UNIT 5 CONCEPTS IN WASTEWATER CHARACTERISTICS AND MANAGEMENT

Structure

5.1 INTRODUCTION

Due to the importance of health problems caused by wastewater, wastewater is transported away from the community, treated and then disposed. Human excreta have been implicated in the transmission of many infectious diseases including cholera, typhoid, hepatitis, polio, cryptosporidiosis, ascariasis and schistosomiasis. These diseases predominantly affect children and the poor and especially in the developing countries.

Infectious agents are not the only health concerns associated with wastewater and excreta. Heavy metals, toxic organic and inorganic substances also can pose serious threats to human health and the environment. Nitrates from the wastes can build up to high concentrations in groundwater and cause methaemoglobinaemia when consumed by bottle-fed infants. Nutrients may cause eutrophication in receiving water bodies potentially leading to cyanobacterial and other harmful algal blooms and the production of toxins by these organisms.

Water-related Disease Incidence Worldwide

Water-related disease places an excessive burden on the population and health services of many countries worldwide and in particular those in developing countries. Table 5.1 shows estimates of worldwide morbidity and mortality rates of some major water-related diseases. These figures are likely to be conservative estimates.

Table 5.1 : Morbidity and Mortality Rates of Some Important Water-related Diseases (WHO, 1995)

Disease	Cases per Year (thousands)	Deaths per Year (thousands)
Cholera	384	11
Typhoid	500	25
Giardiasis	500	low
Amoebiasis	48,000	110
Diarrhoeal disease	1,500,000	4,000
Ascariasis	1,000	20
Trichuriasis	100	low
Ancylostoma	1,500	60
Dracunculiasis (Guinea worm)	> 5,000	–
Schistosomiasis	200,000	800
Trachoma	360,000 (active)	9,000 (blind)

Objectives

After studying this unit, you should be able to

- describe the relative importance of sanitation to the public health which varies with respect to a number of geographical, social, seasonal and microbiological factors,
- explain physical, chemical and biological characteristics indicators of waste water quality,
- appreciate from an engineering viewpoint, the need of rationally selected, integrally planned and suitably designed wastewater management systems, and
- discuss various means of disposal of waste water and storm water.

5.2 PARAMETERS OF WASTEWATER QUALITY

Water contains a variety of physical, chemical and biological substances that are either dissolved or suspended in it. Quality is usually judged as the degree to which water confirms to the set physical, chemical and biological standards.

5.2.1 Physical Characteristics Indicators

Colour

Natural waters may have yellow-green colour; other colours may indicate substantial pollution or pipe corrosion; aesthetically unacceptable. Colour makes water unpleasant for use. Organic matter very often contributes to colour. Even very small amounts of it can result in an unacceptable colour.

Odour

These are usually caused by complex organic substances of natural or industrial origin, and are responsible for most of the complaints. If wastewater has a distinctive "rotten egg" odour, hydrogen sulfide gas is present. A major cause of taste and odour problems is metabolites produced by actinomycetes, algae, or other microorganisms.

Temperature

Causes of temperature change include weather, removal of shading stream, bank vegetation, impoundments, discharge of cooling water, urban storm water, and groundwater inflows to the stream. Temperature affects many physical, biological and chemical characteristics such as amount of oxygen that can be dissolved in water, rate of photosynthesis of plants, metabolic rates of animals and the sensitivity of organisms to toxic wastes, parasites, and diseases. Thermal pollution is an increase in temperature caused by adding relatively warm water to cooler stream water. The warm water can be stormwater running off warmed urban surfaces, such as streets and parking lots, which are often constructed of black, heat-absorbing asphalt. Turbidity in water increases the amount of heat absorbed from sunlight. Measurement of temperature change can help detect sources of thermal pollution and suggest the size of habitat for organisms that are more sensitive to temperature variation.

Turbidity

Turbidity is a measure of cloudiness in water. Suspended materials include soil particles (clay, silt and sand), algae, plankton, microbes and other substances. Turbidity can be caused by soil erosion, waste discharge, urban runoff and algal growth. Turbid waters become warmer as suspended particles absorb heat from sunlight, causing oxygen levels to fall. Warm water holds less oxygen than cooler water. Photosynthesis decreases with lesser light, resulting in even lower oxygen levels. Suspended solids in turbid water can clog fish gills, reduce growth rates, decrease resistance to disease and prevent egg and larval development. Settled particles smother eggs of fish and aquatic insects. Turbidity can be useful as an indicator of the effects of runoff from construction, agricultural practices, logging activity, discharges and other sources.

Total Solids

The total amount of solids present in the wastewater sample, which includes dissolved solids, suspended particles and colloids, and volatile solids are termed as total solids.

Total Suspended Solids

A fixed volume of sample is filtered through a preweighed and washed glass fibre filter. The filter is then rinsed and dried at 103 to 105^{o}C. The change in the weight of the filter represents the weight of suspended material. This test is typically done for wastewater treatment plants.

Total Dissolved Solids

These are determined by filtering a measured volume of the sample through a standard glass fibre filter. The filtrate (i.e., filtered liquid) is then evaporated to dryness at a constant temperature of 180^{o}C.

