Water (prevetion and control of pollution) Act 1974 was adopted by 16 states upto 1977. The central water control board is set up to co-ordinate the work of state board and union territories.

**The power and function :** The functions of central pollution control board are as follows :

1. To advice the central government on any matter relating to the prevention and control of water pollution.
2. To collect, compile and publish technical and statistical data relating to water pollution and the measures taken to prevent it.
3. To co-ordinate the activities of the state pollution control boards.
4. To create public awareness against water pollution.
5. To lay down the standards or purification.
6. To plan and organise the training of persons engaged or to be engaged by the board.
7. To provide technical assistance and guidance to the state pollution control boards.

## DISSOLVED OXYGEN

**Dissolved oxygen analysis measures the amount of gaseous oxygen ($O_2$) dissolved in an aqueous solution.** Oxygen gets into water by diffusion from the surrounding air, by aeration (rapid movement), and as a waste product of photosynthesis. Fish, invertebrates, plants, and aerobic bacteria all require oxygen for respiration. Much of the dissolved oxygen in water comes from the atmosphere. After dissolving at the surface, oxygen is distributed by current and turbulence. Algae and rooted aquatic plants also deliver oxygen to water through photosynthesis.

The main factor contributing to changes in dissolved oxygen levels is the build-up of organic wastes. Decay of organic wastes consumes oxygen and is often concentrated in summer, when aquatic animals require more oxygen to support higher metabolisms. Depletions in dissolved oxygen can cause major shifts in the kinds of aquatic organisms found in water bodies. Temperature, pressure, and salinity affect the dissolved oxygen capacity of water. The ratio of the dissolved oxygen content (ppm) to the potential capacity (ppm) gives the percent saturation, which is an indicator of water quality.

### Environmental Impact

Total dissolved gas concentrations in water should not exceed 110 percent. Concentrations above this level can be harmful to aquatic life. Fish in waters containing excessive dissolved gases may suffer from "gas bubble disease"; however, this is a very rare occurrence. The bubbles or emboli block the flow of blood through blood vessels causing death. External bubbles (emphysema) can also occur and be seen on fins, on skin and on other tissue. Aquatic invertebrates are also affected by gas bubble disease but at levels higher than those lethal to fish.

Adequate dissolved oxygen is necessary for good water quality. Oxygen is a necessary element to all forms of life. Natural stream purification processes require adequate oxygen levels in order to provide for aerobic life forms. As dissolved oxygen levels in water drop below 5.0 mg/l, aquatic life is put under stress. The lower the concentration, the greater the stress. Oxygen levels that remain below 1-2 mg/l for a few hours can result in large fish kills.

### Measurement of DO

When performing the dissolved oxygen test, only grab samples should be used, and the analysis should be performed immediately. Therefore, this is a field test that should be performed on site. Their are two methods of measurement of D.O.

1. An iodometric method commonly known as the Winkler titration.
2. An electrometric method using a Dissolved Oxygen meter.

Here we discus Winkler titration method only.

## Apparatus

1. 300 mL BOD bottle(s) with stopper(s)
2. 500 mL Erlenmeyer Flask
3. Pipette (20 mL)
4. Burette

- Magnetic Stirplates and Stirbars
- Magnetic Stirbar Retriever

## Reagents

1. Manganous sulfate solution
2. Alkali-iodide-azide.
3. Concentrated Sulfuric acid.
4. Starch solution – Dissolve 2 g of soluble starch in 100 mL of hot distilled water. To preserve the solution, add 0.2 g salicylic acid.
5. Sodium thiosulfate (0.025 *M*)
6. Potassium bi-iodate $KH(IO_3)_2$ - (0.0021 *M*) –
7. Potassium iodide – free from iodate

## Storage / Preservation

When used for the direct determination of DO, the samples measured must be analyzed immediately. There is no method available for preservation of DO samples. Therefore, all samples are grab samples. The DO level of the sample can be *fixed* (by performing the "Preparation of Sample" step) to allow time to transport to a laboratory setting for completion of the analysis. The sample should be kept cool and protected from sunlight until the analysis can be completed.

## Procedure

### I. Standardization of Sodium Thiosulfate

1. In a 500 mL wide-mouth Erlenmeyer flask place 2 g potassium iodide in 100-150 mL distilled water. Swirl to dissolve.
2. Add 2 drops of concentrated sulfuric acid and 20.0 mL of standard potassium bi-iodate solution.
3. Record the initial volume of sodium thiosulfate in the burette.
4. Titrate the potassium iodide solution with sodium thiosulfate to a straw yellow color.
5. Add several drops of starch, a blue / purple color will develop. Titrate dropwise until the blue / purple color disappears (solution will become clear).
6. Record the final volume of sodium thiosulfate in the burette.
7. Calculate the volume of sodium thiosulfate used.

**Note:** The amount of sodium thiosulfate used should be equal to the amount of potassium bi-iodate solution titrated (20 mL). This verifies that the sodium thiosulfate is 0.025 *M* (± 0.001).

### II. Preparation of Sample

1. Fill a 300 mL BOD bottle with the sample to be analyzed.
2. With a pipette, add 1 mL of manganous sulfate.
3. With a pipette, add 1 mL of alkali-iodide-azide.
4. Stopper and invert the bottle several times to mix.
5. Allow the floc in the solution to settle to about half the volume of the bottle.
6. Invert the bottle several times to mix the floc back into the solution.
7. Allow the floc in the solution to settle to about half the volume of the bottle.

