chemicals. Good soil and a congenial climate for productivity are valuable assets for any nation. But due to human activities, soil is the receptor of many pollutants.

WHAT IS SOIL

The word **soil** is derived from a Latin word Solum, which means earthy material in which plants grow. Soil study is commonly referred to as **Soil Science or Pedology (Pedos-Earth) or Edaphology (Edaphos soil). Soil** *can be defined as the weathered layer of the earth's crust with living organisms and their products of decay intermingled.*

Soil is the upper most part of the earth crust and is a mixture of organic as well as weathered rock and materials necessary for the plant growth. Soil is also the medium for detritus food chain.

Soil is a highly generalized structure of the shallow upper layers of land surface of the earth, which by weathering of underlying rocks, intimate association with organic matter and with living organisms, has become a suitable habitat for the living beings.

Soil is a mineral material that exists in solid or unbroken form like boulders and gravels or finely divided particles of mineral matters such as sand, silt or clay, depending upon the texture.

Soil is a natural body of animal, mineral and organic constituents which differ from the material below in morphology, chemical constituents, composition and biological characteristics.

Soil is the result of the actions and reciprocal influences of parent rocks, climate, topography, plants and animals with aging of land.

Soil is a complex physico-biological system providing water, mineral salts, nutrients, dissolved oxygen and anchorage to plants.

Any part of the earth's surface that support vegetation also bears a covering of soil. Muddy bottoms of ponds, porous rock surfaces, bottoms of lakes, peats or glacial deposits are all soils.

SOIL FORMATION

Soil system is indeed very complex and dynamic. Soil is actually formed as a result of long term process of complex interactions, disintegration and decomposition of rocks due to weathering leading to the production of mineral matrix in close association with interstitial organic matter. Although soils are formed from the underlying rocks, these may be transported to long distances by **rivers, glaciers** and **strong winds**. **Sand** and **clay** constitute the hard mineral fractions of the soil. Actually humus mixed with sand and clay results in the formation of soil. The whole process of soil formation involves two stages *i.e.,* weathering and soil development or pedogenesis.

A. Weathering Process.

It involves the breakdown of bigger rocks into fine, smaller mineral particles and may be physical or chemical.

1. Physical Weathering. Agents such as temperature, water, ice, gravity and wind etc., exert mechanical effect on the rocks as a result of which fragments are broken down to

regoliths. Physical weathering includes several processes like wetting-drying, heating-cooling, freezing, glacination, solution and sand blast.

2. Chemical Weathering. The presence of moisture and air are essential for chemical weathering. It takes place through the following reactions :

- **Solution.** Water soluble minerals like gypsum, limestone etc., of the weathered rock get weathered by the solvent action which increases in the presence of carbon dioxide and organic acids, formed by the decay of organic remains of plants and animals. The solution of these minerals gets absorbed on the surface of negatively charged colloidal particles or removed by leaching.
- **Hydrolysis.** Hydrolysis mostly takes place in combination with other reactions (such as oxidation, reduction or carbonation) and involves the chemical action of water with strong bases producing hydroxides of iron, magnesium, aluminium and calcium etc. For example,

$$\underset{\text{Orthoclase(Primary mineral)}}{K_2Al_2Si_6O_{16}} + 2H_2O + CO_2 \longrightarrow \underset{\text{Kaolin (Secondary clay mineral)}}{Al_2O_3.2SiO_2.2H_2O} + 4SiO_2 + K_2CO_3$$

The process of hydrolysis releases Ca, Mg, K, Na and silicates into the soil solution. These materials enhance the growth of plants in the soil.

- **Oxidation.** In this process oxygen reacts with minerals to produce oxides. The latter when dissolved in water weaken the rock and bring about weathering. Oxidation occurs best in well aerated and well drained soil. For example, oxidation of iron in the minerals gives red ferric oxide.

$$4FeO + O_2 \longrightarrow 2Fe_2O_3$$

Oxides and sulphides of iron, aluminium and manganese etc., are easily oxidised and cause the chemical weathering of rocks.

- **Reduction.** The red ferric oxide may also be reduced to grey ferrous oxide. The reduction mainly occurs in deep zones of earth crust, which are poorly aerated.

$$2Fe_2O_3 \longrightarrow 4FeO + O_2$$

- **Carbonation.** The process of carbonation is the combination of CO_2 and H_2O to form carbonic acid. The latter combines with hydroxides of Ca, Mg and other minerals of the rock to form carbonates as well as bicarbonates.

$$CO_2 + H_2O \rightleftharpoons H_2CO_3 \quad Ca(OH)_2 + CO_2 \longrightarrow CaCO_3 + H_2O$$

$$CaCO_3 + H_2O + CO_2 \longrightarrow Ca(HCO_3)_2$$

The sparingly soluble carbonates of these minerals either accumulate deeper in the rock material or carried away, depending upon the amount of water passing through.

- **Hydration.** In this process water molecules get attached to the rock material. As a result of hydration, volume of the original material increases and hydrated mineral becomes soft. The soft rock can be readily weathered.

$$\underset{\text{Haematite}}{2Fe_2O_3} + 3H_2O \longrightarrow \underset{\text{Limonite}}{2Fe_2O_3.3H_2O} \; ; \; CaSO_4 + 2H_2O \longrightarrow CaSO_4.2H_2O$$

3. Biological Weathering. A number of micro-organisms such as bacteria, fungi, protozoa, lichens and mosses transform the rock into a dynamic system, storing energy and synthesizing organic matter. As a result, physical structure as well as mineral composition of the rock undergo some change. The lichens and mosses extract mineral nutrients such as Mg, Ca, Na, K, Fe, P, Si, Al etc., from the rock. These nutrients are combined with organic matter and thereby return to the developing soil when the vegetation decomposes.

The soil formed by weathering of soil forming rocks is known as primary soil or embryonic soil. The latter may mature into **residual soil or sedimentary soil** (mature soil lying immediately over the parent rock), **immature soil** (partly weathered material without maturation) and **secondary or transported soil** (weathered parent material has been transported to different places by moraine soil), glacial drift and tilt (agency of glacier), **alluvial soil** (streams and rivers), **colluvial soil** (gravitational forces as landslides), aeolian soil (wind), **sand dunes** (sand storms) and **marine soil** (oceanic waves) etc.

The soils have also been classified as zonal, intrazonal and azonal soils. Soils are called **zonal soils**, because climate is the important factor over the process of soil formation. The soils are called **intrazonal soils**, because local geological conditions preclude the normal pattern of soil formation. **Alluvial soil** is an example of **azonal soil**. This soil is rich in colloids, and because it is not leached, it may also be rich in nutrient materials. It however, lacks **humus**, which is finely divided, amorphous, incompletely decomposed black coloured matter added to the mineral matter of soil.

Soils can also be classified as **mineral soils** (rich in mineral particles), **peat and muck** (rich in organic matter accumulated in wet areas), mor (low in basic minerals) and mull (rich in basic minerals), depending upon the organic matter content. **Moder humus** is an intermediate form between the mor and mull humus. Moder humus has a richer and varied fauna.

B. Pedogenesis. It is the modification of mineral matter through interaction between biological, topographic and climatic effects which leads to the development of a number of layers *i.e.*, horizons of soil, known as soil profile.

Factors affecting soil formation. Soil formation is affected by active **factors** *viz.*, rainfall, temperature, wind, humidity and evaporation.

Passive factors include parent materials and topography which influences aeration, texture and chemical characteristics of the soil.