Total Volatile Solids

The residue for total dissolved solids testing is then ignited at a temperature of 500^{o}C. The change in the weight represents the amount of suspended or dissolved solids that are organic in nature or volatilized. The parameter is typically used in wastewater treatment plants because it provides an estimate of the organic matter content within the waste stream.

Electrical Conductivity

Conduction of electricity is due to presence of dissolved salts in it and it can be correlated with the total solids. The theoretical definition of conductivity is the "reciprocal of the resistance of a cube of a substance 1 cm on a side at a specified temperature". Typically, the units of measure are micro-mhos/cm. Conductivity or specific conductance is a measure of the ability of a fluid to carry a charge, which is directly related to the concentration of dissolved substances.

5.2.2 Chemical Characteristics Indicators

pH

pH is a term used to indicate the alkalinity or acidity of a substance as ranked on a scale from 0 to 14. A pH of 7 is neutral. The technical definition of pH is that it is a measure of the activity of the hydrogen ion (H^+) and is reported as the reciprocal of the logarithm of the hydrogen ion activity. Therefore, a water with a pH of 7 has 10^{-7} moles per litre of hydrogen ions; whereas a pH of 6 is 10^{-6} moles per litre. Most organisms have adapted to life in water of a specific pH and may die if it changes even slightly. The toxicity level of ammonia to fish, for example, varies tremendously within a small range of pH values. Acid rain containing nitric and sulphuric acids can sharply lower the pH of a stream as the rain runs quickly off streets and roofs into creeks. Acidic water can cause heavy metals such as copper and aluminum to be released into the water. Copper from worn automobile brake pads is often present in runoff. Rapid growing algae remove carbon dioxide from the water during photosynthesis, which can result in a significant increase in pH levels.

Alkalinity

The acid neutralizing capacity of water is known as alkalinity. It is due to presence of bicarbonate, carbonate or hydroxide ions in water. For surface waters alkalinity has been called "The Protector of the Stream", since the alkalinity of the water resists sudden changes in the pH of the stream associated with the influx of acid deposition, water containing organic acids, groundwater discharges or industrial wastes.

Acidity

The base neutralizing capacity of water is known as acidity. Acids contribute to corrosiveness, influence chemical reactions and chemical/biological processes.

Chloride

One of the oldest indications of water pollution, chloride comes from many natural sources or from water use (e.g., domestic use results in 10-20 mg/l increase of Cl-concentration). It may affect taste if the concentration is more than 250 mg/l. Waters with high Cl concentrations cannot be used for irrigation of sensitive crops. It causes increased corrosion. Although, higher concentrations may be found in groundwater because of naturally high levels of chloride in soils in some areas or contamination by road salt. Chloride is the most abundant anion in the human body and any excess is excreted in the urine. There is no evidence that ingestion of chloride is harmful to humans. Excess chloride imparts an objectionable taste.

Sulphate

Sulphate is a primary concern related to crown corrosion in concrete sewers; at concentrations > 250 mg/l may impart bitter taste to water or cause temporary gastrointestinal disorders. Sulphates, which occur naturally in numerous minerals, are often discharged into surface waters as wastes from industries such as mining and smelting operations, craft pulp and paper mills. Sulphate is one of the least toxic anions and large quantities would have to be ingested in order for diarrhoea type symptoms to occur.

Fats, Oils and Grease

Grease is the common term for animal fats and vegetable oils, which are classified as lipids. Lipids are organic molecules essential to animal life for the production of hormones and energy storage. If a lipid is liquid at room temperature, it is usually referred to as oil. If it is solid at room temperature, the lipid is referred to as a fat or grease. Fats, oils and grease are a natural consequence of cooking and can also occur naturally in many foods, such as meat. Waste fats and oils are frequently poured down the sink drain. Grease also routinely enters the sanitary sewer system as a result of normal kitchen operations, including residential and food service facility. Large amounts of oil and grease in wastewater cause trouble in the sewer collection system pipes. Grease in warm wastewater may not appear harmful but as the liquid cools, the solidification of grease takes place, which causes buildup in the interior of the pipes, accumulating into a hardened mass. This buildup restricts the flow of sewage and clogs the pipes. Clogged pipes may result in sewer overflows, which can cause health hazards, damage home interiors, and threaten the environment. Raw sewage overflowing in parks and streets, and even into homes and yards, requires an extensive and unpleasant cleanup.

Ammonia

Nitrogen occurs in natural waters as nitrate (NO_3), nitrite (NO_2), ammonia (NH_3) and organically bound nitrogen. As aquatic plants and animals die, bacteria break down large protein molecules containing nitrogen into ammonia. Sewage is the main source of ammonia added by humans to rivers. The ammonia arises mostly from the hydrolysis of urea in urine, but additional ammonia is generated by the decomposition of other nitrogenous materials in sewage. In a flowing stream, the presence of ammonia in high concentrations indicates recent pollution. Excessive amounts can cause a reduction in salmon hatching success and a reduction in growth rate among other things. The criterion for ammonia is dependent on other factors in the stream – such as pH and Temperature.

