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Unit-II

Wastewaters and their characteristics

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Physico-chemical and biological characteristics of water

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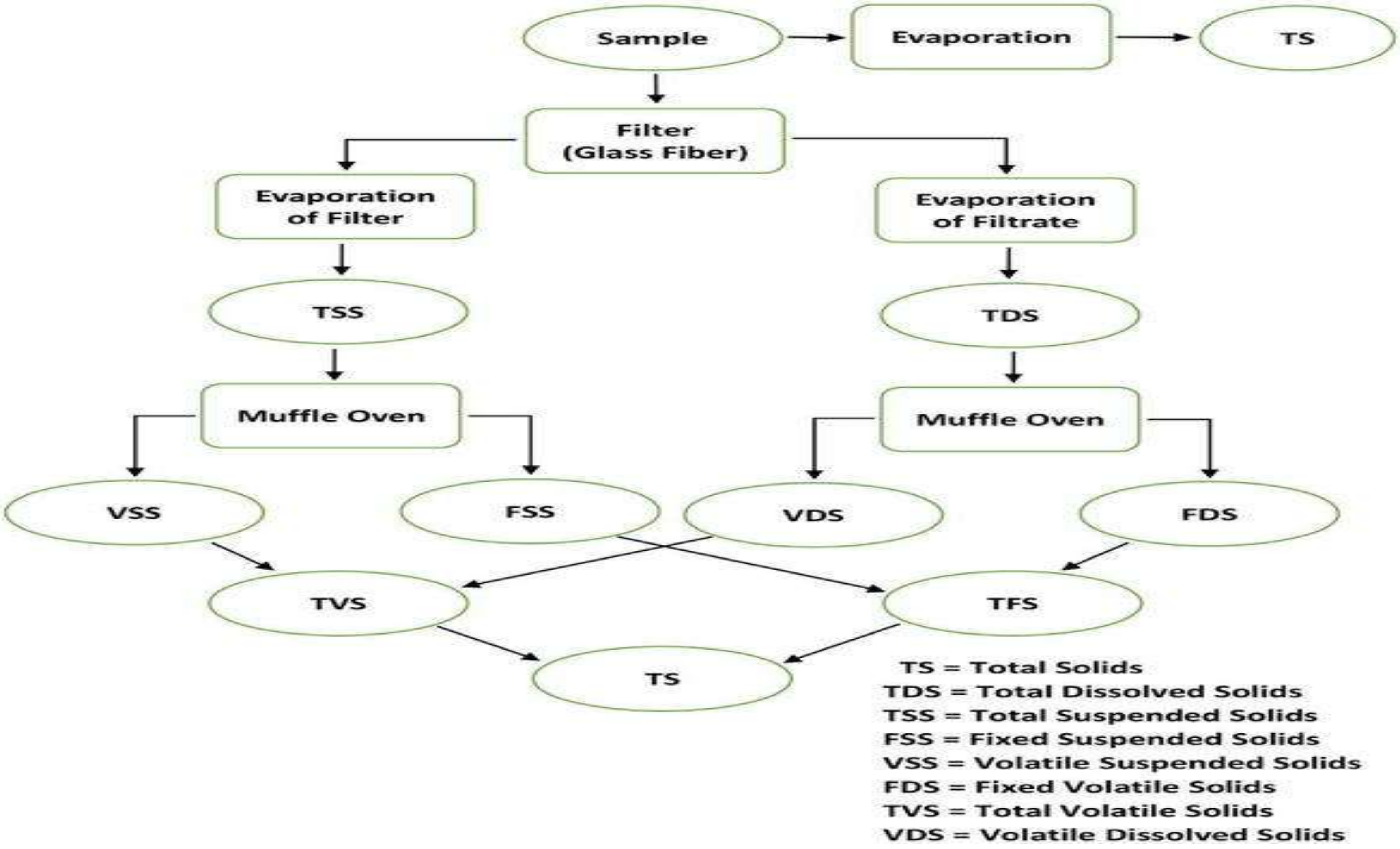
Physical,chemical and biological properties of water

- Water quality is determined by physical, chemical and microbiological properties of water. These water quality characteristics throughout the world are characterized with wide variability. Therefore the quality of natural water sources used for different purposes should be established in terms of the specific water-quality parameters that most affect the possible use of water.
- Physical Characteristics of Water: (temperature, colour, taste, odour and etc.) are determined by senses of touch, sight, smell and taste.
- Temperature :of water affects some of the important physical properties and characteristics of water: thermal capacity, density, specific weight, viscosity, surface tension, specific conductivity, salinity and solubility of dissolved gases and etc. Chemical and biological reaction rates increase with increasing temperature. Reaction rates usually assumed to double for an increase in temperature of 10 °C. The temperature of water in streams and rivers throughout the world varies from 0 to 35 °C.
- Colour :in water is primarily a concern of water quality for aesthetic reason. Coloured water give the appearance of being unfit to drink, even though the water may be perfectly safe for public use. On the other hand, colour can indicate the presence of organic substances, such as algae or humic compounds. More recently, colour has been used as a quantitative assessment of the presence of potentially hazardous or toxic organic materials in water.

- Color is measured by comparing the water sample with standard color solutions or colored glass disks . One color unit is equivalent to the color produced by a 1 mg/L solution of platinum (potassium chloroplatinate (K_2PtCl_6)) .
- The color of a water sample can be reported as follows:
- *Apparent color* is the entire water sample color and consists of both dissolved and suspended components color .
- *True color* is measured after filtering the water sample to remove all suspended material .
- Color is graded on scale of 0 (clear) to 70 color units. Pure water is colorless, which is equivalent to 0 color units

- Taste and Odour : are human perceptions of water quality. However sweet and bitter tastes are produced by more complex organic compounds. Organic materials discharged directly to water, such as falling leaves, runoff, etc., are sources of tastes and odour-producing compounds released during biodegradation.
- Turbidity: is a measure of the light-transmitting properties of water and is imparted by the suspended and colloidal material. It is important for health and aesthetic reasons.
- Total Solids: Solids are classified as settleable solids, suspended solids,dissolved and filterable solids. Settleable solids (silt and heavy organic solids) are the one that settle under the influence of gravity. Suspended solids and filterable solids are classified based on particle size and the retention of suspended solids on standard glass-fibre filters. Further the solids in the dissolved state also exists in water.

Total solids



- Solids occur in water either in solution or in suspension. These two types of solids can be identified by using a glass fiber filter that the water sample passes through. By definition, the suspended solids are retained on the top of the filter and the dissolved solids pass through the filter with the water .
- If the filtered portion of the water sample is placed in a small dish and then evaporated, the solids as a residue. This material is usually called total dissolved solids or TDS .
- Total solid(TS)=Total dissolved solid(TDS)+Total suspended solid(TSS)E2
- Water can be classified by the amount of TDS per liter as follows:
- freshwater: <1500 mg/L TDS;brackish water: 1500–5000 mg/L TDS;saline water: >5000 mg/L TDS.
- The residue of TSS and TDS after heating to dryness for a defined period of time and at a specific temperature is defined as fixed solids. Volatile solids are those solids lost on ignition (heating to 550°C) [10].
- These measures are helpful to the operators of the wastewater treatment plant because they roughly approximate the amount of organic matter existing in the total solids of wastewater, activated sludge, and industrial wastes

- **Electrical conductivity (EC)**
- The electrical conductivity (EC) of water is a measure of the ability of a solution to carry or conduct an electrical current . Since the electrical current is carried by ions in solution, the conductivity increases as the concentration of ions increases. Therefore, it is one of the main parameters used to determine the suitability of water for irrigation and firefighting.
- U.S. units = micromhos/cm
- S.I. units = milliSiemens/m (mS/m) or dS/m (deciSiemens/m)
- where (mS/m) = 10 umho/cm (1000 µS/cm = 1 dS/m).
- Pure water is not a good conductor of electricity . Typical conductivity of water is as follows:
- Ultra-pure water: 5.5×10^{-6} S/m; Drinking water: 0.005–0.05 S/m;Seawater: 5 S/m. The electrical conductivity can be used to estimate the TDS value of water as follows [10, 22]:
- TDS(mg/L)≅EC(dS/m or umho/cm)×(0.55–0.7)
- TDS can be used to estimate the ionic strength of water in the applications of groundwater recharging by treated wastewater . The normal method of measurement is electrometric method .