Biospheric factors. Micro-organisms in soil modify the physico-chemical processes in the soil.

COMPOSITION OF SOIL

The soil is in fact the very heart of the life layer called biosphere. It consists of mineral particles and a complex biological system of living organisms. Volumetric composition of mineral (inorganic) soil is :

1. Mineral matter 45%
2. Organic matter 5%
3. Soil water 25%
4. Soil air 25%

1. Mineral Matter in the Soil.

A typical soil contains a variety of elements which are geochemically distributed on the basis of their bonding characteristics into five main groups.

(i) **Lithophile elements.** These elements get readily ionised forming oxyanions viz., Li, Na, K, Ca, Mg, Ba, Sr, Mn, Fe, Si, B, Ga, Ge, Sn, Bi, Ni, Co, S, Se, Cu, Zn, halogens and rare earths.

(ii) **Chalcophile elements.** These elements tend to form covalent bonds with sulphide such as Fe, Ni, Co, Cu, Zn, Pb, Mo, Ag, Sb, Sn, In, Tl, As, Bi, Ga, Ge, S, Se, Te and As etc.

(iii) **Siderophile elements.** The elements such as Fe, Co, Ru, Rh, Pd, Os and Au are capable of forming metabolic bonds.

(iv) **Atmosphile elements.** Elements like O, N, He, Ne, Ar tend to remain in atmospheric gases.

(v) **Biophile elements.** These elements remain associated with living organisms such as C, H, O, N, P, S, Cl, I, Ca, Mg, Ag, Be, Sn, V etc.

Inorganic Components in Soil. The soil is essentially a silicate mineral. The composition of common elements in the soil is : O 46·6%, Si 27·7%, Fe 5%, Al 8·1%, Ca 3·6%, Na 2·8%, K 2·6%, Mg 2%. Finely divided quartz, SiO_2, commonly occurs in soil. Among the silicates, orthoclase $KAlSi_3O_8$, albite $NaAlSi_3O_8$ and epidote $4CaO.3(AlFe)_2O_3.6SiO_2.H_2O$ are common components of soil minerals. In some soils, iron oxides FeO(OH), magnetite Fe_3O_4, Mn_2O_3, TiO and $CaCO_3$ are relatively abundant. The clay minerals in soil are secondary minerals, essentially hydrated aluminium and iron silicates, which serve to bind cations such as Na^+, K^+, Ca^{2+}, Mg^{2+} and NH_4^+. These elements are not leached by water and are available as plant nutrients. Rocks which form the earth crust (**Petrology** *i.e.*, science of rocks) are made up of minerals.

2. Organic Matter in Soil.

The organic matter content of soil varies from 3·5% by weight in a top soil. In addition to the partly decayed plant and animal residues, soil organic matter contains microbially synthesized compounds. Organic matter functions as a granulator mineral particles. It is responsible for the loose, easily managed conditions of productive soils.

Importance of organic matter in soil.

(i) The organic matter provides food for micro-organisms.

(ii) It takes part in chemical reactions such as ion-exchange, governs physical properties of soil and increase water holding capacity of soil.

(iii) It is the major source of nutrients (N, P, K) and energy for microbes.

(iv) It improves aeration, contributes to the weathering of mineral matter and reduces soil erosion.

Major classes of organic compounds in soil.

(i) **Humus** (Heart and soul of soil). Humus is formed by microbial degradation of plants and animals remain. Humic materials constitute the most important classes of

complexing agents. They show high-uptake of heavy polyvalent cations. The process of humus formation is called humification. Humic substances have an elementary composition C 45 to 55%, O 30 to 45%, H 3 to 6%, N 1 to 5%, S 1%. **Humin, humic acid and fulvic acid** comprise a wide range of compounds. In general, humic substances are high molecular weight polyelectrolytic macro molecules. They consist of a carbon skeleton with a high degree of aromatic character and a large percentage of functional groups containing oxygen. They also contain carbohydrate fraction and a protein like materials. These fractions can be easily hydrolysed from the aromatic nucleus.

Some typical decomposition products of humic acid are catechol, syringaldehyde and 3, 5-dihydroxybenzoic acid. Humic substances are usually classified on the basis of solubility. If a lunatic substance is extracted with a strong base and the resulting solution acidified, the products are :

(a) non-extractable plant residue called humin

(b) a material which precipitates from the acidified extract, known as humic acid and

(c) a soluble material called fulvic acid.

The insoluble humin and humic acid affect the water quality through exchanges of cations, organic materials with water and can accumulate enormous quantities of metals. On the basis of stages of decomposition, humus formed from litter may be classified as

- **Raw humus.** It consists of partially decomposed organic matter.
- **Mor.** This layer of humus is not mixed with mineral soil.
- **Mull.** A completely decomposed humus is intimately mixed with mineral soil.

The dark brown humus is very beneficial for the soil and exhibits following properties.

- Humus constitutes the most abundant organic matter. It improves physical properties of the soil, increasing its water holding capacity and the rate of circulation of air and water through it.
- Humus is a reservoir of fixed N and constitutes the much needed food for soil microbes.
- It reduces pore size and makes the clumps of soil.
- Growth promoting humic acid is present in the humus.
- It makes aeration better, enhances percolation and easy penetration of roots.

(ii) Saccharides in organic matter. Saccharides include cellulose, starches, gums, hemicellulose and sugar etc. Sugars are water soluble compounds and constitute available source of C, N and energy for the micro-organisms. When the nutrient or oxygen supplies are restricted, different oxidised compounds (such as CO_2, H_2O, HCOOH, CH_3COOH, hydroxy acids and alcohols) are formed by starch. Soil micro-organisms through ammonification convert amino acids, amides etc., into ammonia. Nitrification (conversion of NH_3 to NO_2 and then to NO_3) and denitrification (NO_3 to N_2) is also accomplished in organic matter of soil.

The micro-organisms break up cellulose into cellubiose and glucose. The latter gets converted into organic acids and then to CO_2 and H_2O. The freshly synthesized hemicelluloses also form a part of humus. Saccharides are significant as they constitute the major food source for micro-organisms and help in stabilising soil aggregates.

(iii) **Fats, resins and waxes in organic matter** are lipid extractable. Fats degrade by the enzyme lipase into glycerol and fatty acids and then to CO_2 and water. Resins, waxes and fats are phyto-toxic and adversely affect soil properties by repelling water.

(iv) **Nitrogen containing** organics in soil include nitrogen bound to humus, amino acids and amino sugars. These compounds provide N for soil fertility.

(v) **Phosphorus compounds** in organic matter occur as phosphate esters, phospholipids and are sources of plant phosphate.

(vi) **Some organic compounds** contribute to the weathering of mineral matter. Calcium oxalate, produced as a soil fungi metabolite, dissolves minerals accelerating weather process and involving complexation of Fe and Al in minerals.

$$M(OH)_3(s) + 2CaC_2O_4(s) + 3H^+ \longrightarrow M(C_2O_4)_2^+(aq) + 2Ca^{2+}(aq) + 3H_2O$$

where M = Al or Fe.

Some soil fungi yield citric acid and other chelating organic acids which react with silicate minerals and liberate K^+ and other nutrient metal ions held by these minerals.

(vii) The biologically active components of organic matter consist of polysaccharides, nucleotides, amino sugars, organic S and P compounds.

