, glass etching and superphosphate fertilizer industries and combustion of coal. Fluoride burns the tip of plant leaves. It's low amounts impair plant growth, result in excessive dropping of bloom and young fruits, development of small, partially or completely seedless fruits and premature formation of soft red flesh and splitting of peach. In human being, it irritates and corrode all body passages.

6. Hydrocarbons. Biological decomposition of organic matter, spill and seepage from natural gas and oil fields and volatile emissions from plants are some major natural causes for the release of hydrocarbons such as methane, terpenes, ethylene and aniline. Incomplete combustion of fuels, automobile exhaust (Fig. 14.1), petroleum-refineries, agricultural burning, motor fuel marketing, manufacture of explosives and cracking of natural gas in petrochemical plants (as a blow-off emissions) constitute the man-made sources that emit hydrocarbons. The hydrocarbon **ethylene** causes yellowing and occasional necrosis of leaves, chlorosis of floral buds, inhibition of terminal growth, epinasty of leaves, shortening of internodes, thickening of stems, lack of apical dominance, stunted growth, dry sepal disease of orchids and decrease in the amount of chlorophyll. Another hydrocarbon **aniline** results in the appearance of bands on leaves as if they are water-soaked, necrotic spots and abscission of leaves. In man, hydrocarbons bring about irritation of mucous membrane, bronchial constriction and eye irritation.

7. Hydrogen chloride. This pollutant is released from combustion of coal, paper, plastics, chlorinated hydrocarbons, accidental spills from the chemical manufacturing plants and ignition of solid-fuel rocket engines in plants, hydrogen chloride causes plasmolysis and collapse of epidermal cells of leaves.

8. Ammonia. The main anthropogenic sources of this gaseous pollutant are refrigerator, pre-cooler systems of cold storages, manufacture of dyes, explosives, lacquers (varnishes) and anhydrous ammonium fertilizers and nitric acids and domestic incineration. Ammonia causes in plants, bleaching of leaves, rusty spots on leaves and flowers, reduction of root and shoot growth. In man, it inflames upper respiratory passages.

9. Tobacco smoke. Tobacco smoke contains about 300 chemical compounds including nicotine and carcinogens such as tar ("aromatic hydrocarbon"). It is mainly produced by smoking cigarettes and bidis. It is gradually becoming a pollutant especially in closed atmospheres such as buses, trains, auditoria, discotheques and so on. **Nicotine** stimulates some types of synapse of nervous system, increase blood pressure and heart rate by the production of adrenaline, causes vasodilation in the muscles and vaso-constriction in the skin. When a person smokes, tiny particles in the smoke get caught on the lining of the windpipe and bronchial tubes. Extra mucus is produced and the cilia stop beating. The mucus collects in the bronchial tube and this gives rise to a "smoker's cough".

B. Particulate Pollutants

1. Fluorides. The particulate fluorides originate in the same way as the gaseous fluorides. They settle and accumulate on the grass and other vegetation. They are less toxic to these plants causing occasional leaf-tip burns. However, ingestion by cattle of various fluorine compounds falling on forage, causes **fluorosis,** a disease characterized by abnormal calcification of bones and teeth, eventually resulting in loss of teeth, body weight and in lameness.

2. Lead. Lead, a heavy metal, is injected in the atmosphere mainly from automobile exhaust. Automobile gasoline contains tetraethyl lead that is used as an antiknock additive. Lead is emitted into the air with the exhaust as volatile **lead halides** (bromides and chlorides). About 75% of lead burnt in gasoline comes out as lead halides through tail pipe in exhaust gases. Of this about 40% settles immediately on the ground and the rest (60%) goes into air. That is why its concentration is higher in urban areas where automotive and industrial exhausts are more.

3. Mercury. It is a liquid volatile heavy metal which is found in rocks and soil. It is present in air due to human activities such as the use of mercury compounds in production of fungicides, paints, cosmetics, paper pulp, etc. Inhalation of 1 mg/m3 of mercury in air for three months may lead to human death. Nervous system, liver and eyes are damaged. Infant may be deformed. Other symptoms of mercury toxicity are headache, fatigue, anxiety, lethargy, loss of appetite, etc.

4. Zinc. Zinc in air occurs mostly as white zinc oxide fumes and is toxic to man. It exists in air around zinc smelters and scrap zinc refineries.

