

# 33

## Water Pollution

### 33.1 INTRODUCTION

Water is essential for all forms of life on earth. We need several litres of water everyday for drinking and cleaning purposes. Unfortunately, at many places in our country, we have not been able to provide clean, safe water for human consumption. Contamination of drinking water by biological sources such as human and animal fecal wastes and toxic wastes from industries and agricultural pesticides have often caused deadly waterborne diseases and human deaths due to toxic chemicals.

In this lesson, we shall explain the various types of water pollutants, their effects on human well-being and environment, and finally suggest some preventive methods of water pollution.

### 33.2 OBJECTIVES

After reading this lesson, you will be able to :

- list the earth's water resources
  - list the major types of water pollutants, their sources and effects
  - distinguish between natural impurities and man made pollutants
  - use the concept of biological oxygen demand (BOD) and account for the changes in a water body
  - cite methods for the prevention of water pollution
  - compare primary, secondary and tertiary treatment of sewage
  - recall necessary legislative measures for prevention of water pollution in the country.
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### 33.3 EARTH'S WATER RESOURCES

Most of the water on earth is salt water of the seas (about 97%). It is too salty to be of any use for drinking, agriculture and industrial purposes. The remaining  $\approx$  3% is fresh water. About 75% of fresh water is locked up in the polar ice-caps and in glaciers and the remaining amount lies quite deep under the earth's surface as underground water. The fresh water which we use comes to us from two sources :

- i) Surface water (streams, rivers, lakes etc.)
- ii) Ground water (water buried under the earth's surface.)

Let us learn about these in detail :

(i) **Surface Water** : It is estimated that of all the precipitation (rain water and snow) that falls on the earth about one-third runs off the surface into streams and rivers. Another one-third is absorbed by the plants and the remaining one-third seeps down the soil as ground water.

**Precipitation (rain or snow) that runs-off into streams, rivers and lakes is called Surface Water.**

Surface water has a natural tendency to clean itself because it contains certain organisms that break down pollutants into harmless substances.

(ii) **Ground Water** : Ground water (wells and springs) is often the only source of water supply especially in villages and small towns. The ground water can move over large distances by virtue of the large empty space available below the earth's surface. This way if some impurities seep into the ground water at one point, they may be observed at a different point far removed from the point of source. However, suspended impurities and bacterial contamination are removed by the soil material which acts as an absorbent and water filter.

### 33.4 TYPES OF WATER POLLUTANTS (FRESH WATER POLLUTION)

**Water pollution is any physical, chemical or biological change in a water body that has an undesirable effect on living organisms. It is basically caused by two factors : industrialization and population explosion.**

The problem of water pollution is complicated by the great solvent properties of water. Any usage of water may be for washing, irrigation, flushing of sewage or domestic waste, cooling and industrial purposes adds some undesirable impurities to it. Fresh water pollution may be classified into two types : **surface water pollution** and **ground water pollution**. When pollutants enter a stream, river or lake it is known as surface water pollution. If, however, the pollutant seeps into the ground and enters an aquifer,\* it is called ground water pollution.

#### 33.4.1 Surface Water Pollution

Often two types of sources of water pollution are considered, i.e., point and non-point sources of water pollution.

\* Aquifer is any underground geological formation that contains sufficient amount of water to meet human needs.

Point source of water pollution is a well defined source that puts pollutants or effluents (such as domestic or industrial waste) into different water bodies of fresh water. This type of pollution sources can be effectively checked.

Non-point sources of water pollution are often scattered sources that are spread over large areas. For example, the contaminated water that runs off from agriculture farms, construction sites, abandoned mines, enters streams and lakes. Water pollution in such a case is quite difficult to control.

Let us now learn about the various sources of water pollution.

**Natural Sources of Water Pollution :** The natural sources of water pollution are listed below :

(i) Siltation (which includes soil, sand and mineral particles) is a common natural phenomena which occurs in most water bodies. Indiscriminate deforestation makes soil loose and flood waters bring silt from mountains into streams, rivers and lakes.

(ii) The high concentration of fluoride ions ( $F^-$ ) in natural waters is a serious health hazard as concentrations beyond 0.7 parts per million (ppm), can cause fluorosis\*. In India there are 12 fluoride states: Andhra Pradesh, Delhi, Gujarat, Karnataka, Punjab, Rajasthan, Tamil Nadu, Uttar Pradesh, Maharashtra, Madhya Pradesh, Bihar and Orissa. People in these states have shown a high percentage of dental and skeletal fluorosis.

(iii) Vast regions in West Bengal have contamination of arsenic in the ground water. Drinking of this water has caused Arsenicosis (arsenic poisoning), a particular type of cancer in different parts of the body.

