# UNIT 11 WATER POLLUTION

## Structure



## 11.1 INTRODUCTION

Water pollution is one of the most serious environmental problems. It occurs when water is contaminated by such substances as human and animal wastes, toxic industrial chemicals, agricultural residues, oil and heat. Most of our water bodies—rivers, lakes, seas, oceans, estuaries and underground water sources (i.e., tubewells, bore wells) are gradually becoming polluted. In the course covered so far, you have seen how deforestation, urbanisation, intensive agriculture and industrialisation have caused pollution of water bodies. You are familiar with various aspects of air pollution, including harmful effects of acid rain. In this unit we will summarise various types of water pollution caused by different pollution sources, and also explain some important concepts such as point and non-point sources, biological oxygen demand (BOD), eutrophication, self-purification capacity of natural waters, infiltration of pollutants to groundwater, thermal pollution and pollution caused by accidents in oil tanker ships. In the next unit you will read about the degradation of land resources and terrestrial features of earth.

Polluted water may look clean or dirty, but it invariably contains germs, chemicals or other materials that can cause inconvenience, illness or death.

### Objectives

After studying this unit you will be able to :

- account for the course of changes in a water body resulting from eutrophication
- use the concept of biological oxygen demand (BOD)
- enumerate various sources of pollution of water bodies
- list various types of water pollution
- distinguish between the nature of freshwater and marine water bodies
- compare primary and secondary treatment of sewage
- exemplify infiltration of pollutants to groundwater in India
- list the sources and explain effects of marine pollution and the nature of problems arising from oil slicks, thermal discharge and from harvesting polymetallic nodules.

## 11.2 SOME CONCEPTS IN WATER POLLUTION

Commonly, two broad classes of sources of water pollution are recognised. One is **point** pollution sources, where the source is a well-defined location, e.g., a sewage outlet or a factory drain, the pipe through which factory discharges its waste water into streams. Such a pollution source can be checked effectively with appropriate technical skills. The other category consists of **non-point** pollution sources, which are spread over larger areas. For example, the water that runs off farms, grazing land, construction sites, abandoned mines and pits, etc., carries silt (soil particles) via diffuse and undefined routes into streams and lakes. Water pollution control in this case is not easy and requires constant, widespread efforts on a large scale.

Water pollution also upsets various processes that occur naturally in water. These processes which use oxygen dissolved in water, help to make wastes harmless. Let us study some of these processes.

### 11.2.1 Self-purification of Natural Waters

If you allow a water body, containing limited amount of degradable organic wastes, to recover, it will purify itself in course of time. You have read in Block 1 Unit 3 that decomposer aerobic (oxygen requiring) microorganisms convert the organic wastes into inorganic nutrients. Apart from clearing the water body of pathogenic bacteria, this activity is important for regenerating the health of a water body by releasing nutrients for utilisation by green plants that were locked up in the organic matter. The length of time taken in this process depends on the organic load and temperature of the surroundings.

Any natural water course contains dissolved gases normally found in air in equilibrium with the atmosphere. Thus, fish and other aquatic life obtain oxygen for respiration. The amount of oxygen which water holds at saturation depends on temperature and follows the law of decreased solubility of gases with a temperature increase. If you increase temperature of water the dissolved gases will escape in the form of bubbles.

Degradable or oxidisable substances in waste water deplete oxygen through action of bacteria and related aerobic organisms which feed on organic waste materials. The aerobic microorganisms use available dissolved oxygen for their respiration and organic wastes for their food. If the amount of such wastes is large and if this activity proceeds at a rate fast enough to depress seriously the oxygen level, the fish and other fauna of a water body are adversely affected. If the oxygen is entirely used up, a condition of exhaustion occurs which suffocates the aerobic organisms in a natural water body. Under such conditions the water body is said to be eutrophied and is likely to smell offensively and give an ugly look, because its **self-purification capacity** is hampered.

**SAQ 1**

State whether the following statements are true or false. Write T or F in the space provided and compare your answers with those given at the end of this unit:

a) Any natural water body is able to purify itself provided:

   i) further pollution is stopped and the water body is given sufficient time to recover. ☐

   ii) the water body consists of biodegradable pollutants only. ☐

   iii) there is sufficient dissolved oxygen in the water. ☐

   iv) the temperature is right for oxidation of organic matter. ☐

b) After purification the water body is left with only:

   i) pathogenic bacteria ☐

   ii) non-degradable chemicals ☐

   iii) organic wastes ☐

   iv) only non-degradable chemicals and non-pathogenic bacteria ☐

## 11.2.2 Biological Oxygen Demand (BOD)

Aerobic bacteria use oxygen dissolved in water when breaking down wastes. Scientists can find out how much organic matter the waste water contains by measuring how much oxygen the aerobic bacteria use in breaking it down. The quantity of oxygen utilised by microorganisms in aerobic degradation of organic matter in a water body is called its biological oxygen demand (BOD). Since BOD value is generally proportional to the amount of organic matter present in water, it can be used as a measure of waste strength and also as an indicator of the degree of pollution. The more the oxidisable organic matter present in water, the greater the amount of oxygen required to degrade it biologically and hence the higher the BOD value of water sample. Unpolluted waters, on the other hand, show comparatively low values of BOD.

BOD value is helpful in water pollution control management as a criterion of usefulness of the process design, loading calculations, as a measure of efficiency of operation of the treatment plants, and in evaluating self-purification capacity of natural waters. BOD is evaluated by determining oxygen concentration in a water sample, before and after incubation at 20°C in dark for 5 days. The difference is represented in per cent values. The various factors which influence BOD value are types of organisms, pH, presence of toxins, presence of organic matter, available nutrients and the rate of nitrification. Further details regarding the scope of this concept appear in the section on Eutrophication.

**SAQ 2**

In the following sets of statements, tick the correct ones and compare your answers with those given at the end of this unit

a) BOD denotes—

   i) the amount of oxygen taken up by the microorganisms in a sample of water.

   ii) the amount of oxygen used for biochemical oxidation by a unit volume of water sample at a given temperature in a given time.

b) BOD test is used to assess—

   i) the quantity of organic and inorganic waste matter in a water sample.

   ii) the quantity of organic waste matter in a water sample.

   iii)the quantity of inorganic waste matter in a water sample.

