Topic 7
Drainage and Sewage Disposal Systems

Sources of Household sewage

Toilets - 40%

Bathing - 30%

Laundry - 15%

Kitchen - 10%

Miscellaneous - 5%

Excluding about 1% solids, household sewage is 99.9% water.

Constituent Materials	Concentrations (ppm)
Dissolved Solids	500
Suspended Solids	200
Settleable Solids	(1%)
Biochemical Oxygen Demand (BOD) material	200
Chemical Oxygen Demand (COD) material	500
Nitrogen	40
Organic	15
Free Amonia	25
Nitrite	0
Nitrate	0
Phophorus	10
Organic	3
Inorganic	7
Chloride	50
Alkalines	100
Grease	100

Table 7.2 Composition of Household Wastewater

Traps

- Traps prevent the unpleasant and unhealthy gases in sanitary drainage pipes from entering occupied rooms.
- The separation is via the amount of water left in the fixture trap after each discharge from the fixture.
- Sufficient water must flow to keep the remaining water in the fixture (w.c.) clean.
- Traps are made of steel, cast iron, copper, plastic or brass. Traps for w.c.s and urinals are made from vitreous china cast integrally with the fixture.
- All traps should be self cleaning.
- There are few exceptions to the rule that each fixture should have its own trap.
- Traps are usually placed within 610mm from the fixture.

Vents

To admit air and discharge gases soil and waste stacks are extended through the roof and a system or air vents largely parallel to the drainage system. The ventilating stacks extend through the roof or vent through the drainage stack. The main purposes of the vent are:

- To ventilate the system by allowing air from the fresh air inlet to rise through the system and carry away offensive gases.
- Breaks the siphonage of water from the floor traps.
- Providing a local escape for gases to prevent them from bubbling through the eater traps under pressure.

Air gaps and Vacuum Breakers

Almost all fixtures is supplied with pure water at one pure water at one point and most discharge contaminated fluids at another. Some typical fixtures have the two quite close to each other, sewage could accidentally be siphoned into a pipe carrying potable water.

Interceptors

- From any plumbing fixture to the end of the disposal process all parts of the system should be openable through cleanouts and other points of access to relieve the clogging that will often occur in the piping
- Problems can be reduced by devices called interceptors which catch foreign matter before it travels too far into the system.
- These include devices to catch hair, grease, plastic, lubricating oil, glass grindlings, or troublesome unwanted material from many industrial processes

Design of Residential Waste Piping

- There is considerable advantage in planning of baths and kitchens as this allows the piping assembly to pick up the drainage from both sides.
- When all the fixtures are on the same level it is not necessary to have a separate vent stack standing beside the soil stack as is the case for multi-storey construction.
- In single storey construction the upper part of the soil stack forms a vent called a stack vent to which the branch vents connect. A separate major vertical vent is called a vent stack.

Treatment Systems

- Effective sewage treatment prevents a variety of ailments that can be spread by exposure to pathogens that can be present in untreated sewages, and thus helps prevent disease. Discharges of untreated sewage can contaminate groundwaters and surface waters used for drinking, recreation, and fish and shellfish fisheries

- Untreated sewage from failed conventional septic systems or sewage discharged directly into the environment can percolate into groundwater, contaminating drinking-water wells with pathogens.
- The discharge of untreated sewage to streams can spread disease through direct contact, making such streams unfit for forms of recreation that involve skin contact with the water such as swimming and boating.
- Disease can also spread by indirect (secondary) contact such as through contact with rodents or insects that received primary exposure and in turn harbor the pathogens.
- Discharged, untreated sewage also can damage the receiving streams' ability to support healthy, living communities of aquatic organisms and can contaminate fisheries

The sewage treatment process is generally considered to be in three stages:

- Primary treatment
- Secondary Treatment
- Tertiary or advanced treatment

Biochemical Oxygen Demand (BOD)

- The BOD is an important measure of water quality. It is a measure of the amount of oxygen needed (in milligrams per liter or parts per million) by bacteria and other micro-organisms to oxidize the organic matter present in a water sample over a period of 5 days.
- The BOD of drinking water should be less than 1. That of raw sewage may run to several hundred.
- It is also called the "biological" oxygen demand.

Primary Treatment

- Primary treatment is the physical or at times chemical treatment for the removal of settleable and floatable material.

