Water is one of the most important natural resources and a regular supply of clean water is very essential for the survival of all living organisms. By definition, a water pollutant is anything put into water which was not there in its natural state. The sources and effects of water pollution are as follows :

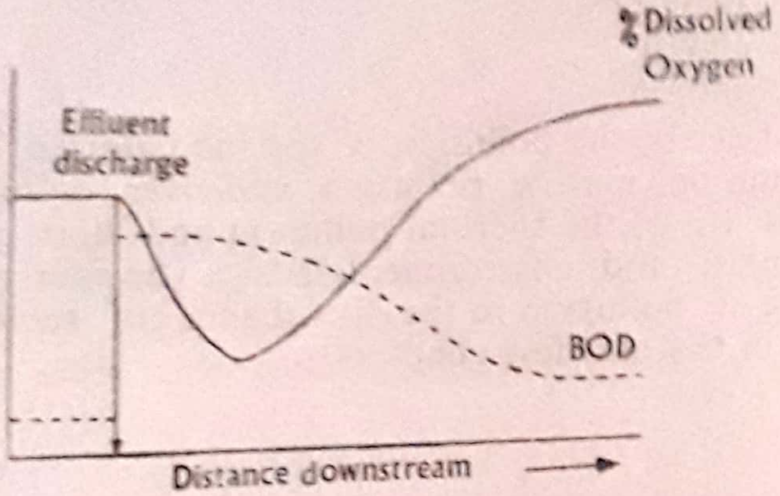

Fig. 19.1. Oxygen saturation percentage and biological oxygen demand (BOD) downstream of an effluent discharge.

1. **Sewage and domestic wastes :** About 75% of water pollution is caused by sewage and domestic wastes. Organic pollution originates from incompletely digested sewage which usually has some remaining *biological oxygen demand* (BOD) when it is released (Fig. 19.1).

The royal commission on Sewage disposal (1912) first adopted the well known *BOD test* as a measure of the polluting organic matter present in a sample of water. BOD can be defined as the amount of oxygen consumed by chemical and micro-biological action when a sample of water is incubated for 5 days at 20°C in the dark. BOD is expressed as mg/l or ppm of oxygen taken up by the sample. When the test is carried out, the water sample is suitably diluted with aerated water and divided into two portions. The dissolved oxygen content of the first portion is estimated at once and the second portion is incubated for 5 days, which is the time required for the oxygen consumption to reduce to a minimum under natural conditions. By comparing the dissolved oxygen content of the two portions, the BOD value is determined. If the volume of incompletely digested sewage is small in relation to the volume of water into which it is released, the oxygen demand may be easily satisfied. But when the volume of sewage is greater than the dilution water, the oxygen demand may remain unsatisfied for a long period of time and create an oxygen-deficient situation harmful for the aquatic organisms. Near the point of effluent discharge the bacterial population rapidly increases with active growth of sewage fungus. Protozoa species that feed on bacteria increase in numbers, but the oxygen deficit causes a decrease of algae and clean water fauna (Fig. 19.2). Fish, being sensitive to dissolved oxygen concentrations, are often eliminated, and only a few invertebrate species, such as the sludge worms (*Tubificidae*) and blood worms (*Chironomus*) can exist in low oxygen concentrations.

