

Lecture Notes
on
Environmental Engineering (MCMC3001)
3rd Year Civil, Electrical, Mechanical, Computer
Science Engineering
Module II: Sewage



By

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Module-II

Sewage

Sewage and sullage are both types of wastewater, but they differ in their sources and composition. Sewage is wastewater that contains human waste (feces and urine) along with other household, commercial and industrial wastewater. Sullage, also known as greywater, is wastewater from domestic activities like washing dishes, laundry and bathing, but it does not include toilet waste.

Sewage:

- **Definition:**

Wastewater that includes human waste (feces and urine) and other liquid waste from households, commercial buildings, and industries.

- **Composition:**

Contains organic matter, inorganic solids, and pathogens.

- **Sources:**

Toilets, sinks, showers, laundry, industrial discharge, and stormwater runoff.

- **Treatment:**

Requires treatment to remove pollutants and pathogens before discharge or reuse.

Sullage (Greywater):

* **Definition:** Wastewater from domestic activities like washing dishes, laundry, and bathing.

* **Composition:** Typically contains less organic matter and fewer pathogens than sewage.

* **Sources:** Kitchen sinks, showers, bathtubs, washing machines and dishwashers.

* **Treatment:** Can often be treated and reused for non-potable purposes like irrigation.

Domestic and Storm water

Domestic Water (Wastewater/Sewage) includes household used water or wastewater (from sinks, toilets, showers) going to treatment plants.

- **Source:** Homes, businesses (toilets, showers, laundry, sinks).
- **Flow:** Carried through sanitary sewers.
- **Treatment:** Goes to a wastewater treatment plant for cleaning before discharge.

Storm water is rain from surfaces (from roofs, streets) collected in gutters and drains, often going untreated to lakes or rivers

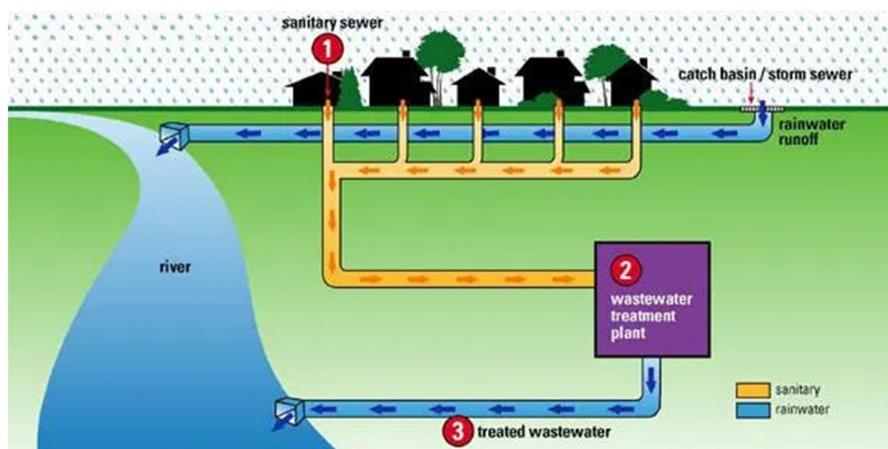
- **Source:** Rain, snowmelt from roofs, streets, lawns.
- **Flow:** Drains into gutters, pits and storm sewers.
- **Treatment:** Often discharged directly to rivers/creeks without treatment

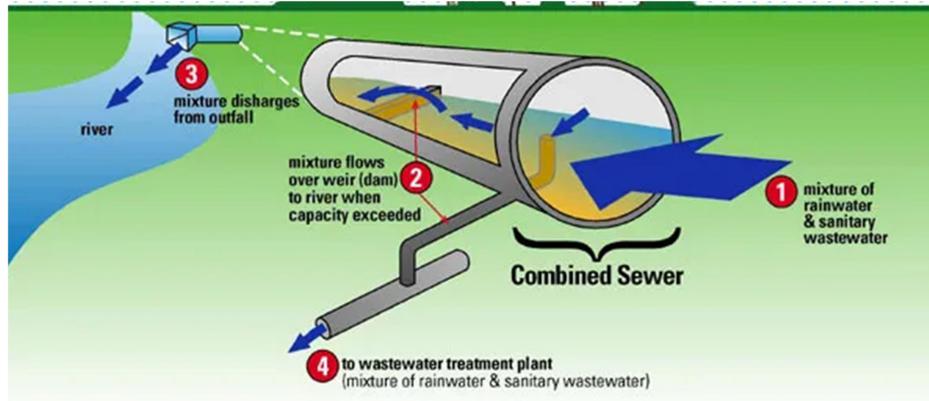
Conveyance of sewage

The process of collecting and transporting wastewater from different homes, businesses and industries to either a treatment facility or disposal site using a network of underground pipes (sewers) is called Conveyance of sewage. This is achieved through either gravity flow or pressure systems, utilizing combined sewers (sewage + stormwater), separate sewers (sewage only, stormwater separate), or partially separate systems, ensuring public health and environmental protection by moving waste efficiently.