3. Soil Water.

Soil water does not only act as solvent and transporting agent but also maintains soil texture, arrangement and compactness of soil particles. It makes the soil a perfect habitat for plants and animals. It is the major constituent of plant protoplasm. Soil water is essential for photosynthesis and conversion of starches to sugars. It is a main regulator of physical, chemical and biological activities in the soil.

Soil solution is a dilute solution of various dissolved solids, liquids, gases, organic and inorganic components. It is held in the soil by capillary and absorptive forces between soil layers and soil surface particles. On the basis of water retention by the soil, the soil water may be physically classified into

(i) Gravitational water
(ii) Capillary water
(iii) Hygroscopic water and
(iv) Combined water.

Gravitational water is the free water which moves down in to the soil because of gravity till it reaches water table. **Capillary water** is present in the interspaces of soil particles. The amount of capillary water in soil depends on surface tension, organic matter, soil texture and structure. The water held firmly on the surface of soil particles is called **hygroscopic water.**

Soil water under **biological classification** is categorised into available water, unavailable water and superfluous water. The plant and climate factors are related to the losses of water vapour under the system referred to as **soil plant atmospheric continuum** (SPAC). The movement of water within the soil may occur as saturated or unsaturated flow. However, *the total amount of water present in the soil is called* **holard.** The amount of water that can be absorbed by plants out of holard is known as **chesard** while the remaining unabsorbed water is called **echard.** Soil water may also occur through percolation, evaporation and transpiration. It is an important carrier of nutrients, provides turgidity to plants and protects them from drought and froast etc.

4. Soil Air.

Soil air occupies the pore space between soil particles which is not water filled. The exchange of CO_2 and O_2 between the soil pore space and the air is called soil aeration. The crumb and intercrumb pores are involved in soil aeration. A loam soil with humus containing 34% of air and 66% of water is considered best for majority of crops. Most of the gaseous interchange in soil occurs by diffusion.

Importance of soil air.

(a) Soil air is essential for the respiration of soil micro-organisms and plants.

(b) Poor aeration results in the formation of toxic substances such as H_2S, oxalic acid and formic acid in soil.

(c) Soil aeration increases the permeability of roots to water.

Acid-Base and Ion-Exchange Reactions in Soil.

One of the important functions of soil is the exchange of cations, whereby essential trace metals are made available to plants as nutrients. Both mineral and organic fractions of soils exchange cations. Clay minerals exchange cations because of the presence of negatively charged sites on the mineral while organic materials exchange cations by means of their carboxylate groups and other basic functional groups. Humus shows very high cation exchange capacity (300 to 400 meq/100 g). Cation exchange in soil provides trace metals to plants. These metal ions are taken up by the roots while H^+ is exchanged for the metal ions.

$$\text{Soil}\} \quad Ca^{2+} + 2CO_2 + 2H_2O \longrightarrow \text{Soil}\} \; 2H^+ + Ca^{2+}\,(\text{root}) + 2HCO_3^-$$

Soil serves as a buffer and resists change in pH. The type of soil governs its buffering capacity. The oxidation of pyrite in soil causes formation of acid sulphate soils called cat clays.

$$FeS_2 + 3{\cdot}5\,O_2 + H_2O \longrightarrow Fe^{2+} + 2H^+ + 2SO_4^{2-}$$

Most common plants grow best in a soil with near neutral pH. If the soil becomes too acidic, it may be improved by liming *i.e.*, addition of $CaCO_3$.

$$\text{Soil}\} \; H^+ + CaCO_3 \longrightarrow \text{Soil}\} \; Ca^{2+} + CO_2 + H_2O$$

In drought-prone areas with low rainfall, soil may turn too alkaline due to the presence of basic salts such as Na_2CO_3. Alkaline soils may be treated with $Al_2(SO_4)_3$ or $Fe_2(SO_4)_3$ which liberate free acid on hydrolysis.

$$2Fe^{3+} + 3SO_4^{2-} + 6H_2O \longrightarrow 2Fe(OH)_3 \downarrow + 6H^+ + 3SO_4^{2-}$$

Alkaline soils are also acidified by addition of S, which is oxidised in soil by bacterially mediated reactions to H_2SO_4.

$$S + 1{\cdot}5\,O_2 + H_2O \longrightarrow 2H^+ + SO_4^{2-}$$

Ion-exchange of anions occurs at the surface of oxides in the mineral portion of soil. At low pH the oxide surface assumes a net positive charge, holding anion such as Cl^- by electrostatic attraction.

$$M(OH)_n + H^+ \longrightarrow M(OH)_{n-1}(H_2O)^+$$

posed to soil pollution are due to the fact that while number of earth's inhabitants are increasing, the earth's natural resources are by and large fixed as well as limited. The crux of the waste problems in land lies in the leachates and mounting amount of wastes. Such leachates which ooze out of the garbage heap are known to move slowly through the layers of the soil beneath and contaminate the water resources deep down the land. However, the problem of soil pollution differs from air and water pollution in the respect that the pollutants remain in direct contact with the soil for relatively longer periods. The wide-spread industrialization and increasing consumption have changed the very complexion of soil. Thus the soil is getting heavily polluted day by day by toxic materials and dangerous micro-organisms which enter the air, water and the food chain. For all this, **man is the original and basic pollutant responsible for pollution hazards.**

SOURCES OF SOIL POLLUTION

1. Industrial wastes
2. Urban wastes
3. Radioactive pollutants
4. Agricultural practices
5. Metallic pollutants
6. Biological agents
7. Mining activities
8. Municipal garbage
9. Soil sediments

1. Soil Pollution by Industrial Wastes.

Industrial effluents are mainly discharged from pulp and paper mills, chemical industries, oil refineries, sugar factories, tanneries, textiles, steel, distillaries, fertilizers, pesticide industries, coal and mineral mining industries, metal processing industries, drugs, glass, cement, petroleum and engineering industries etc. It has been estimated that about 50% of the raw materials ultimately become waste products in industry and about 20% of these wastes are extremely deleterious.

With the advent of technology, ne er types of industrial wastes are produced and deposited on the land. **Thermal, atomic** and **electric power plants** are also the villain to add pollutants to the soil. In India, about 100 million tonnes of coal flyash (unburnt black substance) are produced by the power plants. Industrial wastes mainly consist of organic compounds along with inorganic complexes and non-biodegradable materials which affect the chemical and biological properties of soil.

Industrial Sludges. Industrial sludges are even more dangerous than industrial solid wastes to dispose of tidily. The composition of industrial sludge vary enormously, the common boiler scale, for example, consists of calcium carbonate and flue gas sludge. This flue gas **desulphurization sludge (FGDS)** is generated when calcium hydroxide or lime stone slurries are used to trap sulphur dioxide from escaping gases in coal fired power plants. These wastes also consist of calcium salts and several toxic volatile elements, such as, arsenic, selenium, mercury, lead and cadmium, which pose detrimental effects on the environment.

2. Soil Pollution by Urban Wastes.

Urban wastes comprise both **commercial** and **domestic wastes** consisting of dried sludge of sewage. *All the urban solid wastes are commonly referred to as refuse.* This refuse

contains garbage and rubbish materials like plastics, glasses, metallic cans, fibres, paper, rubbles, street sweepings, fuel residues, leaves, containers, abandoned vehicles and other discarded manufactured products. Recent reports indicate that in United Kingdom nearly 15 million tonnes of domestic sewage are disposed off into the land. In the United States also, each sunset sees a new mountain of 4,10,000 tonnes of solid wastes. New York itself throws out 25,000 tonnes of solid stink.