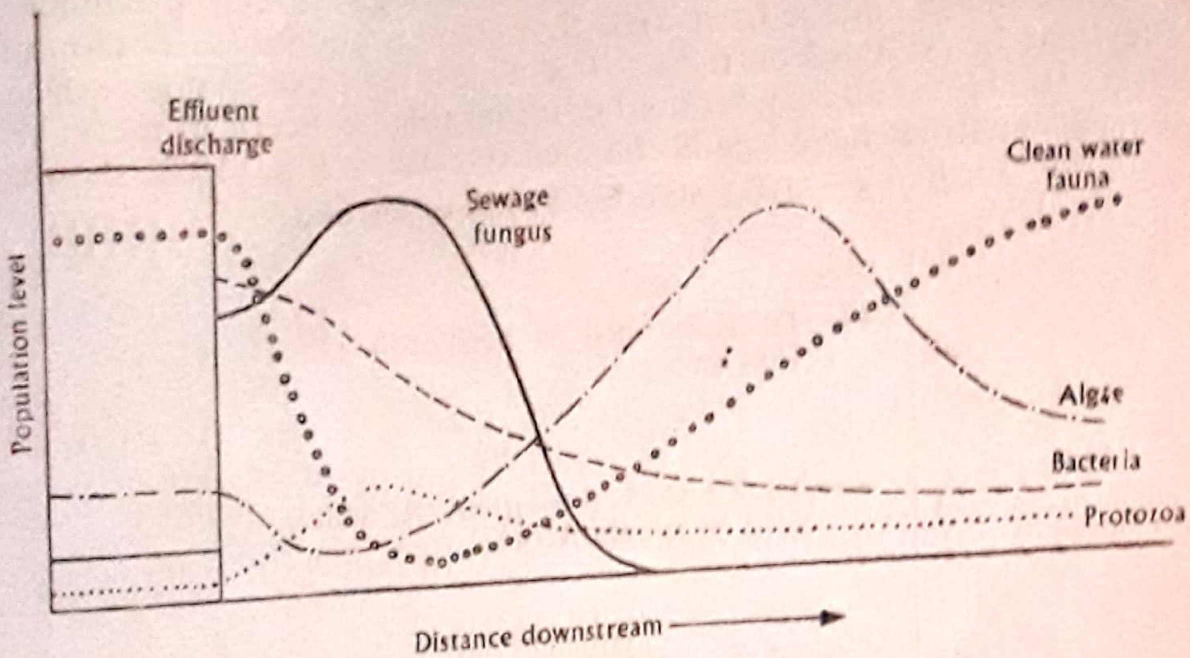

Fig. 19.2. Effect of organic pollution on the biota of a river.

Completely oxidised sewage effluent also creates problems because of its heavy load of phosphorus. The latter stimulates the growth of algae which, in turn, create pollution when they die and decay.

2. **Industrial wastes and effluents** : All industrial plants produce some organic or inorganic chemical wastes which cause water pollution. These nonusable chemicals are usually dumped in water as a means of getting rid of them. The toxicity of these industrial pollutants to fishes is variable but all of them contaminate the aquatic environment to a greater or lesser extent and some accumulate on the bottom of watar courses and smother or poison the bottom organisms. In this way they reduce the foods for some kinds of fishes. Resistant objects like the cans, tyres, metals, and other metallic and plastic wares also act as water pollutants.

3. **Insecticides** : Insecticides are biologically active chemicals used for pest control, but their spectrum of activity often extends far beyond the pests and justifies the use of another term 'biocide' for them. A major

source of pesticides in the rivers, streams and lakes is from runoff from the agricultural fields. Some pesticides also enter inland waters from industries which use pesticides in their manufacturing processes, or from the manufacturing of pesticides themselves.

Many of these chemical compounds are quite stable and some break down partially to form compounds that may be even more toxic to certain desirable fauna than were the original chemical compounds. Most pesticides used to control destructive insects are either chlorinated hydrocarbons or organic phosphorus compounds. Chlorinated hydrocarbons (DDT, endrin, toxaphene, dieldrin, aldrin, etc.) are more stable than organic phosphorus insecticides (chlorothion, guthion, parathion, malathion, EPN. etc.) and for that reason they may contaminate the aquatic environment with sublethal amounts which tend to accumulate in the tissues of aquatic animals (*Nicholson*, 1964). This accumulation of chlorinated hydrocarbons may reach such high levels in animals at the summit of the aquatic food web that they are unable to reproduce or they may be poisoned outright. The widespread use of one such compounds, DDT, has already aroused considerable concern in recent years and some countries have legally banned its use. Fig. 19·3 shows the