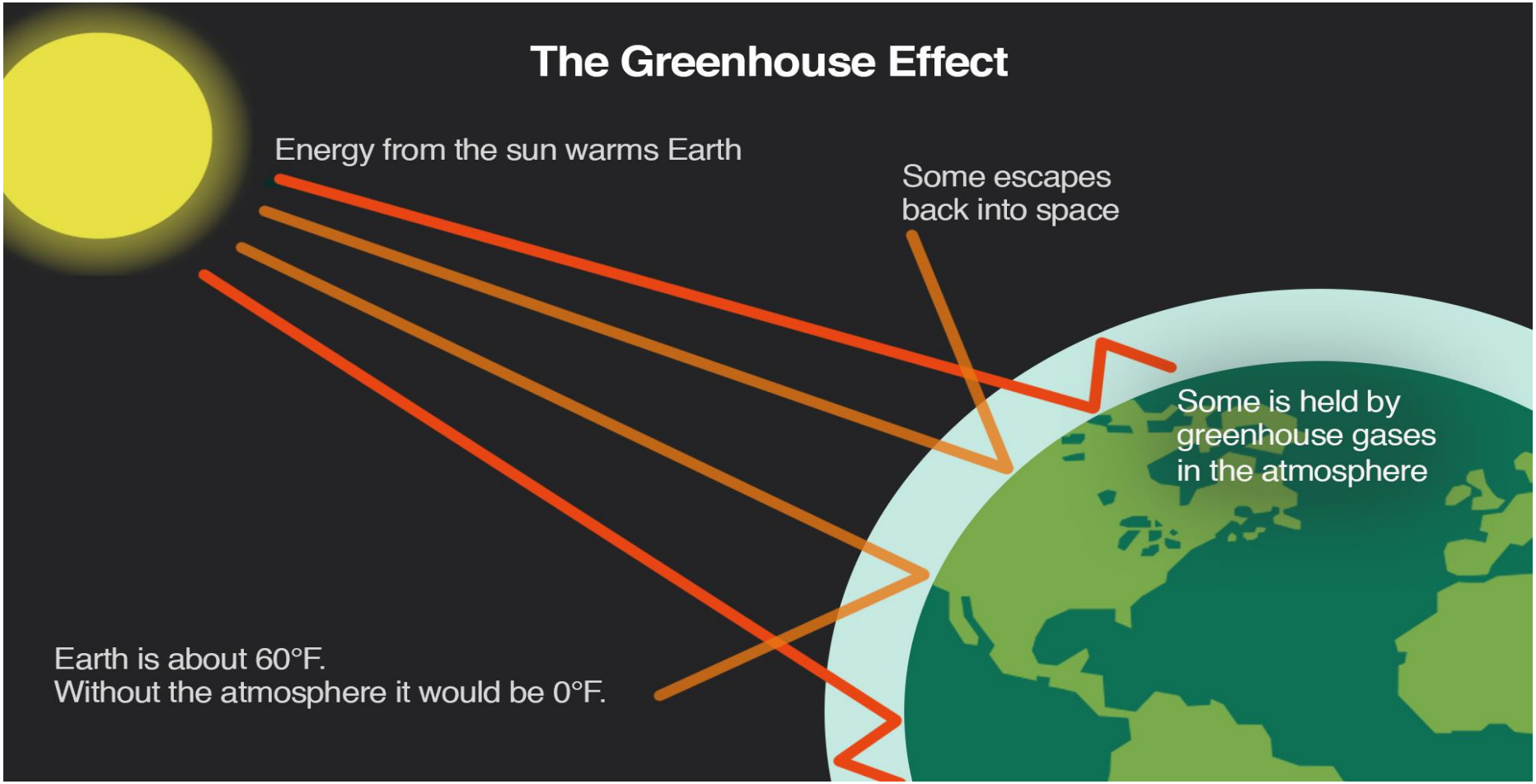
5. Cadmium. This metal is emitted to air by human activities and industries (*e.g.*, electroplating and welding of cadmium containing materials; industries producing pesticides and phosphate fertilizers. Cadmium occurs in the air in the form of oxide, sulphate or chloride compounds. It is poisonous at very low levels and is known to accumulate in human liver and kidney, Cadmium causes hypertension, emphysema and kidney damage. It may also act as carcinogen in mammals.