8. After settling, add 1 mL concentrated sulfuric acid, stopper and gently invert several times. Continue until the precipitate has dissolved back into solution.
9. If a brown color develops, there is dissolved oxygen in the sample. If no color develops or it is very faint, it may be appropriate to obtain another sample at this time to ensure that there has not been an error in the sample preparation.

**Titration**

1. Pour 200 mL of the sample to be titrated in a 500 mL wide-mouth flask.
2. Record the initial volume of sodium thiosulfate in the burette.
3. Titrate with standardized sodium thiosulfate solution to a pale yellow endpoint (swirl the flask gently while titrating or use a magnetic stirrer).
4. Add several drops of starch solution and continue titrating dropwise until the disappearance of the blue / purple coloration.
5. Record the final volume of sodium thiosulfate in the burette.
6. Calculate the volume of sodium thiosulfate used.

**Calculations**

When a 200 mL sample is used, 1 mL of sodium thiosulfate solution (0.025 *M*) is equivalent to 1 mg/L Dissolved Oxygen in the sample. (If 8.7 mL of sodium thiosulfate was used, then the DO of the sample is 8.7 mg/L).

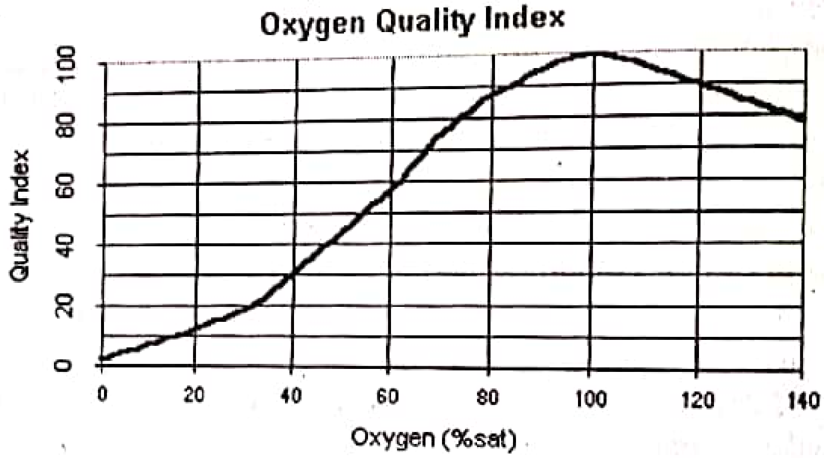


**Fig 4.3. Water quality index (Note- If dissolved oxygen is greater than 140%, the quality index equals 50)**

## BIOCHEMICAL OXYGEN DEMAND (BOD)

### (The Measure of Water Pollution)

To measure the purity of water BOD (Biochemical oxygen demand) unit is used. **BOD is the quantity of oxygen which is required by micro-organisms to decompose harmful substances present in one liter water.** BOD value of pure drinking water must be 1 ppm. When oxygen is not available according to BOD micro-organisms fail to decompose harm ful substances, then these substances are decomposed by anaerobic method and again some other harmful substances are formed, as a result of this water gives bad smell..

The BOD test is the most important measure of the polluting capacity of organic effluents. BOD is measured by keeping a sample of water containing known amount of oxygen for five days at 20° C in the dark. At the end of this period the oxygen content is again measured. A high BOD indicates intense level of microbial pollution.

BOD measures the potential of the organic matter in a sample to deplete the available dissolved oxygen. The degradation of organic matter by the microorganisms present in a water body requires oxygen. This can quickly deplete the available (Dissolve) oxygen in the water. When the dissolved oxygen levels drop too low, many aquatic species perish. In fact, if the oxygen level drops to zero, the water will become septic. When organic compounds decompose without oxygen, it gives rise to the undesirable odours usually associated with septic or putrid conditions.

Biological Oxygen Demand (BOD) is one of the most common measures of pollutant organic material in water. BOD indicates the amount of putrescible organic matter present in water. Therefore, a **low BOD is an indicator of good quality water**, while a **high BOD indicates polluted water.**

DO is the actual amount of oxygen available in dissolved form in the water. When the DO drops below a certain level, the life forms in that water are unable to continue at a normal rate. The decrease in the oxygen supply in the water has a negative effect on the fish and other aquatic life. Fish kills and an invasion and growth of certain types of weeds can cause dramatic changes in a stream or other body of water. Energy is derived from the oxidation process.

**Table 4.4: BOD level of different types of water.**

| **BOD Level** *(in ppm)* | **Water Quality** |
|---|---|
| **1 - 2** | **Very Good** There will not be much organic waste present in the water supply. |
| **3 - 5** | **Fair - Moderately Clean** |
| **6 - 9** | **Poor - Somewhat Polluted** Usually indicates organic matter is present and bacteria are decomposing this waste. |
| **100 or greater** | **Very Poor - Very Polluted** Contains organic waste. |

{**Note**: Generally, when BOD levels are high, there is a decline in DO levels. This is because the demand for oxygen by the bacteria is high and they are taking that oxygen from the oxygen dissolved in the water. If there is no organic waste present in the water, there won't be as many bacteria present to decompose it and thus the BOD will tend to be lower and the DO level will tend to be higher. At high BOD levels, organisms such as macroinvertebrates that are more tolerant of lower dissolved oxygen (i.e. leeches and sludge worms) may appear and become numerous. Organisms that need higher oxygen levels (i.e. caddisfly larvae and mayfly nymphs) will NOT survive}.

