INTEGRATED WASTEWATER TREATMENT ENGINEERING & SAFETY PRACTICES			
Course Code	**1MCWH201**	*Scheme*	*2026*
Type of Course	*Integrated Professional Core Courses (IPCC)*	*Semester*	*II*
Teaching Hours/Week (L:T:P)	*70 (3:0:2)*	*CIE Marks*	*50*
Total Hours of Pedagogy per Semester CI (L /T): LI(P):TW&SL	*120 (42:0:28:50)*	*SEE Marks*	*50*
Credits	*4*	*Total Marks*	*100*
Type of Examination (IPCC):	*Theory- CIE +SEE, and Lab- CIE only.*	*Exam Hours*	*03*

Course outcome (Course Skill Set):

At the end of the course, the student will be able to:

1. *Explain wastewater sources, characteristics, sampling methods, and regulatory requirements.*
2. *Analyse wastewater treatment systems using physical, chemical, biological, and advanced treatment principles.*
3. *Design and evaluate primary, secondary, tertiary, and resource-recovery units for wastewater treatment.*
4. *Conduct standard wastewater-quality tests and interpret treatment-plant performance data.*
5. *Identify hazards associated with wastewater treatment, sewerage systems, chemicals, equipment, and confined spaces.*
6. *Develop safety procedures, risk assessments, emergency plans, and sustainable operational strategies for wastewater facilities.*

Module-1

Wastewater Characteristics and Treatment Fundamentals

- *Sources and types of wastewater: domestic, municipal, institutional, commercial, industrial, and stormwater.*
- *Quantity estimation: per-capita wastewater generation, flow variation, peak factors, infiltration and inflow.*
- *Physical characteristics: colour, odour, temperature, turbidity, solids, settleable solids, suspended solids, and dissolved solids.*
- *Chemical characteristics: pH, acidity, alkalinity, chlorides, sulphates, sulphides, nitrogen, phosphorus, oil and grease, heavy metals, and toxic substances.*
- *Organic pollution indicators: BOD, COD, TOC, biodegradability, BOD/COD ratio, and wastewater strength.*
- *Biological characteristics: pathogens, indicator organisms, parasites, viruses, and microbial ecology.*
- *Sampling methods, preservation, chain of custody, laboratory quality assurance, and safety during sampling.*
- *Wastewater treatment objectives, process selection, treatment trains, and mass-balance concepts.*

Linked COs: CO1, CO4 **Number of Hours: 08**

Module-2

Preliminary and Primary Treatment

- *Screening: coarse and fine screens, mechanically cleaned screens, screening handling, and disposal.*
- *Comminution, grit removal, grease and oil removal, and equalisation.*
- *Design considerations for bar screens, grit chambers, aerated grit chambers, and equalisation tanks.*
- *Primary sedimentation: theory of settling, discrete, flocculent, hindered, and compression settling.*
- *Design of primary clarifiers, surface overflow rate, detention time, weir loading, sludge collection, and scum removal.*
- *Chemical precipitation and coagulation-flocculation for phosphorus and suspended-solids removal.*
- *Chemical storage, dosing systems, compatibility, labelling, and safe handling of treatment chemicals.*
- *Primary sludge characteristics, thickening, pumping, and preliminary stabilisation.*

Linked COs: CO2, CO3, CO5 **Number of Hours: 09**

Module-3

Biological Wastewater Treatment

- *Fundamentals of biological treatment: microbial growth, substrate utilisation, aerobic and anaerobic metabolism.*
- *Suspended-growth systems: activated sludge process, plug-flow and completely mixed reactors.*
- *Process parameters: F/M ratio, sludge age, MLSS, MLVSS, SVI, oxygen requirement, and return activated sludge.*
- *Design concepts for aeration tanks, secondary clarifiers, sludge recycle, and wasting.*
- *Modifications of activated sludge: extended aeration, oxidation ditch, sequencing batch reactor, and membrane bioreactor.*
- *Attached-growth systems: trickling filters, rotating biological contactors, moving-bed biofilm reactors, and hybrid systems.*
- *Nutrient removal: nitrification, denitrification, biological phosphorus removal, and process control.*
- *Anaerobic treatment: anaerobic digesters, UASB reactors, biogas generation, and operational limitations.*
- *Bulking, foaming, toxicity, shock loading, odour generation, and corrective measures.*

Linked COs: CO2, CO3, CO4 **Number of Hours: 09**

Module-4

Tertiary Treatment, Sludge and Resource Recovery

- *Need for tertiary and advanced treatment.*
- *Filtration: rapid sand filters, pressure filters, multimedia filters, and cloth filters.*
- *Disinfection: chlorination, breakpoint chlorination, chlorine contact tanks, ultraviolet radiation, and ozonation.*
- *Disinfection by-products, residual disinfectant, pathogen control, and safe chlorine handling.*
- *Advanced treatment: activated carbon, ion exchange, membrane processes, reverse osmosis, electrodialysis, and advanced oxidation.*
- *Treated wastewater reuse: irrigation, landscaping, toilet flushing, industrial reuse, groundwater recharge, and environmental discharge.*
- *Sludge processing: thickening, conditioning, dewatering, drying beds, filter presses, centrifuges, and screw presses.*
- *Sludge stabilisation, anaerobic digestion, biogas utilisation, composting, co-processing, and safe disposal.*
- *Resource recovery: water, energy, nutrients, biosolids, and circular-economy principles.*
- *Life-cycle assessment, energy efficiency, carbon footprint, and climate-resilient wastewater treatment.*

Linked COs: CO3, CO5, CO6 **Number of Hours: 08**

Module-5

Safety Practices and Risk Management

- *Occupational hazards in wastewater treatment plants and sewerage systems.*
- *Biological hazards: pathogens, aerosols, wastewater exposure, infection pathways, and occupational hygiene.*
- *Chemical hazards: chlorine, hypochlorite, acids, alkalis, polymers, solvents, and laboratory reagents.*
- *Toxic and flammable gases: hydrogen sulphide, methane, ammonia, carbon monoxide, and oxygen deficiency.*
- *Confined-space hazards and entry procedures for sewers, manholes, wet wells, tanks, digesters, and pits.*
- *Permit-to-work systems, atmospheric testing, ventilation, isolation, lockout/tagout, attendant duties, communication, and rescue planning.*
- *Mechanical and electrical safety: rotating equipment, pumps, blowers, mixers, conveyors, electrical panels, and wet-area protection.*

- *Personal protective equipment: selection, inspection, use, decontamination, storage, and disposal.*
- *Ergonomics, slips and falls, lifting operations, working at height, traffic movement, and excavation hazards.*
- *Emergency response: chemical release, gas exposure, fire, drowning, electrical shock, biological exposure, and spill control.*
- *Safety management systems, job safety analysis, risk matrix, incident reporting, safety audits, toolbox talks, and safety training.*
- *Safety data sheets, signage, labelling, first aid, vaccination, medical surveillance, and occupational health records.*

Linked COs: CO1, CO5, CO6 **Number of Hours: 08**

PRACTICAL COMPONENTS OF IPCC

LIST OF EXPERIMENTS (LI=28 Hrs)

1. 2. *Determine pH, temperature, electrical conductivity, turbidity, colour, and odour of wastewater samples.*
3. *Determine total solids, suspended solids, dissolved solids, volatile solids, and settleable solids.*
4. *Determine acidity, alkalinity, chlorides, sulphates, and hardness in wastewater.*
5. *Determine dissolved oxygen using the Winkler method and analyse oxygen-sag-related observations.*
6. *Determine BOD and COD of wastewater and compare BOD/COD relationships.*
7. *Determine ammonia nitrogen, nitrate nitrogen, and total Kjeldahl nitrogen.*
8. *Determine phosphate/phosphorus concentration using a suitable colorimetric method.*
9. *Conduct settling-column analysis and determine settling characteristics of suspended solids.*
10. *Determine MLSS, MLVSS, sludge-volume index, and return-sludge characteristics.*
11. *Prepare a job safety analysis and risk assessment for a selected wastewater-treatment activity.*
12. *Demonstrate PPE selection, chemical spill response, gas monitoring, and confined-space entry checklist procedures.*
13. *Prepare a permit-to-work, lockout/tagout, and emergency-response plan for a treatment-plant task.*

Suggested Learning Resources:

Text Books:

1. *Metcalf & Eddy/AECOM, Wastewater Engineering: Treatment and Resource Recovery, McGraw-Hill.*
2. *Tchobanoglous, G., Burton, F. L., Stensel, H. D., and Tsuchihashi, R., Wastewater Engineering: Treatment and Resource Recovery, McGraw-Hill.*
3. *Qasim, S. R., Wastewater Treatment Plants: Planning, Design, and Operation, CRC Press.*
4. *Spellman, F. R., Handbook of Water and Wastewater Treatment Plant Operations, CRC Press.*
5. *Gray, N. F., Biology of Wastewater Treatment, Imperial College Press.*
6. *Hammer, M. J. and Hammer, M. J. Jr., Water and Wastewater Technology, Pearson.*
7. *Rangwala, S. C., Water Supply and Sanitary Engineering, Charotar Publishing House.*

Reference Books / Manuals

1. *CPHEEO, Manual on Sewerage and Sewage Treatment, Ministry of Housing and Urban Affairs, Government of India.*
2. *CPHEEO, Manual on Sewerage and Sewage Treatment: Engineering, Operation and Maintenance, and Management.*
3. *Central Pollution Control Board, standards and guidelines for sewage treatment plants and treated-effluent discharge.*
4. *Bureau of Indian Standards, relevant methods for water and wastewater sampling and analysis.*
5. *APHA, AWWA and WEF, Standard Methods for the Examination of Water and Wastewater.*

6. *WHO, Guidelines for the Safe Use of Wastewater, Excreta and Greywater.*
7. *OSHA, Permit-Required Confined Spaces and wastewater-treatment safety guidance.*
8. *National Building Code of India: fire and life-safety provisions relevant to treatment facilities.*
9. *Environment (Protection) Act, 1986, Environment (Protection) Rules, 1986, and Water Act, 1974.*
10. *Factories Act, 1948, and applicable occupational health and safety provisions.*

Web links and Video Lectures (e-Resources) & Software tools

1. *CPHEEO resources on sewerage and sewage treatment.*
2. *CPCB standards and guidelines for sewage-treatment plants.*
3. *NPTEL/SWAYAM courses on environmental engineering and wastewater treatment.*
4. *APHA/AWWA/WEF resources on wastewater analysis and laboratory quality assurance.*
5. *WHO resources on wastewater reuse and health protection.*
6. *OSHA resources on confined-space entry, chemical safety, and lockout/tagout.*
7. *Manufacturer manuals for pumps, blowers, aeration systems, clarifiers, chlorination systems, UV units, and sludge-dewatering equipment.*
8. *Virtual laboratory demonstrations for BOD, COD, solids, nutrient analysis, and jar testing.*

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes. Suggested Innovative Delivery Methods may include (but are not limited to):

- *Flipped classroom using treatment-process videos and reading assignments.*
- *Problem-based learning involving treatment-plant design and process selection.*
- *Case-based teaching using municipal STPs, industrial wastewater plants, and reuse projects.*
- *Laboratory demonstrations and hands-on wastewater-quality analysis.*
- *Simulation-based learning using process-modelling software.*
- *Safety drills involving PPE, gas detection, chemical spills, emergency communication, and confined-space procedures.*
- *Industrial visits to sewage-treatment plants, common effluent-treatment plants, sludge-processing facilities, and reuse schemes.*
- *Industry expert lectures on operation, maintenance, compliance, and plant safety.*
- *Group-based safety audits and treatment-plant performance evaluations.*
- *ICT-enabled teaching using process animations, digital flow diagrams, virtual tours, and online quizzes.*

Assessment Structure (both CIE and SEE)

The weightage assigned to Continuous Internal Evaluation (CIE) and Semester End Examination (SEE) shall be 50% each. A student shall secure a minimum of 50% of the maximum marks prescribed for CIE and a minimum of 40% of the maximum marks prescribed for SEE to be eligible for a pass in the course.
A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to a subject /course only if he/she secures not less than 50% of the aggregate marks obtained in CIE and SEE taken together.

Continuous Internal Evaluation:

(i)Theory component
The CIE marks of 25 shall be earmarked for two tests.
The first test shall be conducted after completing two modules of the syllabus and the second one after completing the rest three modules.
Each test shall be conducted for 25 marks. The average of the two tests scaled down to 25 marks shall constitute the test marks for a maximum of 25 marks.
(ii) Laboratory component
Out of 25 marks, 15 marks shall be assigned for assessment of regular laboratory classwork as per the rubrics listed in Table - ICs/IPCCs1.
The remaining 10 marks shall be based on the practical test conducted by two Internal examiners appointed by the HoD. The allotment of marks shall be as per the rubrics defined for the practical test as indicated in the Table – ICs/IPCCs 1.
To qualify and become eligible to appear for the SEE of the IC/IPCC, a student shall secure at least 13 marks out of

25 in the CIE theory component, and at least 12 marks in the CIE Practical component.

Table – ICs/IPCCs 1 Distribution of marks corresponding to laboratory component		
Component	*Description*	*Marks*
Allotment of marks for regular classwork		
Ability in Conducting Experiments	*Initiative, skill, safety practices, teamwork, and independent handling of equipment during regular lab sessions.*	*5 marks*
Laboratory Record / Journal	*Regular and neat maintenance of lab record, accuracy of results, and timely submission.*	*10 marks*
Subtotal		*15*
Allotment of marks for CIE practical test		
Laboratory Test / Experiment Performance	*Ability to set up apparatus, follow procedure, take observations, and obtain correct results in the test experiment.*	*5 marks*
Viva-Voce	*Understanding of theory, concepts, and experimental procedure; ability to explain results and answer related questions.*	*5 marks*
Subtotal		*10*
Total		*25*

Students' activities for TW/SL under NCrF:

As per National credit framework (NCrF) students must spend 120 hours of study for 4 credit courses, which include Course instructions (CI-70 hour) and Teamwork/Self learning (TW/SL-50 hours). Hence, students must complete minimum of two activities as part of NCrF. The evaluation activities will be done using set of rubrics developed for each activity. The following sample activities are listed below. The course coordinator can also design learning activities based on course outcomes.

Sl. No.	**Term Work (TW) Activity**	**Number of Hours / Semester**
1	*TW1 – Wastewater-treatment plant performance audit: Prepare an inventory of treatment units, collect available operational data, assess treatment efficiency, and identify process deficiencies.*	*25*
2	*TW2 – Safety audit of a wastewater facility: Identify hazards, prepare a risk matrix, evaluate PPE and signage, and recommend corrective actions.*	*25*
3	*TW3 – Treated-wastewater reuse and resource-recovery plan: Develop a reuse, sludge-management, energy-recovery, or nutrient-recovery proposal for a selected facility.*	*25*
SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.		
Sl. No.	**Self-Learning (SL) Activity**	**Number of Hours / Semester**
1	*SL1 – Review of an advanced wastewater-treatment technology: Prepare a technical note on MBR, SBR, MBBR, RO, UV, ozonation, or advanced oxidation.*	*25*
2	*SL2 – Wastewater-treatment safety case study: Study a chemical exposure, confined-space incident, gas hazard, or plant emergency and prepare preventive measures.*	*25*
3	*SL3 – Regulatory and sustainability review: Compare applicable treated-effluent standards, reuse requirements, energy use, sludge management, and sustainability indicators.*	*25*

Sample rubrics for TW activities:

Criterion	*4 – Excellent*	*3 – Good*	*2 – Satisfactory*	*1 – Needs Improvement*
Problem understanding	*The problem is clearly defined with strong justification, objectives, and scope.*	*The problem is mostly clear with minor gaps in framing or justification.*	*The problem is stated, but clarity or justification is limited.*	*The problem is poorly defined or unclear.*
Data and method	*Data collected/used is appropriate and sufficient; methods/tools are well chosen and logically applied.*	*Data and methods are generally appropriate with minor issues or omissions.*	*Data is limited or partially relevant; methods are basic or inconsistently applied.*	*Data is inadequate/irrelevant; methods are inappropriate or missing.*
Analysis	*Analysis is thorough; interpretations are logically argued and results are valid.*	*Analysis is generally sound with minor errors or missing details.*	*Analysis is partial; contains gaps or superficial interpretation.*	*Analysis is weak, incorrect, or largely missing.*
Recommendations	*Recommendations are feasible, context-specific, and clearly derived from analysis.*	*Recommendations are relevant but may have minor limitations or lack detail.*	*Recommendations are generic or only loosely connected to analysis.*	*Recommendations are incomplete, unrealistic, or absent.*
Presentation	*Work is very well organized, neat, and professionally presented, including structure, figures, and language.*	*Work is well organized with minor issues in formatting or clarity.*	*Presentation is acceptable but uneven; structure or formatting needs improvement.*	*Work is poorly organized, difficult to follow, or untidy.*

Suggested rubrics for Practical continuous assessment:

Performance Indicators	*Excellent*	*Very Good*	*Good*	*Satisfactory*
Fundamental Knowledge (4) (PO1)	*The student has well depth knowledge of construction planning, BIM-enabled 4D/5D workflows, project controls and site logistics. (4)*	*Student has good knowledge of some topics related to construction planning and BIM workflows. (3)*	*Student is capable of narrating the answer but not capable to show in depth knowledge. (2)*	*Student has not understood the concepts clearly. (1)*
Design Of Experiment (5)	*Student is capable of discussing more than*	*Student is capable of discussing a few*	*Student is capable of discussing a single*	*Student can explain the*

(PO2 & PO3)	*one planning workflow/design for the problem statement and selecting the best suitable approach with proper reason. (5)*	*workflows but not fully capable of selecting the best. (4)*	*planning workflow with merits and demerits. (3)*	*planning/design approach only partly. (1-2)*
Implementation (8) (PO3 & PO8)	*Student is capable of implementing WBS, schedule logic, model linkage, resource mapping and issue tracking with an optimal and traceable workflow. (7-8)*	*Student is capable of implementing the workflow and explaining it with minor gaps. (5-6)*	*Student is capable of implementing the workflow with partial explanation. (3-4)*	*Student can implement only limited parts of the workflow. (1-2)*
Result &Analysis (5) (PO4)	*Student is able to run the workflow for various cases and compare 4D sequence, resource, progress and logistics results with proper analysis. (5)*	*Student will be able to run the workflow for all the cases. (4)*	*Student will be able to run the workflow for a few cases and analyze the output. (3)*	*Student will be able to run the workflow but not able to analyze the output. (1-2)*
Demonstration (8) (PO9)	*The lab record/portfolio is well organized, with clear sections such as brief, method, WBS, schedule, model QA, 4D output, resource sheet, issue log, results and conclusion. (7-8)*	*The lab record/portfolio is organized, with clear sections, but some sections are not well-defined. (5-6)*	*The lab record lacks clear organization or structure. Some sections are unclear or incomplete. (3-4)*	*The lab record is poorly organized, with missing or unclear sections. (1-2)*

INDUSTRIAL WASTEWATER ENGINEERING & POLLUTION PREVENTION			
Course Code	**1MCWH202**	*Scheme*	*2026*
Type of Course	**Professional Core Course**	*Semester*	*II*
Teaching Hours/Week (L:T:P)	*42(3:0:0)*	*CIE Marks*	*50*
Total Hours of Pedagogy per Semester CI (L /T): LI(P):TW&SL	*90 (42:0:0:48)*	*SEE Marks*	*50*
Credits	*3*	*Total Marks*	*100*
Type of Examination (PCC):	*Theory- CIE +SEE*	*Exam Hours*	*03*