6. Potassium salts. These particulate pollutants are derived mainly from potash mines and cause in plants abnormalities such as branch tip death, chlorosis and necrosis of leaves.

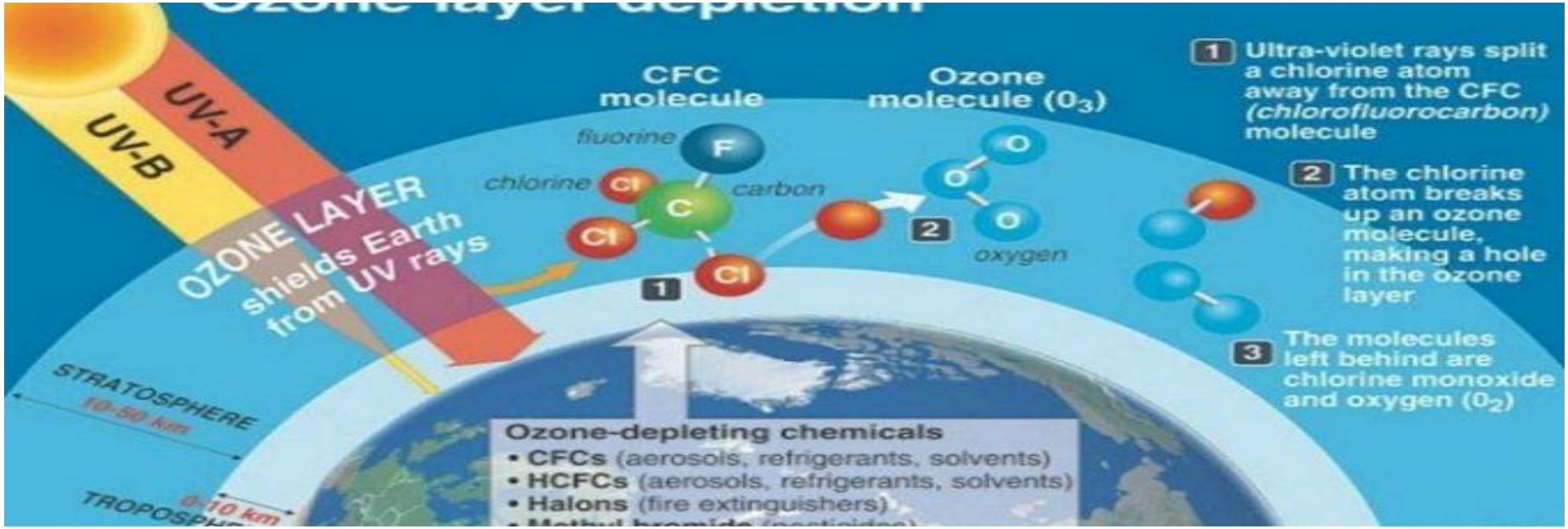
7. Sodium chloride. Certain de-icing salts such as sodium chloride, used to remove ice and snow from roads in winters, are found to cause multiple damage to the roadside trees such as leaf necrosis, defoliation, suppression of flowering, and dieback of terminal shoots in apple.

8. Agricultural chemicals. Several types of chemicals such as insecticides, herbicides, fungicides and pesticides, used widely in agriculture are found to result in foliar lesions, chlorosis and abscission of leaves and reduction in fruit set.

9. Particulate matter. The word particulate has been derived from particle and includes all solid or liquid substances primarily in the air. Particulate matter is usually divided into two categories : suspended particulates and dust fall.



The increased amount of CO_2 in atmosphere is found to increase the temperature of earth. The spectral properties of CO_2 in the atmosphere are such that it tends to prevent the long wave radiations (i.e., infra-red heat radiation) from earth from escaping into outer space and deflect it back to earth. The latter has an increased temperature at surface (**Turk** *et. al., 1974).* This phenomenon is called **atmospheric effect (Lee,** 1974) or **greenhouse effect** (see **Southwick**, 1976, **Smith,** 1977). The simultaneous cooling and heating effects of air pollution on earth have increased variability in the world-wide weather patterns which may be a serious threat to global food production