## 11.2.3 Eutrophication

Too high levels of nutrients in water may cause eutrophication. Eutrophication denotes the enrichment of a water body by input of organic waste containing nutrients, chiefly nitrates and phosphates. Many nutrients result from the natural disintegration of rocks and from mineralisation of organic matter. Natural eutrophication is a very slow process, taking often a period of over hundred years. But artificial eutrophication which results from human activities is a dramatically fast process. This happens when domestic waste, agricultural residues, land drainage and industrial wastes reach a water body. The problem of eutrophication arises from nutrients released from organic wastes by the activity of aerobic bacteria in presence of oxygen. These nutrients induce changes in the ecosystem balance and composition of aquatic life. Fig. 11.1 shows the natural process of eutrophication. All the nutrients fertilise microscopic water plants called algae, as well as larger water plants, such as duckweed and water hyacinth. More of these plants grow as a result of additional nutrients. As more plants grow, more also die. They also decay. Both these processes consume oxygen resulting in oxygen deficit. Nutrients and organic wastes added by people imbalance the cycle, as shown in Fig. 11.1; addition of nutrients at an increased rate increases the rate of growth of algae. As the algae die, they add to wastes. Bacteria sometimes use so much oxygen converting large amounts of wastes into nutrients that few fish survive because of depletion of oxygen. Such a lake is said to be eutrophied. It smells offensively as BOD rises and its aesthetic value goes down.

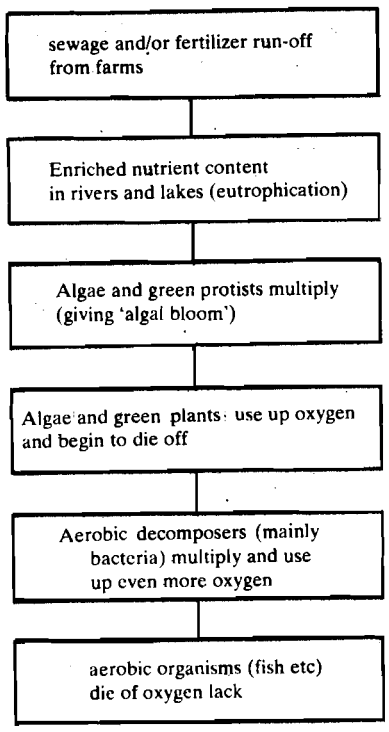


**Figure 11.1** Flow chart showing the sequence of events which may result from eutrophication.

Eutrophication leads to an increase in the growth of aquatic plants and often to algal blooms, ultimately the water body disappears.

**SAQ 3**

Fill in the blanks using appropriate words and compare your answers with those given at the end of this unit:

a) The natural aging process of lakes and ponds whereby they become marshes and eventually terrestrial ecosystems is known as.....

b) Eutrophication can also be man-made, wherein rate of nutient enrichment of a water body is ..... .....

c) An eutrophied water body is characterised by an ..... accumulation of ..... that support a ..... growth of plant and animal life, the decay of their dead bodies causes growth of oxygen-demanding organisms in shallow waters. Such a water body is likely to smell .....

d) State, in three or four lines, the effects of discharging organic wastes rich in nutrients in a water body. Give your answers in the space provided.

.....

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Eutrophication can also be man-made, wherein rate of nutrient enrichment of a

### 11.2.4 Types of Water Pollution

Classification of water pollution depends on the criterion used for categorisation of pollution. Based on the medium in which pollutants occur, types of water pollution may be distinguished as **fresh water** pollution and **marine pollution.** Fresh water pollution can be categorised into pollution of surface water and pollution of groundwater. When the pollutant enters a lake, pond, or river it is known as surface water pollution. If, however, the pollutant finds its way into aquifer, along with water of percolation, it deteriorates the quality of groundwater, and is called groundwater pollution. You have noticed that groundwater bodies and surface water bodies together have been kept under the class **fresh water bodies** because their salt content is very low; always less than 5 ppt (parts per thousand). As against this, the water bodies containing salt concentration equal to or above that of sea water (i.e., 35 ppt or above) are called as marine water bodies. Estuaries and brackish waters have salt content somewhere in between 5 to 35 ppt. The pollution of oceans, seas, estuaries, salt marshes and other similar water bodies is known as marine pollution or ocean pollution. We will discuss this separately because the factors polluting oceans acquire different dimensions ensuing from the magnitude of water bodies involved.

## 11.3 FRESH WATER POLLUTION

Sometimes the natural causes of water pollution are so intricately mixed up with man-made causes, that the two become indistinguishable from each other. For example siltation (which means active transport of suspended particle by water or wind in a series of bounces) together with sedimentation (which means passive deposition of silt in a water body) is a common problem of most of the water bodies. Rivers bring silt from mountains as a result of rumbling of rocks during their flow towards plains. The natural deposition of silt in the form of sediments results from sharp fluctuations in the flow of water, ranging between zero flow to flash floods, within a short span of time. The man-made sedimentation of water bodies may also take place. Sewage, industrial effluents and discharge from agricultural farmlands sometimes bring tonnes of silt into river beds, turning them into swampy, marshy streches of foul smelling land. The natural and artificial or man-made causes, in this case, are difficult to separate.

Similarly, fluoride—a strong pollutant, which causes knock knee disease, occurs naturally in water bodies but it also result from industrial activities such as ceramic industries, phosphate fertiliser plants and aluminium factories.

We will now discuss some of the man-made sources of water pollution i.e., pollutants released into water bodies as a result of human activities.

## 11.3.1. Sources of Surface Water Pollution

Domestic sewage, industrial waste, agricultural residues, radioactive substances and heated waste waters are some of the important pollutants which result from human activities. Although the same water body may receive pollutants from more than one source(s) simultaneously, for the purpose of simplification, sources of water pollution may be studied under the following sub-headings:

- Domestic waste water and sewage
- Industrial wastes
- Agricultural wastes
- Physical pollutants (radioactive and thermal)

Of these, the first three are discussed here. The physical pollutants include the radioactive and thermal pollutants. Although thermal pollution as you will see in section 11.5.3 can occur in fresh water bodies as well, but most of the instances have been reported in marine ecosystems. Therefore thermal pollutants are discussed in the section on marine pollution, 11.5.3. You have already read about radioactive pollutants in Unit 10. We shall discuss underground disposal of radioactive pollutants in Unit 13, Section 13.4.4.

a) **Domestic Waste Water and Sewage**—It includes water-borne wastes derived from household activities such as bathing, laundering, food processing and washing of utensils. Domestic waste contains garbage, soaps, detergents, waste food, paper, cloth, used cosmetics, toiletories and human excreta. This waste water which is known as sewage, is the largest primary source of water pollution.