**Artificial (Man-Made) Sources of Water Pollution :** For hundreds of years rivers, lakes, streams and seas have been used by mankind for flushing domestic (sewage and waste water), industrial and agricultural wastes. Also certain materials are leached from the land by run-off water and enter the various water bodies. The different artificial sources of water pollution are (fig.33.1)

- (i) Sewage Pollution (Domestic waste and Animal Waste)
- (ii) Industrial Pollution
- (iii) Agricultural Pollution
- (iv) Radioactive and Thermal Pollution

(i) **Sewage :** The sewage contains garbage, soaps, detergents, waste food, human excreta and is the single largest sources of water pollution. Pathogenic (disease causing) microorganisms \*\* enter the water system through sewage. Typhoid, cholera, gastroenteritis and dysentery are commonly caused by drinking infected water. Water polluted by sewage may carry certain other bacteria and viruses\*\*\* which are resistant to treatment and so can have serious ill effects on human health. Some of these pollutants, like the organic matter,

\* Fluorosis : Chronic poisoning due to fluorine. A disease which makes bones and joints brittle and the teeth lose their strength.

\*\* Microorganisms refer to bacteria, fungi, protozoa, algae. They are all living catalysts that are associated in a number of chemical processes in water or on soil.

\*\*\* Viruses cannot grow by themselves, but reproduce in the cells of host organisms. They cause a number of diseases, such as, polio, viral hepatitis and may be cancer.

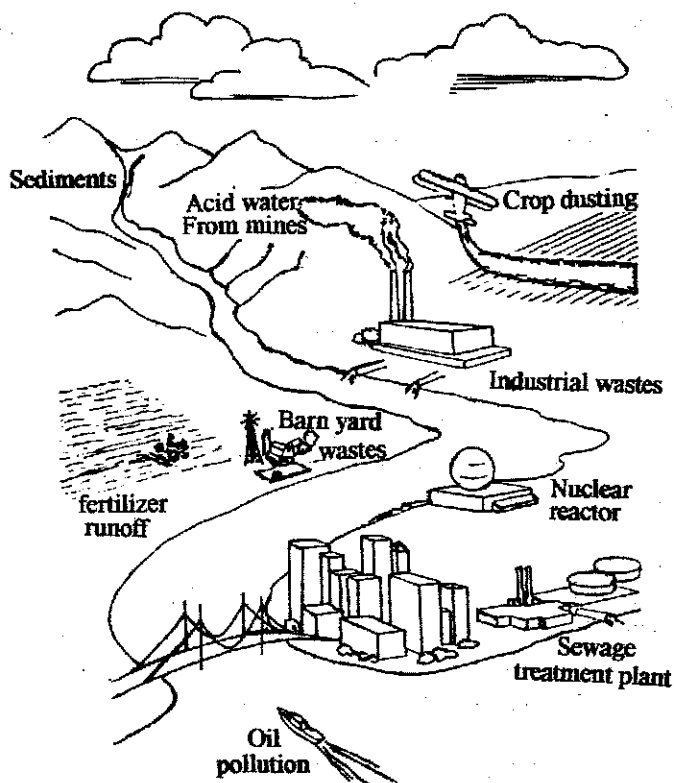


Fig. 33.1 Artificial Sources of Water Pollution

are oxygen demanding substances. They are responsible for deoxygenation of water-bodies which is harmful for aquatic life.

Other ingredients which enter the various water bodies are the plant nutrients, i.e., nitrates and phosphates. They support growth of algae, commonly called **algal bloom** (blue-green species). This process is called **eutrophication**. This is discussed in detail in the next section.

(ii) **Industrial Waste** : Many industries are located near rivers or fresh water streams. These industries discharge their untreated effluents into the rivers. Most of the industries discharge highly toxic heavy metals such as chromium, arsenic, lead, mercury etc., along with hazardous organic and inorganic wastes (like acids, alkalies, cyanides, chlorides etc.) For example, river Ganges, receives wastes from textile, sugar, paper and pulp mills, tanneries, rubber and pesticide industries. Most of these pollutants are resistant to breakdown by microorganisms (non-biodegradable) and chemically polluted water damages the growth of crops and is unsafe for drinking purposes.

Factories manufacturing plastic, caustic soda and some fungicides and pesticides release mercury (a heavy metal) along with other effluents in the nearby water body. Mercury

enters the food chain through bacteria, algae, fish and finally into the human body. The toxicity of mercury became evident by the **Minamata Bay tragedy** in Japan during the period 1953-60. Fish died due to mercury consumption and those who ate fish were affected by mercury poisoning and quite a few died. The milder symptoms of mercury poisoning are depression and irritability but acute toxic effects can cause paralysis, blindness, insanity, birth defects and even death. The high concentration of mercury in water and in fish tissues results from the formation of soluble monomethylmercury ion,  $(\text{CH}_3 \text{Hg}^+)$  and volatile dimethylmercury,  $[(\text{CH}_3)_2 \text{Hg}]$  by anaerobic bacteria in sediments.

