

# SANITARY ENGINEERING

ENCE 305

Lecture : 3  
Tutorial : 2  
Practical : 1

Year : III  
Part : I

## Course Objectives:

The objective of this course is to provide a comprehensive knowledge of sanitary and wastewater engineering and management. It covers basic theories, principles, designs, and practical knowledge in these fields. Topics include sources and quantity of wastewater, methods of wastewater examination (physical, chemical, and biological), wastewater microbiology, disposal techniques, design of sewers, treatment plant components, sludge management and wastewater treatment methods. The course is focused to hands-on learning through examples and lab experiments, which are considered highly effective for students to grasp and apply the course material.

## 1 Introduction (2 hours)

- 1.1 Sanitary engineering: Environment, water sanitation, and hygiene aspects
- 1.2 Objective of wastewater treatment, disposal, and management
- 1.3 Definitions: Sewage/wastewater; Domestic sewage; Industrial sewage; Sanitary sewage; Storm water; Sullage; Sewer; Black water; Brown water; Yellow water; Grey water; Sewerage; Garbage; Rubbish; Solid waste
- 1.4 Historical development and importance of wastewater management (Global to national context)
- 1.5 Sanitation systems (Conservancy and water carriage systems) with merits and demerits
- 1.6 Sewerage systems and types (Separate, combined and partially separate systems) with merits, demerits, and engineering significance
- 1.7 Typical schematic diagram of wastewater, and solid waste management methods: Collection, conveyance, treatment, and disposal

## 2 Quantity of Wastewater (4 hours)

- 2.1 Dry weather flow and wet weather flow
- 2.2 Sources of sanitary sewage: Private and public; Groundwater infiltration; Unauthorized connections
- 2.3 Factors affecting the quantity of sanitary sewage: Population; Rate of water supply; Groundwater infiltration; Unauthorized connections
- 2.4 Quantity estimate of sanitary sewage: Variations; Peak factor; Peak flow
- 2.5 Quantity estimate of storm water: Rational and empirical formulae, time area graph and their limitations; Empirical formula for rainfall intensities
- 2.6 Factors affecting the quantity of storm water
- 2.7 Design discharge of wastewater for separate, combined and partially separate systems

### **3 Design and Construction of Sewers**

**(4 hours)**

- 3.1 Sewer and its function (Open and closed channel flow)
- 3.2 Shapes of sewers: Circular and non-Circular sections (Merits and demerits)
- 3.3 Sewer materials: Requirements; Types (Salt glazed stoneware, cement concrete, cast iron, vitrified clay, wooden, PVC, CPVC, HDPE)
- 3.4 Design criteria of sewers
  - 3.4.1 Specific gravity of wastewater
  - 3.4.2 Design period and selection criteria
  - 3.4.3 Minimum and maximum velocities; Self-cleansing velocity
  - 3.4.4 Sewer size and gradient range
  - 3.4.5 Hydraulic design of sewers by Manning's, Chezy's and Hazen Williams formulae
  - 3.4.6 Hydraulic elements of sewers for partial flow condition
  - 3.4.7 Partial flow diagrams and its significance
  - 3.4.8 Design of sewers of separate and combined systems
- 3.5 Introduction to storm water drainage system
- 3.6 Construction of sewer: Desk study; Setting out; Alignment and gradient; Excavation of trench; Timbering of trench; Dewatering of trench; Laying and jointing; Testing of sewer (Straightness, obstruction, water and air tests) Backfilling of trench; Maintenance

### **4 Sewer Appurtenances**

**(3 hours)**

- 4.1 Necessity of sewer appurtenances
- 4.2 Introduction, importance, use, construction, and working mechanism of sewer appurtenances: Manhole; Drop manhole; Lamp hole; Street inlets; Catch basin; Flushing devices; Sand, grease and oil traps; Inverted siphon; Sewer outlet; Ventilating shaft; Wastewater / storm water regulators

### **5 Wastewater Microbiology**

**(4 hours)**

- 5.1 Microbes of interest and their roles in wastewater: Bacteria; Fungi; Algae; Protozoa; Rotifers; Crustaceans
- 5.2 Types of microorganisms in wastewater: Based on carbon source, energy, and environmental factors (Oxygen requirement, pH, salt, temperature)
- 5.3 Requirement for microbial growth: Nutrient; Electron donor; Acceptor; Macronutrients and micronutrients; Environmental conditions
- 5.4 Bacterial growth and biomass yield: Bacterial reproduction; Population dynamics; Growth curve and kinetics; Metabolism process (Anabolism and catabolism); Waste removal mechanism
- 5.5 Decomposition of wastewater and type of bacteria: Aerobic; Anoxic; Facultative; Anaerobic decomposition with process microbiology
- 5.6 Fates of carbon, nitrogen, phosphorous in wastewater
- 5.7 Fresh and stale wastewater: Microbiological aspects

