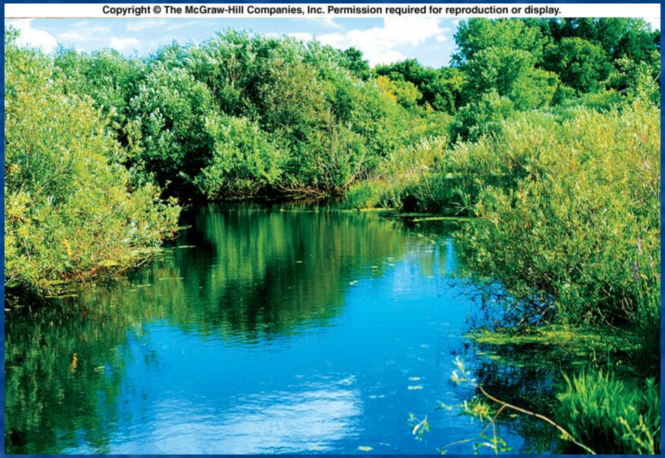
Module 3

- Water pollution

The Importance of Water

- All living things need water
  - Composes majority of the body of organisms
  - Habitat for many organisms
- Helps regulate climate
- Shapes earth's surface
- Dilutes & degrades wastes



Use of water

- Uses of Freshwater Water resources are used in various fields such as agricultural, industrial, domestic, recreational, and environmental activities. Most of the uses require fresh water.
- However, around 97 percent of the water on the earth is saltwater and only three percent is freshwater. About two-thirds of the available freshwater is frozen in glaciers and polar ice caps. The remaining freshwater is found underground and a negligible portion of it is present on the ground or in the air.The following are detailed views on how water is used in different sectors.

Water footprint

Agricultural Use

- **Agriculture** accounts for about 69 per cent of all water consumption especially in agricultural economies like India. Agriculture thereby becomes the largest consumer of the Earth's available freshwater. By 2050, the global water demand for agriculture is estimated to increase by an additional 19% due to irrigation needs. Increasing irrigation needs are likely to put immense pressure on water storage. It is still not concluded whether further expansion of irrigation and additional water withdrawals from rivers and groundwater is possible in the future.

Industrial Use

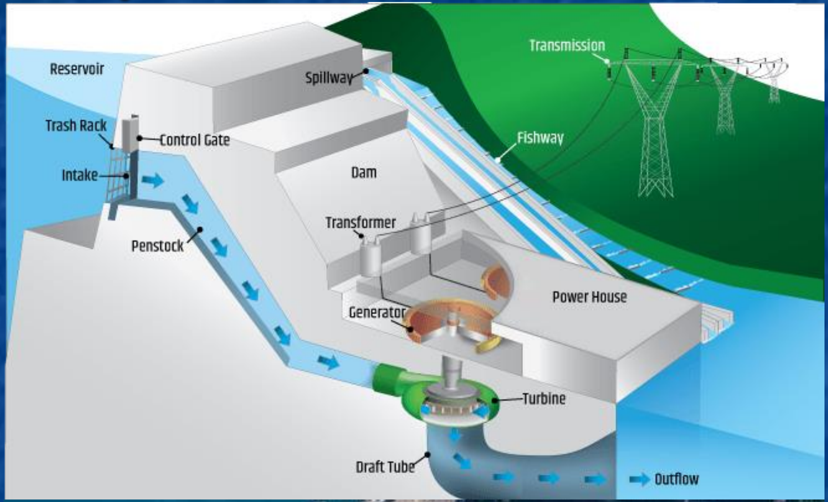
- Water is the lifesaver of the industry. It is used for various purposes such as a raw material coolant, a solvent, a transport agent, and as a source of energy. Manufacturing industries are considered to have a considerable share of the total industrial water consumption. Besides, paper and allied products, chemicals, and primary metals are major industrial users of water. Worldwide, the industry consumes around 19 percent of total water consumption. In industrialized countries, the industries use more than half of the water available for human use.

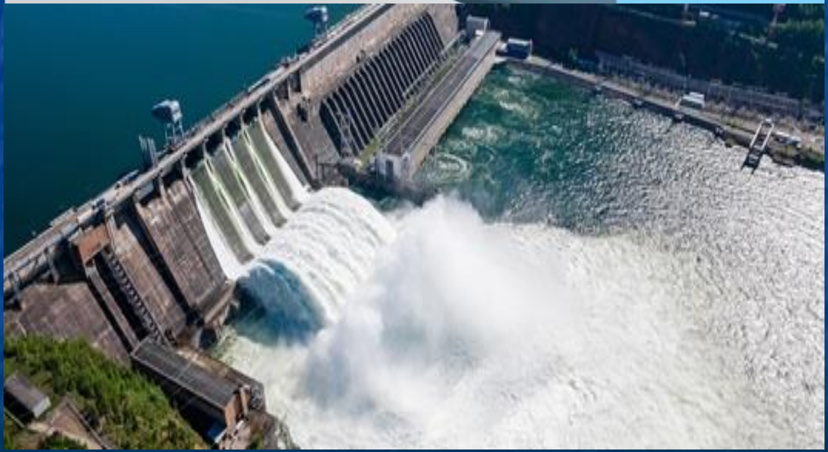
Domestic Use

- Itincludes usages like drinking, cleaning, personal hygiene, garden care, cooking, washing of clothes, dishes, vehicles, etc. Since the end of World War II, there has been a trend of people migrating out of the country to the ever-expanding cities. This trend has an important role in our water resources.The government and communities are in a need to provide large water-supply systems to deliver water to new growing populations and industries. Comparing all water consumption in the world, domestic uses about 12 percent of the total water consumed.

Use for Hydropower

- Electricity generated from water is called hydropower. Hydropower is one of the highly renewable sources of electricity in the world. It accounts for around 16 percent of the total electricity generated globally. There are numerous opportunities for hydropower development around the world.At present, the leading hydropower generating countries are China, the US, Brazil, Canada, India, and Russia.



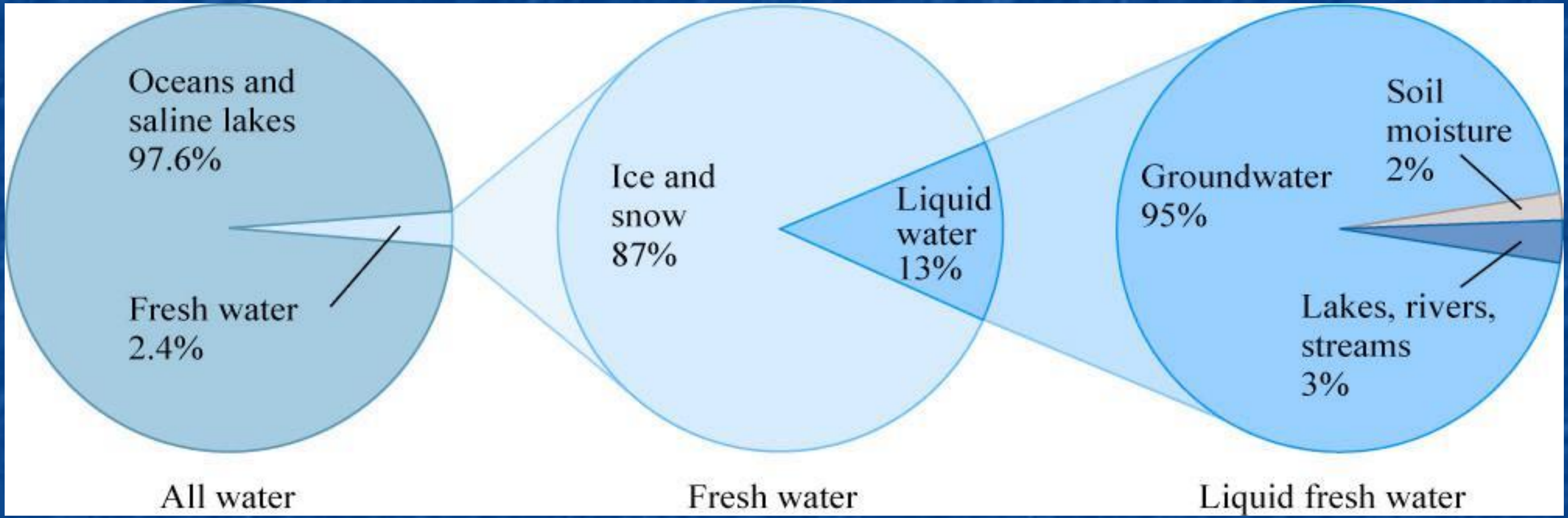


Use for Navigation and Recreation

- Navigable waterways are defined as watercourses that can be used to transport interstate or foreign commerce. Moving of agricultural and commercial goods on the water is done on a large scale around various parts of the world. Water is also used for recreational purposes like boating, swimming, and sporting activities. These usages affect the quality of water and pollute it. The highest priority should be given to public health and drinking water quality while permitting such activities in reservoirs, lakes, and rivers.

Water on Earth

- About 97% Earth's water is salty-less than 1% of the planet's water is available fresh H_2O



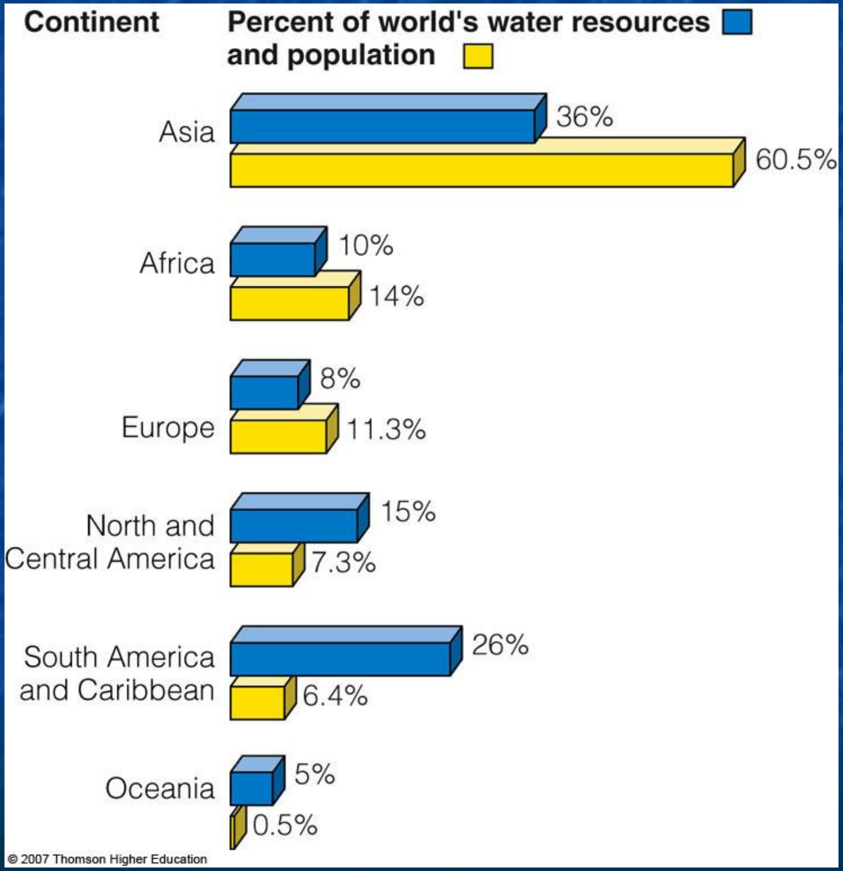
- Fresh water is distributed unevenly
- 2025: 1/3 human population will live in areas lacking fresh water

Types of water resources

- Marine water or saline water
- Surface water
- Groundwater

Fresh water

Water, water, everywhere? (NOT)

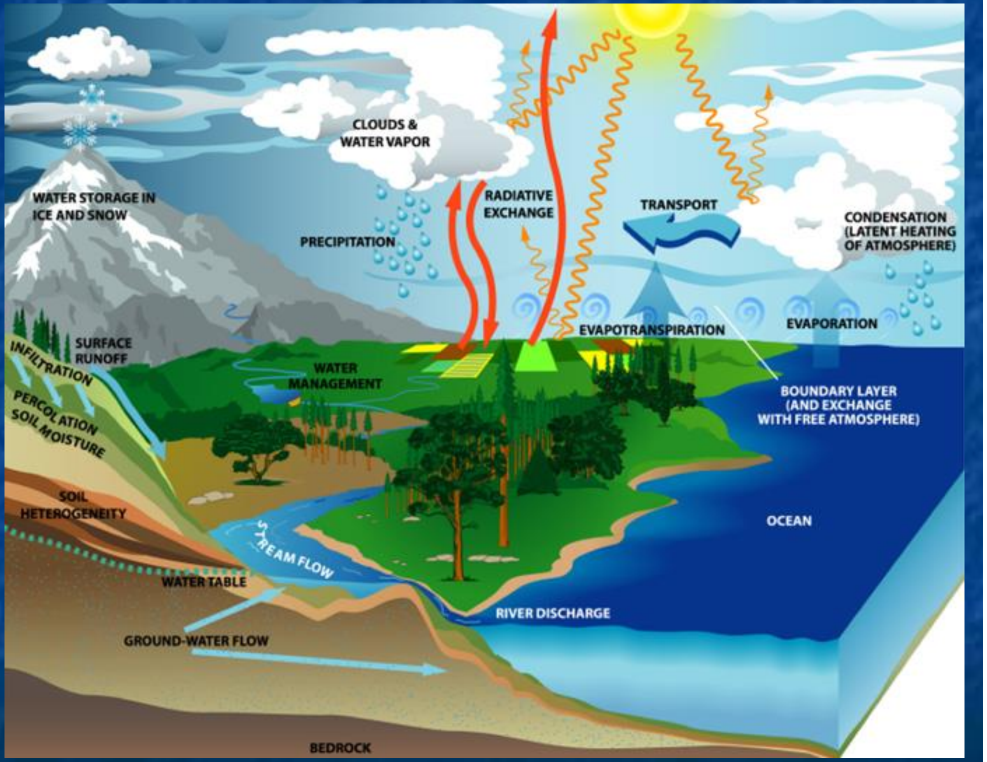


- Comparison of population sizes and shares of the world's freshwater among the continents. (Only 7 countries account for 60% of global water availability)

Water Wars

- Many countries in the Middle East, which has one of the world's highest population growth rates, face water shortages.
- Desalinization
- Rainwater harvesting

The Hydrologic Cycle



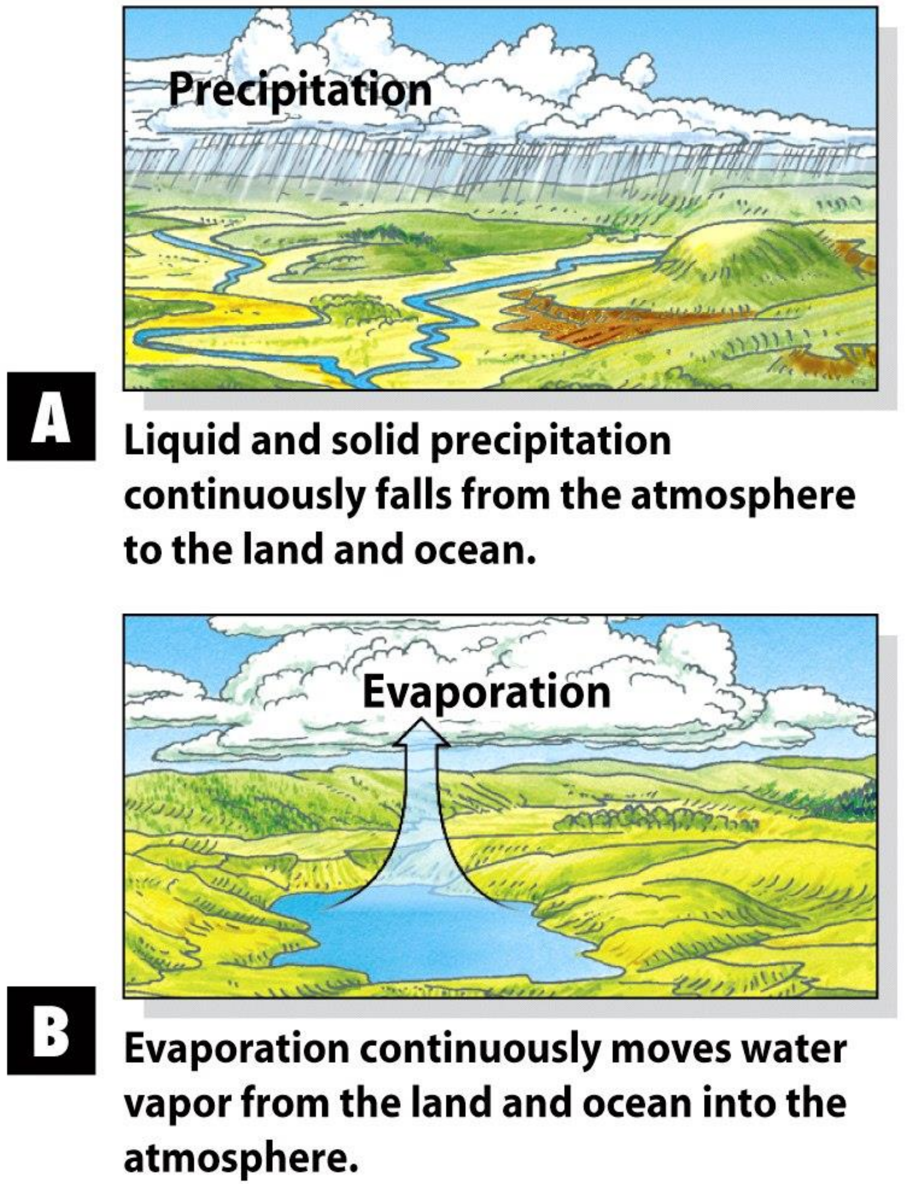
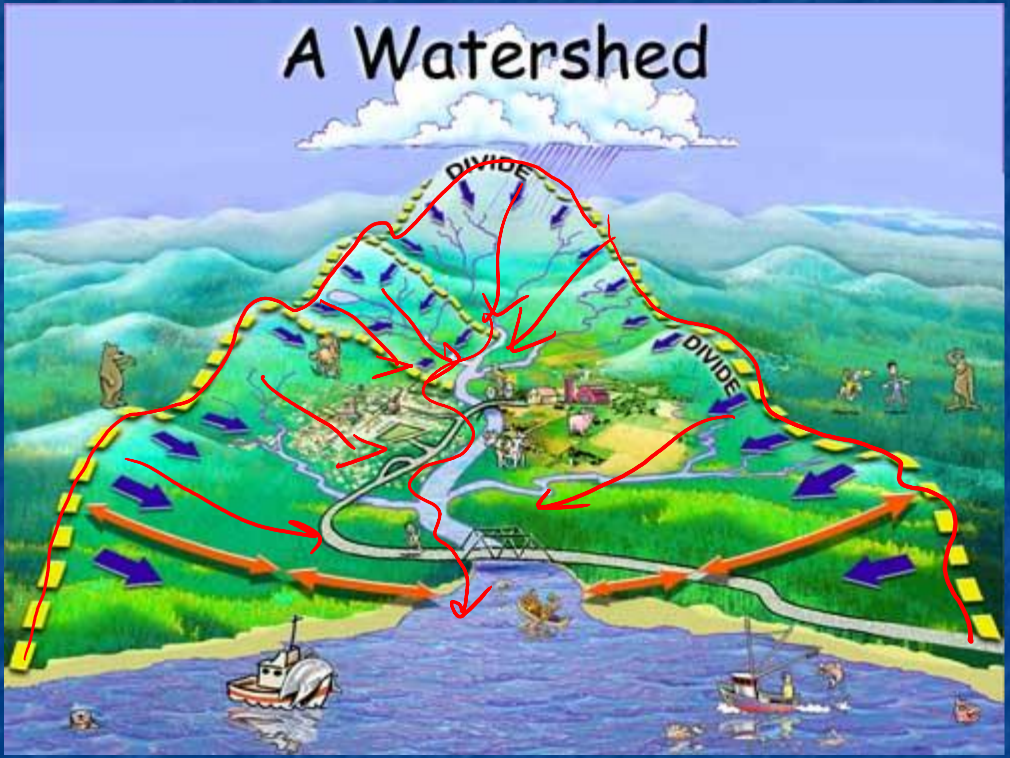


Figure 10-2 Visualizing Environmental Science, 1/e

Surface Water

- Streams, rivers, lakes, ponds, reservoirs, wetlands
- Runoff replenishes surface water
- Watershed (A **watershed** is an area of land that drains or "sheds" water into a specific waterbody.



A watershed is an area of land that drains all the streams and rainfall to a common outlet such as the outflow of a reservoir, mouth of a bay, or any point along a stream channel.