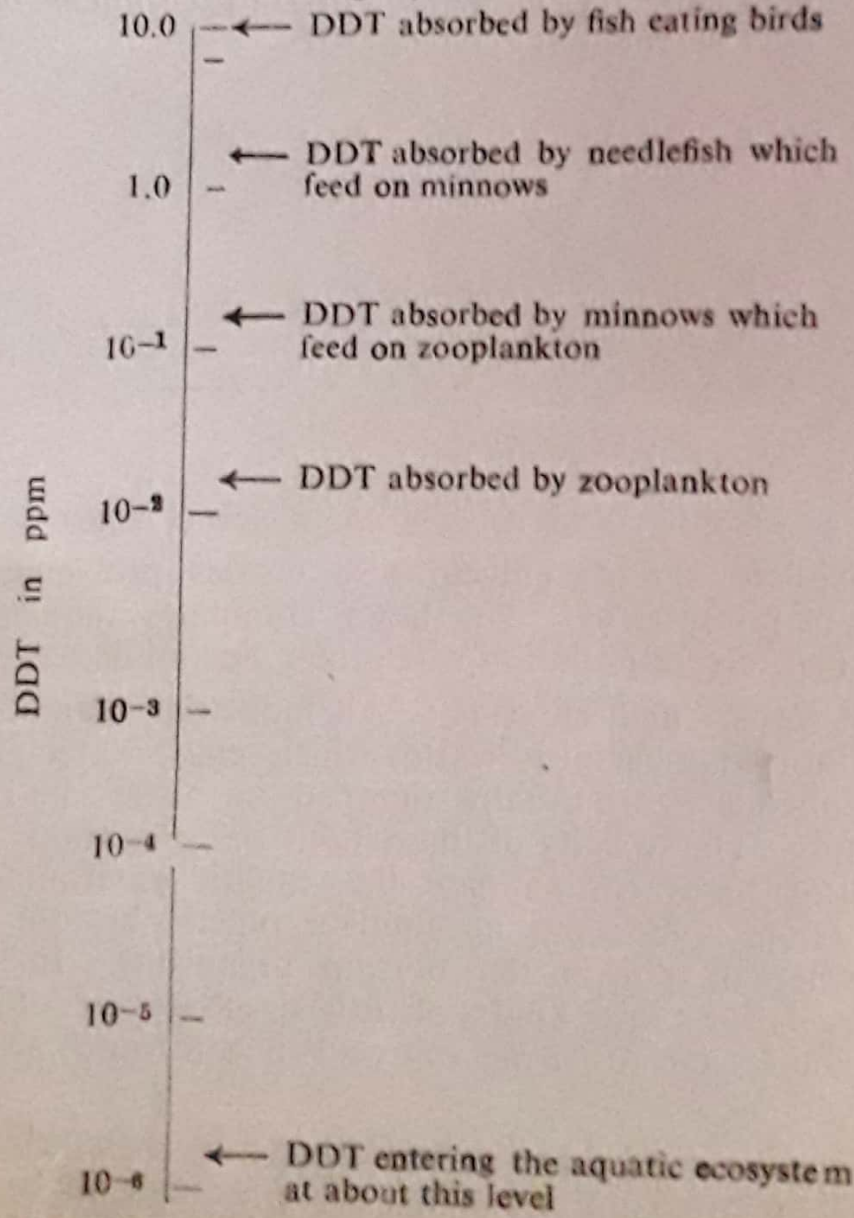

Fig. 19.3. **Biological magnification of DDT through the food chain**

biological concentration of DDT through an aquatic food chain. Animals belonging to the higher trophic levels in the food chains, such as seals, porpoises, and birds, may have upto 55 g/m^3 of DDT in their fatty tissues. Estimations of DDT in human body fat were made in 1964 and these varied from 3.3 g/m^3 in the UK to 25 g/m^3 in India.

4. **Detergents and fertilizers** : By definition, a detergent is anything that cleanses including ordinary soap. However, usually the term detergent is applied to washing materials that exhibit soapiness without the disadvantages of soap when used in hardwater. The use of detergents has been responsible for a marked increase in the phosphorus released in sewage effluents since the early 1950s. Detergents are composed of complex phosphates (alkyl benzene sulfonate or alkylate sulfonates) which eventually break down into phosphates usable by aquatic plants. Although detergents are not highly toxic to fishes, they do cause damage to gills and remove protective mucus from gills, skin and intestine (*Nerhring*, 1962). Aquatic invertebrates also may be affected by detergents. Alkyl benzene sulfonate kills several species of mayfly nymphs when the nymphs are exposed to 16 ppm for 10 days. Crayfish are reduced in numbers by a 2-week exposure to 10 ppm (*Surber* and *Thatcher*, 1963).

In modern agriculture fertilizers like nitrates and phosphates are used. Some of these are washed off the agricultural fields through irrigation, rainfall, and drainage into rivers and ponds where they may seriously disturb the aquatic ecosystem. Excessive use of fertilizers often leads to accumlation of nitrates in water. When such waters are used by animals, these nitrates are reduced to toxic nitrites by intestinal bacteria. Nitrites can cause a serious disease called methaeglobinemia which which can damage respiratory and vascular systems and even cause suffocation.