A major ingredient of detergents is phosphate. When discharged into water, phosphate supports luxuriant growth of algae, called algal blooms. These produce offensive smell and choke the water bodies.

b) **Industrial Waste**—Most of the rivers and fresh water streams which pass near the major cities, townships or other human dwellings are polluted by industrial wastes or effluents. You may spend sometime studying Table 11.1 which lists some of the major Indian rivers and the corresponding industry(ies) polluting them. You will notice that some of the common industries are paper industry, textile and sugar mills, distilleries and thermal power plants among others. The kinds of effluents generated by industries are also numerous. The paint and varnish industries produce aromatic long-chained hydrocarbons, textile industries put out various dyestuffs and metal salts which are used as mordants. The other industrial effluents contain a host of pollutants such as oils, greases, plastics, metallic wastes, e.g., copper, zinc, arsenic, cadmium, lead, mercury, acids, alkalis, cyanides and chlorides, produced by various industries.

**Table 11.1 : Some Polluted Indian Rivers and their Major Sources of Pollution**

| Name of the River | Sources of Pollution |
|---|---|
| Bhadra (Karnataka) | Paper and steel industries |
| Cauvery (Tamil Nadu) | Tanneries, distilleries, paper and rayon mills |
| Chambal (M.P.) | Rayon mills, caustic soda mills |
| Cooum (Tamil Nadu) | Automobile workshops |
| Damodar (between Bokaro and Panchet) | Fertilisers, steel mills, coal washeries and power stations. |
| Ganga (at Kanpur U.P.) | Chemical, metal, and surgical instrument industries; tanneries, textile mills |
| Godavari (A.P.) | Paper mills |
| Gomti (near Lucknow) | Paper and pulp mills. |
| Hooghly (near Calcutta) | Power stations, paper pulp, jute, textiles, chemical mills, paint, varnishes, metal, steel, vegetable oils, rayon, and soap, match, shellac, and polythene industries |
| Jamuna (near Delhi) | DDT factory, Indraprastha Power Station, Mathura refineries |
| Kali (at Meerut) | Sugar mills, distilleries, paint, soap, rayon silk, yarn, tin and glycerine industries |
| Narmada (M.P.) | Paper mills |

| | |
|---|---|
| Siwan (Bihar) | Paper, cement, sulphur and sugar mills |
| Sone (U.P.) | Paper mills |
| Suwap (Balrampur) | Sugar industries |

In contrast to the general uniformity of substances found in domestic waste waters, the industrial waste waters show increasing variation as complexity of industrial processes increases. Table 11.2 lists major industrial categories along with the general nature and/or undesirable characteristics of their waste waters.

**Table 11.2 : General Nature of Industrial Wastes Found in Polluted Waste Waters**

| Industry | Process or waste | Byproduct and/or Effect |
|---|---|---|
| Brewery | Malt fermentation, fermented liquors | Organic wastes |
| Dairy | Milk processing, bottling, Packing, butter and cheese making | Organic acids and wastes |
| Food Processing | Canning and Freezing | Organic load acidic and alkaline |
| Laundry | Washing, dry cleaning clothes | Phosphates, organic solvents |
| Chemical Industry | General | Acidic, alkaline |
| Textile manufacture and dyeing | Sizing, Bleaching and dyeing of cloth, wool scouring | Organic and Inorganic load, dye stuffs, metal salts, acidic and alkaline wastes |
| Leather Industry | Leather cleaning and tanning | Organic load, acidic and alkaline wastes |
| Metal Industry | Ore mining, beneficiation smelting | Inorganic load, silt, acidic wastes |
| Paper Industry | Pulp and paper manufacturing | Acidic waste water, metal salts, waste wood fibres |
| Electroplating Industry | Pickling, plating | Acidic wastes and metal salts |

**c) Agricultural Waste**—It includes the following types of waste: manure, and other wastes from farm and poultry houses, slaughterhouse waste, fertiliser runoff from croplands, harvest wastes, pesticides, and salt and silt drained from irrigated or eroded land. These wastes enter waterways as runoff from agricultural lands. You have read in Unit 8 that if a water body receives fertilisers (phosphates, nitrates) or manures, the water becomes rich in nutrients leading to eutrophication and oxygen depletion. Seepage of excessive nitrates into groundwater followed by its consumption by children produces a serious disease known as methaemoglobinaemia. Nitrate poisoning has been reported in various areas of Rajasthan. You will read about pollution of groundwater in more detail in the Section 11.4 of this unit.

Pesticides, especially DDT (Dichloro-diphenyl-trichloro-ethane) used in the control of mosquitoes and agricultural pests, have become the most serious pollutants of water. Being long-lasting under natural conditions, the pesticide goes on increasing in soil and water with successive applications. Serious cases of fish mortality have occurred following leaching of pesticides from agricultural fields to nearby rivers after rainfall. Most of the pesticides, being fat soluble, reach the adipose tissue of animals including man. On fat breakdown, the pesticides are released in the blood stream producing toxic effects. Some of the common biocides are BHC (Benzene hexachloride), 2, 4-D (2, 4-Dichrophenoxyacetic acid), 2, 4, 5-T (2, 4, 5-Trichlorophenoxyacetic acid).

### SAQ 4

Fill in the blanks using appropriate words and compare your answers with those given at the end of this unit.

a) Sometimes seemingly clean water may contain ....., ....., or other materials which may cause ..... illness or .....

b) The water bodies containing salt concentration above 30 ppt are called as ..... waters.

c) As against the general uniformity of pollutants coming from domestic waste waters, the industries generate much greater ..... of chemicals as complexity of industrial ..... rises.

d) Domestic water pollution causes serious pathological disorders collectively termed as ..... diseases.

e) DDT is fat soluble compound which finds its way to adipose tissue of man. On fat breakdown, the pesticide is released into ....., producing toxic effects.

f) Excess of nitrates in water causes serious disease known as .....