Groundwater

- Supply of fresh water found under Earth's surface--recharged when water at surface infiltrates into the ground
- Stored in under ground aquifers
- Discharged into rivers, springs, etc…

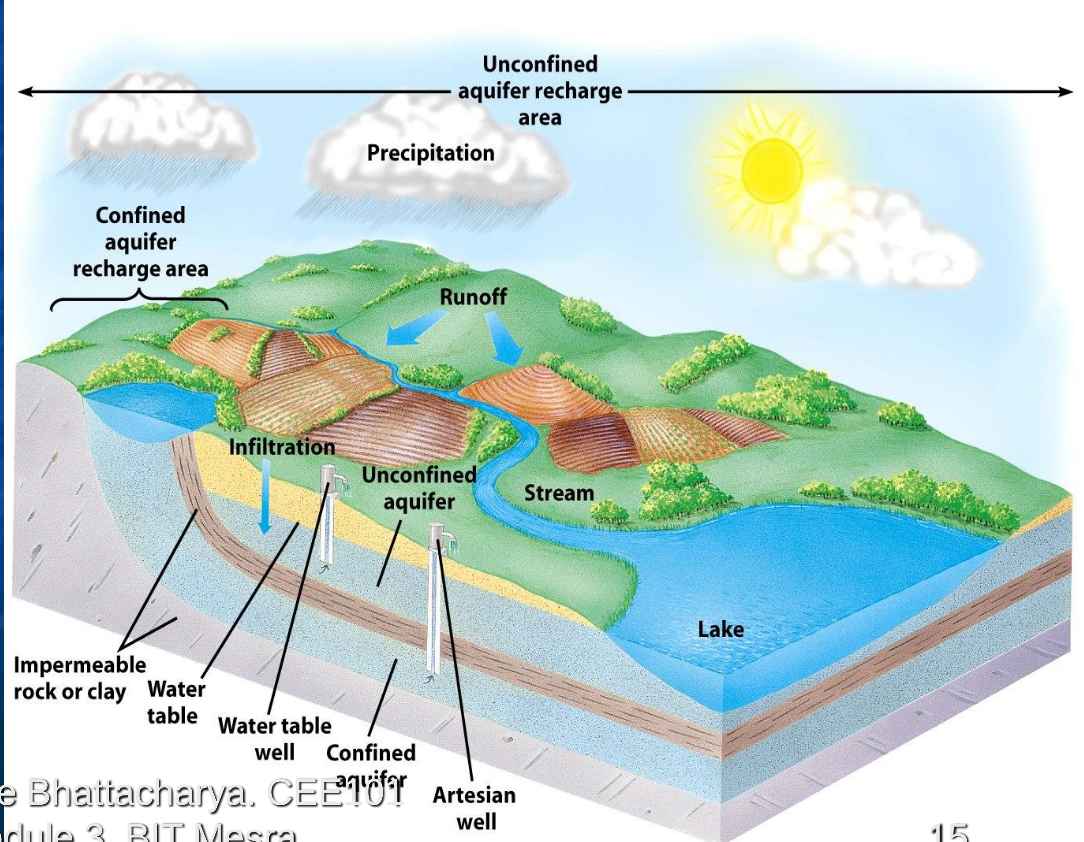
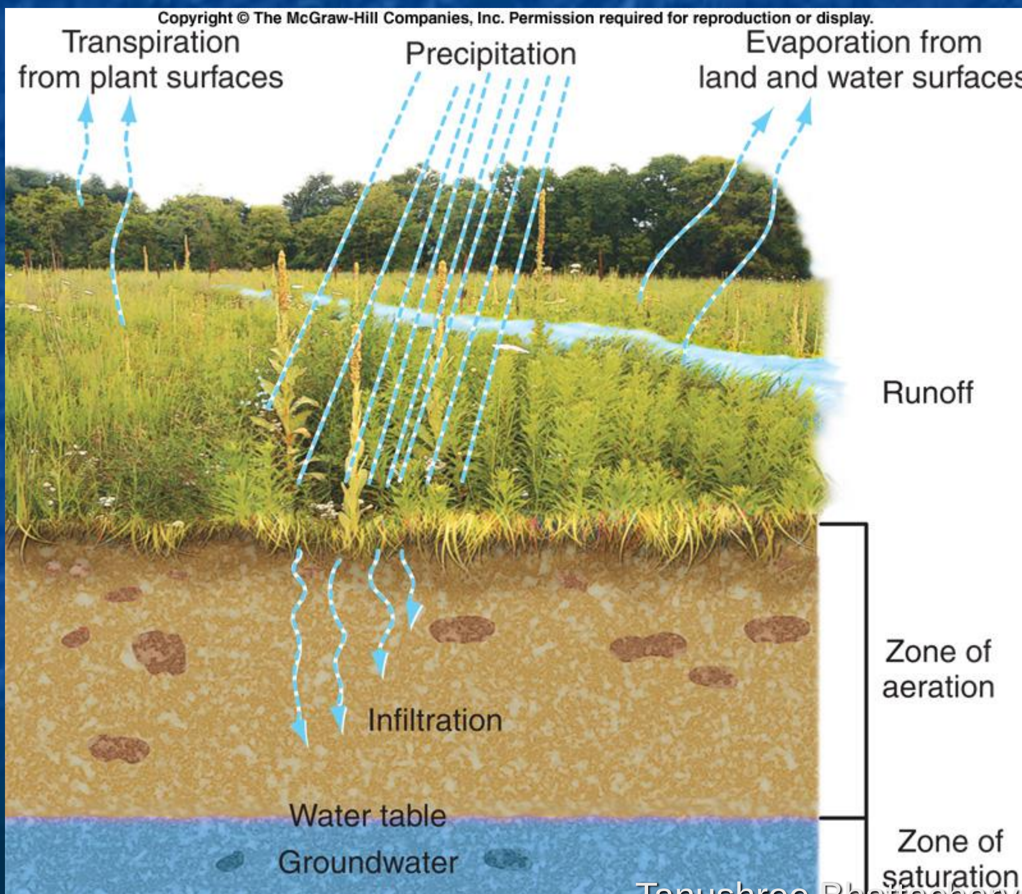


Figure 10-3 Visualizing Environmental Science, 1/e

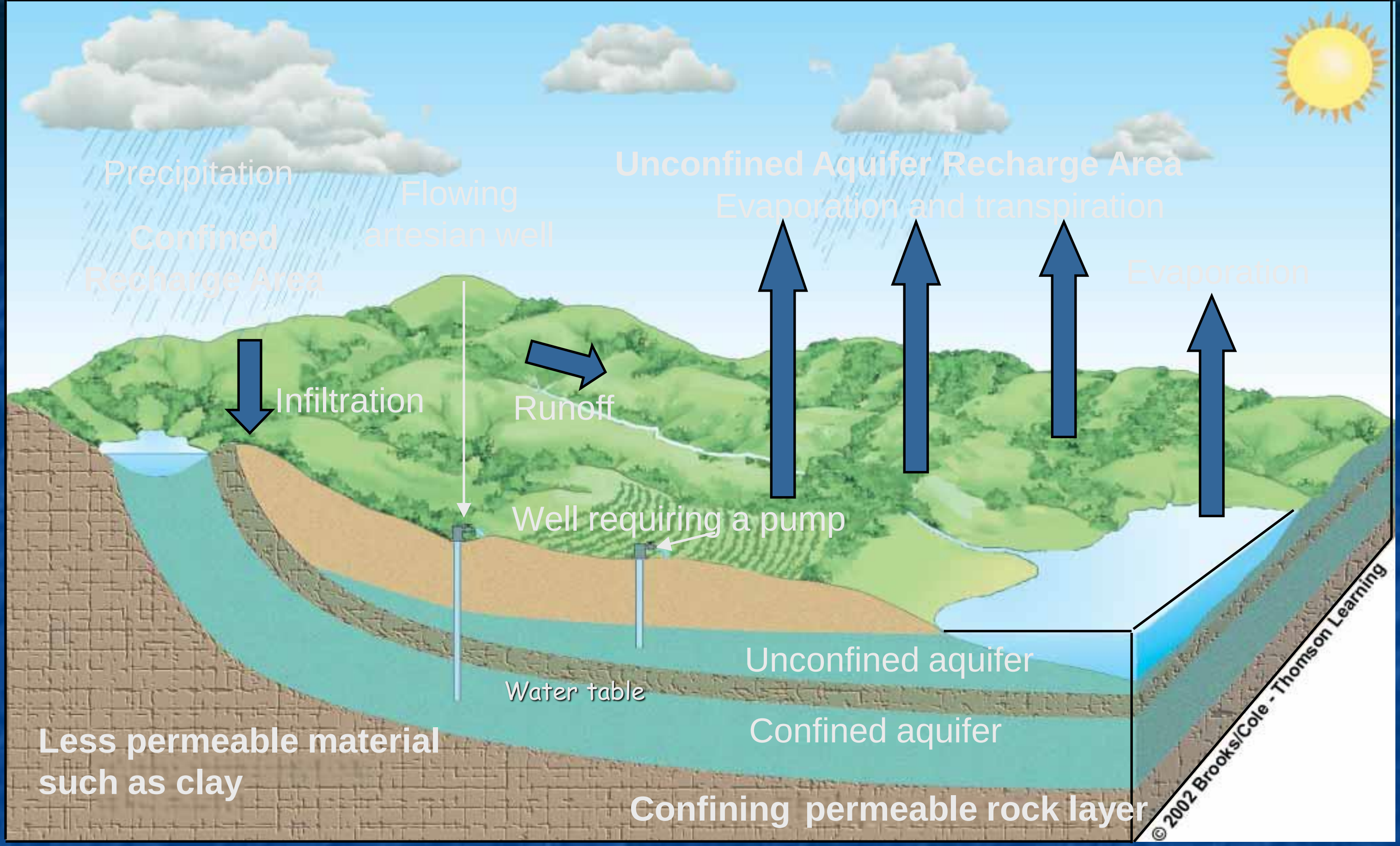
Infiltration - Process of water percolating through the soil and into cracks and permeable rocks.



Zone of Aeration – Upper soil layers that hold both air and water.

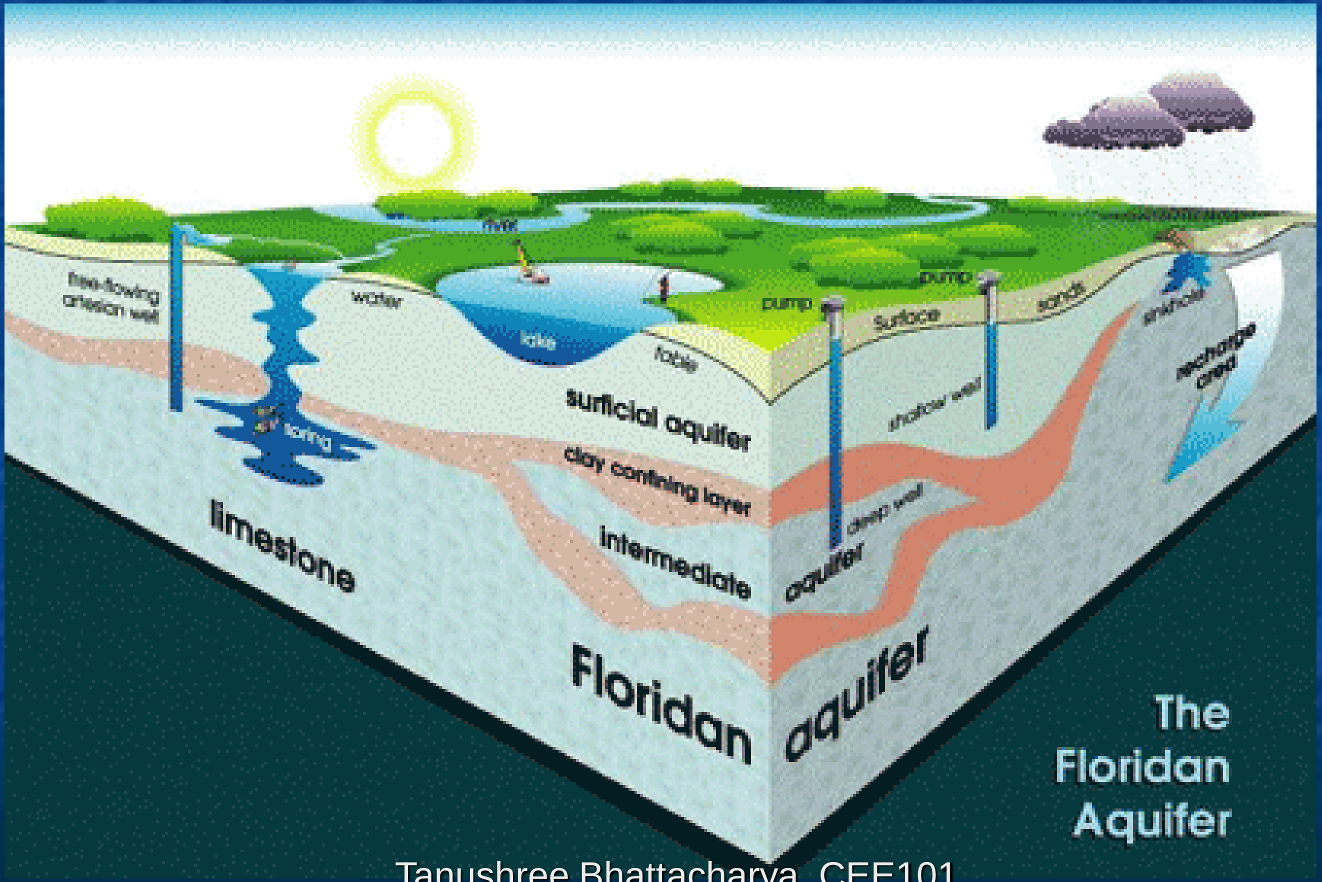
Zone of Saturation Lower soil layers where all spaces are filled with water.

Water Table – Top of zone of saturation



- Recharge Zone - Area where water infiltrates into an aquifer.
    - -Recharge rate is often very slow.
    - -Presently, groundwater is being removed faster than it can be replenished.

- Aquifers - Porous layers of sand, gravel, or rock lying below the water table.



Water Resource Problems

- Too much water
- Too little water
- Poor-quality water

Pollution and water protection

Water pollution is one of the main concerns of the world today. The governments of numerous countries have striven to find solutions to reduce this problem. Many pollutants threaten water supplies, but the most widespread, especially in developing countries, is the discharge of raw sewage into natural waters; this method of sewage disposal is the most common method in underdeveloped countries, but also is prevalent in quasi-developed countries such as China, India and Iran. Sewage, sludge, garbage, and even toxic pollutants are all dumped into the water.

According to the Water (Prevention and Control of Pollution) Act, 1974, —

- water pollution means such contamination of water or such alteration of the physical, chemical or biological properties of water or such discharge of any sewage or trade effluent or of any other liquid, gaseous or solid substance into water (whether directly or indirectly) as may or is likely to, create a nuisance or render such water harmful or injurious to public health or safety or to domestic, commercial, industrial, agricultural or other legitimate uses, or the life and health of animals or plants or of aquatic organisms.

Pollution and water protection

Even if sewage is treated, problems still arise. Treated sewage forms sludge, which may be placed in landfills, spread out on land, incinerated or dumped at sea. In addition to sewage, nonpoint source pollution such as agricultural runoff is a significant source of pollution in some parts of the world, along with urban stormwater runoff and chemical wastes dumped by industries and governments.

SOURCES OF WATER POLLUTION

1, Domestic wastes

2. Industrial wastes

3. Agricultural wastes, insecticides and pesticides

4. Radioactive wastes.

Domestic source

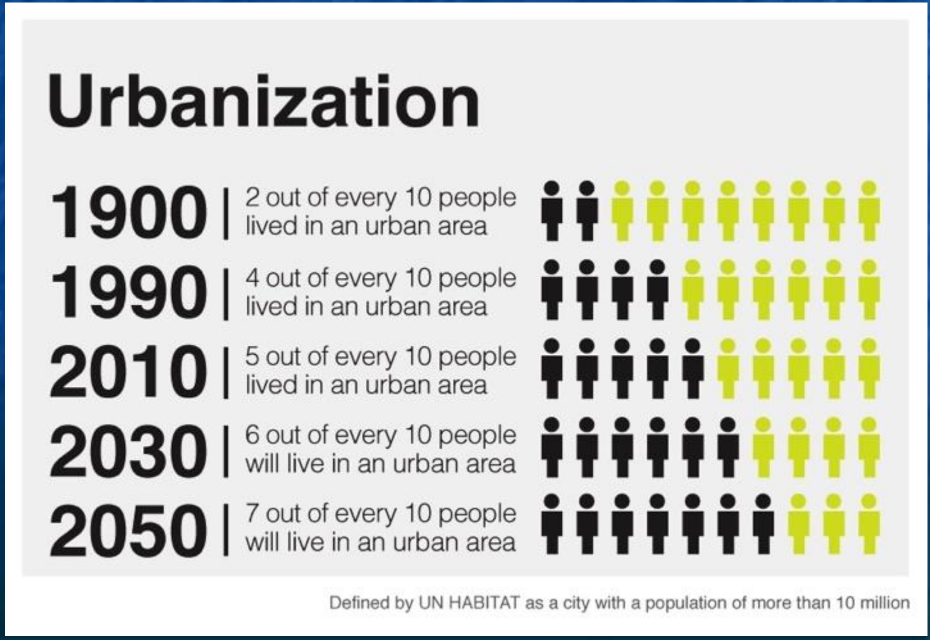
- Domestic wastewater contains a great variety of pollutants, such as nutrients, oil and grease, detergents, biowastes, household chemicals, heavy metals, bathing and kitchen waste, salts, pathogens, medicinal constituents, and soluble and particulate organic matter.

Causes..

- Growing Population
  - Every year we add millions of people to the world population and our country is no exception. The earth is now overcrowded and consumption habit of the people is on the rise. The growth of population gave rise to increase in wants and demands of mankind and has succeeded in creating acute problem of water pollution.

- Industrialization
  - Rapid industrialization is another cause of worry as far as water pollution is concerned. Immediately after the independence, major steps were taken in our country in its stride for development in order to give its economy a big push.
  - Industrialization along with development brought with it a danger to the human civilization- the problem of environmental pollution

- Urbanization
  - big cities also developed just near the water courses particularly besides the big rivers subsequently attracted the establishment of industrial and commercial basis in and around the cities.
  - Since many towns and cities lack a proper sewerage system, the condition worsened further.



- Nature of Modern Technology
  - The nature of productive technology in recent years has been largely responsible for the generation of synthetic and non biodegradable substances such as plastics, chemical nitrogen fertilizers, synthetic detergents, synthetic fibres, petrochemical and other environmentally injurious industries and —disposable culture.

- Modern Agricultural Practices
  - Fertilizers like phosphates and nitrates cause widespread damage when applied carelessly to crops. The fertilizers can be transmitted to groundwater by leaching and to surface waters by natural drainage and storm run-off.
  - In addition to fertilizers various kinds of pesticides and insecticide also applied. Almost all the pesticides those are used are toxic to human and animals
-

Radioactive wastes

- Natural sources and man made sources like, atomic explosions and nuclear fall out.

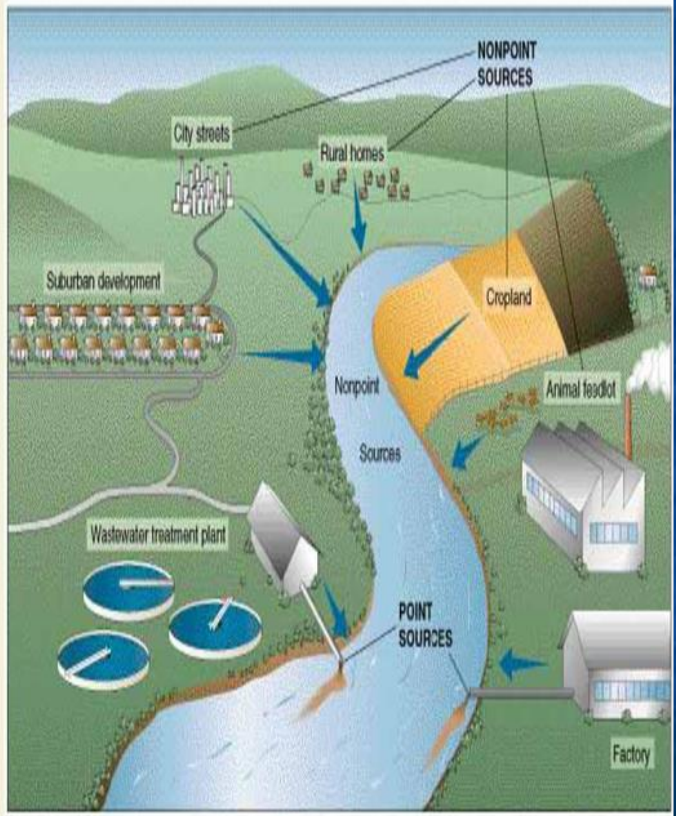
Point source and non point source

Nonpoint sources

- Broad, diffuse areas
- Difficult to identify and control
- Expensive to clean up
- Examples

Point sources

- Located at specific places
- Easy to identify, monitor, and regulate
- Examples

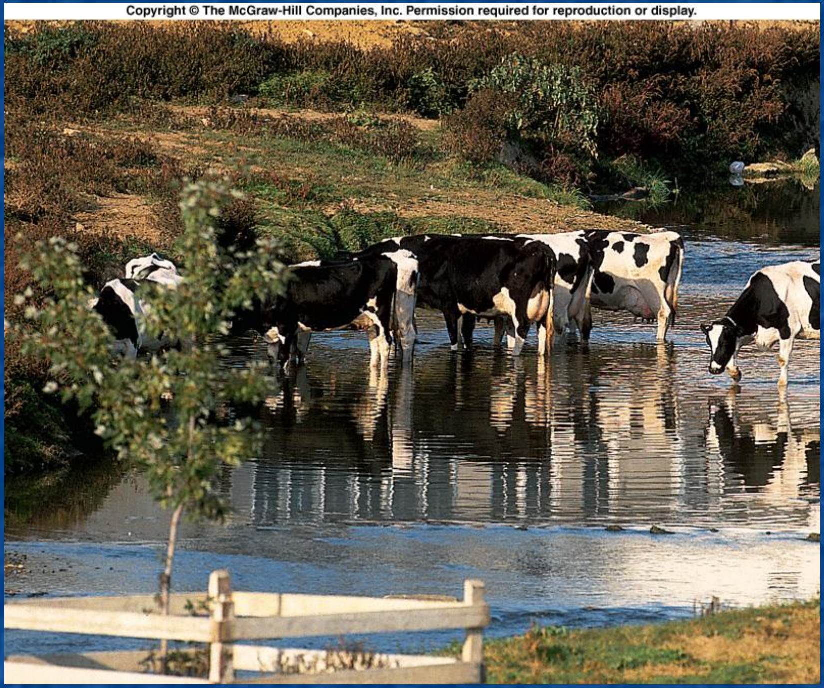


Changes in Surface Runoff

- Prior to 1970 about 10% of stormwater became runoff
- Now 55% of stormwater is transported as runoff as development exceeds 75% of the permeable soil area

Stormwater Runoff (greatest contributor to nonpoint source pollution) contains:

- Nutrients*
- Metals*
- Suspended solids*
- Pesticides
- Hydrocarbons
- Microorganisms



Types of water pollution

- Types of water pollution
- Surface water:- Water resources like huge oceans, lakes, and rivers etc. are called surface waters. Contaminants such as chemicals, nutrients, and heavy metals are carried from farms, factories, and cities into streams and rivers and then to seas and oceans. Our seas are also sometimes spoiled by oil spills.
- Marine pollution: Marine pollution is a combination of chemicals and trash, most of which comes from land sources and is washed or blown into the ocean. This pollution results in damage to the environment, to the health of all organisms, and to economic structures worldwide.
- Ground water:- Water stored underground in aquifers is known as groundwater. Groundwater gets polluted when contaminants (pesticides, fertilizers) or waste leached from landfills and septic systems make their way into an aquifer, rendering it unsafe for human use. It is virtually impossible to remove contaminants from groundwater. Groundwater can also spread contamination into streams, lakes, and oceans.
- Themal Pollution:
- Thermal pollution is defined as a sudden increase or decrease in the temperature of a natural body of water, which may be an ocean, lake, river, or pond, by human influence., thermal pollution is when an industry or other human-made organization takes water from a natural source and cools or heats it before eventually ejecting it back into the natural resource, which changes the oxygen levels, disastrously affecting local ecosystems and communities.

Contaminants	Reason for Importance
Suspended solids	Suspended solids can lead to the development of sludge deposits and anaerobic conditions when untreated wastewater is discharged in the aquatic environment.
Biodegradable organics	Composed principally of proteins, carbohydrates, and fats, biodegradable organics are measured most commonly in terms of BOD (biochemical oxygen demand) and COD stabilization can lead to the depletion of natural oxygen resources and to the development of septic conditions
Pathogens	Communicable diseases can be transmitted by the pathogenic organisms in wastewater.
Nutrients	Both nitrogen and phosphorus, along with carbon, are essential nutrients for growth. When discharged to the aquatic environment, these nutrients can lead to the growth of undesirable aquatic life. When Discharged in excessive amounts on land, they can also lead to the pollution of groundwater.
Priority pollutants	Organic and inorganic compounds selected on the basis of their known or suspected carcinogenicity, mutagenicity, teratogenicity, or high acute toxicity. Many of these compounds are found in wastewater.
Refractory organics	These organics tend to resist conventional methods of wastewater treatment. Typical examples include surfactants, phenols, and agricultural pesticides.
Heavy metals	Heavy metals are usually added to wastewater from commercial and industrial activities and may have to be removed if the wastewater is to be reused.
Dissolved inorganics	Inorganic constituents such as calcium, sodium, and sulfate are added to the original domestic water supply as a result of water use and may have to be removed if the wastewater is to be reused.

Source : Metcalf and Eddy, 1991, p. 58

Major type of water pollutants

Classification of pollutants

CLASSIFICATION OF WATER POLLUTANTS[16]

Occurrence	Nature	Examples
Physical	Temperature	Waste neat from industry.
	Turbidity	
	Colour	Dyes and pigments
	Suspended and floating matter	Silt, sand, metal pieces, rubber, wood chpis, paper, foam, scum, carcasses, sewage.
Chemical	Inorganic	Nitrites, phosphates, chlorides, fluorides, salts etc.
	Organic	Detergents, tar, plastic, pesticides.
Biological	Pathogenic	Bacteria, virus, nematodes, worms, protozoans.
	Nuisance organisms	Slime, mollusc, algae, Ascellus, nematodes.