Course outcome (Course Skill Set):

At the end of the course, the student will be able to:

1. *CO1: Explain the sources, characteristics, environmental impacts, and regulatory framework associated with industrial wastewater.*
2. *CO2: Analyze industrial wastewater quantity and quality using material balances, pollution-load estimation, and laboratory data.*
3. *CO3: Select and develop treatment-train configurations using physical, chemical, biological, and advanced treatment processes.*
4. *CO4: Apply pollution-prevention principles, cleaner production, water auditing, resource recovery, reuse, and zero-liquid-discharge concepts to industrial processes.*
5. *CO5: Evaluate industry-specific wastewater management strategies and prepare technically feasible and sustainable industrial effluent management proposals.*

Module-1

Introduction to Industrial Wastewater and Pollution Prevention

- *Definition, scope, and significance of industrial wastewater engineering.*
- *Sources of industrial wastewater: process water, cooling water, boiler blowdown, washing water, domestic sewage, stormwater, and accidental releases.*
- *Quantity and characteristics: flow variation, temperature, pH, colour, odour, TSS, TDS, BOD, COD, TOC, oil and grease, nutrients, sulphides, cyanides, phenols, solvents, toxicity, and heavy metals.*
- *Environmental and public-health impacts of industrial effluents; aquatic toxicity, eutrophication, bioaccumulation, groundwater contamination, and soil degradation.*
- *Sampling, preservation, monitoring, and laboratory analysis of industrial wastewater.*
- *Pollution prevention hierarchy: source reduction, reuse, recycling, recovery, treatment, and safe disposal.*
- *Indian regulatory framework: Water (Prevention and Control of Pollution) Act, Environment (Protection) Act, consent mechanism, discharge standards, industry-specific standards, and compliance responsibilities.*

Linked COs: CO1, CO2 **Number of Hours: 8 hrs**

Module-2

Wastewater Characterization, Process Integration, and Preliminary Treatment

- *Industrial process flow diagrams and identification of wastewater-generating operations.*
- *Material and water balances; estimation of wastewater flow and pollutant loads.*
- *Strength, biodegradability, treatability, toxicity, and inhibition indices.*
- *Equalization and flow balancing; segregation of compatible and incompatible streams.*
- *In-plant control measures: good housekeeping, leak detection, preventive maintenance, spill control, counter-current rinsing, dry cleaning, and water-use minimization.*
- *Preliminary and primary treatment: screening, comminution, grit removal, oil and grease separation, dissolved-air flotation, neutralization, and equalization.*
- *Coagulation, flocculation, chemical precipitation, and removal of suspended solids and heavy metals.*
- *Selection and preliminary sizing considerations for industrial pretreatment units.*

Linked COs: CO2, CO3, CO4 **Number of Hours: 9 hrs**

Module-3

Biological and Advanced Treatment Processes

- *Biodegradation of industrial pollutants; aerobic and anaerobic processes.*
- *Biological treatability studies and acclimatization of microorganisms.*
- *Activated sludge process, extended aeration, sequencing batch reactors, moving-bed biofilm reactors, trickling filters, rotating biological contactors, and membrane bioreactors.*
- *Anaerobic reactors for high-strength industrial wastewater; biogas generation and energy recovery.*
- *Biological nutrient removal and removal of refractory organic compounds.*
- *Adsorption using activated carbon and other adsorbents; ion exchange.*
- *Membrane processes: microfiltration, ultrafiltration, nanofiltration, reverse osmosis, and electrodialysis.*
- *Advanced oxidation processes: ozonation, UV-peroxide, Fenton oxidation, electrochemical oxidation, and photocatalysis.*
- *Process selection, fouling and inhibition control, energy requirements, and performance evaluation.*

Linked COs: CO2, CO3, CO5 **Number of Hours: 9 hrs**

Module-4

Pollution Prevention, Cleaner Production, and Resource Recovery

- *Pollution prevention versus end-of-pipe treatment; cleaner-production assessment methodology.*
- *Process modification, raw-material substitution, product reformulation, segregation, recycling, and recovery of by-products.*
- *Water pinch concepts, water-use minimization, wastewater minimization, and cascading reuse.*
- *Water auditing: water balance, unit-operation audit, specific water consumption, wastewater audit, and performance indicators.*
- *Energy conservation in wastewater treatment; anaerobic energy recovery, heat recovery, and renewable-energy integration.*
- *Recovery of chemicals, metals, nutrients, salts, solvents, and useful products from industrial wastewater.*
- *Reuse applications: process water, cooling water, boiler feed, construction, landscaping, and agricultural applications subject to quality requirements.*
- *Sludge management: characteristics, thickening, dewatering, stabilization, resource recovery, hazardous sludge handling, and secure disposal.*
- *Zero-liquid-discharge systems: pretreatment, membrane concentration, evaporators, crystallizers, brine management, and techno-economic limitations.*

Linked COs: CO1, CO4, CO5 **Number of Hours: 8 hrs**

Module-5

Industry-Specific Wastewater Management and Case Studies

- *Dairy and food-processing industries: high biodegradable organic load, fat and oil removal, anaerobic treatment, and nutrient management.*
- *Distillery and sugar industries: spent wash, colour, high COD, biomethanation, evaporation, and condensate polishing.*
- *Textile, dyeing, and printing industries: colour, salinity, refractory organics, equalization, oxidation, adsorption, and membrane treatment.*
- *Tannery and leather industries: chromium, sulphides, salinity, segregation, recovery, precipitation, and biological treatment.*
- *Pulp and paper industries: colour, lignin, suspended solids, bleaching chemicals, biological*

treatment, and advanced polishing.

- *Petroleum refinery and petrochemical industries: oil, phenols, sulphides, ammonia, dissolved-air flotation, biological treatment, and tertiary polishing.*
- *Pharmaceutical and chemical industries: toxicity, solvents, active compounds, advanced oxidation, adsorption, and source control.*
- *Fertilizer, electroplating, metal-finishing, mining, and coke-oven wastewater: nutrients, cyanides, heavy metals, acid mine drainage, and selective treatment.*
- *Integrated effluent treatment plants, common effluent treatment plants, online monitoring, compliance auditing, and case-study evaluation.*
- *Preparation of an industrial wastewater management proposal incorporating pollution prevention, treatment, reuse, residuals management, risk, and sustainability.*

Linked COs: CO1, CO3, CO4, CO5 **Number of Hours: 8 hrs**

Suggested Learning Resources:

Textbooks:

1. *Nemerow, N. L. and Dasgupta, A., Industrial and Hazardous Waste Treatment, Van Nostrand Reinhold.*
2. *Eckenfelder, W. W., Industrial Water Pollution Control, McGraw-Hill.*
3. *Metcalf & Eddy/AECOM, Wastewater Engineering: Treatment and Resource Recovery, McGraw-Hill.*
4. *Rao, M. N. and Dutta, A. K., Wastewater Treatment, Oxford and IBH Publishing.*
5. *Arceivala, S. J. and Asolekar, S. R., Wastewater Treatment for Pollution Control and Reuse, McGraw-Hill Education.*
6. *Wang, L. K., Hung, Y.-T., Lo, H. H. and Yapijakis, C., Handbook of Industrial and Hazardous Wastes Treatment, Marcel Dekker.*

Reference Books

1. *Patterson, J. W., Industrial Wastewater Treatment Technology, Butterworth-Heinemann.*
2. *Frank Woodard, Industrial Waste Treatment Handbook, Butterworth-Heinemann.*
3. *Crites, R. and Tchobanoglous, G., Small and Decentralized Wastewater Management Systems, McGraw-Hill.*
4. *UNEP, Cleaner Production Assessment Manual and related cleaner-production guidance.*
5. *CPCB, General Standards for Discharge of Environmental Pollutants and industry-specific effluent standards.*
6. *Relevant BIS, CPCB, MoEFCC, SPCB, and international guidance documents on industrial effluent monitoring, reuse, sludge, and hazardous-waste management.*

Web links and Video Lectures (e-Resources)

1. *NPTEL – Industrial Wastewater Treatment*
2. *CPCB – Effluent and Emission Standards*
3. *CPCB – Water Quality Standards*
4. *CPCB – General Standards for Industrial Effluents*
5. *U.S. EPA – Pollution Prevention*
6. *UNEP – Resource-Efficient and Cleaner Production*
7. *Spreadsheet and open-source tools for water auditing, mass balancing, treatment-process evaluation, and lifecycle assessment.*

Teaching-Learning Process (Innovative Delivery Methods)

The following strategies may be adopted to enhance the effectiveness of the teaching-learning process and facilitate achievement of course outcomes:

- *Flipped classroom.*
- *Problem-based learning using industry wastewater datasets.*
- *Case-based teaching on textile, tannery, dairy, distillery, refinery, and pharmaceutical industries.*
- *Process-flow-diagram and treatment-train design exercises.*

- *Water-audit and cleaner-production workshops.*
- *Simulation and virtual laboratory activities for treatment-process selection.*
- *Laboratory or field demonstration of wastewater sampling and analysis.*
- *Industrial visit to an effluent treatment plant, common effluent treatment plant, or zero-liquid-discharge facility.*
- *Partial delivery by industry experts and regulatory practitioners.*
- *ICT-enabled teaching using spreadsheets, process simulators, GIS, dashboards, and online monitoring data.*
- *Group projects involving pollution-load estimation, treatment selection, and resource-recovery assessment.*

Assessment Structure (both CIE and SEE)

The weightage assigned to Continuous Internal Evaluation (CIE) and Semester End Examination (SEE) shall be 50% each. A student shall secure a minimum of 50% of the maximum marks prescribed for CIE and a minimum of 40% of the maximum marks prescribed for SEE to be eligible for passing.

A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to a subject/course only if he/she secures not less than 50% of the aggregate marks obtained in CIE and SEE taken together.

Continuous Internal Evaluation:

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

A minimum of two Internal Assessment Tests (IA) shall be conducted. Each test shall be conducted for a maximum of 25 marks. The average of the two test marks shall be the marks secured by a student in IA.

In addition, Continuous Comprehensive Assessment (CCA) shall be conducted for a total of 25 marks

Students' activities for TW/SL under NCrF: Samples only

As per National credit formwork (NCrF) students must spend 90 hours of study for 3 credit courses, which include Course instructions (CI-42 hour) and Teamwork/ Self learning (TW/Sl-48 hours). Hence, students must complete minimum of two actives as part of NCrF. These learning activities shall be considered as CCA components of CIE. The evaluation activities will be done using set of rubrics developed for each activity. The following sample activities are listed below. The sample activities are given below. The course coordinator can also give their own TW/SL activities as per the course outcomes.

Sl. No.	Term Work (TW) Activity	Number of Hours / Semester
1	**TW1: Conduct a water and wastewater audit for a selected industrial unit***; prepare a process flow diagram, water balance, pollutant-load estimate, and pollution-prevention plan.*	*24*
2	**TW2: Develop and justify a treatment-train proposal** *for a selected industrial wastewater using characterization data, design criteria, reuse objectives, and residuals-management requirements.*	*24*

SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.

Sl. No.	Self-Learning (SL) Activity	Number of Hours / Semester
1	**SL1:** *Study CPCB discharge standards and prepare a compliance matrix for a selected industry and receiving environment.*	*24*
2	**SL2:** *Review a case study on zero-liquid discharge or industrial water reuse and evaluate its technical, environmental, and economic performance.*	*24*
3	**SL3***: Complete an NPTEL or equivalent online module on industrial wastewater treatment, cleaner production, or pollution prevention and submit a reflective technical note.*	*24*

Sample rubrics for TW activities:

Criterion	*4 – Excellent*	*3 – Good*	*2 – Satisfactory*	*1 – Needs Improvement*
Problem understanding	*Problem is clearly defined with strong justification and clear objectives.*	*Problem is mostly clear with minor gaps in framing or justification.*	*Problem is stated but lacks clarity or detailed justification.*	*Problem is poorly defined or unclear.*
Data and method	*Data collected/used is appropriate and sufficient; methods/tools are well chosen and logically applied.*	*Data and methods are generally appropriate with minor issues or omissions.*	*Limited or partially relevant data; methods are basic or inconsistently applied.*	*Data is inadequate/irrelevant; methods are inappropriate or missing.*
Analysis	*Analysis is thorough; interpretations are logically argued and results are valid.*	*Analysis is generally sound with minor errors or missing details.*	*Analysis is partial; contains gaps or superficial interpretation.*	*Analysis is weak, incorrect, or largely missing.*
Recommendations	*Recommendations are feasible, context-specific, and clearly derived from analysis.*	*Recommendations are relevant but may have minor limitations or lack detail.*	*Recommendations are generic or only loosely connected to analysis.*	*Recommendations are incomplete, unrealistic, or absent.*
Presentation	*Work is very well organized, neat, and professionally presented.*	*Work is well organized with minor issues in formatting or clarity.*	*Presentation is acceptable but uneven.*	*Work is poorly organized, difficult to follow, or untidy.*

ENVIRONMENTAL HEALTH, TOXICOLOGY & OCCUPATIONAL SAFETY			
Course Code	**1MCWH203**	*Scheme*	*2026*
Type of Course	**Professional Core Course**	*Semester*	*II*
Teaching Hours/Week (L:T:P)	*42(3:0:0)*	*CIE Marks*	*50*
Total Hours of Pedagogy per Semester CI (L /T): LI(P):TW&SL	*90 (42:0:0:48)*	*SEE Marks*	*50*
Credits	*3*	*Total Marks*	*100*
Type of Examination (PCC):	*Theory- CIE +SEE*	*Exam Hours*	*03*

Course outcome (Course Skill Set):

At the end of the course, the student will be able to:

1. *CO1: Explain the principles, scope, objectives, and importance of occupational health and industrial hygiene in workplaces.*
2. *CO2: Identify occupational hazards and describe their effects on worker health, safety, productivity, and the environment.*
3. *CO3: Apply industrial hygiene principles for recognition, evaluation, and control of chemical, physical, biological, ergonomic, and psychosocial hazards.*
4. *CO4: Plan workplace exposure assessment, environmental monitoring, health surveillance, and interpretation of occupational hygiene data.*
5. *CO5: Develop integrated occupational health and industrial hygiene programmes based on risk management, legislation, emergency preparedness, and continual improvement.*

Module-1

Environmental Health and Public Health Foundations

- *Concept, scope, and evolution of environmental health.*
- *Determinants of health: environmental, occupational, social, behavioural, and genetic factors.*
- *Environmental pathways and health effects: air, water, soil, food, housing, sanitation, noise, radiation, and climate-related factors.*
- *Communicable and non-communicable diseases associated with environmental conditions.*
- *Environmental epidemiology: incidence, prevalence, relative risk, attributable risk, surveillance, and outbreak investigation.*
- *Vulnerable populations, health equity, environmental justice, and One Health perspective.*
- *Environmental health assessment, indicators, health impact assessment, and basic public-health interventions.*

Linked COs: CO1 **Number of Hours: 8 hrs**

Module-2

Fundamentals of Toxicology and Environmental Risk

- *Definition, scope, branches, and significance of toxicology.*
- *Routes of exposure: inhalation, ingestion, dermal, ocular, and injection; absorption, distribution, metabolism, and excretion.*
- *Toxicokinetics and toxicodynamics; acute, sub-acute, sub-chronic, and chronic toxicity.*
- *Dose–response relationships, threshold concepts, NOAEL, LOAEL, reference dose, permissible exposure limits, and uncertainty factors.*
- *Target-organ toxicity: neurotoxicity, hepatotoxicity, nephrotoxicity, respiratory toxicity, reproductive toxicity, genotoxicity, carcinogenicity, and endocrine disruption.*
- *Mixture toxicity, synergism, antagonism, bioaccumulation, biomagnification, persistence, and environmental fate.*
- *Toxicological testing, biomarkers, safety data sheets, and interpretation of toxicity information.*

Linked COs: CO2 **Number of Hours: 9 hrs**

Module-3

Exposure Assessment and Environmental Health Risk Management

- *Hazard identification, exposure assessment, dose–response assessment, and risk characterization.*
- *Sources and exposure pathways of air pollutants, heavy metals, pesticides, solvents, persistent organic pollutants, plastics, pharmaceuticals, and emerging contaminants.*
- *Environmental monitoring and sampling strategies for air, water, soil, food, and biological media.*
- *Personal monitoring, area monitoring, biomonitoring, and quality assurance/quality control.*
- *Risk perception, risk communication, risk management, and uncertainty analysis.*
- *Health risk assessment for contaminated sites, industries, waste-management facilities, and infrastructure projects.*
- *Health impact assessment, cumulative impacts, climate change, heat stress, vector-borne diseases, and disaster-related health risks.*

Linked COs: CO2, CO5 **Number of Hours: 9 hrs**

Module-4

Occupational Hazards and Industrial Hygiene

- *Occupational health and safety: objectives, principles, responsibilities, and safety culture.*
- *Hazard identification and risk assessment: HIRA, JSA/JHA, What-if analysis, checklist analysis, FMEA, and bow-tie analysis.*
- *Chemical hazards: toxic gases, vapours, dusts, fumes, fibres, flammable substances, corrosives, reactive materials, and carcinogens.*
- *Physical hazards: noise, vibration, heat, cold, illumination, radiation, pressure, electrical energy, and confined spaces.*
- *Biological hazards: bacteria, viruses, fungi, parasites, allergens, biomedical waste, and occupational infections.*
- *Ergonomic and psychosocial hazards: manual handling, awkward postures, repetitive work, fatigue, stress, violence, and shift work.*
- *Industrial hygiene programme: anticipation, recognition, evaluation, and control of workplace exposures.*
- *Occupational diseases, medical surveillance, health records, fitness assessment, and return-to-work programmes.*

Linked COs: CO3, CO4 **Number of Hours: 8 hrs**

Module-5

Occupational Safety Management and Emergency Preparedness

- *Hierarchy of controls: elimination, substitution, engineering controls, administrative controls, and PPE.*
- *Safe operating procedures, permit-to-work systems, lockout/tagout, work-at-height safety, excavation safety, lifting operations, and construction safety.*
- *Selection, use, maintenance, limitations, and fit testing of PPE and respiratory protective equipment.*
- *Fire prevention and protection: fire triangle, classes of fire, detection, alarms, extinguishing systems, evacuation, and drills.*
- *Chemical process safety, hazardous-material storage and transport, spill control, emergency response, and disaster management.*
- *Incident, accident, near-miss, and occupational illness investigation; root-cause analysis and corrective actions.*
- *Safety audits, inspections, leading and lagging indicators, behavioural safety, contractor safety, and safety training.*

- *Occupational health and safety management systems; integration with environmental management, quality management, and sustainability.*
- *Case studies on industrial accidents, public-health emergencies, construction incidents, and community exposure events.*

Linked COs: CO4, CO5 **Number of Hours: 8 hrs**

Suggested Learning Resources:

Textbooks:

1. *D. D. Chiras, Environmental Science: Creating a Sustainable Future, Jones & Bartlett Learning.*
2. *M. A. M. Montgomery, Environmental Health: From Global to Local, Jossey-Bass.*
3. *C. D. Klaassen, Casarett & Doull's Toxicology: The Basic Science of Poisons, McGraw-Hill.*
4. *L. J. Cralley, L. J. Cralley, and R. A. Bierbaum, The Industrial Environment—Its Evaluation and Control, NIOSH.*
5. *R. S. F. Schilling, Occupational Health Practice, Butterworth-Heinemann.*
6. *R. Goetsch, Occupational Safety and Health for Technologists, Engineers, and Managers, Pearson.*
7. *David A. Crowl and Joseph F. Louvar, Chemical Process Safety: Fundamentals with Applications, Pearson.*

Reference Books

1. *D. A. Grimaldi and R. H. Simonds, Safety Management, AITBS Publishers.*
2. *B. S. Dhillon, Safety, Reliability, and Risk Analysis, CRC Press.*
3. *M. L. Brunk and R. A. Nies, Environmental Health and Safety Management, Wiley.*
4. *Barry L. Johnson, Impact of Chemicals on Human Health, Princeton Scientific Publishing.*
5. *International Labour Organization, Encyclopaedia of Occupational Health and Safety.*
6. *WHO, Environmental Health Criteria monographs and guidance documents.*
7. *NIOSH, Occupational Safety and Health Guidelines and Criteria Documents.*
8. *Relevant BIS, ISO, OSHA, CPCB, MoEFCC, and national occupational-safety guidance documents..*

Web links and Video Lectures (e-Resources)

1. *World Health Organization: Environmental Health and Occupational Health resources.*
2. *International Labour Organization: Occupational Safety and Health resources.*
3. *National Institute for Occupational Safety and Health: workplace exposure and hazard-control resources.*
4. *Central Pollution Control Board: environmental monitoring and pollution-control guidance.*
5. *Ministry of Environment, Forest and Climate Change: environmental regulations and notifications.*
6. *NPTEL and SWAYAM courses on environmental health, toxicology, industrial hygiene, and occupational safety.*
7. *Open-access Safety Data Sheets and chemical hazard databases for exposure-assessment exercises.*

Teaching-Learning Process (Innovative Delivery Methods)

The following strategies may be adopted to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes:

- *Flipped classroom using pre-class videos, readings, and safety data sheets.*
- *Problem-Based Learning (PBL) on workplace exposure and environmental-health problems.*
- *Case-based teaching using industrial accidents, chemical releases, occupational diseases, and contaminated-site investigations.*
- *Field-based learning through workplace safety surveys, environmental-health observations, and hazard mapping.*
- *Demonstration of noise, illumination, thermal comfort, air-quality, and gas-monitoring instruments.*
- *Simulation and virtual laboratories for HIRA, emergency response, fire safety, and risk assessment.*
- *Role play involving safety committees, incident investigation teams, regulators, workers, and affected communities.*
- *Industry expert lectures, industrial visits, toolbox-talk demonstrations, and safety-drill participation.*
- *ICT-enabled teaching using risk-assessment software, spreadsheets, GIS-based exposure mapping, and*

digital dashboards.

Assessment Structure (both CIE and SEE)

The weightage assigned to Continuous Internal Evaluation (CIE) and Semester End Examination (SEE) shall be 50% each. A student shall secure a minimum of 50% of the maximum marks prescribed for CIE and a minimum of 40% of the maximum marks prescribed for SEE to be eligible for passing.

A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to a subject/course only if he/she secures not less than 50% of the aggregate marks obtained in CIE and SEE taken together.

Continuous Internal Evaluation:

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

A minimum of two Internal Assessment Tests (IA) shall be conducted. Each test shall be conducted for a maximum of 25 marks. The average of the two test marks shall be the marks secured by a student in IA.

In addition, Continuous Comprehensive Assessment (CCA) shall be conducted for a total of 25 marks

Students' activities for TW/SL under NCrF: Samples only

As per National credit formwork (NCrF) students must spend 90 hours of study for 3 credit courses, which include Course instructions (CI-42 hour) and Teamwork/ Self learning (TW/Sl-48 hours). Hence, students must complete minimum of two actives as part of NCrF. These learning activities shall be considered as CCA components of CIE. The evaluation activities will be done using set of rubrics developed for each activity. The following sample activities are listed below. The sample activities are given below. The course coordinator can also give their own TW/SL activities as per the course outcomes.

Sl. No.	Term Work (TW) Activity	Number of Hours / Semester
1	*TW1: Conduct a workplace safety and hazard assessment for a selected construction site, laboratory, industry, wastewater-treatment plant, or solid-waste facility; prepare HIRA/JSA and recommend controls.*	*24*
2	*TW2: Conduct an environmental-health exposure assessment for a selected community or facility using available air, water, noise, sanitation, or occupational-health observations; prepare a risk communication report.*	*24*

SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.

Sl. No.	Self-Learning (SL) Activity	Number of Hours / Semester
1	**SL1:** *Study a major industrial or environmental contamination incident and analyze the source, exposure pathway, health effects, emergency response, and preventive measures.*	*24*
2	**SL2:** *Prepare a toxicological profile and safety data-sheet-based risk summary for a selected chemical used in construction, water treatment, laboratories, or industry.*	*24*
3	**SL3***: Complete a relevant MOOC, NPTEL/SWAYAM course, or structured online learning module on environmental health, toxicology, industrial hygiene, or occupational safety and submit a reflective report.*	*24*

Sample rubrics for TW activities:

Criterion	*4 – Excellent*	*3 – Good*	*2 – Satisfactory*	*1 – Needs Improvement*
Problem understanding	*Problem is clearly defined with strong justification and clear objectives.*	*Problem is mostly clear with minor gaps in framing or justification.*	*Problem is stated but lacks clarity or detailed justification.*	*Problem is poorly defined or unclear.*
Data and method	*Data collected/used is appropriate and sufficient; methods/tools are well chosen and logically applied.*	*Data and methods are generally appropriate with minor issues or omissions.*	*Limited or partially relevant data; methods are basic or inconsistently applied.*	*Data is inadequate/irrelevant; methods are inappropriate or missing.*
Analysis	*Analysis is thorough; interpretations are logically argued and results are valid.*	*Analysis is generally sound with minor errors or missing details.*	*Analysis is partial; contains gaps or superficial interpretation.*	*Analysis is weak, incorrect, or largely missing.*
Recommendations	*Recommendations are feasible, context-specific, and clearly derived from analysis.*	*Recommendations are relevant but may have minor limitations or lack detail.*	*Recommendations are generic or only loosely connected to analysis.*	*Recommendations are incomplete, unrealistic, or absent.*
Presentation	*Work is very well organized, neat, and professionally presented.*	*Work is well organized with minor issues in formatting or clarity.*	*Presentation is acceptable but uneven.*	*Work is poorly organized, difficult to follow, or untidy.*

SMART WASTEWATER SYSTEMS, DIGITAL SAFETY & EMERGENCY RESPONSE			
Course Code	**1MCWH204**	*Scheme*	*2026*
Type of Course	**Professional Core Course**	*Semester*	*II*
Teaching Hours/Week (L:T:P)	*42(3:0:0)*	*CIE Marks*	*50*
Total Hours of Pedagogy per Semester CI (L /T): LI(P):TW&SL	*90 (42:0:0:48)*	*SEE Marks*	*50*
Credits	*3*	*Total Marks*	*100*
Type of Examination (PCC):	*Theory- CIE +SEE*	*Exam Hours*	*03*

Course outcome (Course Skill Set):

At the end of the course, the student will be able to:

1. *CO1: Explain the principles, components, architecture, and applications of smart wastewater collection, treatment, and reuse systems.*
2. *CO2: Analyze wastewater system data using sensors, IoT platforms, GIS/BIM, dashboards, and basic data analytics for operational decision-making.*
3. *CO3: Design and evaluate digital monitoring, control, predictive maintenance, and resource-recovery strategies for wastewater infrastructure.*
4. *CO4: Assess occupational, process, cyber, and environmental hazards associated with wastewater facilities and formulate digital safety-control measures.*
5. *CO5: Develop an integrated emergency response and business-continuity plan for wastewater incidents using risk assessment, communication, simulation, and incident documentation.*

Module-1

Foundations of Smart Wastewater Systems

- *Evolution from conventional to smart wastewater management.*
- *Wastewater system components: collection networks, pumping stations, treatment units, sludge handling, reclaimed-water systems, and receiving environments.*
- *Smart-city and circular-economy perspectives; water-energy-nutrient nexus.*
- *System architecture: field layer, communication layer, data layer, application layer, and decision layer.*
- *Performance indicators: flow, load, treatment efficiency, energy use, water quality, resilience, and service continuity.*
- *Digital twins and asset information models for wastewater infrastructure.*

Linked COs: CO1 **Number of Hours: 8 hrs**

Module-2

Sensing, IoT, GIS/BIM and Data Management

- *Sensors and instrumentation for flow, level, pressure, pH, temperature, dissolved oxygen, turbidity, conductivity, ORP, ammonia, nitrate, and gas detection.*
- *SCADA, PLC, telemetry, IoT gateways, edge computing, and cloud platforms.*
- *Communication technologies and data quality: calibration, validation, missing data, drift, alarms, and cybersecurity basics.*
- *GIS-based network inventory, hydraulic-zone mapping, spatial analysis, and integration with BIM/open data environments.*
- *Time-series databases, dashboards, data visualization, and basic descriptive analytics.*
- *Data governance, access control, privacy, backup, interoperability, and ethical use of operational data.*

Linked COs: CO1, CO2 **Number of Hours: 9 hrs**

Module-3

Smart Treatment, Control and Resource Recovery

- *Real-time monitoring and control of preliminary, primary, secondary, tertiary, and advanced treatment processes.*
- *Model-based and rule-based control; feedback, feed-forward, cascade, and supervisory control concepts.*

- *Aeration optimization, nutrient-removal control, pumping optimization, and energy management.*
- *Predictive maintenance, condition assessment, failure modes, anomaly detection, and remaining-useful-life concepts.*
- *Digital decision support for sludge management, biogas, energy recovery, nutrient recovery, and water reuse.*
- *Lifecycle performance, resilience, sustainability, and case studies of smart wastewater utilities*.

Linked COs: CO2, CO3 **Number of Hours: 9 hrs**

Module-4

Digital Safety and Risk Management

- *Safety philosophy and hierarchy of controls in wastewater facilities.*
- *Hazards: toxic and flammable gases, confined spaces, biological agents, chemicals, electrical systems, mechanical equipment, falls, drowning, traffic, and excavation.*
- *Hazard identification, risk assessment, job safety analysis, permit-to-work, lockout/tagout, gas testing, ventilation, PPE, and safe work procedures.*
- *Digital safety tools: electronic permits, wearable sensors, geofencing, lone-worker monitoring, mobile inspection applications, CCTV, and AI-assisted alerts.*
- *Cyber-physical security of SCADA/OT systems: threat awareness, segmentation, authentication, patching, backups, incident logging, and recovery.*
- *Safety performance indicators, near-miss reporting, audits, training, competency, and safety culture.*

Linked COs: CO4 **Number of Hours: 8 hrs**

Module-5

Emergency Response, Resilience and Incident Command

- *Emergency scenarios: sewer surcharge, pump failure, treatment-process upset, toxic-gas release, chemical spill, fire, electrical incident, cyberattack, flood, drought, and contamination event.*
- *Emergency preparedness cycle: prevention, mitigation, preparedness, response, recovery, and continual improvement.*
- *Risk and vulnerability assessment; consequence analysis; emergency action plans and standard operating procedures.*
- *Incident command, roles and responsibilities, evacuation, rescue, first aid, mutual aid, public warning, stakeholder coordination, and media communication.*
- *Digital emergency systems: GIS dashboards, mobile reporting, automated alarms, crisis communication, remote inspection, and response simulation.*
- *Business continuity, critical-service prioritization, backup power, redundancy, recovery objectives, post-incident review, and corrective action.*
- *Case studies and tabletop exercises for integrated wastewater emergencies.*

Linked COs: CO4, CO5 **Number of Hours: 8 hrs**

Suggested Learning Resources:

Textbooks

1. *Metcalf & Eddy/AECOM, Wastewater Engineering: Treatment and Resource Recovery, McGraw-Hill Education.*
2. *George Tchobanoglous, Franklin L. Burton, H. David Stensel et al., Wastewater Engineering: Treatment and Resource Recovery, McGraw-Hill.*
3. *David Butler and Christopher Digman, Urban Drainage, CRC Press.*
4. *W. Wesley Eckenfelder, Industrial Water Pollution Control, McGraw-Hill.*
5. *R. S. Sinha, Wastewater Treatment and Management, relevant Indian edition.*
6. *Frank R. Spellman, Handbook of Water and Wastewater Treatment Plant Operations, CRC Press.*

Reference Books

1. *Henze et al., Biological Wastewater Treatment: Principles, Modelling and Design, IWA Publishing.*
2. *Oliver Grievson, The Water and Wastewater Treatment Industry, relevant professional references.*
3. *N. F. Gray, Water Technology: An Introduction for Environmental Scientists and Engineers, Butterworth-Heinemann.*
4. *S. M. R. Walski et al., Advanced Water Distribution Modeling and Management, Haestad Press.*
5. *Relevant CPHEEO manuals, BIS standards, Central Pollution Control Board guidance, and state pollution-control requirements.*
6. *Relevant occupational safety, confined-space, emergency-management, information-security, and industrial-control-system guidance documents.*

Web links and Video Lectures (e-Resources)

1. *NPTEL courses on wastewater treatment, environmental engineering, IoT, GIS, SCADA, safety engineering, and disaster management.*
2. *CPHEEO and Ministry of Housing and Urban Affairs resources on urban water and wastewater management.*
3. *Central Pollution Control Board resources on effluent standards, monitoring, and environmental compliance.*
4. *United States Environmental Protection Agency resources on wastewater operations, cybersecurity, and emergency response.*
5. *International Water Association resources on digital water, utility management, resource recovery, and resilience.*
6. *Open-source platforms and tutorials for QGIS, Python time-series analysis, IoT dashboards, and digital-twin workflows..*

Teaching-Learning Process (Innovative Delivery Methods)

The following strategies may be adopted to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes:

- *Flipped classroom using treatment-process and safety videos.*
- *Problem-Based Learning (PBL) using a municipal wastewater utility scenario.*
- *Case-based teaching on sewer overflows, treatment upsets, gas incidents, and cyber-physical failures.*
- *Demonstration of sensors, SCADA screens, GIS dashboards, and digital inspection tools.*
- *Simulation and virtual laboratory exercises for process control and emergency response.*
- *Field visit to a wastewater treatment plant, pumping station, laboratory, or control centre.*
- *Industry-expert sessions on utility digitization, occupational safety, and incident command.*
- *Team-based tabletop exercise and role play involving operators, emergency services, regulators, and the public.*
- *ICT-enabled teaching with dashboards, digital twins, GIS, spreadsheets, and Python-based analytics.*

Assessment Structure (both CIE and SEE)

The weightage assigned to Continuous Internal Evaluation (CIE) and Semester End Examination (SEE) shall be 50% each. A student shall secure a minimum of 50% of the maximum marks prescribed for CIE and a minimum of 40% of the maximum marks prescribed for SEE to be eligible for passing.

A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to a subject/course only if he/she secures not less than 50% of the aggregate marks obtained in CIE and SEE taken together.

Continuous Internal Evaluation:

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

A minimum of two Internal Assessment Tests (IA) shall be conducted. Each test shall be conducted for a maximum of 25 marks. The average of the two test marks shall be the marks secured by a student in IA.

In addition, Continuous Comprehensive Assessment (CCA) shall be conducted for a total of 25 marks		
Students' activities for TW/SL under NCrF: Samples only *As per National credit formwork (NCrF) students must spend 90 hours of study for 3 credit courses, which include Course instructions (CI-42 hour) and Teamwork/ Self learning (TW/Sl-48 hours). Hence, students must complete minimum of two actives as part of NCrF. These learning activities shall be considered as CCA components of CIE. The evaluation activities will be done using set of rubrics developed for each activity. The following sample activities are listed below. The sample activities are given below. The course coordinator can also give their own TW/SL activities as per the course outcomes.*		
Sl. No.	**Term Work (TW) Activity**	**Number of Hours / Semester**
1	*TW1: Develop a GIS-based smart wastewater asset inventory and dashboard for a selected ward, campus, or treatment-plant catchment, including key sensors and performance indicators.*	*24*
2	*TW2: Prepare an integrated digital safety and emergency response plan for a selected wastewater facility, including hazard register, risk matrix, emergency procedures, communication flow, and response map.*	*24*
SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.		
Sl. No.	**Self-Learning (SL) Activity**	**Number of Hours / Semester**
1	*SL1: Study a smart wastewater case and prepare a brief report on sensing, automation, data use, operational benefits, and limitations.*	*24*
2	*SL2: Complete a suitable online module/tutorial on QGIS, IoT dashboards, SCADA, Python data analysis, wastewater treatment, or confined-space safety and submit evidence of learning.*	*24*
3	*SL3: Conduct a tabletop exercise for a selected emergency such as toxic-gas release, pump failure, chemical spill, cyberattack, or sewer overflow and document lessons learned.*	*24*

Sample rubrics for TW activities:

Criterion	*4 – Excellent*	*3 – Good*	*2 – Satisfactory*	*1 – Needs Improvement*
Problem understanding	*Problem is clearly defined with strong justification and clear objectives.*	*Problem is mostly clear with minor gaps in framing or justification.*	*Problem is stated but lacks clarity or detailed justification.*	*Problem is poorly defined or unclear.*
Data and method	*Data collected/used is appropriate and sufficient; methods/tools are well chosen and logically applied.*	*Data and methods are generally appropriate with minor issues or omissions.*	*Limited or partially relevant data; methods are basic or inconsistently applied.*	*Data is inadequate/irrelevant; methods are inappropriate or missing.*
Analysis	*Analysis is thorough;*	*Analysis is generally sound*	*Analysis is partial; contains*	*Analysis is weak, incorrect, or largely*

Criterion	*4 – Excellent*	*3 – Good*	*2 – Satisfactory*	*1 – Needs Improvement*
	interpretations are logically argued and results are valid.	*with minor errors or missing details.*	*gaps or superficial interpretation.*	*missing.*
Recommendations	*Recommendations are feasible, context-specific, and clearly derived from analysis.*	*Recommendations are relevant but may have minor limitations or lack detail.*	*Recommendations are generic or only loosely connected to analysis.*	*Recommendations are incomplete, unrealistic, or absent.*
Presentation	*Work is very well organized, neat, and professionally presented.*	*Work is well organized with minor issues in formatting or clarity.*	*Presentation is acceptable but uneven.*	*Work is poorly organized, difficult to follow, or untidy.*

ADVANCED BIOLOGICAL NUTRIENT REMOVAL			
Course Code	**1MCWH205A**	*Scheme*	*2026*
Type of Course	*Professional Core Course*	*Semester*	*II*
Teaching Hours/Week (L:T:P)	*42(3:0:0)*	*CIE Marks*	*50*
Total Hours of Pedagogy per Semester CI (L /T): LI(P):TW&SL	*90 (42:0:0:48)*	*SEE Marks*	*50*
Credits	*3*	*Total Marks*	*100*
Type of Examination (PCC):	*Theory- CIE +SEE*	*Exam Hours*	*03*