Chemical characteristics of water

- pH:pH is one of the most important parameters of water quality. It is defined as the negative logarithm of the hydrogen ion concentration . It is a dimensionless number indicating the strength of an acidic or a basic solution . Actually, pH of water is a measure of how acidic/basic water is . Acidic water contains extra hydrogen ions (H^+) and basic water contains extra hydroxyl (OH^-) ions .
- pH ranges from 0 to 14, with 7 being neutral. pH of less than 7 indicates acidity, whereas a pH of greater than 7 indicates a base solution . Pure water is neutral, with a pH close to 7.0 at 25°C. Normal rainfall has a pH of approximately 5.6 (slightly acidic) owing to atmospheric carbon dioxide gas . Safe ranges of pH for drinking water are from 6.5 to 8.5 for domestic use and living organisms need .
- Excessively high and low pHs can be detrimental for the use of water. A high pH makes the taste bitter and decreases the effectiveness of the chlorine disinfection, thereby causing the need for additional chlorine . The amount of oxygen in water increases as pH rises. Low-pH water will corrode or dissolve metals and other substances .Pollution can modify the pH of water, which can damage animals and plants that live in the water

- Chemical Characteristics of Water: are a reflection of the soils and rocks with which the water has been in contact. In addition, agricultural and urban runoff and municipal and industrial treated wastewater impact the water quality. Microbial and chemical transformations also affect the chemical characteristics of water.
- Inorganic Minerals :Runoff causes erosion and weathering of geological formation, rocks and soils as the runoff travels to the surface-water bodies. During this period of contact with rocks and soils the water dissolves inorganic minerals, which enter the natural waters. Inorganic compounds may dissociate to varying degrees, to cations and anions.
- Major Cations: found in natural water include calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^{+}) and potassium (K^{+}). Calcium (Ca^{2+}), is the most prevalent cation in water.

- The principal concern about calcium is related to the fact that calcium is the primary constituent of water hardness. Calcium precipitates as $CaCO_3$ in iron and steel pipes.
- However, excessive accumulation of $CaCO_3$ in boilers, hot water heaters, heat exchangers, and associated piping affects heat transfer and could lead to plugging of the piping. Calcium concentration of up to 300 mg/L or higher have been reported. However, calcium concentrations of 40 to 120 mg/L are more common.
- Magnesium is not abundant in rocks as calcium. Therefore, although magnesium salts are more soluble than calcium, less magnesium is found in surface water.
- Sodium and potassium are commonly found as free ions. The concentration of these cations in natural water usually are low.
- Other constituents in natural water in concentration of 1 mg/L or higher include aluminium, boron, iron, manganese, phosphorus and etc.

- Potassium ranks seventh among the elements in order of abundance, behaves similar to sodium and remains low. Though found in small quantities (<20mg/L) it plays a vital role in the metabolism.
- Sodium is one of the most abundant elements and is a common constituent of natural waters. The sodium concentration of water is of concern primarily when considering their solubility for agricultural uses or boiler feed water. The concentration ranges from very low in the surface waters and relatively high in deep ground waters and highest in the marine waters. It is calculated by flame photometric method.

- Major Anions :Major anions include chloride, sulfate, carbonate, bicarbonate, fluoride and nitrate.
- Bicarbonate (HCO3-) is the principal anion found in natural water. These ions are very important in the carbonate system, which provides a buffer capacity to natural water and is responsible in a great measure for the alkalinity of water.
- One source of bicarbonate ions (HCO3-) in natural water is the dissociation of carbonic acid (H2CO3) that is formed when carbon dioxide (CO2) from the atmosphere, or from animal (e.g. fish) and bacterial respiration, dissolves in water. In addition to bicarbonates (HCO3-) anions such as chlorides (Cl-), sulfates (SO42-), and nitrates (NO3-) are commonly found in natural water.
- These anions are released during the dissolution and dissociation of common salt deposits in geologic formations. The concentration of the chlorides (Cl-) determines the water quality because the quality of water get worse after increasing in the concentration of this anions which limit possibilities of using of natural water for different purposes (household, agriculture, industry and etc.).

- Principal source of the chloride ion (Cl^-) in natural water are magmatic rock formations that include chlorine-content minerals.
- The second source of this anions is Ocean from where a considerable amount of chloride ion (Cl^-) enter in the atmosphere. From atmosphere chloride ion (Cl^-) enter in the natural water in result of interaction between precipitation and soil.

- **Nitrate** anions (NO_3^-) are found in natural water as the result of the bacteriological oxidation of nitrogenous materials in soil. That is why the concentration of these anions rapidly increases in summer when the process of the nitrification takes place very intensively. Another important source for dressing of the surface water with Nitrate anions (NO_3^-) are precipitation, which absorb nitric oxides and convert them into nitric acid. A great deal of nitrate ions (NO_3^-) enter in surface water together with domestic water and water from industry, agriculture and etc. Nitrate ions (NO_3^-) are one of the indicators for the degree of the pollution with organic nitrate-content substances.
- Other anions found in water include **fluorides** (F^-), **carbonates** (CO_3^{2-}) and **phosphates** (PO_4^{3-}).

- **pH and Alkalinity**
- Alkalinity is defined as the capacity of natural water to neutralize acid added to it. The first is to **titrate** the water with acid titrant to the **phenolphthalein** end point. This is called the **phenolphthalein alkalinity**. Since **phenolphthalein** changes color at pH~8.3, this corresponds to a pH where all the CO_3^{2-} present would be protonated.
- The **methyl orange** end point **titration** indicates total **alkalinity**.
- Total alkalinity = $[HCO^{3-}] + 2[CO_3^{2-}] + [OH^-] - [H^+]$
- Total alkalinity includes Hydroxide alkalinity $[OH^-]$, Bicarbonate alkalinity $[HCO^{3-}]$ and Carbonate alkalinity $[CO_3^{2}-]$.
- **Alkalinity** is expressed as **phenolphthalein alkalinity** or **total alkalinity**. **Phenolphthalein alkalinity** measures the hydroxides and half the carbonates at a pH 8.3. **Total alkalinity** measures all carbonate, bicarbonate, and hydroxide **alkalinity** at a pH 4.5 (approximately).

Acidity

- Acidity is the "quantitative capacity of aqueous media to react with hydroxyl ions". Titration with a strong base (NaOH) to define end points (pH = 4.3 and pH = 8.3).
- Acidity indicates the corrosiveness of acidic water on steel, concrete and other materials. Acidity is the measure of acids in a solution. The acidity of water is its quantitative capacity to neutralize a strong base to a selected pH level [10]. Acidity in water is usually due to carbon dioxide, mineral acids, and hydrolyzed salts such as ferric and aluminum sulfates . Acids can influence many processes such as corrosion, chemical reactions and biological activities .
- Carbon dioxide from the atmosphere or from the respiration of aquatic organisms causes acidity when dissolved in water by forming carbonic acid (H2CO3). The level of acidity is determined by titration with standard sodium hydroxide (0.02 N) using phenolphthalein as an indicator.

Inorganic Indicators of Water Quality

- Some of the inorganic parameters include hardness, total dissolved solids, conductivity, .
- Hardness: Hardness is correlated with TDS (Total dissolved solids). It represents total concentration of Ca^{2+} and Mg^{2+} ions, and is reported in equivalent $CaCO_3$. Other ions (Fe^{2+}) may also contribute. Hardness expressed as mg/L $CaCO_3$ is used to classify waters from "soft" to "very hard". This classification is summarized in Table 1.
- Table 1 Relationship of Hardness Concentration and Classification of Natural water
- Hardness as mg/L $CaCO_3$ Classification
- 0 – 60 Soft
- 61 – 120 Moderately hard
- 121 – 180 Hard
- >180 Very hard
- Hardness observed for streams and rivers throughout the world ranges between 1 to 1000 mg/L.
- Hardness is an indicator to industry of potential precipitation of calcium carbonates in cooling towers and boilers, interference with soaps and dyes in cleaning and textile industries and with emulsifiers in photographic development.

- Total Dissolved Solids:Total dissolved solids (TDS) is a measure of salt dissolved in a water sample after removal of suspended solids. TDS is residue remaining after evaporation of the water.
- Conductivity:The concentration of total dissolved solids (TDS) is related to electrical conductivity (EC; mhos/cm) or specific conductance. The conductivity measures the capacity of water to transmit electrical current. The conductivity is a relative term and the relationship between the TDS concentration and conductivity is unique to a given water sample and in a specific TDS concentration range. The conductivity increases as the concentration of TDS increases.

TDS(mg/L) = EC (µS/cm) X 0.67

- TDS and conductivity affect the water sample and the solubility of slightly soluble compounds and gases in water (e.g. $CaCO_3$, and O_2). In general, the corrosiveness of the water increases as TDS and EC increase, assuming other variables are kept constant.

Organic Indicators of Water Quality

- Dissolved Oxygen
- Typical dissolved oxygen concentrations observed in streams and rivers throughout the world are 3 to 9 mg/l. The observed range of dissolved oxygen concentrations is 0 mg/L (anoxic conditions) to 14 mg/L (supersaturated conditions).
- Dissolved oxygen is important in natural water because many microorganisms and fish require it in aquatic system. Dissolved oxygen also establishes an aerobic environment in which oxidized forms of many constituents in water are predominant. Under anoxic conditions in water, reduced forms of chemical species are formed and frequently lead to the release of undesirable odours until oxic conditions develop.

