Lecture 9

Causes, effects and control of water and marine pollution.

Water is one of the most important commodities which Man has exploited than any other resource for sustenance of his life. Most of the water in this planet is stored in oceans and ice caps which is difficult to be recovered for our diverse needs. It can be said that no water is pure or clean owing to the presence of some quantities of gases, minerals and life. Pure water is considered to be that which has low dissolved and suspended solids and obnoxious gases as well as low biological life. Water can be regarded polluted when it changes its quality or composition either naturally or as a result of human activities, thus becoming less suitable for drinking, domestic, agricultural, industrial, recreational, wildlife and other uses.

Some pollutants can be formed by way of concentrations and transformations of naturally occurring compounds during their domestic, agricultural or industrial use. The generation of sewage and the waste waters containing agrochemicals, certain pesticides and surfactants, petrochemicals, hydrocarbons, heavy metals and radionuclides are some important examples of pollutants originated in this way.

Sources of Water Pollutants

To understand the effects of water pollution and the technology applied in its control, it is useful to classify pollutants into various groups or categories. Water pollutant can be classified according to the nature of its origin as either a **point source** or a **dispersed source pollutant**.

A **point source** pollutant is one that reaches the water from a pipe, channel or any other confined and localized source. The most common example of a point source of pollutants is a pipe that discharges sewage into a stream or river. Most of these discharges are treatment plant effluents.

A **dispersed or non point source** is a broad, unconfined area from which pollutants enter a body of water. Surface runoff from agricultural areas carries silt, fertilizers, pesticides, and animal wastes into streams, but not at only one particular point. These materials can enter the water all along a stream as it flows through the area. Acidic runoff from mining areas is a dispersed pollutant. Storm water drainage systems in towns and cities are also considered to be dispersed sources of many pollutants, because, even though the pollutants are often conveyed into streams or lakes in drainage pipes or storm sewers, there are usually many of these discharges scattered over a large area.

Point source pollutants are easier to deal with, while pollutants from dispersed sources are much more difficult to control. Many people think that sewage is the primary culprit in water pollution problems, but dispersed sources cause a significant fraction of the water pollution. The most effective way to control the dispersed sources is to set appropriate restrictions on land use.

Oxygen – Demanding Wastes

One of the most important water quality parameters is the dissolved oxygen (DO) present. Oxygen – demanding wastes are substances that oxidize in the receiving body of water, reducing the amount of DO available. As DO drops, fish and other aquatic life are threatened and, in the extreme case, killed. In addition, as dissolved oxygen levels fall, undesirable odors, tastes, and colors reduce the acceptability of the water as a domestic supply and reduce its attractiveness for recreational uses. Oxygen-demanding wastes are usually biodegradable organic substances contained in municipal wastewaters or in effluents from certain industries, such as food processing and paper production. In addition, the oxidation of certain inorganic compounds may also contribute to the oxygen demand. Even naturally occurring organic matter, such as leaves and animal droppings, that find their way into surface water add to the DO depletion. Minimum amounts required for a healthy fish population may be as high as 5-8 mg/L for active species, such as trout, or as low as 3 mg/L for less desirable species, such as carp.

There are several measures of oxygen demand commonly used. The chemical oxygen demand, or COD, is the amount of oxygen needed to chemically oxidize the wastes, while the biochemical oxygen demand, or BOD, is the amount of oxygen required by microorganisms to biologically degrade the wastes. BOD has traditionally been the most important measure of the strength of organic pollution, and the amount of BOD reduction in a wastewater treatment plant is a key indicator of process performance.

Pathogens

It has long been known that contaminated water is responsible for the spread of many contagious diseases. Pathogens are disease-producing organisms that grow and multiply within the host. Examples of pathogens associated with water include bacteria responsible for cholera, bacillary dysentery, typhoid, and paratyphoid fever; viruses responsible for infectious hepatitis and poliomyelitis; protozoa, which cause amoebic dysentery and giardiasis; and helminthes, or parasitic worms, which cause diseases such as schistosomiasis and dracontiasis (guinea worm). The intestinal discharges of an infected individual, a carrier, may contain billions of these pathogens, which, if allowed to enter the water supply, can cause epidemics of immense proportions. Carriers may not even necessarily exhibit symptoms of their disease, which makes it even more important to carefully protect all water supplies from any human waste contamination.

Nutrients

Nutrients are chemicals, such as nitrogen, phosphorus, carbon, sulfur, calcium, potassium, iron, manganese, boron, and cobalt, that are essential to the growth of living things. In terms of water quality, nutrients can be considered as pollutant when their concentrations are sufficient to allow excessive growth of aquatic plants, particularly algae. When nutrients stimulate the growth of algae, the attractiveness of the body of water for recreational uses, as a drinking water supply, and as a viable habitat for other living things can be adversely affected. Nutrient enrichment can lead to blooms of algae which eventually die and decompose. Their decomposition removes oxygen from the water, potentially leading to levels of DO that are insufficient to sustain normal life forms.

Major sources of both nitrogen and phosphorus include municipal wastewater discharges, runoff from animal feedlots, and chemical fertilizers. In addition, certain bacteria and blue-green algae can obtain nitrogen directly from the atmosphere. These life forms are usually abundant in lakes that have high rates of biological productivity, making the control of nitrogen in such lakes extremely difficult. Certain forms of acid rain can also contribute nitrogen to lakes. While there are several special sources of nitrogen, the only unusual source of phosphorus is from detergents. When phosphorus is the limiting nutrient in a lake that is experiencing an algal problem, it is especially important to limit the nearby use of phosphate in detergents.

Not only is nitrogen capable of contributing to eutrophication problems, but when found in drinking water a particular form of it can pose a serious public health threat. Nitrogen in water is commonly found in the form of nitrate (NO_3), which is itself not particularly dangerous. However, certain bacteria commonly found in the intestinal tract of infants can convert nitrates to highly toxic nitrites (NO_2). Nitrites have a greater affinity for hemoglobin in the bloodstream than does oxygen, and when they replace that needed oxygen a condition known as methemoglobinemia results. The resulting oxygen starvation causes a bluish discoloration of the infant; hence, it is commonly referred to as the "blue baby" syndrome. In extreme cases the victim may die from suffocation.

Salts

Water naturally accumulates a variety of dissolved solids, or salts, as it passes through soils and rocks on its way to the sea. These salts typically include such cations as sodium, calcium, magnesium, and potassium, and anions such as chloride, sulfate, and bicarbonate. Commonly used measure of salinity is the concentration of total dissolved solids (TDS). As a rough approximation, fresh water can be considered to be water with less than 1500 mg/L TDS; brackish waters may have TDS values up to 5000 mg/L; and, saline waters are those with concentrations above 5000 mg/L. Seawater contains 30 000 – 34 000 mg/L TDS.

The concentration of dissolved solids is an important indicator of the usefulness of water for various applications. Drinking water, for example, has a recommended maximum contaminant level for TDS of 500 mg/L. Livestock can tolerate higher concentrations. Of greater importance, however, is the salt tolerance of crops. As the concentration of salts in irrigation water increases above 500mg/L, the need for careful water management to maintain crop yields becomes increasingly important. With sufficient drainage to keep salts from accumulating in the soil, up to 1500 mg/L TDS can be tolerated by most crops with little loss of yield but at concentrations above 2100 mg/L, water is generally unsuitable for irrigation except for the most salt tolerant of crops.

Thermal Pollution

A large steam-electric power plant requires an enormous amount of cooling water. A typical nuclear plant, for example, warms about $40m^3/s$ of cooling water by 10^0C as it passes through the plant's condenser. If that heat is released into a local river or lake, the resulting rise in temperature can dramatically affect life in the vicinity of the thermal plume.

As water temperature increases, two factors combine to make it more difficult for aquatic life to get sufficient oxygen to meet its needs. The first results from the fact that metabolic rates tend to increase with temperature, generally by about a factor of 2 for each 10^0C rise in temperature. This causes an increase in the amount of oxygen required by organisms. At the same time, the available supplies of dissolved oxygen are reduced both because waste assimilation is quicker, drawing down DO at a faster rate, and because the amount of DO that the water can hold decreases with temperature. Thus, as temperatures increases, the demand for oxygen goes up while the amount of DO available goes down.

Heavy Metals

In chemical terms heavy metal refer to metals with specific gravity greater than about 4 or 5, but more often, the term is simply used to denote metals that are toxic. The list of toxic metals includes aluminum, arsenic, beryllium, bismuth, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, nickel, selenium, strontium, thallium, tin, titanium, and zinc. Some of these metals, such as chromium and iron, are essential nutrients in our diets, but in higher doses are extremely toxic.

The most important route for the elimination of metals is via the kidneys. In fact, kidney can be considered to be complex filters whose primary purpose is to eliminate toxic substances from the body. The kidneys contain millions of excretory units called nephrons, and chemicals that are toxic to the kidneys are called nephrotoxins. Cadmium, lead, and mercury are examples of nephrotoxic metals. Metals have a range of adverse impacts on the body, including nervous system and kidney damage, creation of mutations, and induction of tumors.

Pesticides

The term pesticide is used to cover a range of chemicals that kill organisms that humans consider undesirable and includes the more specific categories of insecticides, herbicides, rodenticides, and fungicides. There are three main groups of synthetic organic insecticides: *organochlorines* (also known as *chlorinated hydrocarbons), organophosphates,* and *carbamates*. In addition, a number of herbicides, including the chlorophenoxy compounds 2,4,5-T (which contains the impurity dioxin, which is one of the most potent toxins known) and 2,4-D are common water pollutants.

The most well-known organ chlorine pesticide is DDT (dichlorodiphenyltrichloroethane) which has been widely used to control insects that carry diseases such as malaria, typhus, and plague. By contributing to the control of these diseases, DDT is credited with saving literally millions of lives worldwide. In spite of its more recent reputation as a dangerous pesticide, in terms of human toxicity DDT is considered to be relatively safe. It was its impact on food chains, rather than human toxicity that led to its ban. Organo chlorine pesticides, such as DDT, have two properties that cause them to be particularly disruptive to food chains. They are very *persistent,* which means they last a long time in the environment before being broken down into other substances, and they are quite *soluble* in lipids, which means they easily accumulate in fatty tissue. This phenomenon in which the concentration of a chemical increases at higher levels in the food chain is known as *biomagnification* or *bioconcentration.*

Other widely used organochlorines included methoxychlor, chlordane, heptachlor, aldrin, dieldrin, endrin, endosulfan, and kepone. Animal studies have shown dieldrin, heptachlor, and chlordane produce liver cancers, and aldrin, dieldrin, and endrin have been shown to cause birth defects in mice and hamsters. Given the ecosystem disruption, the toxicity, and the biological resistance to these pesticides that many insect species have developed, organochlorines have largely been replaced with organophosphates and carbamates.