Peeling of ozone umbrella by CFMs. Certain fluorocarbon compounds which are called chlorofluoromethanes or CFMs or "freon" are used as propellants in pressurized aerosol cans. They are inert in normal chemical and physical reactions, but they get accumulated in greater amounts at high altitudes and there in the stratosphere these inert gaseous compounds (*i.e.*, CFMs) release chlorine atoms under the influence of intense short-wave ultraviolet radiation. Each atom of chlorine chain then reacts with more than 1,00,000 molecules of ozone, converting ozone to oxygen. The reduction in stratospheric ozone permits greater penetration of ultraviolet light, which intensifies UV radiation at the earth's surface. Some scientists such as **Ahmed** (1975), **Brodeur** (1975), and **Russell** (1975), feel that this intensified radiation will cause a significant increase in skin cancer and eventually have a lethal effects on many organisms, including man. In plants such enhanced level of UV radiations are feared to cause stunted growth, short, thick stems, smaller leaves, plasmolysis of cells, destruction of anthocyanin, chlorophyll and nuclei.

Water Pollution

The term **water pollution** is referred to any type of aquatic contamination between following two extremes: (1) a highly enriched, over productive biotic community, such as a river or lake with nutrients from sewage or fertilizer (**cultural eutrophication**), or (2) a body of water poisoned by toxic chemicals which eliminate living organisms or even exclude all forms of life (see **Southwick**, 1976). Normally water contains two types of impurities- dissolved and suspended. Dissolved impurities are gases (H_2S, CO_2, NH_3, etc.) and minerals (Ca, Mg, Na, salts). Suspended matter includes clay, silt and sand and even microbes. Polluted waters are turbid, unpleasant, foul smelling, unfit for drinking, bathing and washing or other purposes. They are harmful and means of many diseases as cholera, dysentery, typhoid, hepatitis, etc.

Types of Water Pollution

Types of water pollution may be classified by the *medium* in which they occur, such as surface water pollution, ground water pollution, soil water pollution, etc.; the *habitat* in which they occur, such as river pollution, lake pollution, estuarine pollution, coastal water pollution, open ocean pollution, etc.; and *source* or *type* of contamination, such as nutrient pollution, bacterial pollution, viral pollution, metallic pollution, petrochemical pollution, pesticide pollution, thermal pollution, radioactive pollution, etc.

Pollutants entering water sources are classified broadly into following categories: domestic sewage and oxygen-demanding wastes; infectious agents; plant nutrients; chemicals such as insecticides, herbicides, and detergents; other minerals and chemicals; sediment from land erosions; radioactive substances; and heat from power and industrial plants. These aquatic pollutants come from many sources. Excessive nutrients, such as nitrates and phosphates, commonly originate in domestic sewage, run-off from agricultural fertilizer, waste materials from animal feed lots, packing plants, etc. Toxic chemicals as agents of water pollution originate in industrial operations, acid mine drainage, surface erosion from strip mines, washing of herbicides and insecticides, radioactive fall out from atomic explosion, and commercial accidents such as oil spills or the rupture of chemical tanks.

Ecology of Water Pollution

1. Sewage Pollution

Contamination of freshwaters and shallow offshore seas by sewage is a common occurrence. Domestic sewage and waste-water is about 99.9 per cent water and 0.02-0.04 per cent solids of which proteins and carbohydrates each comprise 40–50 per cent and fats 5–10 per cent (**Simmons**, 1974). In other words, sewage includes mostly biodegradable pollutants such as human faecal matter, animal wastes, and certain dissolved organic compounds *(e.g.*, carbohydrates, urea, etc.) and inorganic salts such as nitrates and phosphates of detergents and sodium, potassium, calcium and chloride ions. Under natural processes most of the biodegradable pollutants of sewage are rapidly decomposed, but, when they accumulate in large quantities, they create problem, *i. e.*, when their input into environment exceeds the decomposition or dispersal capacity of the latter. Developing countries such as India have evolved certain engineering systems, such as, **septic tanks, oxidation ponds, filter beds, waste water treatment plants and municipal sewage treatment plants** for the removal of many harmful bacteria and other microbes, organic wastes and other pollutants from the sewage, before it is tipped into river or sea.