## 11.3.2 Treatment of Sewage

Sewage is anything carried by sewers. Waste water coming from domestic or industrial houses or garbage dumps is generally called sewage. Sometimes, it may even contain rain water and surface run off. The treatment of waste water involves the following six steps:

Sedimentation
Coagulation
Filtration
Disinfection
Softening
Aeration

If waste water is to be disposed off into a river, stream or any other receiving water body, it is treated only upto the first four steps, i.e, sedimentation, coagulation, filtration and disinfection. This is known as **primary treatment.** The wastes these days have become so complex, it is no longer permitted to drain sewage into receiving water body without treatment. In other words, waste water is given primary treatment to remove gross impurities and the recovered water is then disposed into stream. If, however, the recovered water is to be used for drinking purpose, it has to undergo further treatment, i.e., softening and aeration, these two are collectively known as **secondary treatment.**

The treatment of waste water/sewage is conducted in plants built specially for this purpose. We would advise you to visit a city sewage treatment plant situated near your locality, if you have not already done so. The treatment of waste water/sewage is done in order to restore its original purity and make it safe for drinking or disposal into the receiving water bodies. In the following passage we will discuss various steps involved in treatment of sewage:

**Sedimentation** occurs naturally in reservoirs and is accomplished in treatment plants by storing sewage or waste waters in basins or settling tanks. Silt, clay and other fine materials settle to bottom if water is allowed to stand or flow quietly at low velocity. Plain sedimentation will not remove extremely fine particles or colloidal material. This step is used principally as a prelude to other treatment methods.

Fine particles and colloidal materials are combined into conglomerates by **coagulation.** These are called floc (plural : flocs) and are large enough to settle in basins and to be caught on surface of filters. Coagulation is brought about by using special chemicals known as coagulants/flocculants, such as potash alum. This step is also known as **flocculation.**

Suspended solids, colloidal material, bacteria and other organisms are **filtered** out by passing the waste water through a bed of sand or finely graded coal or through a matrix of fibrous material supported on a perforated core. Soluble materials such as salts and metals in ionic form are not removed by filtration.

After filtration the water undergoes **disinfection.** There are several methods of treatment of water to kill living organisms particularly pathogenic bacteria. The application of chlorine or its compounds such as bleaching powder is commonly used for disinfection. Less frequently used methods of disinfection include the use of ultraviolet light, ozone, or silver ions. Boiling is the favourite household emergency measure for disinfection.

The gross impurities obtained from primary treatment are collectively known as sludge, which releases sludge gas on composting. Composting means the action of anaerobic bacteria on organic matter contained in the sludge to produce sludge gas. **Sludge gas,** consisting mainly of methane can be used for cooking, lighting and other household activities. You will read, in Unit 21 on Conservation of Physical Resources-II in Block 5, about the use of sludge gas in India. After composting the left over sludge which is known as **spent slurry,** when dried and solidified forms a residue. This solid mass or **residue** can be used as a good fertiliser. It may sometimes be used for landfilling as you will read in Unit 13 on Hazardous Waste Chemicals.

The waste treatment steps upto this stage are included in what is known as **primary treatment** and sewage or waste water treated in this manner can be safely disposed off after due checking for toxic wastes left over, in trace quantities. This water is however not fit for drinking, and has to undergo softening and aeration before it can be safely used for drinking purposes. This is known as **secondary treatment.**

**Softening** is a process of treatment of water by which undesirable cations of calcium and magnesium are removed from hard waters. Two methods are used for softening : (1) the water is treated with lime and soda ash to precipitate calcium and magnesium ions as carbonates, after which the precipitate is filtered; (2) the water is passed through porous cation exchangers and is left cation free.

**Aeration** is a process of exposing water to air by forcing air through water in the form of bubbles to add oxygen and reduce carbon dioxide, hydrogen sulphide, and taste producing gases or vapours.

### 11.3.3 Characteristics of Treated Sewage

As a result of treatment, the sewage gets rid of silt, water becomes colourless, the number of pathogenic bacteria decline to almost zero, biological oxygen demand (BOD) and coli count (see glossary) go down, and the toxic wastes are neutralised. Water losses turbidity, becomes free of suspended particles, and gets loaded with life giving oxygen.

A curious pattern in Delhi and other major cities of India is that we take our drinking water from the same river that we use as dump for releasing human and chemical waste. To be sure we purify drinking water by giving it secondary treatment; but just as surely, we do not get absolutely everything out during the purification process. The communities located downstream are exposed to pollutants, pathogens and other inconveniences. Sometimes, careless discharge of partially treated water causes eruption of epidemics. Eruption of a cholera epidemic in 1988 in Delhi took a toll of 300 people in the city.

Interestingly, **disinfection** using chlorine kills the pathogens and also on combination with traces of organic matter may lead to formation of chlorinated hydrocarbons, that have cancer inducing (carcinogenic) potential. Chlorine is a halogen element. Most of our city water supplies test positive for halogenated compounds. Therefore, it is imperative to reduce the organic matter content of water, before chlorinating it. Preferably other methods of disinfection such as ultraviolet, ozone and silver ions, etc., should be used for this purpose. However, these methods are more expensive.

Scientists have developed various criteria for measurement of water quality. These are based on the knowledge of characteristics of polluted waters and the mechanisms operating in natural water bodies. You can, if you are interested, obtain standard water quality criteria for safe usage from booklets published and distributed free of cost by the Bureau of Indian Standards, New Delhi.

Careless release of toxic industrial wastes threatens groundwater supplies. You will read in the following few paragraphs how groundwater pollution has deteriorated the quality of rural drinking water supply and what can be the possible results of drinking such water. But before that you may try the following SAQ.