Secondary Treatment

- The main purpose of Secondary treatment is to reduce BOD (Biochemical Oxygen Demand).
- Sludge dominantly made up of bacteria is a by-product. Many plants use the activated sludge process in which sludge is added to more effectively reduce BOD
- Here the effluent is brought in contact with oxygen and aerobic microorganisms. They break down much of the organic matter to harmless substances such as carbon dioxide.
- Primary and secondary treatment together can remove up to 90% of the BOD. After chlorination to remove its content of bacteria, the effluent from secondary treatment is returned to the local surface water.

Advanced (Tertiary) Waste Treatment

- The major purpose is to reduce nitrogen and phosphates. Nitrogen and phosphates act as fertilizers, and can cause serious problems when they get into our streams, ponds, lakes, oceans and sounds by enhancing the growth of algael blooms which results in eutrophication.
- Tertiary treatment uses bacteria to denitrify nitrates in the water producing nitrogen gas which is then released into the atmosphere($NH_3 \rightarrow NO_3 \rightarrow N_2$).
- Several techniques are available to remove dissolved salts from sewage effluent, but all are quite expensive.

Cesspool

- The simplest, and least effective, method of treatment is to allow the undissolved solids in raw sewage to settle out of suspension in a cesspool.
- The settled matter from the sewage is formed into **sludge**, which is periodically removed.
- Such **primary treatment** removes only one-third of the **BOD** and virtually none of the dissolved minerals.

- In many areas the main type of sewage disposal is a septic tank system. The septic tank is also the first stage of treatment in small plants. Sewage is allowed to stand in the septic tank which will usually have a capacity of 16 to 48 h flow.
- Sludge will settle to the bottom, scum will form at the top and a clear liquid called liquor will overflow as new flows come in. Digestion will take place to some degree.
- This process is the breaking down of the organic content by the anaerobic bacteria, which can thrive under the conditions of a septic tank.
- This process reduces the quantity of sludge and renders the odours less offensive

The size of septic tanks is governed by several factors:

- Tanks must be large enough to ensure the the contents are not disturbed by any entering flows.
- This fixes the minimum size at $3.5 m^3$
- The tank must be large enough to allow the sewage to remain in it for an adequate time i.e. 16 – 48 h.
- The tank must be large enough to contain the accumulation of sludge that will take place between emptyings.
- Capacity (m^3) = number of persons in full time residence x 0.14 +1.8
- Septic tanks must be designed to allow flows to enter and leave without being affected by scum and to allow a gentle passage of liquid without short-circuiting.

Biological Filters (or percolating filters)

- Traditionally known as biological filters , these devices treat the sewage not by filtration but by oxidation.
- For convenience biological filters are sited close to the septic tanks which serve them, although this is not essential.

- An IST comprises two chambers connected in a series. In the first chamber, solids from the incoming sewage settle forming a "sludge", while greases and oils float to the surface forming a "scum" layer.
- Effluent from between the scum and sludge layers then passes into the second chamber where further sedimentation occurs.
- Finally, the effluent leaves the second chamber and is discharged into a drain or allowed to percolate into the soil.
- The sludge in the tank undergoes anaerobic digestion and is converted into more stable organic compounds and gases such as carbon dioxide (CO2), methane (CH4) and hydrogen sulfide (H2S).

- ISTs are usually designed for a 24-hour retention time. Enough storage capacity is provided so that scum and sludge can be deposited in the tank for up two years after which it must be desludged to keep the tank operating satisfactory.
- ISTs are suitable for single dwellings or individual buildings with a population equivalent (PE) up to 150 and installed where there is no central sewerage systems and where effluent discharges will not adversely effect the environment.
- It is a cheap solution to disposing of sewage.
- However, ISTs only partially treat sewage and concentrated groups of tanks can overload the capacity of the receiving environment creating health and odour problems.
- There are currently over one million ISTs in Malaysia, making it by far the most common type of sewage treatment system.

- Imhoff tanks constitute 24 per cent (800 numbers) of all sewage treatment plants in Malaysia and are the second most common form of treatment plant.
- They provide limited treatment of sewage and are not a suitable long-term solution.
- The effluent from Imhoff tanks can rapidly deteriorate if the tanks are not properly maintained.

- An IT comprises two chambers positioned one above the other.
- In the upper compartment sedimentation occurs with solids passing through an opening into the lower chamber.
- Settled solids form sludge in the lower chamber and undergo anaerobic digestion. Gases from the lower tanks are discharged to the air. Scum is accumulated in the upper tank.
- Sewage from the connected premises enters the sedimentation tank where settlement of solids occurs. Heavier solids settle at the bottom of the tank as sludge.
- Liquid effluent from the sedimentation tank then trickles through a rock filter bed. The sedimentation tank needs to be desludged regularly.