Sewage treatment is usually performed in following three stages: (1) **Primary treatment**, which removes large objects and suspended un-dissolved solids of raw sewage and converts them into a biologically inactive and aesthetically inoffensive state, the **sludge,** a valuable fertilizer. (2) **Secondary treatment,** which supplies aeration and bacteriological action to decompose organic compounds into harmless substances such as CO2, sulphate and water. (3) **Tertiary treatment,** which removes nitrates and phosphates and releases pure water. These three stages of sewage treatment have become increasingly expensive and only in most advanced countries all the three treatments of sewage are done.

BOD test. BOD or biological oxygen demand is the amount of oxygen required for biological oxidation by microbes in any unit volume of water. The test is done at 20°C for at least five days. BOD value generally approximates the amount of oxidisable organic matter (such as sewage and other organic wastes, animals and human excreta, all of which are called **oxygen demanding wastes)** and is, therefore, used as a measure of degree of water pollution and waste level. Thus, due to addition of sewage and waste, oxygen levels are depleted which are reflected in terms of BOD values of water. The quantity of oxygen in water (called **dissolved oxygen** or **DO)** along with BOD is indicated by the kind of organism present in water. For example, fish become rare at DO value of 4 to 5 ppm of water. Further decrease in DO value may lead to increase in anaerobic bacteria. Typical BOD value for raw sewage run from 200 to 400 mg of oxygen per liter of water (therefore, 200—400 ppm). Water for drinking should have a BOD less than 1.

Eutrophication. According to **Hutchinson** (1969), the eutrophication is a natural process which literally means "well nourished or enriched." It is a natural state in many lakes and ponds which have a rich supply of nutrients, and it also occurs as part of the aging process in lakes, as nutrients accumulate through natural succession. Eutrophication becomes excessive, however, when abnormally high amounts of nutrients from sewage, fertilizer, animal wastes and detergents, enter streams and lakes, causing excessive growth or 'bloom' of microorganisms and aquatic vegetation. Most secondary sewage treatment plants, though, precipitate solids and inactivate most bacteria in domestic sewage, yet they do not remove the basic nutrients such as ammonia, nitrogen, nitrates, nitrites and phosphates. These nutrients stimulate the growth algae and referred to as "Algal Bloom"

Eutrophication in a Pond

Effects of organic pollution on aquatic animal life. Organic pollution tends to bring about changes in faunal composition in a freshwater ecosystem. Nymphs of stone flies and may flies are the first to disappear from water which has high organic pollution. As pollution increases, caddishfly larvae and many fish which require high levels of environmental oxygen move into less polluted area of the stream. Shrimps, water fleas, leeches; snails and most of the fish vanish as the pollution becomes severe. At such levels of pollution there is very little of dissolved oxygen and the animals present are chironomid larvae (blood worms) and the oligochaete worms *Tubifex*. Some decomposing plants are known to produce toxins as **strychnine** which kills animals including cattle.

2. Industrial Pollution

Most of the Indian rivers and freshwater streams are seriously polluted by industrial waste of effluents (see Table 14-3). **Effluents** are waste products in a liquid form resulting from industrial processes and domestic activities. They are released by different industries such as petro-chemical complexes; fertilizer factories; oil refineries; pulp, paper, textile, sugar and steel mills, tanneries, distilleries, coal washeries, synthetic material plants for drugs, fibres, rubber, plastics, etc. The industrial wastes of these industries and mills include metals (copper, zinc, lead, mercury, etc.), detergents, petroleum, acids, alkalis, phenols, carbamates, alcohols, cyanide, arsenic, chlorine and many other inorganic and organic toxicants. All of these chemicals of industrial waste are toxic to animals and many cause death or sublethal pathology of the liver, kidneys, reproductive systems, respiratory systems, or nervous systems in both invertebrate and vertebrate aquatic animals.

Heavy fish mortality in river **Sone** near Dehri-on-sone in Bihar is reported to cause by free chlorine content of the chemical wastes discharged by factories near Mirzapur in U.P.