DO estimation

- Principle: Dissolved oxygen (DO) determination measures the amount of dissolved (or free) oxygen present in water or wastewater. Aerobic bacteria and aquatic life such as fish need dissolved oxygen to survive. If the amount of free or DO present in the wastewater process is too low, the aerobic bacteria that normally treat the sewage will die. DO is determined by the titrimetric method developed by Winkler called Modified winkler method.
- Dissolved molecular oxygen in water is not capable of reacting with KI, therefore an oxygen carrier such as manganese hydroxide is used.
- $Mn(OH)_2$ is produced by the action of KOH on $MnSO_4$.
- $Mn(OH)_2$ so obtained reacts with dissolved molecular oxygen to form a brown precipitate of basic manganic oxide, $MnO(OH)_2$.
- $MnO(OH)_2$ then reacts with concentrated sulphuric acid to liberate nascent oxygen.
- Nascent oxygen results in oxidation of KI to I_2.
- This liberated iodine is then titrated against standard sodium thiosulphate solution using starch as an indicator.

- Thiosulphate reduces iodine to iodide ions and itself gets oxidized to tetrathionate ion.
- Reactions
- $2KOH^- + MnSO_4 \longrightarrow Mn(OH)_2 + K_2SO_4$ ...(1)
- $2Mn(OH)_2 + O_2 \longrightarrow 2MnO(OH)_2$ ...(2)
- $MnO(OH)_2 + H_2SO_4 \longrightarrow MnSO_4 + 2H_2O + [O]$ ...(3)
- $2KI + H_2SO_4 + [O] \longrightarrow K_2SO_4 + H_2O + I_2$ ...(4)
- $I_2 + I^- \longrightarrow I_3$ ...(5)

- For quantity assessment of concentrations of organic materials, indicator Total Oxygen Demand are used. The Total Oxygen Demand includes Chemical Oxygen Demand (COD) and Biochemical Oxygen Demand
- Biological oxygen demand (BOD), the most widely used parameter, is a measure of the amount of oxygen used by indigenous microbial population in water in response to the introduction of degradable organic material. This parameter depends on water characteristics: dilution, essential nutrients (Add 1 mL each of PO4 buffer; $MgSO_4$, $CaCl_2$, and $FeCl_3$ per Liter), aeration and bacterial seed. The 5-day BOD (BOD5) is most widely used. The BOD5 of natural water is related to the dissolved oxygen concentration, which is measured at zero time and after 5 days of incubation at 20 °C.
- The difference is the dissolved oxygen used by the microorganisms in the biochemical oxidation of organic matter. The BOD5 can be calculated as BOD5 = D0 - D1, in which the BOD5 is in mg/L and D0 and D1 are the dissolved oxygen concentration in mg/L at time 0 and 5 days, respectively.
- Typical concentration of BOD5 for streams and rivers throughout the world are < 2 to 15 mg/ L and the observed range is < 2 to 65 mg/L.

- Chemical Oxygen Demand
- The chemical oxygen demand (COD) test of natural water yields the oxygen equivalent of the organic matter that can be oxidized by strong chemical oxidizing agent in an acidic medium.
- **Silver sulfate** is added as a catalyst and to minimize the interference of chloride on the COD test. **Mercuric sulfate** is also added to inhibit interferences of metals on the oxidation of organic compounds. The reaction of the dichromate with organic matter is presented here in general way:

Organic matter (organic matter) + $Cr_2O_7^{2-}$ + H^- $\longrightarrow$ $2Cr^{3+}$ + CO^2 + H_2O

- The COD observed in natural streams and rivers is < 2 mg/L to 100 mg/L.
- Dissolved Gases: The principal transfer of gas in natural water is the transfer of oxygen from the atmosphere to the water. However, gas transfer is also used to strip hydrogen sulfide (H2S), ammonia (NH3) and volatile organic compounds (VOC) from water. In both processes material is transferred from one bulk phase to another across a gas-liquid interface. For example , oxygen is transferred from the bulk gaseous phase (atmosphere) across the gas-liquid interface into bulk liquid phase (water). In the case of striping volatile organic compounds (VOC) from liquid, the VOC is transferred from the bulk liquid phase (water) across the liquid-gas interface into the bulk gaseous phase (atmosphere).

Toxic inorganic substances

- A wide variety of inorganic toxic substances may be found in water in very small or trace amounts. Even in trace amounts, they can be a danger to public health . Some toxic substances occur from natural sources but many others occur due to industrial activities and/or improper management of hazardous waste . They can be divided into two groups:
- Metallic compounds: This group includes some heavy metals that are toxic, namely, cadmium (Cd), chromium (Cr), lead (Pb), mercury (Hg), silver (Ag), arsenic (As), barium (Ba), thallium (Tl), and selenium (Se) . They have a wide range of dangerous effects that differ from one metal to another. They may be acute fatal poisons such as (As) and (Cr^{6+}) or may produce chronic diseases such as (Cd, Hg, Pb, and Tl). The heavy metals concentration can be determined by atomic absorption photometers, spectrophotometer, or inductively coupled plasma (ICP) for very low concentration [10].
- Nonmetallic compounds: This group includes nitrates (NO_3^-) and cyanides (CN^-), nitrate has been discussed with the nitrogen in the previous section. Regarding cyanide, as Mackenzie stated it causes oxygen deprivation by binding the hemoglobin sites and prevents the red blood cell from carrying the oxygen . This causes a blue skin color syndrome, which is called cyanosis. It also causes chronic effects on the central nervous system and thyroid . Cyanide is normally measured by colorimetric, titrimetric, or electrometric methods .

- Toxic organic substances
- There are more than 100 compounds in water that have been listed in the literature as toxic organic compounds . They will not be found naturally in water; they are usually man-made pollutants. These compounds include insecticides, pesticides, solvents, detergents, and disinfectants . They are measured by highly sophisticated instrumental methods, namely, gas chromatographic (GC), high-performance liquid chromatographic (HPLC), and mass spectrophotometric .
- Radioactive substances
- Potential sources of radioactive substances in water include wastes from nuclear power plants, industries, or medical research using radioactive chemicals and mining of uranium ores or other radioactive materials When radioactive substances decay, they release beta, alpha, and gamma radiation . Exposure of humans and other living things to radiation can cause genetic and somatic damage to the living tissues .
- Radon gas is of a great health concern because it occurs naturally in groundwater and is a highly volatile gas, which can be inhaled during the showering process [35]. For drinking water, there are established standards commonly used for alpha particles, beta particles, photons emitters, radium-226 and -228, and uranium .
- The unit of radioactivity used in water quality applications is the picocurie per liter (pCi/L); 1 pCi is equivalent to about two atoms disintegrating per minute. There are many sophisticated instrumental methods to measure it .

Biological characteristics of water

- One of the most helpful indicators of water quality may be the presence or lack of living organisms . Biologists can survey fish and insect life of natural waters and assess the water quality on the basis of a computed species diversity index (SDI) ; hence, a water body with a large number of well-balanced species is regarded as a healthy system . Some organisms can be used as an indication for the existence of pollutants based on their known tolerance for a specified pollutant .
- Microorganisms exist everywhere in nature . Human bodies maintain a normal population of microbes in the intestinal tract; a big portion of which is made up of coliform bacteria . Although there are millions of microbes per milliliter in wastewater, most of them are harmless . It is only harmful when wastewater contains wastes from people infected with diseases that the presence of harmful microorganisms in wastewater is likely to occur .