BOD specifies the strength of sewage. In sewage treatment, to say that the BOD hrocedure that measures the amount of oxygen consumed by living organisms while they are utilizing the organic matter present in waste, under conditions similar in nature.

## Measurement of B.O.D.

The BOD test takes **5 days to complete** and is performed using a dissolved oxygen test kit. The BOD level is determined by comparing the DO level of a water sample taken immediately with the DO level of a water sample that has been incubated in a dark xygen required for the decomposition of any organic material in the sample and is a good approximation of the BOD level.

1. Take 2 samples of water
2. Record the DO level (ppm) of one immediately using the method described in the dis-

solved oxygen test.

3. Place the second water sample in an incubator in complete darkness at 20 °C for 5 days. If you don't have an incubator, wrap the water sample bottle in aluminum foil or black electrical tape and store in a dark place at room temperature (20 °C or 68 °F).

6. After 5 days, take another dissolved oxygen reading (ppm) using the dissolved oxygen test kit.

7. Subtract the Day 5 reading from the Day 1 reading to determine the BOD level. Record your final BOD result in ppm.

## CHEMICAL OXYGEN DEMAND (COD)

In environmental chemistry, the **chemical oxygen demand (COD) test is commonly used to indirectly measure the amount of organic compounds in water.** Most applications of COD determine the amount of organic pollutants found in surface water (e.g. lakes and rivers), making COD a useful measure of water quality. It is expressed in milligrams per liter (mg/L), which indicates the mass of oxygen consumed per liter of solution.

The basis for the COD test is that nearly all organic compounds can be fully oxidized to carbon dioxide with a strong oxidizing agent under acidic conditions. The amount of oxygen required to oxidize an organic compound to carbon dioxide, ammonia, and water is given by-

$$CnHaObNc + (n + a - b - 3)\,O_2 \longrightarrow nCO_2 + (a - 3c)\,H_2O + NH_3$$

This expression does not include the oxygen demand caused by the oxidation of ammonia into nitrate. The process of ammonia being converted into nitrate is referred to as *nitrification*. The following is the correct equation for the oxidation of ammonia into nitrate.

$$NH_3 + 2O_2 \longrightarrow NO_3^- + H_3O^+$$

The second equation should be applied after the first one to include oxidation due to nitrification if the oxygen demand from nitrification must be known. Dichromate does not oxidize ammonia into nitrate, so this nitrification can be safely ignored in the standard chemical oxygen demand test.

### Measurement of COD

The test of COD is carried out to measure the the contents of organic matter of sewage and natural water. Most types of organic matter are oxidized by a boiling mixture of chromic and sulfuric acids. A sample is refluxed (Boiled) for two hoursin strongly acid solution with a known excess of potassium dichromate ($K_2Cr_2O_7$) in presence of a catalyst $AgSO_4$ and $HgSO_4$. It is then cooled and the remaining unreduced $K_2Cr_2O_7$ is titrated with ferrous ammonium sulphate to determine the amount of $K_2Cr_2O_7$ consumed and the oxidizable matter is calculated in terms of oxygen equivalent.

$$\text{Sample} + K_2CrO_7 \xrightarrow{\text{AgS O4 and HgSO4}} CO_2 + H_2O + \text{Ammonia}$$

$$K_2Cr_2O_7 + \text{ferrous ammonium sulphate} \longrightarrow \text{Salt}$$

### Calculations

The COD is calculated with the help of following formula

$$\text{COD mg/l} = \frac{(V_1 - V_2) \times 8 \times 1000}{X}$$

Where : $V_1$ = Initial volume of ferrous ammonium sulphate

$V_2$ = Final volume of ferrous ammonium sulphate

X = Volume of sample taken.

## Advantage of COD over BOD

COD is usually carried out to determine the pollutional strength of sewage because of its several advantages over BOD test. These advantages are-

1. It takes relatively less time (Only 2 hours).
2. Industrial waste do not responds to BOD test, so COD test is a must.
3. If toxic materials are present in sewage, they are likely to interfere with BOD, in such cases COD is found to be very useful.

## EUTROPHICATION

**Eutrophication is a process whereby water bodies, such as lakes, estuaries, or slow-moving streams receive excess nutrients that stimulate excessive plant growth (algae, periphyton attached algae, and nuisance plants weeds).** This enhanced plant growth, often called an algal bloom, reduces dissolved oxygen in the water when dead plant material decomposes and can cause other organisms to die. Nutrients can come from many sources, such as fertilizers applied to agricultural fields, golf courses, and suburban lawns; deposition of nitrogen from the atmosphere; erosion of soil containing nutrients; and sewage treatment plant discharges. Water with a low concentration of dissolved oxygen is called hypoxic.

Eutrophication is caused by the decrease of an ecosystem with chemical nutrients, typically compounds containing nitrogen or phosphorus. It may occur on land or in the water. Eutrophication is frequently a result of nutrient pollution such as the release of sewage effluent into natural waters (rivers or coasts) although it may occur naturally in situations where nutrients accumulate (e.g. depositional environments) or where they flow into systems on an ephemeral basis (e.g. intermittent upwelling in coastal systems).

## Sources of high nutrient runoff

Their are two main sources of high nutrient runoff (Eutrophication)-

**1. Point sources:** Point sources are directly attributable to one influence. In point sources the nutrient waste travels directly from source to water. For example, factories that have waste discharge pipes directly leading into a water body would be classified as a point source. Point sources are relatively easy to regulate.