Course outcome (Course Skill Set):

At the end of the course, the student will be able to:

1. *CO1 Explain the need for biological nutrient removal (BNR), nitrogen and phosphorus cycles, and the microbiology and kinetics underlying advanced nutrient removal processes.*
2. *CO2 Analyse and design biological nitrogen removal systems (nitrification, denitrification, shortcut and anammox-based processes) for municipal and industrial wastewaters.*
3. *CO3 Describe and design enhanced biological phosphorus removal (EBPR) systems, including PAO/DPAO metabolism, process requirements, and classical EBPR configurations.*
4. *CO4 Integrate nitrogen and phosphorus removal in combined BNR configurations (A2/O, UCT, Bardenpho, SNDPR, NDEBPR, EBPR-SN–Anammox) and evaluate their performance, energy, and carbon requirements.*
5. *CO5 Apply design, modelling, and troubleshooting approaches to full-scale BNR plants, including parameter selection, process control, and case study evaluation for sustainable nutrient removal.*

Module-1

Fundamentals of biological nutrient removal

- *Water quality, eutrophication, and rationale for nutrient (N and P) control; regulatory drivers and discharge standards.*
- *Nitrogen and phosphorus cycles in wastewater treatment systems; forms of N (ammonia, nitrite, nitrate) and P (orthophosphate, polyphosphate).*
- *Overview of biological nutrient removal (BNR) concepts; comparison of physical-chemical versus biological nutrient removal.*
- *Microbiology of BNR: nitrifiers (e.g., Nitrosomonas, Nitrobacter), denitrifies, phosphorus-accumulating organisms (PAOs), denitrifying PAOs (DPAOs), ordinary heterotrophs.*
- *Kinetic and stoichiometric considerations for BNR (yield, oxygen demand, alkalinity consumption, COD requirements).*
- *Introduction to activated sludge process configurations for BNR (anaerobic, anoxic, aerobic zones; recycle streams).*

Linked COs: CO1 **Number of Hours: 8**

Module-2

Biological nitrogen removal

- *Nitrification: microbiology, two-step oxidation of ammonia to nitrite and nitrate, environmental requirements (DO, pH, SRT, temperature), alkalinity and oxygen demand.*
- *Denitrification: heterotrophic denitrification pathways (nitrate to nitrogen gas), electron donors and COD requirements, anoxic conditions, alkalinity recovery.*
- *Conventional nitrification–denitrification systems: pre- and post-denitrification, internal recycles, design considerations for anoxic and aerobic zones.*
- *Shortcut nitrogen removal: nitritation–denitritation and partial nitritation; benefits in oxygen and carbon savings; control of nitrite pathway.*
- *Anammox-based nitrogen removal: principles of anaerobic ammonium oxidation, integrated processes combining partial nitritation and anammox for mainstream and sidestream treatment.*

- *Process performance indicators and troubleshooting (ammonia, nitrite, nitrate profiles; DO, alkalinity; inhibition and toxicity issues).*

Linked COs: CO2 **Number of Hours: 9**

Module-3

Enhanced biological phosphorus removal (EBPR)

- *Principles of biological phosphorus removal; comparison with chemical precipitation; advantages and limitations.*
- *PAO metabolism: uptake of volatile fatty acids (VFAs), storage as polyhydroxyalkanoates (PHA), anaerobic P release and aerobic/anoxic P uptake; role of internal carbon storage.*
- *Process requirements for EBPR: sequential anaerobic and aerobic exposure, VFA availability, BOD5:TP ratio (typical 20:1), anaerobic HRT and SRT requirements, control of DO and nitrate in anaerobic zones.*
- *Classical EBPR configurations: A/O, A2/O, Phoredox, Bardenpho, and University of Cape Town (UCT) processes; layout and operating principles.*
- *Operational challenges: competition between PAOs and glycogen-accumulating organisms (GAOs), secondary phosphorus release, recycle streams, and process stability.*
- *Introduction to side-stream EBPR (S2EBPR) and biofilm-based EBPR approaches.*

Linked COs: CO3 **Number of Hours: 9**

Module-4

Integrated nitrogen and phosphorus removal processes

- *Concept of biological nutrient removal (BNR) as integration of nitrogen removal and EBPR in activated sludge systems.*
- *Combined N and P removal processes: A2/O, Bardenpho (four- and five-stage), UCT, and Virginia Initiative Plant (VIP) configurations; recycles, zone functions, and design features.*
- *Simultaneous nitrification, denitrification, and phosphorus removal (SNDPR) in sequencing batch reactors under low DO; role of DPAOs and internal carbon storage.*
- *NDEBPR (nitrification–denitrification enhanced biological phosphorus removal) and EBPR-SN systems; integration with anammox for advanced nitrogen and phosphorus removal.*
- *Integration with high-rate activated sludge, A–B processes, and side-stream EBPR (S2EBPR) for carbon capture and resilient phosphorus removal.*
- *Case studies of integrated BNR plants (municipal wastewater) highlighting process selection, performance, and operational issues.*

Linked COs: CO3, CO4 **Number of Hours: 8**

Module-5

Design, modelling, and operation of BNR systems

- *Design parameters for BNR systems: selection of SRT, HRT, MLSS/MLVSS, DO in aerobic zones, anoxic/anaerobic mixing, recycle ratios, and clarifier considerations.*
- *Process modelling and simulation: overview of Activated Sludge Models (ASM) for nutrient removal; use of commercial simulators (e.g., GPS-X, BioWin, WEST) for BNR design and optimization (conceptual coverage only).*
- *Monitoring and control strategies: online measurements (DO, ammonia, nitrate, orthophosphate), process control (aeration control, internal recycle control, external carbon dosing), and energy optimization.*
- *Start-up, stabilization, and troubleshooting of BNR plants; common failure modes (nitrification loss, P-removal deterioration, filamentous bulking) and remedial measures.*

- *Case studies on design and performance evaluation of advanced BNR and EBPR systems for Indian and international contexts; sustainability, resource recovery, and emerging trends (P recovery, carbon-neutral BNR).*

Linked COs: CO4, CO5 **Number of Hours: 8**

Suggested Learning Resources:

Textbooks

1. **Metcalf & Eddy**, *Wastewater Engineering: Treatment and Resource Recovery, latest edition, McGraw-Hill – nutrient removal and BNR design chapters.*
2. **Henze, Grady, Gujer, Marais, van Loosdrecht**, *Biological Wastewater Treatment: Principles, Modelling and Design, IWA Publishing*
3. **Grady, Daigger, Love, Filipe**, *Biological Wastewater Treatment, CRC Press/IWA – advanced BNR and EBPR concepts.*
4. **Tchobanoglous, Burton, Stensel et al.**, *Wastewater Engineering: Treatment and Reuse (earlier editions) – BNR process configurations and design.*
5. **BNR/EBPR design manuals** *from regulatory agencies (e.g., Biological Nutrient Removal Manual, Minnesota Pollution Control Agency).*

Reference Books

1. *Specialist monographs and IWA Scientific and Technical Reports on EBPR, SNDPR, NDEBPR, and anammox processes.*
2. *Recent research papers on integrated EBPR–anammox and S2EBPR systems for mainstream municipal wastewater.*
3. *National and international guidelines on nutrient removal and effluent standards (CPCB, USEPA, EU)*

Web links and Video Lectures (e-Resources)

1. *NPTEL courses on Biological Wastewater Treatment, Advanced Wastewater Treatment, and Wastewater Treatment and Recycling, covering BNR and EBPR topics.*
2. *Open-access online modules on nitrification–denitrification, biological phosphorus removal, and BNR plant operation (e.g., educational sites explaining nitrification, denitrification, and BPR).*
3. *Recorded webinars and workshops by professional bodies (IWA, WEF, CPHEEO) on advanced nutrient removal and resource recovery.*
4. *Spreadsheets and open-source tools for BNR design calculations (oxygen demand, alkalinity, COD requirements, zone sizing) and performance assessment.*

Teaching-Learning Process (Innovative Delivery Methods)

The following strategies may be adopted (indicative and not exhaustive) to enhance attainment of course outcomes:

- *Flipped classroom for key concepts such as nitrification–denitrification and EBPR, with pre-class video/viewing and in-class problem solving.*
- *Problem-based learning (PBL) using realistic BNR design/operation problems for small groups (e.g., designing an A2/O plant for a given city).*
- *Case-based teaching using documented success and failure cases of BNR/EBPR plants, including Indian and international installations.*
- *Simulation and virtual labs for activated sludge and BNR processes using demo software or spreadsheets, emphasising parameter sensitivity and control.*
- *Partial industry delivery through guest lectures/visits to sewage treatment plants practicing BNR and phosphorus removal.*
- *ICT-enabled teaching, including annotated process flow animations, online quizzes, and interactive dashboards for nutrient profiles.*

Assessment Structure (both CIE and SEE)

The weightage assigned to Continuous Internal Evaluation (CIE) and Semester End Examination (SEE) shall be 50% each. A student shall secure a minimum of 50% of the maximum marks prescribed for CIE and a minimum of 40% of the maximum marks prescribed for SEE to be eligible for passing.
A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to a subject/course only if he/she secures not less than 50% of the aggregate marks obtained in CIE and SEE taken together.

Continuous Internal Evaluation:

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]
A minimum of two Internal Assessment Tests (IA) shall be conducted. Each test shall be conducted for a maximum of 25 marks. The average of the two test marks shall be the marks secured by a student in IA.
In addition, Continuous Comprehensive Assessment (CCA) shall be conducted for a total of 25 marks

Students' activities for TW/SL under NCrF: Samples only

As per National credit formwork (NCrF) students must spend 90 hours of study for 3 credit courses, which include Course instructions (CI-42 hour) and Teamwork/ Self learning (TW/Sl-48 hours). Hence, students must complete minimum of two actives as part of NCrF. These learning activities shall be considered as CCA components of CIE. The evaluation activities will be done using set of rubrics developed for each activity. The following sample activities are listed below. The sample activities are given below. The course coordinator can also give their own TW/SL activities as per the course outcomes.

Sl. No.	Term Work (TW) Activity	Number of Hours / Semester
1	**TW1:** *Prepare a conceptual and preliminary design report for a BNR (A2/O or UCT) plant for a given town, including process selection, mass balance, and preliminary sizing.*	*24*
2	**TW2:** *Develop a spreadsheet-based model for nitrification–denitrification and EBPR performance (mass balances on N, P, COD, alkalinity) for a given influent and operating strategy*	*24*
SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.		
Sl. No.	**Self-Learning (SL) Activity**	**Number of Hours / Semester**
1	**SL1:** *Study a documented BNR/EBPR plant (Indian or international) and prepare a brief report on configuration, performance, and challenges.*	*24*
2	**SL2:** *Complete an online/NPTEL module on advanced wastewater treatment or biological nutrient removal and submit a reflective summary mapping learning to COs.*	*24*
3	**SL3:** *Review and present a recent research paper on SNDPR, NDEBPR, EBPR-SN–Anammox, or S2EBPR, highlighting process innovation and applicability in Indian context.*	*24*

Sample rubrics for TW activities:

Criterion	*4 – Excellent*	*3 – Good*	*2 – Satisfactory*	*1 – Needs Improvement*
Problem understanding	*Problem is clearly defined with strong justification and clear objectives.*	*Problem is mostly clear with minor gaps in framing or justification.*	*Problem is stated but lacks clarity or detailed justification.*	*Problem is poorly defined or unclear.*
Data and method	*Data collected/used is appropriate and sufficient; methods/tools are well chosen and logically applied.*	*Data and methods are generally appropriate with minor issues or omissions.*	*Limited or partially relevant data; methods are basic or inconsistently applied.*	*Data is inadequate/irrelevant; methods are inappropriate or missing.*
Analysis	*Analysis is thorough; interpretations are logically argued and results are valid.*	*Analysis is generally sound with minor errors or missing details.*	*Analysis is partial; contains gaps or superficial interpretation.*	*Analysis is weak, incorrect, or largely missing.*
Recommendations	*Recommendations are feasible, context-specific, and clearly derived from analysis.*	*Recommendations are relevant but may have minor limitations or lack detail.*	*Recommendations are generic or only loosely connected to analysis.*	*Recommendations are incomplete, unrealistic, or absent.*
Presentation	*Work is very well organized, neat, and professionally presented.*	*Work is well organized with minor issues in formatting or clarity.*	*Presentation is acceptable but uneven.*	*Work is poorly organized, difficult to follow, or untidy.*

OCCUPATIONAL HEALTH & INDUSTRIAL HYGIENE			
Course Code	**1MCWH205B**	*Scheme*	*2026*
Type of Course	**Professional Core Course**	*Semester*	*II*
Teaching Hours/Week (L:T:P)	*42(3:0:0)*	*CIE Marks*	*50*
Total Hours of Pedagogy per Semester CI (L /T): LI(P):TW&SL	*90 (42:0:0:48)*	*SEE Marks*	*50*
Credits	*3*	*Total Marks*	*100*
Type of Examination (PCC):	*Theory- CIE +SEE*	*Exam Hours*	*03*

Course outcome (Course Skill Set):

At the end of the course, the student will be able to:

1. *CO1: Explain the principles, scope, objectives, and importance of occupational health and industrial hygiene in workplaces.*
2. *CO2: Identify occupational hazards and describe their effects on worker health, safety, productivity, and the environment.*
3. *CO3: Apply industrial hygiene principles for recognition, evaluation, and control of chemical, physical, biological, ergonomic, and psychosocial hazards.*
4. *CO4: Plan workplace exposure assessment, environmental monitoring, health surveillance, and interpretation of occupational hygiene data.*
5. *CO5: Develop integrated occupational health and industrial hygiene programmes based on risk management, legislation, emergency preparedness, and continual improvement..*

Module-1

Fundamentals of Occupational Health and Industrial Hygiene

- *Definitions, objectives, scope, and historical development of occupational health, occupational hygiene, and occupational safety.*
- *Relationship among hazard, exposure, risk, dose, health effect, and occupational disease.*
- *Sources and pathways of workplace exposure; routes of entry into the human body.*
- *Accident causation, unsafe acts and conditions, human factors, safety culture, and hierarchy of controls.*
- *Roles and responsibilities of employers, employees, occupational health physicians, industrial hygienists, safety officers, and regulatory agencies.*
- *Basic principles of workplace health promotion, welfare facilities, housekeeping, and health-conscious work design.*

Linked COs: CO1, CO2 **Number of Hours: 8 hrs**

Module-2

Occupational Hazards and Health Effects

- *Chemical hazards: dusts, fumes, mists, vapours, gases, solvents, metals, pesticides, carcinogens, and sensitizers.*
- *Physical hazards: noise, vibration, heat stress, cold stress, illumination, radiation, pressure, and electricity.*
- *Biological hazards: bacteria, viruses, fungi, parasites, bioaerosols, wastewater, biomedical waste, and occupational infections.*
- *Ergonomic hazards: manual handling, repetitive work, awkward postures, workstation design, lifting, and musculoskeletal disorders.*
- *Psychosocial hazards: work stress, fatigue, shift work, violence, harassment, workload, and work–life imbalance.*
- *Occupational diseases and disorders: respiratory, dermatological, auditory, neurological, musculoskeletal, reproductive, and systemic effects***.**

Linked COs: CO1, CO2 **Number of Hours: 9 hrs**

Module-3

Recognition, Evaluation, and Control of Workplace Hazards

- *Industrial hygiene process: anticipation, recognition, evaluation, control, and confirmation.*
- *Hazard identification and risk assessment: job safety analysis, task-based assessment, exposure profiling, and risk matrix.*
- *Engineering controls: elimination, substitution, enclosure, isolation, local exhaust ventilation, dilution ventilation, and process modification.*
- *Administrative controls: safe operating procedures, training, job rotation, preventive maintenance, permits, signage, and restricted access.*
- *Personal protective equipment: selection, limitations, fit, use, maintenance, storage, and respiratory protection programmes.*
- *Control of noise, heat, dust, vapours, gases, vibration, biological agents, and ergonomic risks.*
- *Principles of ventilation, local exhaust systems, noise control, containment, and pollution prevention.*

Linked COs: CO2, CO3 **Number of Hours: 9 hrs**

Module-4

Exposure Assessment, Monitoring, and Occupational Health Surveillance

- *Exposure assessment strategy: objectives, sampling plan, representative sampling, personal and area monitoring, and exposure groups.*
- *Sampling methods and instruments for airborne contaminants, gases, vapours, dust, noise, vibration, heat, illumination, and radiation.*
- *Calibration, quality assurance, sample preservation, laboratory analysis, detection limits, and uncertainty.*
- *Interpretation of monitoring results; occupational exposure limits, time-weighted average, short-term exposure limit, ceiling limit, and biological exposure indices.*
- *Occupational medical examinations: pre-placement, periodic, return-to-work, and fitness assessment.*
- *Health surveillance for chemical, noise, respiratory, biological, ergonomic, and radiation exposures.*
- *Record keeping, confidentiality, reporting, trend analysis, and communication of monitoring results.*

Linked COs: CO3, CO4 **Number of Hours: 8 hrs**

Module-5

Occupational Health Management, Legislation, and Emergency Preparedness

- *Occupational health and safety management systems; policy, planning, implementation, performance evaluation, audit, and continual improvement.*
- *Overview of Indian occupational health and safety legislation, rules, codes, and institutional responsibilities.*
- *International framework: ILO principles, ISO 45001 concepts, and integration with environmental and quality management systems.*
- *Emergency preparedness: fire, explosion, chemical release, confined-space incidents, biological emergencies, and mass-casualty events.*
- *First aid, occupational injury management, incident investigation, root-cause analysis, corrective and preventive action.*
- *Contractor safety, construction and process-industry health programmes, and community interface.*
- *Case studies on industrial hygiene surveys, occupational disease prevention, and workplace health improvement.*

Linked COs: CO4, CO5 **Number of Hours: 8 hrs**

Suggested Learning Resources:

Textbooks:

1. *Barbara A. Plog, Patricia J. Quinlan, and John M. L. editors, Fundamentals of Industrial Hygiene, National Safety Council.*
2. *Michael S. Bisesi and Robert L. K. K. editors, Industrial Hygiene Evaluation Methods, CRC Press.*
3. *William D. Y. editors, Occupational Health and Safety Management Systems, relevant standard-based editions.*
4. *Frank P. Lees, Loss Prevention in the Process Industries, Butterworth-Heinemann.*
5. *David L. Goetsch, Occupational Safety and Health for Technologists, Engineers, and Managers, Pearson.*
6. *R. K. Jain and Sunil S. Rao, Industrial Safety, Health and Environment Management Systems, Khanna Publishers.*

Reference Books

1. *C. Ray Asfahl and David W. Rieske, Industrial Safety and Health Management, Pearson.*
2. *William H. Heinrich, H. W. Petersen, and N. Roos, Industrial Accident Prevention: A Scientific Approach, McGraw-Hill.*
3. *Richard W. Hearl and Daniel H. H. editors, Patty's Industrial Hygiene and Toxicology, Wiley.*
4. *ILO, Encyclopaedia of Occupational Health and Safety.*
5. *Relevant BIS standards, occupational exposure-limit guidance, safety codes, and regulatory publications.*
6. *WHO and ILO technical guidance on occupational health, workplace health promotion, and occupational disease prevention...*

Web links and Video Lectures (e-Resources)

1. *ILO resources on occupational safety and health: https://www.ilo.org/global/topics/safety-and-health-at-work*
2. *WHO resources on occupational health: https://www.who.int/health-topics/occupational-health*
3. *NIOSH workplace safety and health resources: https://www.cdc.gov/niosh/*
4. *OSHA safety and health topics: https://www.osha.gov/topics*
5. *NPTEL lectures on industrial safety, occupational health, environmental health, and safety management.*
6. *BIS and Government of India portals for applicable standards, rules, and occupational safety guidance.*

Teaching-Learning Process (Innovative Delivery Methods)

The following strategies may be adopted to enhance the effectiveness of the teaching-learning process and facilitate achievement of course outcomes:

- *Flipped classroom using short lectures on hazard recognition and exposure limits.*
- *Problem-Based Learning involving workplace risk assessment and control selection.*
- *Case-based teaching using industrial accidents and occupational disease investigations.*
- *Demonstration of noise meters, sound-level meters, lux meters, anemometers, WBGT instruments, and air-sampling equipment.*
- *Industrial visits and interaction with occupational health professionals and safety practitioners.*
- *Simulation of chemical-spill response, fire emergency, confined-space entry, and incident reporting.*
- *ICT-enabled teaching using exposure databases, risk-assessment spreadsheets, digital checklists, and GIS-based workplace mapping.*
- *Role play involving employer, worker, safety officer, occupational physician, and regulator perspectives.*

Assessment Structure (both CIE and SEE)

The weightage assigned to Continuous Internal Evaluation (CIE) and Semester End Examination (SEE) shall be 50% each. A student shall secure a minimum of 50% of the maximum marks prescribed for CIE and a minimum of 40% of the maximum marks prescribed for SEE to be eligible for passing.