Emerging water pollutants

These pollutants include a variety of compounds such as antibiotics, drugs, steroids, endocrine disruptors, hormones, industrial additives, chemicals, and also microbeads and microplastics. Emerging pollutants are chemicals and compounds that have recently been identified as dangerous to the environment, and consequently to the health of human beings. Precisely, they have been labeled "*emerging*" because of the rising level of concern linked to them. In addition, many of these emerging pollutants have not been regulated under national or international legislation, hence posing a greater risk to our livelihood.

Concept of water quality

According to UNEP / WHO 1996 “Water quality” is a term used here to express the suitability of water to sustain various uses or processes. Any use will have certain requirements for the physical, chemical or biological characteristics of water, for example, if the water is for drinking purpose then contaminants should not be present, as well as the water should be acceptable, that is devoid of any colour or objectionable odour and taste.

Water quality plays a pivotal role in public health, habitat protection, agriculture, and industry. Water requirements have emerged over time for drinking, hygiene, fisheries, irrigation, livestock, and industries, cooling in fossil fuel power plants, nuclear power plants, hydropower generation, and recreational activities. Drinking water supplies and specialized industrial manufacturers exert the most sophisticated demands on water qualitatively but largest demands for water quantity, such as for agricultural irrigation and industrial cooling, require the least in terms of water quality.

Water quality parameters that imparts several problems in industrial water use.

Problem	pH	Cond	TH*	Fe	Mn	Alk	SO_4	Cl	SiO_2	SS	COD
Corrosion											
Scaling											
Fouling											
Blockages											
Abrasion											
Embrittlement											
Discolouration											
Resin blinding											
Foaming											
Sediment											
Gas production											
Taste/odours											
Precipitates											
Turbidity											
Colour											
Biological growth											

Type of Pollutants
Oxygen-Demanding Substances

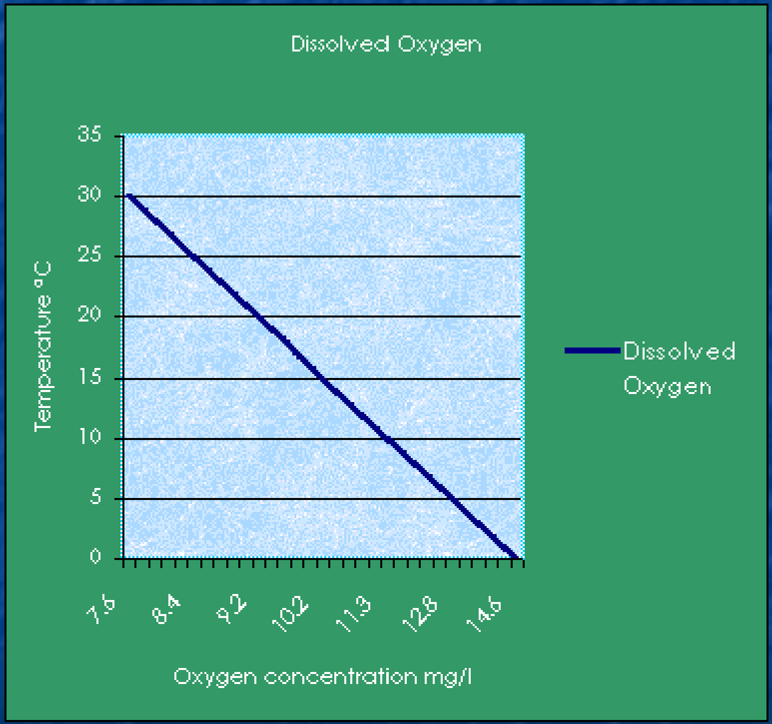
- Dissolved oxygen is a key element in water quality that is necessary to support aquatic life.
- A demand is placed on the natural supply of dissolved oxygen by many pollutants in wastewater. This is called biochemical oxygen demand, or BOD,

- **Organic matter and ammonia** are "oxygen-demanding" substances. **Oxygen-demanding substances are contributed by domestic sewage and agricultural and industrial wastes of both plant and animal origin, such as those from food processing, paper mills, tanning, and other manufacturing processes.**

- These substances are usually destroyed or converted to other compounds by bacteria if there is sufficient oxygen present in the water, but the dissolved oxygen needed to sustain fish life is used up in this break down process.

Dissolved oxygen

- The oxygen dissolves by diffusion from the surrounding air; aeration of water that has tumbled over falls and rapids; and as a waste product of photosynthesis.



As dissolved oxygen levels in water drop below 5.0 mg/l, aquatic life is put under stress.

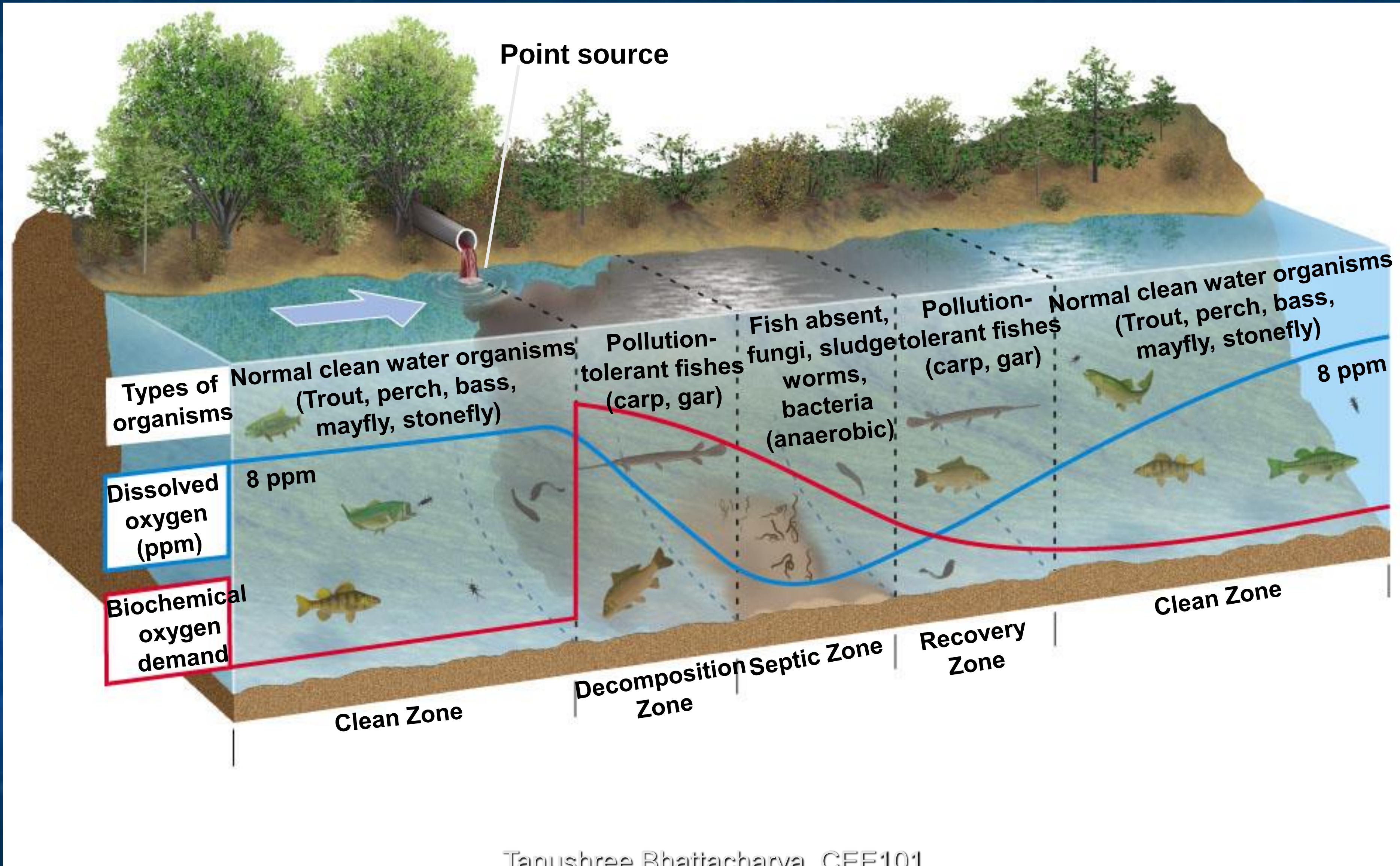
<u>How Dissolved Oxygen Affects Water Supplies</u>

A high DO level in a community water supply is good because it makes drinking water taste better. However, high DO levels speed up corrosion in water pipes. For this reason, industries use water with the least possible amount of dissolved oxygen. Water used in very low pressure boilers have no more than 2.0 ppm of DO, but most boiler plant operators try to keep oxygen levels to 0.007 ppm or less.

Biochemical oxygen demand (**BOD**) is the amount of **dissolved oxygen** needed by aerobic **biological** organisms in a body of water to break down organic material present in a given water sample at certain temperature over a specific time period.
BOD 5 test.
CBOD
NBOD

COD
Chemical oxygen demand (COD) is defined as “a measure of the oxygen equivalent of the organic matter content of a sample that is susceptible to oxidation by a strong chemical oxidant.* ” Trivalent manganese (Mn III) is a strong, non-carcinogenic chemical oxidant that changes quantitatively from purple to faint pink when it reacts with organic matter.

Oxygen sag curve



Pathogens

- **Infectious micro-organisms, or pathogens, may be carried into surface and groundwater by sewage from cities and institutions, by certain kinds of industrial wastes, such as tanning and meat packing plants, and by the contamination of storm runoff with animal wastes from pets, livestock and wild animals, such as geese or deer.**
- Humans may meet these pathogens either by drinking contaminated water or through swimming, fishing, or other contact activities.
- Modern disinfection techniques have greatly reduced the danger of waterborne disease.

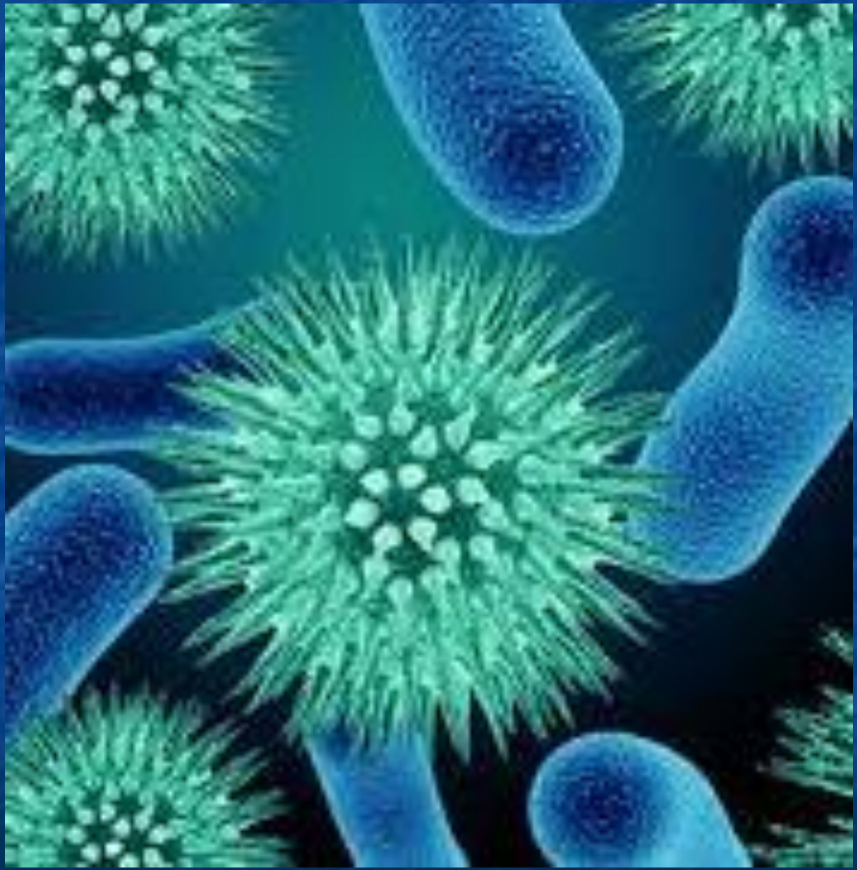


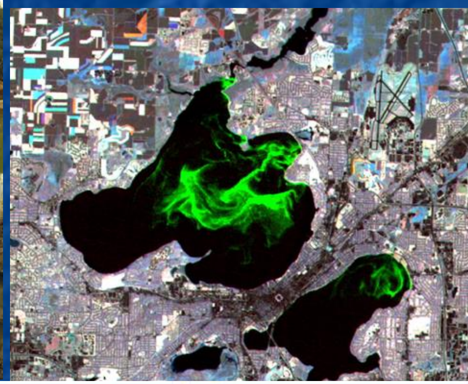
TABLE 5.5 Classification Of Infectious Diseases Associated With Water

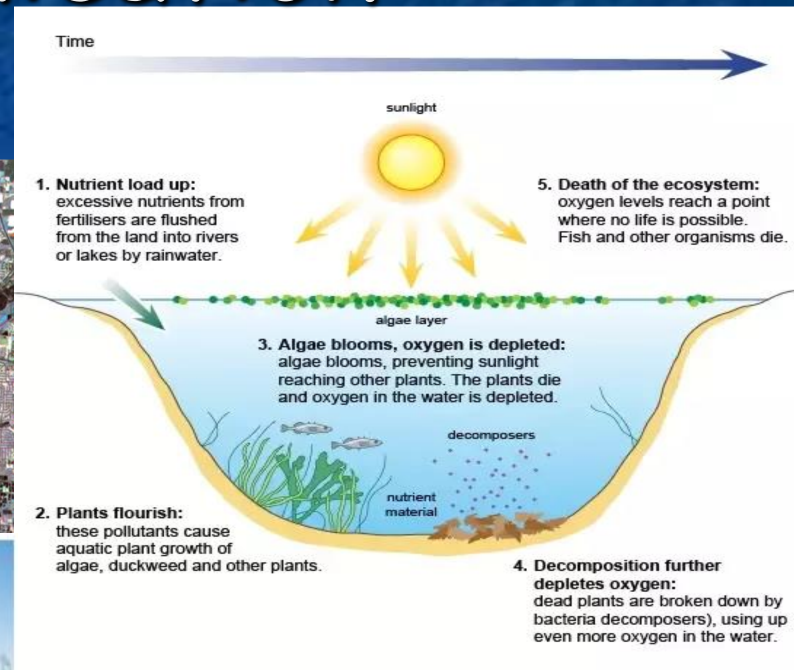
Transmission mechanism	Description	Examples of diseases
Waterborne	Oral ingestion of pathogens in water contaminated by urine or feces	Cholera, typhoid, bacillary dysentery, infectious hepatitis
Water-washed	Disease spread enhanced by scarcity of water making cleanliness difficult	Trachoma, scabia, dysentery, louseborne fever
Water-based	Water provides the habitat for intermediate host organisms, transmission to humans through water contact	Schistosomiasis (bilharziasis), dracunculiasis (guinea worm)
Water-related	Insect vectors (e.g., mosquitoes) rely on water for habitat, but human water contact not needed	Malaria, filariasis, yellow fever onchocerciasis (river blindness), dengue

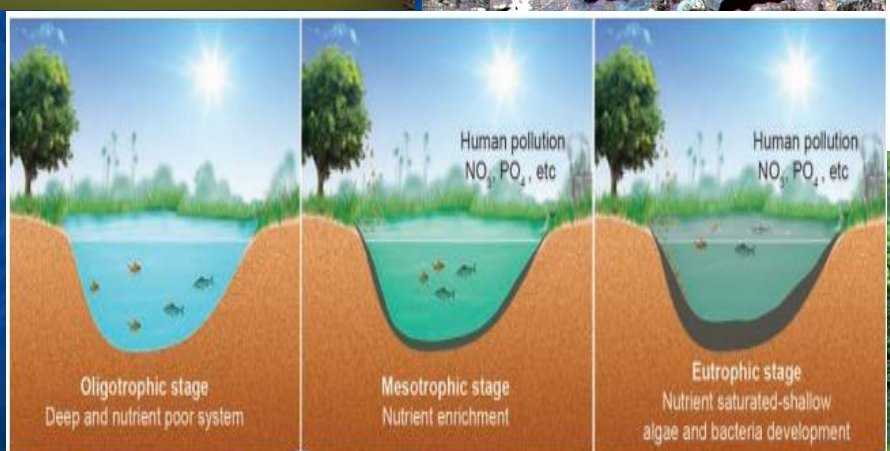
Nutrients

- **Carbon, nitrogen, and phosphorus are essential to living organisms and are the chief nutrients present in natural water.** Large amounts of these nutrients are also present in sewage, certain industrial wastes, and drainage from fertilized land.
- **Conventional secondary biological treatment processes do not remove the phosphorus and nitrogen to any substantial extent -- in fact, they may convert the organic forms of these substances into mineral form, making them more usable by plant life.**
- **When an excess of these nutrients overstimulates the growth of water plants, the result causes** excessive growth of algae. Uncontrolled algae growth blocks out sunlight and chokes aquatic plants and animals by depleting dissolved oxygen in the water at night.
- The release of nutrients in quantities that exceed the affected waterbody's ability to assimilate them results in a condition called eutrophication.

Eutrophication







Stages of Eutrophication

- Causes of Eutrophication
- The availability of nutrients such as nitrogen and phosphorus limits the growth of plant life in an ecosystem. When water bodies are overly enriched with these nutrients, the growth of algae, plankton, and other simple plant life is favoured over the growth of more complex plant life.

- How do Water Bodies Become Overly Enriched?
- Phosphorus is considered one of the primary limiting factors for the growth of plant life in freshwater ecosystems. Several sources also claim that the availability of nitrogen is an important limiting factor for the growth of algae.

- Phosphates tend to stick to the soil and are transported along with it. Therefore, soil erosion is a major contributor to the phosphorus enrichment of water bodies. Some other phosphorus-rich sources that enrich water bodies with the nutrient include:

- Fertilizers
- Untreated sewage
- Detergents containing phosphorus
- Industrial discharge of waste.
- Among these sources, the primary contributors to eutrophication include agriculture and industrial wastes.

- What Happens to the Huge Biomass of Algae in Eutrophic Waters?
- The excessive growth of algae in eutrophic waters is accompanied by the generation of a large biomass of dead algae. These dead algae sink to the bottom of the water body where they are broken down by bacteria, which consume oxygen in the process.
- The overconsumption of oxygen leads to hypoxic conditions (conditions in which the availability of oxygen is low) in the water. The hypoxic conditions at the lower levels of the water body lead to the suffocation and eventual death of larger life forms such as fish.

- **Effects of Eutrophication**
- Primarily, the adverse effects of eutrophication on aquatic bodies include a decrease in biodiversity, increase in toxicity of the water body, and change in species dominance. Some other important effects of this process are listed below.

- Phytoplanktons grow much faster in such situations. These phytoplankton species are toxic and are inedible.
- Gelatinous zooplankton blooms fast in these waters.
- Increased biomass of epiphytic and benthic algae can be observed in eutrophic waters.
- Significant changes arise in the species composition of macrophytes and the biomass.
- The water loses its transparency and develops a bad smell and colour. The treatment of this water becomes difficult.
- Depletion of dissolved oxygen in the water body.
- Frequent fish kill incidents occur and many desirable fish species are removed from the water body.
- The populations of shellfish and harvestable fish are lowered.
- The aesthetic value of the water body diminishes significantly.

Ecological Effects of Eutrophication

Natural standing waters range from ultra oligotrophic to eutrophic with progressive increase in productivity and related parameters. In addition to such general changes, eutrophication also affects the vertical structure of lakes with further implications for the biology of freshwater organisms. The transition from eutrophic to hypertrophic status is usually the result of human activities, and ultimately affects the whole ecological balance of the freshwater system.

Decrease in Biodiversity

When an aquatic ecosystem is enriched with nutrients by either natural or artificial means, the conditions become extremely beneficial to primary producers. Commonly, algae and other similar species utilize these nutrients and a huge increase in their population (algal bloom) is observed.

These algal blooms hinder the flow of sunlight to the bottom of the aquatic body and also cause wide swings in the dissolved oxygen levels in the water.

When the dissolved oxygen in the water reduces to an amount below the hypoxic level, many marine animals suffocate and die. This reduces the effective biodiversity of the water body.

Increase in Water Toxicity

A few algae are toxic to many plants and animals. When these algae bloom in eutrophic waters, they release neurotoxins and hepatotoxins. These toxins can also move up the food chain via shellfish or other marine animals and lead to the death of many animals.

Toxic algal blooms can also be harmful to humans and are the root cause of many cases of neurotoxic, paralytic, and diarrhoetic shellfish poisoning.

- **Invasion of New Species**
- A limiting nutrient corresponding to a water body can be made abundant by the eutrophication process, leading to a shift in the species composition of the aquatic body and the ecosystem surrounding it.

- If a nitrogen deficient water body is suddenly enriched with it, many other competitive species might relocate to the water body and out-compete the original inhabitants of the ecosystem. One such example of a new species invading eutrophic conditions is the common carp, which has adapted to these conditions.

Inorganic and Synthetic Organic Chemicals

- **A vast array of chemicals are included in this category. Examples include detergents, household cleaning aids, heavy metals, pharmaceuticals, synthetic organic pesticides and herbicides, industrial chemicals, and the wastes from their manufacture.**
- Many of these substances are toxic to fish and aquatic life and many are harmful to humans. Some are known to be highly poisonous at very low concentrations. Others can cause taste and odor problems, and many are not effectively removed by conventional wastewater treatment.

Thermal

- Thermal pollution is any deviation from the natural temperature in a habitat and can range from elevated temperatures associated with industrial cooling activities to discharges of cold water into streams below large impoundments.
- Heat reduces the capacity of water to retain oxygen.
- In some areas, water used for cooling is discharged to streams at elevated temperatures from power plants and industries. Even discharges from wastewater treatment plants and storm water retention ponds affected by summer heat can be released at temperatures above that of the receiving water and elevate the stream temperature.
- Unchecked discharges of waste heat can seriously alter the ecology of a lake, a stream, or estuary.

Drinking water standards

- IS 10500 : 2012, amended in 2015.