(iii) **Agricultural Waste** : Manure, fertilizers, pesticides, wastes from farms, slaughterhouses, poultry farms, salts and silt are drained as run-off from agricultural lands. The water body receiving large quantities of fertilizers (phosphates and nitrates) or manures becomes rich in nutrients which leads to eutrophication and consequent depletion of dissolved oxygen. Consumption of water rich in nitrates is bad for human health especially for small children.

Pesticides (DDT, dieldrin, aldrin, malathion, carbaryl etc.) are used to kill insect and rodent pests. Toxic pesticide residues enter the human body through drinking water or through food chain (biomagnification). These compounds have low solubility in water but are highly soluble in fats. For example, the concentration of DDT in river water may be very low but some fish over a period of time accumulate so much of DDT that they become unfit for human consumption. The use of pesticides in our country is increasing very rapidly.

Some of these chemicals which are highly toxic become metabolized by animals that graze on fields. Therefore, these poisonous chemicals have been often observed in the human food chain. The presence of these chemicals in humans even in minute amounts can cause hormonal imbalance and may lead to cancer.

(iv) **Physical Pollutants** : Physical pollutants can be of different types. Some of them are discussed below :

a) **Radioactive wastes** : Radionuclides found in water are radium and potassium-40. These isotopes originate from natural sources due to leaching from minerals. Water bodies are also polluted by accidental leakage of waste material from uranium and thorium mines, nuclear power plants and industries, research laboratories and hospitals which use radioisotopes. Radioactive materials enter human body through water and food, and may be accumulated in blood and certain vital organs. They cause tumours and cancer.

b) **Thermal Pollution** : Various industries, nuclear power plants and thermal plants require water for cooling and the resultant hot water is often discharged into rivers or lakes. This results in thermal pollution and leads to the imbalance in the ecology of the water body. Higher temperature lowers the dissolved oxygen level (which is very essential for marine life) by decreasing the solubility of oxygen in water. Fish and other aquatic organisms can be killed by a sudden change in water temperatures.

c) **Oil Pollution** : From time to time we hear the news of accidental spill of crude oil and other related products into marine waters by oil tankers. Besides these accidental spills, oil refineries, oil exploration sites and automobile service centres pollute different water

bodies. Oil slick which floats on the water surface causes death of marine life and severely affects the ecosystem of the ocean.

Water Pollutants can be divided into some general categories. They are summarized in Table 33.1

**Table 33.1 Different Types of Water Pollutants**

Sources of Pollutant	Pollutant	Effects and Significance
1. Sewage, human and animal wastes, natural and urban runoff from land, industrial waste	Oxygen demanding wastes, disease causing agents (pathogens & viruses)	Depletion of dissolved oxygen in water (foul odour) health effects (outbreaks of water borne diseases)
2. Organic Chemicals Oil and grease	Automobile and machine waste, tanker spills, offshore oil leakage.	Disruption of marine life, aesthetic damage
Pesticides & weedicides	Chemicals used for better yield from agriculture	Toxic effects (harmful for aquatic life), possible genetic defects and cancer Kills fish
Plastics	Industrial and household waste	
Detergents (phosphates)	Industries and homes	Eutrophication, aesthetics
3. Inorganic Pollutants Fertilizers (phosphates and nitrates)	Agricultural runoff.	Algal bloom and eutrophication, nitrates cause methaemoglobinaemia
Acidity, alkalinity and Salinity	Mine drainage, industrial wastes, natural and urban runoff	Kill fresh water organisms, unfit for drinking, irrigation and industrial use
4. Radionuclides	Natural sources, uranium mining and processing, hospitals and research laboratories using radiosotopes	Cancer and genetic defects
5. Heat	Cooling water for industrial, nuclear and thermal plants	Decreases solubility of oxygen in water, disrupts aquatic ecosystems
6. Sediments	Natural erosion, runoff from agricultural land and construction sites	Affects water quality, reduces fish population

### 33.4.2 Ground Water Pollution

In most of our villages and many townships, ground water is the only source of drinking water. Therefore, pollution of groundwater is a matter of serious concern. Groundwater gets polluted in a number of ways. The practice of dumping raw sewage on soil, pollutants contained in seepage pits and septic tanks cause pollution of groundwater. (fig.33.2) The porous layers of soil hold back solid particles while the liquid is allowed to pass through. The solid contaminants are generally absorbed by the soil and are thus retained. However,

soluble pollutants are able to mix with the groundwater. Since the movement of groundwater through the porous rock is very slow, pollutants which get mixed with the groundwater are not readily diluted. Furthermore, groundwater does not have access to air (in contrast to surface water). Therefore, oxidation of pollutants into harmless products in the groundwater does not occur.