It is estimated that in **India** alone, about 115 million of urban population produces nearly 15 million tonnes of solid wastes causing chronic pollution of land and water. In critically polluted cities like **Mumbai, Kolkata, Kanpur** and **Chennai,** about 8000 tonnes of waste material collects in a day. **Delhi, which is the third most polluted city,** collects about 9000 tonnes of garbage from its streets every day, to be thrown into its five land fills, thereby polluting the land areas. Connaught place alone generates 50,000 plastic bags every day.

Urban domestic wastes though disposed off separately from the industrial wastes, can still be dangerous. This is so because they can not be easily **degraded.** Over population and increasing consumption have totally changed the very complexion of domestic wastes into a complex mixture. The leachates from dumping sites and disposal tanks of sewage mixed with industrial effluents and wastes are extremely harmful and toxic. Actually the leachates that oozes out of the polluted soil, contain poisonous gases along with the partly decomposed organic material especially food remanents, vegetables, toxic hydrocarbons and pathogenic microbes many of which can be disease causing.

Pollution concentration in urban areas and unplanned industrial progress in and around these urban areas, have to a greater extent contributed to **soil pollution problems** in **India.** It is estimated that Rs. 50 crore have been spent simply for burning, composting and thermally decomposing the refuse of Mumbai and Kolkata only.

3. Radioactive Pollutants.

Radioactive substances resulting from explosions of nuclear devices, atmospheric fall out from nuclear dust and radioactive wastes penetrate the soil and accumulate there creating land pollution. Radio nuclides of radium, thorium, uranium, isotopes of potassium (K-40) and carbon (C-14) are very common in soil, rocks, water and air. Explosion of **hydrogen weapons** and cosmic radiations induce neutron-proton reactions by which nitrogen (N–15) produces C–14. This C–14 participates in the carbon metabolism of plants which is then introduced into animals and man. **Radioactive wastes** contain several radio nuclides such as strontium–90, iodine–129, cesium–137 and isotopes of iron which are most injurious. Sr–90 gets deposited in bones and tissues instead of calcium.

Nuclear reactor produces waste containing, iodine–131 and lanthanum–140, cesium–144 with promethium–144 along with the primary nuclides Sr–90 and Cs–137. Rain water carry Sr–90 and Cs–137 to be deposited on the soil, where they are held firmly with the soil particles by electrostatic forces. All these radionuclides deposited on the soil emit gamma radiations. Recently it has been indicated that some plants such as lichen and mushroom can accumulate Cs–137 and other radio nuclides which concentrates in grazing animals.

4. Agricultural Practices.

Today with the advancing **agro-technology,** huge quantities of fertilizers, pesticides, herbicides, weedicides and soil conditioning agents are employed to increase the crop yield. Apart from these farm wastes, manure slurry, debris, soil erosion containing mostly inorganic chemicals are reported to cause soil pollution. USA alone produces about 18 million tonnes of agricultural wastes every year. Some of the agents responsible for this pollution are as follows :

(i) Fertilizers. Now-a-days agricultural practices rely heavily on artificial fertilizers, which generally contain one or more of the plant nutrients, *i.e.*, nitrogen, phosphorus and potassium. Critical pollution problems arise mainly from their excessive application rates. Although the fertilizers are used to fortify the soil, yet they also contaminate the soil with their impurities. Reports indicate that if phosphate and nitrate concentration exceeds one part and thirty parts per hundred million parts of water respectively, it results in eutrophication, chocking the whole stretch of aquatic ecosystem. **India** utilizes 16 kg per hectare of fertilizers whereas the world average is 55 kg/ha. Recently **NCA** have estimated the increased use of fertilizers from 2·8 million tonnes in 1976 to 15 million tonnes in 2004. However, it is not only the increasing utilization of fertilizers but also escalated production which create soil pollution hazards.

(ii) Pesticides. The need of increased food production due to growing population density was emphasized since long, which consequently led to manipulations of land resources. Different kinds of pesticides used to control pests are causing a stress in the natural environment. However, scattered informations all over India on paddy fields alone have indicated that there was 108% increase in the yield of **IR-8** and 195% in **TN-1** varieties when grown under plant protection umbrella using some biocides. The consumption of pesticides increased to 75033 tonnes in 1994–95 from a mere 2350 tonnes at the beginning of the planning period.

Among pesticides the most important are the chlorinated hydrocarbons, *e.g.*, DDT, BHC, aldrin, endrin, dieldrin, lindane, chlordane, heptachlor and endosulphan. **Organo-phosphates** include malathion, parathion, ethion, fenthion, trithion, dursban, dimethoate, phosdrin and metasystox etc. The remnants of these pesticides may get absorbed by soil particles which may contaminate root crops grown in soils. Unfortunately these pesticide residues coexist within biological system with other forms of life. The elimination of pests in the soil must inevitably produce changes and disrupt the balanced natural cycles and food chains within natural ecosystems.

(iii) Soil Conditioners, Fumigants and Other Chemical Agents. These chemical agents are reported to cause alterations in both agricultural and horticultural soil areas. They contain several toxic metals like lead, arsenic, cadmium, mercury and cobalt etc. which when applied to a land will accumulate on the soil permanently thereby introducing these chemical components into growing crops.

(iv) Farm Wastes. Increasing population of cows, cattles, pigs and poultries have resulted in considerable soil pollution. The wet slurry deposited on soil may seep into ground water and pollute it. When these farm wastes are dumped into heaps, they may become a good breeding ground for insects and several nuisance may arise. It has been

reported that a cow produces as much organic waste as twenty people while a pig as much as three people. Their faecal matter mainly consists of phosphates which in conjunction with nitrates cause numerous undesirable effects in the soil texture. Animal wastes contain several pathogenic bacteria and viruses which enter into plant metabolism and ultimately to man. Even the cow dung burning is hazardous to health due to the presence of benzo-pyrene in smoke, which is a cancer promoting chemical. By burning cow dung-nitrogen rich manure, which is so essential to our cultivation, is reduced to ashes.

This raw sewage has a high value of BOD (200 ppm), COD (400 ppm) and nitrogen (40 ppm) while the feedlot run off have 1000 ppm of BOD, 8000 ppm of COD and 700 ppm of nitrogen. So the animal wastes are difficult to treat and the methods applied to treat municipal wastes cannot be used for farm wastes. However, a few biological degradation methods are reported to be satisfactory in their control.

5. Metallic Pollutants.

A number of industries including textiles, pesticides, paints, dyes, soap and synthetic detergents, drugs, cement, petroleum, paper and pulp, electroplating and metal industries pour their hazardous metallic effluents in soil and water creating disastrous effects on living organisms. Synthetic chemicals are a source of trace metals which are added to the soil. For example, As, Pb and Cd the common trace metals in rock phosphate, also occur in superphosphate fertilizers. Toxic selenium species get less readily oxidized so it cannot be removed easily from soil by weathering. The selenite ion in iron rich soils forms insoluble basic ferric selenite or sorbs strongly on the iron oxides. In acidic soils of **Hawaii,** selenium content occurs as 20 ppm, but a very little is available to plants; while the rest Se is often found associated with sulphur.