**SAQ 5**

i) Match the terms given in column A with their definitions given in column B, and compare your answers with those given at the end of this unit:

| | Column A | | Column B |
|---|---|---|---|
| a) | Flocculation | a) | treatment of water to kill living organisms particularly pathogenic bacteria |
| b) | Sedimentation | b) | passing water through a bed of sand or through a matrix of fibrous material supported on a perforated core to get rid of impurities |
| c) | Disinfection | c) | allowing silt, clay and other fine material to settle down to botton if water flows quietly at low velocity |
| d) | Filtration | d) | fine particles and colloidal materials are aggregated into floes using special chemicals. |

ii) Fill in the blanks and compare your answers with those given at the end of this unit :

The treatment of water is usually divided into two stages. The upstream consumers first use the water and drain their sewage after..... treatment into receiving water body. The consumers situated downstream the receiving water draw water from the same source but give it a ..... treatment before using it for drinking and other household purposes.

iii) State whether the following statement is true or false.

If untreated water is let into receiving water bodies, there is a good chance that its contamination level may go beyond the decomposing capacity of its aerobic bacteria.

## 11.4 GROUNDWATER POLLUTION

The widespread practice of releasing raw sewage in shallow soakpits has caused pollution of groundwater in many cities. Pollutants contained in seepage pits, refuse pits, septic tanks and barnyards may percolate through layers of earth and find their way into groundwaters. Some times transport accidents may also lead to contamination of underground sources of waters. Some industrial products and process wastes may also cause pollution of groundwater. In the industrial areas of Punjab and Haryana, for example, Ambala, Ludhiana, and Sonepat where bicycles and woollen garments are manufactured, significantly high concentration of nickel, iron, copper, chromium and cyanide have been detected in groundwater samples. (see Fig. 11.2)

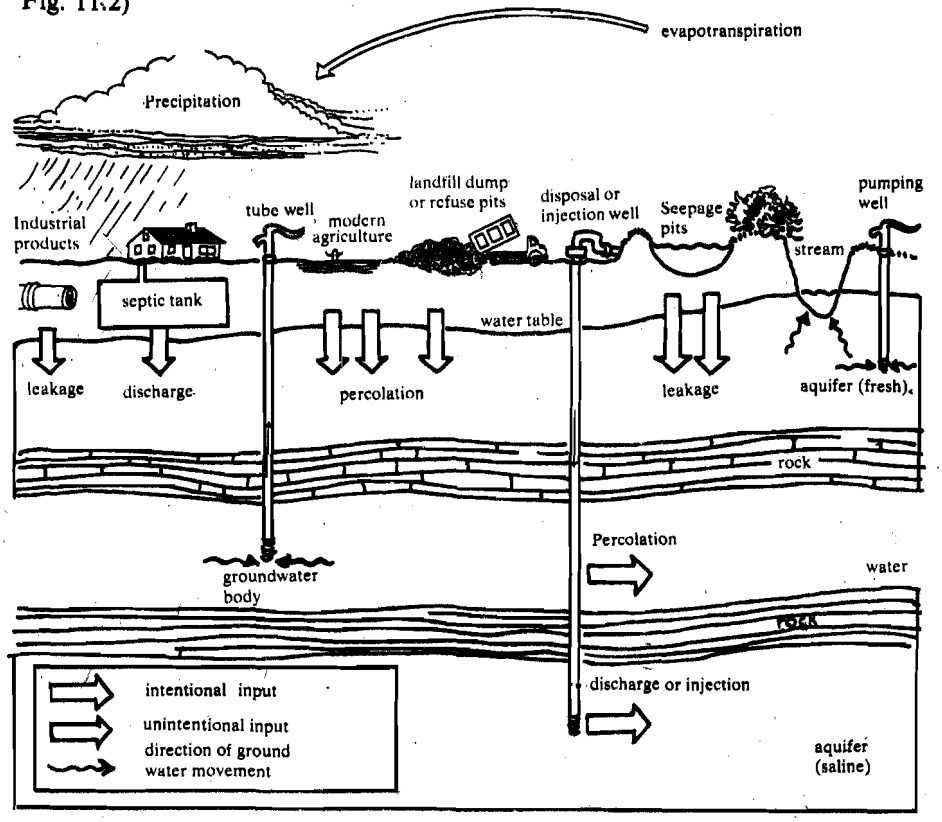


Figure 11.2 Sources of groundwater contamination

**Figure 11.2 Sources of groundwater contamination**

Modernisation of agriculture has led to excessive use of nitrogenous fertilisers. You have read in section 11.2.3 as to how methaemoglobinaemia is caused because of seepage of irrigation water into groundwater recesses. How about going back to Unit 8 to recall that the excessive addition of nitrates in modern agricultural fields has become a serious health hazard these days in rural areas. The nitrates being soluble in water trickle down through layers of soil into deeper layers of earth and ultimately are added to the underground stores of water. In many villages and townships where groundwater is the only source of drinking water this causes methaemoglobinaemia, particularly in bottlefed infants, because they are very sensitive to this pollutant.

You may wish to know how this disease is caused. What happens is that when water containing nitrates is consumed, it goes to intestines, where intestinal bacteria convert nitrates into nitrites. Nitrite ion combines with haemoglobin to form methaemoglobin, which inhibits the oxygen carrying capacity of the blood, causing a kind of anaemia known as **methaemoglobinaemia**. The removal of nitrate from water is not accomplished very easily. Nitrate is a soluble toxic waste. Removal of soluble toxic wastes requires elaborate treatment procedures such as chemical coagulation and filtration, carbon absorption chemical oxidation, ion-exchange, electrodialysis and reverse osmosis. Any one or a combination of the methods can be used for removal of nitrates depending on availability of resources.

The indiscriminate release of toxic industrial wastes such as arsenic, lead, cadmium and mercury compounds, and pesticides like polychlorinated biphenyls (PCB) may result in their trickling down to nature's underground water stores. This seriously threatens the quality of groundwater supply, specially in areas where **water table is high** that is situated near surface of earth. Scientists are concerned that drinking even small quantities over many years may lead to bioaccumulation of these toxins in the body. What happens is that these compounds being difficult to metabolise, are stored in the body, usually in the fatty tissue. The persons dependent on contaminated water supply retain small quantities of these compounds each day. This phenomenon is termed as **bio-accumulation.** Human beings consume also the products obtained from various plants which thrive on polluted waters and store these toxic compounds in their biomass. Non-vegetarian diet such as fish, pork and steak is also likely to come from animals which store these pollutants in their biomass (see also Section 11.5.2). Man here acts as a centre into whose body, pollutants from various kinds of sources pour in. The quantity of toxic substances thus gets magnified (see Fig. 11.3). You can see that pollutants are getting concentrated into man through biological sources. And because the amount of toxic substances is increased through biological food chain, this process is also known as **Biological magnification.** During starvation when the body draws upon reserve food sources, these compounds are released into blood stream producing toxic effects.