5. **Other chemicals** : Of the various other chemicals that pollute our inland waters mercury is the most important. As a result of its use in many products and subsequent release, the amount of mercury in inland waters has sufficienty increased. The mercury of waste products is converted by anaerobic bacteria into CH_3Hg (methyl mercury), and $(CH_3)_2Hg$, dimethyl mercury which are poisonous molecules. The effects of mercury poisoning include chromosomal damage. Toxic effects of mercury on liver, kidney and gills of fishes have been studied by many workers (Hinton *etal* 1973; Gardner 1975).

In some coal mining areas, pollution from water used in washing coal or from mine seepage also causes a serious problem. The sulfur in coal produces acids in the water which is sometimes responsible for lowering the pH of streams. The lowered pH usually kills all life in the stream. However, in new mines the problem has been eliminated by the use of modern mining practices, but old mines continue seeping acid discharges.

Some other widely used industrial chemicals like polychlorinated biphenyls also pollute our waters. They are released into the environment through the atmosphere and by dumping and leakage into water-ways. They degrade very slowly and accumulate in the food chain. They can be toxic by themselves and may interact with other chlorinated hydrocarbons such as DDT to increase their toxicity.

6. **Siltation** : Is one of the more damaging and widespread pollutants. Although high turbidities from soil particles may not be lethal to fishes, turbid waters may affect the productivity of an aquatic environment and the growth of fishes (*Murphy*, 1962).

7. **Thermal pollution** : A large number of industrial plants use cold water from the rivers and discharge it hot. In developed countries atomic energy plants have become a major source of thermal pollution which is harmful to fishes and aquatic invertebrates. The biological effects of such pollution depend upon how much the water temperature is raised. For example, trout are killed by a temperature of over 25°C and their eggs will not develop in water above 14°C. Most fresh water fauna populations decline with rising temperatures, and few species can exist in a water temperature of over 40°C. Above about 30°C green algae are reduced in numbers, but there is an increased growth of blue-green algae and sewage fungus. As warm water holds less oxygen, thermal pollution speeds up the biodegradation of organic matter resulting in the disturbed ecological balance of the streams and rivers.

8. **Radioactivity** : *Klement* and *Wallen* (1960) have described biological effects of fallout and radioactive wastes released into rivers. Adsorption and absorption are of major importance in the uptake of radioisotopes by plants (*Foster* and *Rostenbach*, 1954). Fishes take up radioactive materials by ingestion and assimilation with food (*Davis*, 1962) and by absorption, but there is little agreement as to which is more important.

Davis and *Foster* (1958) have worked on bioaccumulation of radioisotopes through aquatic food chains and have shown that the insects in the Columbia River possessed many times more radioactivity than the water they inhabit. The most abundant nuclides found in insects were P-32, Cu-64, Cr-51, Zn-65, and Na-24. With the potential for increased buildup of radioactive isotopes in fishes, it is very important to prevent their contamination, particularly because they may be a source of contemination for man.

Thus, it may be concluded that the main sources of water pollution are : sewage and domestic wastes, industrial wastes and effluents, insecticides, detergents and fertilizers, other chemicals, silt, heat (thermal pollution), and radioactivity. Of these pollutants, waste chemicals, and pesticides are more harmful, whereas sewage pollution may represent a mixed benefit. Organic sewage increases production after certain demands that it makes upon water are met.

Assessment and Control of water pollution : According to *Odum*, successful pollution abatement, of course, depends not only on treatment and control but also on efficient monitoring of the general environment so that we will know for sure when control measures are needed and whether those in use are working. According to *Cairns* (1981), monitering implies regular or continuous assessment of one or more parameters and may be divided into chemical-physical monitoring and biological monitoring. It includes (*i*) direct measurement of the concentration of pollutants or of key substances, such as *oxygen*, which are depleted by pollution, and (*ii*) the use of biological indices (biotic index and diversity indices) which range from bioassays and BOD to the kind of total community indicators.

Biological means of pollution assessment can be grouped into three categories (*Cairns*, 1979). These are (*i*) early-warning systems, which monitor the physiological responses of test organisms to effluents, (*ii*) bioassays designed to measure the effects of pollutants on specific organisms (a *bioassay* may be defined as "a test in which the quantity or strength of material is determined by the reaction of a living organism to it", *Sprague*, 1973), and (*iii*) field studies, usually involving description and analysis of community responses to pollution. According to *Cairns* (1981), instead of single species tests which are essential for measuring such things as lethality, alterations of growth rate, fecundity, behaviour, and the like, the highest priority in biological monitoring of pollution should be given to multispecies and system level tests. The latter are needed for such things as estimating transfer rates of a chemical through biological processes such as predation.