Examples: (i). Wastewater effluent (municipal and industrial).
(ii). Runoff and leachate from waste disposal systems.
(iii). Runoff and infiltration from animal feedlots.
(iv). Runoff from mines, oil fields, unsewered industrial sites.
(v). Overflows of combined storm and sanitary sewers.

**2. Nonpoint Sources:** Nonpoint source pollution (also known as 'diffuse' or 'runoff' pollution) is that which comes from ill-defined and diffuse sources. Non-point sources are difficult to regulate and usually vary spatially and temporally (with season, precipitation, and other irregular events). There are three reasons that nonpoint sources are especially troublesome- soil retention, runoff to surface water and leaching to groundwater and atmospheric deposition.Examples:

(i). Runoff from agriculture/irrigation.
(ii). Urban runoff from unsewered areas.
(iii). Septic tank leachate.
(iv). Runoff from abandoned mines.

## Ecological effects

Eutrophication adversely affects lakes, reservoirs, rivers and coastal marine waters in the following ways-into, for instance, a river or a sprin

## WATER QUALITY CRITERIA

The quality of drinking water is analysed on the basis of four parameters-

**1. Physical Characteristics:** These parameters are based on physical properties of water such as colour, taste, odour, temperature and turbidity.

**2. Chemical Characteristic:** It includes acidity, alkalinity, pH,total dissolved solids, hardness, electrical conductivity, acid radicles such as chlorides, fluorides, metals, nitrates, phosphates, sulphates etc.

**3. Biological Properties:** It includes both dead and alive plants and animals that are found in water.t Bacteria, algae, viruses, protozoans, helminths are the most common organisms found in water.These organisms seriously effects the quality of water and changes it odour and taste.The most biological organisms in water are pathogenic for human beings.

**4. Radilogical Characteristics:** It is associated with the radioactive elements present in water. These elements may be natural or anthropogenic. eg. $Ra^{226}$, $Ra^{228}$ are sometimes foud in ground water whereas $U^{232}$, $U^{236}$ are discharge from nuclear power plants.

The **Central Pollution Control Board** has proposed 5 qualities of water on the basis of their coliform organisms, pH, dissolved oxygen and biological oxygen demand.(Table 4.1)

**Table 4. 1 : Water quality criteria as proposed by Central Pollution Control Board.**

| S.N. | Designed best use | Class of Water | Criteria | | | |
|---|---|---|---|---|---|---|
| | | | Total Coliform organisms (MPN/100ml) | pH | D.O (mg/l) | BOD ( mg/l) |
| 1. | Drinking water source without conventional treatment but after disinfection | A | 50 or less | 6.5- 8.5 | 6 | 2 |
| 2. | Outdoor bathing (organized). | B | 500 or less | 6.5 - 8.5 | 5 | 3 |
| 3. | Drinking water source after | C | 5000 or less | 6.0 - 9.0 | 4 | 3 |
| 4. | Propagation of wild life and fisheries | D | - | 6.5 - 8.5 | 4 | - |
| 5. | Irrigation, industrial cooling controlled waste disposal | E | - | 6.0 - 8.5 | 3 | - |
| | | Below E | Not meeting A, B, C, D, and E criteria | | | |

## Indian Standards of Drinking Water

The Bureau of Indian Standards has defined (Table 4.2) the level of solvents in drinking water for safety purposes.

## WATER POLLUTION

Comprising over 70% of the Earth's surface, water is undoubtedly the most precious natural resource that exists on our planet. Without the seemingly invaluable compound comprised of hydrogen and oxygen, life on Earth would be non-existent. It is essential for everything on our planet to grow and prosper.

Although we as humans recognize this fact, we disregard it by polluting our rivers, lakes, and oceans. Subsequently, we are slowly but surely harming our planet to the point where organisms are dying at a very alarming rate. In addition to innocent organisms dying off, our drinking water has become greatly affected as is our ability to use water for recreational purposes. In order to combat water pollution, we must understand the problems and become part of the solution.

**Table 4. 2 : Common solvents in water and the permitted levels.**

| Substance/ Test | Test | Unit | Desirable Maximum Permissible Limit* |
|---|---|---|---|
| 1 . Physical Turbidity | NTU | 5 | 10 |
| 2. Chemical pH | Number | 6.5-8.5 | No relaxation |
| 3. Hardness | As( CaCo)mg/l | 300 | 600 |
| 4. Chloride | (asCl)mg/l | 250 | 1000 |
| 5. Iron | (as Fe)mg/l | 0.3 | 1.0 |
| 6. Nitrate | (as No)mg/l | 45 | No relaxation |
| 7. Fluoride | (as F) mg/l | 1.0 | 1.5 |
| 8. Residual Chlorine | Mg/l | 0.2-0.5 | No relaxation |
| 9. Arsenic | (as A)mg/l | 0.05 | No relaxation |
| 10. Bacteriological Coliforms | MPN/100ml | 10** | No relaxation |
| 11. E Coli | MPN/100ml | 0 | No relaxation |

* When there is no alternative source for drinking.
** Colitone organisms should not be detectable in 100ml of any two consecutive samples.