Table 1 Organoleptic and Physical Parameters
(*Foreword* and *Clause* 4)

Sl No.	Characteristic	Requirement (Acceptable Limit)	Permissible Limit in the Absence of Alternate Source	Method of Test, Ref to Part of IS 3025	Remarks
(1)	(2)	(3)	(4)	(5)	(6)
i)	Colour, Hazen units, *Max*	5	15	Part 4	Extended to 15 only, if toxic substances are not suspected in absence of alternate sources
ii)	Odour	Agreeable	Agreeable	Part 5	a) Test cold and when heated b) Test at several dilutions
iii)	*p*H value	6.5-8.5	No relaxation	Part 11	—
iv)	Taste	Agreeable	Agreeable	Parts 7 and 8	Test to be conducted only after safety has been established
v)	Turbidity, NTU, *Max*	1	5	Part 10	—
vi)	Total dissolved solids, mg/l, *Max*	500	2 000	Part 16	—

Table 2 General Parameters Concerning Substances Undesirable in Excessive Amounts

(*Foreword* and *Clause* 4)

Sl No. (1)	Characteristic (2)	Requirement (Acceptable Limit) (3)	Permissible Limit in the Absence of Alternate Source (4)	Method of Test, Ref to (5)	Remarks (6)
i)	Aluminium (as Al), mg/l, *Max*	0.03	0.2	IS 3025 (Part 55)	—
ii)	Ammonia (as total ammonia-N), mg/l, *Max*	0.5	No relaxation	IS 3025 (Part 34)	—
iii)	Anionic detergents (as MBAS) mg/l, *Max*	0.2	1.0	Annex K of IS 13428	—
iv)	Barium (as Ba), mg/l, *Max*	0.7	No relaxation	Annex F of IS 13428* or IS 15302	—
v)	Boron (as B), mg/l, *Max*	0.5	1.0	IS 3025 (Part 57)	—
vi)	Calcium (as Ca), mg/l, *Max*	75	200	IS 3025 (Part 40)	—
vii)	Chloramines (as Cl_2), mg/l, *Max*	4.0	No relaxation	IS 3025 (Part 26)* or APHA 4500-Cl G	—
viii)	Chloride (as Cl), mg/l, *Max*	250	1 000	IS 3025 (Part 32)	—
ix)	Copper (as Cu), mg/l, *Max*	0.05	1.5	IS 3025 (Part 42)	—
x)	Fluoride (as F) mg/l, *Max*	1.0	1.5	IS 3025 (Part 60)	—
xi)	Free residual chlorine, mg/l, *Min*	0.2	1	IS 3025 (Part 26)	To be applicable only when water is chlorinated. Tested at consumer end. When protection against viral infection is required, it should be minimum 0.5 mg/l
xii)	Iron (as Fe), mg/l, *Max*	0.3	No relaxation	IS 3025 (Part 53)	Total concentration of manganese (as Mn) and iron (as Fe) shall not exceed 0.3 mg/l
xiii)	Magnesium (as Mg), mg/l, *Max*	30	100	IS 3025 (Part 46)	—
xiv)	Manganese (as Mn), mg/l, *Max*	0.1	0.3	IS 3025 (Part 59)	Total concentration of manganese (as Mn) and iron (as Fe) shall not exceed 0.3 mg/l
xv)	Mineral oil, mg/l, *Max*	0.5	No relaxation	Clause **6** of IS 3025 (Part 39) Infrared partition method	—
xvi)	Nitrate (as NO_3), mg/l, *Max*	45	No relaxation	IS 3025 (Part 34)	—
xvii)	Phenolic compounds (as C_6H_5OH), mg/l, *Max*	0.001	0.002	IS 3025 (Part 43)	—
xviii)	Selenium (as Se), mg/l, *Max*	0.01	No relaxation	IS 3025 (Part 56) or	—

xviii)	Selenium (as Se), mg/l, *Max*	0.01	No relaxation	IS 3025 (Part 56) or IS 15303*	—
xix)	Silver (as Ag), mg/l, *Max*	0.1	No relaxation	Annex J of IS 13428	—
xx)	Sulphate (as SO_4) mg/l, *Max*	200	400	IS 3025 (Part 24)	May be extended to 400 provided that Magnesium does not exceed 30
xxi)	Sulphide (as H_2S), mg/l, *Max*	0.05	No relaxation	IS 3025 (Part 29)	—
xxii)	Total alkalinity as calcium carbonate, mg/l, *Max*	200	600	IS 3025 (Part 23)	—
xxiii)	Total hardness (as $CaCO_3$), mg/l, *Max*	200	600	IS 3025 (Part 21)	—
xxiv)	Zinc (as Zn), mg/l, *Max*	5	15	IS 3025 (Part 49)	—

Table 3 Parameters Concerning Toxic Substances
(*Foreword* and *Clause* 4)

Sl No.	Characteristic	Requirement (Acceptable Limit)	Permissible Limit in the Absence of Alternate Source	Method of Test, Ref to	Remarks
(1)	(2)	(3)	(4)	(5)	(6)
i)	Cadmium (as Cd), mg/l, *Max*	0.003	No relaxation	IS 3025 (Part 41)	—
ii)	Cyanide (as CN), mg/l, *Max*	0.05	No relaxation	IS 3025 (Part 27)	—
iii)	Lead (as Pb), mg/l, *Max*	0.01	No relaxation	IS 3025 (Part 47)	—
iv)	Mercury (as Hg), mg/l, *Max*	0.001	No relaxation	IS 3025 (Part 48)/ Mercury analyser	—
v)	Molybdenum (as Mo), mg/l, *Max*	0.07	No relaxation	IS 3025 (Part 2)	—
vi)	Nickel (as Ni), mg/l, *Max*	0.02	No relaxation	IS 3025 (Part 54)	—
vii)	Pesticides, µg/l, *Max*	See Table 5	No relaxation	See Table 5	—
viii)	Polychlorinated biphenyls, mg/l, *Max*	0.000 5	No relaxation	ASTM 5175*	— or APHA 6630
ix)	Polynuclear aromatic hydro-carbons (as PAH), mg/l, *Max*	0.000 1	No relaxation	APHA 6440	—
x)	Total arsenic (as As), mg/l, *Max*	0.01	0.05	IS 3025 (Part 37)	—
xi)	Total chromium (as Cr), mg/l, *Max*	0.05	No relaxation	IS 3025 (Part 52)	—
xii)	Trihalomethanes:				
	a) Bromoform, mg/l, *Max*	0.1	No relaxation	ASTM D 3973-85* or APHA 6232	—
	b) Dibromochloromethane, mg/l, *Max*	0.1	No relaxation	ASTM D 3973-85* or APHA 6232	—
	c) Bromodichloromethane, mg/l, *Max*	0.06	No relaxation	ASTM D 3973-85* or APHA 6232	—
	d) Chloroform, mg/l, *Max*	0.2	No relaxation	ASTM D 3973-85* or APHA 6232	—

limit in the absence of alternate source' in col 4, above which the sources will have to be rejected.

Table 4 Parameters Concerning Radioactive Substances

(*Foreword* and *Clause* 4)

Sl No.	Characteristic	Requirement (Acceptable Limit)	Permissible Limit in the Absence of Alternate Source	Method of Test, Ref to Part of IS 14194	Remarks
(1)	(2)	(3)	(4)	(5)	(6)
i)	Radioactive materials:				
	a) Alpha emitters Bq/l, *Max*	0.1	No relaxation	Part 2	—
	b) Beta emitters Bq/l, *Max*	1.0	No relaxation	Part 1	—

NOTE — It is recommended that the acceptable limit is to be implemented. Values in excess of those mentioned under 'acceptable' render the water not suitable, but still may be tolerated in the absence of an alternative source but up to the limits indicated under 'permissible limit in the absence of alternate source' in col 4, above which the sources will have to be rejected.

Table 5 Pesticide Residues Limits and Test Method

(*Foreword* and *Table* 3)

Sl No.	Pesticide	Limit µg/l	Method of Test, Ref to	
			USEPA	AOAC/ ISO
(1)	(2)	(3)	(4)	(5)
i)	Alachlor	20	525.2, 507	—
ii)	Atrazine	2	525.2, 8141 A	—
iii)	Aldrin/ Dieldrin	0.03	508	—
iv)	Alpha HCH	0.01	508	—
v)	Beta HCH	0.04	508	—
vi)	Butachlor	125	525.2, 8141 A	—
vii)	Chlorpyriphos	30	525.2, 8141 A	—
viii)	Delta HCH	0.04	508	—
ix)	2,4- Dichlorophenoxyacetic acid	30	515.1	—
x)	DDT (*o, p* and *p, p* – Isomers of DDT, DDE and DDD)	1	508	AOAC 990.06
xi)	Endosulfan (alpha, beta, and sulphate)	0.4	508	AOAC 990.06
xii)	Ethion	3	1657 A	—
xiii)	Gamma — HCH (Lindane)	2	508	AOAC 990.06
xiv)	Isoproturon	9	532	—
xv)	Malathion	190	8141 A	—
xvi)	Methyl parathion	0.3	8141 A	ISO 10695
xvii)	Monocrotophos	1	8141 A	—
xviii)	Phorate	2	8141 A	—

NOTE — Test methods are for guidance and reference for testing laboratory. In case of two methods, USEPA method shall be the reference method.

Table 6 Bacteriological Quality of Drinking Water[1]
(*Clause* 4.1.1)

Sl No. (1)	Organisms (2)	Requirements (3)
i)	*All water intended for drinking*:	
	a) *E. coli* or thermotolerant coliform bacteria[2, 3]	Shall not be detectable in any 100 ml sample
ii)	*Treated water entering the distribution system*:	
	a) *E. coli* or thermotolerant coliform bacteria[2]	Shall not be detectable in any 100 ml sample
	b) Total coliform bacteria	Shall not be detectable in any 100 ml sample
iii)	*Treated water in the distribution system*:	
	a) *E. coli* or thermotolerant coliform bacteria	Shall not be detectable in any 100 ml sample
	b) Total coliform bacteria	Shall not be detectable in any 100 ml sample

[1] Immediate investigative action shall be taken if either *E.coli* or total coliform bacteria are detected. The minimum action in the case of total coliform bacteria is repeat sampling; if these bacteria are detected in the repeat sample, the cause shall be determined by immediate further investigation.

[2] Although, *E. coli* is the more precise indicator of faecal pollution, the count of thermotolerant coliform bacteria is an acceptable alternative. If necessary, proper confirmatory tests shall be carried out. Total coliform bacteria are not acceptable indicators of the sanitary quality of rural water supplies, particularly in tropical areas where many bacteria of no sanitary significance occur in almost all untreated supplies.

[3] It is recognized that, in the great majority of rural water supplies in developing countries, faecal contamination is widespread. Under these conditions, the national surveillance agency should set medium-term targets for progressive improvement of water supplies.

Water Parameters	Health Effects	Other Effects
Temperature	Regulates biochemical and metabolic reactions.	Affects photosynthesis, dissolved oxygen.
pH	Gastrointestinal irritation.	Affects enzyme kinetics; corrosive; affects aquatic life.
TDS	Affects kidney and heart functioning, laxative or constipation effects, gastrointestinal irritation.	Corrosive to water-supply systems; causes hardness.
Hardness	Skin irritation; worsens some health conditions (cancer, diabetes, etc.).	Poor lather with detergent; cloth quality deterioration.
Mg	Deficiency- hypertension, cardiac and cardiovascular diseases, diabetes mellitus, osteoporosis.	Poor lather with detergent; cloth quality deterioration.
Ca	Deficiency- osteoporosis, hypertension.	Poor lather with detergent; cloth quality deterioration.
Cl^-	Laxative effects.	Corrosive; deleterious effects on plants, can clog soil pores if it is in dissolved condition.
NO_3^-	Methemoglobinemia in infants.	Algal bloom; adverse impacts on aquatic life.
PO_4^{3-}	Digestive problems.	Eutrophication.
SO_4^{2-}	Laxative effects, gastrointestinal irritation.	Acid rain; associated with acid mine drainage; corrosive.
Na	Hypertension, heart diseases, kidney related problems.	Can impart salinity hazard in soil if it is used for irrigation purpose.
Al	Kidney disorders, neurological problems.	Prevents nutrient intake by roots; interferes with gill functioning.
Heavy metals	Most of the heavy metals affect liver and kidney functioning; ATPase inhibitor; degrades enzyme transport.	Most of the heavy metals affects soil microbial activity; deleterious impact on plants; ROS production (stress).

Biological Oxygen Demand	High BOD levels- hazardous.	Affects water quality and effluent biodegradability.
Chemical Oxygen Demand	Correlated to ill effect on human health (algal blooms, sea food contamination).	Hypoxic water reduces cell functioning, death of aquatic organisms.
Bacteria	Causes dysentery (Salmonella), cholera (Vibrio), typhoid (Salmonella).	Some aquatic animals affected similar to human beings; indicates DO, BOD.
Protozoa	Causes amoebiasis (Entamoeba histolytica), giardiasis (Giardia lamblia).	Affects plant growth; causes illness in various animals like horse, zebra, dog etc.
Virus	Causes SARS (Coronavirus), hepatitis A, polio (Poliovirus), common cold.	Affects various animals, plants and even bacteria.
Algae	Causes Desmodesmus infection; produces toxic compounds (e.g.- Anaebaena and Nostoc).	Algal bloom; disrupts photosynthesis in aquatic plants and phytoplankton; affects water colour, odour and taste.
Helminths	Causes schistosomiasis (Schistosoma japonicum), cysticercosis (Cysticercus cellulosae).	Many animals are hosts to such helminths such as pig, sheep etc.
Pathogenic indicators (e.g.- Escherichia coli)	Mostly harmless; diarrhoea, vomiting, abdominal cramps.	Mostly harmless; Can contaminate young plants; Animals could act as its carrier.

What is Water Quality index?

To get a comprehensive picture of the overall quality of groundwater or surface water, the WQI is used.

WQI is defined as a rating reflecting the composite influence of different water quality parameters on the overall quality of water.

The Indian standard specified for drinking water (BIS, 1991) is used for the calculation of WQI.

WQI

- Water Quality Index (WQI) is considered as the most effective method of measuring water quality. A number of water quality parameters are included in a mathematical equation to rate water quality, determining the suitability of water for drinking

- The index was first developed by Horton in 1965 to measure water quality by using 10 most regularly used water parameters.
- The method was subsequently modified by different experts. These indices used water quality parameters which vary by number and types.
- The weights in each parameter are based on its respective standards, and the assigned weight indicates the parameter's significance and impacts on the index.

Calculation

- A usual WQI method follows three steps which include

(1) selection of parameters,

(2) determination of quality function for each parameter, and

(3) aggregation through mathematical equation

The index provides a single number that represents overall water quality at a certain location and time based on some water parameters.

The index enables comparison between different sampling sites.

The single-value output of this index, derived from several parameters, provides important information about water quality that is easily interpretable, even by lay people

Chemical parameters[a]	Indian Standard[b]	Weight (w_i)	Relative weight (W_i) $W_i = \frac{w_i}{\sum_{i=1}^{n} w_i}$
pH	6.5–8.5	4	0.0952
Total dissolved solids (TDS)	500–2000	4	0.0952
Total hardness (TH)	300–600	2	0.0476
Bicarbonate	244–732	3	0.0714
Chloride	250–1000	3	0.0714
Sulphate	200–400	4	0.0952
Nitrate	45–100	5	0.1190
Fluoride	1–1.5	4	0.0952
Calcium	75–200	2	0.0476
Magnesium	30–100	2	0.0476
Iron	0.3–1.0	4	0.0952
Manganese	0.1–0.3	4	0.0952
Zinc	5–15	1	0.0238
		$\sum w_i = 42$	$\sum W_i = 1.000$

[a] Chemical parameters in mg/L.

[b] Lower value indicates desirable limit, and higher value indicates permissible limit in absence of alternate source (Bureau of Indian Standards, 1991).

Second, the relative weight (Wi) of the chemical parameter was computed using the following equation:

$$W_i = \frac{w_i}{\sum_{i=1}^{n} w_i}$$

Where,

W_i is the relative weight,
w_i is the weight of each parameter, and
n is the number of parameters.

Calculated relative weight (W_i) values of each parameter are given in Table 2. In the third step, a quality rating scale (q_i) for each parameter is assigned by dividing its concentration in each water sample by its respective standard according to guidelines (BIS, 1991), and the result is multiplied by 100:

$$q_i = (C_i/S_i) \times 100$$

Where,

q_i is the quality rating,
C_i is the concentration of each chemical parameter in each water sample in mg/L, and
S_i is the Indian drinking water standard for each chemical parameter in mg/L.

For computing WQI, the sub index (SI) is first determined for each chemical parameter, as given below:

$$SI_i = W_i \times q_i$$

$$WQI = \sum SI_{i-n}$$

Where,

SI_i is the sub index of ith parameter;
W_i is relative weight of ith parameter;
q_i is the rating based on concentration of ith parameter, and
n is the number of chemical parameters.

The computed WQI values are classified into five categories: excellent water (WQI < 50); good water (WQI $= 50–100$); poor water (WQI $= 100–200$); very poor water (WQI $= 200–300$); and water unsuitable for drinking (WQI > 300).

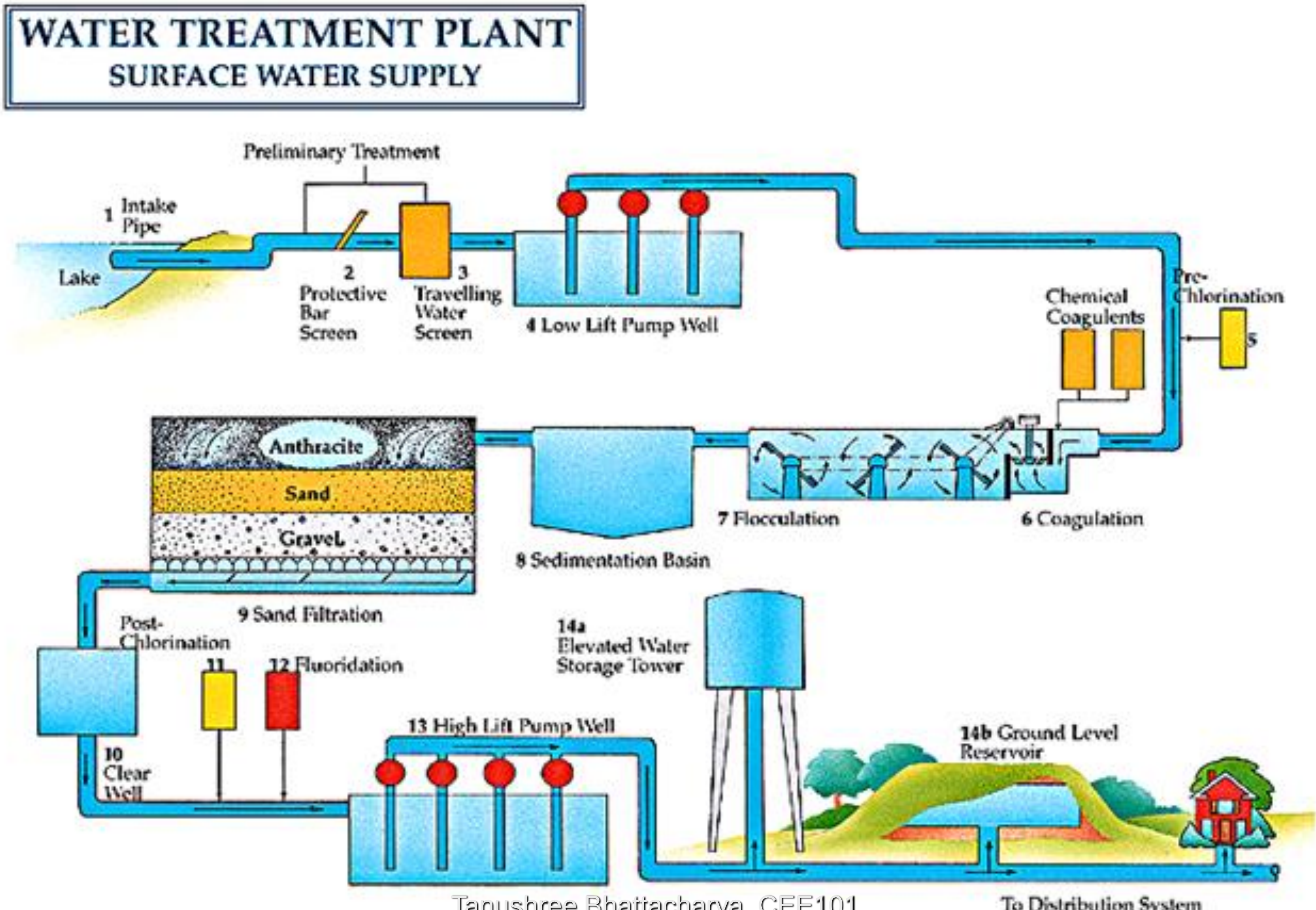
Calculate wqi for the following dataset

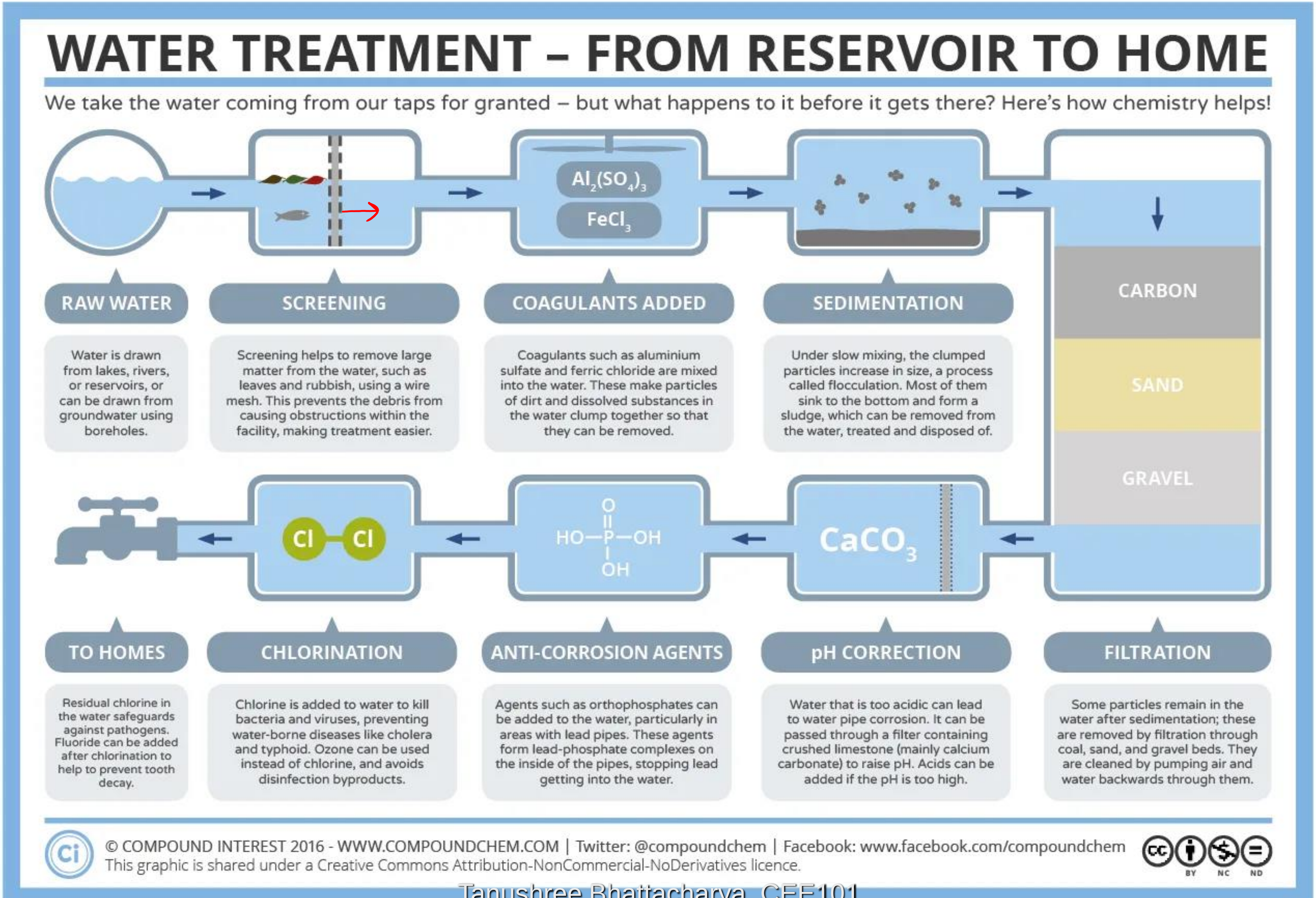
- pH=6.61, TDS=70, TH=70
  Bicarbonate 45
  Chloride 4.9
  Sulphate 1.5
  Nitrate 261
  Fluoride 1.43
  Calcium 1.60
  Magnesium 0.24
  Iron 1.95
  All units except pH is in mg/l

Water treatment

Indian Standards for Discharge of Sewage in Surface Waters

Characteristic of the Effluent	**Tolerance *limit for Discharge of Sewage in Suface Water Sources***
BOD_5	30 mg/L
COD	250
TSS	100 mg/L


