Aquatic Pollution and Coastal Zone Management

Aquatic pollution

Introduction

Pollution of Aquatic environment is a relatively recent development and today it is of great concern. Before the 19th century industrial revolution, people lived in harmony with their immediate environment. As the industrialization has spread around the globe, the problem of water pollution has intensified. Today with over 8 billion people on the planet, the pressure on the water resources has increased and water pollution has become an emerging threat. In order to combat water pollution we must understand the problems associated with water pollution and become the part of the solution. In this context the course Aquatic Pollution and Coastal Zone Management has been designed to expose the under graduate students of Fisheries Science to various dimensions of Aquatic Pollution, resulting Environmental and Public Health Hazards and various tools available for monitoring and abatement of pollution. In addition, the coastal ecosystems which are highly productive and rich in biodiversity has been explained. The course Aquatic Pollution and Coastal Zone Management has been divided into two parts. The first part covers Aquatic Pollution and the second part Coastal Zone Management.

Classification of aquatic pollution

Pollution

Pollution is defined as an undesirable change in the physical, chemical or biological characteristics of the environment, which can harmfully affect the health, survival or activities of humans or other living organisms. Environmental pollution is an emerging threat and of great concern in today's context pertaining to its effect on the ecosystem. The technological developments in agriculture, industries and related fields have resulted in unlimited exploitation of natural resources disturbing the delicate ecological balance between the living and nonliving components of the biosphere.

Marine Pollution

GESAMP defined marine pollution as "introduction by man, directly or indirectly, of substances or energy into the marine environment (including estuaries) resulting in such deleterious effects as harm to living resources, hazards to human health, hindrance to marine activities including fishing, impairment of quality for use of sea-water, and reduction of amenities.

GESAMP (Group of Experts on the Scientific Aspects of Marine Environmental Protection) is a group of experts that since 1969 has advised the United Nations system on scientific aspects of marine environmental protection. GESAMP is presently sponsored by ten UN agencies with interests and responsibilities in marine environmental matters: IMO, FAO, UNESCO-IOC, WMO, IAEA, UN, UN Environment, UNIDO, UNDP and ISA. This joint advisory mechanism is needed first to provide a cross-sectoral, interdisciplinary, and science-based approach to international policy development in marine environmental affairs, and second to meet the practical requirement for coordination and cooperation among UN agencies.

Pollutant

Pollutant is a substance that pollutes the air, water or land. This term is used to describe things in the environment that do not belong. In a broader sense, the term 'pollutant' has even been used to describe undesirable levels of sound or light. For example, the lights and never-ending traffic noise on the Las Vegas Strip are examples of light and noise pollutants.

Difficulties on Pollution Measurement

Natural levels of most contaminants are unknown Pollutant effects can be complex and take a long time to develop Pollutants enter into aquatic environment through a great variety of mechanisms The number of compounds that humans introduce into the ocean is so enormous, it will be difficult to track.

Classification of Aquatic Pollution

Aquatic pollution can be classified mainly into three categories. These are Physical pollution Chemical pollution Biological pollution

Physical Pollution

Of the different types of pollution, physical pollution may be the most recognizable. Simply stated, physical pollution is the introduction of discarded materials into the environment. Physical pollution is what you might refer to as trash and is the direct result of human actions. In other words, nature does not produce physical pollution because in natural systems, all byproducts or wastes are eventually recycled back into the environment. For example, in nature, a fallen tree will degrade and eventually return nutrients to the soil.

However, physical pollutants, such as discarded water bottles and plastic bags along with waste materials from industrial or manufacturing processes, do not naturally degrade and can accumulate or leach chemicals into the water supplies as they breakdown.

Some of the important examples for physical pollutions

i. Colour

Colour change is not harmful unless it is associated with a toxic chemical but it may affect the quality of sunlight that penetrates to a given depth inhibiting plant and animal metabolism. Turbidity

Turbidity in water mainly arises from colloidal matter, fine suspended particles and soil erosion. Generally greater the turbidity, stronger is the sewage and the industrial effluent concentrations and worst are the effects. If the turbidity inceases in the aquatic environment it affect water quality by reducing photo synthesis and also decreases the dissolved oxygen.

ii. Taste

Unpleasant earthy or musty taste and odour are produced by industrial effluents containing Fe, Mn, free chorine, phenols and aquatic actinomycetes. For example, even 0.1 ppm of Fe can produce an inky taste, while phenol produces a bitter taste at 7 ppm. Mn, oils, hydrocarbons, chlorophenols, petroleum products, synthetic detergents, pesticides, etc produce characteristic tastes in water. The decomposed organic matter, algae, fungi, bacteria and pathogens impart peculiar taste.

iii. Odour

Odour pollution of water is caused both by chemical agents (like hydrogen sulphide, free chlorine, ammonia, phenols, alcohols, esters, hydrocarbons) and biological agents (such as algae, fungi, microorganisms). The lower the pH, the higher will be the amount of H_2S produced and greater will be the odour nuisance.

Microorganisms like algae, *Oscillatoria* and *Rivularia* cause muddy odour, while Anabaena produces a strong grassy odour. A protozoa (*Dinobryon*) imparts fishy odour to water. According to Fair and Whipple, the liberation of essential oils is the main cause of odour pollution.

iv. Foam

Foam is produced by soaps, synthetic detergents and untreated organic effluents from paper and pulp industries.

Chemical Pollution

Chemical pollution is another type of pollution. It is defined as the introduction of chemicals into the environment. Chemicals may not be seen by the naked eye, but they can cause problems in all areas of the environment. It may be caused either by organic pollutants or inorganic pollutants or by both. Organic pollutants can be biodegradable or non-biodegradable.

Biodegradable organic pollutants

These pollutants include Proteins from domestic sewage waste from canneries and slaughterhouses Fats from sewage, soap production, food processing and wool processing Carbohydrates, sugars, starch etc from sewage, textiles mills and paper mills Polymers, resins, coal, oil and various other organic substances found in domestic and industrial wastes and those synthetic compounds which are non-toxic to some microorganisms.

Non-biodegradable organic pollutants

These pollutants are those which persist in the aquatic system for a long time for example, pesticides, fungicides, bactericides, herbicides, insecticides, nematocides, rodenticides, miticides, etc. Through the use of these organic compounds, toxic chemicals ultimately find their way into the nearby water course. Several gases, toxic metals and compounds have been included in inorganic pollutants, because they also degrade water quality seriously.

Biological Pollution

Biological pollution is the introduction of living organisms, which grow and become invasive, into the environment. Most of them are micro-organisms that are harmful to humans and other forms of life. They are responsible for many different waterborne diseases. The original source of these pollutants is people or animals already infected with the micro-organisms concerned. If faeces from infected people are not correctly contained and treated, the pollutants can get into surface and groundwater. The main groups of biological pollutants are bacteria, viruses, protozoa and helminths (worms).

Sources of pollution

The loading of contaminants to surface waters, groundwater, sediments and drinking water occurs via two primary routes: (1) point source pollution and (2) non point-source pollution.

Point source pollution

This originates from distinct sources whose inputs into the aquatic systems can often be defined in a spatially explicit manner. Examples of point-source pollution include industrial effluents (pulp and paper mills, steel plants, food processing plants), municipal sewage treatment plants and combined sewage-storm water overflows, resource extraction (mining) and land disposal sites (landfill sites, industrial impoundments).

Non-point source pollution

In contrast it originates from poorly defined, diffuse sources that typically occur over broad geographical scales. Examples of non-point source pollution include agricultural runoff (pesticides, pathogens, fertilizers), storm water and urban runoff, and atmospheric deposition (wet and dry deposition of persistent organic pollutants such as polychlorinated biphenyls, mercury).

Measurement of water quality

There is no single or simple measure of water quality. Scientists have therefore developed specialized approaches to measure quality. Water quality is measured by a set of indicators, these are a group of parameters that can be used to assess environmental condition in a water body which are then compared to a set of standards/criteria. Water quality measurements fall into three broad categories.

Physical characteristics: Temperature, colour and odour, suspended solids and turbidity.

Chemical characteristics: Dissolved oxygen, Biological Oxygen Demand, Chemical Oxygen Demand, nutrients, pH, minerals, metals and organic compound.

Biological characteristics: Types and quantities of aquatic organisms (bacteria, algae, plankton – species richness, composition, primary production, feacal coliforms).

Sewage pollution

Sewage or waste water

Sewage is defined as waste water/matter from domestic or industrial establishments that is carried away in sewers and drains. Sewage pollution dates back to more than a century and during the late 19th century, marine systems have been considered as a sink for sewage disposal. By far, the greatest volume of waste discharged to watercourses, estuaries and the sea is sewage, which is primarily organic in nature and subject to bacterial decay. Demographic pressure in the urban areas has resulted in the production of enormous quanties of domestic waste. It was estimated in 2007 that approximately 33,000 million liters of domestic sewage reaches the coastal environment of the country in a day.

Composition of Sewage

Sewage effluents contain a wide variety of dissolved and suspended impurities from municipal/domestic waste, rainwater and anything washed down. Even though, the quantity of sewage disposed varies from place to place, the chemical characteristics remain similar. In general, sewage contains dissolved solids, suspended solids, nutrients (N, P), sulphate, chloride and heavy metals (Fe, Cu, Co, Zn, Pb, Ni), bacteria and viruses. Sewage consists of 99% water and 1% solids. Of the solids present in sewage, 70% are organic and 30% are inorganic in nature. The organic fraction contains proteins (60%), carbohydrates (20%) and fats (10%). The inorganic fraction contains grit, salts and metals.

Measurement of Organic Pollution/Assessment of Sewage

Impact Organic pollution can be measured by a number of chemical and biological parameters, which are directly related to the level of organic matter present in the water. Measurement of organic pollution is made by four ways, these are

Biochemical Oxygen Demand (BOD)

BOD is defined as the rate of removal of oxygen by microorganisms in the aerobic degradation of organic matter in waters. It is measured as the difference in the oxygen between the initial sample and after its incubation for five days at 20^0C or for three days at 27^0C.

Chemical Oxygen Demand (COD)

COD is a measure of the oxygen requirement of organic matter in the sample that is susceptible to oxidation by strong chemical oxidants like potassium permanganate, ferric sulphate, potassium iodate and potassium dichromate.

Total Oxygen Demand (TOD)

TOD refers to the total quantity of oxygen required to burn the whole sample. TOD analyzers are used to measure residual oxygen continuously in the stream of gases coming out as gas effluent after burning the sample.

Biological Indices of Organic Pollution

Biological indicators (bio-indicators) are considered to be organisms which by their own presence or absence indicate the existence in abundance of a particular critical factor. The structure of the biotic community is the reflection of conditions prevailing in waters and can be exploited for the biological assessment of the water quality with regard to organic pollution.

The proliferation of polychaete, *Capitella capitata*, absence of interstitial copepods and the ratio between the micro and macro fauna are some of the basic characteristics for assessing sewage impact.

Effects of Sewage Pollution on Aquatic Environment

Physico-Chemical Characteristics Ecological Damage Health Risks Amenity Loss/Economic Loss.

Physio-Chemical Characteristics

The chemistry of water is greatly affected by organic pollution because of the accumulation of degradation products and decline in oxygen. The hypoxic conditions prevent the oxidation of ammonia and hydrogen sulphide formed after the degradation of organic matter, thus allowing their build up to dangerous levels. The original quantity of nitrate (NO_3) present in the system also falls because of its conversion to ammonia or nitrogen gas by a process of de-nitrification, under low oxygen conditions. In the flowing waters, however, the initial decline in nitrate can be made good by nitrification of ammonia as the oxygen starts increasing in water. Organic pollution also increases the phosphorus content because it is released in the medium after decomposition. The buildup of CO2 affects pH and equilibrium in waters.

The reduction in pH and DO2 modifies the redox potential that governs the movement of nutrients across the water and sediment interface. Large quantity of suspended sediments also gets settled at the bottom and promotes anaerobic conditions in the sediments.

Ecological Damage

Sewage is primarily organic in nature and therefore subject to bacterial decay. As a result of bacterial activity the oxygen concentration in the water is reduced, and sewage is said to have high biological oxygen demand.

$C_6H_{12}O_6 + 6O_2$ ---------> $6H_2O + 6CO_2$

If the oxygen concentration falls below 1.5 ppm, the rate of aerobic oxidation is reduced and anaerobic bacteria start oxidizing organic molecules without oxygen. This can starve aquatic life of the oxygen it needs and also leads to the breakdown of proteins and other nitrogenous compounds, releasing hydrogen sulphide (H_2S) and ammonia (NH_3+), both of which are potentially toxic to aquatic organisms in low concentrations. Solids suspended in sewage may also blanket river and seabeds preventing respiration of the benthic flora and fauna. Decaying organic matter and nutrients in sewage enhance plant growth. Excessive algal growth and oxygen depletion can lead to alterations in ecosystem structure and to eutrophication. The dumping of sewage sludge at sea is another cause of ecological damage. Depending on the hydrography, sludge can smother the benthos, increase biomass, decrease species diversity and increase heavy metal concentration.

Health Risks

There are a number of strains of bacteria and viruses that are found in raw sewage. Coliform bacteria are excreted by wild and domestic animals and also existing in the human gut. The greater the sewage contamination and exposure of people, the higher is the risk of contracting ear, nose and throat infection and stomach upsets such as gastroenteritis. Faecal streptococci are more closely associated with human sewage and their presence in a sample is believed to be a better indicator of sewage contamination than that of the coliforms. Faecal streptococci can cause illnesses, especially gastroenteritis. Other disease causing agents, which may be present in the sewage, include enteric viruses, Salmonella and the Hepatitis A virus. Shellfish grown in sewage contaminated waters may cause food poisoning as mussels and oysters accumulate human pathogens through their filter feeding apparatus.

Amenity Loss/Economic Loss

Debris associated with sewage probably has the highest monetary cost associated with its presence as our beaches, due to loss of tourism and blockage removal. Many people are becoming aware of the risks associated with sewage related debris and they may avoid beaches/recreational waters. Closure of shellfish beds due to contamination can lead to severe loss of income and closure of businesses.

Sewage Treatment

Sewage treatment is the process of removing contaminants from wastewater, primarily from household sewage. It includes physical, chemical, and biological processes to remove these contaminants and produce environmentally safe treated wastewater.

Objectives of sewage treatment

- Removal of micro-organic which may be the cause of dangerous diseases
- Removal of floatable and postponed particles
- To improve the quality of wastewater.
- To make the wastewater usable for agricultural, aquaculture etc.

Types of sewage treatment

Sewage treatment, however, can also be organized or categorized by the nature of the treatment process operation-

- Physical
- Chemical
- Biological

Phases of sewage treatment

- Preparatory or Preliminary Treatment
- Primary or Physical Treatment
- Secondary or Biological Treatment
- Tertiary or Advanced Treatment
- Disinfection
- Sludge Treatment

Preparatory or Preliminary Treatment

The major aim of preliminary treatment is to remove the larger solid debris and floating materials (wood, paper rags and plastics). The waste is passed through screens consisting typically of parallel iron bars for the removal of floating objects (rags, plastics and wood). ‘comminutor’ or macerator is often provided for grinding the coarse material into smaller particles. A separate grit chamber is often provided where the waste is given retention for only a few minutes to settle down grit and other heavy materials

Primary treatment

The objective of primary treatment is the removal of settleable organic and inorganic solids by sedimentation, and the removal of materials that will float (scum) by skimming. Approximately 25 to 50% of the incoming biochemical oxygen demand (BOD_5), 50 to 70% of the total suspended solids (SS), and 65% of the oil and grease are removed during primary treatment. Some organic nitrogen, organic phosphorus, and heavy metals associated with solids are also removed during primary sedimentation but colloidal and dissolved constituents are not affected. The effluent from primary sedimentation units is referred to as primary effluent.

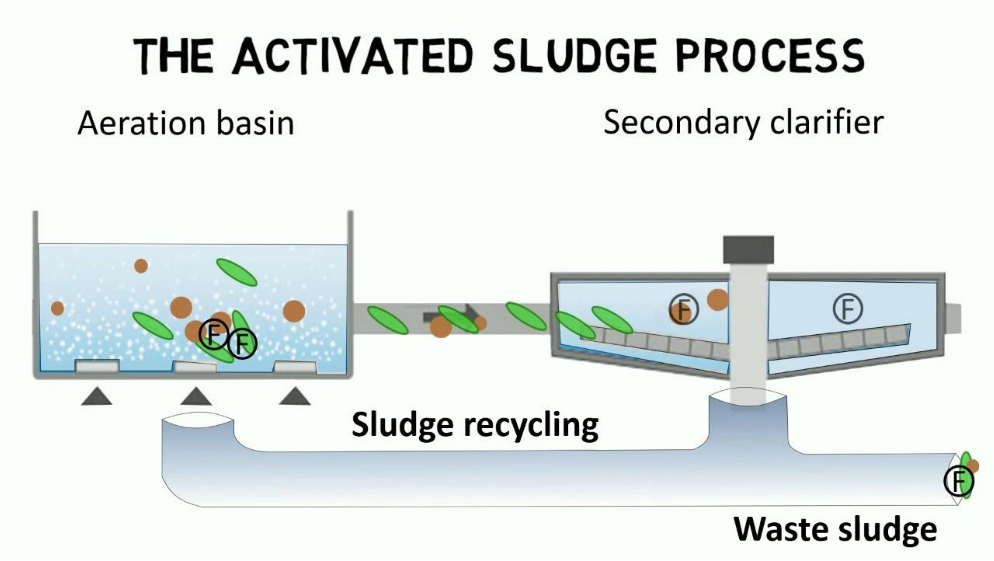
In many industrialized countries, primary treatment is the minimum level of preapplication treatment required for wastewater irrigation. It may be considered sufficient treatment if the wastewater is used to irrigate crops that are not consumed by humans or to irrigate orchards, vineyards, and some processed food crops. However, to prevent potential nuisance conditions in storage or flow-equalizing reservoirs, some form of secondary treatment is normally required in these countries, even in the case of non-food crop irrigation. It may be possible to use at least a portion of primary effluent for irrigation if off-line storage is provided.

Secondary treatment

The objective of secondary treatment is the further treatment of the effluent from primary treatment to remove the residual organics and suspended solids. In most cases, secondary treatment follows primary treatment and involves the removal of biodegradable dissolved and colloidal organic matter using aerobic biological treatment processes. Aerobic biological treatment (see Box) is performed in the presence of oxygen by aerobic microorganisms (principally bacteria) that metabolize the organic matter in the wastewater, thereby producing more microorganisms and inorganic end-products (principally CO_2, NH_3, and H_2O). Several aerobic biological processes are used for secondary treatment differing primarily in the manner in which oxygen is supplied to the microorganisms and in the rate at which organisms metabolize the organic matter.

i. *Activated Sludge*

In the activated sludge process, the dispersed-growth reactor is an aeration tank or basin containing a suspension of the wastewater and microorganisms, the mixed liquor. The contents of the aeration tank are mixed vigorously by aeration devices which also supply oxygen to the biological suspension . Aeration devices commonly used include submerged diffusers that release compressed air and mechanical surface aerators that introduce air by agitating the liquid surface. Hydraulic retention time in the aeration tanks usually ranges from 3 to 8 hours but can be higher with high BOD_5 wastewaters.



Following the aeration step, the microorganisms are separated from the liquid by sedimentation and the clarified liquid is secondary effluent. A portion of the biological sludge is recycled to the aeration basin to maintain a high mixed-liquor suspended solids (MLSS) level. The remainder is removed from the process and sent to sludge processing to maintain a relatively constant concentration of microorganisms in the system. Several variations of the basic activated sludge process, such as extended aeration and oxidation ditches, are in common use, but the principles are similar.

ii. *Trickling Filters*

A trickling filter or biofilter consists of a basin or tower filled with support media such as stones, plastic shapes, or wooden slats. Wastewater is applied intermittently, or sometimes continuously, over the media. Microorganisms become attached to the media and form a biological layer or fixed film. Organic matter in the wastewater diffuses into the film, where it is metabolized. Oxygen is normally supplied to the film by the natural flow of air either up or down through the media, depending on the relative temperatures of the wastewater and ambient air. Forced air can also be supplied by blowers but this is rarely necessary. The thickness of the biofilm increases as new organisms grow. Periodically, portions of the film 'slough off the media. The sloughed material is separated from the liquid in a secondary clarifier and discharged to sludge processing. Clarified liquid from the secondary clarifier is the secondary effluent and a portion is often recycled to the biofilter to improve hydraulic distribution of the wastewater over the filter.

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iii. *Rotating Biological Contactors*

Rotating biological contactors (RBCs) are fixed-film reactors similar to biofilters in that organisms are attached to support media. In the case of the RBC, the support media are slowly rotating discs that are partially submerged in flowing wastewater in the reactor. Oxygen is supplied to the attached biofilm from the air when the film is out of the water and from the liquid when submerged, since oxygen is transferred to the wastewater by surface turbulence created by the discs' rotation. Sloughed pieces of biofilm are removed in the same manner described for biofilters.

High-rate biological treatment processes, in combination with primary sedimentation, typically remove 85 % of the BOD_5 and SS originally present in the raw wastewater and some of the heavy metals. Activated sludge generally produces an effluent of slightly higher quality, in terms of these constituents, than biofilters or RBCs. When coupled with a disinfection step, these processes can provide substantial but not complete removal of bacteria and virus. However, they remove very little phosphorus, nitrogen, non-biodegradable organics, or dissolved minerals.

Tertiary and/or advanced treatment

Tertiary and/or advanced wastewater treatment is employed when specific wastewater constituents which cannot be removed by secondary treatment must be removed. As shown in Figure 3, individual treatment processes are necessary to remove nitrogen, phosphorus, additional suspended solids, refractory organics, heavy metals and dissolved solids. Because advanced treatment usually follows high-rate secondary treatment, it is sometimes referred to as tertiary treatment. However, advanced treatment processes are sometimes combined with primary or secondary treatment (e.g., chemical addition to primary clarifiers or aeration basins to remove phosphorus) or used in place of secondary treatment (e.g., overland flow treatment of primary effluent).

An adaptation of the activated sludge process is often used to remove nitrogen and phosphorus and an example of this approach is the 23 Ml/d treatment plant commissioned in 1982 in British Columbia, Canada (World Water 1987). The Bardenpho Process adopted is shown in simplified form in Figure 6. Effluent from primary clarifiers flows to the biological reactor, which is physically divided into five zones by baffles and weirs. In sequence these zones are: (i) anaerobic fermentation zone (characterized by very low dissolved oxygen levels and the absence of nitrates); (ii) anoxic zone (low dissolved oxygen levels but nitrates present); (iii) aerobic zone (aerated); (iv) secondary anoxic zone; and (v) final aeration zone. The function of the first zone is to condition the group of bacteria responsible for phosphorus removal by stressing them under low oxidation-reduction conditions, which results in a release of phosphorus equilibrium in the cells of the bacteria. On subsequent exposure to an adequate supply of oxygen and phosphorus in the aerated zones, these cells rapidly accumulate phosphorus considerably in excess of their normal metabolic requirements. Phosphorus is removed from the system with the waste activated sludge.

Disinfection

Disinfection normally involves the injection of a chlorine solution at the head end of a chlorine contact basin. The chlorine dosage depends upon the strength of the wastewater and other factors, but dosages of 5 to 15 mg/l are common. Ozone and ultra violet (uv) irradiation can also be used for disinfection but these methods of disinfection are not in common use. Chlorine contact basins are usually rectangular channels, with baffles to prevent short-circuiting, designed to provide a contact time of about 30 minutes. However, to meet advanced wastewater treatment requirements, a chlorine contact time of as long as 120 minutes is sometimes required for specific irrigation uses of reclaimed wastewater. The bactericidal effects of chlorine and other disinfectants are dependent upon pH, contact time, organic content, and effluent temperature.

Sewage sludge

Sewage sludge is a byproduct of treated wastewater. It is composed of both organic and inorganic materials, a large concentration of plant nutrients, organic chemicals, as well as pathogens. Therefore, it is extremely important to properly treat such sludge in order to minimize its environmental repercussions. Here is a brief overview of the sludge treatment process to help you gain a better understanding of the treatment techniques and process requirements:

Step 1 – Sludge Thickening

The first step in the sewage sludge treatment plan is called thickening. In this step, the sewage sludge is thickened in a gravity thickener to reduce its overall volume, thus enabling the easy handling of the sludge. Dissolved air flotation is another alternative that can be used to effectively to thicken the sludge by using air bubbles to allow the solid mass to float to the top.

Step 2 – Sludge Digestion

After amassing all the solids from the sewage sludge begins the sludge digestion process. This is a biological process in which the organic solids present in the sludge are decomposed into stable substances. This process also helps reduce the total mass of solids, while destroying any present pathogens to enable easy dewatering. The sludge digestion process is a two-phase process. In the first stage, the dry solid sludge is heated and mixed in a closed tank to enable anaerobic digestion by acid-forming bacteria. These bacteria hydrolyze the large molecules of proteins and lipids present in the sludge and break them down into smaller water-soluble molecules, which they then ferment into various fatty acids. The sludge then flows into the second tank where it is converted by other bacteria to produce a mixture of carbon dioxide (CO_2) and methane, after which the methane is collected and reused to power the digestion tank and generate power (depending on the quantity retrieved).

Step 3 – Dewatering

After retrieving useful gases and other byproducts, the remaining sludge is then dewatered before final disposal. In most cases, dewatered sludge usually contains a significant amount of water, as much as 70 percent, in spite of its solidified state. Therefore, it is important to dry and dewater the sludge beforehand. While using sludge-drying beds is the most common way to carry out this process, it is extremely time-consuming and may take weeks before the process is complete. In order to quicken these processes, waste management plans are also employing solid-liquid separation devices to carry out this process. In fact, centrifugation is slowly becoming one of the most preferred methods of dewatering sludge. By passing the sludge through a centrifuge, it becomes easier to retrieve all the water and enable easier handling of the solid waste in shorter durations at reduced costs. Other alternatives include the rotary drum vacuum filter and the belt filter press.

Step 4 – Disposal

Once the sludge has been effectively dewatered, it can be buried underground in a sanitary landfill or can be used as a fertilizer, depending on its chemical composition. In cases where the sludge is too toxic to be reused or buried, you can simply incinerate the sludge and convert it into ash.

While sewage sludge is usually treated using a standard plan of action, it is extremely important to factor in aspects like the origin of the sewage, the treatment process used to reduce the sewage to sludge, as well as the possible byproducts that can be retrieved from it for further use before choosing a sludge treatment plan. This will not only help you optimize your overall output, but will also help you reduce costs by salvaging useful materials for secondary use before ultimate disposal. Irrigation Production of single cell proteins and biofertilizers Generation of biogas and energy Compost.

Utilization of treated wastes

Biological and Non-Biological Wastes

Biological wastes are those which originate primarily from living or previously living sources, for example: sewage and discharges from tanneries, paper and pulp mills, food processing plants, slaughter houses, sugar mills, distilleries and breweries etc. Such wastes have a predominance of degradable organic matter.

The non-biological wastes are rich in non-degradable matter consisting of solids and liquids in suspended or dissolved form, including various inorganics and organics. Example: Industrial contaminants-acids and bases Acids: HCl, H2SO4, phosphoric and hydrofluoric Bases: NaOH, Ca2OH, NH3OH, cyanides, metals and salts, sodium bicarbonate, benzene, ether etc.

Pollutants: There are two categories of pollutants Dissolved solids and liquids Suspended solids and liquids Most of the chemicals released in the effluents are generally soluble in water. They form aqueous solutions and therefore, cannot be separated by ordinary physical processes like screening, settling and filtration. Dissolved solids and liquids are removed from the wastes following one of the following methods i.e. Neutralization, Oxidation, Reduction, Reverse osmosis, Ion-exchange, Carbon adsorption, Phenol destruction and Evaporative stripping.

The suspended solids and liquids are removed by Filtration, Sedimentation, Floatation Flocculation, Centrifugation and Incineration Oil- water separation.

Waste production in agriculture

The types and quantities of wastes vary between farms. Common agricultural wastes include: Packaging, Silage plastics, Redundant machinery, Tyres, Netwrap, Oils Batteries, Old fencing, Scrap metal, Building waste and Other less common wastes include unused pesticides and veterinary medicines, horticultural plastics and spent sheep dip.

Dissolved oxygen

Measures of dissolved oxygen (DO) refer to the amount of oxygen contained in water, and define the living conditions for oxygen-requiring (aerobic) aquatic organisms. Oxygen has limited solubility in water, usually ranging from 6 to 14 mg/l. DO concentrations reflect an equilibrium between oxygen-producing processes (e.g. photosynthesis) and oxygen-consuming processes (e.g. aerobic respiration, nitrification, chemical oxidation), and the rates at which DO is added to and removed from the system by atmospheric exchange (aeration and degassing) and hydrodynamic processes (e.g. accrual/addition from rivers and tides vs. export to ocean).

Causes of dissolved oxygen depletion

Solubility of oxygen varies inversely with salinity, water temperature and atmospheric and hydrostatic pressure. Dissolved oxygen consumption and production are influenced by plant and algal biomass, light intensity and water temperature (because they influence photosynthesis), and are subject to diurnal and seasonal variation. DO concentrations naturally vary over a twenty-four hour period due to tidal exchange, and because there is net production of oxygen by plants and algae during the daytime when photosynthesis occurs. By comparison, plants and algae only respire at night time, and this process consumes oxygen. Highly productive systems are expected to have large diurnal DO ranges.

The macro and micro plant nutrients in aquatic systems

The essential elements can be divided into macronutrients and micronutrients.

Macronutrients

Nutrients that plants require in larger amounts are called macronutrients. About half of the essential elements are considered macronutrients: carbon, nitrogen, phosphorus, potassium, calcium, magnesium, and sulfur.

Carbon (C)

The first of these macronutrients, carbon, is required to form carbohydrates, proteins, nucleic acids, and many other compounds; it is, therefore, present in all macromolecules. On average, the dry weight (excluding water) of a cell is 50 percent carbon, making it a key part of plant biomolecules.

Nitrogen (N)

The next-most-abundant element in plant cells is nitrogen; it is part of proteins and nucleic acids. Nitrogen is also used in the synthesis of some vitamins. Hydrogen and oxygen are macronutrients that are part of many organic compounds and also form water. Oxygen is necessary for cellular respiration; plants use oxygen to store energy in the form of ATP.

Phosphorus (P)

Phosphorus, another macromolecule, is necessary to synthesize nucleic acids and phospholipids. As part of ATP, phosphorus enables food energy to be converted into chemical energy through oxidative phosphorylation. Light energy is converted into chemical energy during photophosphorylation in photosynthesis; and into chemical energy to be extracted during respiration. Sulfur is part of certain amino acids, such as cysteine and methionine, and is present in several coenzymes. Sulfur also plays a role in photosynthesis as part of the electron transport chain where hydrogen gradients are key in the conversion of light energy into ATP.

Potassium (K)

Potassium is important because of its role in regulating stomatal opening and closing. As the openings for gas exchange, stomata help maintain a healthy water balance; a potassium ion pump supports this process.

Magnesium (Mg) and calcium (Ca)

Magnesium and calcium are also important macronutrients. The role of calcium is twofold: to regulate nutrient transport and to support many enzyme functions. Magnesium is important to the photosynthetic process. These minerals, along with the micronutrients, also contribute to the plant's ionic balance.

Micronutrients

In addition to macronutrients, organisms require various elements in small amounts. These micronutrients, or trace elements, are present in very small quantities. The seven main micronutrients include boron, chlorine, manganese, iron, zinc, copper, and molybdenum. Boron (B) is believed to be involved in carbohydrate transport in plants; it also assists in metabolic regulation. Boron deficiency will often result in bud dieback. Chlorine (Cl) is necessary for osmosis and ionic balance; it also plays a role in photosynthesis. Copper (Cu) is a component of some enzymes. Symptoms of copper deficiency include browning of leaf tips and chlorosis (yellowing of the leaves). Iron (Fe) is essential for chlorophyll synthesis, which is why an iron deficiency results in chlorosis. Manganese (Mn) activates some important enzymes involved in chlorophyll formation. Manganese-deficient plants will develop chlorosis between the veins of its leaves. The availability of manganese is partially dependent on soil pH. Molybdenum (Mo) is essential to plant health as it is used by plants to reduce nitrates into usable forms. Some plants use it for nitrogen fixation; thus, it may need to be added to some soils before seeding legumes. Zinc (Zn) participates in chlorophyll formation and also activates many enzymes. Symptoms of zinc deficiency include chlorosis and stunted growth.

Significance of dissolved oxygen

Most aquatic organisms require oxygen in specified concentration ranges for respiration and efficient metabolism, and DO concentration changes above or below this range can have adverse physiological effects. Even short-lived anoxic & hypoxic events can cause major "kills" of aquatic organisms. Exposure to low oxygen concentrations can have an immune suppression effect on fish which can elevate their susceptibility to diseases for several years. Moreover, the toxicity of many toxicants (lead, zinc, copper, cyanide, ammonia, hydrogen sulphide and pentachlorophenol) can double when DO is reduced from 10 to 5 mg/l. The death of immobile organisms and avoidance of low-oxygen conditions by mobile organisms can also cause changes in the structure and diversity of aquatic communities. In addition, if dissolved oxygen becomes depleted in bottom waters (or sediment), nitrification, and therefore denitrification, may be terminated, and bioavailable orthophosphate and ammonium may be released from the sediment to the water column. These recycled nutrients can give rise to or reinforce algal blooms. Ammonia and hydrogen sulphide gas, also the result of anaerobic respiration, can be toxic to benthic organisms and fish assemblages in high concentrations.

Biological Oxygen Demand

Biochemical oxygen demand (BOD) is a measure of the quantity of oxygen used by microorganisms (e.g., aerobic bacteria) in the oxidation of organic matter. Natural sources of organic matter include plant decay and leaf fall. However, plant growth and decay may be unnaturally accelerated when nutrients and sunlight are overly abundant due to human influence. Urban runoff carries pet wastes from streets and sidewalks; nutrients from lawn fertilizers; leaves, grass clippings, and paper from residential areas, which increase oxygen demand. Oxygen consumed in the decomposition process robs other aquatic organisms of the oxygen they need to live.

Chemical Oxygen Demand

Chemical oxygen demand (COD) is a measure of the capacity of water to consume oxygen during the decomposition of organic matter and the oxidation of inorganic chemicals such as ammonia and nitrite. COD measurements are commonly made on samples of waste waters or of natural waters contaminated by domestic or industrial wastes. COD is measured as a standardized laboratory assay in which a closed water sample is incubated with a strong chemical oxidant under specific conditions of temperature and for a particular period of time. A commonly used oxidant in COD assays is potassium dichromate ($K_2Cr_2O_7$) which is used in combination with boiling sulfuric acid (H_2SO_4). Because this chemical oxidant is not specific to oxygen-consuming chemicals that are organic or inorganic, both of these sources of oxygen demand are measured in a COD assay. COD is related to biochemical oxygen demand (BOD), the standard test for assaying the oxygen-demanding strength of waste waters. However, BOD only measures the amount of oxygen consumed by microbial oxidation and is most relevant to waters rich in organic matter. It is important to understand that COD and BOD do not necessarily measure the same types of oxygen consumption. For example, COD does not measure the oxygen-consuming potential associated with certain dissolved organic compounds such as acetate. However, acetate can be metabolized by microorganisms and would therefore be detected in an assay of BOD. In contrast, the oxygen-consuming potential of cellulose is not measured during a short-term BOD assay, but it is measured during a COD test.

Effects of organic matter on soil properties

Organic matter affects both the chemical and physical properties of the soil and its overall health. Properties influenced by organic matter include: soil structure; moisture holding capacity; diversity and activity of soil organisms, both those that are beneficial and harmful to crop production; and nutrient availability. It also influences the effects of chemical amendments, fertilizers, pesticides and herbicides. Soil organic matter consists of a continuum of components ranging from labile compounds that mineralize rapidly during the first stage of decomposition to more recalcitrant residues (difficult to degrade) that accumulate as they are deposited during the advanced stages of decomposition as microbial by-products Biological properties Soil microorganisms are of great importance for plant nutrition as they interact directly in the bio-geo-chemical cycles of the nutrients. Chemical properties Many important chemical properties of soil organic matter result from the weak acid nature of humus. The ability of organic matter to retain cations for plant use while protecting them from leaching, i.e. the cation exchange capacity (CEC) of the organic matter, is due to the negative charges created as hydrogen is removed from weak acids during neutralization. Many acid forming reactions occur continually in soils. Some of these acids are produced as a result of organic matter decomposition by microorganisms, secretion by roots, or oxidation of inorganic substances. Commonly used nitrogenous fertilizers work through the microbial conversion of NH_4+ to NO_3-. In particular, ammonium fertilizers, such as urea, and ammonium phosphates, such as monoammonium and diammonium phosphate, are converted rapidly into nitrate through a nitrification process, releasing acids in the process and thus increasing the acidity of the topsoil Physical properties Organic matter influences the physical conditions of soil in several ways. Plant residues that cover the soil surface protect the soil from sealing and crusting by raindrop impact, thereby enhancing rainwater infiltration and reducing runoff. Increased organic matter also contributes indirectly to soil porosity (via increased soil faunal activity). Fresh organic matter stimulates the activity of macrofauna such as earthworms, which create burrows lined with the glue-like secretion from their bodies and intermittently filled with worm cast material. Surface infiltration depends on a number of factors including aggregation and stability, pore continuity and stability, the existence of cracks, and the soil surface condition. Organic matter also contributes to the stability of soil aggregates and pores through the bonding or adhesion properties of organic materials, such as bacterial waste products, organic gels, fungal hyphae and worm secretions and casts. Moreover, organic matter intimately mixed with mineral soil materials has a considerable influence in increasing the moisture holding capacity. The quality of the crop residues, in particular its chemical composition, determines the effect on soil structure and aggregation.

Eutrophication

Aquatic plants and algae gradually fill in freshwater lakes and estuaries over time in a natural process called eutrophication. This process is controlled by low concentrations of certain nutrients (like phosphate and nitrogen) that the plants and algae require to grow. Usually, phosphorus is the limiting nutrient in freshwater and nitrogen in estuaries and salt water. However, when humans release nutrients like phosphate (agriculture ~50%, human metabolism ~20%, industry ~10%, detergents ~10% and natural erosion ~10%), the process of eutrophication is accelerated. In a worst-case scenario, the excess growth of plants and algae can smother other organisms when they die and begin to decay. An eutrophication indictor is derived by converting the different chemical forms of phosphorus and nitrogen into a common or equivalent form. Then, the proportion normally found in aquatic algae is used to weigh the phosphorus and nitrogen. These values are added into an overall indicator.

Red tide

Red tide is a naturally-occurring, higher than-normal concentration of the microscopic algae Karenia brevis (formerly Gymnodinium breve). This organism produces a toxin that affects the central nervous system of fish so that they are paralyzed and cannot breathe. As a result, red tide blooms often result in dead fish washing up on the beaches. When red tide algae reproduce in dense concentrations or "blooms," they are visible as discolored patches of ocean water, often reddish in colour.

Causes of red tide

Red tide is a natural phenomenon not caused by human beings. When temperature, salinity, and nutrients reach certain levels, a massive increase in Karenia brevis occurs. No one knows the exact combination of factors that causes red tide, but some experts believe high temperatures combined with a lack of wind and rainfall is usually at the root of red tide blooms. There are no known ways that humans can control it, but many scientists around the world are studying red tide at present.

Neurotoxic shellfish poisoning (NSP)

Oysters and other shellfish such as clams, mussels, whelks and scallops can accumulate red tide toxins in their tissues. People that eat oysters or other shellfish containing red tide toxins may become seriously ill with neurotoxic shellfish poisoning (NSP).There are, however, other risks associated with bacteria and other contaminants in raw oysters.

Algal blooms in Indian waters

The red tide is not an unknown phenomenon in Indian waters. Until 1973, sporadic blooms of *Noctiluca scintilans*, *Trichodesmium erythraeum*, *Rhizosolenia* sp., etc. have been reported, but none were of HAB type. However, since 1981, cases of paralytic shellfish poisoning (PSP) from coastal Tamil Nadu, Karnataka and Maharashtra were reported with adverse effects. In 1981, PSP resulted in the hospitalization of 85 people and death of three persons due to the consumption of bloom-affected mussel *Meretrix casta* in Tamil Nadu. A similar incidence took place in Mangalore in 1983, but in both the cases causative species were not identified. In 1996, *Gymnodinium catenatum*, a potent PSP species both as planktonic cells and cysts in sediment, in the coastal waters of Karnataka (off Mangalore) was reported, but the low number of cells had no toxic effect. In September 1997, an outbreak of PSP was reported in three villages of Kerala, resulting in the death of seven persons and hospitalization of over 500, following consumption of mussel, *Perna indica*. During a reconnaissance cruise in 2001, on the coastal vessel Sagar Shukti, a toxic algal bloom by hitherto unreported dinoflagellate *Cochlodinium polykrikoides* was reported by the NIO team. Though this species is a fish-killer in Korea, the cause for fish mortality noticed off Goa could not be confirmed. These few examples underline the unpredictable nature of the bloom and perhaps answer the query regarding whether India should really worry about the blooms.

Pesticide pollution in aquatic ecosystems

Pesticide

The term "pesticide" is a composite term that includes all chemicals that are used to kill or control pests. In agriculture, this includes herbicides (weeds), insecticides (insects), fungicides (fungi), nematocides (nematodes), and rodenticides (vertebrate poisons). In recent years, there has been increasing awareness all over the world of the adverse effects of the indiscriminate use of pesticides. Many pesticides are present today in different concentrations in different components of our environment such as air, water and soil. Some 500,000 people are either killed or incapacitated by poisoning every year, and most of these casualties occur in developing nations.

Types of pesticides

Bactericides:

These destroy, suppress or prevent the spread of bacteria. eg.chlorine containing chemicals.

Baits:

These are ready-prepared products which need to be mixed with a food to control a pest. eg. baits for cockroaches and ants.

Fungicides:

These control, destroy, render ineffective or regulate the effect of a fungus. Eg: Bordeaux mixture

Herbicides: These destroy, suppress or prevent the spread of a weed or other unwanted vegetation. eg. glyphosate.

Insecticides: These destroy, suppress, stupefy or inhibit the feeding of or prevent infestation or attack by an insect. eg. Dichlorodiphenyltrichloroethane, gammahexachlorocyclohexane.

Lures: These are chemicals that attract a pest for the purpose of its destruction.

Rodenticides: These are used for controlling rodents eg.zinc phosphide, warfain

Repellents: These repel rather than destroy a pest eg. camphor, clove oil

Classification of pesticides based on the chemical nature

Organic pesticides

Pesticides in this group, for example rotenone, pyrethrum, nicotine, neem oil, and all of the botanical pesticides are products of living organisms. Often they are chemicals that plants and microbes use to protect themselves from parasites, predators and pathogens.

Nicotine, for example, is produced by plants in the genus *Nicotiana* as a powerful herbivore (plant-feeding) deterrent. Nicotine is also a potent insecticide and is highly toxic to mammals. In small doses, delivered by smoking dried tobacco leaves, nicotine is a stimulant.

Organic pesticides are often lower in toxicity than older synthetic pesticides but this is not always the case. Organic does not necessarily equal low toxicity and environmentally safer.

Inorganic pesticides

Pesticides in this group, for example borates, silicates and sulfur, are minerals that are mined from the earth and ground into a fine powder. Some work as poisons and some work by physically interfering with the pest. Older "inorganics" included such highly toxic compounds as arsenic, copper, lead and tin salts. Current inorganic pesticides are relatively low in toxicity and have low environmental impact. Borate insecticides, such as Bora Care and Timbor have many uses in structural pest management and are very safe compared to older conventional pesticides (see Bora Care Insecticide and Timbor Insecticide).

Biorational pesticides

This term refers to synthetic, organic, or inorganic pesticides that are both low toxicity and exhibit a very low impact on the environment. "Biorationals" also have minimal impact on species for which they are not intended (called *non-target species*). Biorational pesticides include oils, insecticidal soaps, microbials (such as *Bacillus thurengienesis* and entomopathogenic nematodes), botanicals (plant-based) and insect growth regulators. *The* biorational pesticides should therefore be your first choice whenever a pesticide is needed.

Organochlorine pesticides

Organochlorine pesticides are chlorinated hydrocarbons used extensively from the 1940s through the 1960s in agriculture and mosquito control. Representative compounds in this group include DDT, methoxychlor, dieldrin, chlordane, toxaphene, mirex, kepone, lindane, and benzene hexachloride. As neurotoxicants, many organochlorine pesticides were banned in the United States, although a few are still registered for use in this country.

Organochlorine pesticides and human

People can be exposed to organochlorine pesticides through accidental inhalation exposure if you are in an area where they were recently applied. The chemicals can also be ingested in fish, dairy products, and other fatty foods that are contaminated. Organochlorine pesticides accumulate in the environment. They are very persistent and move long distances in surface runoff or groundwater. Prior to the mid-1970s, organochlorines resulted in widespread reproductive failure among birds because birds laid eggs with thin shells that cracked before hatching.

Heath impact

Exposure to organochlorine pesticides over a short period may produce convulsions, headache, dizziness, nausea, vomiting, tremors, confusion, muscle weakness, slurred speech, salivation and sweating. Long-term exposure to organochlorine pesticides may damage the liver, kidney, central nervous system, thyroid and bladder. Many of these pesticides have been linked to elevated rates of liver or kidney cancer in animals. There is some evidence indicating that organochlorine pesticides may also cause cancer in humans.

Persistent organic pollutants (POPs)

Persistent organic pollutants (POPs) are chemicals of global concern due to their potential for long-range transport, persistence in the environment, ability to bio-magnify and bio-accumulate in ecosystems, as well as their significant negative effects on human health and the environment. Humans are exposed to these chemicals in a variety of ways: mainly through the food we eat, but also through the air we breathe, in the outdoors, indoors and at the workplace. Many products used in our daily lives may contain POPs, which have been added to improve product characteristics, such as as flame retardants or surfactants. As a result, POPs can be found virtually everywhere on our planet in measurable concentrations.

The most commonly encountered POPs are organochlorine pesticides, such as DDT, industrial chemicals, most notably polychlorinated biphenyls (PCB), as well as unintentional by-products of many industrial processes, especially polychlorinated dibenzo-p-dioxins (PCDD) and dibenzofurans (PCDF), commonly known as 'dioxins'. POPs bio-magnify throughout the food chain and bio-accumulate in organisms. The highest concentrations of POPs are thus found in organisms at the top of the food chain. Consequently, background levels of POPs can be found in the human body.

Human exposure - for some compounds and scenarios, even to low levels of POPs - can lead, among others, to increased cancer risk, reproductive disorders, alteration of the immune system, neurobehavioural impairment, endocrine disruption, genotoxicity and increased birth defects.

PCBs Polychlorinated biphenyls

Properties of PCBs

PCBs, or polychlorinated biphenyls, are a class of man-made organic chemicals. Each PCB molecule contains two phenyl rings. A phenyl ring is a ring of 6 carbon atoms to which hydrogen atoms are attached. In PCBs, chlorine atoms replace some of these hydrogen atoms. Chlorine atoms may be present at some or all of the 10 possible positions which are numbered 2–6 on one ring, and 2'–6' on the other ring (see figures below). In total, 209 different PCBs can be formed. These different combinations are called congeners, each having a specific number of chlorine atoms located at specific positions.

One example below shows a PCB with five chlorine atoms, two chlorine atoms at the 3 and 5 positions on one ring and three chlorine atoms at the 2’, 4’ and 6’ positions on the other ring. The other example shows a PCB with chlorine atoms at the 2 position on one ring, and the 2’ position on the other.

Two different systems are used for naming PCBs. In the IUPAC system used in the examples above, the numbers at the beginning of the name specify the sites where chlorines are attached to the phenyl rings. Another system assigns a separate number, from 1 to 209, to each of the 209 specific PCB congeners. PCBs which have the same number of chlorine atoms attached but at different positions are referred to as isomers.

The two rings in a PCB molecule can rotate around the bond connecting them. The shape of the molecule is further influenced by the repulsion between nearby chlorine atoms so that the rings of a specific PCB will either lie approximately in the same plane (called coplanar) or in different, more perpendicular planes (termed non-planar). Those PCBs which have both rings lying in the same plane are considered to be most toxic, based on combined health effects considerations. They are also referred to as "dioxin-like".

PCBs were manufactured and sold as mixtures of several congeners, with a variety of trade names, including Aroclor, Pyranol, Pyroclor (USA), Phenochlor, Pyralene (France), Clophen, Elaol (Germany), Kanechlor, Santotherm (Japan), Fenchlor, Apirolio (Italy), and Sovol (USSR).

PCBs build up in living organisms

PCBs tend to build up in living organisms both by uptake from the environment over time (bioaccumulation) and along the food chain (biomagnification). PCBs remain stored in fatty tissues much more than in muscles or other body parts.

The degree of PCB bioaccumulation over time depends on how quickly they are taken up and eliminated by the organism, and on the ability of the organism to break down PCBs. Various animal species can transform some PCB congeners, such as insects, crabs and vertebrates, including some birds, fish, and mammals.

The rate and physiological mechanism of PCB metabolism depend both on the animal species and on the specific PCB congener.

In aquatic organisms bioaccumulation of PCBs depends on the species, its habitat, and on the specific type of PCB.

As the concentration of PCBs in sediments is several times higher than in water, levels are often high in bottom-feeding species.

PCBs generally biomagnify along the food-chain, which leads to greater PCB concentrations in organisms that are higher up in the food chain.

In the aquatic environment, concentrations will thus be greater in shellfish than in the plankton on which they feed, and even greater in animals at the top of the food chain such as large predatory fish or mammals (seals, dolphins, and whales).

On land, the biomagnifications occurs, for instance, through the accumulation of PCBs from soil or plant leaves to worms or insects and finally to birds and mammals. PCBs can also be found in the eggs of contaminated birds.

Humans can also accumulate PCBs from food. On average, in humans, the concentration of PCBs in fatty tissues is over a hundred times greater than in the food they eat.

Ecological effects of pesticides

Pesticides are included in a broad range of organic micro pollutants that have ecological impacts. Different categories of pesticides have different types of effects on living organisms, therefore generalization is difficult. Although terrestrial impacts by pesticides do occur, the principal pathway that causes ecological impacts is that of water contaminated by pesticide runoff. The two principal mechanisms are bioconcentration and biomagnification.

Bioconcentration:

This is the movement of a chemical from the surrounding medium into an organism. The primary "sink" for some pesticides is fatty tissue ("lipids"). Some pesticides, such as DDT, are "lipophilic", meaning that they are soluble in, and accumulate in, fatty tissue such as edible fish tissue and human fatty tissue. Other pesticides such as glyphosate are metabolized and excreted.

Biomagnification:

This term describes the increasing concentration of a chemical as food energy is transformed within the food chain. As smaller organisms are eaten by larger organisms, the concentration of pesticides and other chemicals are increasingly magnified in tissue and other organs. Very high concentrations can be observed in top predators, including man.

The ecological effects of pesticides (and other organic contaminants) are varied and are often inter-related. Effects at the organism or ecological level are usually considered to be an early warning indicator of potential human health impacts. The major types of effects are listed below and will vary depending on the organism under investigation and the type of pesticide. Different pesticides have markedly different effects on aquatic life which makes generalization very difficult. The important point is that many of these effects are chronic (not lethal), are often not noticed by casual observers, yet have consequences for the entire food chain.

- Death of the organism.
- Cancers, tumours and lesions on fish and animals.
- Reproductive inhibition or failure.
- Suppression of immune system.
- Disruption of endocrine (hormonal) system.
- Cellular and DNA damage.

- Teratogenic effects (physical deformities such as hooked beaks on birds).
- Poor fish health marked by low red to white blood cell ratio, excessive slime on fish scales and gills, etc.
- Intergenerational effects (effects are not apparent until subsequent generations of the organism).
- Other physiological effects such as egg shell thinning.

These effects are not necessarily caused solely by exposure to pesticides or other organic contaminants, but may be associated with a combination of environmental stresses such as eutrophication and pathogens. These associated stresses need not be large to have a synergistic effect with organic micro pollutants.

Ecological effects of pesticides extend beyond individual organisms and can extend to ecosystems. Swedish work indicates that application of pesticides is thought to be one of the most significant factors affecting biodiversity.

HEAVY METAL POLLUTION

Heavy metals

The term “heavy metals” is being widely used to refer toxic metals. But there is still a controversy regarding the definition of these metals. In 2002, a technical report published by IUPAC (International Union of Pure and Applied Chemistry) questions the reliability of this term and considered it to be “most loosely defined term”. The word “heavy” signifies higher density which is usually attributed to the toxicity of metals. Heavy metals are well-known environmental pollutants due to their toxicity, persistence in the environment, and bioaccumulative nature. Their natural sources include weathering of metal-bearing rocks and volcanic eruptions, while anthropogenic sources include mining and various industrial and agricultural activities. Mining and industrial processing for extraction of mineral resources and their subsequent applications for industrial, agricultural, and economic development has led to an increase in the mobilization of these elements in the environment and disturbance of their biogeochemical cycles. Being persistent pollutants, heavy metals accumulate in the environment and consequently contaminate the food chains.

Sources of Heavy Metals in the Environment

Sources of heavy metals in the environment can be both natural/geogenic/lithogenic and anthropogenic. The natural or geological sources of heavy metals in the environment include weathering of metal-bearing rocks and volcanic eruptions. The global trends of industrialization and urbanization on Earth have led to an increase in the anthropogenic share of heavy metals in the environment. The anthropogenic sources of heavy metals in the environment include mining and industrial and agricultural activities. These metals (heavy metals) are released during mining and extraction of different elements from their respective ores.

Toxicity of Heavy Metals

The most dangerous are: cadmium, lead, mercury that can be harmful to human health even in very low concentrations, as well as being highly toxic and non-degradable. They accumulate in those organisms that occupy the highest levels in the food pyramid: mercury pollution in the sea provokes the concentration of this metal in fish and the organisms that eat the fish, including men. Mercury that derives from the dumping of industrial waste and that reaches the sea is ever lasting and continues its cycle by passing from one organism to another through the food chain.

Mercury

Mercury is a global pollutant found in the environment in elemental, organic and inorganic forms with varying degrees of toxicity. Most of the mercury in the atmosphere is elemental vapour and inorganic mercury, while the mercury in water, soil and living organisms is primarily organic mercury (methyl mercury). Mercury occurs naturally in the environment form the degassing of earths crust and volcanic emissions.

Sources:

Anthropogenic Sources of Mercury include: Mining and smelting operations, chloralkali plants, paper and pulp industries, leather tanning, electroplating, chemical manufacturing, application of fertilizers and pesticides, disposal of solid waste including batteries and thermometers. Waste incineration and fossil fuel combustion.

Fate and Transport of Mercury:

The global cycling of mercury is a complex process. Mercury evaporates from soils and surface waters to the atmosphere, is redeposited on land and surface waters and then is absorbed by soil or sediments. After redeposition on land and water, mercury is commonly volatilized back to the atmosphere as a gas or as adherents to particles. Atmospheric mercury is dispersed across the globe by winds and return to the earth in rainfall. The long atmospheric lifetime of one year of its gaseous form means the emission, transport and deposition of mercury are a global issue. Once released into the environment, inorganic mercury is converted to organic mercury (methyl mercury) which is the primary form that accumulates in fish and shellfish, biomagnifies up the food chain as it is passed from lower food chain level to a subsequently higher food chain level through consumption of prey organisms or predators. Fish at the top of the aquatic food chain (predation) bioaccumulate methyl mercury approximately 1,000 – 10,000 times greater than found in surrounding waters. Effects: In aquatic organism, mercury adversely affects reproduction, growth, behavior, osmoregulation and oxygen exchange. Mercury also causes kidney lesions, reduced food intake leading.

Miamata disease

In 1952, the first incidents of mercury poisoning appear in the population of MinimataBay in Japan, caused by consumption of fish polluted with mercury, bringing nearly

1000 fatalities. Since the name of the mercury poisaning in human being are called Miamata disease.

Cadmium

Cadmium is a naturally occurring element in the crust of the earth. Coal and other fossil fuel contain cadmium and their combustion releases the element into the atmosphere. Cadmium is found naturally in various ores: lead and copper containing zinc, some iron ores and sulphide ore. Volcanic emissions contain cadmium-enriched particles. Coal and oil burning power plants may emit cadmium compounds to air. Cadmium acts like other particles when in the atmosphere and is subject to deposition caused by rain or wind. The expected lifetime for particles in the atmosphere is about 5-15 days. Industrial emissions of cadmium and/or cadmium compounds can produce elevated, but still low level, concentration in the atmosphere around the source. Motor vehicles may also produce elevated levels of cadmium in areas of higher traffic. Tobacco smoke is the primary source of cadmium indoors. Some cadmium compounds are able to leach through soils into groundwater. When cadmium compounds binds to the sediments in water (river, lakes, bore water), they are less likely to be bioavailable. Cadmium is bio-persistent and once absorbed by an organism, remains resident for many years.

Potential Hazards to Fish, Wildlife and other Non-human Biota:

Cadmium is very toxic to a variety of species of fish and wildlife. Cadmium causes behavior, growth and physiological problems in aquatic life at sub lethal concentrations. Cadmium is the only metal that clearly accumulates with increasing age of animal and the kidneys are the preferred site of cadmium accumulation.

Potential Effects of Cadmium upon Humans:

All cadmium compounds are potentially harmful or toxic. Kidney and/or liver damage have followed respiratory exposure in industry. Inhalation of cadmium dusts, salts and fumes over a number of years can cause kidney and bone marrow diseases. Cadmium contamination resulted in “Itai-Itai” disease (painful disease affecting bones) in Japan. **Arsenic**

Arsenic

Arsenic is naturally occurring in the environment and accounts for small portion of the earth’s crust minerals. Arsenic is released into the environment by the smelting process of copper, zinc and lead as well as manufacturing of chemicals and glasses. Other sources are paints, rat poisons, fungicides and wood preservatives. Arsenic can volatilize into the atmosphere as a result of different biological transformations. It can be absorbed onto soil, washed away by surface runoff or leached into groundwater and be taken up by plants, subsequently entering the food chain. Arsenic and most of its compounds are solids that do not evaporate. They exist as small particles in the atmosphere. Burnt arsenic compounds exist as a gas. Fish generally contain lower concentrations of arsenic than other organisms indicating that it is not readily available for uptake an aquatic environments.

Potential Hazards to Fish, Wildlife and other Non-human Biota:

Plants can take up arsenic in a variety of ways, from fly ash, sludge and by manure dumped on the land. Animals are generally less sensitive to arsenic than plants. Arsenic is one of the most toxic elements to fish. Sediments contaminated with arsenic results in reduction in the abundance of polychaetes, molluscs and crustaceans.

Potential Hazards to Humans:

Arsenic has long been a concern to man because small amounts can be toxic to humans. Relatively high doses of arsenic have been reported to cause bone marrow suppression in humans. Inorganic arsenic in high quantities has been known for centuries as a fast acting human poison.

Lead

Lead enters the environment from a variety of natural and anthropogenic sources. Natural processes such as soil weathering and erosion, volcanoes and forest fires contribute to significant releases of lead. Lead and its compounds, if present in aquatic environments in sufficient amounts, can cause acute or chronic toxicity to organisms. However, the level of toxicity is determined by bioavailability factors such as water chemistry, solubility, salinity and organic matter content.

Potential Hazards to Fish, Wildlife and other Non-human Biota:

Lead is a heavy metal that is very toxic to aquatic organisms, especially fish. In fish, lead deposits in active calcification areas such as scales, fin rays, vertebrae and opercula. In vertebrates, sub-lethal lead poisoning is characterized by neurological problems, kidney disfunction, enzyme inhibition and anaemia.

Potential Hazards to Humans:

Lead poisoning is particularly dangerous in young children (who may ingest lead by eating lead containing chips of paint); it may result in anorexia and –in severe cases—permanent brain damage. Women in the workplace are more likely to experience adverse effects from lead exposure than men because their hematopoietic system is more lead sensitive than men's. Chronic exposure – results in kidney disease "nephrites".

Chromium

Chromium(III) is an essential nutrient for humans and shortages may cause heart conditions, disruptions of metabolisms and diabetes. But the uptake of too much chromium(III) can cause health effects as well, for instance skin rashes.

Chromium(VI) is a danger to human health, mainly for people who work in the steel and textile industry. People who smoke tobacco also have a higher chance of exposure to chromium. Hexavalent Chromium – Chromium (VI) is a species of chromium that is forbidden to use in electrical & electronic industry by RoHS Directive.

Environmental effects of chromium

- Most of the chromium in air will eventually settle and end up in waters or soils
- Chromium in soils strongly attaches to soil particles and as a result it will not move towards groundwater
- In water chromium will absorb on sediment and become immobile
- Only a small part of the chromium that ends up in water will eventually dissolve

OIL POLLUTION

Oil Pollution (Petroleum Hydrocarbons)

Crude oil is a complex mixture hydrocarbons with 4-26 or more carbon atoms in the molecule. Crude oil is extracted usually from the upper strata of the earth. Non-hydrocarbons such as sulphurs, nitrogen, oxygen and vanadium may represent upto 25% of the oil. Classification: Based on the Chemical Structure: Aliphatic compounds Aromatic compounds Based on Uses: Fuel Lubricants Coatings Solvents Hydraulic fuels Cutting and rolling fluids Properties of Crude Oil: Lighter than water Immiscible with water Highly flammable Spreads on water forming slicks Generally liquid at room temperature. Crude oil must be refined before it can be used. Refining is essentially a distillation process with different fractions taken at different boiling range.

Sources-

Inputs of Oil Pollution Petroleum hydrocarbons reach the sea by many routes. It is estimated that on an average 2.5 million tonnes of oil reaches the sea per year. Of the total oil entering the sea 17% is from natural sources, while the remaining 84% is due to direct or indirect anthropogenic activities. Sources: Transportation: Tanker operations - 22% Tanker accidents - 12.5% Bilge and fuel Non tanker accidents - 12.5% Dry docking Fixed Installations: Coastal refineries - 3% Offshore oil production - 1.5% Marine terminals Other Sources: Municipal and industrial waste water (river & urban runoff) 31% Atmosphere fall out 10% Ocean dumping Natural sewage 8%

Tanker Accidents

A large number of accidents involving oil tankers happen every year. Most accidents bring about severe ecological damage, as a large quantity of oil is discharged in a relatively small area (0.121 million tonnes). The causes of accidents are due to collision, grounding, hull failure, fire/explosion. Bilge and Fuel Oils: All shipping needs to pump out bilge water which invariably contains oil from the ships engines. Individually, the quantity of oil released may be small, but since all shipping contributes, the total quantity of oil entering the sea is considerable (0.252 million tons).

Dry Docking

All ships, including oil tankers, require periodic docking for servicing, repairs, cleaning the hull and so on. It is essential that all oil is removed from the cargo compartments of tankers and from the empty fuel tanks of all ships to avoid the risk of explosion from petroleum gases. Situation has now improved and the quantity of oil reaching the sea in association with dry docking has been reduced from 30,000 t (1981) to 4000 t (1989)

Non Tanker Accidents

When a ship is in accident, its fuel oil may be lost to the sea. So this source of oil contamination is not negligible (0.02 milion tonnes). Marine Terminals Accidents through human error and pipeline failure are an inevitable accompaniment to loading oil on to tankers and discharging it at oil terminals (0.03 million tonnes).

Offshore Oil Production

The oil extracted from the seabed invariably contain some water (production water), which must be extracted before the oil is transported to the refinery. This is done by oil separators on the platform and the oil concentration in the water that is discharged is usually 40 ppm, but in total this amounts to a substantial quantity. When an oil well is being drilled, 'drilling muds' are pumped down the well. These maintain a head of pressure and prevent a blow out when oil is struck, cool and lubricate the drill bit, and carry the cuttings back to the surface. The drill mud contains water and oil and the oil contaminates the water.

Coastal Oil Refineries

The waste water discharged from oil refineries should contain only 5 ppm or less of oil (0.10 million tons). Municipal and Industrial Wastes Domestic wastes and sewage contain a quantity of oils and greases and depending on the nature of the industry, industrial wastes may also contain a considerable quantity of petroleum hydrocarbons (lubricating oils). Municipal Waste Oil from cleanings, automobile washings, sewage treatment plants and the degraded asphalt from roads. Industries Metal industries, core plants, woolen textiles, paint industries, meat and fish processing plants.

Urban and River Runoff

Every time it rains, the oil and petrol, as the roads is washed down drains and into water causes and eventually reaches the sea. Dumping at Sea Shipping channels in estuaries and ports commonly need regular dredging. The dredging oil, which is usually dumped at sea, is contaminated with oil. Various industrial wastes and solid municipal wastes that are dumped at sea may also contain petroleum hydrocarbons.

Atmosphere

The incomplete combustion of petrol or diesel in motor vehicles results in petroleum hydrocarbons being released into the atmosphere. These hydrocarbons are washed out in rain into the sea.

Fate of Spilled Oil

When liquid oil is spilled on the sea it spreads over the surface of the water to form a thin film or an "oil slick". The rate of spreading and the thickness of the film depend on the sea temperature, nature of oil, wind and wave action, water currents and coastal configuration. The crude oil in the sea undergoes compositional and chemical changes from the time it spilled. Light fraction evaporates, water soluble components dissolve in the water column and immiscible components become emulsified and dispersed in the water column as small droplets. In some conditions due to photo-oxidation a water in oil emulsion is produced, this may contain 70-80 % water and forms a viscid mass known as "chocolate mouse". It forms thick pancakes on the water or sticky masses if it comes to a shore.

Environmental Factors Environmental factors determine the extent of damage done by oil spill. These factors include:

- Coastal configuration of the area
- Tides and surface currents
- Weather
- Toxicity of Petroleum Hydrocarbons

Oil affects the organisms in a number of ways depending upon the characteristics of the oil fractions and their concentration in water. Aromatic compounds are more toxic than aliphatics and middle molecular weight constituents are more toxic than high molecular weight tars. Some important effects of oil on organisms are given below Oils have smothering effects (suffocation) on most of the aquatic animals. In sea birds, the microstructure and waxy nature of feathers attract oil. Buoyancy and thermal insulation of birds are affected.

Oils penetrate the plumage, which facilitates the entry of water in it. Heavy oils stick to the feathers, and increase its weight to make the bird drown. The body temperature of the birds is kept higher by burning of stored food in the form of muscles. The oiled birds lose their capacity to catch the food efficiently, and can die because of low temperature.

Several fur-bearing animals in sea, like seals, sea lions, sea otters and musk-rats may be affected by oil like birds, when oil penetrates the fur. Small animals can be caught in oil envelops and die.

Sedimentary animals near the shore also die due to oil, as they are unable to move to safe distances away from oil. Oil layers increase the temperature, which may be critical for several organisms, particularly in the tropics.

Tropical coral are greatly affected as the prevailing temperature is already very near to their tolerance limits. The poisonous effects of oil may be of much greater severity than the mechanical effects.

A few aromatics like benzene and its derivatives have a very high penetration power into the body of organisms. They can penetrate the lipid layers of all membrane, thus, affecting the permeability by modifying the spacing of protein molecules on each side of the lipid layer. Brain and nerve cells of animals which depend upon fatty substances are also affected in this manner. A few straight chain and cycloparaffins also cause damage to the nervous system. The effects of the oil on lipids are also manifested in the mal-development of eggs and larvae following oil spills.

A few toxic constituents of oils like non-hydrocarbons such as naphthanic acids and those containing nitrogen, sulphur and oxygen together with carbon and hydrogen are more soluble and can affect the enzymatic system and other vital biomolecules in the body. Transiting in fish, crustacean, molluscs and others.

Effect on feeding and mating behaviour in several species. At 10 ppm reduces it the food finding capacity in lobster. 1% of oil stops feeding in mussels. Sexual behaviour of crabs is also modified at 0.0001 ppm. It decreases the filter feeding capacity, survival and fecundity in animals. It also leads to embryo toxicity and disruption of ionic regulation in sea birds. Some polyaromatic hydrocarbons (PAHs) like benzo (a) pyrene, dibenzo (a) pyrene and benzo(a) anthracene are potential carcinogens to a number of animals. Several PAHs are mutagenic and teratogenic.

Abnormal offsprings have been reported in several aquatic organisms. At 0.01 ppm of oil, eggs hatch late and irregularly. Larvae are deformed. Young stages of lobsters are greatly affected at 1 ppm. Oils affect the migration behavior in salmon.

Control of Oil Pollution

Some common methods to control the oil pollution from marine areas and other bodies of water are briefly described below:

Mechanical Containment

The oil spills spread rapidly in the form of slicks which can be contained by means of some mechanical barriers. One such method is the use of floating containment barriers or booms. These are made up of relatively compatible plastic materials, such as polyethylene, polyurethane, polyvinyl chloride, nylon, neoprene, epoxies and polypropylene and contain inflated sacs at regular intervals for floatation. Any floating or spreading oil can be contained in them from where it can be removed by some other means. Another technique is the use of bubble and current barriers which involves the generation of a surface current in opposite direction of spread of the oil by means of spray nozzles or by generating bubbles at a depth. A simple bubble discharger can be constructed with a submerged pipe with numerous air discharge pores along its length. Its major use is at oil loading terminals where it encircles them to protect the spread of spilled oil.

Dispersion Agents

The natural process of emulsification of oil in the water can be speeded up by spraying chemical dispersants on the oil slick from ships or aircrafts. However, dispersants are not effective against heavy oils and weathered oil and some of these chemicals may be toxic to life and can consume oxygen during their biodegradation. Dispersants are useful for treating small quantities of fresh oil.

Slick Lickers

A variety of slick lickers have been developed in which continuous belt of absorbent material dips through the oil slick and is passed through rollers to extract the oil. Slick lickers can deal with only a small quantity of oil and are useful in harbours and shelter waters polyurethane foams, polyethylene fibres, shredded polystyrene foam, wood cellulose fibres etc can also absorb oil.

Sinking Agents

The use of these agents is made only in deep waters where no fish catch is usually made. These agents are oleophilic and hydrophilic in nature with a high density. [The examples are: chalk treated with stealic acid, barite treated with latex, asbestos, carbonized treated sand, treated-fly ash etc.]

Burning Agents

Burning can provide a rapid disposal of a large quantity of oil in short period. However the volatile substances from the oil are rapidly evaporated leaving behind the oil which requires some support for combustion. A few agents supporting the combustion are straw, cellular glass beads and silage treated fume silica. All these substances work as wicking agents and can support combustion.

Biodegradation/ Bioremediation

Several components of the oil can be degraded by the micro-organisms. A number of experiments have demonstrated the possible use of bacteria in producing single cell protein from certain oil industry wastes. However the use of bacteria in natural degradation of oil in sea is still under experimental stage.

Bioremediation

This can be achieved by spraying the stranded oil with nutrients (nitrates and phosphates) to increase the bacterial degradation of the oil.