**Definitions**

Water pollution can be defined as

"The presence in water of some foreign substances or impurities (Organic, inorganic, radiological or biological) in such quantity so as to constitute a health hazard by lowering the water quality and making it unfite for use and growth of aquatic biota."

or

"Any changes in the physical and chemical properties of water is called water pollution".

or

"Water pollution is the contamination of water bodies such as lakes, rivers, oceans, and groundwater caused by human activities, which can be harmful to organisms and plants which live in these water bodies".

## SOURCES OF WATER POLLUTION

The sources of water pollution are generally grouped into two categories based on their point of origin- point sources and non-point sources.

**1. Point sources:** Point sources are directly attributable to one influence. In point sources the nutrient waste travels directly from source to water. For example, factories that have waste discharge pipes directly leading into a water body, discharges from a wastewater treatment plant, outfalls from a factory, leaking underground tanks would be classified as a point source. Point sources are relatively easy to regulate.

**2. Non-point source pollution:** It refers to contamination that, as its name suggests, does not originate from a single discrete source. Non-point source pollution is often a cumulative affect of small amounts of contaminants gathered from a large area. Nutrient runoff in stormwater from sheet flow over an agricultural field, or metals and hydrocarbons from an area with high impervious surfaces and vehicular traffic are examples of non-point source pollution.

The primary focus of legislation and efforts to curb water pollution for the past several decades was first aimed at point sources. As point sources have been effectively regulated, greater attention has come to be placed on non-point source contributions, especially in rapidly urbanizing/suburbanizing or developing areas.

## CONTAMINANTS OF WATER

Pollutants are contaminants of water are of two types- inorganic and organic .

I. **In organic Pollutants:** Some inorganic water pollutants include-

1. Heavy metals including acid mine drainage.
2. Acidity caused by industrial discharges (especially sulfur dioxide from power plants).
3. Pre-production industrial raw resin pellets, an industrial pollutant.
4. Chemical waste as industrial by products.
5. Fertilizers, in runoff from agriculture including nitrates and phosphates.
6. Silt in surface runoff from construction sites, logging, slash and burn practices or land clearing sites.

II. **Organic Pollutants:** Some organic water pollutants are-

1. Insecticides and herbicides, a huge range of organohalide and other chemicals.
2. Bacteria, often is from sewage or livestock operations.
3. Food processing waste, including pathogens.
4. Tree and brush debris from logging operations.
5. Detergents.
6. Petroleum hydrocarbons including fuels (gasoline, diesel, jet fuels, and fuel oils) and lubricants (motor oil)
7. Various chemical compounds found in personal hygiene and cosmetic products.
8. Disinfection by-products (DBPs) found in chemically disinfected drinking water.

The sources of these organic and inorganic contaminants of water are of two kinds -natural and anthropogenic.

**(a). Natural Sources of Water Pollution**

It inlcudes leaching of minerals, clay and silt from soil erosion, falling of organic matters from the banks.

**(b) Anthropogenic or Man Made Sources of Water Pollution**

**1. Domestic sewage :** Domestic wastes are regularly dicharged from human settlements into rivers, lakes, sea, etc. It includes household wastes which pass through municipal sewage system. Food wastes, synthetic detergents used for washing clothes and cleaning bathrooms and latrines, human excreta and warter based paints are the substances that pollute the water through domestic sewage.

**2. Industrial effuents :** Most of the Indian river are seriously polluted by industrial effluents because the industrial wastes or effuents are discharged in the near by river or stream through flush line of factories. Industries like fertilizer factories, oil refineries, synthetic plants for manufacturing of drugs, rubber, plastic and rayon fibers, the paper mills and the chemicals factories, etc. all contribute to water pollution. Water used for cooling turbines is returned to rivers adding heat pollution. Industrial waste contain chemicals such as phenols, arsenic, lead, acid, alkali, mercury, cyanides, detergents, etc. All coastal nations use seas for disposal of industrial wastes including radioactive waste.

The type of pollutants vary from industry to industry. Some industries and their pollutants are as follows :

(i). **Paper industries :** Bleaching substances, cellulose fibres, organic acids, etc.

(ii). **Food industries :** Putrefied organic matter, bacteria, etc.

(iii). **Pharmaceutical industries :** Various intermediate products of drugs and organic solvent.

(iv). **Detergent industries :** Fatty acids, alkalis, ammonia compounds, etc.

(v). **Mining indusatries :** Metal, $H_2S$, sulphuric acid, etc.

(vi). **Steel industries :** Iron, cyanide, oil, phenol, naptha, chromium, mercury, etc.

(vii). **Chemical industries :** Various type of acids, alkalis, salts, organic acids, aromatic compounds, VOCs (volatile organic compounds), such as industrial solvents from improper storage, DNAPLs (dense non-aqueous phase liquids), such as chlorinated solvents, which may fall at the bottom of reservoirs, since they don't mix well with water and are more dense etc.

3. **Agricultural sources :** In modern agriculture tons of artificial fertilizers (cantaining phosphorous and nitrates) are used to improve the fertility of land to obtain a better yield of crop. Excess of nitrates used as fertilizers seep into the ground water or are carried into ponds or lakes with rainwater. On entering the drinking water system these substances can lead to various health hazards. Phosphorous and nitrates dissolved in water and act as nutrients and accelerate the growth of algae that may form a mat on the surface of water. This increased productivity of water bolies is called **eutrophication.**

4. **Pesticides and weedicides :** Pesticides are widely used to control household pests and agricultural pests can also become dangerous water pollutants. DDT is the most common pesticide used world over. Weedicides are used to clear off the weeds. These are BHC, aldrin, heptachlor, etc. These pesticides and weedicides are carried by winds or percolate through water and are finally washed down the river and streams and enter the sea. Here these become incorporated into the producer and than along the food-chain these accumulate in large quantities in the bodies of higher animals and plants.