In recent years, modernization of agriculture has led to intensive use of nitrogenous fertilizers. The nitrate salts being soluble in water are able to penetrate through the soil into the groundwater. Drinking water containing nitrates is harmful to humans especially to infants and causes a particular kind of anemia called *methaemoglobinaemia*. In the human digestive tract, nitrates are converted into nitrites by certain bacteria. Nitrite ion combines with haemoglobin (red blood cells used for carrying oxygen) and form a new complex called methaemoglobin. This decreases the oxygen carrying capacity of blood and results in suffocation and changes in RBC of human infants. The removal of nitrate ions from water is difficult since nitrate salts are soluble in water.

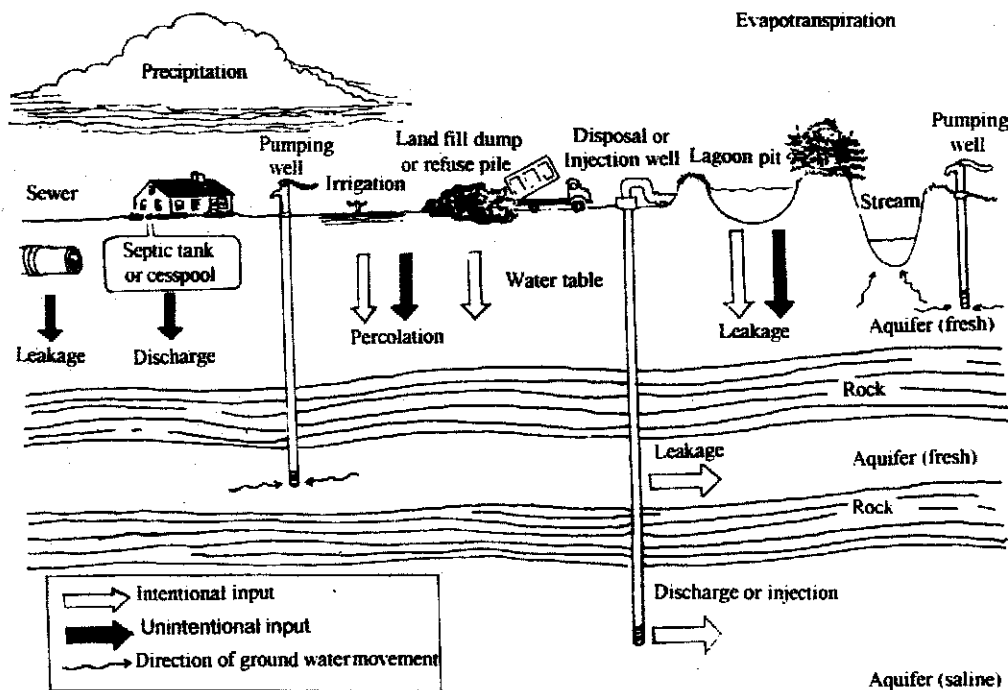


Fig. 33.2 Sources of Ground Water Pollution

The indiscriminate release of toxic wastes and even carcinogenic substances by industrial units may result in these toxic substances slowly trickling down through the earth's surface and mixing with the groundwater. This problem is very serious especially in areas where water table is high (i.e., where water is available near surface of earth). Drinking this contaminated water\* over many years may lead to bioaccumulation\*\* of these toxic materials in the body. These compounds are difficult to metabolise and are stored in the body in its fatty tissues. Over long periods, their concentration in the body may reach dangerous levels and may cause severe damage to vital human organs and even bring nervous disorders.

**INTEXT QUESTIONS 33.1**

1. How does the presence of excess of nitrates in drinking water cause harm to humans?
2. Define water pollution.
3. How does surface water arise?
4. List any three artificial sources of water pollution?
5. Name the element which causes Minamata disease?

**33.5 WATER POLLUTION AND SOME BIOLOGICAL EFFECTS****33.5.1 Eutrophication**

The word eutrophication is derived from the Greek word which means well nourished as (eu:true, trophos:feeding).

**Eutrophication is a process by which a water body slowly becomes rich in plant nutrients such as nitrates and phosphates due to soil erosion and run off from the surrounding land.**

These nutrients promote the growth of algae. Increasing human population, intensive agriculture and rapid industrial growth have led to an increasing release of domestic waste, agricultural residues, industrial wastes and land run-off into various water bodies. Nutrients are released from organic wastes by aerobic (oxygen requiring) bacteria. Dissolved oxygen is consumed in this process. Therefore, as more and more organic matter enters a water body, greater is the deoxygenation of the water body and greater is the production of nutrients. These nutrients fertilize an abnormal growth of algae and other large water plants such as duckweed. As more plants grow, more die also due to oxygen deficiency in the water body (i.e., deoxygenation of the water body). Such a water body is said to be eutrophied.