Water pollution is the classic example of, "*the solution to pollution is dilution*". On this principle several methods are used to control water pollution.

In Norway to remove the phosphorus of the sewage, organic sewage is mixed with 10—15% sea water and subjected to electrolysis. Phosphorus compounds in the sewage are precipitated as Mg and Ca salts. These together with sludge and suspended particles, adhere to magnesium hydroxide at the negative pole. Phosphates and sludge are in turn floated to the surface as a scum by means of hydrogen gas liberated during electrolysis, and scrapped off. Chlorine developed at the positive pole is used for disinfection at the outlet (*Strand* and *Jenkins*, 1961). The three stages of treatment (primary, secondary, and tertiary or advanced) for sewage and similar organic wastes are used in many metropolitan cities all over the world. At present sewage effluent is tested only for the presence of *Escherichia coli*, which is a nonpathogenic intestinal bacterium. The so-called coliform test of water purity is carried out to indicate the presence or absence of faecal matter present in water.

Water pollution by organic insecticides may be reduced by the use of more specific and less stable chemicals applied at the exact time and place and at the absolute minimum dosages. The atomic wastes are treated in various ways. Phosphorus-32 is partially removed from reactor effluents by passage through beds of aluminium turnings (*Olson*, 1961). Oxidation ponds were functional in removing some low-level radioactive wastes, particularly when algal cells were removed once they become contaminated (*Steel* and *Gloyna*, 1955).

The thermal pollution abatement schemes that are used in some developed countries include once-through cooling, cooling ponds, evaporative or wet cooling towers, and dry cooling towers (*Thorndike*, 1976).

In India, the National Environmental Engineering Research Institute (NEERI), Nagpur has recommended some methods for the control of water pollution. The conventional methods of sewage and industrial waste treatment are expensive but NEERI scientists have devised processes that are less expensive and efficient. These methods take advantage of the plentiful sunshine and warm climate that exist in most parts of India. These conditions favour treatmeat of waste in the so-called oxidation or stabilization ponds. Domestic or industrial wastes may be stored in a large shallow pond for a few days. Because of the presence of sunlight and organic nutrients in waste, a healthy bloom of algae flourish alongwith colonies of bacteria. Through this natural process, the bacteria rapidly digest the organic waste, and render it harmless. The effluent then may be used for the irrigation of farms without any danger of pollution. Other low cost methods recommended by NEERI are *oxidation ditches* for extended mechanical aeration. For middle-sized towns, aerated lagoons may be used because they require much smaller surface areas than oxidation ponds.

Waste water reclamation has also been suggested by the NEERI. The sewage treatment yields irrigation water that contains a number of essential nutrients like nitrogen, phosphorus, and potassium to make it a fertilizer. In West Bengal the practice of irrigating fish ponds with sewage for raising fish has been described by *Nair* (1944) and *Saha* (1970). Another interesting aspect is the reuse or reclamation of sewage effluents for industrial purposes. This holds good for coping with the ever increasing demand for water by industrial establishments in big cities. A few industries in Bombay have already taken steps in this direction and the treated sewage is used for air-conditioning and other purposes.

The U.S. National Aeronautics and Space Administration (NASA) at the National Space Technology Laboratories (NSTL) in Mississippi has used water hyacinth (*Eichhornia crassipes*) and duckweeds (*Spirodela* sp., *Lemna* sp., and *Wolffia* sp.) to upgrade waste water treatment lagoons and treat chemical wastewaters (*Wolverton* and *Mc Donald*,, 1979). The controlled use of water hyacinth in conjunction with waste stabilization ponds not only increases the BOD removal capacity of these systems, but also reduces the high total suspended solids normally associated with sewage lagoons. (Table 19.1) Higher plants reduce suspended solids in lagoon effluent by reducing algae which make up a major portion of the suspended solids. Nitrogen, phosphorus, potassium, sulphur, calcium, and other minerals can be removed from domestic sewage by harvesting the plant biomass. The harvested plant material is also a potential source of high quality protein, energy (biogas), fertilizer and other products.