Sewerage Systems

- **Separate Systems:** A system with dedicated pipes for domestic sewage and for stormwater. In this system the sanitary sewage and storm water are carried separately in two sets of sewers.
- The sewage is conveyed to waste water treatment plant (WWTP) and the storm water is discharges into rivers without treatment.
- **Combined Systems:** A system that uses the same pipe for carrying both type of wastewater, then the sewage is treated in STP(sewerage treatment plant). It can overflow during heavy rain, releasing untreated sewage and stormwater into waterways.
- **Partially Separate System:** A system, carrying some stormwater with sanitary sewage to increase flow, diverting excess stormwater separately.





Wastewater Treatment

Important Systems for Conveyance

- **Conservancy System (Dry System)**: It is older method of collecting waste in pits or vessels and removing it periodically by carts. It is less hygienic.
- **Water Carriage System**: It is the modern standard, using water to flush waste through pipes (sewers). It includes **Combined System, Separate System and Partially Separate System**.
- **Vacuum System**: Uses low pressure to draw wastewater through smaller pipes, often reducing excavation.

Pumping of Sewage

Pumping of sewage is required when it is not possible to have a gravitational flow for the entire sewerage system.

Sufficient pumping capacity has to be provided to meet the peak flow, atleast 50% as stand by.

Types of pumps :

1. Centrifugal pumps either axial, mixed and radial flow.
2. Pneumatic ejector pumps.

Sewer appurtenances

Sewer appurtenances are the various accessories on the sewerage system and are necessary for the efficient operation and maintenance of the system including, access points like manholes and lamp holes for inspection, inlets and catch basins for managing surface runoff, inverted siphons to overcome obstacles and devices like flushing devices, grease traps and

clean-outs for system care and removal of debris and impurities, sand, grease and oil trap and sewer outlet.

About various common sewer appurtenances:

Manholes:

Purpose: Provide access for inspection, cleaning and maintenance of sewer lines.

Placement: Located at bends, junctions and changes in sewer line gradient.

Structure: Typically circular or rectangular with a strong cover at ground level.

Lamp Holes:

Purpose: Small openings that allow a lamp to be lowered into the sewer to inspect the pipe from one manhole to another.

Placement: Connected to the sewer line via a T-junction.

Street Inlets and Catch Basins:

Purpose: Inlets are used to admit surface runoff into sewers. Catch basins are provided below inlets to trap heavy debris, preventing it from entering the sewer system.

Concerns: Catch basins can be problematic due to mosquito breeding and maintenance issues.

Inverted Siphons:

Purpose: To carry a sewer line under obstacles like rivers, subways, or buried pipes.

Function: This section of the sewer runs full and under pressure, requiring careful construction and maintenance to prevent solids from settling.

Flushing Devices:

Purpose: Used to maintain appropriate flow velocities and prevent the accumulation of solids.

Grease and Oil Traps:

Purpose: Chambers designed to separate grease and oil from the sewage.

Importance: Prevents hardening and blockages of sewer lines and interference with the wastewater treatment process.

Clean-Outs:

Purpose: Openings that allow water to be forced through a pipe to remove blockages from a sewer line.

Wastewater Treatment Methods

- Preliminary Treatment (screening, grit removal, equalization)
- Primary Treatment (primary settling)
- Secondary Treatment (e.g. activated sludge, trickling filter, RBC etc.)
- Advanced Treatment (e.g. P removal)
- Final Treatment (disinfection)
- Solids Processing (sludge treatment)

Municipal Wastewater Treatment Systems-Preliminary treatment removes materials that can cause operational problems, equalization basins are optional. Primary treatment (remove ~60% of solids and ~35% of BOD. Secondary treatment remove ~85% of BOD and solids. Advanced treatment varies: 95+ % of BOD and solids, N, P). Final Treatment is disinfection. Solids processing involves sludge management.