The organophosphates, such as parathion, malathion, diazinon, TEPP (tetraethyl pyrophosphate), and dimethoate, are effective against a wide range of insects and they are not persistent. However, they are much more toxic than the organochlorines that they have replaced. They are rapidly absorbed through the skin, lungs, and gastrointestinal tract and hence, unless proper precautions are taken, they are very hazardous to those who use them. Humans exposed to excessive amounts have shown a range of symptoms including tremor, confusion, slurred speech, muscle twitching, and convulsions. Popular carbamate pesticides include propoxur, carbaryl, and aldicarb. Acute human exposure to carbamates has led to a range of symptoms, such as nausea, vomiting, blurred vision, and in extreme cases, convulsions.

Volatile Organic Compounds

Volatile Organic Compounds (VOCs) are among the most commonly found contaminants in groundwater. They are often used as solvents in industrial processes and a number of them are known or suspected carcinogens or mutagens. Their volatility means they are not often found in concentrations above a few micrograms per liter in surface waters, but in groundwater their concentrations can be hundreds or thousands of times higher. Their volatility also suggests the most common method of treatment, which is to aerate the water to encourage them to vaporize. *Vinyl chloride* (chloroethylene), *Tetrachloroethylene* (TCE)*, Trichloroethylene 1,2-Dichloroethane, Carbon tetrachloride* are some of important VOCs found in groundwater.

Effects of Water Pollution

1. Physicochemical effects

A large number of pollutants can impart colour, tastes and odours to the receiving waters, thus making them unaesthetic and even unfit for domestic consumption. The changes in oxygen, temperature and pH affect the chemistry of waters often triggers chemical reactions resulting in the formation of unwanted products. The addition of organic matter results in depletion of oxygen with concomitant increase in carbon dioxide owing to bacterial degradation.

2. Biological effects

The addition of pollutants leads to the shift in flora and fauna due to homeostatic factors operating in the aquatic systems. Most of the freshwater algae are highly sensitive to pollutants and their elimination modifies the prey-predatory relationships by breaking down the food chains. This results in the change of the whole plant and animal communities. The diversity of organism decrease due to the presence of only a few tolerant forms in the polluted conditions.

The first response to the added nutrients is increased algal growth which is often composed of obnoxious bloom forming blue-green or green chlorophycean algal forms. Many of the blue-greens are not consumed by predators and some even produce toxic secretions causing allelopathic effects (e.g*., Microcystis* spp.)

3. Toxic effects

These are caused by pollutants such as heavy metals, biocides, cyanide and other organic and inorganic compounds which are detrimental to the other organisms. These substances usually have very low permissible limits in water and their presence beyond limits can render the water unfit for aquatic biota and even for human use

These chemicals are toxic to aquatic organisms, and many of them especially those non-biodegradable, accumulate in the body of the organisms and biomagnify along the tropic levels causing long term effects.

4. Pathogenic effects

Besides the chemical substances, a few wastes like sewage, also contain several pathogenic and nonpathogenic microorganism and viruses. The *Clostridium perfringens* and *Streptococcus faecalis* cause various types of food poisoning. Apart from this, many water borne diseases like cholera, typhoid, paratyphoid, colitis, and infective hepatitis (jaundice) are spread by consumption of sewage contaminated waters.

5. Eutrophication

One of the most severe and commonest water pollution problems is due to enrichment of waters by plant nutrients that increases the biological growth and renders the water bodies unfit for diverse uses. The process of increase in the nutrients of waters and resultant spurt in algal productivity is called ***eutrophication*.**

The term eutrophication has been derived from a Greek word **eutrophos** meaning corpulent or rich. The first use of this term in ecology was made in connection with the remnants of the extinct lakes rather than with live lakes. Weber (1907), while studying the evolution of North German peat bogs, found that the upper layers have more nutrients in comparison to the lower ones as the original lakes received much higher nutrient supply prior to their transformation into bogs. He used the terms **eutrophic** (rich in nutrients) and **oligotrophic** (poor in nutrients) to distinguish between these two layers. The use of these terms in limnology was made for the first time by Naumann (1919), in order to denote nutrient poor (oligotrophic) and nutrient rich (eutrophic) conditions in relation to the development of different algal associations.

The Process Of Eutrophication

The eutrophication is basically a natural phenomenon which gets accelerated by increased nutrient supply through human activities. The process of eutrophication starts as soon as the lakes are formed because of the entry of nutrients by natural means, but the rate of eutrophication remains quite low under natural conditions. The process of eutrophication can be discussed under two heads of natural and accelerated processes, though its basic features remain essentially the same.

1. Natural eutrophication

The lakes generally originate as oligotrophic and have only limited quantities of nutrients depending upon the mode of their formation and composition of original sediments. These nutrients are insufficient to produce any significant algal growth. At this stage the lakes have only autochthonous nutrients (indigenous nutrients cycling therein), which usually recycle completely in the absence of any outside supply. All the biological production is completely decomposed after death. As the **allochthonous** nutrients (nutrients from outside) start entering the lake, the process of eutrophication sets in. The principal natural sources of nutrients are the natural run-off, fall of leaves and twigs from the surrounding vegetation, periodical submergence of the nearby terrestrial vegetation, rain fall and bird droppings etc.

The build-up of nutrients through this slow mode of entry gradually starts increasing the growth of algae. When the algae die and decompose, the locked nutrients are again made available to the fresh algal growth. The tropical or hot climate usually supports a higher rate of eutrophication as it favours higher nutrients utilization and algal growth in comparison to cold and temperate climates.

2. Accelerated Eutrophication

The process of eutrophication is greatly augmented by the increased supply of nutrients through various human activities such as discharge of domestic sewage, industrial wasters, agricultural and urban run-off. Increased levels of air pollution also make the water bodies rich in nutrients through their transport with rains or by dry fallout. This increased supply of nutrients triggers the algal growth at much faster rate, thus increasing the speed of eutrophication, which otherwise would have been a slow natural phenomenon. The process of eutrophication is, therefore, sometimes referred to as ***ageing of lakes****.*

Sources of nutrients

Water bodies may be enriched with nutrients through both natural and man made sources, nevertheless, their quantities may greatly differ from source to source. The man-made sources are much more significant contributors of nutrients than the natural sources.

a) Rainfall and Atmospheric Deposition

Rain water may contain varying amounts of nutrients depending upon the local atmospheric pollution. Experimental data indicate that rain water, on an average, contains 0.16 to 1.06 mg L^{-1} of nitrate nitrogen, 0.04 to 1.7 mg L^{-1} of ammonia nitrogen and from traces to 0.1 mg L^{-1} of phosphorus.

b) Urban and Rural Run-Off

The run-off water adds significant quantities of nutrients and organic matter from the soil and other surfaces. Urban run-off contains storm water drainage with organic and inorganic debris from various surfaces both paved and grassed, and fertilizers from gardens and lawns. Rural run-off originates from sparsely populated areas with little or no land devoted to agriculture.

c) Agricultural Run-off

The enrichment material in the agricultural run-off is derived from fertilizer applied to the crops, and from farm animal houses. Nitrogen used as fertilizers may get converted into nitric acid in soil, solubilizing calcium, potassium and other ions which become highly liable to leaching.

d) Domestic Sewage

Sewage is the commonest source of nutrients and organic matter, and undoubtedly the greatest contributor to the eutrophication of lakes. Large quantities of nitrogen and phosphorus are excreted by humans and animals which get their way into sewage. According to an estimate, an average of 2 g of PO_4-P per day is released through urine and faces by an average person, Phosphatic detergents in sewage are also important contributor of phosphorus.

e) Industrial Wastes

The nutrients in industrial effluents are variable in quality and quantity depending upon the processes and type of industry. The wastes from certain industries, particularly fertilizers, chemicals and food, are rich in nitrogen and phosphorus.

f) Water Fowl

The droppings of water fowl is a source of nutrients which may cause the local problems of eutrophication, especially in small bodies of water. The overall effect of this source on the whole water body may be negligible. It is estimated that wild ducks contribute 5.8 kg of nitrogen/acre/year and 2.55 kg of total phosphorus/acre/year to the lakes.

g) Ground Water

Ground water in some cases may act as a source of nitrogen to the surface waters. It is, however, not a recognized source at all places, but may be an important factor in certain areas. It has been estimated that about 42% of nitrogen in Wisconsin surface waters comes from ground water.

Effects Of Eutrophication

a. Physico – chemical Effects

Pollution can be considered as a departure from the balance between photosynthesis and respiration. At equilibrium (P = R), the chemical and biological composition of water remains unchanged, a stage that mostly occurs only in non-polluted waters with no external supply of nutrients. An eutrophic water body is one where photosynthesis exceeds the respiration activity. It is characterized by a progressive accumulation of algae which ultimately leads to an organic overloading. When respiration exceeds photosynthesis, dissolved oxygen gets rapidly exhausted forcing reduction of several oxidized chemical species like NO_3, SO_4^{-2} and CO_2 into N_2, NH_4^+, H_2S and CH_4 which are harmful to several aquatic species and produce typical odours.

b. Biological Effects

Many desirable species including fish are replaced by undesirable ones. There is an algal succession resulting in the dominance of blue green algae which have very low nutrition value in the food chains, and many of them produce the blooms. Some important bloom forming blue green algal genera include *Microcystis, Anabaena, Oscillatoria and Aphanizomenon.* Filamentous green algae, such as *Spirogyra, Cladophora, and Zygnema* form a dense floating mat or "blanket" on the surface when the density of the bloom becomes sufficient to reduce the intensity of solar light below the surface.

Nutrient enrichment has very limited direct effect on zooplankton communities, but indirect effect may be significant. The diversity of zooplankton remains high if the diversity of phytoplankton is also high as often found in case of oligotrophic or moderately enriched waters. As the changes occur in the water due to eutrophication, the characteristics of sediments also change. There is an accumulation of organic matter which affect the benthic communities.