## **6 Characteristics and Examination of Wastewater**

**(5 hours)**

- 6.1 Introduction and importance of characteristics of wastewater
  - 6.1.1 Physical characteristics and their significance: Colour; Odour; Temperature; Turbidity
  - 6.1.2 Chemical characteristics and their significance: PH; Solids; Carbonaceous nitrogenous: Phosphorous contents
  - 6.1.3 Biological characteristics and their significance: Bacteria (Total and Feecal coliform)
- 6.2 Sampling of wastewater
  - 6.2.1 Grab, composite, and integrated samples
  - 6.2.2 Preservation, storing and transportation
- 6.3 Biochemical oxygen demand (BOD)
  - 6.3.1 Definition of BOD and its significance
  - 6.3.2 BOD in term of population equivalent
  - 6.3.3 Derivation of BOD equation
  - 6.3.4 Rate reaction, ultimate BOD and relation with temperature
  - 6.3.5 Relative stability
- 6.4 Chemical oxygen demand (COD): Definition, types and significance
- 6.5 Examination of wastewater
  - 6.5.1 Necessity of wastewater examination (Forms of phosphorous and nitrogen, solid fractionation, fractionation of total organic carbon)
  - 6.5.2 Examination of wastewater: Suspended; Volatile; Fixed and total solids; Settleable and non-settleable solids; Dissolved oxygen (DO); Theoretical oxygen demand (TOD); BOD with and without dilution; COD; Total organic carbon (TOC); Total and Kjeldahl nitrogen; Total phosphorous

## **7 Wastewater Disposal**

**(5 hours)**

- 7.1 Necessity and objectives of wastewater disposal
- 7.2 National effluent discharge standards and provisions
- 7.3 Wastewater disposal methods: Dilution and Land treatment
  - 7.3.1 Wastewater disposal by dilution process and essential conditions for dilution: Self-purification of rivers/streams; Factors affecting self-purification (Dilution, current, sunlight, sedimentation, temperature, oxidation and reduction); Oxygen sag curve; Streeter Phelp's equation (Derivation not required)
  - 7.3.2 Wastewater disposal by land treatment: suitability of land treatment; Methods of land treatment (Irrigation, overland flow, rapid infiltration, broad irrigation and sewage farming); Methods of application of sewage on land (Flooding, surface irrigation, ridge and furrow method, subsurface irrigation, and spray irrigation); Sewage sickness and its prevention

## 8 Wastewater Treatment

(12 hours)

- 8.1 Treatment processes and impurities removal
- 8.2 Treatment train/process flow diagram
- 8.3 Physical treatment processes
  - 8.3.1 Racks and Screens: Purpose, types and construction (Bar, coarse, and fine screens); design criteria
  - 8.3.2 Grit chamber: Purpose, construction and design criteria
  - 8.3.3 Skimming tank: Purpose, construction, and design criteria
  - 8.3.4 Equalization tank: Introduction, purposes, and types
  - 8.3.5 Sedimentation tank: Principle of settling (Type I, II, III, and IV), purpose, types, and design criteria
- 8.4 Chemical treatment process: Chemical precipitation (Purpose, mixing, and flocculation)
- 8.5 Biological (Secondary) treatment process
  - 8.5.1 Objectives of biological treatment process
  - 8.5.2 Principles of biological treatment process (Attached and suspended growth processes)
  - 8.5.3 Types of biological treatment process
    - 8.5.3.1 Sewage filtration, filter types: Intermittent sand filter (Purpose, construction, working, cleaning, merits and demerits); Contact bed (Purpose, construction, working, cleaning, merits and demerits); Trickling filter (Purpose, construction, working, cleaning merits and demerits, types - high and standard rates, recirculation, two-stage filters, design criteria, operational and maintenance issues)
    - 8.5.3.2 Activated sludge process: Principle, construction and process description; Aeration methods (Design parameters and criteria, secondary clarifier, advantages and disadvantages); Sludge volume/density index and its significance; Control parameters and operational issues (Filamentous bulking, Foaming and mousse formation, Pin-point floc, deflocculation)
    - 8.5.3.3 Oxidation ponds: Purpose, merits and demerits of oxidation ponds; theory of oxidation ponds; construction of oxidation ponds; commissioning; operation and maintenance; operational issues; design criteria
- 8.6 Sequential batch reactor, membrane bioreactor and moving bed bioreactor: Introduction, removal mechanism and application
- 8.7 Tertiary treatment system: Mechanism, impurity removal and application
  - 8.7.1 Pathogen removal: Disinfection, disc filters, and maturation ponds
  - 8.7.2 Nutrient removal (Nitrogen and phosphorous): Decentralized wastewater treatment system (Introduction, Mechanism, and uses); Anaerobic baffled reactor; Nature-based treatment system - Constructed wetland (Types based on flow: Surface and subsurface, Horizontal and vertical flow), advantages and disadvantages