Well documented trace elements such as Fe, Co, Ni, Cu, Zn, Ba, Pb, V, Mn, Ni, As, Hg, Mo and silicon are being added to the soil which have adverse effects on crop productivity. Mn and Fe oxides have a tendency to concentrate trace metals by isomorphous replacement of ions. In many soils 50 to 100% of soil carbon is found complexed with clay containing organic and inorganic components which affect the soil texture, its fertility and stabilization of soil organic matter. Presence of high levels of Na, Mg and K causes calcium deficiency in soil. Magnesium deficiency in soil has been attributed to high concentrations of Ca, Na and K which are added as artificial fertilizers. Excess of sulphur in soil may be absorbed by plant leaves as sulphur dioxide injuring plant tissues. Although Mg, Fe, Zn and V may be involved in photosynthesis but, if present at high levels pose lethal effects on crop production.

The toxic metals may be absorbed by plants grown in contaminated soil. Cadmium, being highly soluble than other heavy metals, is a frequent contaminant. **Accumulation of cadmium in soil** must not exceed 5 kg Cd/ha for soils with less than 5 m mole/kg cation exchange capacity (*e.g.*, **sandy soils**), while PCBs which have half lives similar to DDT must not exceed 10 mg/kg in sludge. **The United Nations Food and Agricultural Organisation (FAO)** states that half of the irrigated farms in the world are damaged by soluble salts deposited in soil. Deicer salts, salty wastes such as $CaSO_4$, $CaCO_3$, dumped in rivers are all the chief sources of soluble salts in soil. The high concentrations of salts are extremely

undesirable because they hinder plant growth, enhance corrosion of metals, make drinking water unpalatable and chronically interfere with several uses of water. **Salt pollution from agricultural run off water is largely non-point pollution,** that is, pollution does not always derive from one source or point but from a combination of sources. An example is cited by lateral seepage flow and salt carried from fields in waste water.

[For effects—refer to trace metals in the Chapter—Water Pollutants].

6. Biological Agents.

Soil gets large quantities of human, animals and birds excreta which constitute the major source of land pollution by biological agents. Digested sewage sludge as well as heavy application of manures to soils without periodic leaching could cause chronic salt hazard to plants within a few years. In addition to these excreta, faulty sanitation, municipal garbage, waste water and wrong methods of agricultural practices also induce heavy soil pollution. Sludges do have faults as they contain enough live viruses and viable intestinal worms. In developing western countries, intestinal parasites constitute the most serious soil pollution problems. Contaminated soil may contain :

(i) **Pathogenic organisms occurring naturally in soil** such as bacteria, fungi, algae, protozoans, molluscs and anthropods etc. These organisms are important agents in altering the soil fertility and physical texture of the soil.

(ii) **Pathogenic organisms excreted by man** include enteric bacteria and parasitic worms.

(iii) **Pathogenic organisms excreted by animals.** Earthworms, millipedes, isopodes, snails including higher animals carry fungal and bacterial spores which badly contaminate the soil. Pathogenic wastes have 85% moisture content and heating value is $2{\cdot}5 \times 10^6$ J/kg.

7. Mining Activities.

Soil damage and environmental degradation during surface mining is inevitable as vegetation and top soil have to be removed and waste rocks are to be shifted to a new location. Mining leads to loss of grazing and fertile land, soil erosion, sedimentation or siltation, danger to aquatic life, damage to flora and fauna as well as water and soil pollution. A **recent estimate** showed that in **India** about 20,000 hectares of land has been degraded from mining and another 55,000 hectares of fertile land was eroded to meet our requirements of bricks. Even open-cast coal mining alone affects seriously 2,00,000 hectares of land area. It is reported that 73% of the blocks identified for exploration by CIL and Singereni coal-fields involve drilling in forest areas.

8. Municipal Garbage.

The major technical problems of garbage disposal are toxic chemicals, pesticides, irritating solvents, leaching of garbage solubles by water, volatilization of solvents and harmful gases formed by anaerobic decomposition of organic wastes. The raw sewage harbours a variety of intestinal parasitic protozoan, ascaris eggs, cysts, pathogenic bacteria and viruses that result in severe soil pollution.

9. Soil Sediments as Pollutant.

Soil sediments refer to the depositions of trace metals, such as, Hg, As, Sb, Pb, Cd, Ni, Co, Mo, Cu and Cr. The process of sedimentation *is a* **comprehensive natural geomorphological process** which operates through the chain of erosion of soils, transportation of sediments (eroded material) and deposition of these eroded materials in different paths of water bodies. Sediments thus consist of soil and mineral particles washed from the land by storms and flood waters, from crop lands and over grazed pastures. Slow removal of soil is a part of the natural geological process of denudation which is both inevitable and universal. Eroded soil becomes a serious pollutant because of chemicals, it carries adsorbed to the particle surface.

Sediments represent extensive pollutant of surface water. These are the sources of inorganic as well as organic matter in water supply. An estimate indicates that level of organic matter in sediment is usually higher than in soils. Bottom sediments have the capacity to exchange cations with surrounding water medium. Unscientific agricultural and forestry practices, uncontrolled dumping of terrestrial effluents, mismanagement of water sheds, ship mining and dredging, construction of dams, roads, reservoirs, overgrazing, infra structural projects and other practices contribute to **sedimentation.**

Sediments generally deposit on the river beds and in the valley floors which bring about several changes in the river regime as follows :

- Flattening of valleys and braiding of river channels which then become unsuitable for navigation.
- It causes rise in river beds due to continuous siltation, thereby reducing water accommodating capacity of the river valleys.
- Valley becomes shallower and flood water covers more and more areas. The bed of **Ganga river** has risen by 3·89 metre within **8 years** due to siltation.

DETRIMENTAL EFFECTS OF SOIL POLLUTANTS

Today ecological changes have a direct impact on living organisms. The environment has deteriorated owing to industrial stress, urbanization, population density and numerous other villains which make the earth as a paradise for infectious agents. **Soil pollution** is the result of urban technological revolution and speedy exploitation of every bit of natural resources. Recently, a report published by **SOCLEEN** (Society for Clean Environment) on the ecology in Chembur area of Mumbai, India has revealed how recklessly man can exploit his land and environment. In Chembur, trees without leaves, buds and flowers are commonly seen due to **soil pollution.** Residents of the area have complained that they can neither grow flowers on the balconies nor vegetables in their gardens. The chief contributors to such a polluted atmosphere are FCI and Tata Thermal Plants which emit and add 1000 tonnes of toxic matters to the **soil.**

Effects of Industrial Pollutants.

1. Industrial wastes consist of a variety of chemicals which are extremely toxic. Industries manufacturing paper, textile, pesticides etc. release metallic wastes, oils,

greases, solvents, plastics, plasticizers, suspended solids, non-biodegradable material in the soil. Consequently these toxicants are transferred to different organisms in their food chain causing a number of undesirable effects.

2. Industrial effluents when discharged through sewage system will poison the biological purification mechanism of sewage treatment causing several soil and water borne diseases. Most of these pathogens are insusceptible to degradation and are injurious to health.
3. It is reported that more than 90 millions of organic chemicals are synthesized every year in the world and have multiplied about ten times since 1950. Amino acids, albumins and gelatins, which undergo putrefaction by bacterial action, release sulphur and phosphorus compounds. These compounds produce sulphuretted gases like H_2S and SO_2 as well as oxides of phosphorus which cause musty and putrid smell in soil.
4. Metallic contaminants (e.g., Hg, Pb, Zn, As, Cd, Cr, Na, K, Cu etc.) destroy bacteria and beneficial micro-organisms in the soil. Heavy metals tend to precipitate phosphatic compounds and catalyse their decomposition. These metals are considered to be indestructible poisons and their accumulation in soil for a long period may be highly fatal to living organisms.
5. Soluble salts cause crop loss, soil loss and metallic corrosion lead to costly cleansing activities. Salt accumulation in the soil has been a perpetual problem.
6. Severe agricultural crop damage is caused by high acidity and alkalinity of the soil coming from chemical industries. About 30% of the irrigated land of the world is now affected by salinity of soil and water logging.
7. Products of industries, such as, synthetic fibres, plastics and waste paper when consigned to incineration, their emissions may contaminate with toxic vapours and particulates causing air pollution. When discarded plastic materials, textiles packagings and toys of polyvinyl chloride are burnt in soil, they emit highly toxic gases SO_2 and NO_x etc.
8. Some of the trade wastes contain pathogenic bacteria. For example, pathogen Anthrax bacilli is present in tannery wastes. Chemicals either emitted into air or applied by aerosol spray ultimately reach the soil where they have significant effects on plants and animals causing a disruption in plant species.