**Eutrophication of a water body results due to release of large amount of nutrients by the action of aerobic bacteria on organic wastes entering a water-body naturally or by human activity.**

The above discussion leads us to a new concept called biological oxygen demand (BOD)

**33.5.2 Biological Oxygen Demand (BOD)**

Aerobic bacteria use dissolved oxygen of water when converting organic waste into nutrients.

**The quantity of oxygen used up by microorganisms in breaking down organic wastes in a water body is called its biological oxygen demand (BOD).**

The greater the amount of organic waste in the water body, the greater is the amount of oxygen required to break it down biologically and therefore higher is the BOD value of water. The less polluted waters show comparatively low values of BOD. This value is a good measure in evaluating the degree of pollution in a water body. Its value is used as a criterion for managing water pollution of a water body. An evaluation is made by determining oxygen concentration in a water sample before and after incubation at 20°C in dark for 5 days.

- \* The concentration of these toxic chemicals in water may be quite small say a few parts per million (ppm) and as such may not be harmful.
- \*\* bioaccumulation : Collection of a toxic substance in the body of an organisms by dissolving in tissue fluids or fat etc.

### 33.5.3 Biomagnification

A variety of toxic chemicals move through food chains. Toxic pesticides may be sprayed for controlling insect pests, fungi, herbs, but they concentrate in the food chain and harm non target organisms. For example DDT was sprayed in the U.S. to control mosquitoes at a concentration expected to be harmless to other (non target) organisms like fish and birds. DDT accumulated in the marshes and plankton. Plankton was eaten by fish and the fish had a higher concentration of DDT in its body. Further when birds ate the fish, they accumulated still higher concentration. This increase in concentration of accumulated toxic chemicals as one goes higher in the food chain is termed **Biomagnification**. Biomagnification has at times threatened the reproduction and survival of carnivores (secondary consumers) who occupy the highest level of the food chain.

Pesticide (toxic chemical)

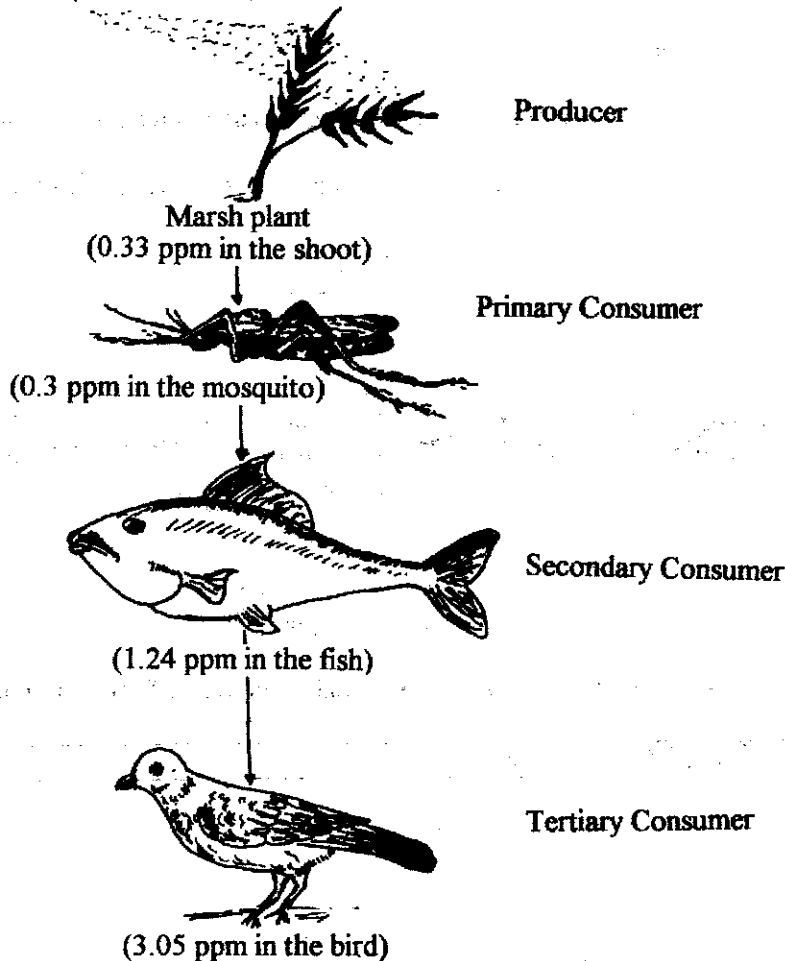
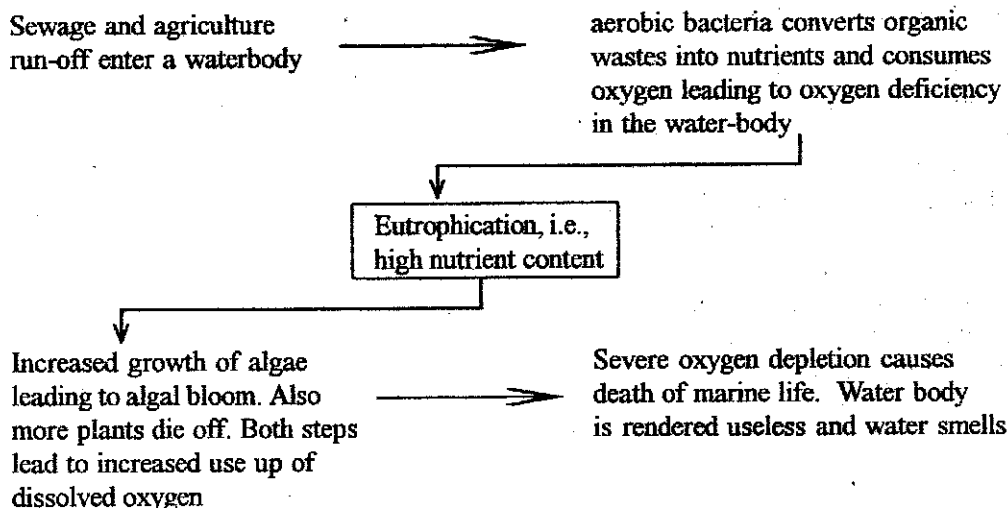