Nitrates

It occurs in natural waters as nitrate (NO_3), nitrite (NO_2), ammonia (NH_3) and organically bound nitrogen. Sewage is the main source of nitrates added by humans to rivers. Another important source is fertilizers, which can be carried into creeks by stormwater runoff. Excessive nitrates stimulate growth of algae and other plants, which later decay and decrease the amount of oxygen available for fish.

Phenol

Phenol is found in nature in animal waste and organic material. The largest single use of phenol is to make plastics, but it is also used as a disinfectant. It may occur in domestic and industrial wastewaters, natural waters, and potable water supplies. Phenol poses acute and chronic toxicity to freshwater aquatic life.

Phosphorus

Phosphorus is usually present in natural water as phosphates (orthophosphates, polyphosphates, and organically bound phosphates), one of the essential nutrients required for growth of aquatic algae. In many ecosystems, phosphorus appears to be a limiting nutrient. It means that if an increased quantity of phosphorus is discharged, a rapid and intense algal growth can be expected. Such growth (called algal bloom or eutrophication) is objectionable for a number of reasons. First, water becomes green. A more important objection to an excessive algal growth is that when they die, microorganisms, which consume oxygen for their metabolism, decompose them. As a result of this consumption, oxygen is depleted in water and other aquatic species, particularly fish, are affected. For these reasons, phosphorus discharge to such sensitive waters is controlled. Since, of the two major sources of phosphorus – agricultural runoff and municipal wastewater – the latter is easier to put under regulatory control, many wastewater treatment plants have phosphorus concentration limit imposed on their effluent.

Metals

Several metal ions such as sodium, potassium, magnesium and calcium are essential to sustain biological life. Traces of metals are essential for optimal growth, development and reproduction. They function mostly as catalysts for enzymatic activity in human bodies. However, all essential traces of metals become toxic when their concentration becomes excessive. Usually this happens when the levels exceed by 40- to 200-fold of those required for correct nutritional response. Some of the metals are toxic like mercury, lead, cadmium, chromium, silver, selenium, aluminum, arsenic and barium. These metals can cause chronic or acute poisoning and should be eliminated from the drinking water if possible. For example mercury and its compounds are very toxic to plants, animals and humans. These compounds bioaccumulate in the food chain and can cause serious acute and chronic disorders.

Dissolved Oxygen

The stream system both produces and consumes oxygen. It gains oxygen from the atmosphere and from plants as a result of photosynthesis. Running water, because of its churning, dissolves more oxygen than still water, such as that in a reservoir behind a dam. Respiration by aquatic animals, decomposition and various chemical reactions consume oxygen. Fish, invertebrates, plants and aerobic bacteria all require oxygen for respiration. Much of the dissolved oxygen in water comes from the atmosphere. After dissolving at the surface, oxygen is distributed by current and turbulence. Algae and rooted aquatic plants also deliver oxygen to water through photosynthesis. The main factor contributing to changes in dissolved oxygen levels is the build-up of organic wastes. Wastewater from sewage treatment plants often contains organic materials, which consumes oxygen. Other sources of oxygen-consuming waste include stormwater runoff from farmland or urban streets, feedlots and failing septic systems. Depletions in dissolved oxygen can cause major shifts in the kinds of aquatic organisms found in water bodies. Temperature, pressure and salinity affect the dissolved oxygen capacity of water. The ratio of the dissolved oxygen content (ppm) to the potential capacity (ppm) gives the percent saturation, which is an indicator of water quality.

Chemical Oxygen Demand (COD)

The organic matter is susceptible to oxidation by strong chemical oxidant. COD is used as a measure of the oxygen equivalent of the organic matter content of the sample. COD is typically used when there are industrial wastewater sources, comparing biological to chemical oxidation in the selection of treatment process and performances.

COD may be defined as the milligrams of oxygen required to chemically oxidize, using chromic acid, the organic contaminants in 1 litre of wastewater. COD is another means of measuring the pollutional strength of a wastewater. By using this method, most oxidizable organic compounds present in the wastewater sample are measured rather than only the more easily oxidizable ones measured using the BOD test. Generally, COD values will be higher than those determined with the BOD text. The reason for this difference is that the BOD test measures only the quantity of organic material capable of being oxidized by microbial action, while the COD test represents a more complete oxidation. The COD test has a major advantage over the BOD analysis because of the short time required – a few hours as opposed to 5 days for the standard BOD test. This advantage permits more responsive operational control of the treatment process. Typical COD values for domestic wastewater range from 200 to 500 mg/l. As the industrial content of the wastewater increases, the ratio of COD to BOD typically also increases.

Biological Oxygen Demand (BOD)

BOD is used by regulatory agencies for monitoring wastewater treatment facilities and monitoring surface water quality. BOD is the biochemical oxygen demand of the water and it is related to the concentration of the bacterial facilitated decomposable organic material in the water.