- Bacteria are considered to be single-celled plants because of their cell structure and the way they ingest food . Bacteria occur in three basic cell shapes: rod-shaped or bacillus, sphere-shaped or coccus, and spiral-shaped or spirellus . In less than 30 min, a single bacterial cell can mature and divide into two new cells .
- Under favorable conditions of food supply, temperature, and pH, bacteria can reproduce so rapidly that a bacterial culture may contain 20 million cells per milliliter after just 1 day. This rapid growth of visible colonies of bacteria on a suitable nutrient medium makes it possible to detect and count the number of bacteria in water .
- There are several distinctions among the various species of bacteria. One distinction depends on how they metabolize their food [38]. Bacteria that require oxygen for their metabolism are called aerobic bacteria, while those live only in an oxygen-free environment are called anaerobic bacteria. Some species called facultative bacteria can live in either the absence or the presence of oxygen .
- At low temperatures, bacteria grow and reproduce slowly. As the temperature increases, the rate of growth and reproduction doubles in every additional 10°C (up to the optimum temperature for the species) . The majority of the species of bacteria having an optimal temperature of about 35°C .
- A lot of dangerous waterborne diseases are caused by bacteria, namely, typhoid and paratyphoid fever, leptospirosis, tularemia, shigellosis, and cholera . Sometimes, the absence of good sanitary practices results in gastroenteritis outbreaks of one or more of those diseases

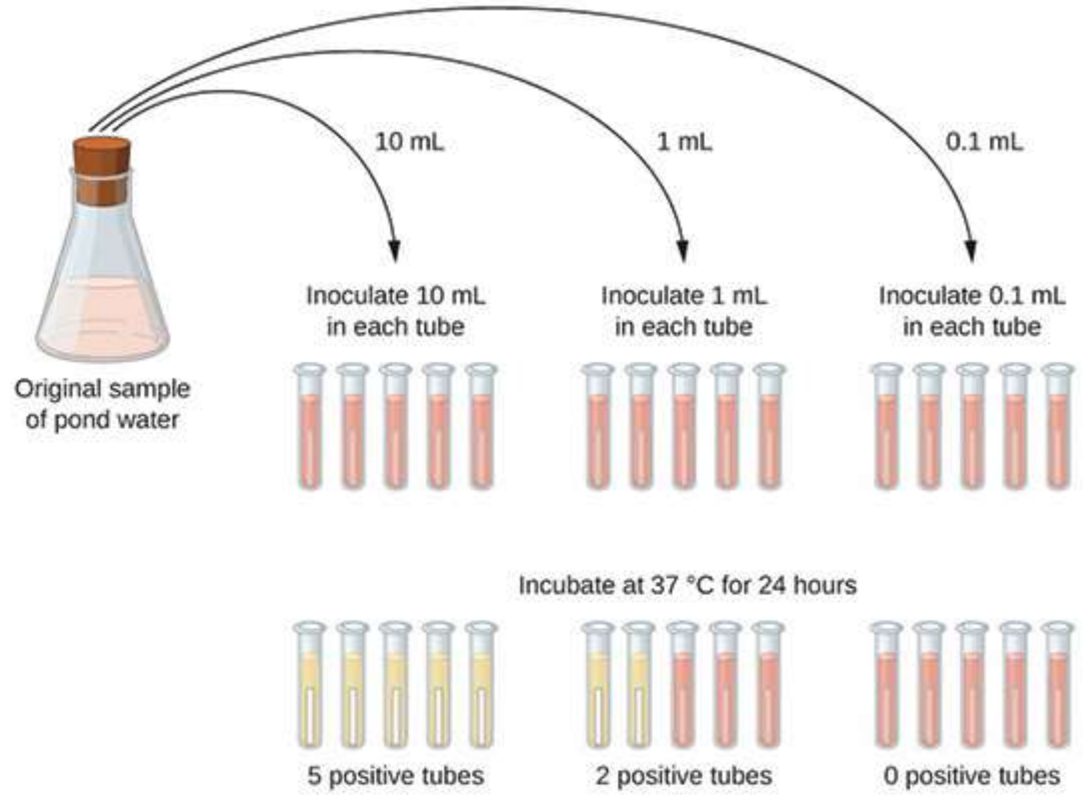
- Algae are tiny, microscopic plants that consist of photosynthetic pigments. **These plants are able to support themselves by effectively converting inorganic matter into organic matter, which is done with energy from the sun**. While this process is ongoing, the algae consume carbon dioxide and release oxygen. Algae are microscopic plants, which contain photosynthetic pigments, such as chlorophyll . They are autotrophic organisms and support themselves by converting inorganic materials into organic matter by using energy from the sun, during this process they take in carbon dioxide and give off oxygen . They are also important for wastewater treatment in stabilization ponds . Algae are primarily nuisance organisms in the water supply because of the taste and odor problems they create . Certain species of algae cause serious environmental and public health problems; for example, blue-green algae can kill cattle and other domestic animals if the animals drink water containing those species .
- Viruses
- Viruses are tiny biological structures that can be harmful to a person’s health. Only strong electronic microscopes are able to view viruses. All viruses require parasites to live. Because of how small viruses are, they are able to pass through the majority of filters. Certain waterborne viruses can cause hepatitis and similar health problems. **Despite the difficulty in treating viruses, most water treatment facilities should be able to eliminate viruses during the disinfection process**.

- Protozoa:Protozoa are single-celled microscopic animal , consume solid organic particles, bacteria, and algae for food, and they are in turn ingested as food by higher level multicellular animals . Aquatic protozoa are floating freely in water and sometimes called zooplankton . They form cysts that are difficult to inactivate by disinfection
- **Indicator organisms**
- A very important biological indicator of water and pollution is the group of bacteria called coliforms . Pathogenic coliforms always exist in the intestinal system of humans, and millions are excreted with body wastes . Consequently, water that has been recently contaminated with sewage will always contain coliforms .
- A particular species of coliforms found in domestic sewage is *Escherichia coli* or *E. coli* . Even if the water is only slightly polluted, they are very likely to be found. There are roughly 3 million of *E. coli* bacteria in 100 mL volume of untreated sewage . Coliform bacteria are aggressive organisms and survive in the water longer than most pathogens. There are normally two methods to test the coliform bacteria—the membrane filter method and multiple-tube fermentation method . Since the test of coliform bacteria is very important for public health, the first method will be described in details in the coming section.

Testing for coliforms: membrane filter method

- A measured volume of sample is filtered through a special membrane filter by applying a partial vacuum .
- The filter, a flat paper-like disk, has uniform microscopic pores small enough to retain the bacteria on its surface while allowing the water to pass through. The filter paper is then placed in a sterile container called a petri dish, which contains a special culture medium that the bacteria use as a food source .
- Then, the petri dish is usually placed in an incubator, which keeps the temperature at 35°C, for 24 h. After incubation, colonies of coliform bacteria each containing millions of organisms will be visible . The coliform concentration is obtained by counting the number of colonies on the filter; each colony counted represents only one coliform in the original sample .
- Coliform concentrations are expressed in terms of the number of organisms per 100 mL of water as follows:
- Coliforms per 100mL =number of colonies×100/mLof sample

Most Probable number technique



- MPN test is completed in three steps:
  - Presumptive test
  - Confirmed test
  - Completed test
- **Presumptive Test**
- This test, a specific enrichment procedure for coliform bacteria, is conducted in fermentation tubes filled with a selective growth medium (MacConkey lactose broth), which contains inverted Durham tubes for the detection of fermentation gas. A series of lactose broth tubes are inoculated with measured amounts of the water sample to be tested. The series of tubes may consist of three or four groups of three, five, or more tubes.
- The main selective factors found in the medium are lactose, sometimes a surfactant such as Na-lauryl sulfate or Na-taurocholate (bile salt), and often a pH indicator dye for facilitating detection of acid production, such as bromcresol purple or brilliant green. The selective action of lactose occurs because many bacteria cannot ferment this sugar, whereas coliform bacteria and several other bacterial types can ferment it. The surfactant and dye do not inhibit coliform bacteria, whereas many other bacteria, such as the spore formers, are inhibited.

- **Confirmed Test**
- This test serves to confirm the presence of coliform bacteria when either a positive or doubtful presumptive test is obtained.
- A loopful of growth from such a presumptive tube is transferred into a tube of brilliant green lactose bile (BGLB) 2% broth (or other lactose broth) and incubated at 35°C for 48 hours. This is a selective medium for detecting coliform bacteria in water, dairy, and other food products. A selective agent in the medium is lactose. The broth tube also contains a Durham tube to detect gas production.
- A plate of LES Endo agar (or EMB agar) is streaked with a loopful of growth from a positive tube and incubated at 35°C for 18–24 hours. Typical coliform bacteria (*E. coli* and *Enterobacter aerogenes*) exhibit good growth on this medium and form red to black colonies with dark centers or a sheen. *Salmonella typhi* exhibits good growth but the colonies are colorless. *S. aureus* growth is inhibited altogether.

- **Completed Test**
- This test helps to further confirm doubtful and, if desired, positive confirmed test results. A typical coliform colony from an LES Endo agar plate is inoculated into a tube of brilliant green bile broth and on the surface of a nutrient agar slant. They are then incubated at 35°C for 24 hours. After 24 hours, the broth is checked for the production of gas, and a Gram stain is made from organisms on the nutrient agar slant. If the organism is a Gram-negative, non-spore-forming rod and produces gas in the lactose tube, then it is positive that coliforms are present in the water sample.