Effects of Urban Waste Products.

1. In India, several million tonnes of waste is dumped along highways and other places in critically polluted cities like Delhi, Mumbai, Kolkata, Chennai, Jaipur and Ahmedabad etc. This urban waste spread several chronic diseases posing a serious threat to human health.
2. The waste including building materials (during construction and demolition), sludge, dead animal skeletons and thrown away garbage pile up at public places and cause obstruction in daily life.
3. Sewage is an excellent medium for the growth of pathogenic bacteria, viruses and protozoa. Vibrio cholera found in sewage causes cholera, Shigella dysenteriae

causes bacillary dysentery while Salmonella typhosa spreads typhoid in man. It is reported that chances of pathogens mingling with ground water even after the treatment of sewage is quite high. River **Coum** flowing through Chennai is so much contaminated by sewage that zooplanktons are unable to thrive in it.

4. Solid wastes cause offensive odour and clogging of ground water filters. Suspended matter in sewage can blanket the soil, thereby interfering with the soil moisture.
5. The use of polluted ground water containing human excreta, sewage sludge, *i.e.*, solids from cess pools, detergents and trace metals for irrigating the agricultural fields damages crops and decreases agricultural production, together with soil fertility by killing bacteria and soil micro-organisms.
6. Today developed countries are fighting against thermal and chemical pollutants, while **Indians** have to combat both chemicals and pathogens with their limited resources.

Effects of Radioactive Pollutants.

Since the radioactive wastes are produced in tremendous quantities and have a high activation energy, they create an extremely difficult public health problem.

1. When rain containing radionuclides falls on the soil, its activity is transferred to the soil by adsorption. As the radioactivity in the soil is available to plants, it enters the food chain resulting in the possibility of eventual ingestion by humans.
2. The aquatic flora and fauna used as food by man could accumulate dangerous amounts of radio-isotopes causing disruption of metabolic changes and physiological process.
3. When food containing radionuclides is taken by man, some of them concentrate in specific body organs where they cause a number of undesirable diseases of digestive tract. Even the thyroid gland is damaged due to accumulation of iodine. Cs-137 is taken by body in place of potassium.
4. It is reported that a high altitude burst, enters the biological cycle and gets distributed according to the biota present while a burst close to the ground makes all the elements of the soil as potential sources of induced radio-activity. A sub surface explosion also converts elements, such as sodium in water, to be radioactive.
5. Radiation acutely affects the soil fertility. These intense radiation kill plant species but differentially. Variations in radio sensitivity among the trees and shrubs are due to differences in their chromosome number and size.

Effects of Modern Agro-Technology.

Effects of Fertilizers. Recent agricultural practices, *i.e.*, the use of fertilizers, pesticides etc. are employed to increase the soil fertility and crop production. These fertilizers crowd out essential nutrients present in top soil layers, the microbes enrich the humus and initiate plant growth, but fertilizer enriched soil can not support microbial flora. So the question is : **Why fertilizers can be used to improve the quality of food stuffs? Do they harm or benefit the soil?**

1. It is reported that there is a 30% decline in protein content when corn, maize, gram and wheat crops were grown on soils fertilized with NPK fertilizers. Moreover, the subtle balance of amino acids with the protein molecule is also disrupted, degrading the carbohydrate and protein quality leading to malnutrition.
2. Potassium fertilizers in soil decreases the valuable nutrient ascorbic acid (vitamin C) and carotene in vegetables and fruits. Fertilized soil produces bigger sized vegetables and fruits which are more prone to pest, insects and diseases.
3. Excessive use of nitrogenous fertilizers in land leads to accumulation of nitrate in the soil which are transferred to man through plants. Nitrates, being highly soluble, go into drinking ground water and become toxic when this concentration exceeds **90 ppm.**, causing diarrhoea and **cyanosis (blue jaundice)** in children. In human body these nitrates and nitrites are converted to nitrisoamines and nitroso compounds which are suspected as agents of **stomach cancer.**
4. Young infants are more susceptible to fatal disease called methemoglobinemia or blue baby syndrome where nitrite interfere with oxygen carrying capacity of blood. Nitrite ions damage respiratory and vascular system causing ultimately death in infants. Normally 0·8% methemoglobin is present in man but in disease its content increases to 10% in blood. Above 20% it causes headache and giddiness. Above 60% it causes unconsciousness and stiffness. Death occurs at 80% of mathemoglobin.
5. Nitrate poisoning in cattle have been reported in Nagpur due to consumption of vegetation grown in nitrate rich soil. According to H.H. Koepf, an eminent soil chemist, modern agriculture can honestly claim two notable crops-disease and pest but now a third factor (nitrate, nitrite fertilizers) can be frequently added to soil contaminants.
6. Phosphatic fertilizer like DAP (that is, P_2O_5) is considered detrimental to crop production. It may lead to Fe, Cu and Zn deficiency in plants.
7. Cereal crops like jawar, maize and pearl millet grown on alkaline soil absorb higher amounts of fluorides and responsible for the spread of **fluorosis.**
8. Excessive use of fertilizers intensively reduces the ability of plants to fix nitrogen.

Effects of Pesticides.

Modern agriculture rely heavily on biocides. Although these chemicals enhance vegetation but they disrupt the natural ecosystem.

1. Pesticides not only pose a potential hazard to man, animal, fish and livestock but they severely affect the desired yield of crop and soil. Even the accepted dose of pesticides create deleterious effects on soil fertility. According to a report **Death in the Grab of Pesticides,** pesticides spread most alarmingly in the environment through migration. They are washed off from the crops into the water, enter water bodies, penetrate with fodder, animals and hence food stuffs. According to **WHO** more than 50,000 people in developing countries are poisoned every year and about 5000 die as a result of the toxic pesticides and other chemicals used in agricultural crops. In **India,** 35000 to 40000 tonnes of hazardous chemicals are sprayed on the agricultural crops each year.