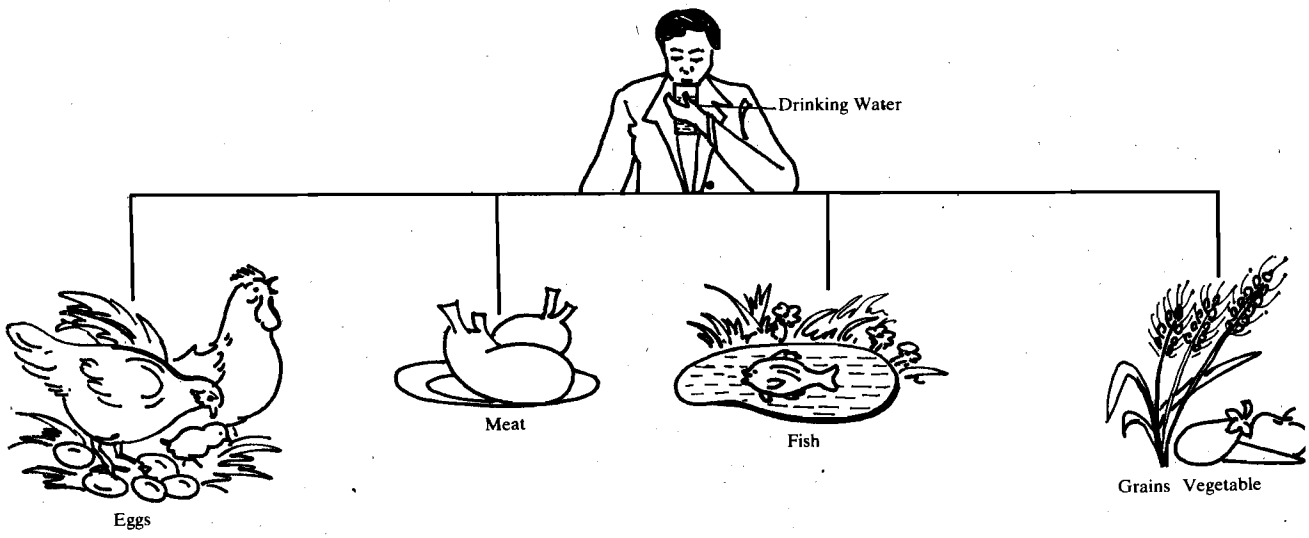


**Fig. 11.3 : Man is at the apex of the food-chain, because he receives food from organisms directly involved in photosynthesis as well as from those which are indirectly dependent on plants for their food.**

Even in regions where **water table is low,** contamination of groundwater may cause serious problems, as will be evident from the following example.

**Case Study :** Water pollution in Pali (Rajasthan) is an excellent example of groundwater pollution. For nearly one lakh population of the city, underground water is the only source of drinking water. There are more than 450 textile units involved in designing, dyeing and bleaching of clothes. All these have been discharging effluents containing sulphuric acid and carcinogenic substances. Coloured effluent containing these toxic substances spread over large areas in the city. A study conducted by Rajasthan State Board for Prevention and Control of

Water and Air Pollution concluded that with the onset of monsoon these toxic substances percolate down the earth, mix with underground water and contaminate it. It was reported that appropriate timely measures taken after monitoring samples of groundwater at different depths in suspected areas could have avoided the problem, altogether.

**SAQ 6**

a) Fill up the blanks in the following statements describing groundwater pollution and compare your answers with those given at the end of this unit:

In the industrial areas of ..... ..... where ..... ..... bicycles and ..... are manufactured, metal pollutants have been detected in groundwater. The case study on Pali in.....is an example ..... pollution. The coloured effluent contains sulphuric acid and ..... substances which reach the groundwater making it unfit for drinking.

b) Tick mark the right statements and put a cross mark against wrong statements.

Methaemoglobinaemia results from:

i) Excessive use of detergents which contain phosphates.

ii) Seepage of arsenic, cadmium, mercury compounds and PCB into underground waters, specially in areas where water table is high.

iii) Drinking underground water contaminated with nitrates.

iv) Drinking surface water containing strychnine-like substances.

## 11.5 MARINE POLLUTION

The oceans which cover about 71 per cent of the earth's surface are crucial to the maintenance of the environment for they contribute to the basic oxygen-carbon-dioxide balance of the biosphere, upon which the human and animal life depend. About 70 per cent of earth's oxygen is produced by ocean phytoplankton.

Water from the oceans evaporates and forms clouds which are carried away to hills and plains where they rain. Ocean is the major source of available water on earth. Any human intervention, addition of pollutants, exploitation of ocean resources such as pollutants from oil spillage and nuclear testing are likely to bring about drastic imbalance in the global water cycle and this may change the pattern of the climate.

Estuaries are the tail end of rivers located on the sea shore. They are one of the most productive ecosystems of earth. Estuaries play an important role in protecting coast line from erosion and damage. Being full of lush green vegetation they provide a buffer zone between coastal and river waters. They are also recognised as delicately balanced ecosystems.

Coral reefs, similarly, are among the habitats of richest biological diversity. They are formed by calcareous remains of colonial coelenterate animals and their skeletons and offer a variety of micro-habitats to many species of invertebrates and fishes. Pollution in the marine ecosystem largely arises out of economic activities of man. While a few problems are chronic and therefore quite complex in some countries, however, they are relatively simpler than in others. India has a coastline of about 7,000 km. Communities located near the seashore, industries and agricultural farmers dispose 1,645 $km^3$ of used waste water into the sea. You know that all rivers, canals and streams ultimately find their way into sea. India's fourteen major rivers drain 85 per cent of their run off into Indian Ocean, the pollutants carried by them are also carried into the sea, ultimately causing pollution of marine waters. This, however, is a highly irrational way of using marine resources. You will find after going through this unit that oceans deserve much greater care from human beings than is being accorded at present.

Apart from the above three sources, the pollution of marine waters takes place in ways unique to seas and oceans. In the section we will discuss marine water pollution caused by oil spills, industrial effluents, discharge of hot waters and mining of polymetallic nodules.