- Organisms living in the rock filter feed on the sewage, treating it in the process. Treated effluent is collected and discharged into a nearby drain.
- Usually, the sedimentation process in the upper chamber is followed by percolating effluent over a coarse stone media before discharge to a receiving water.
- ITs are normally used to service small communities up to a population equivalent (PE) of 1,000.
- They are relatively cheap to install, operate and maintain. However, ITs, like ISTs, only partially treat sewage. The effluent from these tanks will not meet the environmental requirements of the Department of Environment (DOE). Small package treatment plants have more recently sur-planted ITs as the popular method of servicing small communities.

- OPs may comprise one or more shallow ponds in a series
- Bacteria present in the wastewater use the oxygen to feed on organic material, breaking it down into nutrients and carbon dioxide.
- These are in turn used by the algae. Other microbes in the pond such as protozoa remove additional organic and nutrients to polish the effluent.

- There are normally at least two ponds constructed.
- The first pond reduces the organic material using aerobic digestion while the second pond polishes the effluent and reduces the pathogens present in sewage.
- Sewage enters a large pond after passing through a settling and screening chamber. After retention for several days, the flow is often passed into a second pond for further treatment before it is discharged into a drain.
- Bacteria already present in sewage acts to break down organic matter using oxygen from the surface of the pond. Oxidation ponds need to be desludged periodically in order to work effectively.

- OPs require large amounts of land and the degree of treatment is weather dependent.
- They are incapable of achieving a good standard of effluent consistently.
- It is this variation in performance, which require the gradual phasing out of this type treatment plant.
- Depending upon the design. OPs must be desludged approximately every 10 years.

Aerated Lagoons

- Figure 7.29a Aerated Lagoons

- Aerated Lagoons are relatively simple plants to operate and maintain.
- They require large land areas and are therefore rarely found in densely populated urban areas.
- The AL process normally comprises two or three lagoons in a sequence.
- The first lagoon has surface aerators, which are like large "paddle mixers". The aerators float on the surface of the pond and continuously stir the incoming sewage, serving to maintain oxygen content in the sewage and preventing any solids from settling.

- Sewage has an average retention in the first pond of five days. During this time, bacteria consumed the oxygen to breaking down the organic material in the sewage.
- Effluent is passed into the second pond where the degraded organic matter and sediments settle out to form sludge.
- The effluent may then pass to a third pond for polishing or be discharged to a receiving waterway. The average retention time in the second pond is one day.
- Care must be taken in managing the settling pond in warm climates. These ponds can suffer from algal growth and/or odour generated by anaerobic digestion of the sludge at the bottom of the pond. Depending upon their design these ponds must be desludged approximately every 10 years.

Extended Aeration Systems

- Figure 7.30 Extended Aeration System
- Fine Bubble Diffused Air Extended Aeration Systems (FBDAEA) are mechanical secondary treatment systems.
- As the name implies FBDAEA systems introduce air in the form of fine bubbles through submerged diffusers.
- Sewage entering a plant in passed through primary treatment where coarse material and grit is removed.

- The sewage then passes to secondary treatment in the form of any aeration tank where it is injected with fine bubbles of air from submerged diffusers.
- Solids in the sewage are held in suspension by the bubbles and bacteria in the sewage break down organic materials. Sewage is held in the aeration tank between 18-24 hours.
- The effluent with suspended material is then passed into a "clarifier" (sedimentation tank) where the material settles as a sludge.
- The sludge is drawn off with some being returned to the aeration tank to ensure enough bacteria are present in the tank to continue the process of breaking down newly introduced sewage.
- The effluent is then polished and/or discharged to the receiving environment.

- The proprietary "Orbal System" uses three channels or ditches concentrically placed. Each channel is independently aerated and can be configured to act in parallel or series with the other channels, depending upon the degree of treatment required.
- After screening and grit removal, sewage enters the outer channel where most of the biological reaction takes place. The second channel is held at a slightly higher dissolved oxygen content for further BOD and nutrient reduction. The innermost channel is used for polishing the effluent before it passes to a clarifier.