WATER TREATMENT PLANT
SURFACE WATER SUPPLY
Preliminary Treatment
1 Intake Pipe
Lake
2 Protective Bar Screen
3 Travelling Water Screen
4 Low Lift Pump Well
Chemical Coagulents
Pre-Chlorination
5
6 Coagulation
7 Flocculation
8 Sedimentation Basin
Anthracite
Sand
Gravel
9 Sand Filtration
Post-Chlorination
10 Clear Well
11
12 Fluoridation
13 High Lift Pump Well
14a Elevated Water Storage Tower
14b Ground Level Reservoir
To Distribution System


WATER TREATMENT – FROM RESERVOIR TO HOME
We take the water coming from our taps for granted – but what happens to it before it gets there? Here's how chemistry helps!
$Al_2(SO_4)_3$
$FeCl_3$
CARBON
SAND
GRAVEL
RAW WATER
Water is drawn from lakes, rivers, or reservoirs, or can be drawn from groundwater using boreholes.
SCREENING
Screening helps to remove large matter from the water, such as leaves and rubbish, using a wire mesh. This prevents the debris from causing obstructions within the facility, making treatment easier.
COAGULANTS ADDED
Coagulants such as aluminium sulfate and ferric chloride are mixed into the water. These make particles of dirt and dissolved substances in the water clump together so that they can be removed.
SEDIMENTATION
Under slow mixing, the clumped particles increase in size, a process called flocculation. Most of them sink to the bottom and form a sludge, which can be removed from the water, treated and disposed of.
Cl—Cl
HO—P—OH
O
OH
$CaCO_3$
TO HOMES
Residual chlorine in the water safeguards against pathogens. Fluoride can be added after chlorination to help to prevent tooth decay.
CHLORINATION
Chlorine is added to water to kill bacteria and viruses, preventing water-borne diseases like cholera and typhoid. Ozone can be used instead of chlorine, and avoids disinfection byproducts.
ANTI-CORROSION AGENTS
Agents such as orthophosphates can be added to the water, particularly in areas with lead pipes. These agents form lead-phosphate complexes on the inside of the pipes, stopping lead getting into the water.
pH CORRECTION
Water that is too acidic can lead to water pipe corrosion. It can be passed through a filter containing crushed limestone (mainly calcium carbonate) to raise pH. Acids can be added if the pH is too high.
FILTRATION
Some particles remain in the water after sedimentation; these are removed by filtration through coal, sand, and gravel beds. They are cleaned by pumping air and water backwards through them.
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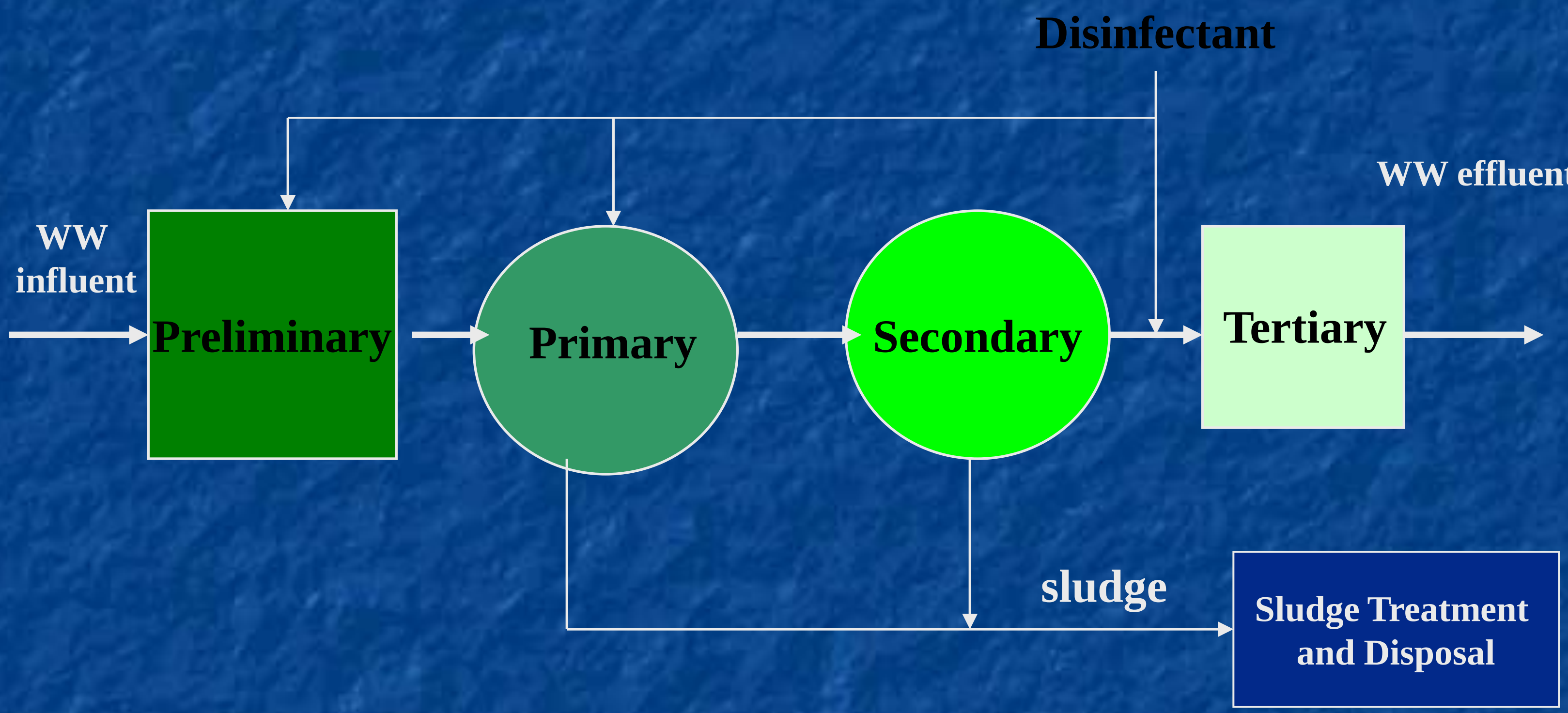
BY NC ND

Wastewater Treatment Scheme



Wastewater treatment processes:

- Preliminary treatment is a physical process that removes large contaminants.
- Primary treatment involves physical sedimentation of particulates.
- Secondary treatment involves physical and biological treatment to reduce organic load of wastewater.
- Tertiary or advanced treatments.

Preliminary Treatment

As wastewater enters a treatment facility, it typically flows through a step called preliminary treatment. A screen removes **large floating objects, such as rags, cans, bottles and sticks that may clog pumps, small pipes, and down stream processes.**

- **Coarse screens** remove large solids, rags, and debris from wastewater, and typically have openings of 6 mm (0.25 in) or larger.
- Typical opening sizes for **fine screens** are 1.5 to 6 mm (0.06 to 0.25 in).
- **Very fine screens** with openings of 0.2 to 1.5 mm (0.01 to 0.06 in)

Screens are generally placed in a chamber or channel and inclined towards the flow of the wastewater. The inclined screen allows debris to be caught on the upstream surface of the screen, and allows access for manual or mechanical cleaning.

Some plants use devices known as comminutors or barminutors which combine the functions of a screen and a grinder. These devices catch and then cut or shred the heavy solid and floating material. In the process, the pulverized matter remains in the wastewater flow to be removed later in a primary settling tank.

Screens

- (a) Coarse Screen :- The spacings of bars are more than 40 mm center to center.
- (b) Medium Screen: The spacing are less than 40mm.
- (c) Fine Screen: The spacings vary from 1.5 mm to 6 mm.
- The screens may be fixed or movable. the inclination of the screen varies from 30° to 60° . The screens are placed at designed inclination in an oblong rectangular chamber. The ends of the chamber are tapered. It is constructed with brick masonry.
- The inner surfaces are plastered and finished with neat cement polish. A perforated rectangular channel is provided at the top of the screen for the collection of floating debrises.

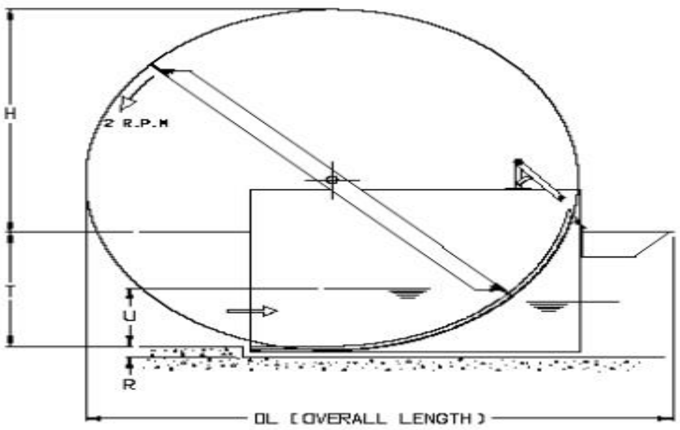
Velocity

- The velocity of flow ahead of and through the screen varies and affects its operation.
- Velocities of ***0.6 to 1.2 mps through the open area for the peak flows*** have been used satisfactorily.
- Further, the velocity at low flows in the approach channel should ***not be less than 0.3 mps*** to avoid deposition of solids.

STP

Screening

STP

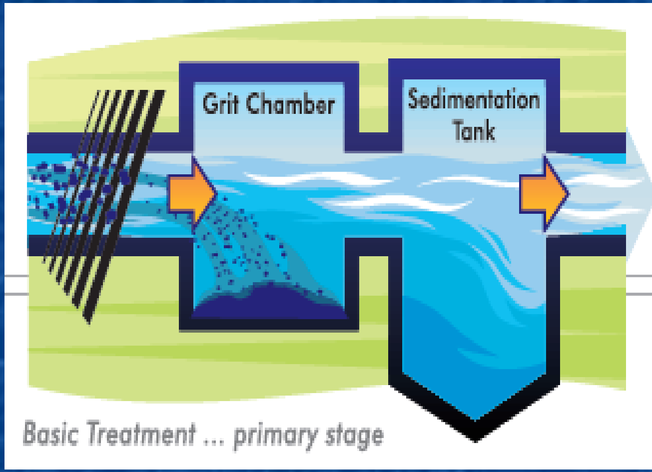


ARC BAR SCREEN

Grit Removal

After the wastewater has been screened, it may flow into a grit chamber where sand, grit, cinders, and small stones settle to the bottom. Removing the grit and gravel that washes off streets or land during storms is very important, especially in cities with combined sewer systems.

Large amounts of grit and sand entering a treatment plant can cause serious operating problems, such as excessive wear of pumps and other equipment, clogging of aeration devices, or taking up capacity in tanks that is needed for treatment.



In some plants, another finer screen is placed after the grit chamber to remove any additional material that might damage equipment or interfere with later processes. The grit and screenings removed by these processes must be periodically collected and trucked to a landfill for disposal or are incinerated.

Grit Chambers

Grit chambers are like sedimentation tanks, designed to separate the intended heavier inorganic materials (specific gravity about 2.65) and to pass forward the lighter organic materials

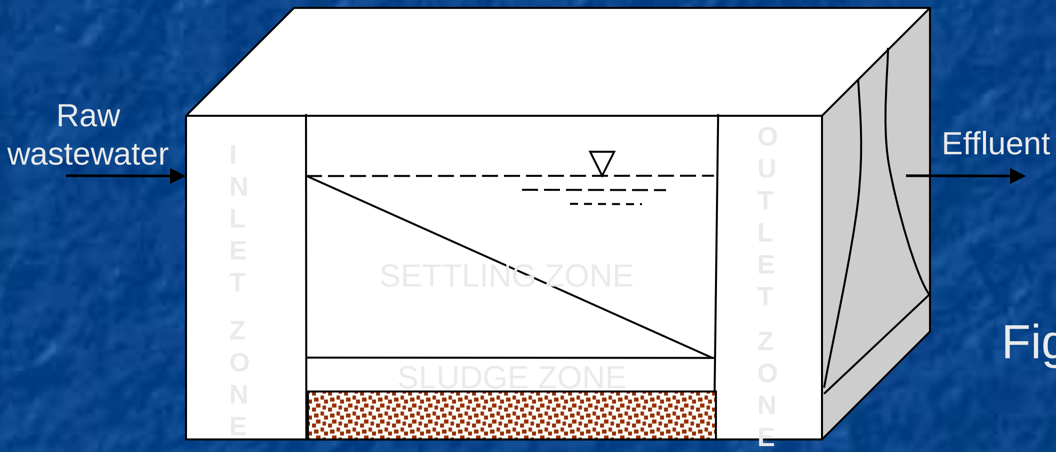


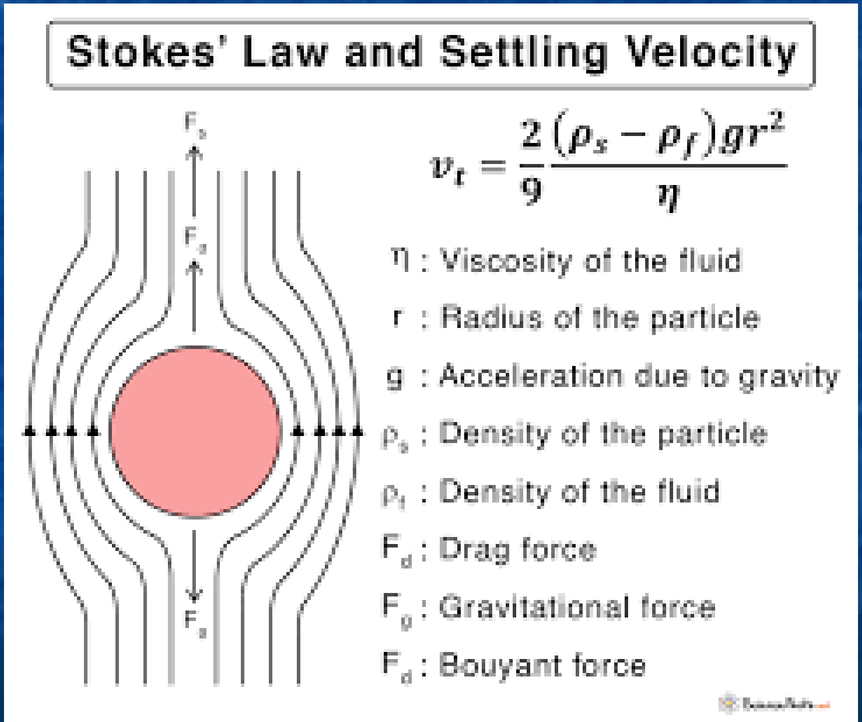
Figure : Typical View of Grit Channel

Types of Velocity Control Devices

- A sutro weir in a channel of rectangular cross section, with free fall downstream of the channel
- A parabolic shaped channel with a rectangular weir
- A rectangular shaped channel with a parshall flume at the end which would also help easy flow measurement

Design of Grit Chambers

- Settling Velocity



Grit Removal

Primary treatment

- Primary Treatment The initial stage in the treatment of domestic wastewater is known as primary treatment. Coarse solids are removed from the wastewater in the primary stage of treatment. In some treatment plants, primary and secondary stages may be combined into one basic operation. At many wastewater treatment facilities, influent passes through preliminary treatment units before primary and secondary treatment begins.

Primary sedimentation

- Primary Sedimentation With the screening completed and the grit removed, wastewater still contains dissolved organic and inorganic constituents along with suspended solids. **The suspended solids consist of minute particles of matter that can be removed from the wastewater with further treatment such as sedimentation or gravity settling, chemical coagulation, or filtration. Pollutants that are dissolved or are very fine and remain suspended in the wastewater are not removed effectively by gravity settling.**
- When the wastewater enters a sedimentation tank, it slows down, and the suspended solids gradually sink to the bottom. This mass of solids is called **primary sludge**. Various methods have been devised to remove primary sludge from the tanks. Newer plants have some type of mechanical equipment to remove the settled solids from sedimentation tanks. Some plants remove solids continuously while others do so at intervals.

Sedimentation

The objective of primary settling tank is to remove the large size suspended organic solids present in the wastewater whose specific gravity is more than 1.

- Factors affecting settling of particles
- Flow velocity
- Shape and size of particle
- Viscosity

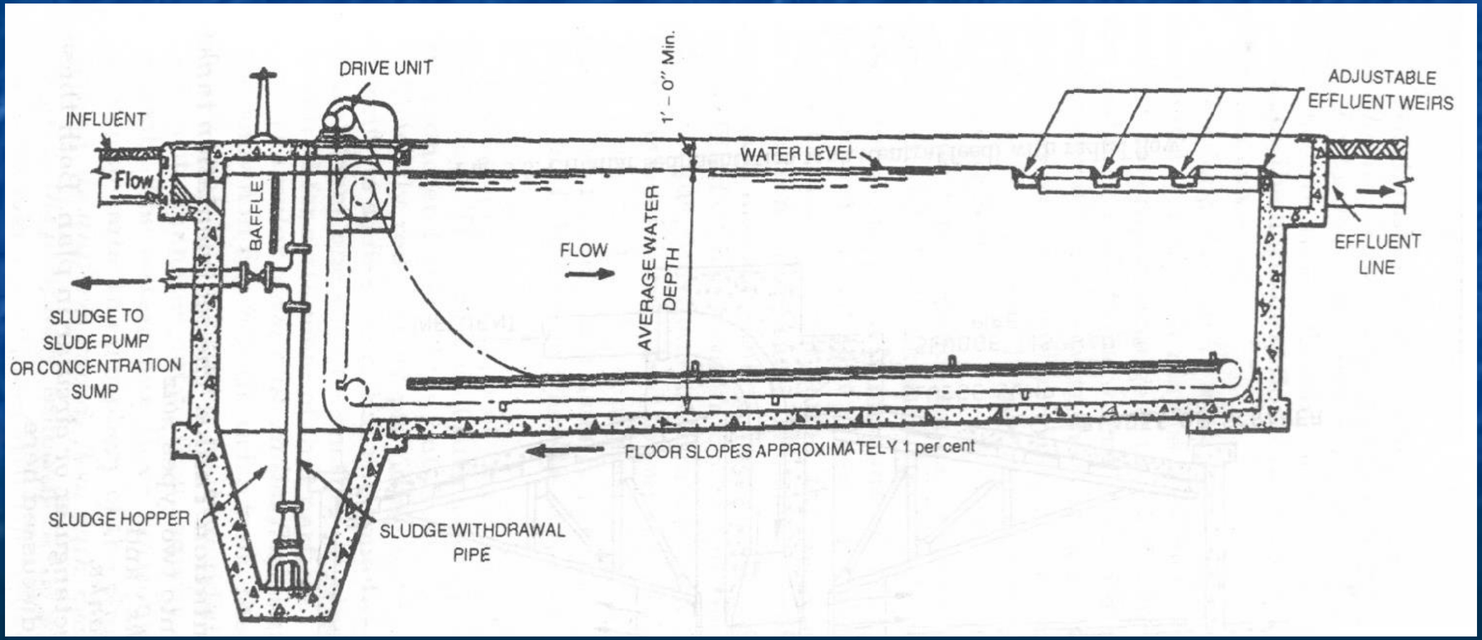


Figure: Typical view of primary settling tank

REMOVAL OF OIL & GREASE

Present day oil separators are provided with inclined plates (plate settlers) which improve their performance considerably. Such separators are available from several vendors to whom the size and specific gravity of the oil globules desired to be removed and their performance efficiency need to be specified.

Removal of free oil and grease from a wastewater stream reduces the potential for equipment problems to occur further downstream. There are three forms of oil encountered in wastewater treatment at a refinery. They are:

Free Oil or floating oil is removed by either skimming the surface in the skim tank or by gravity separation in the API separator.

Emulsified Oil is comprised of oil droplets in stable suspension within the wastewater. Removal requires chemical addition to lower the pH followed by addition of dissolved oxygen or nitrogen to remove the emulsified oils as they break free from the wastewater.

Dissolved Oil is a true molecular solution within the water and can only be removed with biological treatment.

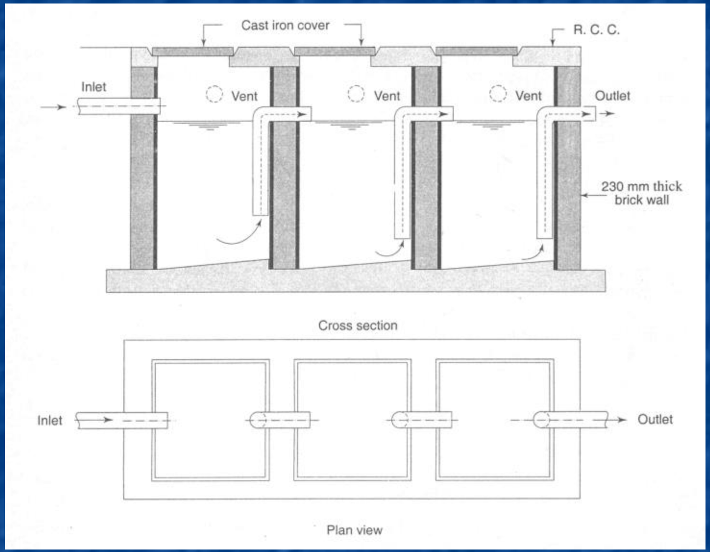


Figure: Oil & Grease Trap for Intercepting Oil and Grease at the Source

Coagulation and flocculation

They occur in successive steps intended to overcome the forces stabilizing the suspended particles, allowing particle collision and growth of floc. If step one is incomplete, the following step will be unsuccessful.

COAGULATION

The first step destabilizes the particle's charges. Coagulants with charges opposite those of the suspended solids are added to the water to neutralize the negative charges on dispersed non-settlable solids such as clay and color-producing organic substances.

Once the charge is neutralized, the small suspended particles are capable of sticking together. The slightly larger particles, formed through this process and called micro-flocs, are not visible to the naked eye. The water surrounding the newly formed micro-flocs should be clear. If it is not, all the particles' charges have not been neutralized, and coagulation has not been carried to completion. More coagulant may need to be added.

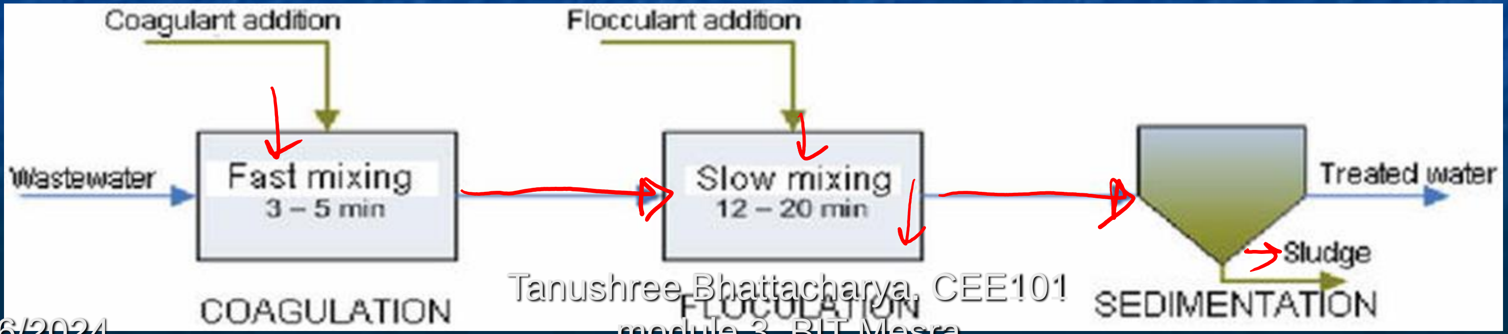
A high-energy, rapid-mix to properly disperse the coagulant and promote particle collisions is needed to achieve good coagulation. Over-mixing does not affect coagulation, but insufficient mixing will leave this step incomplete. Coagulants should be added where sufficient mixing will occur. Proper contact time in the rapid-mix chamber is typically 1 to 3 or max 5 minutes.