## 11.5.1 Oil Spills

An oil spill means the accidental discharge of oil and related products into estuaries, coral reefs or marine waters by oil tanker ships. Although major oil spills are the most publicised and environmentally dramatic events, these constitute only about 25-30 per cent of the total yearly volume of oil spilled throughout the world. Many small oil spills go unrecorded. Besides, oil explorations, petrochemical refineries and waste from auto crank cases and petroleum industrial machinery contribute to oil pollution. Oil is being spilled into the environment at an estimated rate of more than 5 million Mt per year. This is an enormous amount arousing great environmental concern!

Oil is a costly commodity. In addition to economic losses and the initial adverse aesthetic effects of oil covered coastlines, the major ecological effect is death of the waterfowl. Choking of fish, molluscs such as clams and oysters results because their gills or respiratory organs become tainted with an oily layer. Death of marine plants is caused by cutting off light, resulting in inhibition of photosynthetic activity. The toxic effects of the components of oil which dissolve quickly in water may cause more serious damage. They may create chronic inhibition of reproduction or may cause genetic damage to endangered species of flora and fauna. Sometimes, the accident may take place in an ecologically strategic area.

This is particularly true of a recent tragedy involving a massive oil spill. On March 24, 1989 Exxon a 50 million gallon oil tanker leaked oil in Prince William Sounds reef, near Alaska. This reef harbours one of the largest number of marine and terrestrial life forms, and supports, a large number of endangered species. The pollution in the beaches around the Sounds will continue to cause ecological damage for years, before the sea water is totally free of chemicals, including those contained in the oil as well as those used to mop up the oil spilled on sea surface, in just one incidence.

Oil spillage assumes enormous dimensions when it is used as a war weapon. This is true of recent conflict in 1991 between Iraq and Allied coalition forces; in which millions of gallons of crude oil was pumped into the Gulf. Not to speak of the hassels faced by the flora and fauna of oceans, the water desalination plants of the adjoining countries were shut down, lest they get contaminated. Especially Kuwait, Bahrain and Saudi Arabia are immediately affected, where water scarcity is a real threat.

## 11.5.2 Industrial Chemicals

More insidious than oil, which is atleast visible, are the various invisible toxic chemicals produced by industries. Certain aquatic organisms enhance the toxic effects of many chemicals because they have the tendency to accumulate the foreign substances in their bodies in levels far above those found in the surrounding water. This when repeated over several rungs of a trophic ladder, causes biological magnification of the toxic effect. Let us see what we mean by this term.

You have read in Section 11.4 that **Biological Magnification** is increase in the concentration of a chemical in the bodies of organisms with succeeding trophic level. This results from the fact that these chemicals are not excreted by an organism and therefore, their amount accumulates in the tissues and remains there. When several such organisms are consumed by a carnivore of the next trophic level, the carnivore, gains these chemicals thus increasing the total concentration of these chemicals in its body. Continuation of this process can lead to accumulation of rather significant levels in the top carnivore, if the food chains are long. Humans also tend to choose animals from higher rungs of the trophic ladder for food. This has already had an adverse effect on certain fish eating communities as in Japan (see Fig. 11.3).

In the late 1930s, a large industrial organisation established a factory on the shores of Minimata Bay, Japan, to produce vinyl chloride and formaldehyde. Bye-products from this factory containing mercury were discharged into the Bay. Through **biological magnification,** the marine fishes and shellfish accumulated high concentration of the toxic waste compound methyl-mercury chloride. The fishes and shellfish were in turn consumed by inhabitants of the area, who retained still larger quantites of this toxic waste. A strange, permanently disabling neurological disorder

began to appear among the inhabitants. This disorder was called Minmata disease. It was not until 1960 that the active mercury compound was identified as the causative agent of this disease.

SAQ 7

State whether the following statements are True or False and compare your answers with those given at the end of this unit. Which of the following describes **Biological Magnification:**

a) increase in size of an organism after consuming large amounts of toxic substances

b) certain organisms, which become food for their predator tend to accumulate toxic substances in their bodies to very high levels.

c) presence of toxic substances in water favours the growth of small sized organisms only.

d) carnivores alone show the symptoms of poisoning because toxic substances reach high levels only in their body.

e) A variety of toxic substances accumulate in the body of an organism depending upon the number of contaminated food item it consumes.

### 11.5.3 Thermal Pollution

Unlike terrestrial ecosystems, the temperature changes in aquatic ecosystems are not very sharp. The aquatic systems do not experience sudden changes in temperature in nature. Therefore, organisms living in aquatic ecosystems are not adapted to gross temperature changes. Also, oxygen occurs in aquatic ecosystems in the dissolved form. Can you imagine what will happen if the temperature of a water body is suddenly raised by artificial means? We will discuss here how hot water is generated in various human activities and how the release of heated water into oceans and seas affects the organisms inhabiting there.

In Unit 4, you read about the laws of thermodynamics. Energy, you know, is the ability to perform work. You are familiar with the concept of unidirectional flow of energy. The second law of thermodynamics can be stated in many ways including the following: No process involving an energy transformation will spontaneously occur unless there is degradation of energy from concentrated form to dispersed form. This when applied to generation of electricity will mean that electricity can be generated only after releasing a lot of waste heat. Thermal power plants produce superheated steam to generate electricity. After extracting usable energy from this steam, the left over hot water is let out into rivers, streams or oceans depending upon where the thermal power plant is located. We shall discuss the effects of releasing heated waters into oceans where the problem is acute.

Chemical industries, fossil fuel and nuclear power plants use a lot of water for cooling purposes and return this used water to rivers, streams or oceans at a higher temperature. The siting of plants along the seacoast to take advantage of the marine waters has led to the perturbation of marine flora and fauna by heated water discharge. The hot water causes thermal pollution, decreasing dissolved oxygen in water which in turn adversely affects aquatic life. Nuclear power plants release 50 per cent of the generated heat to the coastal marine waters. Flora and fauna in the warm tropical waters live dangerously close to their upper limits of lethal temperature, particularly during the warm summer months. It requires only a slight deviation from this limit to cause a thermal stress to these organisms. Release of hot salty water, when coupled with wind system, alters the current and mixing patterns from offshore to onshore. This is more probable in tropical areas where the range of tides is quiet high.