- **A. Presumptive Test**
- **Positive:** The formation of 10% gas or more in the Durham tube within 24 to 48 hours, together with turbidity in the growth medium and the color change in the medium constitutes a positive presumptive test for coliform bacteria, and hence for the possibility of fecal pollution.
- The test is presumptive only because under these conditions several other types of bacteria can produce similar results.
- **Negative:** No growth or formation of gas in Durham's tube.
- **B. Confirmed Test**
- **Positive:** Formation of gas in lactose broth and the demonstration of a coliform-like colony on the EMB agar indicate the presence of a member of the coliform group in the sample examined.
- Coliforms produce colonies with a greenish metallic sheen which differentiates them from non-coliform colonies (show no sheen). The presence of typical colonies at high temperatures (44.5 ±0.2) indicates the presence of thermotolerant *E.coli.*
- **Negative:** The absence of gas formation in lactose broth or the failure to demonstrate coliform-like colonies on the EMB agar.
- **Completed Test**
- **Positive:** The presence of gas in the brilliant green bile broth tube and Gram-negative, non-spore-forming rods on NA slant constitutes a positive completed test for the presence of coliform bacteria, which, in turn, infers possible contamination of the water sample with fecal matter.
- **Negative:** Absence of growth and gas formation in the broth. Absence of gram-negative, non-sporing rods on Gram staining.

- **Uses of Most Probable Number (MPN)**
- It is commonly used in estimating microbial populations in soils, waters, agricultural products.
- The technique is particularly useful with samples that contain particulate material that interferes with plate count enumeration methods.
- It has also been suggested as a consideration for an alternate method to trend environmental monitoring studies.
- It is also useful for counting bacteria that reluctantly form colonies on agar plates or **membrane filters** but grow readily in liquid media.
- **Advantages of Most Probable Number (MPN)**
- Ease of interpretation, either by observation or gas emission
- Sample toxins are diluted
- Effective method of analyzing highly turbid samples such as sediments, sludge, mud, etc.
- Permits samples that cannot be analyzed by **membrane filtration**.
- **Limitations of Most Probable Number (MPN)**
- Poor accuracy and precision associated with MPN count usually mean that the method is one of last resort — to be considered only when other counting methods are inappropriate.
- Laborious and expensive in terms of materials, glassware, and incubator space.
- It has relatively a large margin of error.

Heavy metals

- Heavy metals are elements (properties of metals satisfied) of high atomic numbers. They have high utilities in industrial applications from papers to automobiles, by their very characteristic properties. They are found in the deep bowels of the earth as ores (complexes of mixtures). The metals are segregated from these ores, leaving behind the tailings that find their way into the environment as toxic pollutants. They get into the water bodies directly from point sources as sewage, and non-point sources as runoff and more insidiously as atmospheric deposition that are transported from long distances. Heavy metals affect every level of the food web, from producers in the trophic levels to the highest order carnivore by residing in the system and magnifying at every trophic status.

Heavy metals

- LEAD
- Lead is relatively a minor element in the earth's crust but is widely distributed in low concentrations in uncontaminated soils and rocks.
- Lead concentration in freshwater is generally much higher.
- High concentration of lead results from atmospheric input of lead originating from its use in the leaded gasoline or from smelting processes.
- Industrial processes such as printing and dyeing, paint manufacturing, explosives, photography and mine or smelter operations may contain relatively high values in lead. Lead is toxic to aquatic organisms.

- COPPER

- Copper is a widely distributed trace element because most copper minerals are relatively insoluble and is sorbed to solid phases, hence only low concentrations are normally present in natural waters.
- Because of the presence of sulphide, copper would be expected to be even less soluble in anoxic systems. The presence of higher concentrations of copper can usually be attributed to corrosion of copper pipes, industrial wastes or particularly in reservoirs, which uses copper as algicides.
- Copper is an essential trace element in the nutrition of plants and animals including man. It is required for the function of several enzymes and is necessary in the biosynthesis of chlorophyll. High levels are toxic to organisms but the response varies greatly with species.

- IRON- is an abundant element in the earth's crust, but exists generally in minor concentrations in natural water systems. Iron is found in the +2 (ferrous) and +3 (ferric) states depending on the oxidation-reduction potentials of the water. The ferric state of iron imparts orange strain to any settling surfaces, including laundry articles, cooking and eating utensils, and plumbing fixtures.
- Cadmium is largely found in nature in the form of sulphide, and as an impurity of zinc - lead ores. The abundance of cadmium is much less than that of zinc. Cadmium may enter the surface waters as a consequence of mining, electroplating plants, pigment works, textile and chemical industries, and is toxic to man. There is evidence that cadmium affects reproductive organs in humans and is also a potential carcinogen. A specific disease called "itai-itai" has been absorbed in Japan due to excess cadmium. In addition, due to bioaccumulation, certain edible organisms may become hazardous to the ultimate consumer.

- ZINC- Zinc is an abundant element in rocks and ores and is present in natural waters only as a minor constituent.
- The main industrial use of zinc is in galvanizing and may enter the drinking waters from galvanized pipes.
- Another important use is in the preparation of alloys, including brass and bronze. It is an essential element in human nutrition.
- Food provides the main source of zinc to the body.
- Zinc may be toxic to aquatic organisms but the degree of toxicity varies greatly depending on water quality characteristics as well as the species being considered.

- CHROMIUM

- The concentration of chromium in natural waters is usually very low. Elevated concentrations of chromium can result from mining and industrial processes. Chromate compounds are routinely used in cooling waters to control erosion. Chromium in water supplies is generally found in the hexavalent form.

References

- http://mvhs.shodor.org/riverweb/jigsaw/PoW.pdf
- echo2.epfl.ch/VICAIRE/mod_2/chapt_2/main.htm

Characteristics of sewage

- Domestic sewage comprises spent water from kitchen, washroom etc. The factors which contribute to variations in characteristics of the domestic sewage are daily per capita use of water, quality of water supply and the type, condition and extent of sewerage system, and habits of the people.
- Municipal sewage, which contains both domestic and industrial wastewater, may differ from place to place depending upon the type of industries and industrial establishment.
- The important characteristics of sewage are as follows:

- **Temperature**: The observations of temperature of sewage are useful in indicating solubility of oxygen, which affects transfer capacity of aeration equipment in aerobic systems, and rate of biological activity.
- Extremely low temperature affects adversely the efficiency of biological treatment systems and the efficiency of sedimentation. In general, under Indian conditions the temperature of the raw sewage is observed to be between 15 and 35 0 C at various places in different seasons.
- **pH** : The hydrogen ion concentration expressed as pH, is a valuable parameter in the operation of biological units. The pH of the fresh sewage is slightly more than the water supplied to the community. However, decomposition of organic matter may lower the pH, while the presence of industrial wastewater may produce extreme fluctuations. Generally the pH of raw sewage is in the range 5.5 to 8.0.

- **Colour and Odour:** Fresh domestic sewage has a slightly soapy and cloudy appearance depending upon its concentration. As time passes the sewage becomes stale, darkening in colour with a pronounced smell due to microbial activity.
- **Solids:** Though sewage generally contains less than 0.5 percent solids, the rest being water, but these solids are highly degradable and therefore need proper disposal. The sewage solids may be classified into dissolved solids, suspended solids and volatile suspended solids. Knowledge of the volatile or organic fraction of solid, which decomposes, becomes necessary, as this constitutes the load on biological treatment units or oxygen resources of a stream when sewage is disposed off by dilution.
- The estimation of suspended solids, both organic and inorganic, gives a picture of the load on sedimentation and grit removal system during sewage treatment. Dissolved inorganic fraction is to be considered when sewage is used for land irrigation or any other reuse is planned.

- **Nitrogen** :The principal nitrogen compounds in domestic sewage are proteins, amines, amino acids, and urea. Ammonia nitrogen in sewage results from the bacterial decomposition of organic constituents. Nitrogen being an essential component of biological protoplasm, its concentration is important for proper functioning of biological treatment systems and disposal on land. Generally, the domestic sewage contains sufficient nitrogen, to take care of the needs of the biological treatment. Generally nitrogen content in the untreated sewage is observed to be in the range of 20 to 50 mg/L measured as TKN.
- **Phosphorus** is contributing to domestic sewage from food residues containing phosphorus and their breakdown products. The use of increased quantities of synthetic detergents adds substantially to the phosphorus content of sewage. Phosphorus is also an essential nutrient for the biological processes. The concentration of phosphorus in domestic sewage is generally adequate to support aerobic biological wastewater treatment. However, it will be matter of concern when the treated effluent is to be reused. The concentration of PO4 in raw sewage is generally observed in the range of 5 to 10 mg/L.

- **Chlorides**: Concentration of chlorides in sewage is greater than the normal chloride content of water supply. The chloride concentration in excess than the water supplied can be used as an index of the strength of the sewage.
- The daily contribution of chloride averages to about 8 gm per person. Based on an average sewage flow of 150 LPCD(lite per capita per day), this would result in the chloride content of sewage being 50 mg/L higher than that of the water supplied.
- Any abnormal increase should indicate discharge of chloride bearing wastes or saline groundwater infiltration, the latter adding to the sulphates as well, which may lead to excessive generation of hydrogen sulphide.