5. **Oil spills:** Oil pollution is more common in sea water in compare to river, ponds and lakes due to (i) leaking and spilling of oil from oil tanker, (ii) naval transport, (iii) accident in naval oil transport and (iv) from off shore oil wells. Leaked ans spilled oil contain petroleum hydrocarbons including fuels (gasoline, diesel, jet fuels, and fuel oils) and lubricants (motor oil) from oil field operations, refineries, pipelines, retail service station's underground storage tanks, and transfer operations. This type of water pollution is harmful to marine plants and animals.

6. **Thermal and nuclear power station :** Water used for cooling machines in the thermal power station is discharged into the water source which increase temperature of water and causes harm to aquatic life. Nuclear wastes from nuclear power station are released into the sea water which affect marine life. *e.g.* $Sr^{90}$, $Cs^{137}$, $I^{131}$ are harmfull isotopes which are responsible for cancer and some genetic variations.

Water pollution in big cities like Delhi, Kolkata, Mumbai, Kanpur, Lucknow, etc. is the most dangerous problem. Many important river which pass through or near industrial cities are highly polluted. Yamuna which passes through Delhi is highly polluted by sewage and industrial waste. Gomti near Lucknow is polluted by various industries such as jute mills, power plants, chemical industries. detertgent, sewage, etc. Ganga near Kanpur is highly polluted by effuent dicharged from leather, jute, chemical and metal industries.

## TYPES OF WATER POLLUTION

Water pollution may be classified variously-

**A. On the basis of properties, water pollution may be of three types-**

1. **Physical Pollution:** Pollution of water due to changes in physical properties (such as colour, taste, odour, turbidity, temperature etc.) of water is called physical pollution. It is caused due to discharge of oil pills, hot water, discharge of sewage etc..

2. **Chemical Pollution:** It is caused due to changes in chemical properties of water such as acidity, alkalinity, pH and addition of inorganic chemicals like As, Ni, Hg, Cd, Pb, phosphates, nitrates, fluorides, organic wastes, organic biocides (pesticides, insecticides, herbicides, fungicides) and polychlorinated biphenyls (PCBs) etc.

3. **Biological Pollution:** This type of water pollution is caused due to the presence of living organisms especially micro-organisms like algae, bacteria, viruses, protozoans, helminths etc.

**B. On the basis of source of water , water pollution may be of following types-**

### 1. Ground Water Pollution

Today the accelerated pace of development, rapid industrialisation and population density have increased demand of water resources. Underground sources of drinking water, especially in outskirts of larger cities and villages are highly polluted. Ground water is threatened with pollution from the following sources.

1. Domestic wastes
2. Industrial wastes
3. Agricultural wastes
4. Run off from urban areas
5. Soluble effluents

(**Note:** For source refer to sources of water pollution and for effects refer to general effects of water pollution)

### 2. Surface Water Pollution

The emergence of industrial revolution encouraged the growth of factories which grossly polluted the surface surface water of rivers, oceans, lakes, ponds and estuaries etc. Surface water comes in direct contact with the atmosphere, seasonal, streams, rivulets and surface drains. So there occurs a continous exchange of dissolved and atmospheric gases while the wastes are added through water conveyances. The chief sources of surface water pollution are as follows-

1. Atmospheric Gases.
2. Surface Run-Off
2. Industrial and Municipal Wastes
4. Agricultural Wastes
5. Decomposed Plant and Animal Matter
6. Radioactive Materials

(**Note:** For source refer to sources of water pollution and for effects refer to general effects of water pollution)

### 3. Marine Pollution

Marine pollution is defined as the discharge of waste substances into the sea resulting in harm to living resources, hazards to human health, hindrance to fishery and impairment of quality for use of sea water. Marine pollution is associated with the changes in physical, chemical and biological conditions of the sea water. this water is also unfit for human consumption and industrial purpose because of high salt content. Chemically it is solution a of 0.5 m NaCl and 0.005 m $MgSO_4$ containing traces of all concievable matter in the universe.

Like the land, the air, the rivers, the lakes, our seas and oceans also suffer from pollution. One of the commonest pollutants of the sea is raw or treated sewage. It is interesting to note that in reasonable quantities sewage can be harmless or even beneficial. For example, nitrates and phosphates in sewage fertilise sea water, leading to the growth of microscopic plant life, phytoplankton in the sea. This acts as a food for minute animals which in their turn, end up as food for fish and large sea animals.

On the ather hand, overburden of nutrients gives rise to eutrophication. The excessive nutrients lead to prolific breeding of the minute plants near the sea surface. This algal bloom prevents the sunlight from reaching deep in the sea. As a result, photosynthesis is either reduced or stopped. The plants start taking in oxygen and giving out $CO_2$, thus using up more oxygen. Thus they die in large numbers and are decomposed by bacteria, further dicreasing the oxygen content. As a result, fish which requires about 3 mg of dissolved oxygen per litre of water, and other animals start to die.