### 11.5.4 Harvesting Polymetallic Nodules

You have read about polymetallic nodules in Section 17.2.2 under oceanic resources in Block V of the FST course. India, West Germany and other countries are planning to extract and process polymetallic nodules from the rich areas of Pacific and Indian Oceans. These potato shaped nodules lie at a depth of 5,000 metres and contain 30 to 40 per cent manganese (used in certain steel alloys) and small amounts of other commercially important metals such as nickel and cobalt. It is proposed that a device much like a giant vacuum cleaner be developed to suck these nodules up from the bottom of the deep ocean and deliver them through a long pipe to a ship

above the mining site. Environmentalists recognise that such seabed mining would probably cause less harm than mining on land. They are concerned, however, that stirring up deep oceanic sediments may generate fine particles which could choke the gills and filtering organs of marine creatures. This activity could also have unknown effects on poorly understood deep sea trophic chains. Surface waters might also be polluted by discharge of sediments from mining ships, floating platforms and island based units.

The seas of the world have been considered an inexhaustible source of food and as having an infinite capacity to absorb and detoxify our wastes. To this has been added, only recently, the urge to use them as a source of industrial raw materials. It is now apparent that these assumptions have their limitations and that the human population at the current level of technological development has the ability to inflict massive destruction on the seas, just as we have done on land. At present, the seas remain in good condition relative to the land, but we cannot afford to permit them to be degraded in future. We must take care to ensure that the potential of oceans is realised without causing them any ecological damage.

## 11.6 SUMMARY

In this unit, we considered water pollution with reference to its sources, types and its impact on aquatic life. We have learnt that:

- The term water pollution refers to the addition to water, an excess of material (or heat) that is harmful to humans, or other desirable aquatic life; or it may otherwise cause significant departures from the normal activities of various living communities in or near the aquatic environment.
- Sewage, domestic waste, industrial waste, agricultural waste and physical pollutants are the various sources of water pollution. These sources may be restricted to certain fixed loci (point sources) or spread over large areas (non-point sources).
- Biocides (insecticides, herbicides, fungicides, etc.), polymers, plastic ingredients and heavy metals are a few of the many hazardous water pollutants.
- Phosphate nutrients cause eutrophication, whereas nitrites and nitrates cause some serious diseases in man.
- Pollutants may sometimes seep down to deeper layers of earth and contaminate underground sources of water.
- Thermal pollution decreases dissolved oxygen in water affecting the aquatic life adversely.
- Big tankers carrying oil may sometimes leak causing pollution of the oceans.
- Biological magnification of toxic compounds indiscriminately released into water bodies is a serious problem, effecting aquatic flora and fauna.

## 11.7 TERMINAL QUESTIONS

1) Which one of the following statements describe the polluted water most adequately?

   The polluted water is:

   a) turbid, not suitable for drinking, bathing, washing and other human activities.

   b) turbid, less suitable for drinking, domestic, agricultural, recreational, fishing and other activities.

   c) turbid and interferes with the functioning of aquatic life.

   d) turbid, sometime smells bad, not pleasant for drinking or harmful to organisms including man.

2) In the space provided below, give short answers in about four or five lines, to the following questions:

a) When water containing excessive nitrate is used for drinking, it causes methaemoglobinaemia disease.

i) How is this disease caused?

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ii) What waste water treatment methods would you suggest for purifying such waters?

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3) Expand the following abbreviations:
BHC, DDT, PCBs, 2, 4-D, 2,4,5-T.

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4) What are the effects of detergents on freshwater bodies?

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5) State, in three or four lines, the sources of groundwater pollution. Give your answer in the space provided.

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6) Suggest measures to stop eutrophication of a water body. Give your answer in the space provided.

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## 11.8 ANSWERS

**SAQ 1**

a) i) T ii) T iii) T iv) T
b) i) F ii) T iii) F iv) T

**SAQ 2**

a) i) X ii) √
b) i) X ii) √ iii) X

**SAQ 3**

a) eutrophication
b) very fast
c) abundant, nutrients, dense, offensively
d) Nutrients enriched organic waste, when it reaches a water body, increases productivity of the aquatic ecosystem leading to **eutrophication.** This, in turn, causes depletion of dissolved oxygen making water unsuitable for the growth and survival of aquatic life

**SAQ 4**

a) germs. chemicals, inconvenience, death
b) marine
c) variety, processes
d) water-borne
e) blood stream
f) methaemoglobinaemia

**SAQ 5**

i)

| Column A | Column B |
|---|---|
| a | d |
| b | c |
| c | a |
| d | b |

ii) primary, secondary
iii) True

**SAQ 6**

a) Punjab and Haryana, woollen garments, Rajasthan, groundwater, carcinogenic.
b) i) X ii) X • iii) √ iv) X

**SAQ 7**

a) F b) T c) F d) F e) T

**Terminal Questions**

1) (d)

2) (a) i) When such water is drunk, nitrates taken in are converted to toxic nitrates by intestinal bacteria. Nitrites, in turn, combine with the haemologlobin to form mathaemoglobin which interferes with the O carrying capacity of the blood causing methaemoglobinaemia.
ii) Chemical coagulation and filtration, Carbon absorption, chemical oxidation, Ion exchange, Electrodialysis, and Reverse osmosis.

3) BHC — Benzene hexachloride
DDT — dichloro-dyphenyl-trichloroethane
PCBs — Polychlorinated biphyenyls
2,4-D —2,4,-Dichlorophenoxyacetic acid
2,4,5-T—2,4,5-Trichlorophenoxyacetic acid

4) Phosphate containing detergents support the luxuriant growth of algaè in fresh water. This, in turn, causes oxygen depletion and and produces a bad smell. On decay, some decomposing plants products strychnine—like toxins, which kills animals including cattle.

5) The widespread dumping of raw sewage in shallow soakpits is the most common source of groundwater pollution. Other sources are: seepage pits, refuse dumps, septic tanks, and some agricultural and industrial pollutants.

6) i) Limitations of nutrient input by treatment of the waste water.
ii) Harvesting and removal of algal blooms periodically.
iii) Reduction in the amounts of nutrients in water through enhanced bacterial decomposition.