3. Thermal Pollution

Various industrial processes may utilize water for cooling, and resultant warmed water has often been discharged into streams or lakes. Coal-or oil-fired generators and atomic energy plants cause into large amount of waste heat which is carried away as hot water and cause **thermal pollution or calefaction** (warming). Thermal pollution produces distinct charges in aquatic biota. A temperature rise of 10°C will double the rate of many chemical reactions and so the decay of the organic matter, the rusting of iron and the solution rate of salts are also accelerated by calefaction. Since the rate of exchange of salts in organisms increase, any toxin is liable to exert greater effects and temperature fluctuations are likely to affect organisms. Some plants and animals are killed outright by the very hot water. Other adverse effects of aquatic pollution on aquatic life include (i) early hatching of fish eggs, (ii) failure of trout eggs to hatch; (iii) failure of salmon to spawn, (iv) increase in BOD, *i.e.*, solubility of oxygen is reduced causing deoxygenation; (v) change in diurnal and seasonal behaviour and metabolic responses of organisms; (vi) significant shift in algal forms and other organisms towards more heat tolerant forms (this leads to decrease in species diversity); (vii) affect changes in macrophytes and (viii) migration of some aquatic forms.

4. Silt Pollution

As a result of intensive agriculture, earth moving for construction projects, poor conservation practices and downpour with resultant floods, is the increased production of silt in streams and lakes. This load of particulate matter cuts down primary productivity by decreasing the depth of light penetration. Silt may also interrupt or prevent the reproduction of fish, by smothering eggs laid on the bottom.

Table 14-3. Some Indian rivers and their major sources of pollution.

Name of the river	Sources of pollution
1. Kali at Meerut (U.P.)	Sugar mills; distilleries; paint, soap, rayon, silk, yarn, tin and glycerine industries.
2. Jamuna near Delhi	D.D.T. factory, sewage, Indraprastha Power Station, Delhi.
3. Ganga at Kanpur	Jute chemical, metal, and surgical industries; tanneries, textile mills and great bulk of domestic sewage of highly organic nature.
4. Gomati near Lucknow (U.P.)	Paper and pulp mills; sewage.
5. Dajora in Bareilly (U.P.)	Synthetic rubber factories.
6. Damodar between Bokaro and Panchet	Fertilizers, fly ash from steel mills, suspended coal particles from washeries, and thermal power station.
7. Hooghly near Calcutta	Power Stations; paper pulp, jute, textile, chemical mills, paint, varnishes, metal, steel, hydrogenated vegetable oils, rayon, and soap, match, shellack, and polythene industries and sewage.
8. Sone at Dalmianagar (Bihar)	Cement, pulp and paper mills.
9. Bhadra (Karnataka)	Pulp, paper and steel industries.
10. Cooum, Adyar and Buckinghum canal (Madras)	Domestic sewage, automobile workshops.
11. Cauvery (Tamil Nadu)	Sewage, tanneries, distilleries, paper and rayon mills.
12. Godavari	Paper mills.
13. Siwan (Bihar)	Paper, sulphur, cement, sugar mills.
14. Kulu (between Bombay and Kalyan)	Chemical factories, rayon mills and tanneries.
15. Suwao (in Balrampur)	Sugar industries.

Biomagnification or bioamplification. Many of pesticides, such as DDT, aldrin and dieldrin, have a long life time in the environment. They are fat-soluble and generally not biodegradable. They get incorporated into the food chain and ultimately deposited in the fatty tissues of animals and man. In the food chain, because of their build up, they get magnified in the higher trophic levels (called **biological magnification** or **biological amplification).** The pesticides have been in use during last 50 years. Their targets are insect pests, fungi, nematodes and rodents which damage crops. But these pesticides have created great problems for non-target organisms consisting largely beneficial species such as earthworms, honeybees, fish, amphibia, some reptiles, birds, mammals and man. The phenomenon of biological magnification is also reported for certain other pollutants such as heavy metals such as lead, mercury and copper and radioactive substances as strontium-90.

Toxicity of pesticides. The toxicity of organo-chlorine pesticides (*i.e.*, DDT or Dichlorodiphenyl trichloroethane, hexachlorocyclohexane, chlordane, aldrin, dieldrin, etc.) lies in their inhibiting Na+, K+ and Mg+ adenosine triphosphatase activity in the nerve endings of animals particularly insects. It affects the sensory, motor nerve fibers and the motor cortex (**Matsuma** and **Patil,** 1961). In the giant axons of cockroach, DDT is known to influence the efflux of potassium ions from the axon. DDT and other organochlorine pesticides are absorbed from the intestinal tract, from the alveoli of lungs and also through the skin, if the pesticides are in solution A high concentration of DDT causes brain damage, centrolobular necrosis of the liver, and liver enlargement in small mammals. Concentration as low as 5—10 ppm in diet cause liver damage. In some birds, DDT concentration of 1—3 ppm destroys the female sex hormone and the egg shell becomes so thin that the eggs break when the parents sit on them for hatching. Organophosphorus insecticides are absorbed by the gastrointestinal and respiratory tracts and the skin. These insecticides inhibit the **acetylcholinesterase** (**Ach E**) enzyme. Thus, an abnormal accumulation of endogenous acetylcholine occurs. This cause excessive activity of the para-sympathetic system, in the form of sweating, abdominal cramp, chest discomfort, vomiting, over-activity of smooth muscles, and so on. It also causes headache, nervousness, and over activity of voluntary muscles. The nervous system is also adversely affected.