- **Organic Material:** Organic compounds present in sewage are of particular interest for environmental engineering.
- A large variety of microorganisms (that may be present in the sewage or in the receiving water body) interact with the organic material by using it as an energy or material source.
- The utilization of the organic material by microorganisms is called metabolism. The conversion of organic material by microorganism to obtain energy is called catabolism and the incorporation of organic material in the cellular material is called anabolism.
- There are two standard tests based on the oxidation of organic material: 1) the Biochemical Oxygen Demand (BOD) and 2) the Chemical Oxygen Demand (COD) tests. In both tests, the organic material concentration is measured during the test.
- The essential differences between the COD and the BOD tests are in the oxidant utilized and the operational conditions imposed during the test such as biochemical oxidation and chemical oxidation.
- The other method for measuring organic material is the development of the Total Organic Carbon (TOC) test as an alternative to quantify the concentration of the organic material.

- **Biochemical Oxygen Demand (BOD):** The BOD of the sewage is the amount of oxygen required for the biochemical decomposition of biodegradable organic matter under aerobic conditions.
- The oxygen consumed in the process is related to the amount of decomposable organic matter. The general range of BOD observed for raw sewage is 100 to 400 mg/L. Values in the lower range are being common under average Indian cities.
- **Chemical Oxygen Demand (COD):** The COD gives the measure of the oxygen required for chemical oxidation. In general, the COD of raw sewage at various places is reported to be in the range 200 to 700 mg/L.
- In COD test, the oxidation of organic matter is essentially complete within two hours, whereas, biochemical oxidation of organic matter takes several weeks.

- In case of wastewaters with a large range of organic compounds, an extra difficulty in using BOD as a quantitative parameter is that the rate of oxidation of organic compounds depends on the nature and size of its molecules.
- Smaller molecules are readily available for use by bacteria, but large molecules and colloidal and suspended matters can only be metabolized after preparatory steps of hydrolysis.
- It is therefore not possible to establish a general relationship between the experimental five-day BOD and the ultimate BOD of a sample, i.e., the oxygen consumption after several weeks.
- For sewage the BOD5 is 0.68 times of ultimate BOD, and ultimate BOD is 87% of the COD. Hence, the COD /BOD ratio for the sewage is around 1.7.
- **Toxic Metals and Compounds**: Some heavy metals and compounds such as chromium, copper, cyanide, which are toxic may find their way into municipal sewage through industrial discharges.
- The concentration of these compounds is important if the sewage is to treat by biological treatment methods or disposed off in stream or on land. In general these compounds are within toxic limits in sanitary sewage; however, with receipt of industrial discharges they may cross the limits in municipal wastewaters.

- **Effluent Disposal and Utilization**: The sewage after treatment may be disposed either into a water body such as lake, stream, river, estuary, and ocean or on to land.
- It may also be utilized for several purposes such as (a) industrial reuse or reclaimed sewage effluent cooling system, boiler feed, process water, etc., (b) reuse in agriculture and horticulture, watering of lawns, golf courses and similar purpose.

- **Economic Value of Sewage**: The sewage contains nutrients, which if not optimally reused may cause eutrophication in receiving water bodies, thus causing their premature ageing.
- Hence, instead of directly discharging the effluents into water bodies it can be used for irrigation or fodder cultivation.
- The economic value of sewage can be assessed based on its nutrient value. This will guide for considering sewage as a source of income, and to make sewage treatment economically viable.
- The nutrient value of sewage in terms of nitrogen 30 mg/L, phosphate 7.5 mg/L, and potassium 25 mg/L is provided by CPCB [1997].
- The total value of nutrient in sewage assuming @ Rs. 4220/- per tone of nutrient (as per 1996 cost), works out to be Rs. 1018 million, i.e., Rs. 890.6 million towards nutrients plus Rs. 127.4 million toward the cost of water.
- A realistic rate for tariff towards sewage supplied for sewage farming should consider the cost of nutrients apart from the cost of water supplied.
- At present the sewage is charged at average rate of Rs. 188/hectare/ annum, which is towards the cost of irrigation water only. If nutrients in the sewage are also to be accounted for, then an additional cost of Rs. 263/MLD or Rs. 1315 per hectare/annum should be levied for application levels of 500 cm per hectare per annum.
- Hence, the tariff should be levied at Rs. 1503 per hectare/annum (Rs.1315 + 188) from cultivators [CPCB, 1997].

- http://nptel.ac.in/courses/105105048/M13L16.pdf

Characteristics of industrial wastewaters

- The wastewater from industries varies so greatly in both flow and pollutional strength. So, it is impossible to assign fixed values to their constituents.
- In general, industrial wastewaters may contain suspended, colloidal and dissolved (mineral and organic) solids. In addition, they may be either excessively acid or alkaline and may contain high or low concentrations of colored matter.
- These wastes may contain inert, organic or toxic materials and possibly pathogenic bacteria. These wastes may be discharged into the sewer system provided they have no adverse effect on treatment efficiency or undesirable effects on the sewer system.
- It may be necessary to pretreat the wastes prior to release to the municipal system or it is necessary to a fully treatment when the wastes will be discharged directly to surface or ground waters.

Industrial Wastewater Characteristics

- Physical characteristics
- The principal physical characteristics of wastewater include solids content, colour, odour and temperature. –
- Total Solids: The total solids in a wastewater consist of the insoluble or suspended solids and the soluble compounds dissolved in water. The suspended solids content is found by drying and weighing the residue removed by the filtering of the sample. When this residue is ignited the volatile solids are burned off. Volatile solids are presumed to be organic matter, although some organic matter will not burn and some inorganic salts break down at high temperatures. The organic matter consists mainly of proteins, carbohydrates and fats. Between 40 and 65 % of the solids in an average wastewater are suspended. Settleable solids, expressed as millilitres per litre, are those that can be removed by sedimentation. Usually about 60 % of the suspended solids in a municipal wastewater are 2 settleable (Ron & George, 1998). Solids may be classified in another way as well: those that are volatilized at a high temperature (600 °C) and those that are not. The former are known as volatile solids, the latter as fixed solids. Usually, volatile solids are organic.

- Colour is a qualitative characteristic that can be used to assess the general condition of wastewater. Wastewater that is light brown in colour is less than 6 h old, while a light-to-medium grey colour is characteristic of wastewaters that have undergone some degree of decomposition or that have been in the collection system for some time. Lastly, if the colour is dark grey or black, the wastewater is typically septic, having undergone extensive bacterial decomposition under anaerobic conditions. The blackening of wastewater is often due to the formation of various sulphides, particularly, ferrous sulphide. This results when hydrogen sulphide produced under anaerobic conditions combines with divalent metal, such as iron, which may be present. Colour is measured by comparison with standards.
- Odour: The determination of odour has become increasingly important, as the general public has become more concerned with the proper operation of wastewater treatment facilities. The odour of fresh wastewater is usually not offensive, but a variety of odorous compounds are released when wastewater is decomposed biologically under anaerobic conditions. The different unpleasant odours produced by certain industrial wastewater are presented in Table.

- Table Unpleasant odours in some industries (Brault, 1991)