**Sources of Marine Pollution**

Major souces of oil pollution in sea water are as follows-

1. **Import Oil Losses:** Collissions in port contribute add a huge quantity of oil in sea water annually.
2. **Cargo Tanker Washing in Sea:** A recent estimate indicates that about 3 million tonnes of oil are added annualy to the sea by using sea water as ballast for empty tankers. It is mixed into water when the ballast gets dumped and carries residual oil from the tanker.
3. **Bige Pumping at Sea:** The dumping of bilge cintents by ships adds nearly 5,00,000 tonnes of oil per year in the sea water, while total influx of oil into ocean has been 5 to 10 million tonnes annually.
4. It is estimated that 2 million tonnes of used lubricating oil are added every year in coastal water. Maritime accidents due to collision, fire, explosion or grounding also result in oil release in water
5. Oil leakage from pipe lines which cross water ways may undergo corrosion, cracks or punctures and would lead to oil pollution in sea water.
6. The blow out of wells, disposal of drilling muds, accidental damages to offshore drilling rigs add to oil pollution in water.

## POLLUTION OF RIVER GANGA (GANGA ACTION PLAN)

Of all the river in India, Ganga is regarded as the most polluted river of India. Ganga passes through many industrial cities thus receives industrial efflluments from them. Ganga also receives nearly 2000 million liters of sewage everday. It is estimated that ashes of 40,000 dead bodies and 10,000 half burnt bodies are thrown into river Ganga every year. It is also polluted due to dead animal and due to bathing in the river.

Government of India has constituted an action plan called **Ganga action plan** in 1985 to reduce the pollution load of Ganga. The action plan will cover 27 cities situated on the bank of Ganga. The main activities of scheme are as follows :

1. Prevention of untreated sewage to escape into Ganga by diverting the existing sewers and preventing overflow.
2. Installation of modern sewage treatment plant in the cities.
3. Use of sewage for generation of biogas and preparation of organic fertilizer.
4. Making low cost sanitation for common people.
5. Removal of harmful chemicals and other pollutants from industrial waste before draining them into the river.
6. Afforestation of river bank to check erosion.
7. Regular monitoring of water quality.

According to the Central Board for the Prevention and Control of Water Pollution (CBPCWP), the B. O. D in Ganga has even reached upto 9.7 mg/litre as against the prescribed acceptable limit of 3.0 mg/litre. **Ganga Project Directorate** and **Central Ganga Authority** are central govenrment agencies to guide and oversee the results and implementations of Ganga action plan.

## EFFECTS OF WATER POLLUTION AND POLLUTANTS

The impact of pollutant depends upon its properties and amount. Pollutants bring about physical and chemical changes that make the water in rivers, lakes and ponds unfit for use and harmful to aquatic orgnisms. Some of the main effects of water pollutants are given below :

### (I) Effects on Human Health or Health Hazards

1. Water polluted with domestic sewage can spread epidemic dieases as cholera, typhoid, dysentery or diarrhoea and water borns diseases.
2. Inorganic nitrates and phosphates in excess amount stimulate excessive plant growth in lakes and reservoirs. These plants deplete the oxygen content of the water during night. This leads to suffocation of fish and other aquatic life. The rapid algal growth (plant) leads to the diminishing of nutrient in the medium causing rapid decay of algal filaments. The increased productivity of lake and stream water brought about by nutrient enrichment is called **eutrophication.**
3. Heavy metals like lead, mercury, copper, zinc, chromium, cadmium, cobalt, arsenic, etc. act astoxic substances for aquatic organisms and cause serveral harmful disease in human beings.

   *e.g.* (i) **Mercury pollution** causes minimata disease this was detected for first time in Japan in 1952.

   **(ii) Cadmium pollution** cames **itai-itai** disease or **ouch-ouch** disease (a painful disease of bone and joint). It also responsible for **liver cancer.**

   **(iii) Arsenic pollution** causes **black food disease.** It also causes diarrhoea, peripheral neutritis, hyperkeratosis and skin and lung cancer.
4. The **toxic compound** like phenol, cyanides and ammonia are also harmful, these are found in industrial effluents.
5. The use of nitrates in fertilizers contaminate drinking water which lead to health hazards. Nitrates on entering the intestine are converted into nitrites by intestinal bacteria. These nitrites enter the blood vascular system. Haemoglobin has stronger affinity for nitrites than oxygen and therefore infants suffer from acute lack of oxygen.This disease is known as **methemoglobinema** or **blue baby syndrome.**

### (II). Effects on Soil

1. The use of polluted water for irrigating agricultural fields severely damages crops and dicreases grain production.
2. Polluted water accutely affects soil fertility by killing bacteria and soil micro-organisms.
3. Contaminated ground water increases alkalinity in the soils.
4. Ground water pollution affects plant metabolism severely and disturbs the whole ecosystem.

### (III). Biological Magnification

Insecticides and herbicides are very harmful, they destroy the larval stages of aquatic animals.These substances also reduce the photosynthetic activity of phytoplankton and algae.Through the food-chain these accumulate in the body of carnivores in more high concentration and produce fatal effects, so large number of fishes are found dead in areas pollued with DDT shows the biological magnification or bio-concentration of DDT throught an aquatic food chain.

### (III) Effect of Thermal pollution

A large number of industial plants use cold water from the river and discharge it hot, this creates thermal pollution which is harmful particularly for fishes and other aquatic organisms. For instance, discharge of hot water may cause fish eggs to hatch so early in the spring that the natural food organisms required by the hatching would not be available. As hot water holds less oxygen thermal pollution usually disturbs the ecological balance of the water body.