A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to a subject/course only if he/she secures not less than 50% of the aggregate marks obtained in CIE and SEE taken

together.

Continuous Internal Evaluation:

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

A minimum of two Internal Assessment Tests (IA) shall be conducted. Each test shall be conducted for a maximum of 25 marks. The average of the two test marks shall be the marks secured by a student in IA.

In addition, Continuous Comprehensive Assessment (CCA) shall be conducted for a total of 25 marks

Students' activities for TW/SL under NCrF: Samples only

As per National credit formwork (NCrF) students must spend 90 hours of study for 3 credit courses, which include Course instructions (CI-42 hour) and Teamwork/ Self learning (TW/Sl-48 hours). Hence, students must complete minimum of two actives as part of NCrF. These learning activities shall be considered as CCA components of CIE. The evaluation activities will be done using set of rubrics developed for each activity. The following sample activities are listed below. The sample activities are given below. The course coordinator can also give their own TW/SL activities as per the course outcomes.

Sl. No.	Term Work (TW) Activity	Number of Hours / Semester
1	*TW1: Conduct a preliminary occupational health and industrial hygiene survey of a selected workplace and prepare a hazard register with risk ratings and recommended controls.*	*24*
2	*TW2: Prepare an exposure-monitoring and health-surveillance plan for a selected industry, including sampling strategy, instruments, exposure limits, control measures, and reporting format.*	*24*
SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.		
Sl. No.	**Self-Learning (SL) Activity**	**Number of Hours / Semester**
1	*SL1: Study a documented industrial accident or occupational disease case and prepare a root-cause analysis with corrective and preventive actions.*	*24*
2	*SL2: Complete an online course, spoken tutorial, or guided learning module on occupational safety, industrial hygiene, ergonomics, or occupational health management and submit a learning report.*	*24*
3	*SL3: Compare occupational exposure-limit approaches and workplace health-and-safety management practices used in India and internationally.*	*24*

Sample rubrics for TW activities:

Criterion	*4 – Excellent*	*3 – Good*	*2 – Satisfactory*	*1 – Needs Improvement*
Problem understanding	*Problem is clearly defined with strong justification and clear objectives.*	*Problem is mostly clear with minor gaps in framing or justification.*	*Problem is stated but lacks clarity or detailed justification.*	*Problem is poorly defined or unclear.*
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Presentation	*Work is very well organized, neat, and professionally presented.*	*Work is well organized with minor issues in formatting or clarity.*	*Presentation is acceptable but uneven.*	*Work is poorly organized, difficult to follow, or untidy.*

HAZARDOUS WASTE MANAGEMENT AND CIRCULAR ECONOMY			
Course Code	**1MCWH205C**	*Scheme*	*2026*
Type of Course	**Professional Core Course**	*Semester*	*II*
Teaching Hours/Week (L:T:P)	*42(3:0:0)*	*CIE Marks*	*50*
Total Hours of Pedagogy per Semester CI (L /T): LI(P):TW&SL	*90 (42:0:0:48)*	*SEE Marks*	*50*
Credits	*3*	*Total Marks*	*100*
Type of Examination (PCC):	*Theory- CIE +SEE*	*Exam Hours*	*03*

Course outcome (Course Skill Set):

At the end of the course, the student will be able to:

1. *CO1: Explain the sources, characteristics, classification, and environmental impacts of hazardous wastes.*
2. *CO2: Evaluate hazardous waste treatment, storage, transportation, recycling, and disposal technologies.*
3. *CO3: Apply environmental risk assessment, waste minimization, and pollution prevention strategies for hazardous waste management.*
4. *CO4: Analyze circular economy principles, resource recovery technologies, and sustainable industrial practices for hazardous waste utilization.*
5. *CO5: Develop integrated hazardous waste management plans complying with national regulations, international conventions, and SDG objectives..*

Module-1

Fundamentals of Hazardous Waste Management and Sustainability

- *Introduction to hazardous waste management: definitions, scope, and importance*
- *Classification and characteristics of hazardous wastes: ignitability, corrosivity, reactivity, toxicity*
- *Sources of hazardous wastes: industrial, biomedical, electronic (e-waste), agricultural, mining, chemical, and municipal sectors*
- *Hazardous waste identification and characterization methods*
- *Toxicity assessment, persistence, bioaccumulation potential, and environmental impacts*
- *Waste hierarchy: prevention, minimization, reuse, recycling, recovery, and disposal*
- *Introduction to Circular Economy concepts: 3R/6R/10R principles, closed-loop systems*
- *Sustainable Development Goals (SDGs) related to waste management: SDG 6, 8, 9, 11, 12, 13, 14, 15*
- *Life cycle thinking and extended producer responsibility in waste management*

Linked COs: CO1 **Number of Hours: 08**

Module-2

Hazardous Waste Treatment, Storage and Disposal Technologies

- *Physical treatment methods: screening, sedimentation, filtration, centrifugation, flotation, evaporation*
- *Chemical treatment methods: neutralization, precipitation, oxidation-reduction, ion exchange, chemical fixation*
- *Biological treatment technologies: aerobic and anaerobic digestion, bioremediation, phytoremediation, composting*
- *Thermal treatment: incineration (rotary kiln, fluidized bed), pyrolysis, gasification, plasma arc technology*
- *Stabilization and solidification: cement-based, lime-based, bituminization, vitrification*
- *Secure landfill design and operation: liner systems, leachate collection, gas management, monitoring wells*
- *Hazardous waste storage and transportation: packaging, labeling, manifest systems, DOT regulations*
- *Treatment, Storage and Disposal Facilities (TSDFs): siting, design criteria, operational protocols, environmental safeguards*
- *Leachate management and environmental monitoring: collection, treatment, groundwater monitoring*

- *Case Study: Design and operation of a TSDF for hazardous industrial waste*

Linked COs: CO2 **Number of Hours: 08**

Module-3

Environmental Risk Assessment and Pollution Prevention

Number of Hours: 08

- *Environmental risk assessment framework: hazard identification, exposure assessment, dose-response evaluation, risk characterization*
- *Human health risk assessment: carcinogenic and non-carcinogenic effects, reference doses, cancer slope factors*
- *Ecological risk assessment: ecosystem receptors, toxicity testing, bioaccumulation models*
- *Fate and transport modeling: air dispersion, groundwater contamination, surface water pollution*
- *Waste minimization strategies: source reduction, process modification, material substitution, good housekeeping*
- *Pollution prevention (P2) hierarchy: prevention, recycling, treatment, disposal*
- *Cleaner production concepts: eco-efficiency, waste audits, material flow analysis*
- *Environmental management systems: ISO 14001, EMS implementation for hazardous waste generators*
- *Green chemistry principles: designing safer chemicals, atom economy, less hazardous synthesis*
- *Case Study: Environmental risk assessment of a hazardous waste disposal site*

Linked COs: CO3 **Number of Hours: 8 hrs**

Module-4

Circular Economy and Resource Recovery from Hazardous Wastes

- *Circular Economy principles: regenerative design, industrial ecology, industrial symbiosis, cradle-to-cradle*
- *10R Framework: Refuse, Rethink, Reduce, Reuse, Repair, Refurbish, Remanufacture, Repurpose, Recycle, Recover*
- *Resource recovery technologies:*
  - *Metal recovery from e-waste: hydrometallurgical, pyrometallurgical, bioleaching*
  - *Solvent recovery and distillation*
  - *Oil re-refining and regeneration*
  - *Acid recovery and neutralization by-product utilization*
  - *Catalyst recovery and regeneration*
- *Energy recovery from hazardous wastes: waste-to-energy, co-processing in cement kilns, RDF production*
- *By-product synergy and industrial symbiosis: case studies from steel, chemical, and manufacturing industries*
- *Sustainable industrial practices: zero liquid discharge (ZLD), zero waste to landfill, circular supply chains*
- **Circular economy metrics and indicators***: circularity rate, material footprint, recycling rates*
- **Business models for circular economy***: product-service systems, sharing platforms, take-back schemes*
- *Case Study: Circular economy implementation in a hazardous waste generating industry (e.g., battery recycling, e-waste management)*

Linked COs: CO4 **Number of Hours: 9 hrs**

Module-5

Regulations, Conventions, and Integrated Management Planning

- *National regulations (India):*
  - *Hazardous and Other Wastes (Management and Transboundary Movement) Rules, 2016 (amended)*

- *Environment Protection Act, 1986*
- *Hazardous Wastes (Management, Handling and Transboundary Movement) Rules framework*
- *CPCB guidelines and standards*
- *State Pollution Control Board regulations*

- *International conventions:*
  - *Basel Convention on transboundary movement of hazardous wastes*
  - *Stockholm Convention on Persistent Organic Pollutants (POPs)*
  - *Rotterdam Convention on Prior Informed Consent*
  - *Minamata Convention on Mercury*
  - *Bamako Convention (African context)*
- *Transboundary movement of hazardous wastes: prior informed consent, manifest systems, illegal trafficking prevention*
- *Extended Producer Responsibility (EPR): e-waste, batteries, plastics, packaging waste*
- *SDG alignment: contributions to SDG 12 (Responsible Consumption and Production), SDG 3 (Good Health), SDG 6 (Clean Water), SDG 13 (Climate Action)*
- *Integrated hazardous waste management planning:*
  - *Waste inventory and characterization*
  - *Technology selection and feasibility analysis*
  - *Cost-benefit analysis and economic instruments*
  - *Stakeholder engagement and public participation*
  - *Emergency preparedness and response plans*
- *Future trends: digital waste tracking, blockchain for waste management, AI in waste characterization, PFAS management challenges*
- *Case Study: Development of an integrated hazardous waste management plan for an industrial cluster*

Linked COs: CO5 **Number of Hours: 9 hrs**

Suggested Learning Resources:

Textbooks:

1. *Hazardous Waste Management by LaGrega, McGraw-Hill Education*
2. *Hazardous Waste Management by V.K. Deshpande, Tata McGraw-Hill*
3. *Circular Economy: A Primer by Walter R. Stahel, Routledge*
4. *Waste Management and Circular Economy by various authors, Springer*

Reference Books

1. *Handbook of Hazardous Waste Management by R.A. Corbitt, McGraw-Hill*
2. *Industrial Waste Management by D.H.F. Liu, CRC Press*
3. *Circular Economy in Practice by European Environment Agency*
4. *Environmental Risk Assessment by Mark S. Johnson, CRC Press*
5. *Hazardous and Radioactive Waste Treatment Technologies Handbook by Oh-Chan Kwon, CRC Press..*

Web links and Video Lectures (e-Resources)

1. *World Health Organization: Environmental Health and Occupational Health resources.*
2. *International Labour Organization: Occupational Safety and Health resources.*
3. *National Institute for Occupational Safety and Health: workplace exposure and hazard-control resources.*
4. *Central Pollution Control Board: environmental monitoring and pollution-control guidance.*
5. *Ministry of Environment, Forest and Climate Change: environmental regulations and notifications.*
6. *NPTEL and SWAYAM courses on environmental health, toxicology, industrial hygiene, and occupational*

safety.

7. *Open-access Safety Data Sheets and chemical hazard databases for exposure-assessment exercises.*

Teaching-Learning Process (Innovative Delivery Methods)

The following strategies may be adopted to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes:

- *Lectures: Core concepts, regulatory frameworks, and technology fundamentals*
- *Case-based learning: Real-world TSDF operations, industrial symbiosis examples, risk assessment scenarios*
- *Problem-solving exercises: Waste characterization calculations, landfill design problems, risk quantification*
- *Guest lectures: Industry practitioners from TSDF operators, CPCB officials, EPR coordinators*
- *Site visits: TSDF facilities, recycling plants, industrial clusters practicing circular economy*
- *Digital tools: Waste tracking software demonstrations, LCA tools, risk assessment modeling*

Assessment Structure (both CIE and SEE)

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Sl. No.	Term Work (TW) Activity	Number of Hours / Semester
1	*TW1: A pharmaceutical industry generates 500 kg/day of solvent waste. Design a solvent recovery system with economic and environmental benefits*	*24*
2	*TW2: Circular Economy Audit and Resource Recovery Plan*	*24*
3	*TW3: Circular Economy Audit and Resource Recovery Plan*	*24*
4	*TW4: Environmental Risk Assessment Case Study*	*24*

SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.

Sl. No.	Self-Learning (SL) Activity	Number of Hours / Semester
1	**SL1:** *Video-Based Learning: Hazardous Waste Management Technologies*	*24*

2	**SL2:** *MOOC Certification: Circular Economy Fundamentals*	*24*
3	**SL3***: Case Study Research: International Best Practices.*	*24*
4	**SL4:** *Technical Article Review: Emerging Technologies*	*24*

Sample rubrics for TW activities:

Criterion	*4 – Excellent*	*3 – Good*	*2 – Satisfactory*	*1 – Needs Improvement*
Problem understanding	*Problem is clearly defined with strong justification and clear objectives.*	*Problem is mostly clear with minor gaps in framing or justification.*	*Problem is stated but lacks clarity or detailed justification.*	*Problem is poorly defined or unclear.*
Data and method	*Data collected/used is appropriate and sufficient; methods/tools are well chosen and logically applied.*	*Data and methods are generally appropriate with minor issues or omissions.*	*Limited or partially relevant data; methods are basic or inconsistently applied.*	*Data is inadequate/irrelevant; methods are inappropriate or missing.*
Analysis	*Analysis is thorough; interpretations are logically argued and results are valid.*	*Analysis is generally sound with minor errors or missing details.*	*Analysis is partial; contains gaps or superficial interpretation.*	*Analysis is weak, incorrect, or largely missing.*
Recommendations	*Recommendations are feasible, context-specific, and clearly derived from analysis.*	*Recommendations are relevant but may have minor limitations or lack detail.*	*Recommendations are generic or only loosely connected to analysis.*	*Recommendations are incomplete, unrealistic, or absent.*
Presentation	*Work is very well organized, neat, and professionally presented.*	*Work is well organized with minor issues in formatting or clarity.*	*Presentation is acceptable but uneven.*	*Work is poorly organized, difficult to follow, or untidy.*

DIGITAL SAFETY ANALYTICS AND MACHINE LEARNING			
Course Code	**1MCWH205D**	*Scheme*	*2026*
Type of Course	**Professional Core Course**	*Semester*	*II*
Teaching Hours/Week (L:T:P)	*42(3:0:0)*	*CIE Marks*	*50*
Total Hours of Pedagogy per Semester CI (L /T): LI(P):TW&SL	*90 (42:0:0:48)*	*SEE Marks*	*50*
Credits	*3*	*Total Marks*	*100*
Type of Examination (PCC):	*Theory- CIE +SEE*	*Exam Hours*	*03*

Course outcome (Course Skill Set):

At the end of the course, the student will be able to:

1. *CO1: Explain the concepts of digital safety, safety analytics, Artificial Intelligence (AI), and Machine Learning (ML) in occupational and industrial safety.*
2. *CO2: Analyze safety data using statistical and machine learning techniques for hazard identification and risk prediction.*
3. *CO3: Apply IoT, sensor technologies, computer vision, and digital monitoring systems for workplace safety.*
4. *CO4: Develop predictive safety models using machine learning algorithms for accident prevention and decision-making.*
5. *CO5: Evaluate digital transformation strategies that support sustainable industries and SDG-based occupational safety management.*

Module-1

Introduction to Digital Safety Analytics and Sustainable Industrial Safety

- *Digital transformation in occupational safety.*
- *Concepts, objectives, scope, and applications of safety analytics.*
- *Evolution of Industry 4.0 and Safety 4.0.*
- *Fundamentals of Artificial Intelligence and Machine Learning.*
- *Types of machine learning: supervised, unsupervised, and reinforcement learning.*
- *Big Data in occupational safety.*
- *Sustainable Development Goals and digital safety.*
- *Ethical, privacy, governance, and legal aspects of AI in workplace safety***.**

Linked COs: CO1 **Number of Hours: 8 hrs**

Module-2

Data Collection, Hazard Identification and Predictive Safety Analytics

- *Safety data sources and data quality considerations.*
- *Incident and accident databases.*
- *Near-miss reporting systems.*
- *IoT sensors for workplace monitoring.*
- *Wearable technologies and environmental monitoring systems.*
- *Data preprocessing and feature engineering.*
- *Exploratory Data Analysis (EDA).*
- *Statistical safety indicators and leading and lagging indicators.*
- *Predictive analytics for hazard identification.*
- **Laboratory/Case Study:** *Analysis of accident datasets using spreadsheet software or Python.*

Linked COs: *CO2* **Number of Hours:** *8 hrs*

Module-3

Machine Learning Applications in Safety Engineering

- *Classification algorithms and regression models.*
- *Decision Trees, Random Forest, and Support Vector Machines (SVM).*

- *Neural Networks and basic concepts of Deep Learning.*
- *Computer Vision for Personal Protective Equipment (PPE) detection.*
- *Image recognition for unsafe acts and unsafe conditions.*
- *Predictive maintenance.*
- *Process safety monitoring.*
- *Case Study: AI-based accident prediction in construction and manufacturing industries.*

Linked COs: CO2, CO4 **Number of Hours: 8 hrs**

Module-4

Intelligent Safety Systems and Digital Technologies

- *Internet of Things (IoT) architecture.*
- *Smart sensors and wireless monitoring.*
- *SCADA systems.*
- *Cloud computing and edge computing.*
- *Digital Twin technology.*
- *Geographic Information Systems (GIS) for safety planning.*
- *Drones for industrial inspection.*
- *Robotics in hazardous environments.*
- *Cybersecurity in industrial safety systems.*
- *Real-time decision-support systems.*
- *Practical Component: Development of an IoT-enabled workplace safety monitoring framework.*

Linked COs: CO3, CO4 **Number of Hours: 9 hrs**

Module-5

Sustainable Digital Safety Management and Future Trends

- *AI-driven Safety Management Systems.*
- *Risk-based decision-making using machine learning.*
- *Digital dashboards and visualization.*
- *ESG reporting.*
- *Explainable AI (XAI) and responsible AI.*
- *Human-centred AI for workplace safety.*
- *Green digital technologies.*
- *Climate resilience through digital safety systems.*
- *National and international case studies.*
- *Emerging trends in AI, ML, Industry 5.0, and autonomous safety systems.*
- **Mini Project:** *Develop a predictive safety analytics model or digital dashboard for monitoring workplace safety performance in an industrial facility.*

Linked COs: *CO5* **Number of Hours:** *9 hrs*

Suggested Learning Resources:

Textbooks:

1. *Mohammed J. Zaki and Wagner Meira Jr., Data Mining and Machine Learning: Fundamental Concepts and Algorithms, Cambridge University Press.*
2. *Andreas François Vermeulen, Practical Machine Learning for Data Analysis Using Python, Apress.*
3. *David L. Goetsch, Occupational Safety and Health for Technologists, Engineers and Managers, Pearson.*
4. *Ian Goodfellow, Yoshua Bengio, and Aaron Courville, Deep Learning, MIT Press.*

Reference Books

1. *Aurélien Géron, Hands-On Machine Learning with Scikit-Learn, Keras and TensorFlow, O'Reilly.*
2. *Trevor Hastie, Robert Tibshirani, and Jerome Friedman, The Elements of Statistical Learning, Springer.*

3. *National Institute for Occupational Safety and Health (NIOSH), guidelines and resources on occupational safety and health analytics.*
4. *Relevant national and international standards, regulations, and guidance documents on occupational safety, industrial AI, IoT, data privacy, and cybersecurity...*

Web links and Video Lectures (e-Resources)

1. *NPTEL courses on machine learning, artificial intelligence, data analytics, occupational safety, and industrial safety management.*
2. *NIOSH resources on occupational safety and health data, surveillance, and analytics.*
3. *Occupational Safety and Health Administration (OSHA) resources on workplace safety and digital monitoring applications.*
4. *Python, Scikit-learn, TensorFlow, and Keras documentation for safety-data analysis and machine-learning implementation.*
5. *Open datasets and case materials related to industrial accidents, near misses, PPE detection, environmental monitoring, and predictive maintenance..*

Teaching-Learning Process (Innovative Delivery Methods)

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes. Suggested innovative delivery methods may include, but are not limited to:

- *Flipped classroom.*
- *Problem-Based Learning (PBL).*
- *Case-based teaching using construction, manufacturing, and process-industry safety incidents.*
- *Demonstration of Python, spreadsheet, dashboard, GIS, IoT, and computer-vision workflows.*
- *Simulation and virtual laboratory activities.*
- *Data-driven laboratory exercises using open safety datasets.*
- *Industry expert interaction and industrial visits.*
- *ICT-enabled teaching using dashboards, videos, digital twins, and cloud platforms.*
- *Group discussion on AI ethics, privacy, cybersecurity, and responsible automation.*
- *Mini project and peer review.*

Assessment Structure (both CIE and SEE)

The weightage assigned to Continuous Internal Evaluation (CIE) and Semester End Examination (SEE) shall be 50% each. A student shall secure a minimum of 50% of the maximum marks prescribed for CIE and a minimum of 40% of the maximum marks prescribed for SEE to be eligible for passing.

A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to a subject/course only if he/she secures not less than 50% of the aggregate marks obtained in CIE and SEE taken together.

Continuous Internal Evaluation:

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

A minimum of two Internal Assessment Tests (IA) shall be conducted. Each test shall be conducted for a maximum of 25 marks. The average of the two test marks shall be the marks secured by a student in IA.

In addition, Continuous Comprehensive Assessment (CCA) shall be conducted for a total of 25 marks

Students' activities for TW/SL under NCrF: Samples only

As per National credit formwork (NCrF) students must spend 90 hours of study for 3 credit courses, which include Course instructions (CI-42 hour) and Teamwork/ Self learning (TW/Sl-48 hours). Hence, students must complete minimum of two actives as part of NCrF. These learning activities shall be considered as CCA components of CIE. The evaluation activities will be done using set of rubrics developed for each activity. The following sample activities are listed below. The sample activities are given below. The course coordinator can also give their own TW/SL activities as per the course outcomes.

Sl. No.	Term Work (TW) Activity	Number of Hours / Semester
1	**TW1:** *Analyze an industrial accident or near-miss dataset*	*24*

	using spreadsheet software or Python and identify significant safety indicators and hazards.	
2	**TW2:** *Develop a predictive safety analytics model or digital dashboard for monitoring workplace safety performance in a selected industrial facility.*	*24*
SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.		
Sl. No.	**Self-Learning (SL) Activity**	**Number of Hours / Semester**
1	*SL1: Study the application of wearable sensors, IoT, or computer vision for occupational safety and prepare a technical note.*	*24*
2	*SL2: Review a national or international case study on AI-enabled safety management and evaluate its benefits, risks, and ethical implications.*	*24*
3	*SL3: Complete a suitable MOOC, spoken tutorial, or online module on Python, machine learning, data visualization, GIS, IoT, or industrial safety analytics and submit evidence of learning.*	*24*

Sample rubrics for TW activities:

Criterion	*4 – Excellent*	*3 – Good*	*2 – Satisfactory*	*1 – Needs Improvement*
Problem understanding	*Problem is clearly defined with strong justification and clear objectives.*	*Problem is mostly clear with minor gaps in framing or justification.*	*Problem is stated but lacks clarity or detailed justification.*	*Problem is poorly defined or unclear.*
Data and method	*Data collected/used is appropriate and sufficient; methods/tools are well chosen and logically applied.*	*Data and methods are generally appropriate with minor issues or omissions.*	*Limited or partially relevant data; methods are basic or inconsistently applied.*	*Data is inadequate/irrelevant; methods are inappropriate or missing.*
Analysis	*Analysis is thorough; interpretations are logically argued and results are valid.*	*Analysis is generally sound with minor errors or missing details.*	*Analysis is partial; contains gaps or superficial interpretation.*	*Analysis is weak, incorrect, or largely missing.*
Recommendations	*Recommendations are feasible, context-specific, and clearly derived from analysis.*	*Recommendations are relevant but may have minor limitations or lack detail.*	*Recommendations are generic or only loosely connected to analysis.*	*Recommendations are incomplete, unrealistic, or absent.*
Presentation	*Work is very well organized, neat, and professionally presented.*	*Work is well organized with minor issues in formatting or clarity.*	*Presentation is acceptable but uneven.*	*Work is poorly organized, difficult to follow, or untidy.*

WASTE-TO-ENERGY & RESOURCE RECOVERY SYSTEMS			
Course Code	**1MCWH206A**	*Scheme*	*2026*
Type of Course	**Professional Core Course**	*Semester*	*II*
Teaching Hours/Week (L:T:P)	*42(3:0:0)*	*CIE Marks*	*50*
Total Hours of Pedagogy per Semester CI (L /T): LI(P):TW&SL	*90 (42:0:0:48)*	*SEE Marks*	*50*
Credits	*3*	*Total Marks*	*100*
Type of Examination (PCC):	*Theory- CIE +SEE*	*Exam Hours*	*03*

Course outcome (Course Skill Set):

At the end of the course, the student will be able to:

1. *CO1: Explain waste generation, characterization, and the principles of waste-to-energy (WtE) and resource recovery in solid and liquid waste management systems.*
2. *CO2: Differentiate and analyze major thermo-chemical and bio-chemical conversion technologies (incineration, gasification, pyrolysis, anaerobic digestion, fermentation, landfill gas, etc.) for energy recovery from diverse waste streams.*
3. *CO3: Design and evaluate basic process flow schemes for WtE and resource recovery facilities including feedstock preparation, energy conversion units, and product/utilities handling.*
4. *CO4: Assess environmental, health, regulatory, and techno-economic aspects of WtE and resource recovery projects using concepts of life cycle assessment (LCA), GHG accounting, and cost–benefit analysis.*
5. *CO5: Integrate WtE and resource recovery systems into sustainable municipal and industrial waste management plans with reference to Indian policies, SDGs, and circular-economy approaches*

Module-1

Introduction to Waste-to-Energy and Resource Recovery

- *Waste generation in municipal, industrial, agricultural and wastewater sectors; types, composition and properties of waste as fuel and resource.*
- *Waste hierarchy and 3R/4R principles (reduce, reuse, recycle, recover); concept of waste as a resource and alternate energy source.*
- *Classification and characterization of solid waste, sludge and other residues for energy and resource recovery: proximate/ultimate analysis, calorific value, moisture, contaminants.*
- *Overview of WtE and resource recovery pathways: energy (heat, power, fuels) and materials (metals, plastics, construction materials, nutrients).*
- *Role of WtE in integrated solid waste management, climate mitigation and circular economy; Indian and global WtE scenarios (brief).*

Linked COs: CO1 **Number of Hours: 8 hrs**

Module-2

Thermo-Chemical Waste-to-Energy Technologies

- *Principles of combustion, incineration and heat recovery; mass-burn, modular and fluidized-bed systems; flue-gas cleaning and ash handling.*
- *Pyrolysis of waste and biomass: process fundamentals, reactor types (fixed bed, rotary kiln, fluidized bed), product distribution (char, oil, gas) and applications.*
- *Gasification of wastes and biomass: gasifier configurations (updraft, downdraft, fluidized bed), syngas characteristics, gas cleaning and utilization in boilers and engines.*
- *Energy recovery from plastic wastes and refuse-derived fuel (RDF) / alternate fuel resources (AFR) in cement plants, thermal power plants and industrial boilers.*
- *Design considerations at conceptual level: feed preparation, energy conversion unit selection, emission control, safety and operational issues.*

Linked COs: *CO2, CO3* **Number of Hours:** *9 hrs*

Module-3

Bio-Chemical Conversion and Resource Recovery from Organic Wastes

- *Fundamentals of anaerobic digestion: process steps, digester types (CSTR, UASB, plug-flow), factors affecting biogas yield and stability.*
- *Biogas production from municipal solid waste (organic fraction), sewage sludge, agro-residues and industrial organic waste; biogas utilisation options (heat, power, upgraded biomethane).*
- *Landfill gas generation, collection and utilisation; engineered landfills and controlled dumpsites; environmental issues and mitigation strategies.*
- *Fermentation and transesterification routes for liquid biofuels from wastes and residues (bioethanol, biodiesel, other advanced biofuels); introduction to microbial fuel cells and emerging bio-electrochemical systems.*
- *Resource recovery from wastewater and sludge: nutrient recovery (struvite, N/P), biosolids management, co-digestion concepts and biorefinery approaches*

Linked COs: CO2, CO3 **Number of Hours: 8 hrs**

Module-4

Resource Recovery Systems for Solid Waste and Special Waste Streams (Linked COs: CO1, CO3, CO5; Number of Hours: 8 hrs)

- *Mechanical pre-treatment and material recovery facilities (MRFs): segregation, size-reduction, densification, screening and sorting for recyclables and RDF production.*
- *Resource recovery from municipal solid waste: composting, biomethanation, production of refuse-derived fuel, construction and demolition (C&D) waste utilisation, and co-processing options.*
- *E-waste and hazardous waste in WtE context: material and energy recovery, environmental and health concerns, regulatory requirements and safe handling.*
- *Recovery of metals, plastics, glass and other materials from mixed waste streams; quality requirements, markets and product standards.*
- *Integration of resource recovery systems with WtE plants and municipal solid waste management plans (flow-schemes, logistics and institutional aspects).*

Linked COs: CO1,CO3, CO5 **Number of Hours: 8 hrs**

Module-5

Environmental, Techno-Economic and Policy Aspects; Case Studies

- *Environmental and health impacts of WtE technologies: air pollutants, leachate, ash and residue management; emission standards and control strategies.*
- *Life cycle assessment (LCA), GHG accounting and carbon footprint of WtE and resource recovery systems; comparison with landfilling and conventional energy options.*
- *Techno-economic analysis (TEA): capital and operating costs, revenue streams (energy, tipping fee, recovered materials), financial indicators (NPV, IRR, payback, levelized cost of energy).*
- *Indian regulatory and policy framework: key provisions of Solid Waste Management Rules, Plastic Waste Management Rules, E-Waste Rules, Bio-medical Waste Rules, and relevant energy/waste policies (overview).*
- *Case studies of WtE and resource recovery projects (Indian and international) highlighting technology choice, performance, environmental compliance, social acceptance and lessons learnt.*

Linked COs:CO4, CO5 **Number of Hours:** *8 hrs*

Suggested Learning Resources:

Textbooks:

1. *Tchobanoglous, G., Theisen, H., and Vigil, S.,* **Integrated Solid Waste Management: Engineering Principles and Management Issues**, *McGraw-Hill,* **1st edition**, **1993**.
2. *Ranade, V.V. and Bhandari, V.M.,* **Industrial Wastewater Treatment, Recycling and Reuse**, *Butterworth-Heinemann (Elsevier),* **1st edition**, **2014**.
3. *Sarkar, D.,* **Thermal Power Plant: Design and Operation**, *Elsevier,* **1st edition**, **2015**.
4. *Relevant national/international reports on WtE and resource recovery (e.g., CPCB/MoEF&CC guidelines,*

IPCC and IEA documents) – typically issued as periodic reports/guidelines rather than numbered book editions; cite by title, year, and issuing agency.

Reference Books

1. *Tchobanoglous, G. and Kreith, F.,* **Handbook of Solid Waste Management***, McGraw-Hill,* **2nd edition***,* **2002** *(original handbook edited by Kreith appeared in* **1994***; the widely cited 2nd ed. is 2002).*
2. *Gupta, S.K. and Sharma, S.,* **Bioenergy: Research, Development and Application***, TERI Press – specific edition/year is not clearly indexed in public bibliographies; TERI Press titles on bioenergy/biofuels are generally issued as* **1st edition** *monographs.*
3. *Selected journal papers on WtE design, LCA/TEA, and resource recovery case studies (Scopus/Web of Science indexed) – cite individually by article, journal, volume, issue, pages, and year.*

Web links and Video Lectures (e-Resources)

1. *NPTEL course on Waste-to-Energy Conversion and allied NPTEL modules on solid waste management and bioenergy.*
2. *MOOC/online courses on circular economy, resource recovery and sustainable solid waste management (Coursera, edX, SWAYAM etc.).*
3. *Government of India portals (MoEF&CC, CPCB, CEA, MNRE) for guidelines, rules and reports on WtE, resource recovery and solid waste management.*
4. *Spreadsheet and simulation tools for energy balance, LCA and techno-economic analysis of WtE projects (e.g., open-source LCA tools, TEA templates)*

Teaching-Learning Process (Innovative Delivery Methods)

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes. Suggested innovative delivery methods may include, but are not limited to:

- *Flipped classroom sessions using NPTEL/online videos followed by problem-solving on WtE and resource recovery case studies.*
- *Problem-Based Learning (PBL) on designing WtE/resource recovery systems for a given city, campus or industry including feedstock assessment and technology selection.*
- *Case-based teaching using Indian and international WtE/resource recovery projects (successes and failures) and structured group discussions.*
- *Simulation and virtual labs for gasifiers, digesters and incinerators using simple models/spreadsheets or available software.*
- *Partial delivery by industry/utility experts and field/industrial visits to MSW processing plants, composting/biogas facilities, recycling centres or WtE plants.*
- *ICT-enabled teaching (interactive dashboards, GIS-based mapping of waste streams, online quizzes and assignments).*

Assessment Structure (both CIE and SEE)

The weightage assigned to Continuous Internal Evaluation (CIE) and Semester End Examination (SEE) shall be 50% each. A student shall secure a minimum of 50% of the maximum marks prescribed for CIE and a minimum of 40% of the maximum marks prescribed for SEE to be eligible for passing.

A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to a subject/course only if he/she secures not less than 50% of the aggregate marks obtained in CIE and SEE taken together.

Continuous Internal Evaluation:

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

A minimum of two Internal Assessment Tests (IA) shall be conducted. Each test shall be conducted for a maximum of 25 marks. The average of the two test marks shall be the marks secured by a student in IA.

In addition, Continuous Comprehensive Assessment (CCA) shall be conducted for a total of 25 marks

Students' activities for TW/SL under NCrF: Samples only *As per National credit formwork (NCrF) students must spend 90 hours of study for 3 credit courses, which include Course instructions (CI-42 hour) and Teamwork/ Self learning (TW/Sl-48 hours). Hence, students must complete minimum of two actives as part of NCrF. These learning activities shall be considered as CCA components of CIE. The evaluation activities will be done using set of rubrics developed for each activity. The following sample activities are listed below. The sample activities are given below. The course coordinator can also give their own TW/SL activities as per the course outcomes.*		
Sl. No.	**Term Work (TW) Activity**	**Number of Hours / Semester**
1	*TW1 – Prepare a WtE and resource recovery feasibility report for a selected city/ULB/industry (waste quantification, technology options, environmental and TEA overview).*	*24*
2	*TW2 – Develop a detailed spreadsheet-based energy and techno-economic appraisal for a proposed WtE/resource recovery system (e.g., biogas plant, RDF-based boiler or integrated MSW processing facility).*	*24*
SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.		
Sl. No.	**Self-Learning (SL) Activity**	**Number of Hours / Semester**
1	*SL1 – Complete an NPTEL/SWAYAM/MOOC module related to WtE, solid waste management or circular economy and submit a reflective summary connecting to course COs.*	*24*
2	*SL2 – Study Indian WtE policies, rules and case studies, and prepare a brief policy/implementation review highlighting gaps and opportunities for resource-recovery-oriented planning.*	*24*
3	*SL3 – Undertake a mini-project on GIS/data-driven mapping of waste streams and potential WtE/resource recovery sites in a chosen urban area.*	*24*

Sample rubrics for TW activities:

Criterion	*4 – Excellent*	*3 – Good*	*2 – Satisfactory*	*1 – Needs Improvement*
Problem understanding	*Problem is clearly defined with strong justification and clear objectives.*	*Problem is mostly clear with minor gaps in framing or justification.*	*Problem is stated but lacks clarity or detailed justification.*	*Problem is poorly defined or unclear.*
Data and method	*Data collected/used is appropriate and sufficient; methods/tools are well chosen and logically applied.*	*Data and methods are generally appropriate with minor issues or omissions.*	*Limited or partially relevant data; methods are basic or inconsistently applied.*	*Data is inadequate/irrelevant; methods are inappropriate or missing.*
Analysis	*Analysis is thorough; interpretations are logically argued and results are valid.*	*Analysis is generally sound with minor errors or missing details.*	*Analysis is partial; contains gaps or superficial interpretation.*	*Analysis is weak, incorrect, or largely missing.*
Recommendations	*Recommendations are feasible, context-*	*Recommendations are relevant but*	*Recommendations are generic or*	*Recommendations are incomplete,*

Criterion	*4 – Excellent*	*3 – Good*	*2 – Satisfactory*	*1 – Needs Improvement*
	specific, and clearly derived from analysis.	*may have minor limitations or lack detail.*	*only loosely connected to analysis.*	*unrealistic, or absent.*
Presentation	*Work is very well organized, neat, and professionally presented.*	*Work is well organized with minor issues in formatting or clarity.*	*Presentation is acceptable but uneven.*	*Work is poorly organized, difficult to follow, or untidy.*

PROCESS SAFETY MANAGEMENT & HAZOP			
Course Code	**1MCWH206B**	*Scheme*	*2026*
Type of Course	**Professional Core Course**	*Semester*	*II*
Teaching Hours/Week (L:T:P)	*42(3:0:0)*	*CIE Marks*	*50*
Total Hours of Pedagogy per Semester CI (L /T): LI(P):TW&SL	*90 (42:0:0:48)*	*SEE Marks*	*50*
Credits	*3*	*Total Marks*	*100*
Type of Examination (PCC):	*Theory- CIE +SEE*	*Exam Hours*	*03*

Course outcome (Course Skill Set):

At the end of the course, the student will be able to:

1. *CO1: Explain the principles, terminology, regulatory context, and elements of Process Safety Management in process and infrastructure-related industries.*
2. *CO2: Identify process hazards, hazardous properties, initiating events, and potential consequences using systematic hazard-identification techniques.*
3. *CO3: Apply HAZOP methodology to process systems using process flow diagrams, piping and instrumentation diagrams, guide words, and deviation analysis.*
4. *CO4: Analyze risk using qualitative and semi-quantitative methods, including risk matrices, LOPA, bow-tie analysis, and evaluation of safeguards.*
5. *CO5: Develop practical recommendations for prevention, mitigation, emergency preparedness, management of change, and continuous improvement of process safety performance.*

Module-1

Introduction to Process Safety Management

- *Concept, scope, objectives, and importance of process safety.*
- *Process safety versus personal/occupational safety; major accident hazards and loss-of-containment events.*
- *Process safety terminology: hazard, risk, consequence, likelihood, incident, near miss, barrier, safeguard, escalation, and ALARP.*
- *Process safety management framework and its elements: process safety information, process hazard analysis, operating procedures, training, mechanical integrity, management of change, pre-start-up safety review, emergency planning, incident investigation, contractor management, and auditing.*
- *Safety culture, leadership, human factors, competency, permit-to-work systems, and safety performance indicators.*
- *Process safety in chemical, petroleum, pharmaceutical, energy, water-treatment, waste-management, and infrastructure facilities.*

Linked COs: CO1 **Number of Hours: 8 hrs**

Module-2

Hazard Identification and Risk Assessment

- *Sources and classification of process hazards: flammable, explosive, toxic, reactive, corrosive, biological, thermal, pressure, electrical, and environmental hazards.*
- *Hazardous properties and behavior of materials: flash point, auto-ignition temperature, flammability limits, toxicity, reactivity, vapor density, and compatibility.*
- *Hazard identification techniques: checklists, What-if analysis, What-if/Checklist, preliminary hazard analysis, job safety analysis, failure modes and effects analysis, fault-tree analysis, event-tree analysis, and scenario analysis.*
- *Risk concepts, risk estimation, risk matrices, tolerability criteria, and risk-reduction principles.*
- *Consequence analysis: fire, explosion, toxic release, overpressure, radiation, domino effects, and environmental release.*
- *Introduction to quantitative risk assessment and safety-critical equipment.*

Linked COs: *CO2, CO4* **Number of Hours:** *9 hrs*

Module-3

HAZOP (Hazard and Operability Study) Methodology

- Origin, objectives, scope, advantages, limitations, and applications of HAZOP.
- HAZOP team composition, roles and responsibilities, preparation, planning, and documentation.
- Process safety information required for HAZOP: process description, design basis, material balance, heat and mass balance, process flow diagrams, P&IDs, equipment data sheets, operating procedures, and control narratives.
- HAZOP terminology: nodes, design intent, parameters, guide words, deviations, causes, consequences, existing safeguards, recommendations, and action tracking.
- Guide words and parameters: No/Not, More, Less, As well as, Part of, Reverse, Other than, Early, Late, Before, and After.
- HAZOP procedure: node selection, design-intent definition, deviation generation, cause and consequence analysis, safeguard review, recommendation development, and close-out.
- HAZOP worksheet preparation and reporting; quality of recommendations and common pitfalls.

Linked COs: CO3 **Number of Hours: 9 hrs**

Module-4

Risk Reduction, Safeguards, and Safety Instrumented Systems

- *Hierarchy of controls and inherently safer design: minimize, substitute, moderate, and simplify.*
- *Prevention and mitigation safeguards: alarms, interlocks, trips, relief devices, containment, fire protection, detection systems, isolation, ventilation, and emergency shutdown systems.*
- *Layers of Protection Analysis (LOPA): initiating events, enabling conditions, independent protection layers, consequence severity, target risk, and order-of-magnitude assessment.*
- *Bow-tie analysis and barrier management.*
- *Safety Instrumented Systems: sensors, logic solvers, final elements, safety instrumented functions, demand modes, and safety integrity levels.*
- *Functional safety concepts; independence, reliability, proof testing, bypass management, and common-cause failure.*
- *Mechanical integrity: inspection, testing, preventive maintenance, corrosion management, pressure equipment, pipelines, tanks, and safety-critical devices.*
- *Human factors, alarm management, control-room design, and fatigue-related risk.*

Linked COs: CO4, CO5 **Number of Hours: 8 hrs**

Module-5

Operational Safety, Emergency Management, and Case Studies

- *Management of change: technical, organizational, temporary, and emergency changes.*
- *Pre-start-up safety review, operating procedures, safe work practices, permit to work, lockout/tagout, confined-space entry, line breaking, and hot work.*
- *Incident and near-miss reporting, investigation methods, root-cause analysis, barrier failure analysis, and corrective-action management.*
- *Emergency preparedness and response: detection, alarm, communication, evacuation, isolation, firefighting, spill control, toxic-release response, and business continuity.*
- *Contractor and supplier process safety management; competency assurance and training.*
- *Process safety auditing, leading and lagging indicators, learning from incidents, and continual improvement.*
- *Case studies: refinery and petrochemical incidents, chemical plant releases, dust explosions, confined-space events, boiler/pressure-vessel failures, dam or water-treatment facility hazards, and construction/maintenance interfaces.*
- *Integrated case exercise: HAZOP of a storage, pumping, treatment, or process unit and preparation of an action-tracking report.*

Linked COs: CO1, CO2, CO3, CO5 **Number of Hours:** *8 hrs*

Suggested Learning Resources:

Textbooks:

1. *Trevor A. Kletz, HAZOP and HAZAN: Identifying and Assessing Process Industry Hazards, Institution of Chemical Engineers.*
2. *Frank P. Lees, Lees' Loss Prevention in the Process Industries, Elsevier.*
3. *Daniel A. Crowl and Joseph F. Louvar, Chemical Process Safety: Fundamentals with Applications, Pearson.*
4. *R. W. King, Safety in the Process Industries, Elsevier.*
5. *Sam Mannan, Lees' Process Safety Essentials: Hazard Identification, Assessment and Control, Elsevier.*
6. *CCPS, Guidelines for Hazard Evaluation Procedures, Wiley/AIChE.*

Reference Books

1. *CCPS, Guidelines for Risk Based Process Safety, Wiley/AIChE.*
2. *CCPS, Layer of Protection Analysis: Simplified Process Risk Assessment, Wiley/AIChE.*
3. *IEC 61882, Hazard and Operability Studies (HAZOP Studies) – Application Guide.*
4. *IEC 61511, Functional Safety – Safety Instrumented Systems for the Process Industry Sector.*
5. *IEC 61508, Functional Safety of Electrical/Electronic/Programmable Electronic Safety-Related Systems.*
6. *ISO 31000, Risk Management – Guidelines.*
7. *Relevant provisions of the Factories Act, Manufacture, Storage and Import of Hazardous Chemical Rules, and applicable Central/State pollution-control and emergency-planning requirements.*
8. *OSHA Process Safety Management guidelines and recognized good-practice documents from HSE and AIChE/CCPS.*

Web links and Video Lectures (e-Resources)

1. *NPTEL and SWAYAM courses on industrial safety, process safety, risk assessment, and chemical engineering safety.*
2. *AIChE Center for Chemical Process Safety resources on HAZOP, risk-based process safety, LOPA, and incident learning.*
3. *International Electrotechnical Commission resources on IEC 61882, IEC 61511, and functional safety.*
4. *Directorate General Factory Advice Service and Labour Institutes resources on industrial safety and hazardous processes.*
5. *Central Pollution Control Board and State Pollution Control Board resources on hazardous substances, emergency planning, and environmental risk.*
6. *HAZOP worksheet templates, process simulators, risk-matrix tools, and spreadsheet-based LOPA exercises.*

Teaching-Learning Process (Innovative Delivery Methods)

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes. Suggested innovative delivery methods may include, but are not limited to:

- *Flipped classroom using short videos and pre-reading on process safety terminology and HAZOP guide words.*
- *Problem-based learning using loss-of-containment, fire, explosion, toxic-release, and pressure-equipment scenarios.*
- *Case-based teaching based on major industrial accidents and barrier failures.*
- *Team-based HAZOP workshop using a simplified PFD/P&ID of a storage, pumping, water-treatment, or process unit.*
- *Simulation and virtual laboratories for process deviations, alarms, interlocks, relief systems, and emergency shutdowns.*
- *Role play involving HAZOP chairperson, process engineer, instrumentation engineer, operations representative, maintenance engineer, and safety professional.*
- *Industrial visit or expert lecture from a process plant, refinery, chemical facility, utility, or safety consultancy.*
- *ICT-enabled teaching using digital P&IDs, incident databases, risk matrices, bow-tie diagrams, and*

collaborative worksheets.

- *Peer review of HAZOP recommendations and action close-out reports.*

Assessment Structure (both CIE and SEE)

The weightage assigned to Continuous Internal Evaluation (CIE) and Semester End Examination (SEE) shall be 50% each. A student shall secure a minimum of 50% of the maximum marks prescribed for CIE and a minimum of 40% of the maximum marks prescribed for SEE to be eligible for passing.

A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to a subject/course only if he/she secures not less than 50% of the aggregate marks obtained in CIE and SEE taken together.

Continuous Internal Evaluation:

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

A minimum of two Internal Assessment Tests (IA) shall be conducted. Each test shall be conducted for a maximum of 25 marks. The average of the two test marks shall be the marks secured by a student in IA.

In addition, Continuous Comprehensive Assessment (CCA) shall be conducted for a total of 25 marks

Students' activities for TW/SL under NCrF: Samples only

As per National credit formwork (NCrF) students must spend 90 hours of study for 3 credit courses, which include Course instructions (CI-42 hour) and Teamwork/ Self learning (TW/Sl-48 hours). Hence, students must complete minimum of two actives as part of NCrF. These learning activities shall be considered as CCA components of CIE. The evaluation activities will be done using set of rubrics developed for each activity. The following sample activities are listed below. The sample activities are given below. The course coordinator can also give their own TW/SL activities as per the course outcomes.

Sl. No.	Term Work (TW) Activity	Number of Hours / Semester
1	*TW1: Conduct a team-based HAZOP study for a selected process node using a PFD/P&ID; submit the worksheet, risk ranking, recommendations, and action-tracking register.*	*24*
2	*TW2: Prepare a bow-tie or LOPA-based risk assessment for a selected major-accident scenario and propose independent protection layers and emergency safeguards.*	*24*

SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.

Sl. No.	Self-Learning (SL) Activity	Number of Hours / Semester
1	*SL1: Study a major industrial accident and prepare a barrier-failure, root-cause, and lessons-learned report.*	*24*
2	*SL2: Review IEC 61882 or an equivalent recognized HAZOP guide and prepare a concise guide-word and deviation-analysis reference sheet.*	*24*
3	*SL3: Compare qualitative risk matrix, LOPA, fault-tree, event-tree, and bow-tie methods for a selected process-safety scenario.*	*24*

Sample rubrics for TW activities:

Criterion	*4 – Excellent*	*3 – Good*	*2 – Satisfactory*	*1 – Needs Improvement*
Problem understanding	*Problem is clearly defined with strong justification and clear objectives.*	*Problem is mostly clear with minor gaps in framing or justification.*	*Problem is stated but lacks clarity or detailed justification.*	*Problem is poorly defined or unclear.*
Data and	*Data collected/used*	*Data and*	*Limited or*	*Data is*

Criterion	*4 – Excellent*	*3 – Good*	*2 – Satisfactory*	*1 – Needs Improvement*
method	*is appropriate and sufficient; methods/tools are well chosen and logically applied.*	*methods are generally appropriate with minor issues or omissions.*	*partially relevant data; methods are basic or inconsistently applied.*	*inadequate/irrelevant; methods are inappropriate or missing.*
Analysis	*Analysis is thorough; interpretations are logically argued and results are valid.*	*Analysis is generally sound with minor errors or missing details.*	*Analysis is partial; contains gaps or superficial interpretation.*	*Analysis is weak, incorrect, or largely missing.*
Recommendations	*Recommendations are feasible, context-specific, and clearly derived from analysis.*	*Recommendations are relevant but may have minor limitations or lack detail.*	*Recommendations are generic or only loosely connected to analysis.*	*Recommendations are incomplete, unrealistic, or absent.*
Presentation	*Work is very well organized, neat, and professionally presented.*	*Work is well organized with minor issues in formatting or clarity.*	*Presentation is acceptable but uneven.*	*Work is poorly organized, difficult to follow, or untidy.*

ADVANCED MEMBRANE & HYBRID TREATMENT SYSTEMS			
Course Code	**1MCWH206C**	*Scheme*	*2026*
Type of Course	**Professional Core Course**	*Semester*	*II*
Teaching Hours/Week (L:T:P)	*42(3:0:0)*	*CIE Marks*	*50*
Total Hours of Pedagogy per Semester CI (L /T): LI(P):TW&SL	*90 (42:0:0:48)*	*SEE Marks*	*50*
Credits	*3*	*Total Marks*	*100*
Type of Examination (PCC):	*Theory- CIE +SEE*	*Exam Hours*	*03*

Course outcome (Course Skill Set):

At the end of the course, the student will be able to:

1. *CO1: Explain the principles, transport mechanisms, materials, and configurations of advanced membrane processes used in water and wastewater treatment.*
2. *CO2: Analyze membrane fouling, concentration polarization, pretreatment requirements, cleaning methods, and operational performance.*
3. *CO3: Design and evaluate membrane-based treatment units using appropriate criteria, operating parameters, and performance indicators.*
4. *CO4: Explain the integration of membrane processes with biological, adsorption, oxidation, disinfection, and resource-recovery systems.*
5. *CO5: Assess the technical, environmental, energy, and economic sustainability of hybrid treatment systems through case studies and process-selection exercises.*

Module-1

Fundamentals of Membrane Processes

- *Need for advanced membrane treatment in water and wastewater management.*
- *Membrane terminology: feed, permeate, retentate, flux, rejection, recovery, selectivity, permeability, and driving force.*
- *Classification of membranes: porous and non-porous; symmetric and asymmetric; polymeric, ceramic, composite, and emerging materials.*
- *Transport mechanisms: pressure-driven, concentration-driven, electrically driven, and thermally driven processes.*
- *Membrane configurations: flat sheet, tubular, hollow fibre, spiral wound, plate-and-frame, submerged, and side-stream modules.*
- *Overview of microfiltration, ultrafiltration, nanofiltration, reverse osmosis, forward osmosis, electrodialysis, membrane distillation, and pervaporation.*

Linked COs: CO1 **Number of Hours: 8 hrs**

Module-2

Membrane Performance, Fouling and Pretreatment

- *Flux and mass-transfer relationships; solution-diffusion and pore-flow concepts.*
- *Concentration polarization, osmotic pressure, cake formation, and boundary-layer effects.*
- *Membrane fouling: particulate, organic, inorganic, biological, and combined fouling.*
- *Fouling indices, resistance-in-series concept, flux decline, rejection variation, and membrane integrity.*
- *Pretreatment methods: screening, coagulation–flocculation, clarification, media filtration, cartridge filtration, dissolved air flotation, softening, and antiscalant application.*
- *Membrane cleaning: physical, hydraulic, chemical, enzymatic, and biological methods; cleaning-in-place procedures.*
- *Monitoring and control: pressure, flow, conductivity, turbidity, silt density index, oxidation–reduction potential, and online data logging.*

Linked COs: *CO1, CO2* **Number of Hours:** *9 hrs*

Module-3

Design and Operation of Membrane Treatment Systems

- Design basis and process selection for municipal, industrial, and drinking-water applications.

- Staging, pass arrangements, recovery, concentrate management, energy requirement, and system hydraulics.
- Preliminary design of MF/UF systems: flux selection, membrane area, backwash, relaxation, air scouring, and chemical-enhanced backwash.
- Preliminary design of NF/RO systems: feedwater characterization, osmotic pressure, permeate quality, salt passage, recovery, array configuration, and energy recovery.
- Operation and maintenance: start-up, shutdown, membrane preservation, replacement, integrity testing, and troubleshooting.
- Brine and concentrate management: discharge, evaporation, crystallization, beneficial use, and zero-liquid-discharge concepts.
- Performance evaluation through mass balance, water quality, specific energy consumption, lifecycle cost, and reliability indicators.

Linked COs: CO2,CO3 **Number of Hours: 9 hrs**

Module-4

Hybrid and Integrated Treatment Systems

- *Concept, need, advantages, limitations, and selection criteria for hybrid treatment systems.*
- *Membrane bioreactors: conventional MBR, submerged and side-stream configurations, biological nutrient removal, fouling control, and energy considerations.*
- *Membrane–adsorption systems: powdered and granular activated carbon, ion exchange, zeolite, biochar, and selective adsorbents.*
- *Membrane–advanced oxidation processes: ozonation, UV/H_2O_2, Fenton and photo-Fenton processes, photocatalysis, and oxidation of trace contaminants.*
- *Membrane–coagulation, membrane–electrocoagulation, membrane–disinfection, and membrane–constructed wetland combinations.*
- *Forward osmosis–reverse osmosis, membrane distillation–RO, anaerobic membrane bioreactors, and resource-recovery systems.*
- *Treatment of emerging contaminants, pharmaceuticals, endocrine-disrupting compounds, PFAS, pathogens, and industrial toxicants.*

Linked COs: CO3, CO4 **Number of Hours: 8 hrs**

Module-5

Sustainability, Resource Recovery and Case Studies

- *Water–energy–chemical nexus in membrane systems.*
- *Energy minimization, renewable-energy integration, energy recovery, and carbon footprint assessment.*
- *Life-cycle assessment, lifecycle costing, environmental impact, resilience, and circular-economy principles.*
- *Recovery of water, nutrients, salts, metals, biogas, and valuable chemicals from membrane concentrate and wastewater streams.*
- *Digital monitoring, sensors, automation, artificial intelligence, predictive fouling control, and digital twins.*
- *Case studies: drinking-water treatment, municipal wastewater reuse, industrial effluent treatment, desalination, landfill leachate, textile wastewater, pharmaceutical wastewater, and semiconductor wastewater.*
- *Process-selection matrix and preparation of a conceptual design report for a selected application.*

Linked COs: CO4, CO5 **Number of Hours:** *8 hrs*

Suggested Learning Resources:

Textbooks:

1. *A. C. S. R. Murthy,* **Membrane Technology and Applications in Water and Wastewater Treatment** *.Indian academic monograph.*
2. *Richard W. Baker,* **Membrane Technology and Applications**, *Wiley,* **3rd edition, 2012**

3. *Mark Wilf*, **The Guidebook to Membrane Desalination Technology: Reverse Osmosis, Nanofiltration and Hybrid Systems – Process, Design, Applications and Economics**, *Balaban Desalination Publications*, **1st edition**, **2006/2007**.
4. *J. G. Crespo and K. W. Beers (Böddeker)*, **Membrane Processes in Separation and Purification**, *Springer (Kluwer Academic Publishers; NATO ASI Series)*, **1st edition**, **1994**.
5. *S. Judd*, **The MBR Book: Principles and Applications of Membrane Bioreactors for Water and Wastewater Treatment**, *Elsevier (Butterworth-Heinemann)*, **2nd edition**, **2011** *(1st ed. 2006).*
6. *C. Visvanathan, R. Ben Aim, and K. L. Tay – no single widely catalogued textbook under exactly this trio; their MBR/advanced wastewater work appears mainly as review articles and chapters (e.g., Visvanathan & Ben Aim, Critical Reviews in Environmental Science and Technology, 2000).*

Reference Books

1. *M. Mulder*, **Basic Principles of Membrane Technology**, *Kluwer Academic Publishers (Springer)*, **2nd edition**, **1996** *(1st ed. 1991; reprinted 1997, 2000, 2003).*
2. *K. Scott*, **Handbook of Industrial Membrane Technology**, *Noyes Publications / Elsevier*, **1st edition**, **1995** *(often cited as "Handbook of Industrial Membranes", 1995).*
7. *A. J. Charcosset (Catherine Charcosset)*, **Membrane Processes in Biotechnology and Pharmaceutics**, *Elsevier*, **1st edition**, **2012**.
8. *N. Li, A. G. Fane, W. S. W. Ho, and T. Matsuura*, **Advanced Membrane Technology and Applications**, *Wiley (Wiley-AIChE)*, **1st edition**, **2008**.
9. *Metcalf & Eddy / AECOM*, **Wastewater Engineering: Treatment and Resource Recovery**, *McGraw-Hill*, **5th edition**, **2014** *(commonly used for membrane and reuse chapters in Indian curricula).*
10. *Relevant BIS, CPCB, CPHEEO, WHO, USEPA, and ASTM standards and guidance documents – cite by document code/title and year (e.g., IS/ISO standards, CPCB MBR guidelines, CPHEEO Manual on Sewerage and Sewage Treatment, WHO Guidelines for the Safe Use of Wastewater, USEPA Water Reuse Guidelines, ASTM membrane test methods).*

Web links and Video Lectures (e-Resources)

1. *NPTEL courses on membrane technology, environmental biotechnology, water and wastewater treatment, and desalination.*
2. *Central Public Health and Environmental Engineering Organisation (CPHEEO) manuals on water supply, wastewater treatment, and reuse.*
3. *Central Pollution Control Board (CPCB) resources on effluent standards, wastewater management, and industrial pollution control.*
4. *International Desalination Association and International Water Association technical resources.*
5. *WHO and USEPA guidance on water reuse, drinking-water treatment, contaminants, and risk management.*
6. *Manufacturer technical manuals and design guides for MF, UF, NF, RO, MBR, and membrane-distillation systems.*

Teaching-Learning Process (Innovative Delivery Methods)

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes. Suggested innovative delivery methods may include, but are not limited to:

- *Flipped classroom using membrane-process videos, technical notes, and pre-class quizzes.*
- *Problem-Based Learning (PBL) for selection and preliminary design of a treatment train.*
- *Case-based teaching using desalination, water reuse, MBR, and industrial-effluent applications.*
- *Demonstration of bench-scale membrane filtration, jar testing, fouling observation, and water-quality analysis.*
- *Spreadsheet or Python-based modelling of flux, rejection, recovery, mass balance, energy, and lifecycle cost.*
- *Simulation and virtual laboratory activities using process-flow diagrams and membrane-system*

operating data.

- *Partial delivery by industry experts and technical visits to water-treatment, wastewater-treatment, or desalination plants.*
- *ICT-enabled teaching using online sensors, dashboards, digital twins, and collaborative design platforms.*
- *Seminar and technical-paper review on emerging membranes, hybrid systems, and resource recovery.*

Assessment Structure (both CIE and SEE)

The weightage assigned to Continuous Internal Evaluation (CIE) and Semester End Examination (SEE) shall be 50% each. A student shall secure a minimum of 50% of the maximum marks prescribed for CIE and a minimum of 40% of the maximum marks prescribed for SEE to be eligible for passing.

A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to a subject/course only if he/she secures not less than 50% of the aggregate marks obtained in CIE and SEE taken together.

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Sl. No.	Term Work (TW) Activity	Number of Hours / Semester
1	*TW1: Conduct a bench-scale or virtual comparison of MF/UF/NF/RO performance using selected feedwater data; determine flux, rejection, recovery, and fouling indicators.*	*24*
2	*TW2: Prepare a conceptual design and process-selection report for a hybrid treatment system for municipal reuse or industrial wastewater, including process flow diagram, mass balance, operating parameters, risk assessment, and preliminary cost/energy discussion.*	*24*

SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.

Sl. No.	Self-Learning (SL) Activity	Number of Hours / Semester
1	*SL1: Review a recent technical paper on membrane fouling, anti-fouling materials, or membrane-cleaning strategies and prepare a structured critical summary.*	*24*
2	*SL2: Study a desalination or water-reuse plant and document its pretreatment, membrane configuration, recovery, concentrate-management approach, energy use, and environmental safeguards.*	*24*
3	*SL3: Complete an NPTEL/MOOC or equivalent online module on membrane technology, advanced oxidation, MBRs, or water reuse and submit evidence of learning.*	*24*

Sample rubrics for TW activities:

Criterion	*4 – Excellent*	*3 – Good*	*2 – Satisfactory*	*1 – Needs Improvement*
Problem understanding	*Problem is clearly defined with strong justification and clear objectives.*	*Problem is mostly clear with minor gaps in framing or justification.*	*Problem is stated but lacks clarity or detailed justification.*	*Problem is poorly defined or unclear.*
Data and method	*Data collected/used is appropriate and sufficient; methods/tools are well chosen and logically applied.*	*Data and methods are generally appropriate with minor issues or omissions.*	*Limited or partially relevant data; methods are basic or inconsistently applied.*	*Data is inadequate/irrelevant; methods are inappropriate or missing.*
Analysis	*Analysis is thorough; interpretations are logically argued and results are valid.*	*Analysis is generally sound with minor errors or missing details.*	*Analysis is partial; contains gaps or superficial interpretation.*	*Analysis is weak, incorrect, or largely missing.*
Recommendations	*Recommendations are feasible, context-specific, and clearly derived from analysis.*	*Recommendations are relevant but may have minor limitations or lack detail.*	*Recommendations are generic or only loosely connected to analysis.*	*Recommendations are incomplete, unrealistic, or absent.*
Presentation	*Work is very well organized, neat, and professionally presented.*	*Work is well organized with minor issues in formatting or clarity.*	*Presentation is acceptable but uneven.*	*Work is poorly organized, difficult to follow, or untidy.*

DISASTER & EMERGENCY PREPAREDNESS FOR WATER UTILITIES			
Course Code	**1MCWH206D**	*Scheme*	*2026*
Type of Course	**Professional Core Course**	*Semester*	*II*
Teaching Hours/Week (L:T:P)	*42(3:0:0)*	*CIE Marks*	*50*
Total Hours of Pedagogy per Semester CI (L /T): LI(P):TW&SL	*90 (42:0:0:48)*	*SEE Marks*	*50*
Credits	*3*	*Total Marks*	*100*
Type of Examination (PCC):	*Theory- CIE +SEE*	*Exam Hours*	*03*

Course outcome (Course Skill Set):

At the end of the course, the student will be able to:

1. *CO1: Explain the concepts, principles, and institutional framework of disaster and emergency preparedness for water utilities.*
2. *CO2: Identify and assess natural, technological, operational, and human-induced hazards affecting water supply and wastewater systems.*
3. *CO3: Develop risk-reduction, preparedness, response, and recovery strategies for resilient water utility operations.*
4. *CO4: Prepare emergency response plans, business continuity plans, communication protocols, and standard operating procedures for water utilities.*
5. *CO5: Apply digital technologies, infrastructure resilience measures, and performance indicators to improve disaster readiness and service continuity.*

Module-1

Fundamentals of Disaster and Emergency Preparedness for Water Utilities

- *Meaning, nature, and classification of disasters and emergencies.*
- *Disaster management cycle: prevention, mitigation, preparedness, response, recovery, and reconstruction.*
- *Importance of water, sanitation, and hygiene services during emergencies.*
- *Characteristics and critical functions of water utilities.*
- *Water supply and wastewater utility components: source, intake, treatment, storage, pumping, transmission, distribution, collection, treatment, and disposal systems.*
- *Vulnerability of water utilities to disasters and climate-related hazards.*
- *Principles of resilience, redundancy, robustness, adaptability, and rapid recovery.*
- *Stakeholders and institutional responsibilities in emergency management.*
- *Disaster management framework in India: Disaster Management Act, National Disaster Management Authority, State Disaster Management Authorities, and local authorities.*
- *Role of water utilities, public health agencies, emergency services, and community organizations.*

Linked COs: CO1 **Number of Hours: 8 hrs**

Module-2

Hazard Identification, Vulnerability and Risk Assessment

- *Hazard, exposure, vulnerability, capacity, risk, and resilience concepts.*
- *Hazard classification relevant to water utilities:*
  - *Floods, flash floods, cyclones, droughts, earthquakes, landslides, and extreme rainfall.*
  - *Power failures, equipment breakdown, pipeline failure, dam or reservoir incidents, and treatment-plant malfunction.*
  - *Chemical spills, biological contamination, cyberattacks, fire, explosions, and security threats.*
- *Source-water contamination and waterborne disease outbreaks.*
- *Failure modes of water supply and wastewater infrastructure.*
- *Utility risk assessment methodology.*
- *Asset inventory and criticality assessment.*
- *Hazard–vulnerability–risk matrices and semi-quantitative risk ranking.*

- *Failure Mode and Effects Analysis, fault-tree analysis, and scenario-based assessment.*
- *Interdependency among water, electricity, transport, telecommunications, fuel, and healthcare systems.*
- *GIS and remote sensing applications for hazard mapping and utility vulnerability assessment.*
- *Climate change, changing rainfall patterns, water scarcity, urban flooding, and sea-level-rise impacts.*
- *Preparation of risk registers and critical asset maps.*

Linked COs: CO2, CO5 **Number of Hours: 9 hrs**

Module-3

Mitigation, Preparedness and Resilient Water Infrastructure

- Structural and non-structural mitigation measures for water utilities.
- Design and retrofitting considerations for disaster-resistant infrastructure.
- Seismic safety of water tanks, treatment units, pumping stations, and pipelines.
- Flood protection of treatment plants, electrical systems, control rooms, and chemical storage areas.
- Drought preparedness, demand management, leakage reduction, water conservation, and alternative water sources.
- Protection of critical pipelines, valves, reservoirs, wells, intake structures, and pumping facilities.
- Backup power supply, standby pumps, emergency storage, mobile treatment units, and spare equipment.
- Redundancy, looped networks, sectionalization, bypass arrangements, and modular treatment systems.
- Water quality protection and emergency disinfection.
- Chemical safety, laboratory preparedness, hazardous-material handling, and occupational safety.
- Preventive maintenance, inspection, testing, and emergency stockpiling.
- Preparedness indicators, early-warning systems, monitoring networks, and trigger levels.
- Training, drills, tabletop exercises, mock exercises, and capacity building.
- Community preparedness and household-level emergency water planning**.**

Linked COs: CO2,CO3 **Number of Hours: 9 hrs**

Module-4

Emergency Response, Continuity Planning and Communication

- *Emergency response organization and incident command system for water utilities.*
- *Emergency Operations Centre, control-room functions, and emergency coordination.*
- *Preparation of Emergency Response Plans for:*
  - *Source contamination.*
  - *Treatment-plant failure.*
  - *Major pipeline rupture.*
  - *Flooding and cyclone events.*
  - *Prolonged power failure.*
  - *Drought and water shortage.*
  - *Cybersecurity and physical security incidents.*
  - *Wastewater overflow and public health emergencies.*
- *Emergency Standard Operating Procedures.*
- *Incident notification, escalation protocols, decision-making, and delegation of authority.*
- *Rapid damage assessment and post-event inspection.*
- *Emergency water supply through tankers, packaged treatment plants, borewells, bottled water, and temporary connections.*
- *Water-quality surveillance, sampling, laboratory testing, boil-water advisories, and public-health protection.*
- *Business continuity planning and continuity of essential utility functions.*
- *Minimum service levels and restoration priorities.*
- *Emergency procurement, logistics, inventory, fuel management, and resource mobilization.*
- *Mutual-aid agreements and coordination with neighbouring utilities.*
- *Communication with employees, government agencies, media, consumers, hospitals, and* **vulnerable**

groups.

- *Risk communication, public advisories, misinformation management, and grievance handling.*
- *Documentation, incident reporting, after-action review, and lessons learned.*

Linked COs: CO3, CO4 **Number of Hours: 8 hrs**

Module-5

Digital Technologies, Recovery and Case Studies

- *Digital transformation for disaster preparedness in water utilities.*
- *SCADA, telemetry, IoT sensors, smart meters, and real-time monitoring.*
- *GIS-based utility mapping, digital asset management, and network visualization.*
- *Hydraulic and water-quality modelling for emergency scenario analysis.*
- *Digital twins, BIM, GeoBIM, and open data standards for resilient utility management.*
- *Remote sensing, drones, satellite data, and mobile applications for rapid damage assessment.*
- *Cybersecurity principles for operational technology and critical water infrastructure.*
- *Data backup, communication redundancy, access control, and incident recovery.*
- *Post-disaster recovery planning and restoration of water and wastewater services.*
- *Damage assessment, prioritization, financing, insurance, and reconstruction.*
- *Build Back Better principles and resilient reconstruction.*
- *Sustainability, circular economy, energy efficiency, and low-carbon emergency planning.*
- *Performance evaluation using service continuity, recovery time, water-quality compliance, response time, and customer-impact indicators.*
- *Case studies of floods, droughts, earthquakes, cyclones, contamination events, and utility failures.*
- *Preparation and presentation of a disaster preparedness plan for a selected water utility.*

Linked COs: CO4, CO5 **Number of Hours:** *8 hrs*

Suggested Learning Resources:

Textbooks:

1. *American Water Works Association, Emergency Planning for Water and Wastewater Utilities, AWWA.*
2. *Federal Emergency Management Agency, Emergency Management Guide for Business and Industry, FEMA.*
3. *World Health Organization, Guidelines for Drinking-water Quality, WHO.*
4. *World Health Organization, Water Safety Plan Manual: Step-by-step Risk Management for Drinking-water Suppliers, WHO.*
5. *United States Environmental Protection Agency, Emergency Response Plan Guidance for Public Drinking Water Systems, EPA.*
6. *Federal Emergency Management Agency, FEMA P-543: Design Guide for Improving Critical Facility Safety from Flooding and High Winds, FEMA.*
7. *Patrick Lagadec, Preventing Chaos in a Crisis: Strategies for Prevention, Control and Damage Limitation, McGraw-Hill.*
8. *David Alexander, Principles of Emergency Planning and Management, Oxford University Press.*

Reference Books

1. *National Disaster Management Authority, National Disaster Management Plan, Government of India.*
2. *Ministry of Home Affairs, Disaster Management in India, Government of India.*
3. *Bureau of Indian Standards, relevant standards for water supply, wastewater systems, structural safety, seismic design, and pipeline infrastructure.*
4. *World Bank, Building Urban Resilience: Principles, Tools and Practice.*
5. *UNDRR, Sendai Framework for Disaster Risk Reduction 2015–2030.*
6. *International Water Association, reports and guidance on water utility resilience and emergency preparedness.*

7. *United States Environmental Protection Agency, Incident Action Checklists for*

Web links and Video Lectures (e-Resources)

1. *National Disaster Management Authority: https://ndma.gov.in*
2. *National Disaster Management Information System and Government of India disaster-management resources.*
3. *World Health Organization water, sanitation, hygiene, and emergency-response resources.*
4. *United States Environmental Protection Agency Water Security Division resources.*
5. *United Nations Office for Disaster Risk Reduction: https://www.undrr.org*
6. *International Water Association: https://www.iwa-network.org*
7. *Central Public Health and Environmental Engineering Organisation manuals and advisories.*
8. *NPTEL and SWAYAM courses on disaster management, urban resilience, water supply engineering, GIS, and infrastructure management.*
9. *Open-source GIS, hydraulic-modelling, SCADA, and digital-twin learning resources.*
10. *Case-study reports published by municipal corporations, water boards, and international development agencies*

Teaching-Learning Process (Innovative Delivery Methods)

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes. Suggested innovative delivery methods may include, but are not limited to:

- *Flipped classroom using disaster-management guidelines, videos, and utility case studies.*
- *Problem-based learning involving failure scenarios in water supply and wastewater systems.*
- *Case-based teaching on floods, droughts, contamination incidents, and infrastructure failures.*
- *GIS-based mapping of critical water-utility assets and hazard-prone zones.*
- *Scenario simulation and tabletop exercises for emergency response.*
- *Preparation of an Emergency Response Plan for a selected water utility.*
- *Demonstration of SCADA, IoT, hydraulic modelling, GIS, and digital asset-management tools.*
- *Field visit to a water-treatment plant, pumping station, reservoir, control room, or wastewater-treatment plant.*
- *Interaction with water-utility professionals, disaster-management officers, public-health officials, and emergency responders.*
- *Role play involving the utility manager, incident commander, laboratory officer, government authority, media, and affected community.*
- *Group discussion on climate-resilient and disaster-resilient water infrastructure.*
- *ICT-enabled teaching through digital maps, dashboards, simulations, and online resources.*
- *Student seminars and technical presentations on utility-disaster case studies..*

Assessment Structure (both CIE and SEE)

The weightage assigned to Continuous Internal Evaluation (CIE) and Semester End Examination (SEE) shall be 50% each. A student shall secure a minimum of 50% of the maximum marks prescribed for CIE and a minimum of 40% of the maximum marks prescribed for SEE to be eligible for passing.

A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to a subject/course only if he/she secures not less than 50% of the aggregate marks obtained in CIE and SEE taken together.

Continuous Internal Evaluation:

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

A minimum of two Internal Assessment Tests (IA) shall be conducted. Each test shall be conducted for a maximum of 25 marks. The average of the two test marks shall be the marks secured by a student in IA.

In addition, Continuous Comprehensive Assessment (CCA) shall be conducted for a total of 25 marks

Students' activities for TW/SL under NCrF: Samples only *As per National credit formwork (NCrF) students must spend 90 hours of study for 3 credit courses, which include Course instructions (CI-42 hour) and Teamwork/ Self learning (TW/Sl-48 hours). