Impact of agricultural and industrial pollution on ecosystem and water quality

The learning objectives

1. The objective of the module is to make participants aware of the nature and magnitude of pollution generated from different sources including domestic, industrial and agricultural activities.
2. It would make them aware on various impacts due to pollution on water quality and ecosystem including oxygen depletion, nutrient enrichment leading to eutrophication, toxicity. They would also be exposed to fate of different pollutants in aquatic ecosystems including interaction between hydrological conditions, watershed processes and in-stream processes.

The learning outcomes

This session would essentially bring out the following

1. nature of different sources of pollution; a) industrial pollution: main polluting categories of industries, nature and magnitude of pollution discharged from these industries, control strategies, b) agricultural pollution: major agrochemicals (fertilizers and pesticides) used and processes involved in their transport to the aquatic environment, c) domestic pollution: nature and magnitude of contribution of domestic pollution in developing countries;
2. processes involved in oxygen depletion in water, consequences of low-oxygen or no-oxygen level in a surface water body (river, lake), oxygen sag-curve, processes and stages involved in recovery;
3. processes involved in eutrophication, main consequences of eutrophication, major factors responsible for eutrophication;
4. fate of toxic pollutants in watershed and aquatic environment: a) effects of various watershed processes b) physical, c) chemical, d) hydrological and e) biological processes on bioavailability and fate;
5. understanding on synergistic, antagonistic, additive, bioaccumulative, biomagnifying effects of toxic pollutants;
6. understanding on how structural and functional components of ecosystems are affected;
7. some important structural and functional effects that can be used as tools to monitor the health of an aquatic ecosystem.

Introduction

Aquatic ecosystems perform numerous valuable environmental functions. They recycle nutrients, purify water, attenuate floods, augment and maintain stream flow, recharge ground water, and provide habitat for wildlife and recreation for people. Rapid population increases in many parts of the India— accompanied by intensified industrial, commercial, and residential development— have led to the pollution of surface waters by sewage, industrial wastes, fertilizers, insecticides, toxic landfill leachates, and feedlot waste. At the same time that water pollution and releases of nutrient-laden municipal sewage effluents have increased, water consumption has also increased, thus reducing the flows available for the dilution of wastes. Increased sediment delivery resulting from urban construction, agriculture, and forestry also has resulted in greater turbidity and sedimentation in downstream channels, lakes, and reservoirs, with attendant losses of water storage and conveyance capacity, recreational and aesthetic values, and quantity and quality of habitat for fish and wildlife.

When water is used it gets polluted. Water has been traditionally used as carrier of our wastes. We use water for cleaning, washing, flushing, processing, cooling and drinking. In all these activities we pollute it. Generally following main sources of pollution of water courses are encountered:

1. Domestic sewage
2. Industrial wastewater
3. Agricultural run-off

Nature of Pollution from Domestic Sources

Domestic sources generally contribute household waste including wastewater from kitchen, bathroom, toilet and floor washings. This wastewater is called sewage. It is mostly organic matter. In developing countries sewage is mostly generated from large urban areas. Rural and smaller town population often does not generate sewage. It is because, there is mostly no organized piped water supply and people fetch water from distance and thus use it very economically. In India it is observed that class-I cities (population >100,000) generate about 90% of total sewage while class-II towns (population between 50,000 and 100,000) generate only about 10%. If we go further down to class-III or VI categories of urban centers, practically very insignificant amount of sewage is generated from there.

Urbanization has encouraged the migration of people from villages to the urban areas. This has given rise to a number of environmental problems such as water supply, wastewater generation and its collection, treatment and disposal. In urban areas, water is tapped for domestic and industrial use from rivers, streams, wells and lakes. Approximately 80% of the water supplied for domestic use passes out as wastewater. In most of the cases, wastewater is let out untreated and it either percolates into the ground and in turn contaminates the groundwater or is discharged into the natural drainage system causing pollution in downstream areas.

If you look at the domestic wastewater management scenario of India, the total wastewater generated from 423 class I cities is 29700 mld and 499 class-II towns generated about 3300 mld of sewage. The treatment system exists for only about 7000 mld (26%) before letting out, thus a large part is disposed off untreated.

Industrial Wastewater

Majority of industrial activities use water. They pollute the water depending on the production processes adopted. Generally three important uses of water are there in industrial sector i.e. domestic use, process use, cooling. The other significant contributors of wastewater are paper mills, steel plants, textile industries, distilleries, refineries, fertilizer plants and sugar industries.

The major contributors of pollution in terms of organic load are distilleries followed by paper mills. Since the distilleries generate very concentrated wastewater, it is hard to treat it. Despite the efforts on treatment of distillery waste, the targeted effluent quality is hard to achieve. The paper and board mills also generate heavy organic pollution load. A large number of paper mills are in small-scale sector. These industries do not have adequate arrangement for treatment of wastewater. Thus, create heavy pollution in many areas. The other significant contributors of organic load are sugar and engineering industries. Considering that treatment plants in all the industries are working efficiently, the major contributors of organic load in the treated effluent are paper mills followed by distilleries and tanneries.

The industries generating chemical pollution can be divided in two categories i.e. i) those which generate high dissolved solids (TDS) bearing wastes like pharmaceuticals, rayon plants, chemicals, caustic soda, soap and detergents, smelters etc. (ii) those which generates toxic wastes e.g. pesticides, smelter, inorganic chemicals, organic chemicals, steel plants, pharmaceuticals and tanneries etc. Major contributors of TDS load are distilleries followed by pharmaceuticals, textile industries and rayon plants. Major contributors of suspended solid load are thermal power plants that generate a significant quantity of cooling water followed by paper mills and tanneries. Toxic waste such as cyanide and arsenic are generated by fertilizer plants (nitrogenous) and steel plants.

Steel plants and oil refineries are major contributors of phenol. Engineering industries contribute maximum amount of oil and grease followed by oil refineries and edible oil vanaspati industry. Major pollution in terms of ammonia load is contributed by fertilizer plants (nitrogen) followed by steel plants. Pollutants such as chloride are generated by tanneries while fluorides are generated by fertilizer plants (phosphate) and sulphide by oil refineries. Waste such as mercury is generated by caustic soda industries employing mercury cell process.

Classification of Major Polluting Industries According to Nature of Pollutants

Nature of pollutants	Type of industries
Organic pollution	Distillery, Sugar, Tannery, Pulp and Paper, Dairy, Coke-oven, Refinery and Food industry
Dissolved solids	Chemical industry, Fertilizer, Pharmaceutical, Pesticides
Toxic chemicals	Electroplating, Coke-oven, Tannery, Chemical industry, Pesticides, Pharmaceuticals, H-acid, G-acid plants, Dye and Dye intermediates
Cooling water	Thermal Power Plants, Cable, Rolling Mills, PVC and plastic mounting

The pollution is contributed through following main routes:

Point Source Pollution

When pollution is transported through a defined route like sewer line, drain or a channel then it is termed as point source. The end of their pipes, known as outfalls, are located in one spot and the source of the wastewater can be identified. Sewer plans will show all of the connecting sewer pipes which ultimately feed into the pipe that is seen emptying into the river. Because the source of this wastewater is known --- discharging from a wastewater treatment plant or a storm sewer system in a neighborhood, it can be more easily tested for pollutants and better managed.

Non-Point or Diffuse Source Pollution

When pollution is contributed through storm water run-off , which has run over land and picked the pollution from large area. Every time it rains, water runs over the land, which in urban, industrial or agricultural premises is often contaminated, and flows into a waterway. This type of pollution is called non-point source pollution because the pollution is not coming from a specific source, but from many sources which are difficult to pinpoint. Motor oil, soda cans, cigarette butts, fertilizers, pesticides, open defecation residues, cattle wastes and dog wastes are all examples of non-point source pollution because they are often lying all over the watershed, just waiting to be swept away with the next rain storm.

Watershed Processes

The following main processes are very important in non-point pollution:

1. Exchange processes:
   a. Bioconcentration
   b. Sorption
   c. Volatilization
2. Transformation processes
   a. Metabolism
   b. Mineralization
3. Speciation processes
   a. Partial degradation: photochemical
   b. Reversible reactions: ionization
   c. Complexation: dissociation

Source-Related Characteristics of Diffuse Water-Pollution

For a proper understanding of the nature and the magnitude of diffuse water-pollution under different circumstances, it would be necessary to consider some source-related characteristics, briefly discussed below for diffuse pollution from some more common sources.

Pollution From Small Rural Hamlets/Villages

Almost as a rule these would not have running water supply nor sewered sanitation. In many developing countries (as is the case of India) most people would use open field for defecation, with a few using pit-latrines or septic-tanks. Much of the bathing and washing (clothes, utensils etc.) shall be in or near the water-body reducing abstraction and transport of water but causing in-situ diffuse pollution. Generation of liquid effluents would be minimal and all wastewater generated shall soak into the nearby land. One would be tempted to say that such habitats would cause no water pollution. And yet a careful materials-balance as also field experience would show significant quantities of various types of pollutants including salts, nutrients, organics and micro-organisms from such hamlets and rural areas reaching ground or surface water bodies through leachate see pages and as washings in the storm run-offs. On the basis of varies experience, the Indian Central Pollution Control Board estimated an average 15g BOD_{5-20} per capita per day of the rural population reaching the major river draining that particular basin and used this as a basis of computations in its "Basin Sub-Basin Inventory of Water Pollution" series (CPCB 1982-1995). Corresponding loads of salts, nutrients, micro-organic and other pollutants would also be reaching streams and rivers, while the amounts of pollutants percolating to ground waters may be much larger.

Wastewaters and Pollutants from Unsewered Towns

For improving standards of life, running water- supply has been established in most of the towns and even in some villages over the past three decades, even in developing countries. This has, in turn, led to flush- latrines and much large use of water in homes for bathing, washing of clothes utensils etc, generating significant amounts of wastewaters. Use of soaps and detergents and amounts of various food materials going to the sink have also grown with improved life standards.

Sewage, Sullage and Pollutants from Urban Areas with Inadequate or Faulty Sewerage and/or Sewage Treatment System

With exponential growth in urbanisation through migration of the poorest section of populations to cities in search of livelihood, it would be difficult to name many cities or urban areas in developing countries that have adequate and effective sewerage.

Industrial Pollutants from Cottage/ Small Scale Industries:

Encouragement of cottage and small-scale industries through subsidies, market-preferences or other benefits has been an important component of economic development programmes of many developing countries. These units, in general, neither have nor can afford appropriate sanitation and/ or pollutant disposal systems, and yet have not been hesitant in adopting highly polluting production technologies such as chrome-tanning of leather, use of azo-dyes in fabrics, use of cadmium in ornaments and silver-ware, electroplating with cyanide baths, production of dye-intermediates and other refractory and toxic chemicals etc. Their solid wastes and sludge’s get scattered-around or dumped in unlined pits and effluents flow to streams through storm-drains or stagnate in depressions to percolate, leach or get washed-off during next rainy season.

Industrial Pollutants from Large Industries

While they might claim to have installed costly treatment and disposal, these are also often causing leachates and wash-over from storage yards, waste dumping, ash-ponds, sludge-pits etc. And treated effluents, having at least some pollutants, are leached or washed to streams as diffuse pollution.

Leachates and Wash-over from Municipal, Industrial, Mining and other Solid Wastes

This is also a very important source of pollution of water bodies in developing countries.

Pollutants in Leakages and Those Escaping Due to Accidents During Transportation, Storage or Handling

With increasing storage, handling and transport of various chemicals, including those highly toxic and/ or hazardous, the contribution of these has been growing. Accidents involving mineral oils, acids, chlorine, ammonia etc are too well known.

Effluents, Leachates and Wash-over from Cattle-farms and Animal Husbandry

Cattle-farms rarely have adequate arrangements for collection, treatment and proper disposal of their solid and liquid wastes and thus could be an important source of pollution

Pollutants in Agricultural Drainage Waters

Drainage waters from irrigated agricultural land are always high in salts, since they also have to carry the salts originally contained in the trans- evaporated fraction of the irrigation water. In economically developed areas such as State of California, USA, this had been appreciated fifty years back and arrangements made to drain away such saline waters without causing undue damage to fresh- water bodies. In developing countries, while irrigation has been expanding exponentially, little is done to tackle the problem of the high salinity return-waters. Intensive and ever- increasing usage of chemical fertilizers, pesticides, weedicides and other chemicals is adding a new facet to such pollution, though the problem in this respect may yet be at a lower stage than in developed countries. Flood-plane cultivation may be another significant contributor in many cases.

Drainage from Wetlands and Pollutants from Aqua- culture

These could contribute significant loads of salts, nutrients, chemicals etc in seepage and wash - over.

Deposition of Air- Pollutants

Atmospheric pollutants may deposit directly on surface waters. Also the pollutants depositing on vegetation and soils may get leached or washed- over to water bodies. Acid rains causing water-pollution has been well-known and heavy metal deposition from air-emissions on-to-water has been causing concern.

Effect of Water Pollution

Effect of Organic Pollution on Water Quality

All organic materials or wastes can be broken down or decomposed by microbial and other biological activity (biodegradation). Although some inorganic substances are included in this category, most are organic compounds that can exhibit a biochemical oxygen demand (BOD) because oxygen is used in the degradation process. Oxygen is a basic requirement of almost all aquatic life except anaerobic microbes. If sufficient oxygen is not available to the aquatic life, the ecosystem will be adversely affected. Typical sources of organic pollution include sewage from domestic and animal sources; industrial wastes from food processing, paper mills, tanneries, distilleries, sugar and other agro-based industries.

This category of pollution becomes a problem when the oxygen required for biodegradation due to organic pollution is greater than the available oxygen in the water body. Natural systems do have a limited capacity to accommodate self-purification through biodegradationby employing re-oxygenation processes. However, in many situations the anthropogenic pollution overwhelms the given system.

Effect of Nutrients on Water Quality

The nutrients are always present in water and thus it supports aquatic life. Here the primary focus is on fertilizing chemicals such as nitrates and phosphates. While important for plant growth, too much of nutrients encourage the overabundance of plant life and can result in environmental damage called “eutrophication”. This can occur at both microscopic level in form of algae or macroscopic level in form of larger aquatic weeds. The diurnal change in dissolved oxygen is of serious concern. During day time oxygen remain supersaturated due to photosynthetic contribution of oxygen. But during night the oxygen is depleted as the algal mass consumes significant amount of oxygen. Nitrates and phosphates contributed through anthropogenic sources such as sewage, agricultural run-off and run-off from un-sewered residential areas.

Normally, blue-green algae are very important in the river ecosystem, photosynthesising sunlight energy, and liberating oxygen into the water. In large numbers, however, algae can become excessive, discolouring the water, giving an unpleasant smell and robbing the water of valuable oxygen as bacteria work overtime feeding on dead algae remains. Blue-green algae can also produce toxins, which kill wildlife, cause skin rashes, and cause pains and stomach upsets. Eutrophication is thus depriving the river of oxygen (called "oxygen debt"). As algae dominate and turn the water green, the growth of other water plants is suppressed; these die first, disrupting the food chain. Death of invertebrates and fish follow on, and their dead remains in turn lead to excess bacterial activity during decomposition, reducing oxygen levels still further. Water with high BOD figures are badly polluted, lower figures are better

Effect of High Dissolved Solids (TDS) on Water Quality

As water is best solvent known on the earth, it can dissolve variety of substances to which it come incontact during hydrological cycle. In natural waters, the dissolved solids mainly consist of bicarbonates, carbonates, sulphates, chlorides, nitrates and phosphates of calcium, magnesium, sodium, potassium with traces of iron, manganese and other minerals. The amount of dissolved solid is important consideration in determining its suitability for irrigation, drinking and industrial uses. In general, waters with a total dissolved solids <500 mg/l are most suitable for drinking. Higher dissolved solids may leads to impairement in physiological processes in the human body. For irrigation water dissolved solid is very important criteria due their gradual accumulation resulting in salinization of soil, thus, rendering the agriculture land non-productive.

Dissolved solids are undesirable in industrial water due to many reasons. They form scales, cause foaming in boilers, accelerate corrossion, and interfer with the colour and tastes of many finished products.

Effect of Toxic Pollutants on Water Quality

The toxic Pollutants are mainly heavy metals, pesticides & other industrial xenobiotic pollutants. The ability of a water body to support aquatic life, as well as its suitability for other uses depends on many trace elements.Some metals e.g. Mn, Zn and Cu present in trace quantity are important for the life as it helps and regulates many physiological functions of the body. The same metals, however, causes severe toxicological effects on human health and the aquatic ecosystem. Water pollution by heavy metals resulting from anthropogenic impact is causing serious ecological problems in many parts of the world. This situation is aggravated by the lack of natural elimination processes for metals. Thus, metals shift from one compartment of environment to another, including the biota, often with detrimental effects. Where sufficient accumulation of the metals in biota occurs through food chain transfer, there is also an increasing toxicological risk for man. As a result of absorption and accumulation, the concentration of metals in bottom sediments is much higher than in the water above, which may cause secondary pollution problem. The toxicity of metals in water depends on the degree of oxidation of a given metal ion together with the forms in which it occurs. As a rule, the ionic form of a metal is the most toxic form. However the toxicity is reduced if the ions are bound into complexes with, for example, natural organic matter. Under certain conditions, metallo-organic, low-molecular compounds formed in natural waters exhibit toxicities greater than the uncombined forms. An example is the highly toxic alkyl-derivatives of mercury (methylmercury) from inorganic mercury by aquatic microorganisms. A famous episode of Minamata disease occured in Japan in fifties due to consumption of fish contaminated by methyl mercury. Metals in natural water can exists in truly dissolved, colloidal and suspended forms. The proportion of these forms varies for different metals and for different water bodies.

Many thousands of organic compounds enter water bodies as a result of human activities. Monitoring every individual compound is not feasible. However, it is possible to select priority organic pollutants based on their prevalence, toxicity and other properties. Mineral oils, petroleum products, phenols, pesticides, polychlorinated biphenyls (PCBs) and surfactants are examples of such compounds. However, these compounds are not universally monitored because their determination requires sophisticated instrumentation and highly trained personnel. Therefore, they are evaluated in terms of toxicity as a summary parameter. Many of these compounds are highly toxic and sometimes are carcenogenic and mutagenic in nature. Some selected compounds are measured by gas chromatography method.

Effect of Thermal Discharges on Water Quality

The discharge of cooling water from industrial and commercial operations may artificially heat up the aquatic environment. Organisms may become physiologically stressed from exposure to heated water or can be directly killed if escape is not possible. Some can adapt to the point of dependency and suffer if the thermal source is suddenly removed. If artificial heat loading is combined with natural seasonal warming of an aquatic system, the impact can be severe. Beside causing outright death, the problem also may result in the interference with natural life processes such as growth rates, respiration, reproduction and distribution of species. However, thermal pollution primarily causes a decrease in oxygen content which may directly kill aquatic life through asphyxiation. If toxic pollutants are present in the aquatic environment, thermal pollution may increase their toxicity to the aquatic life. Bioavailability of many pollutants may also increase due to thermal pollution, which may ultimately affect the aquatic life adversely.

Pathogenic Effects

Water borne diseases are single most important factor responsible for nearly 80% of human mortality in India. Children are worst affected, especially in rural areas and urban slums. Typical water borne diseases and their causative factors are summarised in the table 1.

Table 1:Water related diseases and Causative factors

Name of the disease	Causative organism
1. Water-borne diseases	
Bacterial	
• Typhoid	Salmonella typhi
• Cholera	Vibrio cholerae
• Paratyphoid	Slmonella parayphi
• Gastroenteritis	Enterotoxigenic Escherichia coli
• Bacterial dysentery	Variety of Escherichia coli
Viral	
• Infectious hepatitis	Hepatitis-A virus
• Poliomycetis	Polio-virus
• Diarrhoeal diseases	Rota-virus, Norwalk agent, other virus
• Other symptoms of enteric diseases	Echono-virus, Coxsackie-virus
Protozoan	
• Amoebic dysentery	Entamoeba hystolitica
2 Water-washed diseases	
• Scabies	Various skin fungus species
• Trachoma	Trachoma infecting eyes
• Bacillary dysentery	E. coli
3 Water-based diseases	
• Schistosomiasis	Schistosoma sp.
• Guinea worm	Guinea worm
4 Infection through water related insect vectors	
• Sleeping sickness	Trapanosoma through tsetse fly
• Malaria	Plasmodium through Anaphelis
5 Infections primarily due to defective sanitation	
• Hookworm	Hook worm, Ascaris

Testing pathogens in water in a water quality monitoring laboratory on routine basis is a difficult task. This is mainly due to sophisticated methodology involved in testing pathogens, their smaller number in water and thus, their absence in test sample does not always ensure their absence in the water being monitored. for ensuring Examinations for faecal indicator organisms remain the most sensitive and specific way of assessing the hygenic quality of water. Faecal indicator bacteria should fulfil certain criteria to give meaningful results. They should be universally present in high numbers in the faeces of humans and warm blooded animals, and readily detectable by simple methods, and they should not grow and multiply in natural water. For an indicator species it is essential that their persistence in water and their degree of removal in treatment of water are similar to those of waterborne pathogens. The major indicators of faecal pollution are *Escherichia coli*, the thermotolerant and other coliform bacteria, the faecal streptococci, and the spores of sulfite-reducing clostridia. While the criteria described above for an ideal faecal indicator are not all met by any one organism, many of them are fulfilled by *E. coli* and, to a lesser extent, by the thermotolerant coliform group of bacteria. The faecal streptococci satisfy some of the criteria, although not to the same extent as *E. coli*, and they can be used as supplementary indicators. It is recommended that *E. coli* is the indicator of first choice when resources for microbiological examination are limited. Recently, However, it has been suggested that *E. coli* may be found and even multiply in tropical waters that are not subject to human faecal pollution. Spores of sulfite reducing bacteria can also be used as an additional indicator.

There are various types of pathogenic microbes that pass through their host species and may enter the aquatic ecosystem by way of contamination from human or animal wastes. Through drinking water consumption or through various water contact activities, the spread of diseases such as typhoid, cholera, hepatities, dysentery etc. may occur. Pathogens may spread to water only sporadically, and once there, do not survive long, but still may cause health related problems. In this category, we may also want to consider man's activities resulting in the creation of an environment that fosters diseases. Disease-vector like mosquitoes, flies breeding environments can be created, for example, by certain construction activities that may create stagnant water.

When polluted water is transported through a defined All water used is polluted. In a big city, large amounts of wastewater are produced each day, which presents a real health hazard to the people that live there. Historically, cities built sewers to collect polluted water and carry it away – usually to a river, which in turn carried it to the ocean. In developing countries like India collection system for large amount of sewage is not existing resulting in its flow in storm water drains and joining the water courses with or without treatment. In time, the fish died because pollution robbed the water of dissolved oxygen which fish need to live. People who worked along the rivers also became sick from the pathogens present in the sewage. Since the rivers were also the cities' sources of drinking water, this meant that people were drinking polluted water. People who drank the river water became sick because of waterborne diseases such as typhoid and cholera. Back then, we did not fully understand the connections between our health and that of our natural resources.

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