A laboratory measurement of wastewater that is one of the main indicators of the quantity of pollutants present; a parameter used to measure the amount of oxygen that will be consumed by microorganisms during the biological reaction of oxygen with organic material. The total milligrams of oxygen required over a 5-day test period to biologically assimilate the organic contaminants in 1 litre of wastewater maintained at 20°C, is termed as BOD. Now-a-days BOD tests are performed for 3 days at 27^{o}C. The BOD of a wastewater is widely used as an indicator of the fraction of organic matter that may be degraded by microbial action in a given time period at a temperature of 20°C. BOD is a measure of the pollution strength of a wastewater and the test is related to the oxygen that would be required to stabilize the waste after discharge to a receiving body of water. The BOD test has been widely used by regulatory agencies to gauge overall treatment plant performance. The traditional measurement of BOD of the plant effluent, primary tank effluent and final effluent gives the most common measure of treatment plant efficiency. The drop in BOD from raw effluent to final effluent is usually used in calculating the solids growth rate in the aeration tank. This test is too slow to provide timely information to the operator for control purposes. It can, however, provide the operator with the historic results of previous operating decisions. Tests for BOD are to be made on composite samples daily. BOD tests run for at least 20 days should also be made on the effluent periodically to determine the oxygen requirements of the nitrogen compounds present in the effluent.

COD measurements are preferred for a mixed domestic-industrial wastewater or where a more rapid determination of the load is desired. The COD test will record the oxygen demand for certain industrial wastes that cannot be used readily as food by the treatment plant organisms. The COD test may be run in several hours, giving the operator a more timely measurement of what is entering the plant and how the plant is performing.

5.2.3 Biological Characteristics Indicators

The wide variety of waterborne diseases is the most important concern about water quality. The pathogens concerned include many types of viruses, bacteria, protozoa and helminths, which differ widely in size, structure and composition. This implies that their survival in the environment and resistance to water treatment processes differs significantly. However, the waterborne transmission of infectious diseases can be controlled effectively by practical and economic methods. The approach must be based on protection of the source, selection of appropriate treatment methods, fail-safe application of the treatment methods, well-protected distribution networks and appropriate quality monitoring. Relatively simple and inexpensive indicator methods are available for routine monitoring of the microbiological safety of water and the efficiency of treatment processes.

Most reliable results are obtained by high frequency testing for indicator organisms selected for particular purposes. For instance, routine-monitoring programmes for drinking water may be based on tests for faecal streptococci, thermo tolerant coliform organisms or *Escherichia coli*. Under certain circumstances, tests for the heterotrophic plate count and coliphages may be included. These tests are simple, inexpensive and yield results in a relatively short time. More complicated and expensive tests such as those for human viruses and protozoan parasites are required only for particular purposes, including research and assessment of the efficiency of treatment processes.

Coliform-Group Bacteria

A group of bacteria predominantly inhabiting the intestines of man or animal, but also occasionally found elsewhere are known as coliform-group bacteria. These include all aerobic and facultative anaerobic Gram-negative, nonspore-forming bacilli that ferment lactose with production of gas. Also included are all bacteria that produce a dark, purplish-green colony with a metallic sheen by the membrane-filter technique used for coliform identification. The two groups are not always identical, but they are generally of equal sanitary significance.

SAQ 1

(a) Differentiate between total dissolved solids, total volatile solids and total suspended solids.

(b) Is there any relation between electric conductivity and total dissolved solids of wastewater?

(c) Define dissolved oxygen (DO), BOD and COD.

(d) What is an indicator organisms?

5.3 QUALITY OF SEWAGE

Household wastewater derives from a number of sources. Wastewater from the toilet is termed 'blackwater'. It has a high content of solids and contributes a significant amount of nutrients (nitrogen, N and phosphorus, P). Blackwater can be further separated into faecal materials and urine. Each person on average excretes about 4 kg N and 0.4 kg P in urine, and 0.55 kg N and 0.18 kg P in faeces per year. Table 5.2 shows characteristics of human excreta and a comparison with nutrient contents of plant matter to indicate its value as a soil conditioner and fertiliser.

Table 5.2* : Human Excreta – Per Capita Quantities and Their Resource Value

Quantity and Consistency	Faeces	Urine	Excreta
Gram/capita/day (wet)	250	1,200	1,450
Gram/capita/day (dry)	50	60	110
Chemical Composition (% of Dry Solids)			
Organic matter	92	75	83
Carbon, C	48	13	29
Nitrogen, N	4-7	14-18	9-12
Phosphorus (as P_2O_5)	4	3.7	3.8
Potassium (as K_2O)	1.6	3.7	2.7
Comparison with other wastes (% of dry solids)	N	P_2O_5	K_2O
Human excreta	9-12	3.8	2.7
Plant matter	1-11	0.5-2.8	1.1-11
Pig manure	4-6	3-4	2.5-3
Cow manure	2.5	1.8	1.4

*Adopted from *Strauss, M. (1996) Health (pathogen) considerations regarding the use of human waste in aquaculture. In: J. Staudenmann, A. Schönborn and C. Etnier (Eds.), Recycling the Resource, Proceedings of the Second International Conference on Ecological Engineering for Wastewater Treatment, School of Engineering Wädenswil-Zürich, September 18-22, 1995, Transtec Publications, Zurich, pp. 83-98.*

Greywater consists of water from washing of clothes, from bathing/showering and from the kitchen. The latter may have a high content of solids and grease, and depending on its intended reuse/treatment or disposal can be combined with toilet wastes and form the blackwater. Both greywater and blackwater may contain human pathogens, though concentrations are generally higher in blackwater.