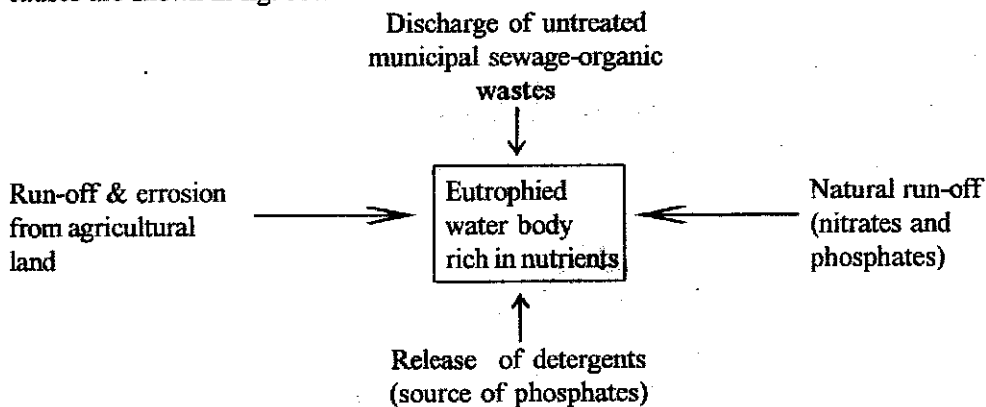
Fig. 33.3 Increasing Concentration of Toxic Chemical along the Food Chain

Figure 33.4 shows the sequence of steps leading to entrophication of water body.



**Fig.33.4 : Sequence of steps leading to eutrophication of a water body.**

There are many reasons which lead to man made eutrophication of water body. The major causes are shown in fig. 33.5



**Fig.33.5:Major Causes Leading to Artificial (man made) Eutrophication of Water Body**

**INTEXT QUESTIONS 33.2**

1. Define (i) Eutrophication (ii) Biomagnification.  
.....
2. What does BOD assess?  
.....
3. Why does aquatic life get killed in an eutrophied pond?  
.....

### 33.6 REMEDIES OF WATER POLLUTION (TREATMENT OF SEWAGE)

Waste water generated by household activity, industries or garbage landfills is called sewage.

The treatment of waste water is carried out in the following three stages:

- (i) Primary treatment
- (ii) Secondary treatment, and
- (iii) Tertiary treatment

If the waste water is to be dumped off into a river or flowing stream, the treatment is carried out in these steps : *sedimentation, coagulation and filtration*. This is known as primary treatment. If the water is required for drinking purposes, it has to undergo further treatment called secondary and tertiary treatments.

**(i) Primary Treatment :** The following steps are performed to do primary treatment of water :

**(a) Sedimentation :** This step is carried out in large tanks specially built for this purpose in a sewage treatment plant. The polluted water is allowed to settle so that silt, clay and other matter settle to the bottom and water is slowly allowed to move out. Fine particles do not settle and are thus required to be removed in the next step.

**(b) Coagulation :** Fine particles and colloidal suspension are combined into large particles by coagulation. This step is carried out by the addition of special chemicals called coagulants (or flocculants) such as potash alum. The large particles either settle to the bottom or are removed in the next step.

**(c) Filtration :** Suspended particles, flocculants, bacteria and other organisms are filtered out by passing the water through a bed of sand or finely divided coal or through some fibrous disc.