## DISEASES DUE TO WATER POLLUTION

Water-borne diseases are infectious diseases spread primarily through contaminated water. Though these diseases are spread either directly or through flies or filth, water is the chief medium for spread of these diseases and hence they are termed as **water-borne diseases.** Waterborne diseases are caused by pathogenic microorganisms which are directly transmitted when contaminated drinking water is consumed. Contaminated drinking water, used in the preparation of food, can be the source of foodborne disease through consumption of the same microorganisms. It was estimated that 88% of that burden is attributable to unsafe water supply, sanitation and hygiene, and is mostly concentrated in children in developing countries.

Polluted drinking water contain several types of pathogenic organisms. Eg. bacteria, viruses, protozoa, helminths etc.These pathogenic organisms cause different types of infectious diseases. Various water borne diseases are listed in table 4.5.

### Minamata: environmental contamination with methyl mercury

In Minamata, Japan, inorganic mercury was used in the industrial production of acetaldehyde. It was discharged into the nearby bay as waste water and was ingested by organisms in the bottom sediments. Fish and other creatures in the sea were soon contaminated and eventually residents of this area who consumed the fish suffered from MeHg

**Table:4. 3: Waterborne disease caused by protozoa, viruses, bacteria, and intestinal parasites**

| S. N. | Group of disease | Name of disease | Name of pathogen |
|---|---|---|---|
| 1. | Bacterial diseases | 1. Cholera<br>2. Typhoid fever<br>3. Bacillary dysentery<br>4. Gastroenteritis<br>5. Tuberculosis | *Vibrio cholerae*<br>*Salmonella typhosa*<br>*Shigella*<br>*Escheritia coli*<br>*Mycobacterium tuberculosis* |
| 2 | Viral diseases | 1. Poliomylitis<br>2. Aseptic meningitis<br>3. Hepatitis | Polio virus<br>Coxsackie virus A and B<br>Hepatitis A virus |
| 3. | Protozoan diseases | 1. Amoebic dysentery<br>2. Giardiasis | *Entamoeba histolytica*<br>*Giardia lamblia* |
| 4. | Helminth diseases | 1. Schistosomiasis<br>2. Taeniasis<br>3. Ascariasis<br>4. Echinococcoisis | *Schistosoma*<br>*Taenia solium*<br>*Ascaris lumbricoides*<br>*Echinococcus* |
| 5. | Algal diseases (Blue green algae) | 1. Gastroenteritis | *Microcystis aeruginosa*, *Anabaena flos-aquae* and *Schizothrix calciola* |

(methyl mercury) intoxication, later known as the Minamata disease. The disease was first detected in 1956 but the mercury emissions continued until 1968. But even after the emission of mercury stopped, the bottom sediment of the polluted water contained high levels of this mercury.

Various measures were taken to deal with this disease. Environmental pollution control, which included cessation of the mercury process; industrial effluent control, environmental restoration of the bay; and restrictions on the intake of fish from the bay. This apart research and investigative activities were promoted assiduously, and compensation and help was offered by the Japanese Government to all those affected by the disease.The Minamata disease proved a turning point, towards progress in environment protection measures. This experience clearly showed that health and environment considerations must be integrated into the process of economic and industrial development from an early stage.

## CONTROL OF WATER POLLUTION

The control of water pollution is very difficult but the following methods will certainly help to minimize it to a great extent :

### (i) Preventive Methodes

1. Use of harmful pesticides should be banned.
2. Discharge of effluents directly into rivers, lakes and sea should be strictly prohibited without treatmant.
3. Oil spill should be prevented.
4. Proper disposal of sewage so that it dose not find its way into water bodies.
5. Preventing bathing, washing cloths, throwing dead bodies and other wastes into water source.

### (II) Cerative Methods

**1. Adequate Waste Water Treatment :** The domestic sewage and the industrial waste should be properly treated in Effluent Treatment Plant (ETP) before its disposal into water ways.

**2. Treatment of Industrial Effluents :** Industrial effluents should be properly treated to remove the pollutants. These involve neutralization of acid and alkalis, removal of harmful chemicals, coagulation of colloidal impurities, precipitation of metallic compounds and reducing the temperature of wastes to decrease thermal pollution. Chemical oxidation can be achieved by chlorination or through reaction with ozone. However, there are certain chemicals which are difficult to remove.

**3. Recycling :** One of the best methods of prevention and control of water pollution is the recycling of the various kinds of pollutants and wastes. *e.g.* , dung of cow and buffalo can be used for the production of gobar gas, a cheap source of fuel and also of manure.

**4.** Using septic tanks.

**5.** Water released from thermal and nuclear power station must be cooled before releasing them into the water source.

6. Keeping fishes like **Gambutia** in water sources which eat larvae and eggs of harmful organisms are useful to keep water clean.

7. Certain strains of bacteria can reduce the oil spill effect and can use up cyanides and heavy metals if judiciously used.

### (III) Control of Water Pollution by Law

To control water pollution Indian Goverment has proposed Water (prevention and control) Act 1974. Important legislations of this act are as follows :

1. Control and managment of water pollution.
2. To make necessary arragements for purity and availability of drinking water.
3. To organise and appoint Board and Commissions for prevention and control of water pollution.

There exist numerous types of problems in India which are concerned with industrial and trade wastes and require pre-treatment of the waste before discharging in water. The bulk of water pollution is mainly of domestic origin rather than industrial but in our country, local authorities lack funds to install sewerage system or any treatment plant.