The volume of wastewater and concentration of pollutants produced depend on the volume of water used and water conservation measures. The use of dry pit latrines and the practice of water conservation produce low volume and high concentration wastewater, while use of flushing toilets results in higher wastewater volumes and lower concentrations. The flow of wastewater is generally variable with peak flows coinciding with high household activities in the morning and evening; while in the night minimal flow occurs. Pollutant loads vary in a similar manner.

Stormwater in a community settlement is produced from house roofs, paved areas and from roads during rainfall events. In addition stormwater is produced from the catchment of a stream or river upstream of the community settlement. The amount of stormwater is, therefore, related to the amount of rainfall precipitation, and the nature of surfaces, with impervious surfaces producing more run-off. During a storm event the peakflow is higher and duration shorter with an impervious surface, while the peakflow is lower and duration longer with a vegetated surface. Stormwater run-off may contain as much solids as household wastewater depending on the debris and pollutants in the path of the stormwater run-off, although in general the pollutant load of stormwater is lower than that of wastewater. Table 5.3 shows a comparison of typical urban stormwater sources and untreated sewage.

Table 5.3 : Comparison of the Characteristics of Stormwater Sources and Untreated Sewage

Type of Wastewater	BODs (mg/L)	Suspended Solids (mg/L)	Total N (mg/L)	Total P (mg/L)	Total Coliforms (MPN/100mL)
Urban stormwater	10-250 (30)	3-11,000 (650)	3-10	0.2-1.7 (0.6)	10^3-10^8
Construction site run-off	NA	10,000-40,000	NA	NA	NA
Combined sewer overflows	60-200	100-1,100	3-24	1-11	10^5-10^7
Light industrial area	8-12	45-375	0.2-1.1	NA	10
Roof run-off	3-8	12-216	0.5-4	NA	10^2
Untreated sewage	(160)	(235)	(35)	(10)	10^7-10^9
Wastewater treatment plant effluent (secondary treatment)	(20)	(20)	(30)	(10)	10^4-10^6

5.4 IMPACT OF WASTEWATER AND STORMWATER

Solids in both wastewater and stormwater form sediments and can eventually clog drains, streams and rivers. Grease particles form scum and are aesthetically undesirable. The nutrients N and P cause eutrophication of water bodies, with lakes and slow moving waters affected to a greater degree than faster flowing waters. In the former the algae, which are fertilised by the nutrients, settle as sediment when they decay. The sediment acts as a store of nutrients and regularly releases the nutrients to the water column, thus the cycle of bloom and decay of the algae is intensified. In the early stages of eutrophication, aquatic life is made more abundant, because fish, for example, graze on the algae. With too high a concentration of algae, the decaying algae contribute to BOD and the water is deoxygenated. Thus wastewater, which has been treated to reduce BOD but still high in nutrients, can still have a significant impact on the receiving water. Some algae produce toxins, which can be harmful to bird life and irritate skins coming into contact with the water. Eutrophic water adds to the cost of water treatment, when the water is used for drinking purposes.

Other pollutants in wastewater and stormwater are heavy metals and possible toxic and household hazardous substances. Heavy metals include copper, zinc, cadmium, nickel, chromium and lead. The content and concentration are dependent on the pipe materials employed to convey drinking water, household-cleaning agents used, and for stormwater the type of materials used for roofing and guttering. In high enough concentrations, these heavy metals are toxic to bacteria, plants and animals, and to people. Toxic materials may also be disposed with household wastewater. These could be medicines, pesticides and herbicides, which are no longer used, excess solvents, paints and other household chemicals. These substances can corrode sewer pipes and seriously affect operation of treatment plants. They will also limit the potential of water reuse, and, therefore, should not be disposed with household wastewater.

Spills of chemicals, particulates from motor vehicle exhaust and deposition of atmospheric pollutants can similarly contaminate stormwater. These pollutants will affect downstream receiving waters, and treatment systems if the stormwater is treated. Wastewater and contaminated stormwater can contaminate groundwater. This is through infiltration of the wastewater or stormwater through the soil to unconfined groundwater aquifer. Soil can filter some pollutants, but soluble pollutants (e.g. nutrients and heavy metals) and very small particles (e.g. virus) travel with the water to the groundwater aquifer.

Heavy storm events can cause flooding. The effects of flooding can be severe. Water levels in drain, stream and rivers rise considerably and the flow of water can erode soils and embankments. Sediments, which have been deposited in quiescent stretches of a stream, can be resuspended and transported further downstream. In urban areas the water picks up litter and solid wastes in its path as well as other diffuse pollution sources, and spread these in the downstream flooded areas. Aquatic environments and water-fowl habitats can be destroyed, and these may take some time to recover. The amenity value of these, as well as recreational lakes, is therefore degraded. Engineered structures, such as culvert and bridges, can be choked with wastes and debris, causing more widespread flooded areas.

SAQ 2

Discuss the impacts of inadequate management of wastewater and stormwater.

5.5 MANAGEMENT OF WASTEWATER AND STORMWATER

5.5.1 Wastewater and Stormwater Collection and Transfer

In most situations, gravity sewers follow the natural topography, and are used for collecting sanitary sewerage. The components of a typical system are :

House Connections

Also referred to as building sewers, connect to building pumping systems. Normally, the house connection begins outside of the house. In most municipalities, septic tanks are taken out of service when a building is connected to the sewer.

Laterals

Laterals are the first municipal sewers serving a group of houses. They are usually150mm diameter minimum and located in streets or special easements.

Main Sewers

Collect wastewater from several laterals.

Trunk Sewers

The largest elements, which deliver raw sewage to treatment facilities or disposal points.

Collection of wastewater is by use of a sewerage system. Depending on whether blackwater is generated separately from greywater, or mixed with it, we need to collect greywater or the mixture of blackwater and greywater (sewage). Gravity is used wherever possible to convey the wastewater. The principle of using gravity as the driving force for conveying wastewater in a sewerage system should be applied wherever possible, because this will minimise the cost of pumping. Natural stormwater drainage occurs in what is usually termed a catchment basin. In a catchment basin, rainwater run-off flows to a common point of discharge, and in doing so it form streams and rivers.

Sewerage systems can be classified into combined sewerage and separate sewerage. Combined sewerage carries both stormwater and wastewater, while separate sewerage carries stormwater or wastewater separately. Recent trends have been for the development of separate sewerage systems. The main reason for this is that stormwater is generally less polluted than wastewater, and that treatment of combined wastewater and stormwater is difficult during heavy rainfalls, resulting in untreated overflows. Conventionally sewerage pipes are laid deep beneath the ground. A minimum velocity is needed to ensure that self-cleansing conditions occur at least once daily. Pumping is generally required at various stages of the sewer pipe network, especially if the landscape is fairly flat.

5.5.2 Wastewater Treatment

Simply defined wastewater is water that has picked up various contaminants during its use in domestic, commercial or industrial applications. In order to safeguard environment and in-turn public health these components must be removed before the wastewater can be put back into a natural water body. The natural cycles provide an insight into the natural basis of wastewater and stormwater management. For disposal of wastewater and stormwater into a natural ecosystem, as long as the *natural purification capacity or assimilation capacity* of the ecosystem is not exceeded, we can rely on the existing natural processes to assimilate the wastes without degrading the quality of the environment. On the other hand once the natural capacity is exceeded, engineered systems are required. However, the similar physical, chemical and biological processes taking place in nature can be used as a basis for technology development and for waste management.

Various unit operations of the wastewater treatment system are decided based upon the treatment objectives and pollutants present. Normally the wastewater treatment system is divided into primary, secondary and tertiary treatment. A brief account of these is presented below.

Primary Treatment involves physical removal of solid material. Screening removes grit (sand, stones and other large particles). Sedimentation settles out remaining particulate matter into a mudlike sediment called sludge which must be disposed off. Treated wastewater continues to secondary treatment or is released. Normally, 30 to 40% of pollutants are removed through primary treatment.

Secondary Treatment refers to biological treatment. Microorganisms, such as bacteria, play an important role in the natural cycling of materials and particularly in the decomposition of organic wastes. The role of microorganisms is important in the treatment of wastewater. In both natural and engineered treatment systems, microorganisms such as bacteria, fungi, protozoa and crustaceans play an essential role in the conversion of organic waste to more stable less polluting substances. About 90% of pollutants are removed after secondary treatment.

Tertiary Treatment refers to advanced treatment to reduce concentrations of selected pollutants identified in effluent. It removes nutrients, organic pollutants, etc.

5.5.3 Wastewater Reuse

Human excreta and wastewater contains some useful materials. These are water, organic carbon and nutrients. They should be regarded as a resource. In their natural cycles they are broken down by microorganisms and become useful to plants and animals, thus sustaining natural ecosystems. When improperly disposed these substances can cause pollution, because the organic materials exert oxygen demand, and the nutrients promote algal growth in lakes, rivers and near-shore marine environments.

Human excreta and wastewater contain pathogens. Reuse of the wastes must ensure that public health is maintained. Planned reuse is the key to wastewater reuse. Planning for reuse ensures that public health and protection of the environment are taken into account. Reuse of treated wastewater for irrigation of crops, for example, will need to meet

(a) standards for indicator pathogens, and

(b) plant requirement for water, nitrogen and phosphorus.

Unplanned or unintentional wastewater reuse is already taking place widely. Water is withdrawn from the river by a community, treated for water supply and distributed. After its use the water is collected, treated and discharged to the river. This process is repeated many times along the river.

Wastewater Reuse for Agriculture and Aquaculture

Treated wastewater from a treatment plants can be reused for irrigation of parks and gardens, agriculture and horticulture, tree plantation and aquaculture, if these exist or can be established not far from the wastewater treatment plants. For these purposes the wastewater should generally be treated to secondary wastewater standard (< 20 mg/L BOD and < 30 mg/L SS). Total coliforms should be < 1000 organisms per 100 mL for irrigation by spraying. When sub-surface irrigation is used this requirement may not be necessary. Land application for treatment of wastewater described in (slow rate land application and grass filtration) when combined with growing of grasses for grazing by sheep or cattle.