- An RBC unit comprises a series of closely spaced "circular disks" normally made from a plastic material. The disks are partially submerged in the sewage and are slowly rotated through it.
- The rotating disks support the growth of bacteria and micro-organisms present in the sewage, which breakdown and stabilise organic pollutants. To be successful, micro-organisms need both oxygen to live and food grow. Oxygen is obtained from the atmosphere as the disks rotate. As the micro-organisms grow, they build up on the media until they are sloughed off due to shear forces provided by the rotating discs in the sewage.

- Effluent from the RBC is then passed through final clarifiers where the micro-organisms in suspension settle as a sludge. The sludge is withdrawn from the clarifier for further treatment.
- The Submerged Biological Contactor (SBC) is the modified version of the conventional RBC where the disks are 80% -100% submerged and forced air is introduced.
- RBC units are suitable where land is restricted. They are quiet and consistently produce a high quality effluent. Because they are modular they are also suitable for a staged development. Operations and maintenance costs are lower than for other forms of mechanical treatment.
- There are currently approximately 40 RBC plants in Malaysia.

- Rock beds are typically 2 meters deep and are circular. A revolving arm is used to distribute the sewage over the media. Plastic media varies in design with depths ranging from 4 to 12 meters depending upon the organic load.
- Filters under the media drain the effluent and biological solids, which have become detached from the media. Air is circulated back through the drainage system to the media. The effluent from the drain is settled before discharge to the receiving environment.
- Some effluent from the drain is recycled to dilute the strength of the incoming sewage and to ensure the media remain moist.

- As the effluent passes through the media organic material is absorbed onto the biological film or slime layer covering the media. Here is it degraded by aerobic micro-organisms. As the slime layer grows an anaerobic environment is created near the media interface. Eventually the micro-organisms at the media interface loose their ability to cling to the media and the slime is washed off. A slime layer begins to grow again and the cycle is repeated.
- Filters are classified by hydraulic or organic loading rates. Classifications are low rate, intermediate rate, high rate, super high rate and roughing. Re-circulation of filter effluent permits higher organic loadings in high rate filters.

Combined Process

- Recent developments in sewage treatment technology include the combination of various aerobic treatment processes to obtain the best performance and most economical treatment of sewage.
- Combining the various aerobic processes available can derive a large number of treatment systems. The main reason for combining these processes is that they provide the stability and resistance to shock loads of attached growth processes and the high-quality effluent of suspended growth systems.
- Various standard combinations exist such as **Activated Bio-Filter Process, Roughing - Filter Activated Sludge Process, Bio-Filter Activated Sludge Process and Series Trickling Filter Activated Sludge Process.**

PACKAGE/MECHANICAL SEWAGE TREATMENT PLANTS

- Commercially available prefabricated treatment plants known as "package plants" are often used to serve small communities up to population equivalent (PE) of **5,000**.
- Package plants require little design work and can be installed quickly although they require the same operational and maintenance care as conventional treatment plants. Claims that package plants produce no sludge is incorrect.
- Care must be taken in using package plants where large variations in flow (hydraulic shock are experienced), in addition adequate provision must be made for sludge removal, scum and grease removal and the proper control of air supply.
- The most common types of package plants use **Extended Aeration, Contact Stabilisation, Bio-Filter, Sequenced Batch Reactors** and **Rotating Biological Contactor** processes.

PROCESS

- The Hi-Kleen system adopts the modified activated sludge process basically uses the micro-organisms in suspension to oxidize soluble and colloidal organic matters in the presence of molecular oxygen, induced by air compressors (see overleaf).

FLEXIBILITY & ADAPTABILITY

- There are more than 50 standard models of Hi-Kleen designed to suit small and medium scale development projects ranging from 31 to 5,000 populations equivalent (PE). These projects include housing and commercial projects, hospital resort, factory, military camp, police depot, bus terminal, shopping complex, university/school, highway rest area/toll plaza, petrol station etc.
- The Hi-Kleen system adopts the modified activated sludge process basically uses the micro-organisms in suspension to oxidize soluble and colloidal organic matters in the presence of molecular oxygen, induced by air compressors

ADVANTAGES

- Made of fiber reinforced plastic (FRP) which has the characteristics of water-tightness, light weight, corrosion resistance and high strength and tenacity, the Hi-Kleen systems process the following advantages:
- Simple and fast installation
- No noise and odor nuisance
- Small land area required
- Aesthetical view
- Less excavation
- Adaptable to site conditions
- High and reliable treatment efficiency
- Can be upgraded if needed
- Simple and low cost in operation and maintenance