The total impurities collected in these steps are called *sludge*. This is used as a valuable fertilizer. On composting (i.e., the action of anaerobic bacteria), it releases sludge gas. It consists mainly of methane gas which is used for cooking purposes.

**(ii) Secondary or Biological Treatment :** The water after primary treatment is not fit for drinking purposes and has to undergo further treatment. This is done through secondary or biological treatment.

**(a) Softening :** By this treatment undesirable cations of calcium and magnesium are removed from hard waters. Either the water is treated with lime and soda ash to precipitate  $\text{Ca}^{2+}$  and  $\text{Mg}^{2+}$  ions as carbonates or the water is passed through cation exchangers. This makes the water soft.

**(b) Aeration :** In this process the soft water is exposed to air by forcing air through it to add oxygen to water. This encourages bacterial decomposition of organic matter into harmless products such as carbon dioxide and water. The addition of oxygen reduces carbondioxide, hydrogen sulphide etc. A commonly used method is to allow polluted water to spread over

a large bed of stones and gravel so that the growth of different microorganisms needing nutrients and oxygen is encouraged. Over a period of time a fast moving food chain is set up. For example, bacteria consume organic matter from the polluted water; protozoa live on bacteria. Every form of life including algae and fungi help in the cleaning up process.

This is called secondary treatment of water. The water is as yet not fit for drinking purposes. The pathogenic and other microorganisms need to be killed. This is done in the next treatment.

### (iii) Tertiary Treatment

This step involves disinfecting water. Chlorine is the most commonly used disinfectant used for killing bacteria. However, chlorine also reacts with traces of organic matter present in water and forms undesirable chlorinated hydrocarbons (toxic and potentially carcinogenic). It is therefore desirable to reduce the organic matter in water before passing chlorine gas. Other methods of disinfection such as ultraviolet radiation, ozone gas treatment or reverse osmosis are preferred over chlorine treatment. But these methods are more expensive. Fig. 33.6 gives a clear picture of the whole process.