Unit Operations/Processes	Functions	Treatment Devices
Screening	Removal of large floating, suspended and settleable solids	Bar racks and screens of various description
Grit Removal	Removal of inorganic suspended solids	Grit chamber
Primary Sedimentation	Removal of organic/inorganic settleable solids	Primary sedimentation tank
Aerobic Biological Suspended Growth Process	Conversion of colloidal, dissolved and residual suspended organic matter into settleable biofloc and stable inorganics	Activated sludge process units and its modifications, Waste stabilisation ponds, Aerated lagoons
Aerobic Biological Attached Growth Process	same as above	Trickling filter, Rotating biological contactor
Anaerobic biological growth processes	Conversion of organic matter into CH ₄ & CO ₂ and relatively stable organic residue	Anaerobic filter, Fluid bed submerged media anaerobic reactor, Upflow anaerobic sludge blanket reactor, Anaerobic rotating biological contactor
Anaerobic Stabilization of Organic Sludges	same as above	Anaerobic digester

Wastewater treatment methods can be broadly categorized into physical, chemical and biological processes. Physical methods include screening, sedimentation and

filtration. Chemical methods involve the use of chemicals to neutralize, disinfect or coagulate pollutants. Biological treatment utilizes microorganisms to break down organic matter.

Physical Treatment:

- **Screening:** Removes large debris like plastics and rags.
- **Sedimentation:** Allows heavier solids to settle out of the wastewater.
- **Filtration:** Uses various media (sand, gravel, etc.) to remove suspended particles.
- **Adsorption:** Uses a solid material (adsorbent) to remove dissolved substances from the wastewater.

Chemical Treatment:

- **Coagulation and Flocculation:** Chemicals are added to bind small particles together, forming larger flocs that can be easily removed.
- **Disinfection:** Uses chemicals like chlorine or UV light to kill pathogens.
- **Neutralization:** Adjusts the pH of the wastewater to a neutral level.

Biological Treatment:

- **Activated Sludge Process:**

Uses a combination of aeration and microorganisms to break down organic matter.

- **Trickling Filters:**

Wastewater is sprayed over a bed of media where microorganisms decompose pollutants.

- **Oxidation Ponds:**

Large shallow ponds where natural biological processes treat the wastewater.

- **Membrane Bioreactors (MBR):**

Combines biological treatment with membrane filtration for high-quality effluent.

Other Important Aspects:

- **Sludge Treatment:**

Processes like digestion (anaerobic or aerobic) stabilize and reduce the volume of sludge produced during wastewater treatment.

- **Tertiary Treatment:**

Further polishing steps like filtration and disinfection to achieve high-quality effluent for discharge or reuse.

- **Solids Removal:**

Different methods like chemical precipitation and filtration are used to remove various types of solids from wastewater,

Suspended and attached growth system

Suspended and attached growth systems are two main types of biological wastewater treatment, differing by where microorganisms grow

Suspended growth keeps microbes free-floating (example: activated sludge), while **attached growth** uses inert media (rock, plastic) for microbes to form a fixed biofilm, (example: trickling filters). Attached systems offer greater resilience to toxins and shocks, smaller footprints and simpler operation, while suspended systems are often used in large urban plants. Hybrid systems combine both for enhanced efficiency.

Sewage flow variations

Sewage flow variations are the fluctuations in wastewater volume throughout the day, week and seasons, driven by human activity, industrial output and rainfall. Wastewater volume is peak in morning/evening and low at night, requiring careful engineering to manage capacity, prevent silting (during low flow) and flooding (during high flow) in sewers and ensure effective treatment.

Causes of Variation

- **Daily Patterns:** Higher usage during mornings and evenings (for getting ready, cooking, cleaning).
- **Weekly/Seasonal:** Differences between weekdays and weekends, holidays or seasonal weather changes.
- **Infiltration & Inflow (I&I):** Stormwater entering sanitary sewers through illegal connections or cracks during rain events.
- **Industrial Activity:** Businesses releasing large water volumes at specific times.
- **Population Density:** Higher density often means more pronounced peaks.

Flow velocity in sewers and drains

Mannings Formula

Manning's formula is a key equation in hydraulics used to calculate flow velocity or discharge (flow rate) in **open channels** (like rivers, canals) or partially full pipes, based on channel geometry, slope, and roughness

$$\text{Velocity (v): } v = \frac{1}{n} R^{2/3} S^{1/2}$$

$$\text{Discharge (Q): } Q = A \times v = \frac{A}{n} R^{2/3} S^{1/2}$$

Chezy's formula

Chezy's formula is a fundamental equation used to calculate the mean velocity of flow in open channels and pipes, relating velocity to the channel's hydraulic radius and slope.

$$V = C\sqrt{RS}$$

- V: Mean velocity of flow (m/s).
- C: Chezy's coefficient, a dimensionless factor depending on roughness, channel size, and shape.
- R: Hydraulic Radius (or Hydraulic Mean Depth, m), calculated as the flow Area divided by the Wetted Perimeter (A/P).
- S: Slope of the energy grade line or hydraulic gradient

Q1. Calculate the velocity and discharge in a circular sewer with a diameter of 1 m, a gradient of 1:600, and a Manning's coefficient (n) of 0.012, when the sewer is running full.

Ans.