Wastewater reuse for aquaculture has been practiced in many countries for a considerable period of time. It has the potential of wider application in the tropics. A combination of wastewater for irrigation and aquaculture is also an option that can be considered.

Wastewater Reuse for Industry

Treated wastewater can also be used for industrial purposes, if suitable industries are not far from the treatment plant. Industry's requirement for water quality ranges widely, from very pure water for boilers of electricity generation to lower water quality for cooling towers. Treated wastewater can fulfil the lower range of this requirement, e.g. water for cooling towers. Secondary-treated wastewater after chlorination may be adequate for this purpose.

Wastewater Reuse for Domestic Purposes

To implement wastewater reuse in houses for toilet flushing, watering of gardens and other purposes which do not need drinking quality water, care is also needed to prevent cross-connection between drinking water and treated wastewater.

Stormwater Reuse

Stormwater is generally of a higher water quality than wastewater. Reuse (or strictly 'use') of stormwater can take place at two levels (household and municipal) or even at a larger (regional) scale if desired. Use at the household and municipal levels are described below.

Rainwater Harvesting at Household Level

Householders can use rainwater by collecting roof run-off in a tank for use as drinking water (common in arid regions), flushing toilets or for irrigation of the garden. Dust particles, leaf litter and animal droppings can contaminate the first flush of roof run-off. The first flush can be simply diverted using a simple diverter. A screen can be placed at the inlet to the tank to filter gross particles. Water for drinking will still need to be boiled to denature pathogens.

Water from the roof can be directed to the garden beds directly rather than through soakways, and in this way shallow rooted vegetation can benefit from the water, especially in arid regions.

Stormwater Reuse at Municipal Level

At the municipal level, stormwater can be stored in ponds for use for irrigation of parks and gardens and for fire-fighting purposes. This is in addition to employing the ponds for flood control and for improving the amenity value of the water. Other uses are for groundwater recharge, either as a means of storing water, e.g. during the rainy season, for withdrawal in the dry season. Groundwater recharge can also be used to prevent encroachment of seawater near the coast where there is heavy groundwater withdrawal in excess of natural replenishment by precipitation.

SAQ 3

Name the different components of a stromwater collection system.

5.6 WASTEWATER AND STORMWATER DISPOSAL

Disposal of wastewater and stormwater should preferably be considered only when reuse options are not feasible. Ultimate disposal of wastewater is either onto land or water (river, lake, ocean). Table 5.4 below presents some minimal national standards for removal of some of the major constituents in wastewater.

Table 5.4 : General Standards for Discharge of Environmental Pollutants (as per Environment Protection Rules, 1989, MoEF, GoI)

Sl. No.	Parameter	Inland Surface Water	Public Sewers	Land for Irrigation	Marine/Coastal Areas
		(a)	(b)	(c)	(d)
1.	Colour and odour	All efforts should be made to remove colour and unpleasant odour as far as practicable		All efforts should be made to remove colour and unpleasant odour as far as practicable	All efforts should be made to remove colour and unpleasant odour as far as practicable
2.	Suspended solids mg/l, max.	100	600	200	(a) For process wastewater (b) For cooling water effluent 10 per cent above total suspended matter of influent.
3.	Particle size of suspended solids	Shall pass 850 micron IS Sieve	–	–	(a) Floatable solids, solidsmax. 3 mm (b) Settleable solids, max. 856 microns
4.	pH value	5.5 to 9.0	5.5 to 9.0	5.5 to 9.0	5.5 to 9.0
5	Temperature	Shall not exceed 5°C above the receiving water temperature			Shall not exceed 5°C above the receiving water temperature
6.	Oil and grease, mg/l max,	10	20	10	20
7.	Total residual chlorine, mg/l max	1.0	–	–	1.0
8.	Ammonical nitrogen (as N), mg/l, max.	50	50	–	50
9	Total kjeldahl nitrogen (as N); mg/l,max. mg/l, max.	100	–	–	100
10	Free ammonia (as NH_3), mg/l,max.	5.0	–	–	5.0
11	Biochemical oxygen demand (3 days at 27°C), mg/l, max.	30	350	100	100
12	Chemical oxygen demand, mg/l, max.	250	–	–	250
13	Arsenic (as As).	0.2	0.2	0.2	0.2
14	Mercury (As Hg), mg/l, max.	0.01	0.01	–	0.01
15	Lead (as Pb)	0.1	1.0	–	2.0

	mg/l, max				
16	Cadmium (as Cd) mg/l, max	2.0	1.0	–	2.0
17	Hexavalent chromium (as Cr + 6), mg/l, max.	0.1	2.0	–	1.0
18	Total chromium (as Cr) mg/l, max.	2.0	2.0	–	2.0
19	Copper (as Cu) mg/l, max.	3.0	3.0	–	3.0
20	Zinc (as Zn) mg/l, max.	5.0	15	–	15
21	Selenium (as Se)	0.05	0.05	–	0.05
22	Nickel (as Ni) mg/l, max.	3.0	3.0	–	5.0
23	Cyanide (as CN) mg/l, max.	0.2	2.0	0.2	0.2
24	Fluoride (as F) mg/l, max.	2.0	15	–	15
25	Dissolved phosphates (as P), mg/l, max.	5.0	–	–	–
26	Sulphide (as S) mg/l, max.	2.0	-	-	5.0
27	Phenolic compounds (as C_6H_5OH) mg/l, max.	1.0	5.0	-	5.0
28	Radioactive materials: (a) Alpha emitters micro curie mg/l, max. (b) Beta emitters micro curie mg/l	10^{-7} 10^{-6}	10^{-7} 10^{-6}	10^{-8} 10^{-7}	10^{-7} 10^{-6}
29	Bio-assay test	90% survival of fish after 96 hours in 100% effluent	90% survival of fish after 96 hours in 100% effluent	90% survival of fish after 96 hours in 100% effluent	90% survival of fish after 96 hours in 100% effluent
30	Manganese	2 mg/l	2 mg/l	-	2 mg/l
31	Iron (as Fe)	3mg/l	3mg/l	-	3mg/l
32	Vanadium (as V)	0.2mg/l	0.2mg/l	-	0.2mg/l
33	Nitrate Nitrogen	10 mg/l	-	-	20 mg/l

** These standards shall be applicable for industries, operations or processes other than those industries, operations or process for which standards have been specified in Schedule of the Environment Protection Rules, 1989.*

5.6.1 Land-Based Disposal of Wastewater

Disposal onto land takes the form of effluent from on-site and off-site treatment systems being allowed to percolate through the ground. For a septic tank, for example, this occurs through the soakage of overflow from the septic tank in a leach drain. Disposal onto land generally pollutes groundwater, and may reach surface water when groundwater eventually discharges into surface water. The impact of BOD and nutrients in the wastewater on the surface water has been attenuated by soil processes and is, therefore, not as severe as direct disposal into surface water. Disposal from an off-site treatment plant for groundwater recharge to control encroachment of seawater in coastal areas is a form of reuse.

Injection of wastewater into a deep confined aquifer via a borehole is a possibility. Only treated wastewater with very low content of suspended and colloidal solids can be injected into a deep aquifer to prevent blockage of the pore spaces surrounding the borehole. The long-term effect of deep well injection is still unclear and the method is not generally recommended.

Use of treated wastewater is considered to be a disposal method as opposed to a reuse method. This keeps wastewater from being discharged into bodies of water (rivers, streams, groundwater and the ocean). Nutrients (nitrogen and phosphorus) are taken up by the crop, thus protecting the groundwater. This system has many advantages as follows :

(a) Nutrients act as a fertiliser thus reducing amounts from traditional types of fertilizers.

(b) Reduces surface water and groundwater pollution potential.

(c) It is an environmentally better scheme, which is more likely to get approval of regulating bodies.

5.6.2 Wastewater Disposal to Water Environments

Disposal into a lake, stream or ocean needs to take into account the ability of the receiving water to assimilate wastewater. The natural purification capacity of the environment is limited. Even when wastewater is disposed to the ocean, the area surrounding the outfall can be sufficiently polluted and the pollutants (including pathogens) can be washed towards the beaches. The effects of improper disposal of biodegradable substances became a source of public outrage in the early 1800s. The flush toilet was becoming popular and sewage was discharged directly into the nearest waterway. The receiving waters were quickly polluted. Fish in the receiving waters died and the water had a very offensive odour. Although there are many reasons why we no longer discharge untreated sewage into the environment, (including disease transmission, sediment buildup...) one of the reasons is directly related to the fact that sewage contains much that is biodegradable. This section will focus on effect of oxygen demanding compounds on streams. DO content is one of the most widely used indicators of overall ecological health of a body of water, e.g. fish need 4 to 5 mg/l to survive.

Nutrients (nitrogen and phosphorus) promote the growth of algae in the receiving water. In lakes and sensitive water environments, the removal of nutrients may be required. Furthermore, if the wastewater contains high levels of heavy metals and toxic chemicals, these may have to be removed before wastewater disposal. Over the years the requirement for disposal into water environments have become stricter as the impact of pollutants is better appreciated. It can be expected that this trend towards more stringent discharge requirements will continue.

5.6.3 Stormwater Disposal

Ultimate disposal for stormwater is onto land (by infiltration to groundwater) and to water environments (river, lake, ocean). Techniques for reuse are those that delay its ultimate flow to water environments to improve flow management and hence reduce the frequency and extent of flooding. At the same time, these techniques also generally remove pollutants (particulates and oils) prior to the water reaching a river, lake or the sea, while creating amenities such as wetlands, waterfowl habitats and water-based passive and active recreational facilities.

List the various options of wastewater disposal.

5.7 SUMMARY

This unit describes wastewater characteristics indicator – physical, chemical and biological parameters. Standards for discharge of environmental pollutants are presented in the unit to give an idea about the regulatory aspects of wastewater management. Further, this unit provides a brief overview of wastewater management system including collection, conveyance, treatment, disposal and reuse.

5.8 ANSWERS TO SAQs

SAQ 1

(a) Please refer section 5.2.1

(b) Please refer section 5.2.1

(c) Please refer section 5.2.2

(d) Please refer section 5.2.3

SAQ 2

(a) Please refer section 5.4

SAQ 3

(a) Please refer section 5.5.1

SAQ 4

(a) Please refer section 5.6