## **9 Sludge Treatment and Disposal**

**(3 hours)**

- 9.1 Sources and characteristics of sludge
- 9.2 Estimation of sludge volume; Volume-Moisture relation
- 9.3 Sludge treatment methods
  - 9.3.1 Grinding and blending
  - 9.3.2 Thickening: Gravity thickener (Purpose, construction and loading criteria)
  - 9.3.3 Digestion: Aerobic and anaerobic digestion, digestion process, control of digestion, construction and design criteria of digester
  - 9.3.4 Drying: Sludge drying beds (Purpose and construction)
  - 9.3.5 Sludge disposal methods: Dumping; Landfilling; Lagoons; Spreading on land; Composting (Purpose, principles, types - Windrow and mechanical); Incineration (Purpose and construction)
- 9.4 Faecal sludge management practices (Treatment train): Issues, and challenges in Nepal

## **10 Onsite Sanitation of Waste from Isolated Facilities**

**(3 hours)**

- 10.1 On site sanitation: Definition, necessity, and types
- 10.2 Solid Waste Management: Definition, necessity, 3R principles, composting and types
- 10.3 Pit privy: Purpose and construction; Ventilated improved pit latrine (VIP) - Purpose, construction, design criteria, types (Single pit, double pits and multiple pits, advantages and disadvantages)
- 10.4 Pour flush latrine: Purpose, construction, and design criteria
- 10.5 Septic tank: Purpose, construction, design criteria, working and maintenance
- 10.6 Septic tank effluent disposal methods: Drain field (Purpose, construction, and design criteria); Soak pit (Purpose, construction, and design criteria); Evapotranspiration mound (Purpose and construction); Leaching cesspool (Purpose and construction)
- 10.7 Design of VIP latrine, pour flush latrine, septic tank, drain field, and soak pit

## **Tutorial**

**(30 hours)**

1. Preparation of typical schematic diagrams of wastewater, solid waste treatment and management
2. Estimation of sanitary sewage, storm water and wastewater for separate, combined and partially separate systems
3. Design of sewers for separate and combined systems, design criteria of sewers, partial flow conditions in sewers
4. Preparation of schematic diagrams of various sewer appurtenances
5. Preparation of bacterial growth curve, biomass calculation, degradation steps for carbon and nitrogen
6. Numerical on solids, BOD, and forms of carbon and nitrogen on BOD test

7. Streeter-Phelp's equation, Numerical on purification of rivers/streams, and requirements of degree of treatment
8. Numerical on screening, grit chamber, sedimentation tank, trickling filter, activated sludge process, and oxidation pond, preparation of treatment trains
9. Numerical on sludge volume determination, Volume-Moisture relation and design of digesters, schematic diagram of type of digesters
10. Design of VIP latrine, pour flush latrine, septic tank, drain field, and soak pit, sanitary calculation and drawing of an urban household
11. Numerical on bar screens, grit chamber, and sedimentation tank
12. Numerical on oxidation ponds and activated sludge process

### Practical

(15 hours)

1. Determination of suspended, dissolved, volatile and total solids
2. Determination of biochemical oxygen demand
3. Determination of chemical oxygen demand
4. Determination of sludge volume index, MLSS, and MLVSS
5. Determination of ammonia/nitrate and phosphate
6. Video presentation or observation of wastewater treatment plant

### Assignment

Design of community wastewater treatment system or faecal sludge treatment plant (Quantity estimation, treatment system and sludge disposal). A treatment train system can be modelled and designed using free tools such as WRC STOAT.

### Final Exam

The questions will cover all the chapters in the syllabus. The evaluation scheme will be as indicated in the table below:

Chapter	Hours	Mark distribution*
1	2	3
2	4	5
3	4	5
4	3	3
5	4	6
6	5	6
7	5	6
8	12	17
9	3	5
10	3	4
<b>Total</b>	<b>45</b>	<b>60</b>

\* There may be minor deviation in marks distribution.

## Reference

1. American Public Health Association (APHA). (2017). Standard methods for the examination of water and wastewater (23rd Edition). APHA.
2. DWSS – GON. (2021). Urban water supply and sanitation (sector) project, design guidelines (Version 4). Project Management Office, Panipokhari, Kathmandu.
3. Metcalf & Eddy. (2014). Wastewater Engineering: Treatment and Resource Recovery (5th Edition). McGraw-Hill.
4. CPHEEO. (2013). Manual on sewerage and sewage treatment systems. Ministry of Housing and Urban Affairs, Government of India.
5. Davis, M. (2010). Water and wastewater engineering: Design principles and practices. McGraw-Hill.
6. UN-HABITAT. (2008). Constructed wetlands manual. UN-HABITAT.
7. Metz, D., Modi, P.N. (2020). Sewage treatment & disposal and wastewater engineering. Standard Book House.
8. Peavy, D.R., Rowe, D., Tchobanoglous, G. (1985). Environmental engineering. McGraw-Hill.