2. Pesticides retained in soil concentrates in crops, vegetables, cereals and fruits which taint them to such an extent that they are not useable.
3. Various vegetables, fruits, rice, grain, wheat, gram, barley and maize are known to contain significant amount of DDT, BHC and other organochlorine pesticides. They persist in the soil producing long term effects on vegetative cover. **Poly chlorinated biphenyls (PCBs)** cause deformities in foetus, nervous disorders, liver and stomach cancer in animals. Persons who used vegetables contaminated with 0·5 g or more PCBs developed darkened skin, eye damage and severe acne.
4. DDT accumulates in the food chain. It is continuously recycled in living systems. It is reported that DDT concentration in man's body fat varies from 3·3 g/m^3 in UK and 25 g/m^3 in **India.** It is also reported to cause impotency in man.
5. Pesticides like DDT, endrin, dieldrin, heptachlor etc. are known to seep gradually through soil into ground water and eventually contaminate public drinking water supplies.
6. Longer lasting effects of pesticides are visible in animals and man, where they affect the tissues and interfere with normal metabolic activities by disturbing the enzymatic functioning in the body.
7. Organophosphate pesticides cause extreme muscular weakness, tremors and dizziness in poisoned animals.
8. Herbicides and chlorinated pesticides are very potent pollutants of the soil and affect soil texture and function of the ecosystem. Many of these have longer lasting effects and if used indiscriminately may be suicidal for people. Even certain herbicides, such as dioxane is found to cause congenital birth defects in offspring of experimental female, who have ingested or inhaled certain concentration of dioxane at critical periods.

   As a result of damaging ecological impacts of pesticide pollution, biologists have become interested in **integrated pest control,** the concept of which involves co-ordinated use of a mixed bag of weapons, including common cultural practices, judicious use of degradable or **short lived** chemical pesticides and greater use of biological control (nature's own control methods).
9. The excessive use of pesticides have also resulted in defoliation of forests adversely affecting flora and fauna.
10. Many hunting birds feeding on grains, particularly contaminated with high levels of DDT, are threatened with extinction. It has also been implicated as the cause of thin and fragile egg shells because of inhibition of enzymes and interference with hormones which control calcium metabolism.
11. People in contact with pesticides, such as, farmers, farm workers and agriculturists are much more prone to be poisoned by them. Their excess absorption leads to greater accumulation of acetylcholine in the body. Chronic absorption damages liver and kidney causing malfunctioning, excess of amino acid in blood and urine, blood abnormalities, cancer and electro-encephalogram deformation of brain tissues.

12. Pesticides cause several disastrous effects. In **India** on **December 3, 1984** in a tragic accident at **Bhopal,** about 3,000 to 4,000 people died and thousands suffer chronically from serious diseases of eye, skin, lung, brain etc. due to methyl isocyanate (MIC) leakage being manufactured by Union Carbide. Today children born have to start their life with a body burden of pesticides which increases with age.

Effects of Sediments.

Slow removal of soil is caused by the erosion of loose and unconsolidated material as well as parent rocks. Soil itself becomes a spectacular pollutant when excessive amounts of soil particles slide down to cover homes or roadways or when receded flood water leaves behind muddy masses or reservoirs and harbours fill with silt. **Pollution by sediments affects the environment in the following manner :**

1. Suspended sediment is usually eroded top soil and is the most fertile portion of the soil. Eroded soil is deteriorated and the carried top soil could deposit in places where fertility is a liability.
2. Water reservoirs can be filled by sediments and decrease their storage capacity. **Tarbela Dam Reservoir in Pak,** world's largest, has a silt load of about 16 times larger than predicted by dam's engineers.
3. In **India, Kosi canal** has been so heavily silted in its 20 years existence (because of over grazing its water shed) that it now provides water to only few irrigation areas. It has reduced from 570,000 hectares to 81,000 hectares.
4. Sediment on land can cover good soil with poorer or even rocky debris. Major river basins of the world have become ecologically imbalanced because of accelerated sedimentation.
5. S. Gong and G. Xiong have reported that highest rate of soil erosion occurred from the **yellow basin of China** where the annual soil erosion per square kilometre is 54,000 tonnes causing the loss of 34 kg of soil from every square metre of the river basin.
6. **Amazon basin** with highest catchment area (6,100,000 km^2) carries sediment load of 850 million tonnes per year. The recent, sediment load per square kilometre per year of the **Ganga, the yellow river, and the Mississippi** is 4,500 tonnes, 5,400 tonnes and 91 tonnes respectively.
7. Sediments fill stream channels and reduce the amount of sunlight available to aquatic plants. They blanket fish nests, spawn, food supplies and decrease fish population.
8. Suspended sediments make water unfit for municipal water supplies and for industrial purposes. Excess amount of suspended load of clay and silt in the river water damages turbines which are used to generate hydroelectricity.
9. Sediments adversely affect the physical and chemical compositions of water. It carries numerous ions (*e.g.*, Na^+, K^+, NO_3^-, Cl^-, SO_4^{2-} and PO_4^{3-}) from the agricultural fields contaminated with pesticides,. It thus causes **eutrophication** in the whole stretch of water bodies affecting severely the aquatic life.

Diseases Caused by Soil Pollution.

Soil inhabit distinctive flora and fauna, such as, bacteria, algae, fungi, protozoa, rotifers nematodes, mulluses, arthropods, earth worms, actinomycetes and several pests which make the biological system of soil complex. Some organisms also help in maintenance of soil fertility while majority of the micro-organisms act as chronic pollutants. Soil has been a potential carrier of microbial growth, non-biodegradable matters and pathogens which can endanger human health and life.

1. Pathogenic soil bacteria are chronic disease carrier which are transmitted from man to soil or vice versa causing cholera, typhoid, bacillary dysentery, paratyphoid fever etc.
2. The eggs of parasitic worms helminthes get incubated in the soil, these eggs and larvae are highly infective. Soil transmitted helminthes include Trichuris trichiura (whip worm), Ascaris lumbricoids and Ancyclostoma duodenale which cause intestinal hook worm diseases.
3. Pathogenic soil bacteria are Mycobacterium, Salmonella typhosa, Leptospira, Pasteurella and tuberculosis which pose a serious threat to man's health. They cause infections of intestinal tract like amoebic dysentery, cholera, typhoid, polio and hepatitis. Many of these are endemic to particular population.
4. Geohelminthes are reported to suck vitamins and proteins from the intestinal nutrients of the host. Such absorption of essential nutritional constituents results in severe malnutrition. It has been reported that loss of blood and iron in large quantities occurs due to sucking motions of hook worms which results in chronic anaemia.
5. Viruses are infectious agents of plants and animal cells. Common viruses present in sewage added to soil are Adenoviruses, Enteroviruses, polio viruses and hepatitis viruses. Most dreadful viral disease is poliomylitis in which body parts get paralysed due to destruction of nerve cells controlling the muscles.
6. Fungi and actinomycetes—the saprophytes normally develop in soil or vegetation. They cause most serious subcutaneous and systemic mycoses. Their spores may either be inhaled or penetrate skin through wounded body parts. These pathogens can directly transmit to man from soil.
7. Some of the animal's diseases are transmissible to man and soil. Leptospirosis, Anthrax and Q. fever are some of the diseases belonging to this category. Leptospirosis is a common disease of man and animals. Leptospires carried by animals are brought to the soil surface by excretion of faecal matter or urine. An estimate suggests that about 100 million leptospires are present in the urine of animals. These leptospires excreted into soil or water may survive for several weaks unaffected by climatic changes. When human beings come in contact with soil or water, these leptospires enter the body through maccrated skin or mucus membrane to cause leptospirosis.
8. Chromomycosis and coccidioidomycosis are dreadful diseases caused by pathogens. Tetanus is caused by clostridium tetani which is excreted by horses. The tetanus bacillus grows anaerobically at the site of its injury.

2. **Recycling of Trees.** In this computer age of shrinking land fill space and growing concern about solid waste disposal, recycling of trees have been used as under water dikes to help stem the erosion of beaches and local marshes. The potted trees can be replanted in green belt areas to control soil pollution.

Other measures include :

3. **Conservation of soil** to prevent the loss of precious top soil from erosion and to maintain it in a fertile state for agricultural purposes.
4. **Transforming intensive agriculture into a sustainable system** by measures such as
   (i) Maintaining a healthy soil community in order to regenerate soil fertility by providing organic manures, increasing fallow periods, avoiding excessive use of chemical fertilizers.
   (ii) Banning the use of highly toxic and resistant pesticides or regulating their use only for special purposes under thorough monitoring.
   (iii) Infusing biodiversity in agriculture by sowing mixed crops and crop rotation.
5. Sponsoring more intensive R and D efforts on bio-fertilizers, microbial degradation of wastes, utilisation of waste by recovery, reusing and recycling solid wastes, safer treatment and disposal of hazardous wastes.
6. Effective treatment of domestic sewage by suitable biological and chemical methods and adopting modern techniques of sludge disposal. Municipal wastes have to be properly collected by segregation, treated and disposed scientifically. Recycling of glass, paper and plastics should be done carefully.
7. Industrial wastes have to be properly treated at source, by segregation of wastes or adopting integrated waste treatment methods. Proper care should be taken in treating heavy metal wastes and other obnoxious wastes.
8. Security land fills have to be constructed for permanent disposal of hazardous and recalcitrant industrial wastes.
9. Enforcing environment audit for industries and promoting eco labelled products.
10. Implementing stringent and pro-active population control programmes.
11. Formulation of stringent pollution control legislation and effective implementation with powerful administrative machinery.
12. Imparting informal and formal public awareness programmes to educate people at large regarding health hazards and undesirable effects due to environmental pollution. Mass media, educational institutions and voluntary agencies should be involved to achieve these objectives.
13. Extending market support for recoverable products through fiscal concessions.

EFFECTIVE MEASURES TO PREVENT SOIL POLLUTION

1. Utilisation of Domestic Sludge.

The dried sludge (moisture content 20%) is rich in NPK. The sludge acts as a good manure and efficient soil conditioner. The effluents from the stabilization ponds can be

profitably utilised for irrigation or pisciculture. The recycled human waste minimizes the spread of diseases, control soil pollution and brings revenue in the form of fuel-free fertilizer.

2. Utilisation of Sewage Gases.

Sewage gas, a mixture of CH_4, CO_2 and H_2S, is utilized in advanced cities. CH_4 can be separated out, compressed and filled in cylinders and used as a energy source. H_2S can dissociate into H_2 and S by microwaves in a microwave reactor. Sulphur vapours are condensed and collected as liquid. H_2 is recycled and other impurities are converted into CO_2 and H_2O.

3. Converting Basic Slag into Nitrophosphatic Fertilizer.

Basic slag, the major by-product of steel industries, consists of necessary ingredients for plant growth, *e.g.*, Mg, Mn, P and silica. The mixed product of basic slag and urea nitrate constitute an excellent nitrophosphatic fertilizer easily assimilated by crops.

4. Biofertilizers Replacing Chemical Fertilizers.

Since chemical fertilizers are made up of only a few minerals, they impede the uptake of other minerals and imbalance the whole mineral pattern of the plants body. To overcome these problems, the use of biofertilizers is being encouraged.

Biofertilizers are biologically active products or microbial inoculants of bacteria, algae and fungi separately, or in combination, which can bring about soil nutrient's enrichment and may help in biological nitrogen fixation for the benefit of crop plants. The annual production of biofertilizers is about 3000 tonnes. The following are some well known biofertilizers :

- Legume-Rhizobium symbiosis.
- Azolla-anabaena symbiosis.
- Loose association of nitrogen-fixing bacteria.
- Diazotrophs (Azotobacter, Azospirillium).
- Cyanobacteria, Mycorrhiza and Frankia.
- Phosphate solubilizing bacteria and fungi.

These biofertilizers may fix over 800 kg of atmospheric nitrogen to a hectare of soil annually, thereby increasing soil fertility. The **non-leguminous micro-organism** like Azobacter has proved beneficial for crops such as wheat, maize, jowar, bajra, potato, paddy, tobacco, sugar cane, fruit trees, sun flower, sweet potato and onion etc.

5. Blue Green Algae as Biofertilizer.

Blue green algae (BGA) in association with ferns, fungi, mosses and liverworts convert atmospheric nitrogen to nitrogenous fertilizers in soil. BGA are also capable of solubilising lime through the secretion of oxalic acid. Such effect of BGA may be helpful in solubilising Kanker of usar soils. The usar soil begins to grow after a week of inoculation of Nostoc commune and lime. **Aulosira** fertilissima, the dominant algae during the water logged

period of reclamation process, is abundantly found in rice fields.The organic matter of algae helps in binding the soil particles and in flocculating them. This leads to the improvement of soil permeability, aeration tilth and physical properties of the soil. The important aspects in BGA technology are their natural occurrence, cultivation, supply, storage, inoculation, interaction with native forms and environment, effect of grown BGA on the rice plants and soil fertility.

Commonly used algae include Nostoc, Anabaena, Aulosira, Tolypothrix, Scytonem and Plactonema as a mixture. To prevent breeding of insects, application of folidol **(0.001 ppm)** or malathion (0·00075 ppm) or carbofuran (3% granules) is used. BGA are applied at the rate of 10 kg per hectare over the standing water for one week in the field after transplantation. Addition of BGA enrich the soil by 50 kg nitrogen per hectare. Azolla is more versatile than BGA because it can also be grown as a green manure.

6. Natural Pesticides Replacing Synthetic Pesticides.

Weeds like Lantana, Notchi, Tulsi, Adathoda etc. act as natural repellent to many pests. The indigenous trees like pungam, wood apple, anona and their by-products have excellent insecticidal value in controlling diamond black moth, heliothis, white flies, leaf hopper and aphid infestation. The fish oil resin soap (FOs) is non-poisonous natural product used for the control of white flies, mealybug and wooly aphid etc.

As many as 2121 plant species are reported to possess pest management properties, 1005 species of plants exhibiting insecticidal properties, 384 with antifeedant properties, 297 with repellent properties, 27 with attractant properties and 31 species with growth inhibiting properties have been identified. The most-commonly used botanicals are neem (*Azadirachta indica*), pongamia (*Pongamia glabra*) and manhua (*Madhuca indica*). Mahua seed kernel extract (5%) is effective against sawfly.

A number of herbal pesticides which not only play a vital role to control pathogen but also increase the soil fertility and crop yields are listed below :

(i) **Pongam (Derris indica).** Its extract is beneficial against leaf eating caterpillars.

(ii) **Tulsi (Ocimum spp).** Whole plant is used as an effective insect repellent.

(iii) **Aloe (Aloe barbedensis)** and Nirgandi leaves (Vitex negundo) have anti-fungal and anti-bacterial properties.

(iv) **Custard apple (Annona spp).** The seeds of custard apple possess insecticidal and **anti-feedant properties.** Seeds act as contact poison to flies, aphides, beetles. Different alkaloids namely annonine, municine, artabotrine etc. can be used as nematicide.

(v) **Sweet flag (Acorus calamus).** The powdered rhizome is used as an insecticide for the destruction of fleas, moths and lice.

(vi) **Garlic (Allium sativum).** The whole plant, bulbs, leaves and flowers may be used as pesticide.

7. Neem—Nature's Bitter Boon as Pesticide.

Neem-sounds like a designer's wonder tree. Almost every part of the tree, leaves, flowers, fruit, bark and seeds are utilised as a pesticide, insecticide, medicine, diabetic food,