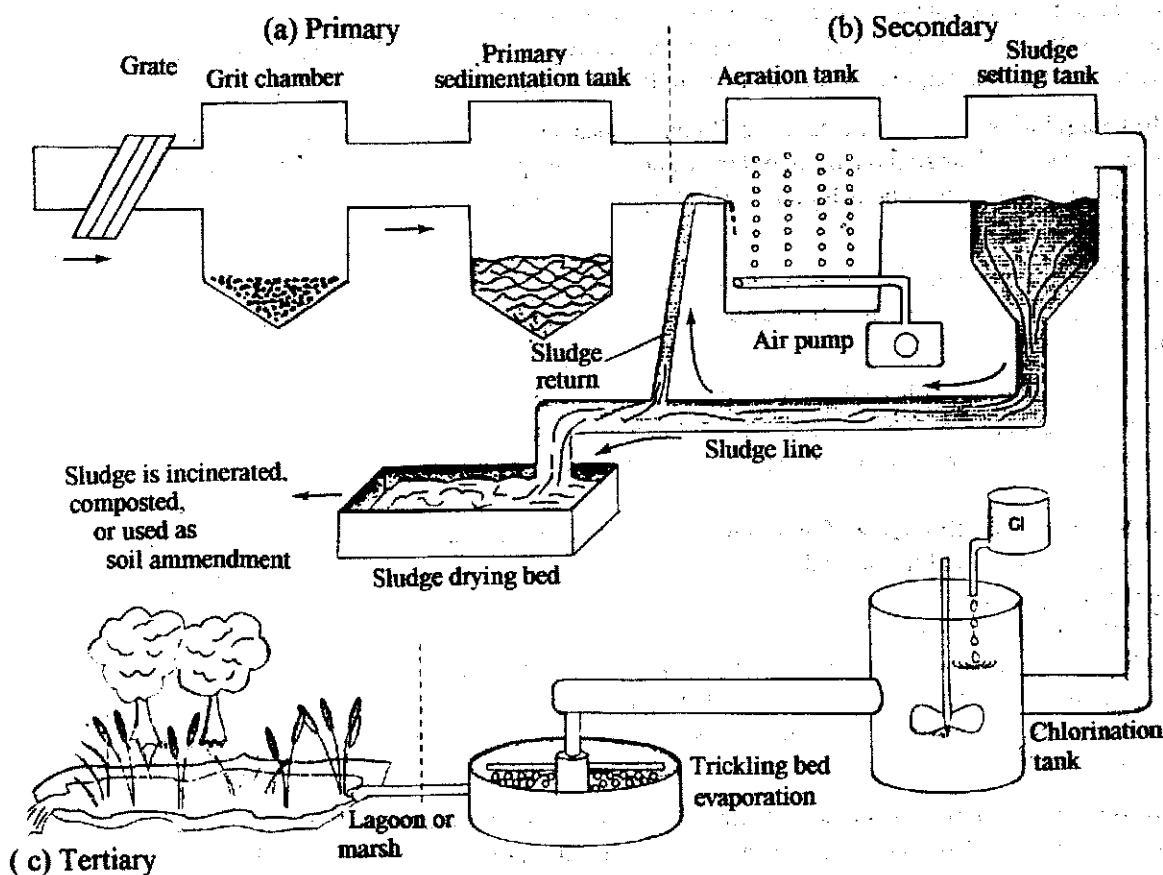


Fig. 33.6 Treatment of Sewage

### 33.7 LEGISLATIVE MEASURES FOR PREVENTION OF POLLUTION OF WATER

The enactment of 'Prevention and Control of Water Pollution Act' in 1974, has helped in the prevention of water pollution. Proper standards have been prescribed for water pollution under Environment (Protection) Act 1986 as follows:

- General standards for water pollutants for discharge of effluents in water bodies on land (inland surface water, public sewers, irrigated land and coastal areas).
- Standards for each type of industry have been specified.
- Standards for the amount of waste water to be discharged for different industries has been fixed.
- Standards limiting the amount of a particular pollutant on the basis of production capacity of an industrial unit.

The state pollution control boards have also been empowered to grant/renew consent to new/existing water polluting industries under water 'Prevention and Control of Pollution Act-1974.' They have been empowered to shut down any industrial unit which fails to meet the prescribed standards under the act 1974. The state governments have also been authorised to take punitive measures against defaulting industries.

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#### INTEXT QUESTIONS 33.3

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1. How is sludge utilized?  
.....
  2. Mention the steps by which polluted water is made fit for drinking purposes?  
.....
  3. Why is chlorination not the most desirable method of disinfecting polluted water?  
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- 

### 33.8 WHAT YOU HAVE LEARNT

- Water pollution refers to any physical, chemical or biological change that has an undesirable affect on living organisms.
  - Sewage, industrial, agricultural pollution and physical pollutants are the various sources of water pollution. These sources may be limited to a point source or spread over large areas (non-point sources).
  - Sewage, fertilizers, detergents, toxic wastes released by industries are some of the sources of groundwater pollution.
  - Phosphates, and nitrogenous fertilizers cause algal bloom and severe oxygen depletion in a water body. The water body is said to be eutrophied.
  - The quantity of oxygen needed by microorganisms in degrading organic wastes in a water body is defined in terms of its biological oxygen demand (BOD).
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- Biological magnification of toxic materials released into water bodies poses a serious threat to aquatic life and eventually to human life.
- Polluted water may be rendered useful for human consumption by subjecting it to various treatments.
- Legislative measures have been enacted in our country to restrict the pollution of various water bodies.

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### 33.9 TERMINAL EXERCISES

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1. What are the various types of water pollutants? State their consequences.  
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  2. What are the effects of detergents on fresh water bodies?  
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  3. What are the various sources of groundwater pollution?  
.....
  4. How is the disease 'methaemoglobinaemia' caused?  
.....
  5. Suggest steps to stop eutrophication of a water body.  
.....
  6. What was Minamata Bay tragedy?  
.....
  7. Which precaution is necessary before purifying the drinking water through chlorination?  
.....
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### CHECK YOUR ANSWERS

#### INTEXT QUESTIONS 33.1

1. Nitrate ions are converted by intestinal bacteria into nitrites. These ions combine with haemoglobin to form methaemoglobin thus inhibiting the supply of oxygen. This causes a disease known as methaemoglobinaemia.
2. Refer to section 33.4
3. Refer to section 33.4.1
4. Refer to table 33.1
5. Mercury

#### INTEXT QUESTIONS 33.2

1. (i) Refer to section 33.5.1  
(ii) Refer to section 33.5.3
  2. Refer to section 33.5.2
  3. Due to oxygen deficiency in the water body.
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### INTEXT QUESTIONS 33.3

1. As fertilizer.
2. Primary treatment including sedimentation, coagulation, filtration. Secondary treatment including softening and aeration and tertiary treatment.
3. Because chlorine reacts with organic matter to produce highly toxic chlorinated hydrocarbons which can cause cancer.

### TERMINAL EXERCISE

1. Refer to Table 33.1.
  2. Detergents contain phosphates (plant nutrients) which promote algal growth in a water body leading to eutrophication.
  3. Refer to section 33.4.2.
  4. By presence of nitrate ions in water; read section 33.4.2.
  5. By eliminating the addition of organic wastes and inorganic nutrients (phosphates & nitrates) into a water body.
  6. Refer to section 33.4.1. This tragedy occurred due to the poisoning of fish due to the release of mercury and its related compounds in water.
  7. Complete removal of even traces of organic matter so as to avoid the formation of organochlorine compounds.
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