Given:

- Diameter (D) = 1 m
- Slope (S) = 1/600 = 0.001667
- Manning's coefficient (n) = 0.012

Calculations:

$$\text{Area (A): } A = (\pi/4) * (1 \text{ m})^2 = 0.785 \text{ m}^2$$

$$\text{Hydraulic Radius (R): } R = D/4 = 1 \text{ m} / 4 = 0.25 \text{ m}$$

- **Velocity (V):**

$$v = (1 / 0.012) * (0.25)^{(2/3)} * (1/600)^{(1/2)} = 1.35 \text{ m/s}$$

- **Discharge (Q):**

- $Q = 0.785 * (1 / 0.012) * (0.25)^{(2/3)} * (1/600)^{(1/2)}$

- $(0.25)^{(2/3)} \approx 0.39685$

- $(1/600)^{(1/2)} \approx 0.04082$

$$Q \approx 83.33 * 0.785 * 0.39685 * 0.04082 \approx 1.06 \text{ m}^3/\text{sec}$$

Q (Assignment) A circular sewer pipe is to be laid on a slope of 1 in 400. Calculate the diameter of the pipe required and discharge, if the pipe has to flow half full with a velocity of 1.9m/sec. Assume Manning's roughness coefficient for the pipe = 0.012

Sol: $v = (1/n)R^{2/3} S^{1/2}$

$$= (1/0.012)R^{2/3} S^{1/2}$$

$$= (1/0.012)(D/4)^{2/3} S^{1/2}$$

$$1.9 = (1/0.012)(D/4)^{2/3} (1/400)^{1/2}$$

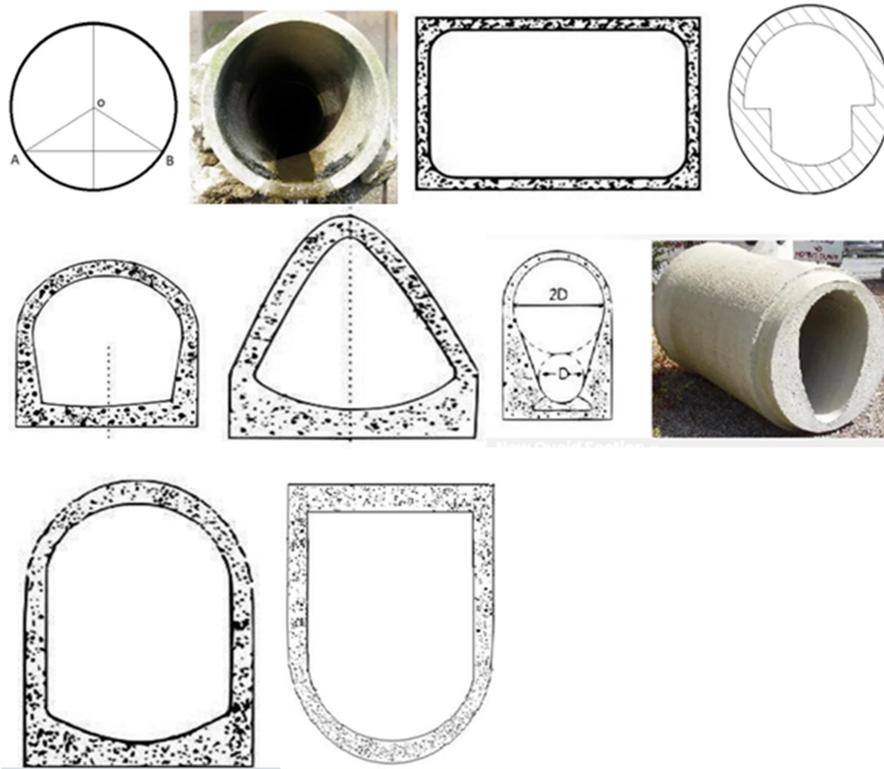
$$(A = \frac{D^2/4}{2}, P = \frac{\pi D}{2}, R = A/P = D/4)$$

$$D = 1.23 \text{ m}$$

$$Q = Av = (\pi D^2/8) \times 1.9 = 1.128 \text{ cumec}$$

Shapes of Sewers

- U-shaped section and Basket handle section
- Egg-shaped Sewer
- Rectangular section
- Parabolic Section
- Semi-elliptic section
- Circular Shaped Sewer



Pollution due to improper disposal of sewage

Improper sewage disposal causes severe pollution

It contaminates water (groundwater, rivers, oceans) and soil with pathogens, nutrients, heavy metals, and chemicals, that leads to disease outbreaks (cholera, typhoid), harmful algal blooms (eutrophication), oxygen depletion, dead zones, and harm to aquatic life.

It also releases greenhouse gases (methane) and damages ecosystems, affecting biodiversity, human health, and food safety through bioaccumulation in the food chain.