Marine Pollution

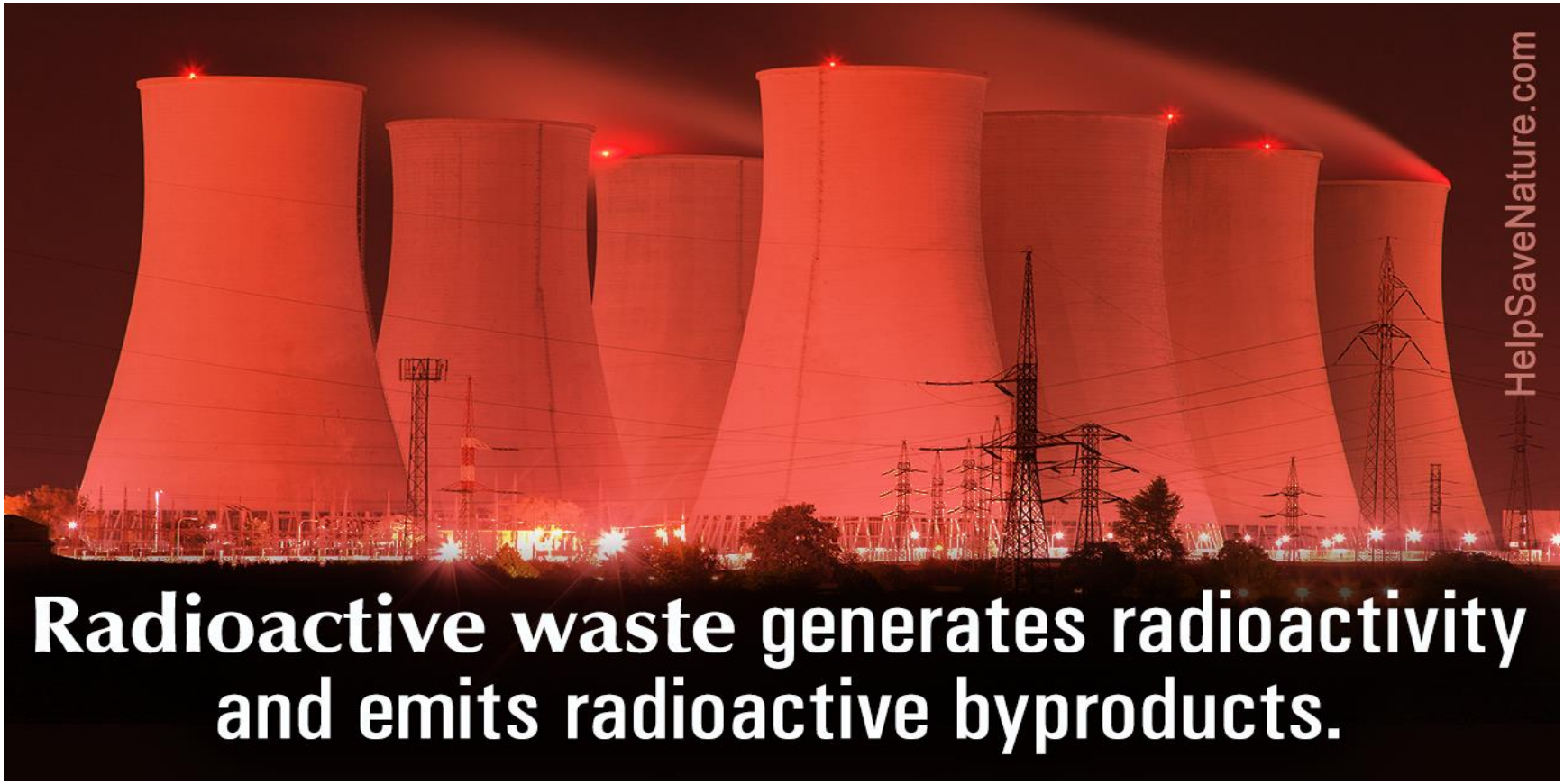
Oil is the most apparent pollutant of the ocean. It discharged into the sea either deliberately when oil tankers are washed out prior to reloading or in accidental spills when tankers are wrecked (during war or otherwise). In coastal areas when oil spreads on the water surface, it clogs the feathers of diving birds making their flight impossible. White preening themselves in an attempt to clear the plumage, they swallow enough oil to poison themselves. Apart from these, oil interferes with the insulation provided by the feathers and the birds die of cold or become susceptible to pneumonia. When oil covers the rocks and sea weeds, molluscs and crustaceans growing on them die. Oil-spills on the coasts of sea-side resorts, drive away holiday makers, affecting the economy of the place.