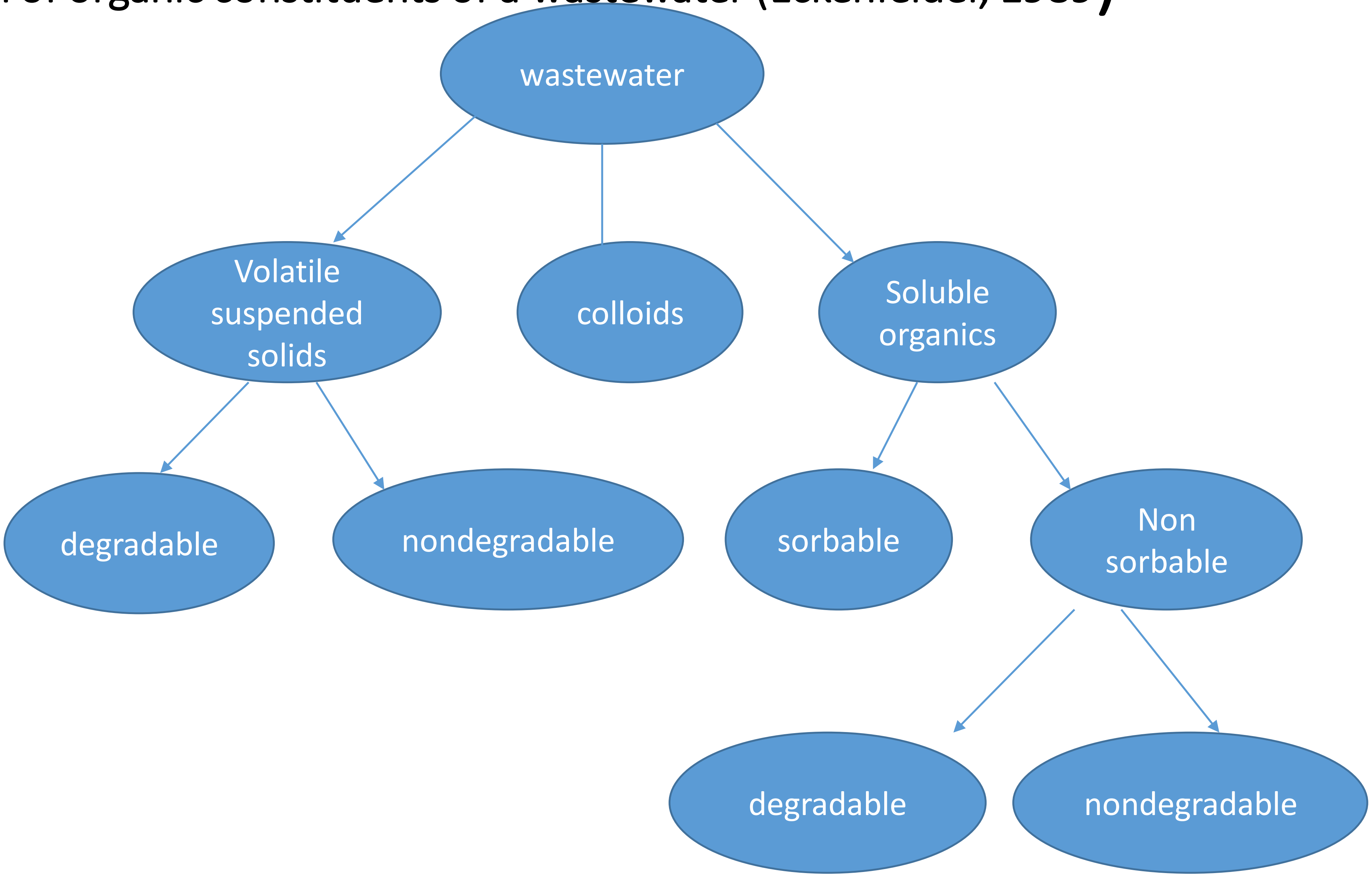
Industries	Origin of odours
Cement works, lime kilns	Acrolein, amines, mercaptans,dibutyl sulphide, H_2S, SO_2, etc.
Pharmaceutical industries	Fermentation produces
Food industries	Fermentation produces
Food industries (fish)	Amines, sulphides, mercaptans
Rubber industries	Sulphides, mercaptans
Textile industries	Phenolic compounds
Paper pulp industries	H_2S, SO_2
Organics compost	Ammonia, sulphur compounds

- Temperature: of wastewater is commonly higher than that of the water supply because warm municipal water has been added. The measurement of temperature is important because most wastewater treatment schemes include biological processes that are temperature dependent. The temperature of wastewater will vary from season to season and also with geographic location. In cold regions the temperature will vary from about 7 to 18 °C, while in warmer regions the temperatures vary from 13 to 24 °C (Ron & George, 1998).
- Chemical characteristics :
- Inorganic chemicals The principal chemical tests include free ammonia, organic nitrogen, nitrites, nitrates, organic phosphorus and inorganic phosphorus. Nitrogen and phosphorus are important because these two nutrients are responsible for the growth of aquatic plants. Other tests, such as chloride, sulphate, pH and alkalinity, are performed to assess the suitability of reusing treated wastewater and in controlling the various treatment processes (Rein, 2005)

- Trace elements, which include some heavy metals, are not determined routinely, but trace elements may be a factor in the biological treatment of wastewater.
- All living organisms require varying amounts of some trace elements, such as iron, copper, zinc and cobalt, for proper growth.
- Heavy metals can also produce toxic effects; therefore, determination of the amounts of heavy metals is especially important where the further use of treated effluent or sludge is to be evaluated.
- Many of metals are also classified as priority pollutants such as arsenic, cadmium, chromium, mercury, etc.
- Measurements of gases, such as hydrogen sulphide, oxygen, methane and carbon dioxide, are made to help the system to operate.
- The presence of hydrogen sulphide needs to be determined not only because it is an odorous and very toxic gas but also because it can affect the maintenance of long sewers on flat slopes, since it can cause corrosion.
- Measurements of dissolved oxygen are made in order to monitor and control aerobic biological treatment processes. Methane and carbon dioxide measurements are used in connection with the operation of anaerobic digesters.

- Organic chemicals
- Over the years, a number of different tests have been developed to determine the organic content of wastewaters.
- In general, the tests may be divided into those used to measure gross concentrations of organic matter greater than about 1 mg/l and those used to measure trace concentrations in the range of 10-12 to 10- 3 mg/l.
- Laboratory methods commonly used today to measure gross amounts of organic matter (greater than 1 mg/l) in wastewater include
- (1) biochemical oxygen demand (BOD),
- (2) chemical oxygen demand (COD)
- and (3) total organic carbon (TOC).
- Trace organics in the range of 10- 12 to   10-3 mg/l are determined using instrumental methods including gas mass spectroscopy and chromatography. Specific organic compounds are determined to assess the presence of priority pollutants (Metcalf & Eddy, 1991).
- The BOD, COD and TOC tests are gross measures of organic content and as such do not reflect the response of the wastewater to various types of biological treatment technologies. It is therefore desirable to divide the wastewater into several categories, as shown in Figure

Partition of organic constituents of a wastewater (Eckenfelder, 1989)



- Volatile organic carbons (VOC) Volatile organic compounds such as benzene, toluene, xylenes, trichloroethane, dichloromethane, and trichloroethylene, are common soil pollutants in industrialized and commercialized areas.
- One of the more common sources of these contaminants is leaking underground storage tanks.
- Improperly discarded solvents and landfills, built before the introduction of current stringent regulations, are also significant sources of soil VOCs.
- Many of organic substances are classified as priority pollutants such as polychlorinated biphenyls (PCBs), polycyclic aromatic, acetaldehyde, formaldehyde, 1,3-butadiene, 1,2-dichloroethane, dichloromethane, hexachlorobenzene (HCB), etc,.
- In Table, a list of typical inorganic and organic substances present in industrial effluents is presented.

Substances present in industrial effluents (Bond & Straub, 1974)

SUBSTANCES	**PRESENT IN WASTEWATERS OF INDUSTRIES**
Acetic acid	Acetate rayon, beet root manufact
Acids	Chem. manufact, mines, textiles manufact
Alkalies	Cotton and straw kiering, wool scouring
Ammonia	Gas and coke and chem. manufacture
Cadmium	Electro plating
Chromium	Electroplating, chrome tanning, alum anodizing
Citric acid	Soft drinks and citrus fruit processing
Copper	Copper plating, copper pickling
Cyanides	Gas manufacture, plating, metal cleaning
Fats, oils, grease	Wool scouring, laundries, textile industry

- Heavy metals and inorganic species - Several industries discharge heavy metals, it can be seen that of all of the heavy metals, chromium is the most widely used and discharged to the environment from different sources. Many of the pollutants entering aquatic ecosystems (e.g., mercury lead, pesticides, and herbicides) are very toxic to living organisms. They can lower reproductive success, prevent proper growth.
- However, chromium is not the metal that is most dangerous to living organisms. Much more toxic are cadmium, lead and mercury. These have a tremendous affinity for sulphur and disrupt enzyme function by forming bonds with sulphur groups in enzymes.
- Protein carboxylic acid (-CO2H) and amino (-NH2) groups are also chemically bound by heavy metals. Cadmium, copper, lead and mercury ions bind to cell membranes, hindering transport processes through the cell wall. Heavy metals may also precipitate phosphate bio-compounds or catalyze their decomposition and development, and even cause death.

- Ammonia is the initial product of the decay of nitrogenous organic wastes, and its presence frequently indicates the presence of such wastes.
- It is a normal constituent of some sources of groundwater and is sometimes added to drinking water to remove the taste and odour of free chlorine. Since the pKa (The negative log of the acid ionization constant) of the ammonium ion, NH_4^+ , is 9.26, most ammonia in water is present as NH_4^+ rather than NH_3.
- · Other inorganic pollutants Hydrogen sulphide, H_2S, is a product of the anaerobic decay of organic matter containing sulphur. It is also produced in the anaerobic reduction of sulphate by microorganisms and is developed as a gaseous pollutant from geothermal waters.
- Wastes from chemical plants, paper mills, textile mills and tanneries may also contain H_2S. Nitrite ion, NO_2^- , occurs in water as an intermediate oxidation state of nitrogen. Nitrite is added to some industrial processes to inhibit corrosion; it is rarely found in drinking water at levels over 0.1 mg/l. Sulphite ion, SO_3^{2-} , is found in some industrial wastewaters.

- Organic pollutants : Effluent from industrial sources contains a wide variety of pollutants, including organic pollutants. Primary and secondary sewage treatment processes remove some of these pollutants, particularly oxygendemanding substances, oil, grease and solids.
- Others, such as refractory (degradation-resistant) organics (organochlorides, nitro compounds etc.), and salts and heavy metals, are not efficiently removed.
- Soaps, detergents and associated chemicals are potential sources of organic pollutants.
- Most of the environmental problems currently attributed to detergents do not arise from the surface-active agents, which basically improve the wetting qualities of water.
- The greatest concern among environmental pollutants has been caused by polyphosphates added to complex calcium, functioning as a builder. Bio-refractory organics are poorly biodegradable substances, prominent among which are aromatic or chlorinated hydrocarbons (benzene, bornyl alcohol, bromobenzene, chloroform, camphor, dinitrotoluene, nitrobenzene, styrene etc,
- Many of these compounds have also been found in drinking water. Water contaminated with these compounds must

- be treated using physical and chemical methods, including air stripping, solvent extraction, ozonation and carbon adsorption.
- First discovered as environmental pollutants in 1966, polychlorinated biphenyls (PCB compounds) have been found throughout the world in water, sediments and bird and fish tissue.
- They are made by substituting between 1 and 10 Cl atoms onto the biphenyl aromatic structure. This substitution can produce 209 different compounds (Rein, 2005).

Type of Industry	Waste charactersitic	Sources of effluents	Method of treatment	Remark
Paper,pulp and Board industry	Foul odour,brown coloured effluent containing less pH, very high TSS	Digestion of wood,screening of pulp, washing of fibres	Coagulation,Flocculation,Secondary biological treatment	Toxic for aquatic life
Electroplating	Low pH, High COD,heavy metals like Cr,toxic substance like CN	Washwater and wastes	Neutralization to pH 8.5 and precipitation Chromium waste treatment with lime for reduction from Cr +6 to Cr +3	
Pharmaceutical	Low pH, various chemicals	Washing and wastes	Neutralization, Sedimentation, Biological Oxidation	
Dairy	Odor,Higher BOD	Processes	Biological treatment	

Distillery	Odor,Higher BOD and suspended solids	Spent wash and waste from heat exchangers	Anaerobic digestion and biogas production, recovery of waste solid as food stuff.	Toxic for aquatic life
Dyeing	Higher BOD and suspended solids,oils,phenols ,starch,alkalies,colour	Dyeing,printing	Biological treatment, aeration, coagulation,neutralization	Toxic for aquatic life
Nuclear powerplant	Radioactive substances	Processing of ores	Proper disposal of wastes	Highly poisonous for living organisms
Fertilizer industries	Nitrate, Phosphate,High BOD and COD	washwaters		

List of parameters for each industrial activity

INDUSTRIAL ACTIVITY	PARAMETERS
Textile manufacturing	**Colour, Temperature, pH, COD, BOD_5, Reactive Phosphorus, Free Chlorine, TSS, Chloride, Sulphate, Sulphide, Ammoniacal Nitrogen, Nitrate as N, Detergents, Cadmium, Total Chromium, Cobalt, Copper,Molybdenum, Sodium, Zinc, Oil & Grease, Total Pesticides, Total Organic Halides.**
Metal Plating & Galvanising	**Temperature, pH, COD, Free Chlorine, TSS, Chloride, Sulphate, Sulphide, Nitrate as N, Cyanide, Cadmium, Total Chromium, Cobalt, Copper, Iron, Lead, Nickel, Zinc, Oil & Grease, Total Organic Halides.**
Slaughtering	**Temperature, pH, COD, BOD_5, TSS, Chloride, Nitrate as N, TKN, Oil & Grease, Total Coliforms, E. Coli**
Canning & Food Processing	**Temperature, pH, COD, BOD_5, Free Chlorine, TSS, Chloride, Nitrate as N, TKN, Sodium, Oil & Grease, Total Coliforms.**
Dairy Processing	**Temperature, pH, COD, BOD_5, TSS, Selenium, Oil & Grease, Detergents, Ammoniacal Nitrogen.**
Soft Drink Bottling	**Temperature, pH, COD, BOD_5, TSS, Sodium, Zinc, Detergents.**
Breweries & Distilleries	**Temperature, pH, COD, BOD_5, TSS, Nitrate as N, Selenium, Zinc, Oil & Grease, Detergents, Ammoniacal Nitrogen.**
Laundry processes	**Temperature, pH, COD, BOD_5, Reactive Phosphorus, Free Chlorine, TSS, Nitrate as N, Total Chromium, Copper, Iron, Lead, Oil & Grease, Total Organic Halides, Detergents**
Edible Oil Refining	**Temperature, pH, COD, BOD_5, TSS, Chloride, Sodium, Oil & Grease, Total Organic Halides, Phenols, Detergents.**
Paint Manufacturing	**Colour, Temperature, pH, COD, BOD_5, TSS, Chloride, Sulphate, Sulphide, Aluminium, Cadmium, Total Chromium, Cobalt, Copper, Lead, Mercury, Molybdenum, Zinc, Oil & Grease, Total Organic Halides.**

Mechanical Workshop	**pH, COD, BOD_5, Oil & Grease, Total Chromium, Lead, Manganese, Zinc.**
Thermal Power Plant	**Temperature, pH, TSS, Oil & Grease, Total Chromium, Copper, Iron, Zinc.**
Soap & Detergents Manufacturing	**Temperature, pH, COD, BOD_5, Reactive Phosphorus, Free Chlorine¸ TSS, Oil & Grease, Total Organic Halides, Detergents, Ammoniacal Nitrogen.**
Manufacture of Pharmaceutical products	**Temperature, pH, COD, BOD_5, Reactive Phosphorus, TSS, Sulphide, Oil & Grease, Phenols and Detergents.**
Tanning	**Colour, Temperature, pH, COD, BOD_5, Reactive Phosphorus, TSS, Sulphate, Sulphide, Nitrate as Nitrogen, Cadmium, Total Chromium, Mercury, Oil & Grease, Total Organic Halides, Total Coliforms, E. Coil Coli, Ammoniacal Nitrogen.**
Manufacture of Chemical Fertilizers	**Temperature, pH, COD, BOD_5, Reactive Phosphorus, TSS, Sulphate, Oil & Grease, Ammoniacal Nitrogen.**
Livestock Breeding	**pH, COD, BOD_5, Reactive Phosphorus, TSS, Nitrate as Nitrogen, TKN, Total Coliforms, E. Coli, Ammoniacal Nitrogen.**

Parameter	**Unit**	**Maximum permissible limit**	
		Land/ Underground	**Surface water courses**
Total coliforms	MPN per 100 ml	-	<400
E. Coli	MPN per 100 ml	<1000	<200
Free Chlorine	mg/l	-	0.5
Total Suspended Solids (TSS)	l	45	35
Reactive Phosphorus	mg/l	10	1
	mg/l		
Colour	-	Not objectionable	
Temperature	^{0}C	40	
pH	-	5 – 9	
Chemical Oxygen Demand (COD)	mg/l	120	
Biochemical Oxygen Demand (BOD$_5$)	mg/l	40	
Chloride	mg/l	750	
Sulphate	mg/l	750	
Sulphide	mg/l	0.002	
Ammoniacal Nitrogen	mg/l	1	
Nitrate as N	mg/l	10	
Total Kjeldahl Nitrogen (TKN)	mg/l	25	
Nitrite as N	mg/l	1	
Aluminium	mg/l	5	
Arsenic	mg/l	0.1	
Beryllium	mg/l	0.1	
Boron	mg/l	0.75	

Cadmium	mg/l	0.01
Cobalt	mg/l	0.05
Copper	mg/l	0.5
Iron	mg/l	2.0
Lead	mg/l	0.05
Lithium	mg/l	2.5
Manganese	mg/l	0.2
Mercury	mg/l	0.005
Molybdenum	mg/l	0.01
Nickel	mg/l	0.1
Selenium	mg/l	0.02
Sodium	mg/l	200
Total Chromium	mg/l	0.05
Vanadium	mg/l	0.1
Zinc	mg/l	2
Oil & Grease	mg/l	10
Total Pesticides	mg/l	0.025
Total organic halides	mg/l	1
Cyanide (as CN^-) *or Free cyanide*	mg/l	0.1
Phenols	mg/l	0.5
Detergents (as LAS*)	mg/l	15