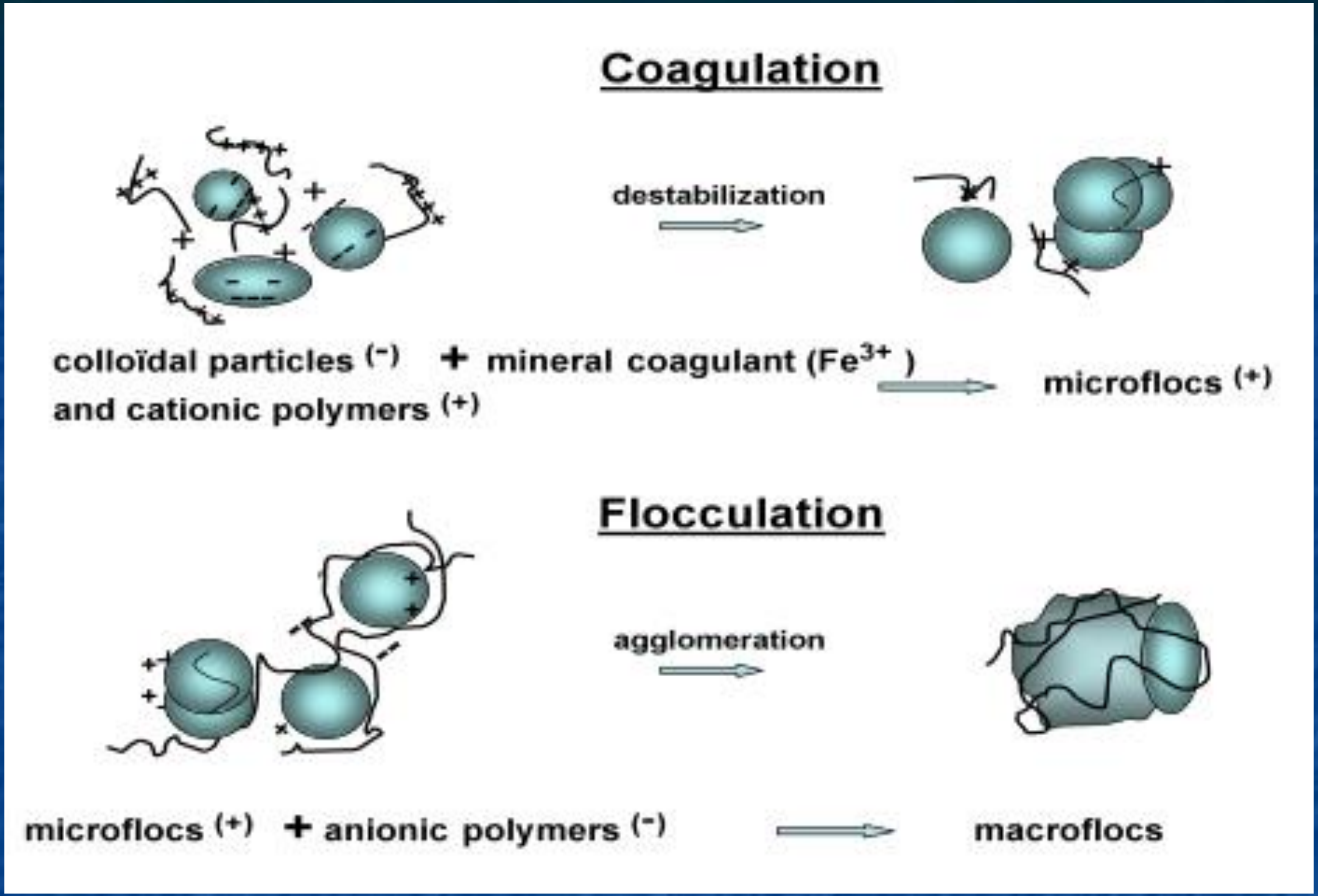
FLOCCULATION

Following the first step of coagulation, a second process called flocculation occurs. Flocculation, a gentle mixing stage, increases the particle size from submicroscopic microfloc to visible suspended particles.

The microflocs are brought into contact with each other through the process of slow mixing. Collisions of the microfloc particles cause them to bond to produce larger, visible flocs called pinflocs. The floc size continues to build through additional collisions and interaction with inorganic polymers formed by the coagulant or with organic polymers added. Macroflocs are formed. High molecular weight polymers, called coagulant aids, may be added during this step to help bridge, bind, and strengthen the floc, add weight, and increase settling rate. Once the floc has reached it optimum size and strength, the water is ready for the sedimentation process.

Design contact times for flocculation range from 15 or 20 minutes to an hour or more.





Flocs start to form during the neutralization step as particle collisions occur. ... Sweep **flocculation** occurs when colloidal contaminants are entrained or swept down by the precipitates as they settle in the suspension. The **optimal pH** range for **coagulation** is 6 to 7 when using alum and 5.5 to 6.5 when using iron.

Commonly used coagulant and flocculants

Name	Advantages	Disadvantages
Aluminiumsulphate (Alum) $Al_2(SO_4)_3 \cdot {}_{18}H_2O$	Easy to handle and apply; most commonly used; produces less sludge than lime; most effective between pH 6.5 and 7.5	Adds dissolved solids (salts) to waster; effective over a limited pH range.
Sodium Aluminate $Na_2Al_2O_4$	Effective in hard waters; small dosage usually needed	Often used with alum; high cost; ineffective in soft waters
Polyaluminium Chloride (PAC) $Al_{13}(OH)_{20}(SO)_4.Cl_{15}$	In some applications, Floc, formed is more dense and faster settling than alum	Not commonly used; little full scale data compared to other aluminium derivatives
Ferric Sulfate $Fe_2(SO_4)_3$	Effective between pH 4-6 and 8.8-9.2	Ads dissolved solids(salts) to water; usually need to add alkalinity
Ferric Chloride $FeCl_3.6H_2O$	Effective between pH 4 and 11	Adds dissolved solids (salts) to water; consumes twice as much alkalinity as alum
Ferrous Sufate (Copperas) $FeSO_4.7H_2O$	Not as pH sensitive as lime	Ads dissolved solids(salts) to water; usually need to add alkalinity
Lime $Ca(OH)_2$	Commonly used; very effective; may not add salts to effluent	pH dependent; produces large quantities of sludge; overdose can result in poor effluent quality

The following natural products are used as flocculants:
Chitosan.
Isinglass.
Moringa oleifera seeds (Horseradish Tree)
Gelatin.
Strychnos potatorum seeds (Nirmali nut tree)
Guar gum.
Alginates (brown seaweed extracts)
Apart from these, polymers or polyelectrolytes originating from starches and alginates are also used as flocculants.

Clarification

Clarification is the removal of suspended solids and floc from chemically treated water, before its application to filters.

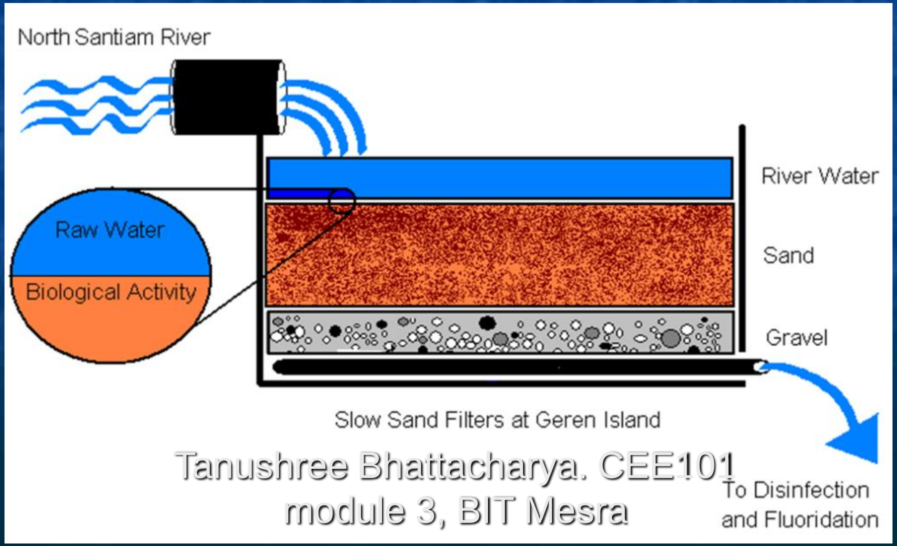
Filtration –a part of tertiary treatment but used after primary treatment for municipal or industrial water supply

What happens to water during filtration? The second step in a conventional water treatment system is filtration, which removes particulate matter from water by forcing the water to pass through porous media. The filtration system consists of filters with varying sizes of pores, and is often made up of sand, gravel and charcoal. The diameter of a grain of fine sand is approximately 0.1 millimetre, so only particles with diameters less than 0.1 millimetre would pass through the fine sand layer. Filtration would not be able to produce safe drinking water, if many contaminants are much smaller than 0.1 millimetre (such as viruses, which can be as small as 0.000001 millimetre in diameter).

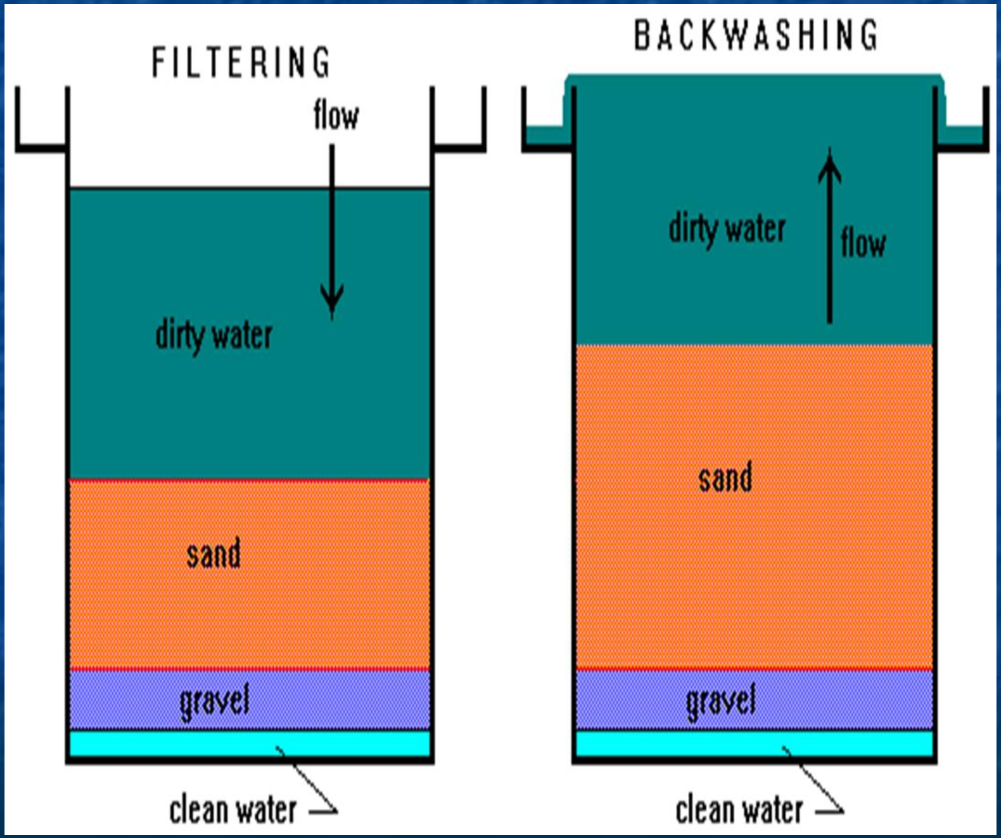
There are two basic types of sand filtration:
Slow sand filtration and
Rapid sand filtration

Slow sand filtration is a biological process, because it uses bacteria to treat the water. The bacteria establish a community on the top layer of sand and clean the water as it passes through, by digesting the contaminants in the water. The layer of microbes is called a schumtzdecke (or biofilm), and requires cleaning every couple of months, when it gets too thick and the flow rate declines. After the schumtzdecke is removed, the bacteria must be allowed several days to reestablish a community before filtering can resume.

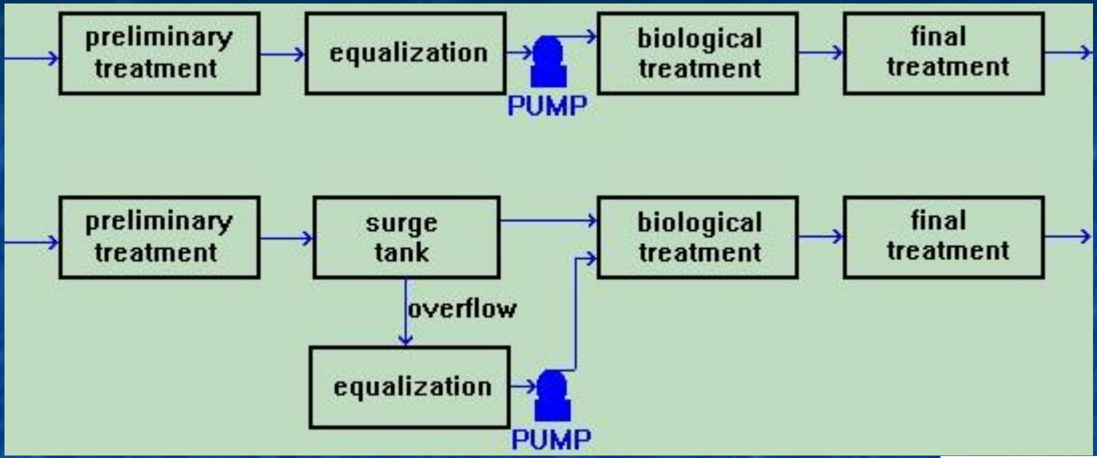
Slow sand filtration systems have been used for many years; the first systems operated in London in the 19th century. However, slow sand filtration systems require large areas of land to operate, because the flow rate of the water is between 0.1 and 0.3 metrecube per hour. Due to the land area that is required and the down-time for cleaning, rapid sand filters, which were developed in the early 20th century, are much more prevalent today.



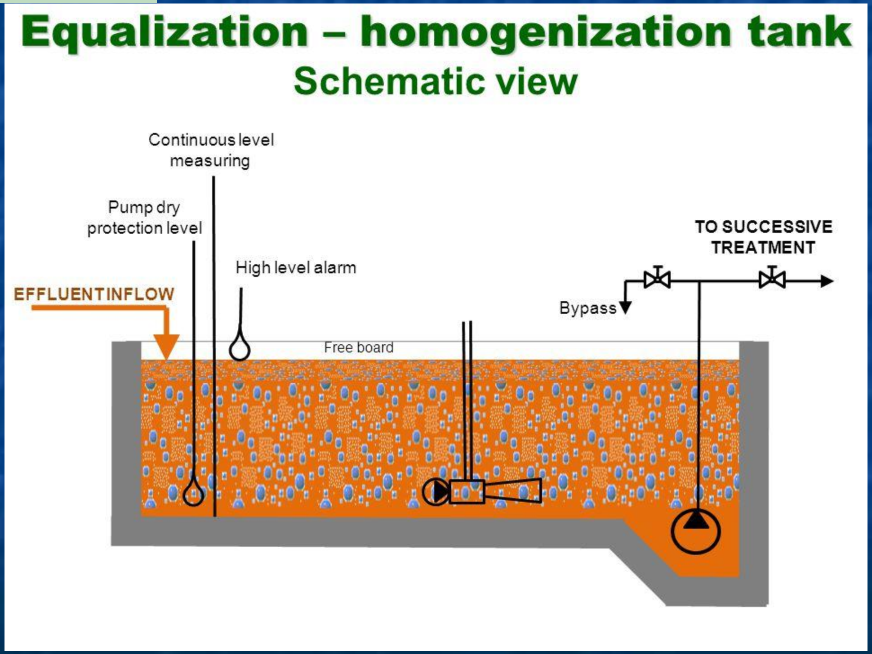
Rapid sand filtration is a physical process that removes suspended solids from the water. Rapid sand filtration is much more common than slow flow sand filtration, because rapid sand filters have fairly high flow rates and require relatively little space to operate. In fact, during rapid sand filtration, the water flows at a rate up to 20 metrecube per hour. The filters are generally cleaned twice per day with backwashing filters and are put back into operation immediately.



Equalization



A well - mixed vessel with fluctuating input flow rates and / or concentration with fairly constant output flow rates and/or concentrations.



Secondary Treatment

After the wastewater has been through Primary Treatment processes, it flows into the next stage of treatment called secondary. Secondary treatment processes can remove up to 90 percent of the organic matter in wastewater by using biological treatment processes. The two most common conventional methods used to achieve secondary treatment are attached growth processes and suspended growth processes.

If the **BOD/COD ratio** for untreated wastewater is 0.5 or greater, the waste is considered to be easily treatable by biological means. If the **ratio** is below about 0.3, either the waste may have some toxic components or acclimated micro-organisms may be required in its stabilization.

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Wastewater Treatment Plant Microorganisms

Floc forming bacteria (saprophytes): primarily facultative heterotrophs, soil and aquatic genera	*Pseudomonas, Achromobacter, Flavobacterium, Alcaligenes, Arthrobacter, Zooglea, Acinetobacter, Citromonas, Bacillus*
Nitrifying bacteria: ammonia oxidizing bacteria (AOB) and nitrite oxidizing bacteria (NOB)	*Nitrosomonas, Nitrobacter, Nitrospirillum*
Predators: protozoa, rotifers, nematodes	*Vorticella, Aspicidica, Paramedium*
Nuisance bacteria and eucaryotes: bulking, foaming, overgrazing	*Nocardia, Microthrix, Sphaerotilus*, fungi, snails
Specialty populations	Phosphate accumulating organisms (PAO), algae (lagoons)
Other	Viruses (bacteriophage), yeast, pathogens (*Campylobacter, E. coli, Salmonella, Giardia, Cryptosporidium*)

F/M Ratio

The term Food to Microorganism Ratio (F/M) is actually a measurement of the amount of incoming food (Lbs of Influent CBOD) divided by the Lbs of Microorganisms in your system.

To determine the amount of incoming food **(F)**, you need to know the CBOD of the influent into your activated sludge(aeration) system. You also need to know the flow(MGD).
So to calculate the amount of food we do the following calculation:

F= Influent Flow (MGD) X Influent CBOD Concentration (mg/l) X 8.34 pounds/gallon waste water

To determine the volume of microorganisms **(M),** you need to know the volume of your aeration system and you need to know the concentration of Volatile Solids in your aeration system (MLVSS) or Mixed Liquor Volatile Suspended Solids.

M= Aeration System Volume (in Millions of Gallons) X MLVSS X 8.34 pounds/gallon waste water

Types of secondary treatment

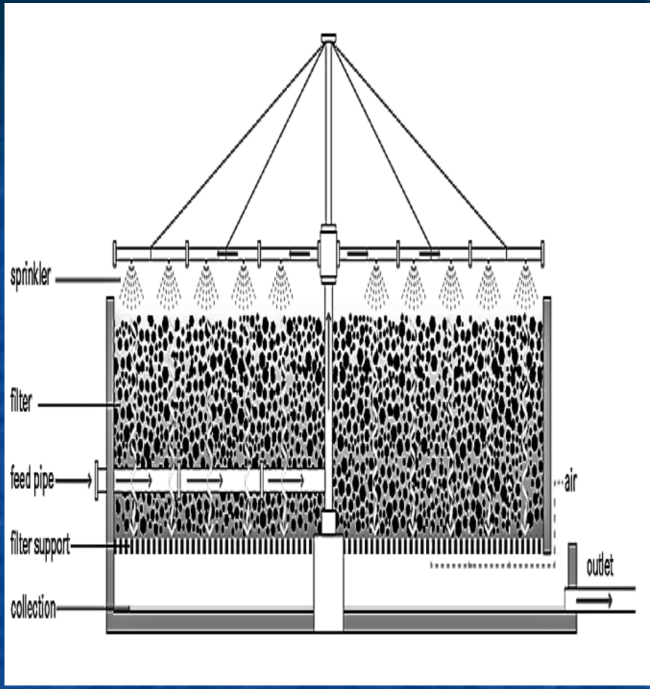
Attached Growth Processes

In attached growth (or fixed film) processes, the microbial growth occurs on the surface of stone or plastic media. Wastewater passes over the media along with air to provide oxygen. Attached growth process units include trickling filters, biotowers, and rotating biological contactors. Attached growth processes are effective at removing biodegradable organic material from the wastewater.

Suspended growth process

In suspended growth processes, the microbial growth is suspended in an aerated water mixture where the air is pumped in, or the water is agitated sufficiently to allow oxygen transfer. Suspended growth process units include variations of activated sludge, oxidation ditches and sequencing batch reactors.

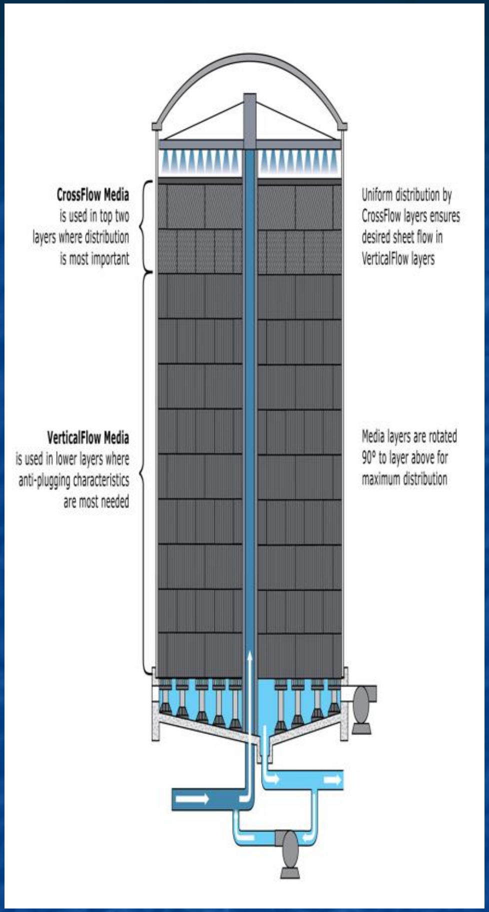
A trickling filter is simply a bed of media (typically rocks or plastic) through which the wastewater passes. The media ranges from three to six feet deep and allows large numbers of microorganisms to attach and grow. Older treatment facilities typically used stones, rocks, or slag as the media bed material. New facilities may use beds made of plastic balls, interlocking sheets of corrugated plastic, or other types of synthetic media. This type of bed material often provides more surface area and a better environment for promoting and controlling biological treatment than rock. Bacteria, algae, fungi and other microorganisms grow and multiply, forming a microbial growth or slime layer (biomass) on the media. In the treatment process, the bacteria use oxygen from the air and consume most of the organic matter in the wastewater as food. As the wastewater passes down through the media, oxygen-demanding substances are consumed by the biomass and the water leaving the media is much cleaner. However, portions of the biomass also slough off the media and must settle out in a secondary treatment tank.



Biotowers

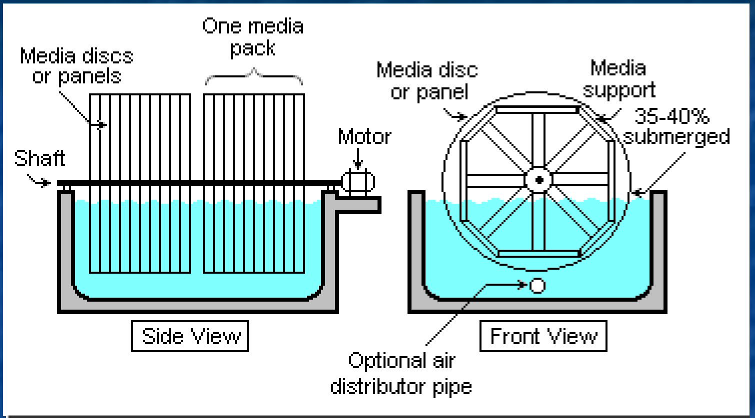
A biotower is used to reduce the BOD value of a liquid effluent. A biotower is an above-ground cylindrical tank or rectangular structure that contains plastic media with a high surface area, such as randomly filled polypropylene shapes or modular blocks of corrugated PVC. Effluent is pumped to the top of the tower and distributed over the surface of the media using rotating distributors, troughs, or nozzles and splash plates. The effluent trickles down over the media, which become coated with microbial films that consume the organic material.