Land Pollution

The land pollution is caused by solid wastes and chemicals. There are many examples of land that has been stripped of vegetation by industrial development and disposal of waste.

The slag heaps from mines bear witness to the destructive effects which this can have on our environment. Areas around smelting and mining complexes are usually soiled by metals such as cadmium, zinc, lead, copper, arsenic and nickel. These are not only phytotoxic even in small amounts but also render plants unsafe for human and animal consumption. Zinc, often with cadmium, is released into the environment during the use or breakdown of lubricating oils, vehicle tyres, galvanized metals and fertilizers. The major sources of land pollution are the industries such as pulp and paper mills, sugar mills, oil refineries, power and heating plants, chemicals and fertilizer manufacturing units, iron and steel plants, plastic and rubber producing complexes and so on. Huge amounts of solid wastes are either dumped, burnt, or emptied into rivers and seas. Most industrial furnaces produce a grey, powdery residue of unburnt material known as fly ash. The fly ash, cinders, solid wastes and litter all are thrown away by industries and form huge mounds which spoil the landscape. Some common examples are groceries, food scraps, vegetable remains, packing materials, cans, cardboard cartons, rags, paper, cinders, ash, broken gadgets, wood, worn-out furniture, metals, bones of dead animals, plastics, polythene bags, ceramics, glass, aluminium, rubber, leather, construction rubbish, brick, sand and other junk. Some man-made materials can be used again such as paper, scrap metal, glass, polythene, plastic, etc. But the majority of these cannot be reused and must be got rid of somehow. All these go to constitute heaps of municipal refuse. If not properly disposed, this rubbish can prove perilous, filthy and unhygienic. Such places often become a home for rats, flies, mosquitoes, bacteria and many other vectors, which may spread numerous human diseases.

Radioactive Pollution



Radioactive isotopes, or radionuclides, are forms of elements with unstable atomic nuclei; that is, they decompose with ionizing radiation in the form of alpha or beta particles, or gamma rays. Many radioisotopes, such as radium-226, uranium-235 or238, thorium-232, potassium-40, or carbon-14, occur naturally in rocks and soil. Other radioisotopes such as those of cesium, cobalt, iodine, krypton. Of more than 450 radioactive isotopes which can occur as fission products, only a few are of major environmental con-cern. These are primarily argon-41, cobalt-60, cesium-137, iodine-131, krypton-85, strontium-90, tritium and plutonium-239

Strontium-90, for example, normally occurs in radioactive fallout, has a half-life of 28 years and behaves like calcium in biogeochemical cycles. Thus it is absorbed by plants, ingested by animals and deposited in bone tissues close to blood forming tissue. Strontium-90 can also concentrate in natural biological systems in following method: water → bottom sediments → aquatic plants → freshwater clams → minnows and small fish → musk rats. It is demonstrated that due to this food chain musk rats concentrate strontium-90, 3500 times above the levels of the water in which they live. Grazing animals concentrate strontium-90 by ingesting it through grass and forage, and it can then be passed on to humans through milk. Radioactive phosphate, cesium and iodine-132 also can readily accumulate in plants and animals through natural food chains. However, in food chains involving arthropods radioactive isotopes of potassium, sodium, and phosphorus accumulate, but isotopes of strontium and cobalt do not