Eutrophication of moderate level may be beneficial to fish production as it increases the food supply for fish in the form of algae. With the increase in the level of eutrophication, dominance of algal groups is taken over by blue greens making the edible or game fish to be replaced by hardy species of very little economic value. The algal blooms cause discolouration of water and attract water fowl which further contribute to the pollution of water. The overall effects make the waters much less suitable for recreation, fish production and domestic uses. The cost of water treatment is also escalated.

Control of Eutrophication

The first step in any control programme should be a regular monitoring of certain parameters *(e.g.,* nutrients, algal species, productivity, *etc.)* in the water body to evaluate the level of eutrophication and its trends. The next step would be to prepare an inventory of inflows, especially to know the sourcewise contribution of nutrients. The reduction of nutrient supply to a water body can be brought about by a number of methods involving either prevention of the entry of nutrients or by some *in situ* water treatment procedures to curtail the nutrient availability to algae.

a. Diversion of Nutrients from a Lake

The diversion of nutrient-bearing flows away from lakes can keep them free from nutrients. This can be achieved when the nutrients enter the lake mainly through point sources such as domestic sewage and industrial wastes. The wastes can be diverted directly to somewhere else like in downstream, estuary or oceans which have comparatively greater self-purification capacities than stagnant waters.

b. Removal of Nutrients from Waste Waters

Any degree of treatment to remove the nutrients and organic matter can be given to wastes depending upon the process selected. Secondary treatment usually removes only organic matter-and is not effective in controlling eutrophication. Though tertiary treatment methods are fairly well known to remove practically all nutrients, interest often lies in the removal of only phosphorus for control of eutrophication.

c. Flushing Out of Polluted Water by Nutrient Poor Water

The technique is useful for relatively small and highly polluted waters where the existing water can be removed to a convenient place and a supply of high quality water is readily available. Two approaches are usually followed for this; in one, the incoming water shall displace an equivalent amount of polluted water and in the other, a quantity of polluted water is removed first to be replaced later by the water of low nutrient content.

d. Removal of Locked-up Nutrients

Nutrients in aquatic ecosystems are locked-up in the tissues of fish, other animals, vegetation (macrophytes) and, of course, in the algae besides being in the water and sediments. Periodical removal of macrophytes and fish, especially when the water level is low, would help in removing a quantity of nutrients from water. The further entry of the nutrients should be checked, since their build up in water can start again after recovery.

e. Dredging of Sediments

A large proportion of nutrients can also be removed by dredging the sediments out of the lake. Dredging may be feasible where simultaneous deepening of the lake is also desired.

f. Covering of Sediments

The nutrients and organic matter present in upper sediments of a lake, under proper conditions, can be re solubilized by microbial action or by change in chemical conditions. The retardation of release of these nutrients shall check the internal fertilization. This can be performed by covering the sediments with some suitable material such as rubber or polythene sheets or some other inert material like clay or fly–ash.

g. Oxygenation and Mixing

Mixing of water column de stratifies the lakes and eliminates the anaerobic reducing conditions in hypolimnetic waters, promoting the development of uniform profiles of dissolved oxygen, temperature, phosphorus and other such parameter. The release of nutrients from the sediments is about10 times more in anaerobic conditions than that in aerobic conditions. Oxygenation by way of mixing eliminates anaerobic conditions and lowers the nutrient release from sediments. A proper mixing and aeration in water column can be carried out by using compressed air pump.

h. Nutrient Inactivation

The technique involves eliminating the nutrients from their natural cycles in the water bodies by various chemical means, in order to make them unavailable for the growth of algae. Phosphorus is the most important nutrient controlled in this manner. The use of calcium hydroxide or aluminium sulphate coprecipitates phosphorus with them which settles at the bottom.

i. Zoning and Watershed Management

Many of the water pollution problems arise due to lack of proper management of watershed areas leading to excessive erosion and entrainment of nutrients and organic matter in run-off. The land use pattern in the watershed or catchment's area will determine the nature of drainage. A check on deforestation and erosion will help reducing the nutrient load of the water resources. Selection of suitable sites for industries, agriculture, urban development and so on will also help in controlling the water quality.

6.Biological Magnification

When a living organism cannot metabolize or excrete ingested substance that substance gradually accumulates in the organisms. This phenomenon, called biological accumulation (or bioaccumulation), refers to the process by which a substance first enters in to a food chain. The extent to which bioaccumulation will occur depends on an organism's metabolism and on the solubility of the substance first enters a food chain. If the substance is soluble in fat, it will typically accumulate in the fatty tissues of the organism. Bioaccumulation is of particular concern when the substance being concentrated is a toxic environmental pollutant and the organism is of a relatively low trophic level in a food chain.

When many contaminated organisms are consumed by second organism that can neither metabolize nor excrete the substance, the concentration of the substance will build to even higher levels in the second organism. This effect is magnified at each successive trophic level, and the process is called **biological magnification** (or biomagnification). In other words, biomagnification is the increasing concentration of a substance as it moves from one level of a food chain to the next (for example, from plankton to fish to birds or to humans). Biomagnification is of particular importance when chemicals are concentrated to harmful levels in organisms higher up in the food chain. Even very low concentrations of environmental pollutants can eventually find their way into organisms in high enough doses to cause serious problems.

Biomagnification occurs only when the pollutants are environmentally persistent (last a long time before breaking down into simpler compounds), mobile, and soluble in fats.

Biomagnification can't occur

- if they are not persistent, they will not last long enough in the environment to be concentrated in the food chain. (persistent substances are generally not biodegradable).
- If they are not mobile, that is, not easily transported or moved from place to place in the environment, they are not likely to be consumed by many organisms.
- if they are soluble in water rather than fatty tissue, they are much more likely to be excreted by the organism before building up to dangerous levels.

Impact of DDT

The incidence of mercury poisoning in people who consumed contaminated fish in the Minamata Bay region of Japan in 1950s is just one example of the detrimental effects of biomagnification. Another classic example involves DDT, an abbreviation for the organic chemical dichlorodiphenyltrichloroethane. It is a type of chemical known as chlorinated hydrocarbon, and it takes a long time to break down in the environment. With a "half-life" of 15 years, if 10 kg of DDT were released into the environment in the year 2000, 5 kg would still persist in the year 2015, about 2.5 kg would remain in 2030, and even after 100 years had elapsed, in the year 2100, more than 100 g of the substance would still be detected in the environment. Of course, long before that time span elapsed, some of the DDT could be inadvertently consumed by living organisms as they forage for food, and thereby enter a food chain.

DDT is toxic to insects, but not very toxic to humans. It was much used in World War II to protect U.S. troops from tropical mosquito – borne malaria as well as to prevent the spread of lice and lice-borne disease among civilian populations in Europe. After the war, DDT was used to protect food crops from insects as well as to protect people from insect-borne disease. As one of the first of the modern pesticides, it was overused, and by the 1960s, the problems related to biomagnificantion of DDT became very apparent.

Many other substances in addition to mercury and DDT exhibit bioaccumulation and biomagnification in an ecosystem. These include copper, cadmium, lead, and other heavy metals, pesticides other than DDT, and cyanide, selenium and PCBs.

Control of Water pollution

Raw or untreated sewage comprises about 99.9 per cent water and only about 0.1 per cent impurities. In contrast to this, sea water is only about 96.5 per cent pure water; it contains about 35,000 mg/L, or 3.5 per cent dissolved impurities. Although sea water contains more impurities than does sanitary sewage, we do not ordinarily consider seawater to be polluted. The important distinction is not the total concentration, but the type of impurities. The impurities in seawater are mostly inorganic salts, but sewage contains biodegradable organic material, and it is very likely to contain pathogenic microorganisms as well.

Actually, sewage contain so many different substances, both suspended and dissolved, that it is impractical to attempt to identify each specific substance or microorganisms. The total amount of organic materials is related to the strength of the sewage. This is measured by the biochemical oxygen demand, or BOD. Another important measure or parameter related to the strength of the sewage is the total amount of suspended solids, or TSS. On the average, untreated domestic sanitary sewage has a BOD of about 200 mg/L and a TSS of about 240 mg/L. Industrial wastewater may have BOD and TSS values much higher than those for sanitary sewage; its composition is source dependent.

Another group of impurities that is typically of major significance in waste water is the plant nutrients. Specifically, these are compounds of nitrogen and phosphorous. On the average, raw sanitary sewage contains about 35 mg/ L of N and 10 mg / L of P. Finally, the amount of pathogens in the waste water is expected to be proportional to the concentration of fecal coli form bacteria. The coli form concentration in raw sanitary sewage is roughly 1 billion per liter. Coli form concentration, as well as BOD, TSS, and concentrations of N and P, are parameters of water quality.

Before discharging wastewater back into the environment and the natural hydrologic cycle, it is necessary to provide some degree of treatment in order to protect public health and environmental quality. The basic purposes of sewage treatment are to destroy pathogenic microorganisms and to remove most suspended and dissolved biodegradable organic materials. Sometimes it is also necessary to remove the plant nutrients – nitrogen and phosphorous. Disinfection, usually with chlorine, serves to destroy most pathogens and helps to prevent the transmission of communicable disease. The removal of organics (BOD) and nutrients helps to protect the quality of aquatic eco-systems.

Waste water treatment

These treatment methods are grouped into three general categories: **primary** treatment, **secondary or biological** treatment and **tertiary or advanced** treatment.

Primary Treatment

Untreated or raw wastewater usually flows by gravity from an interceptor or trunk sewer into the head works of a treatment facility; sometimes wastewater may be pumped to the treatment plant in a force. The head works of a treatment plant include a flow measurement device and mechanical systems that provide preliminary treatment. Preliminary treatment systems typically include screens, comminutors, and grit chambers.

The first treatment process for raw wastewater is coarse screening. Bar screens (or racks), as they are called, are made of long, narrow metal bars spaced about 25 mm (1 in.) apart. They retain floating debris, such as wood rags, or other bulky objects, that could clog pipes or damage mechanical equipment in the rest of the plant.

In some treatment plants, a mechanical cutting or shredding device, called a comminutor, is installed just after the coarse screens. The comminutor shreds and chops solids or rags that passed through the bar screen. The shredded material is removed from the waste water by sedimentation or flotation later in the treatment plant.

Grit removal

A portion of the suspended solids in raw sewage consists of gritty material, such as sand, coffee grounds, eggshells, and other relatively inert material. In cities with combined sewer systems, sand and silt may be carried in the sewage. Suspended grit can cause excessive wear and tear on pumps and other equipment in the plant. Most of it is non biodegradable and will accumulate in treatment tanks. For these reasons, a grit removal process is usually used after screening and / or comminuting.

Primary sedimentation (Settling)

After preliminary treatment by screening, comminuting, and grit removal, the wastewater still contains suspended organic solids that can be removed by plain sedimentation. Settling tanks that receive sewage after grit removal are called primary clarifiers. The combination of preliminary screening and gravity settling is called primary treatment. Chemicals may sometimes be added to the primary clarifiers to promote the removal of very small (or colloidal) particles. Primary treatment usually can remove up to 60 per cent of the suspended solids and about 35 per cent of the BOD from wastewater, but this relatively low level of treatment is no longer adequate. In almost all cases, primary treatment must be followed by secondary treatment processes; tertiary treatment may also be required to protect sensitive bodies of water that receive the treated effluent.

Secondary (Biological) Treatment

Primary treatment processes remove only those pollutants that will either float or settle out by gravity, but about half of the raw pollutant load still remains in the primary effluent. The purpose of secondary treatment is to remove the suspended solids that did not settle out in the primary tanks and the dissolved BOD that is unaffected by physical treatment. Secondary treatment is generally considered to meet 85 per cent BOD and TSS removal efficiency and represents the minimum degree of treatment required in most cases.

Biological treatment of sewage involves the use of microorganisms. The microbes, including bacteria and protozoa, consume the organic pollutants as food. They metabolize the biodegradable organics, converting them into carbon dioxide, water and energy for their growth and reproduction. A biological sewage treatment system must provide the microorganisms with a comfortable home. In effect, the treatment plant allows the microbes to stabilize the organic pollutants in a controlled, artificial environment of steel and concrete, rather than in a stream or lake. This helps to protect the dissolved oxygen balance of the natural aquatic environment.

To keep the microbes happy and productive in their task of wastewater treatment, they must be provided with enough oxygen, adequate contact with the organic material in the sewage, suitable temperatures, and other favourable conditions. The design and operation of a secondary treatment plant is accomplished with these factors in mind.

Two of the most common biological treatment systems are the **trickling filter** and the **activated sludge** process. The trickling filter is a type of fixed growth system. The microbes remain fixed or attached to a surface while the wastewater flows over that surface to provide contact with the organics. Activated sludge is characterized as a suspended – growth system, because the microbes are thoroughly mixed and suspended in the waste water rather than attached to a particular surface.

Aerobic waste water treatment method

Trickling filters

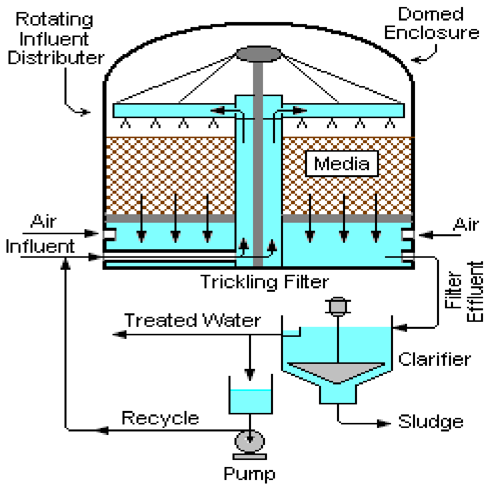
A trickling filter consists basically of a layer or bed of crushed rock about 2m (6ft) deep. It is usually circular in shape and may be built as large as 60 m (200 ft) in diameter. Trickling filters are always preceded by primary treatment to remove coarse and settleable solids. The primary effluent is sprayed over the surface of the crushed stone bed and trickles downward through the bed to an under drain system.

A rotary distributor arm with nozzles located along its length is usually used to spray the sewage, although sometimes fixed nozzles are used. The rotary distributor arm is mounted on a center column in the trickling filter; it is driven around by the reaction force or jet action of the waste water that flows through the nozzles.

The under drain system serves to collect and carry away the wastewater from the bottom of the bed and to permit air circulation upward through the stones. As long as topography permits, the sewage flows from the primary tank to the trickling filter by the force of gravity, rather than by pumping. As the primary effluent trickles downward through the bed of stones, a biological slime of microbes develops on the surfaces of the rocks. The continuing flow of the wastewater over these fixed biological growths provides the needed contact between the microbes and the organics. The microbes in the thin slime layer absorb the dissolved organics, thus removing oxygen – demanding substances from the waste – water. Air circulating through the void spaces in the bed of stones provides the needed oxygen for stabilization of the organics by the microbes.

The stones are usually about 75 mm (3 in.) in size, much too large to filter out suspended solids. The stones in a trickling filter only serve to provide a large amount of surface area for the biological growths, and the large voids allow ample air circulation. The trickling filter effluent is collected in the under drain system and then conveyed to a sedimentation tank called a **secondary clarifier**. The secondary clarifier, or final clarifier as it is sometimes called, is similar in most respects to the primary clarifier, although there are differences in detention time, over flow rate, and other details.

To maintain a relatively uniform flow rate thorough the trickling filter and to keep the distributor arm rotating even during periods of low sewage flow, some of the waste water may be recirculated. In other words, a portion of the effluent is pumped back to the trickling filter inlet so that it will pass through the bed of stones more than once. Recirculation can also serve to improve the pollutant removal efficiency; it allows the microbes to remove organics that flowed by them during the previous pass through the bed.



Activated sludge treatment

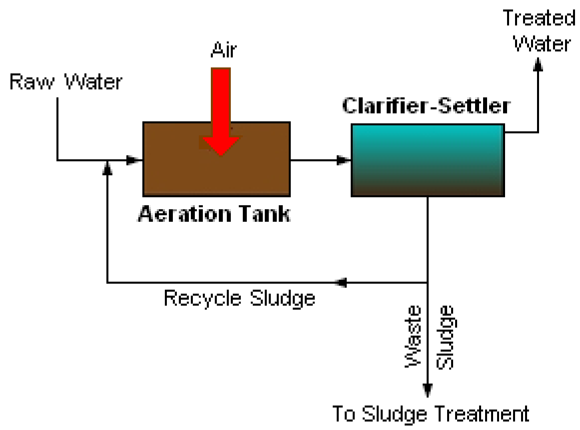
The basic components of an activated sludge sewage treatment system include an aeration tank a secondary settling basin or clarifier. Primary effluent is mixed with settled solids that are recycled from the secondary clarifier and then introduced into the aeration tank. Compressed air is injected continuously into the mixture through porous diffusers located at the bottom of the tank along one side.

In the aeration tank, microorganisms consume the dissolved organic pollutants as food. The microbes absorb and aerobically decompose the organics, using oxygen provided in the compressed air; water, carbon dioxide and other stable compounds are formed. In addition to providing oxygen, the compressed air thoroughly mixes the microbes and wastewater together as it rapidly bubbles up to the surface from the diffusers. Sometimes mechanical propeller like mixers, located at the liquid surface, are used instead of compressed air and diffusers. The churning action of the propeller blades mixes air with the wastewater and keeps the contents of the tank in a uniform suspension.

The aerobic microorganisms in the tank grow and multiply, forming an active suspension of biological solids called **activated sludge**. The combination of the activated sludge and waste water in the aeration tank is called the mixed liquor. In the basic or conventional activated sludge treatment system, a tank detention time of about 6h is required for thorough stabilization of most of the organics in the mixed liquor.

After about 6h of aeration, the mixed liquor flows to the secondary or final clarifier, in which the activated sludge solids settle out by gravity. The clarified water near the surface, called the supernatant, is discharged over an effluent weir; the settled sludge is pumped out from a sludge hopper at the bottom of the tank. Recycling a portion of the sludge back to the inlet of the aeration tank is an essential characteristic of this treatment process. The settled sludge is in an active state. In other words, the microbes are well acclimated to the wastewater and, given the opportunity, will readily absorb and decompose more organics by their metabolism.

By pumping about 30 per cent of the wastewater flow from the bottom of the clarifier back to the head of the aeration tank, the activated sludge process can be maintained continuously. When mixed with the primary effluent, the hungry microbes quickly begin to absorb and metabolize the fresh food in the form of BOD causing organics. Since the microbes multiply and increase greatly in numbers, it is not possible to recycle or return all the sludge to the aeration tank. The excess sludge, called waste activated sludge, must eventually be treated and disposed of (along with sludge from the primary tanks).



Tertiary (Advanced) Treatment

Secondary treatment can remove between 85 and 95 per cent of the BOD and TSS in raw sanitary sewage. Generally, this leaves 30 mg / L or less of BOD and TSS in the secondary effluent. But sometimes this level of sewage treatment is not sufficient to protect the aquatic environment.

Another limitation of secondary treatment is that it does not significantly reduce the effluent concentrations of nitrogen and phosphorous in the sewage. Nitrogen and phosphorous are important plant nutrients. If they are discharged into a lake, algal blooms and accelerated lake aging or cultural eutrophication may be the result. Also, the nitrogen in the sewage effluent may be present mostly in the form of ammonia compounds. These compounds are toxic to fish if the concentrations are high enough. Yet another problem with the ammonia is that it exerts a nitrogenous oxygen demand in the receiving water as it is converted to nitrates. This process is called nitrification.

When pollutant removal greater than that provided by secondary treatment is required, either to further reduce the BOD or TSS concentrations in the effluent or to remove plant nutrients, additional or advanced treatment steps are required. This is also called **tertiary treatment**, because many of the additional processes follow the primary and secondary processes in sequence.

Tertiary treatment of sewage can remove more than 99 per cent of the pollutants from raw sewage and can produce an effluent of almost drinking water quality.

Effluent polishing

The removal of additional BOD and TSS from secondary effluents is sometimes referred to as effluent polishing. It is most often accomplished using a granular media filter much like the filters used to purify drinking water. Since the suspended solids consist mostly of organic compounds, filtration removes BOD as well as TSS.

Phosphorus Removal

When stream or effluent standards require lower phosphorous concentrations, a tertiary treatment process must be added to the treatment plant. This usually involves chemical precipitation of the phosphate ions and coagulation. The organic phosphorous compounds are entrapped in the coagulant flocs that are formed and settle out in a clarifier.

One chemical frequently used in this process is aluminium sulfate (Al_2SO_4). This is called **alum**, the same coagulant chemical used to purify drinking water. The aluminium ions in the alum react with the phosphate ions in the sewage to form the insoluble precipitate called aluminium phosphate. Other coagulant chemicals that may be used to precipitate the phosphorous include ferric chloride ($FeCl_3$), and lime(CaO).

Nitrogen Removal

One of the methods used to remove nitrogen is called biological nitrification – denitrification. It consists of two basic steps. First, the secondary effluent is introduced into another aeration tank, trickling filter, or biodisc. Since most of the carbonaceous BOD has already been removed, the microorganisms that will now thrive in this tertiary step are the nitrifying bacteria, *Nitrosomonas* and *Nitrobacter*. In this first step, called **nitrification**, the ammonia nitrogen is converted to nitrate nitrogen, producing a nitrified effluent. At this point, the nitrogen has not actually been removed but only converted to a form that is not toxic to fish and that does not cause an additional oxygen demand.

A second biological treatment step is necessary to actually remove the nitrogen from the wastewater. This is called **de nitrification**. It is anaerobic process in which the organic chemical methanol is added to the nitrified effluent to serve as a source of carbon. The denitrifying bacteria *Pseudomonas* and other groups use the carbon from the methanol and the oxygen from the nitrates in their metabolic processes. One product of this biochemical reaction is molecular nitrogen (N_2), which escapes into the atmosphere as a gas.

Bioreactors

Certain organic hazardous wastes can be treated in slurry form in an open lagoon or in a closed vessel called a **bioreactor**. A bioreactor may have fine bubble diffusers to provide oxygen and a mixing device to keep the slurry solids in suspension.

b. Anaerobic wastewater treatment methods

The generation and disposal of large quantities of biodegradable waste without adequate treatment result in widespread environmental pollution. Some waste streams can be treated by conventional methods like aeration. Compared to the aerobic method, anaerobic digestion proves to be more advantageous in terms of efficiency of treatment as well as potential energy savings. Biomethanation is the process of conversion of organic matter in the waste (liquid or solid) to biogas and manure by microbial action in the absence of air. Methane produced by methanogenic bacteria is also another potential energy source. Methane is used for generation of mechanical, heat and electrical energy. Anaerobic decomposition of waste materials produces large amounts of methane. Many sewage treatment plants produce this fuel. Efficient generation of methane can be achieved by using algal biomass grown in pond cultures, sewage sludge, municipal refuse, plant residue and animal waste. Methanogens (Archaebacteria) are obligate anaerobes and produce CH_4 by reducing acetate and/or CO_2. **Biogas**, a mixture of different gases is produced by anaerobic microbes using domestic and agricultural wastes. Bulk (about 50 – 70%) of biogas is **methane** (CH_4) and other gases are in low proportions. These include CO_2 (25 – 35%), H_2 (1 – 5%), N_2 (2 – 7%) and O_2 (0 – 0.1%). In India a large number of **gobar gas plants** are already in operation in rural areas. Left overs of these plants are good fertilizers also. Animal waste is first hydrolyzed by hydrolytic bacteria. It is followed by acid formation by a group of acetogenic bacteria, which convert monomers into simple compounds like NH_3, CO_2 and H_2. Finally methanogens reduce acetate and/or CO_2 to CH_4. In India, cattle dung is the chief source of biogas.

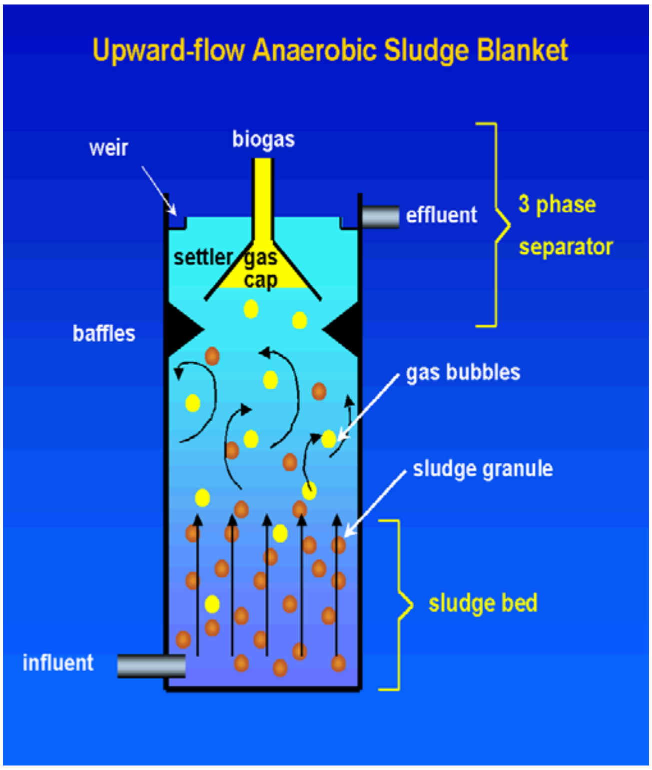
Biomethanation requires adequate infrastructural facilities. The first and the foremost among them is the bioreactor in which the treatment is to be carried out, since extremely large volumes of effluents are encountered for treatment. Thus, an optimally designed bioreactor can decrease the treatment time and increase the treatment efficiency leading to an overall lowering of the treatment cost. Selection and design of bioreactors are dictated by process kinetics. Conventional digesters such as sludge digesters and anaerobic CSTR (Continuous Stirred Tank Reactor) have been used for many decades in sewage treatment plants for stabilizing the activated sludge and sewage solids. Interest in biomethanation as an energy-saving waste treatment has led to the development of a range of anaerobic reactor designs. These high-rate digesters are also known as retained biomass reactors since they are based on the concept of retaining viable biomass by sludge immobilization.

Anaerobic reactors for liquid waste

- Upflow anaerobic sludge blanket
- Anaerobic fluidized bed
- Anaerobic filter
- Expanded granular sludge bed reactor

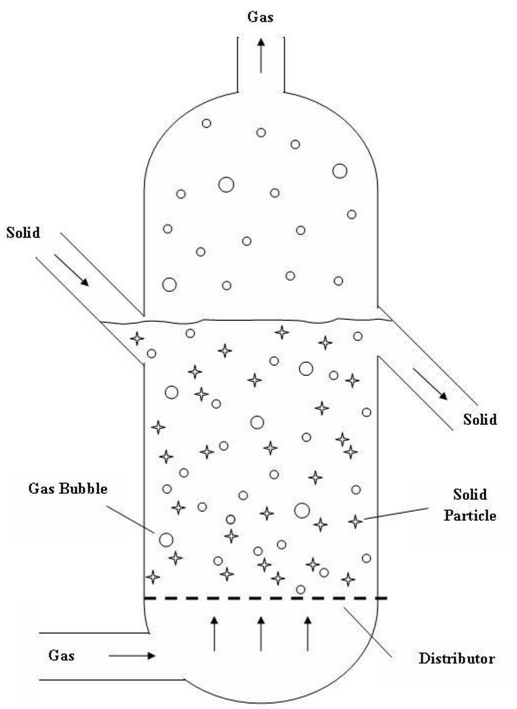
Upflow Anaerobic Sludge Blanket Reactor

Developed at Wageningen Agricultural University, Netherlands (Lettinga, 1978), the UASB reactor employs anaerobic bacteria especially methanogens, which have a propensity to form self-immobilized granular structures with good settling properties inside the reactor. These anaerobic bacteria granules make a "blanket" through which the effluent flows up the reactor. The substrate present in the effluent diffuses into the sludge granules, where it is degraded by the anaerobic route. Thus, these reactors due to their high biomass concentrations can achieve conversions several folds higher than that possible by conventional anaerobic processes and tolerate fluctuations in influent feed, temperature and pH. Moreover, since no support medium is required for attachment of the biomass it decreases the capital cost and minimizes the possibility of plugging. The energy requirement is also small because there is no mechanical mixing within the reactor, no recirculation of sludge, and no high recirculation of effluent.



Anaerobic Fluidized Bed (AFB) Reactors

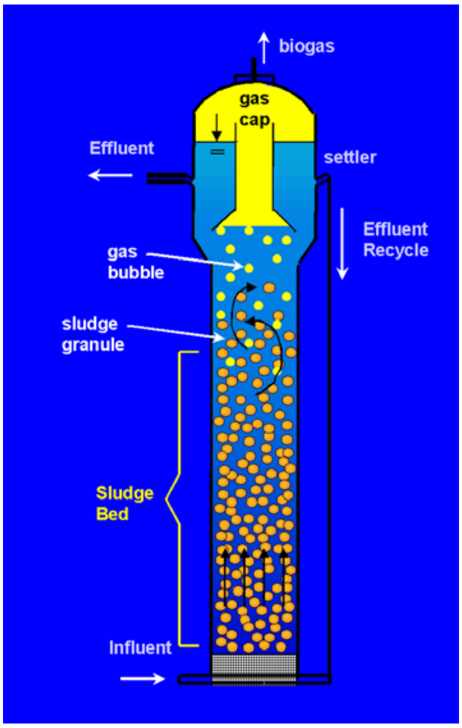
In these reactors mixed culture bacteria are made to grow as a film on the surface of some inert carrier particle. These particles are then maintained inside in a "fluidized" state using the energy of the incoming effluent stream. The linear velocity of the effluent is kept above the minimum fluidization velocity so that the film-covered particles are always in motion and the bed appears to be boiling. The substrate present in the liquid phase diffuses into the biofilm and gets converted to VFAs and ultimately to methane. These products then diffuse out through the biofilm into the bulk liquid. The mixing and mass transfer achieved in these reactors is excellent and the resulting conversions are comparable or even superior to those obtained for UASB reactors. These reactors have typical loading rates of 25 KgCOD/m^3 days. However, as the biofilm grows, the film-covered particles increase in size, which is accompanied by a decrease in their composite density. This causes the particle to move up in the bed ultimately resulting in its leaving the reactor, thereby leading to a reduction in the carrier particle concentration inside the reactor. This problem can be overcome by removing the biofilm from the carrier particle which has exited the reactor and then recycling the carrier particle (minus the biofilm) to the reactor. However, it is observed that the transport of solid particles as a rule creates too many operational problems let alone maintain strict anaerobic conditions within the reactor. Another drawback of AFB reactors is the high energy requirement due to the large recycle rates employed in these systems.



Many improved reactor designs for high rate biomethanation are being tried out in this context. In spite of several bottlenecks in the smooth and efficient operation of both UASB and AFB systems, there is hope that these systems have the potential to offer an extremely high rate of waste stabilization accompanied by methane production.

Expanded Granular Sludge Bed Reactor (EGSB)

- Faster rate of upward-flow velocity
- Increased flux permits partial expansion (fluidization) of the granular sludge bed, improving wastewater-sludge contact as well as enhancing segregation of small inactive suspended particle from the sludge bed
- Increased flow velocity is either accomplished by utilizing tall reactors, or by incorporating an effluent recycle (or both)
- EGSB design is appropriate for low strength soluble wastewaters (less than 1 to 2 g soluble COD/l)
- For wastewaters that contain inert or poorly biodegradable suspended particles which should not be allowed to accumulate in the sludge bed



Membrane Bio reactor (MBRs) brings a new age of biological waste water treatment. With pure oxygen the benefits of MBRs are enhanced resulting in even higher rate biological treatment systems which provide the control of COD, microorganisms and VOCs in waste water. Oxy-Dependent MBR can use high biomass concentrations, which for air-based systems cause oxygen transfer limitations. High purity oxygen resolves this, as well as the foaming and VOC issues associated with air-based systems.

Phytoremediation

Plants show several response patterns to the presence of potentially toxic concentrations of heavy metal ions. Most are sensitive even to very low concentrations, others have developed resistance and a reduced number behave as hyperaccumulators of toxic metals . This particular capacity to accumulate and tolerate large metal concentrations has opened up the possibility to use phytoextraction for remediation of polluted soils and waters Plants with metal resistance mechanisms based on exclusion can be efficient for phytostabilization technologies. Hyperaccumulator plants, in contrast, may become useful for extracting toxic elements and thus decontaminate and restore fertility in polluted areas.

1. Phytoextraction: This technique reduces metal concentrations by cultivating plants with a high capacity for metal accumulation in shoots. Plants used for this purpose should ideally combine high metal accumulation in shoots and high biomass production. Many hyperaccumulator species fulfill the first. but not the second condition. Therefore, species that accumulate lower metal concentrations but are high biomass producers may also be useful.

2. Rhizofiltration: This technique is used for cleaning contaminated surface waters or wastewaters by adsorption or precipitation of metals onto roots or absorption by roots or other submerged organs of metal-tolerant aquatic plants. For this purpose, plants must not only be metal-resistant but also have a high adsorption surface and must tolerate hypoxia.

3. Phytostabilization: Plants are used for immobilizing contaminant metals by root uptake, adsorption onto roots or precipitation in the rhizosphere. By decreasing metal mobility, these

processes prevent leaching and groundwater pollution. Bioavailability is reduced and fewer metals enter the trophic web.

4. Phytodegradation: Elimination of organic pollutants by decomposition through plant enzymes or products.

5. Rhizodegradation: Decomposition of organic pollutants by means of rhizosphere microorganisms

.6. Phytovolatilization: Organic pollutants absorbed by plants are released into the atmosphere by transpiration, either in their original form or after metabolic modification. In addition, certain metals can be absorbed and volatilized by certain organisms.

Mercury Pollution

Mercury enters water naturally as well as through industrial effluents. It is a potent hazardous substance. Both, inorganic and organic forms are highly poisonous. Methyl mercury gives off vapors. Mercury was responsible for the **Minamata** epidemic that caused several deaths, in Japan and Sweden. The tragedy had occurred due to consumption of heavily mercury-contaminated fish (27 to 102 ppm, average 50 ppm) by the villagers. Chloralkali plants seem to be the chief source of mercury containing effluents.

Effluents of industries making switches, batteries, thermometers, fluorescent light tubes and high intensity street lamps also contain mercury. From the effluents mercury compounds enter the water body and at their bottom these are metabolically converted into methyl mercury compounds by anaerobic microbes. Methyl mercury is highly persistent and thus accumulates in food chain. Methyl mercury is soluble in lipids and thus after being taken by animals it accumulates in fatty tissues. The symptoms of Minamata include malaise, numbness, visual disturbance, dysphasia, ataxia, mental deterioration, convulsions and final death. Mercury readily penetrated the central nervous system of children born in Minamata causing teratogenic effects.

Lead Pollution

Lead poisoning is common in adults. The chief source of lead to water is the effluents of lead and lead processing industries. Lead toys may be chewed by children. Painters also have a risk of lead consumption. In some plastic pipes lead is used as stabilizer. The water may become contaminated in these pipes. Lead is also used in insecticides, food, beverages, ointments and medicinal concoctions for flavouring and sweetening.

Lead pollution causes damage to liver and kidney, reduction in hemoglobin formation, mental retardation and abnormalities in fertility and pregnancy, chronic lead poisoning may cause three general disease syndromes (i) gastrointestinal disorders (ii) neuromuscular effects – weakness, fatigue muscular atrophy, and (iii) central nervous system effects or CNS syndrome – that may result to coma and death. Lead poisoning also causes constipation, abdominal pain etc.

Fluoride Pollution

Fluorine is also regularly present in water and soil besides air. In nature it is found as fluoride. The crop plants grown in high-fluoride soils in agricultural, non-industrial areas had a fluoride content as high as 300 ppm. In Haryana and Punjab, consumption of fluoride-rich water from well caused endemic fluorosis. In Andhra Pradesh also high fluoride content water caused dental fluorosis. On an average, about 20-25 million Indian are affected with fluorosis. In our country this problem has become more severe in Rajasthan.

Fluoride is not absorbed in the blood stream. It has an affinity with calcium and thus gets accumulated in bones, resulting in the mottling of teeth, pain in the bones and joint and outward bending of legs from the knees knock knee syndrome. Fluoride levels more than 0.5 ppm over over a period of 5-10 years results in fluorosis terminating in crippling or paralysis. In water of most villages of Rajasthan fluoride level is higher than permissible limit of 1 mg/litre of water. The toxic effects are staining, mottling and abrasion of teeth, high fluoride levels in bone and urine, decreased milk production, and lameness, Animal becomes lethargic.

B. Marine Pollution

The marine water represents a different kind of habitat for microorganisms. The very vastness of the oceans and the variety of microbial life present in these make the study of these a special branch of microbiology called marine microbiology. The marine water contains algae, protozoa, yeasts, moulds, bacteria and viruses. The microorganism which are free - floating are collectively known as the plankton and may consist of algae (phytoplankton) and protozoa and minute animals (zooplankton). Bacteria and fungi may also form part of the plankton. The algae are the primary producers as they can photosynthesize while others are consumers at various levels of the food - chain. The microorganisms found at the bottom of the ocean are called the benthos or benthic microorganisms. A variety of microorganisms are found in the benthic region but the bacteria predominate.

In polluted areas of estuarine regions rich in organic nutrients, organisms such as *Beggiatoa, Thiothrix, Thiovolum* and various species of *Thiobacillu*s may be predominant. The transient bacteria may include species of *Bacillus, Corynebacterium, Sarcina,* Actinomyces and Gram - negative v*ibrio* - like organisms. A terminally bispored species of *Clostridium* which is unique to the ocean is named *Clostridium oceanicum*. Photosynthetic purple sulphur bacteria usually occur below algal mats in anaerobic environs, as most of the light and oxygen is absorbed by algae.

In polluted waters, there are large amounts of organic matter from sewage, feces and industrial complex. The microbes are usually heterotrophic. The digestion of organic matter by these organisms is incomplete, due to which there accumulate acids, bases, alcohols and various gases. The major types of bacteria are coliform bacteria, the Gram-negative nonspore forming bacilli usually found in the intestine. This group includes *E. coli* and species of *Enterobacter*. They ferment lactose to acid and gas. Noncoliform bacteria-*Streptococcus, Proteus* and *Pseudomonas* are also present.

Under some conditions, the polluting organisms multiply rapidly and consume most of the available oxygen. For instance, nutrients enter the river from sources like sewage treatment plants or urban/suburban runoff. Thus river suddenly develops a high nutrient content. Under these conditions algae may bloom rapidly. This leads to depletion of oxygen in water. There is very little oxygen available to the protozoa, small animals, fish and plants. Due to this non-availability of oxygen, a layer of dead organisms, mud and silt accumulate at the bottom and anaerobic species of *Clostridium, Desulfovibrio* etc. will flourish and they produce gases. One gas, H_2S combines with lead or iron to give a precipitate which makes the mud black and the water poisonous. Due to complete depletion of oxygen, the suspended bacteria die in their own waste products. There is hardly any life in water at this stage. The gas bubbles from the anaerobes in the mud break the surface and such processes lead to death of a river.

All that what is carried by rivers ultimately ends up in the seas. On their way, rivers receive huge amounts of sewage, garbage, agricultural discharge, biocides, including heavy metals. These all are added to sea. Besides these discharge of oils and petroleum products and dumping of radionuclides waste into sea also cause marine pollution. Huge quantity of plastic is being added to sea and oceans. Over 50 million Ib plastic packing material is being dumped in sea of commercial fleets.

The pollutants in sea may become dispersed by turbulence and ocean currents or concentrated in the food chain. They may sediment at the bottom by processes like adsorption, precipitation and accumulation. Bioaccumulation in food chain may result into loss of species diversity.

Marine pollution

It is defined as the discharge of waste substances into the sea, posing threat to living sources, hazard to human health, hindrance to fishery and impairment of quality of sea water. Marine pollution is associated with the change in physical, chemical and biological conditions of the sea water. Nearly 71% of Earth surfaces is covered with Oceans, which comprise a total of approximately 1.37×10^{39} litres. Ocean is an ideal place to dump all the man wastes.

Marine pollutants in the sea.