The treated liquid may be recycled over the biotower before the biological solids are settled out. Biotowers can be arranged in series with inter-stage settlement. Fan ventilation may be incorporated where the biomass must be highly aerobic, for example where nitrification is required.



Rotating biological contactor

The RBC process involves allowing the wastewater to come in contact with a biological medium in order to remove pollutants in the wastewater before discharge of the treated wastewater to the environment, usually a body of water (river, lake or ocean). A rotating biological contactor is a type of secondary treatment process. It consists of a series of closely spaced, parallel discs mounted on a rotating shaft which is supported just above the surface of the waste water. Microorganisms grow on the surface of the discs where biological degradation of the wastewater pollutants takes place.



Suspended growth process

Suspended Growth Processes Similar to the microbial processes in attached growth systems, suspended growth processes are designed to remove biodegradable organic material and organic nitrogen-containing material by converting ammonia nitrogen to nitrate unless additional treatment is provided.

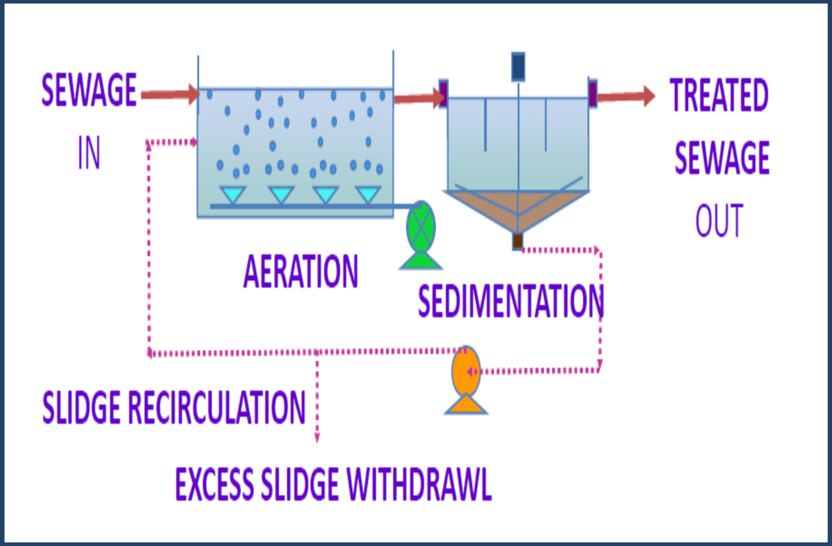
The suspended growth process speeds up the work of aerobic bacteria and other microorganisms that break down the organic matter in the sewage by providing a rich aerobic environment where the microorganisms suspended in the wastewater can work more efficiently. In the aeration tank, wastewater is vigorously mixed with air and microorganisms acclimated to the wastewater in a suspension for several hours. This allows the bacteria sequencing and other microorganisms to break down the organic matter in the wastewater. The microorganisms grow in number and the excess biomass is removed by settling before the effluent is discharged or treated further. Now activated with millions of additional aerobic bacteria, some of the biomass can be used again by returning it to an aeration tank for mixing with incoming wastewater.

ACTIVATED SLUDGE TREATMENT

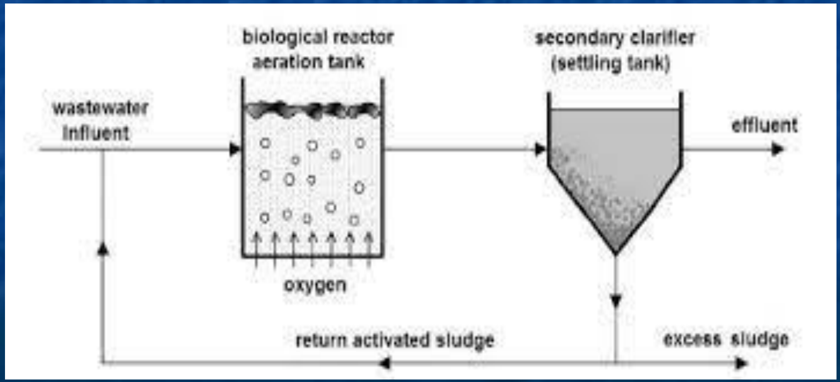
- It basically consists of an *aeration tank* and a *secondary settling basin or clarifier.*
- In aeration tank, microorganisms consume the dissolved organic pollutants as food.
- The aerobic microorganisms in the tank grow and multiply forming a suspension of biological solids called <u>activated sludge.</u>
- The combination of activated sludge and wastewater in aeration tank is called <u>mixed liquor.</u>
- A tank detention time of about 6hrs is required for stabilization of most of organics in mixed liquor.
- The mixed liquor flows to the secondary or final clarifier ,in which activated sludge solids settles out by gravity.

Activated Sludge Process Activated Sludge Process - ASP

- Raw Effluent In
- Aeration
- Sedimentation
- Treated water out
- Sludge Recirculation
- Sludge withdrawal



The activated sludge process, like most other techniques, has advantages and limitations. The units necessary for this treatment are relatively small, requiring less space than attached growth processes. In addition, when properly operated and maintained, the process is generally free of flies and odors. However, most activated sludge processes are more costly to operate than attached growth processes due to higher energy use to run the aeration system. The effectiveness of the activated sludge process can be impacted by elevated levels of toxic compounds in wastewater unless complex industrial chemicals are effectively controlled through an industrial pretreatment program.



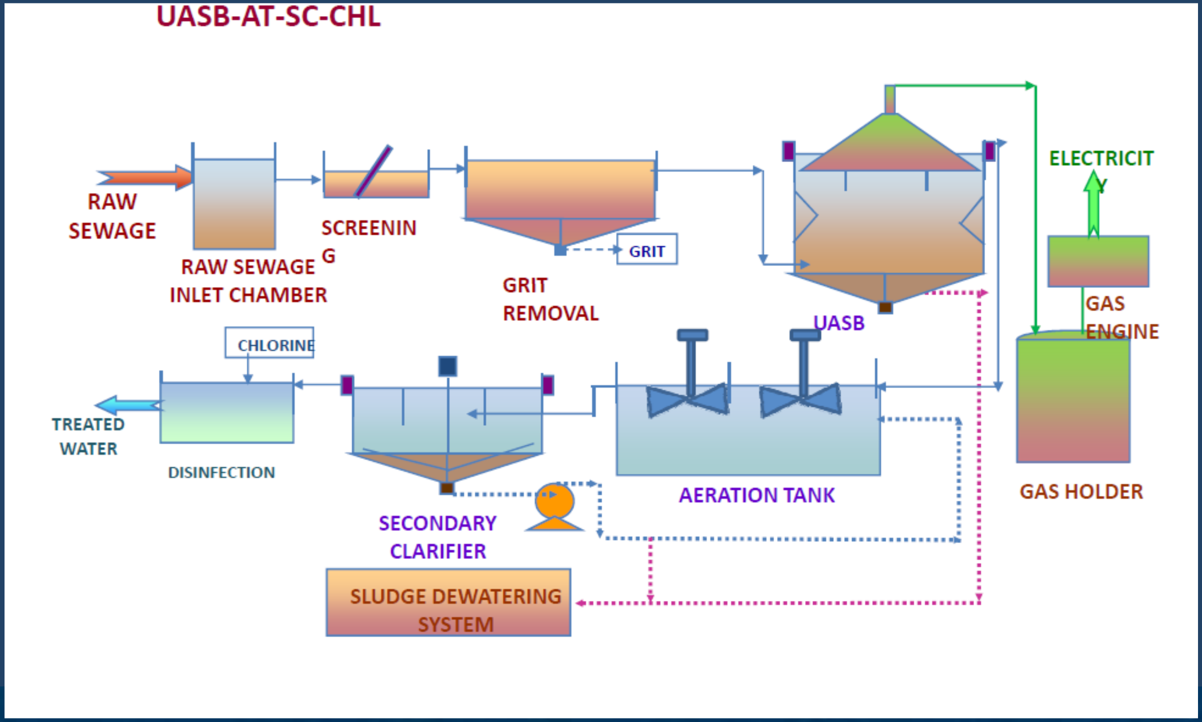
ASP

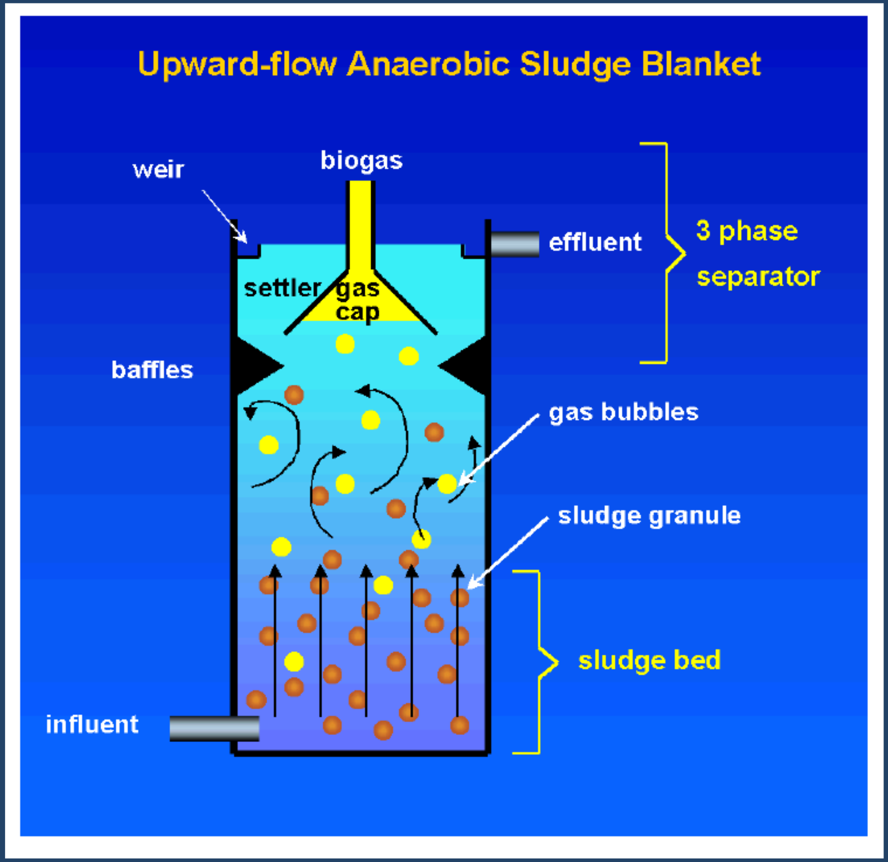
Upflow Anaerobic Sludge Blanket Reactor (UASB)

The Up flow Anaerobic Sludge Blanket reactor (UASB) maintains a high concentration of biomass through formation of highly settleable microbial aggregates. The sewage flows upwards through a layer of sludge.

- The sludge in the UASB is tested for pH, volatile fatty acids (VFA), alkalinity, COD and SS. If the pH reduces while VFA increases, the sewage should not be allowed into the UASB until the pH and VFA stabilise.
- The reactor may need to be emptied completely once in five years, while any floating material (scum) accumulated inside the gas collector channels may have to be removed every two years to ensure free flow of gas.
- All V-notches must be cleaned in order to maintain the uniform withdrawal of UASB effluent coming out of each V-notch. The irregular flow from each V-notch results in the escape of more solids washout. Similarly, blocking of the V-notches of the effluent gutters will lead to uneven distribution of sewage in the reactor.

Up – Flow Anaerobic Sludge Blanket Rector (UASB) Flow Anaerobic Sludge Blanket Rector (UASB) Flow Diagram




Upward-flow Anaerobic Sludge Blanket
weir
biogas
effluent
3 phase
separator
settler
gas
cap
baffles
gas bubbles
sludge granule
sludge bed
influent

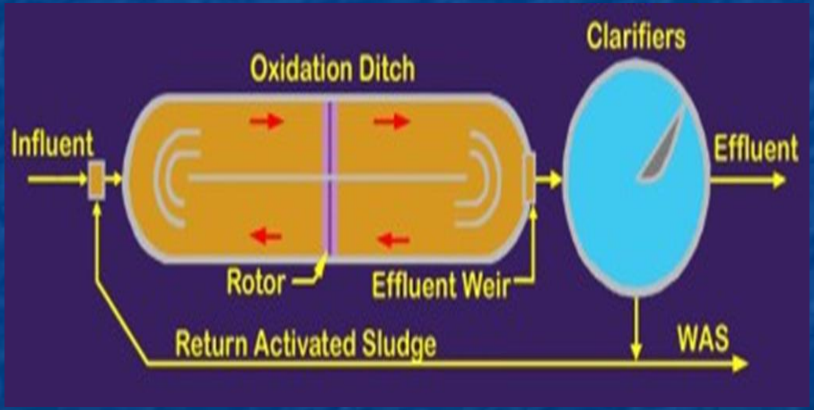
UASB

Advantages

- Requires less power than aerobic processes
- Biogas generated can be used as fuel or electricity.

Disadvantages

- UASB alone does not treat the sewage to desirable limits, therefore downstream aerobic treatment is compulsory
- Requires very large space due to post treatment
- Recovery of biogas is not sufficient to produce substantial electricity in case of municipal



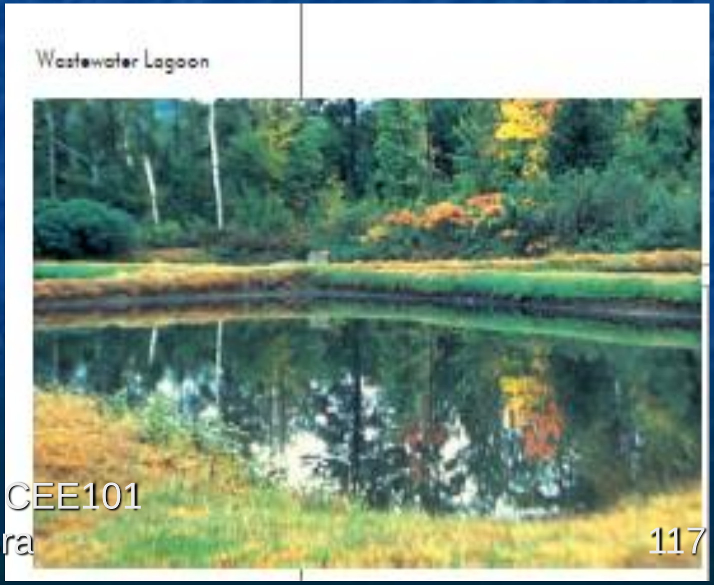
Description of Oxidation Ditch

Oxidation ditch is an extended aeration activated sludge process. An oxidation ditch is a large holding tank in a continuous ditch with oval shape similar to that of a racetrack. The ditch is built on the surface of the ground and is lined with an impermeable lining. This allows the waste water to have plenty of exposure to the open air for the diffusion of oxygen. **The liquid depth in the ditches is very shallow, 0.9 to 1.5 m, which helps to prevent anaerobic conditions from occurring at the bottom of the ditch.** The oxidation ditch effluent is clarified in a secondary clarifier and the settled sludge is returned to maintain a desirable MLSS concentration. The MLSS concentration in the oxidation ditch generally ranges from 3,000 mg/ L to 5,000 mg/ L; however, this is dependent upon the surface area provided for sedimentation, the rate of sludge return, and the aeration process. Longer retention time within the ditch will allow for a greater amount of organic matter to be broken down by the aerobic bacteria. After treatment, the waste water is pumped to a secondary settling tank where the sludge and the water are allowed to separate. From there the effluent goes on to other treatment processes or disposal. The sludge that has accumulated on the bottom of the secondary settling tank is then removed and a portion of it is returned to the ditch to facilitate microbial activity in the next batch of sewage to be treated.

Lagoons

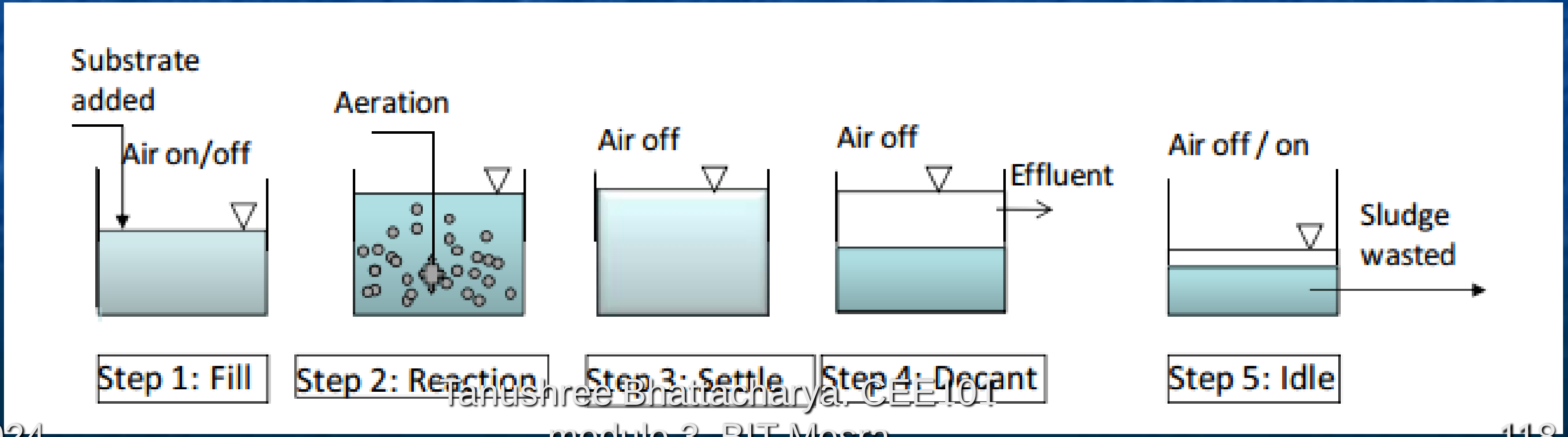
A wastewater lagoon or treatment pond is a scientifically constructed pond, three to five feet deep, that allows sunlight, algae, bacteria, and oxygen to interact. Biological and physical treatment processes occur in the lagoon to improve water quality. The quality of water leaving the lagoon, when constructed and operated properly, is considered equivalent to the effluent from a conventional secondary treatment system. However, winters in cold climates have a significant impact on the effectiveness of lagoons, and winter storage is usually required.

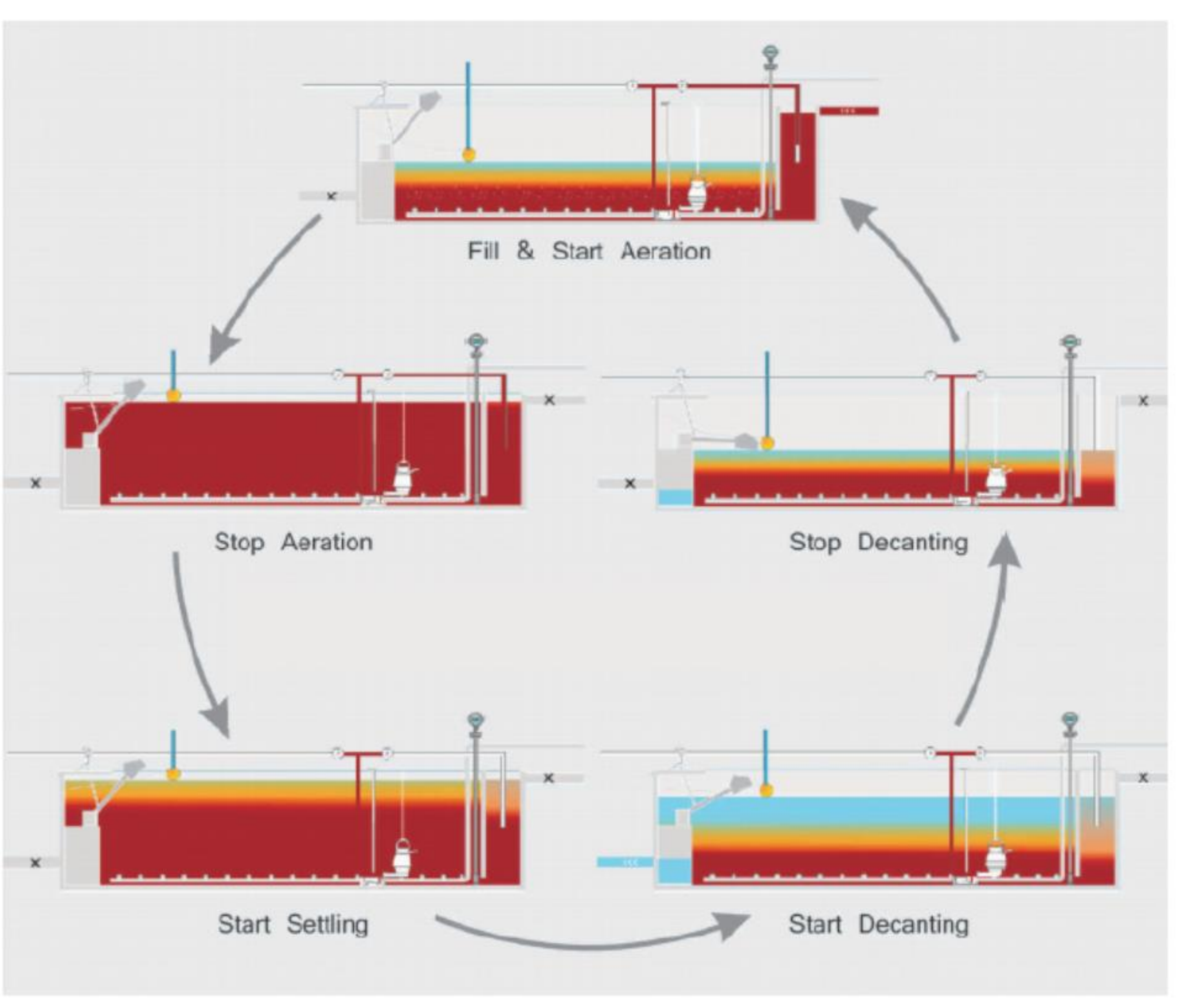
Lagoons have several advantages when used correctly. They can be used for secondary treatment or as a supplement to other processes. Treatment ponds require substantial land area and are predominantly used by smaller communities. Lagoons remove biodegradable organic material and some of the nitrogen from wastewater.



Sequencing batch reactor (SBR)

A sequencing batch reactor (SBR) is used in small package plants and also for centralized treatment of sewage. The SBR system consists of a single completely mixed reactor in which all the steps of the activated sludge process occurs. The reactor basin is filled within a short duration and then aerated for a certain period of time. After the aeration cycle is complete, the cells are allowed to settle for a duration of 0.5 h and effluent is decanted from the top of the unit which takes about 0.5 h. Decanting of supernatant is carried out by either fixed or floating decanter mechanism. When the decanting cycle is complete, the reactor is again filled with raw sewage and the process is repeated. An idle step occurs between the decant and the fill phases. The time of idle step varies based on the influent flow rate and the operating strategy. During this phase, a small amount of activated sludge is wasted from the bottom of the SBR basin. A large equalization basin is required in this process, since the influent flow must be contained while the reactor is in the aerating cycle.