- Pathogens
- Sediments
- Solid wastes
- Heat
- Freshwater
- Brine
- Toxic Inorganics
- Toxic Orgnics
- Pertoleum and oil
- Nutrients
- Radioactive materials
- Oxygen demanding materials
- Acids and Bases

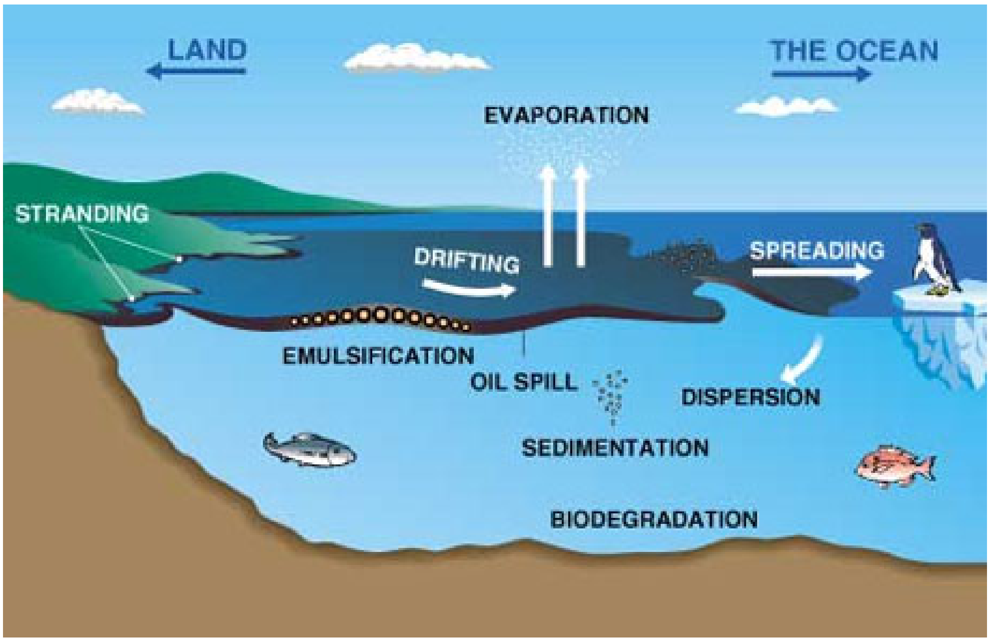
These pollutants comes from various sources. The Marine pollution may also off natural origin.

Sources of pollutants

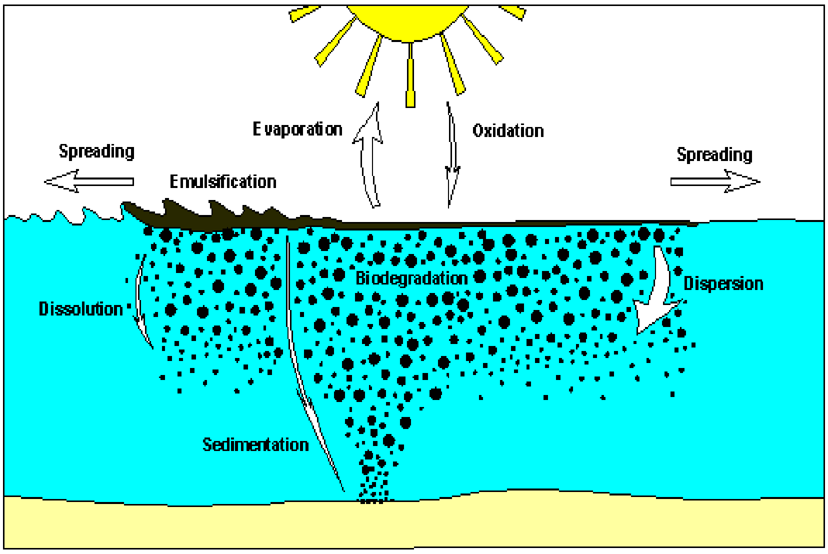
- Marine commerce
- Industry
- Electircal Power generation
- Sewage treatment
- Other Non Industrial Wastes
- Recreation
- Construction

Oil Spills – Oil pollution of the sea normally attracts the greatest attention because of its visibility.

Behaviour of Oil in Sea



Fate of Oil



Weathering

- Modifying physical and chemical properties
- Oil floating- spreading to a wide spectrum of the area
- Crude oil forms sticky layers-prevents free diffusion of gases, decreases the photosynthesis
- Volatile components-evaporate, heavy tar ball- assimilated by bottom organisms

Evaporation

- Series of chemical and physical changes that cause spilled oil to break down and become heavier than water
- Winds, waves, and currents may result in natural *dispersion*, breaking a slick into droplets
- These droplets may also result in the creation of a secondary slick or thin film on the surface of the water

Oxidation

- Occurs when the lighter substances within the oil mixture become vapors
- Leaves heavier components of the oil, which may sink to the ocean floor spills kerosene and gasoline contain a high proportion of flammable components (evaporate completely within a few hours)
- Reducing the toxic effects to the environment.
- Heavier oils leave a thicker, more viscous residue, which may have serious physical and chemical impacts on the environment
- Wind, waves, and currents increase both evaporation and natural dispersion

Biodegradation

- Occurs when microorganisms feed on oil
- To sustain biodegradation, nitrogen and phosphorus are added to encourage the microorganisms to grow and reproduce
- Biodegradation tends to work best in warm water environments

Emulsions

- Emulsions consisting of a mixture of small droplets of oil and water
- Emulsions are formed by wave action, and greatly hamper weathering and cleanup processes
- Two types of emulsions exist: water-in-oil and oil-in-water
- Water-in-oil emulsions are frequently called "chocolate mousse," - formed strong currents or wave action makes water trapped inside the viscous oil
- Oil and water emulsions cause oil to sink

Spreading

- Initially as a single slick depends upon the viscosity of the oil
- Fluid, low viscosity oils spread more quickly than those with a high viscosity
- Slicks quickly spread to cover extensive areas of the sea surface
- Spreading is rarely uniform and large variations in the thickness of the oil

Dispersion

- Waves and turbulence at the sea surface cause all or part of a slick to break up into fragments and droplets of varying sizes
- Oil that remains suspended in the water has a greater surface area than before dispersion occurred
- Encourages other natural processes (dissolution, biodegradation and sedimentation to occur
- Speed of oil disperses is largely dependent upon the nature of the oil and the sea state
- Quick if the oil is light and of low viscosity and if the sea is very rough.

Sedimentation/Sinking

- Heavy refined products have densities greater than one , so sink in fresh or brackish water
- Sea water has a density of approximately 1.025 and very few crudes are dense enough or weather sufficiently
- Sinking usually occurs due to the adhesion of particles of sediment or organic matter to the oil
- Oil stranded on sandy shorelines often becomes mixed with sand and other sediments

There are several sources though which the oil can reach the sea.

- Natural release
- Oil tanker and other ship accidents – Largest Oil Spills (World-Level)
    - Gulf War oil spill, Persian Gulf, January 23 1991
    - Ixtoc I oil well, S Gulf of Mexico, June 3, 1979
    - Nowruz oil field, Persian Gulf, February, 1983
    - Castillo de Bellver, off Cape Town, South Africa, August 6, 1983
    - Amoco Cadiz (BP/Amoco, USA) - Britanny, France, March 16 1978
    - Torrey Canyon, South England, March 18 1967
    - Sea Star,Gulf of Oman, December 19, 1972
    - Urquiola, La Coruna, Spain, May 12, 1976
    - Hawaiian Patriot, N Pacific February 26, 1977
    - Othello, Tralhavet Bay, Sweden, March 20, 1970
- Operation of ships other than tankers
- Offshore oil drilling and production plat forms
- Ship shore oil terminal operation
- Refinery operation

Tanker operations

Half the world production of crude oil , which is closed to three billion tones per year, is transported by sea. After a tanker has unloaded its cargo of oil, it has to take on sea water as ballast for the return journey. This ballast water is stored in the cargo compartments that previously contained the oil. During the unloading f the cargo certain amount oil remains clinging to the walls of the container and this may amount to 800 tonnes in a 2 lakh s container. The ballast water thus becomes contaminated with this oil. When a fresh cargo of oil is to be loaded, these compartments are cleaned with water, which discharges the dirty ballast along with the oil into the sea.

Two techniques have substantially reduced the oil pollution. In the load- on- top system, the compartments are cleaned by high pressure jets of water. The oily water is retained in the compartment until the oil floats to the top. The water underneath that contains only a little oil is then discharged into the sea and the oil is transferred tot a slope tank. At the loading terminal, fresh oil is loaded on top of the oil in the tank and hence the name of the technique. In the second method, called crude oil washing , the cling age is removed by jets of crude oil by the cargo is being unloaded. Some Modern Tankers have segregated ballast, where the ballast water does not come in contact with this oil. Thus with the introduction of these new methods of the ballast, the amount t of oil entering the sea has been considerable reduced.

Dry Docking

All ships need periodic dry docking for servicing repairs, cleaning the hull etc. During this period when the cargo compartments are to be completely emptied, residual oil finds its way into the sea.

Bilge and fuel oils

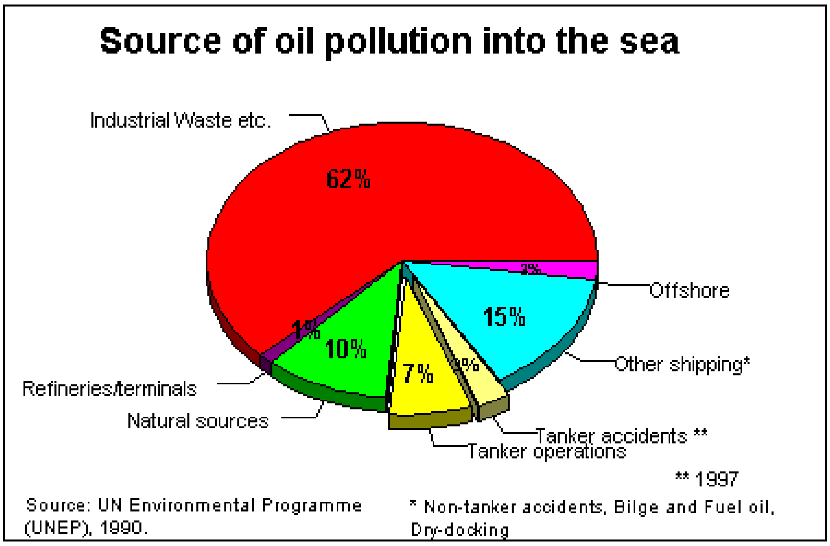
As ballast tanks take up valuable space, additional ballast is sometimes carried in empty fuel tnaks. While being pumped overboard it carries into the sea. Individually, the quantity of oil released may be small, but it sometimes becomes a considerable amount when all the shipping operations are taken into consideration.

Tanker accidents

A large number of oil tanker accidents happen every year. Sometimes this can result in major disasters , such as that of Exxon Valdez on marine environment.

Offshore Oil Pollution

The oil that has extracted from the sea bed contains some water. even after it is passed through oil separators the water that is discharges contains some oil, which adds to marine pollution. Drilling mud, which are pumped down oil wells when they are being drilled, normally contain 70 to 80 % of oil. They are dumped on the sea bed beneath the drilling platform, thus heavily contaminating the water. In addition, the controlled release of oil from the wells can be catastrophic events resulting in oil pollution



Oil spill- India - In 1994, June14Indian authorities began siphoning off 700 tons of oil from the Sea Transporter, a 6,000-ton Greek cargo ship which had been anchored off Aguada after it ran aground following a cyclone on June 5. In March 25, 2005, 110 tonnes oil spilled in Goa port.

Control of Oil Pollution

Physical methods

Skimming: The oil could be removed from the surface

Oil can be removed by suitable absorbents Eg.Saw Dust, Polyurethane foam

Chemical Methods

- Evaporation, Emulsification, Absorbents, burning of oil are effective methods
- Super bug has been proved to be effective to clean up the oil pollution

- Oleophilic fertilizers enrich the soil eating microbes like pseudomonas sp and hence they could be used.
- To reduce the thermal pollution due to industrial effluents, high efficient heat exchangers should be used.
- Each industry should have a separate treatment plant to meet the standards which are given by central and state pollution control Boards.

General awareness must be created among the common people regarding the disposal of various wastes

Oil Degradation by superbug

Although many microorganisms can metabolize petroleum hydrocarbon no single microbe possesses the enzymatic capability to degrade all, or even most of the compounds in a petroleum mixture. Recombinant DNA technology has created a **'superbug'** that is able to degrade many hydrocarbon structures, that is potentially useful in oil pollution abatement programmes. This hydrocarbon-degrading microbe, *Pseudomonas putida* is the first organism for which a patent has been granted in the U.S.A.

Different strains of this bacterium contain a plasmid, which has genes for enzymes that digest a single family of hydrocarbon. These plasmids are designated based on the hydrocarbon they metabolize. Plasmid *CAM* digests camphor, *XYL*- xylene and toluene, *NAH*- naphthalene and *OCT*- octane. By crossing various strains of this bacterium a super bug was created. It carries the plasmids *XYL, NAH* and a hybrid plasmid having *CAM* and *OCT* genes. This multi plasmid bacterium can grow on a diet of crude oil. It has a potential of cleaning up of oil spills as it degrade all the four families of hydrocarbons.

Water quality standards

In the urbanized and industrialized world of today, it is necessary to have a legal basis for protecting water quality. It takes human effort, energy and money to keep water clean enough for the many different uses for which society requires it. Without a legal frame work to allow the enforcement of water quality standards, environmental quality and public health would be in constant jeopardy.

Water quality standards are limits on the amount of physical, chemical, or microbiological impurities allowed in water that is intended for a particular use. These are legally enforceable by governmental agencies and include rules and regulations for sampling, testing and reporting procedures.

S. No.	**Characteristics**	**Inland surface waters**	**Public sewers**	**Irrigation**
1.	TSS (mg/l) max.	100	600	200
2.	DS (inorganics) (mg/l)	2100	2100	2100
3.	PH	5.5 to 9.0	5.5 to 9.0	5.5 to 9.0
4.	Oil and Grease (mg/l)	10	20	10

5.	Total Residual chlorine (mg/l)	1	-	-
6.	Ammoniacal nitrogen (as N) mg/l	50	50	-
7.	BOD_5 (mg/l)	30	350	100
8.	COD (mg/l)	250	-	-
9.	Arsenic (as As) (mg/l)	0.2	0.2	0.2
10.	Mercury (as Hg) (mg/l)	0.01	0.01	-
11.	Lead (as Pb) (mg/l)	0.1	1	1
12.	Cadmium (as Cd) (mg/l)	2.0	1	1
13.	Hexavalent chromium (as Cr) (mg/l)	0.1	2	-

Lecture 9

Causes, effects and control of water and marine pollution.

1	Biological treatment of wastewater aims to remove	
	a)Inorganic Pollutants	**b)Organic Pollutants**
	c)Heavy Metals	d)Dissolved salts
2	Remediation of soil contamination using microorganisms is termed as ----------------	
	a)Bioremediation	b)Phytoremediation
	c)Biosorption	d)Bioreclamation
3	Blue baby syndrome is high concentration of -------------- in drinking water	
	a) Nitrate	b) phosphate
	c) nitrogen	d) Calcium
4	The maximum permissible limit of nitrate in drinking water is	
	a)100 mg/l	b) 100 mg/l
	c)10 mg/l	**d) 50 mg/l**
5	Increase in the concentration of a recalcitrant substance at successive trophic level is called	
	a)Bioaccumulation	**b)Biomagnification**
	c)Biosorption	d)Biofiltration
6	Which of the following is not an aerobic process?	
	a)Activated Sludge Process	**b) Sludge Digestion**
	C) Trickling Filter	d) Oxidation Pond
7	Fluidised reactor provides the effect of	
	a)Trickling filter and activated sludge	b) Trickling filter
	c)Activated Sludge Process	d)Lagoons
8	The use of DDT in India for agricultural use is banned in the year	
	a) 1980	**b) 1985**
	c)1986	d)1984.
9	Which one of the following reactor can be used for treating Slaughter house waste	
	a) USAB	b) Fluidised reactor
	c) RBC ,	d) Air Lift Reactor
10	Plasmid involved in degradation of xenobiotics	
	a) Col plasmid	**b) Xyl Plasmid**
	c) Ti plasmid	d) RI Plasmid
11	Biodegradative ability of *Pseudomonas* is attributed to	
	a)Presence of plasmids	b) Resistance to adverse conditions ,
	c) Presence of transposons	d)Presence of OXidase Enzymes
12	A pure or nearly pure water contains a BOD of approximately (mg/L)	
	a)20-30	**b)30**
	c)0-3	d)10-12
13	Minamata disease was due to	
	a)Phenol	**b) mercury**
	c) Methane	d) Benzene
14	Phytoremediation is	
	a)Protection of plants from pests by integrated pest management	b)Removal of toxicants from plant body by chemical means

	c)Use of plants for removing toxicants from soil and water	d)Use of root mycorrhizae for bioremediation purposes
15	Fixed Biomass principle is followed in	
	a)Activated sludge	b)Trickling Filter
	c) Lagoons	d)biogas Digester
16	Rotating Biological contactors are used for	
	a) Reducing BOD of wastewaters	b) Biofiltration of wastewater
	c)Removing colour of textile effluents	d)Removing pathogens from sewage
17	Fine bubble air diffusers are used in	
	a) Trickling filter	b) Activated sludge process
	c)Rotating biological contractor	d)Oxidation pond
18	Minamata disease was due to	
	Phenyl mercury	b) Inorganic mercury
	c) Methyl mercury	d) Benzyl mercury
19	A highly toxic group of compounds are released with effluents of bleached pulp mills. This group is	
	a)Organocyanides	b) Organochlorines
	c) Ligninchlorides	d) Methylmerdurials
20	A pure or nearly pure water contains a BOD of approximately (mg/Lit)	
	a) 30	b) 20-30
	c)0-3	d) 10-12
21	According to World Health Organization (WHO) the permissible limit for coliforms in drinking water is	
	a)100/L	b) 0/L
	c) 1/L	d) 10/
22	Among the following which one is the best method for treating sewage sludge	
	a) Aerobic digestion	b) Anaerobic digestion
	c) Incineration	d) Pisciculture
23	In India the commonly used method for sewage treatment is	
	a) Oxidation ponds	b) Trickling filters
	c) Activated Sludge Process	d) Rotating Biological Contactor
24	With the increase in temperature of receiving water	
	a) DO content decreases	b) DO content increases
	c) Demand of oxygen increases	d) Demand of oxygen increases
25	The principle in using activated carbon for wastewater treatment is	
	a) Coagulation	b) Absorption
	c) Adsorption	d) All the above.
26	Critical limits of COD to discharge the wastewater into water bodies	
	a) 10 ppm	b) 100 ppm
	c) 250 ppm	d) 1000 ppm
27	Optimum BOD:N:P ratio for aerobic treatment of wastewater	
	a) 100:5:1	b) 75:50:1
	c) 5:100:1	d) 100:50:1
28	Cadmium poisoning leads to	
	a) *Itai Itai* disease	b)Knockknee syndrome
	c)Methamoglobinaemia	d) Cancer.

29	The ability of the solution to conduct electrical current is measured as	
	a) pH	b) EC
	c) TSS	d) None of the above
30	Eutrophication is due to addition of … **…………..** element (**Phosphate**)	
31	The commonly used coagulant in wastewater treatment is ………………… (**Alum)**	
32	Transfer of contaminants through food chain is referred as ……… (**Biomagnification)**	
33	The chemical used to disinfect water is --------------- **(Chlorine)**	
34	The Indicator organism for Fecal Contamination is ------------------ **(Coliforms)**	
35	--------------------- is a bioindicator used to check the potability of drinking water **(Coliforms)**	
36	Major domestic sources of Nitrogen in sewage is -------------------- **(Human Wastes)**	
37	Test for oxygen consumption in water is ------------------ **(BOD)**	
38	An analytical device which converts a biological response into an electrical signal is ------------------- **(Biosensors)**	
39	A device that detects and transmits information regarding a change in the quality of water sample is known as ------------------ **(Biosensors)**	
40	Heavy metal pollution in soils through application of chemical fertilizers is regarded as ------------------------- source of pollution **(Non Point Source of Pollution)**	
41	The actual polluting source is not known in - -------- **(Non Point Source of Pollution)**	
42	The accumulation of Nonbiodegradable substances along the food chain is known as **---------------(Biomagnification)**	
43	Lakes poorly productive in terms of organic matter and poor in nutrients is known as---------------**(Oligotrophic)**	
44	The principle adopted in activated sludge is ------- **-----------(Suspended Growth Principle)**	
45	----------- treatment is commonly used to remove dissolved salts from the wastewater **(Reverse Osmosis)**	
46	---------- is a bioreactor that produces energy from high strength waste water *(UASB)*	
47	Eco friendly detergents are -------------- free **(phosphate)**	
48	Hardness of water is due to ------------------ (**Ca & Mg)**	
49	Nitrate contamination in water causes ……………. in infants. **(Methamoglobinaemia)**	
50	Metals that are toxic to kidneys are called --------------------------- **(nephrotoxins)**	