Fill & Start Aeration
Stop Aeration
Stop Decanting
Start Settling
Start Decanting

The Use or Disposal of Wastewater Residuals and Biosolids

When pollutants are removed from water, there is always something left over. It may be rags and sticks caught on the screens at the beginning of primary treatment. It may be the solids that settle to the bottom of sedimentation tanks.
Whatever it is, there are always residuals that must be reused, burned, buried, or disposed of in some manner that does not harm the environment.

Biosolids are processed wastewater solids (“sewage sludge”) that meet rigorous standards allowing safe reuse for beneficial purposes.

Currently, more than half of the biosolids produced by municipal wastewater treatment systems is applied to land as a soil conditioner or fertilizer and the remaining solids are incinerated or landfilled.

Ocean dumping of these solids is no longer allowed.

Prior to utilization or disposal, biosolids are stabilized to control odors and reduce the number of disease-causing organisms. Sewage solids, or sludge, when separated from the wastewater, still contain around 98 percent water. They are usually thickened and may be dewatered to reduce the volume to be transported for final processing, disposal, or beneficial use.

Dewatering processes include drying beds, belt filter presses, plate and frame presses, and centrifuges. To improve dewatering effectiveness, the solids can be pretreated with chemicals such as lime, ferric chloride, or polymers to produce larger particles which are easier to remove wastewater, still contain around 98 percent water.

Incineration

Incineration consists of burning the dried solids to reduce the organic residuals to an ash that can be disposed or reused. Incinerators often include heat recovery features.

Undigested sludge solids have significant fuel value as a result of their high organic content.

However, the water content must be greatly reduced by dewatering or drying to take advantage of the fuel potential of the biosolids.

For this reason, pressure filtration dewatering equipment is used to obtain biosolids which are sufficiently dry to burn without continual reliance on auxiliary fuels. In some cities, biosolids are mixed with refuse or refuse derived fuel prior to burning. Generally, waste heat is recovered to provide the greatest amount of energy efficiency.

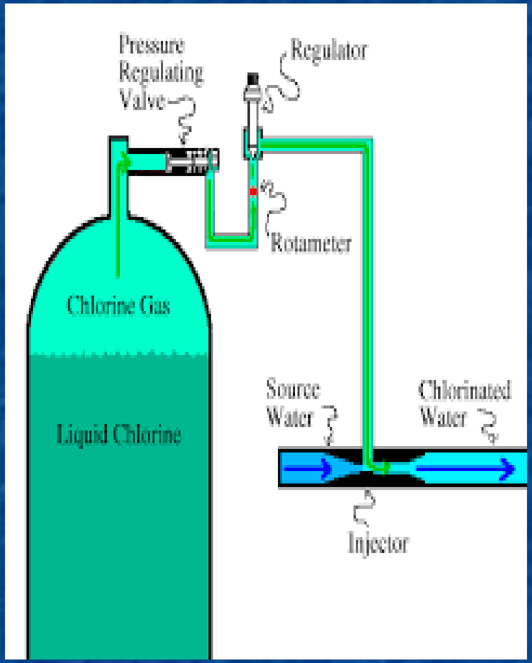
Biosolids and its uses

Heat dried biosolids pellets have been produced and used extensively as a fertilizer product for lawn care, turf production, citrus groves, and vegetable production for many years. Composting of biosolids is also a well established approach to solids management that has been adopted by a number of communities. The composted peat-like product has shown particular promise for use in the production of soil additives for revegetation of topsoil depleted areas, and as a potting soil amendment. Effective pretreatment of industrial wastes prevents excessive levels of unwanted constituents, such as heavy metals (i.e. cadmium, mercury, and lead) and persistent organic compounds from contaminating the residuals of wastewater treatment and limiting the potential for beneficial use.

Effective stabilization of wastewater residuals and their conversion to biosolid products can be costly. Some cities have produced fertilizers from biosolids which are sold to help pay part of the cost of treating wastewater. Some municipalities use composted, heat dried, or lime stabilized biosolid products on parks and other public areas.

Disinfection

Untreated domestic wastewater contains microorganisms or pathogens that produce human diseases. Processes used to kill or deactivate these harmful organisms are called disinfection. Chlorine is the most widely used disinfectant but ozone and ultraviolet radiation are also frequently used for wastewater effluent disinfection.



Tanushree Bhattacharya. CEE101 module 3, BIT Mesra

Chlorine

Chlorine kills microorganisms by destroying cellular material. This chemical can be applied to wastewater as a gas, a liquid or in a solid form similar to swimming pool disinfection chemicals. However, any free (uncombined) chlorine remaining in the water, even at low concentrations, is highly toxic to beneficial aquatic life. Therefore, removal of even trace amounts of free chlorine by dechlorination is often needed to protect fish and aquatic life. Due to emergency response and potential safety concerns, chlorine gas is used less frequently now than in the past.

Chlorination

• WHAT IS CHLORINATION?

• **Chlorination** is the process of adding the element chlorine to water as a method of water purification to make it fit for human consumption as drinking water.

• **Chlorine is the most widely used disinfectant.**
As Chlorine compounds will **destroy disease-causing organisms** quickly — usually after **30 minutes**.

• Why do we chlorinate our water?

• A **leading advantage of chlorination** is that it has proven **effective against bacteria and viruses.**

•The **chlorination process** is also **fairly easy to implement**, when compared to **other water treatment methods**.

•It is an **effective method in water emergency situations** as it **can eliminate an overload of pathogens** relatively **quickly**.

HISTORY OF CHLORINTION

Chlorine was first discovered in Sweden in 1744. At that time, people believed that **odours** from the water were **responsible for transmitting diseases**.

• **In 1835, chlorine was used to remove odours from the water**
• **After 1890,** chlorine became a way to reduce the amount of disease transmitted through water.
• **chlorination began in Great Britain and then expanded to the United States in 1908 and Canada by 1917.**

Free chlorine and combined chlorine

CHLORINE CHEMISTRY

Total = Free chlorine + Combined chlorine

- **Free chlorine:**
  hypochlorous acid + hypochlorite ion
  $HOCl \rightarrow H^+ + OCl^-$ [pH dependent reaction]
- **Combined chlorine (chloramines):**
- $HOCl + NH_3 \leftrightarrow NH_2Cl$ (monochloramine) $+ H_2O$
- $HOCl + NH_2Cl \leftrightarrow NHCl_2$ (dichloramine) $+ H_2O$
- $HOCl + NHCl_2 \leftrightarrow NCl_3$ (trichloramine) $+ H_2O$

Chlorine combined with ammonia or organic nitrogen (causes chlorine taste and odor)

Chlorine demand

CHLORINE DEMAND

Chlorine Demand - **Inherent properties of the water that consume chlorine**

• When chlorine is added to a water source, it purifies the water by damaging the cell structure of bacterial pollutants, thereby destroying them. The amount of chlorine needed to do this is called the **Chlorine Demand** of the water.

9

CHLORINE DEMAND

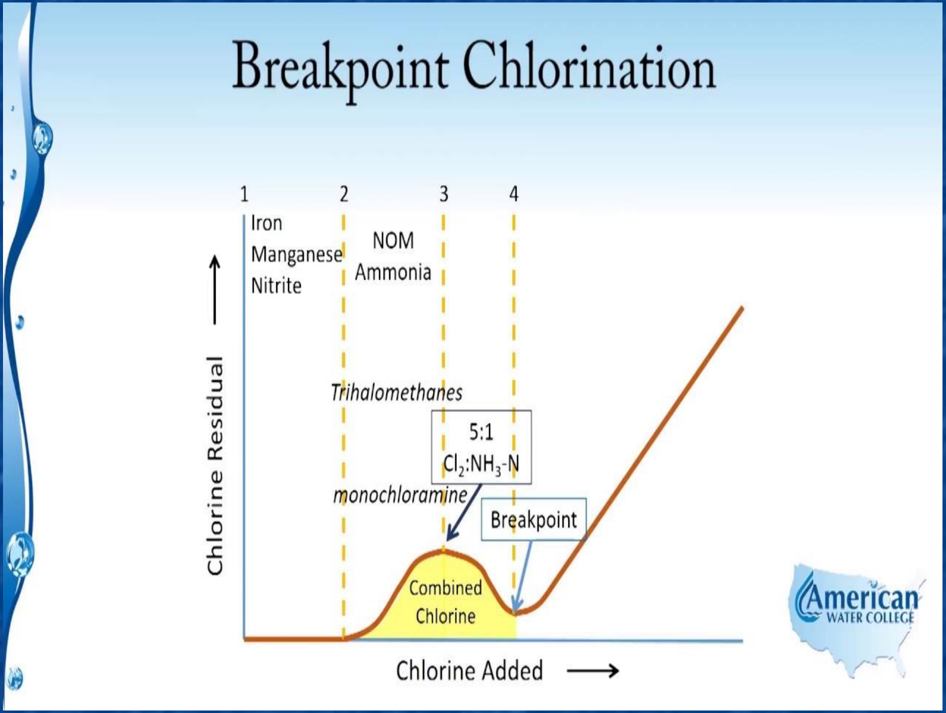
The remaining chlorine concentration after the chlorine demand *is* accounted for is called **total chlorine**.

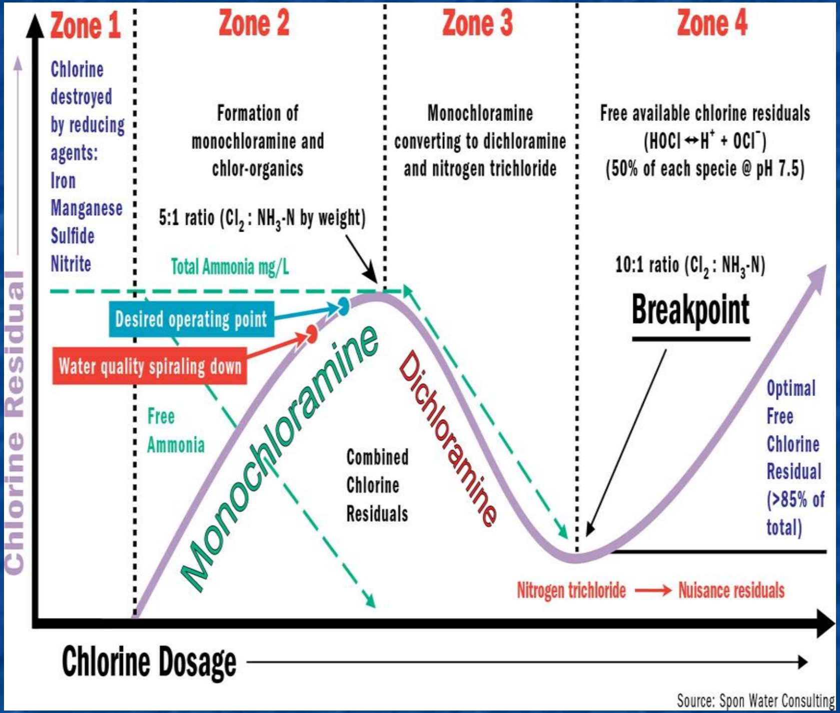
Total chlorine *is further divided into:*

•*The* amount of chlorine that has reacted with nitrates and is unavailable for disinfection which is called ***combined chlorine .***

• ***The free chlorine*** *which is the chlorine available to* inactivate disease-causing organisms, and thus a measure to determine the potability of water.

Breakpoint Chlorination





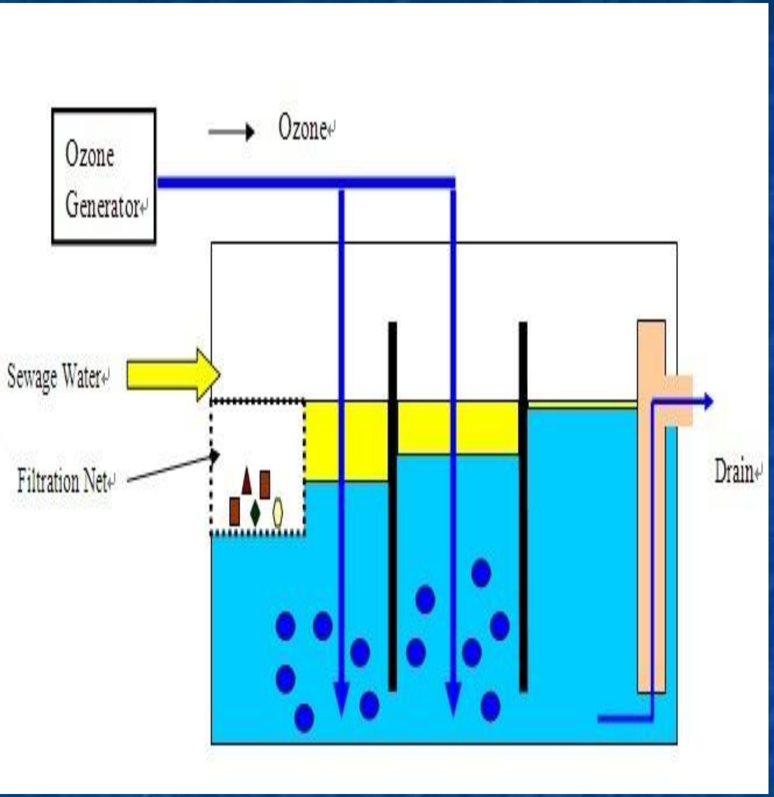
Disadvantages of Chlorination

The use of chlorine to disinfect water produces various disinfection byproducts, which have been classified mainly as halogenated and non-halogenated byproducts. These primary byproducts are trihalomethanes (THMs) and haloacetic acids. THMs are the byproducts of chlorination of water that contains natural organic matter.

The most common THM compounds are dibromochloromethane ($CHClBr_2$), bromoform ($CHBr_3$), chloroform ($CHCl_3$), and dichlorobromomethane ($CHCl_2Br$). The sum of these four compounds is referred to as Total Trihalomethanes (TTHMs).

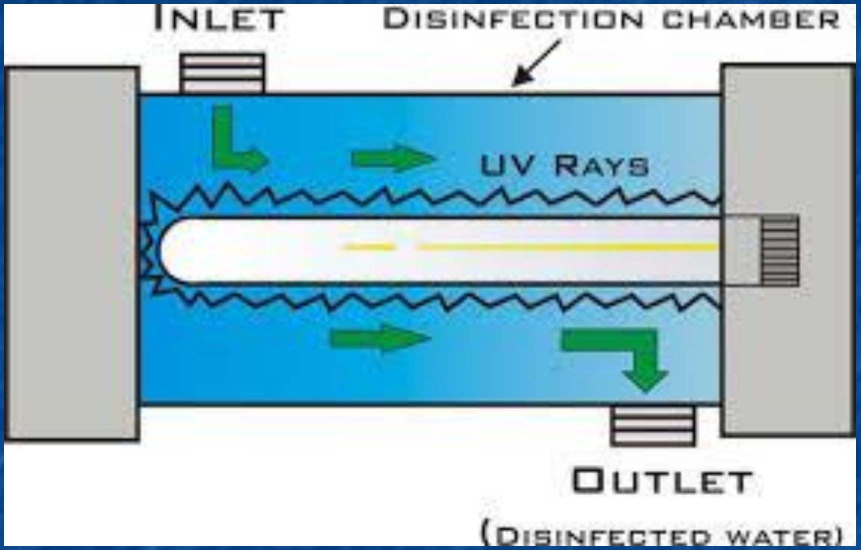
Ozone

Ozone is produced from oxygen exposed to a high voltage current. Ozone is very effective at destroying viruses and bacteria and decomposes back to oxygen rapidly without leaving harmful by products. Ozone is not very economical due to high energy costs.



Ultraviolet Radiation

Ultra violet (UV) disinfection occurs when electromagnetic energy in the form of light in the UV spectrum produced by mercury arc lamps penetrates the cell wall of exposed microorganisms. The UV radiation retards the ability of the microorganisms to survive by damaging their genetic material. UV disinfection is a physical treatment process that leaves no chemical traces. Organisms can sometimes repair and reverse the destructive effects of UV when applied at low doses



Advanced treatment or tertiary treatment

Membrane filtration

What are Membraneprocesses

- The most important feature of a membrane is the semipermeability
- Different membrane separation processes based on different molecular properties like size, vapour pressure, affinity, charge and chemical nature
- It must have high permeability for some species and low permeability for others
- The membrane filtration can be seen as an alternative to flocculation, sedimentation, adsorption, extraction or distillation
- It is used for removal of suspended and colloidal particles, dissolved ionic and non-ionic substance
- Nowadays they have an increased use to produce process water out of ground-, surface and wastewater

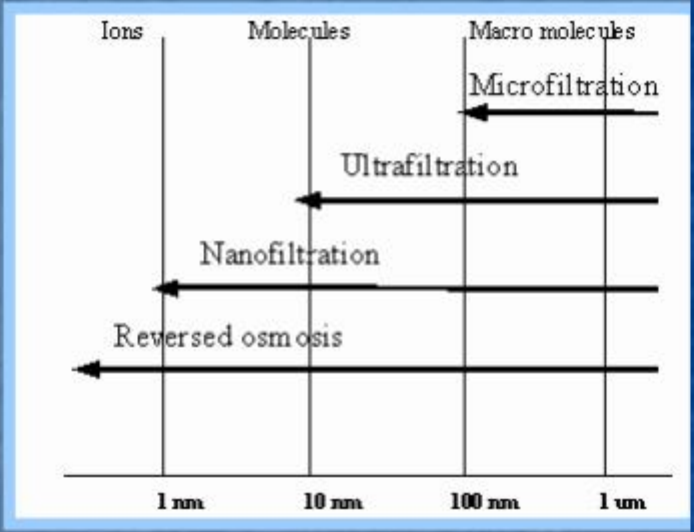
Classification of membranes

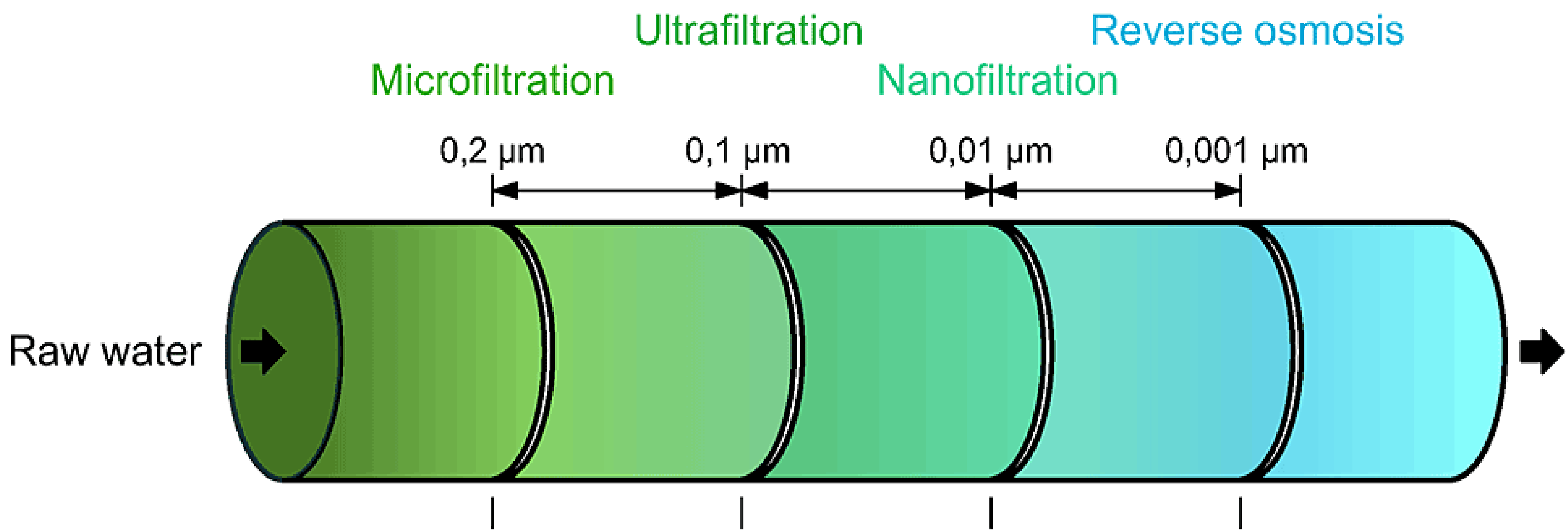
- **Microfiltration (MF)** Pore size: 100 – 1000nm
  Application: Bioengineering, food industry, water and wastewater

- **Ultrafiltration (UF)** Pore size: 10 – 100nm
  Application: Food industry, water/wastewater treatment

- **Nanofiltration (NF)** Pore size ~ 1nm
  Application: Softening, industrial water recycling, desalination of brackish water

- **Reverse osmosis (RO)** non-porous
  Application: Desalination of water (especially seawater)





The following substances can be held back:

- Plankton
- Algies
- Turbidity
- Bacteria
- suspended substances/ solids

- Macro- molecules
- Viruses
- Colloids

- DOC
- large Ions

- Ions

Required trans- membrane pressures: 0,2-5 bar 1-10 bar 5-10 bar 10-150 bar

Disadvantages of membrane separation processes

- Concentration polarisation
- Fouling
- Short membrane life-time
- Generally low selectivity

Advantages of membrane separation process for industrial applications

- Energy savings
- Can be Easily coupled with other processes and operations
- Environmentally friendly
- Clean technology
- Produces high quality products with variable operating parameters
- Greater flexibility in designing systems with easy scale up
- No additives and chemicals

Nitrogen Control

Nitrogen in one form or another is present in municipal wastewater and is usually not removed by secondary treatment. If discharged into lakes and streams or estuary waters, nitrogen in the form of ammonia can exert a direct demand on oxygen or stimulate the excessive growth of algae. Ammonia in wastewater effluent can be toxic to aquatic life in certain instances.

By providing additional biological treatment beyond the secondary stage, nitrifying bacteria present in wastewater treatment can biologically convert ammonia to the non-toxic nitrate through a process known as nitrification. The nitrification process is normally sufficient to remove the toxicity associated with ammonia in the effluent. Since nitrate is also a nutrient, excess amounts can contribute to the uncontrolled growth of algae. In situations where nitrogen must be completely removed from effluent, an additional biological process can be added to the system to convert the nitrate to nitrogen gas. The conversion of nitrate to nitrogen gas is accomplished by bacteria in a process known as denitrification. Effluent with nitrogen in the form of nitrate is placed into a tank devoid of oxygen, where carbon-containing chemicals, such as methanol, are added or a small stream of raw wastewater is mixed in with the nitrified effluent. In this oxygen free environment, bacteria use the oxygen attached to the nitrogen in the nitrate form releasing nitrogen gas. Because nitrogen comprises almost 80 percent of the air in the earth's atmosphere, the release of nitrogen into the atmosphere does not cause any environmental harm.

Biological Phosphorus Control

Like nitrogen, phosphorus is also a necessary nutrient for the growth of algae. Phosphorus reduction is often needed to prevent excessive algal growth before discharging effluent into lakes, reservoirs and estuaries. Phosphorus removal can be achieved through chemical addition and a coagulation sedimentation process discussed in the following section. Some biological treatment processes called biological nutrient removal (BNR) can also achieve nutrient reduction, removing both nitrogen and phosphorus. Most of the BNR processes involve modifications of suspended growth treatment systems so that the bacteria in these systems also convert nitrate nitrogen to inert nitrogen gas and trap phosphorus in the solids that are removed from the effluent.

Carbon adsorption

Carbon adsorption technology can remove organic materials from wastewater that resist removal by biological treatment. These resistant, trace organic substances can contribute to taste and odor problems in water, taint fish flesh, and cause foaming and fish kills. Carbon adsorption consists of passing the wastewater effluent through a bed or canister of activated carbon granules or powder which remove more than 98 percent of the trace organic substances. The substances adhere to the carbon surface and are removed from the water. To help reduce the cost of the procedure, the carbon granules can be cleaned by heating and used again.

Ion exchange process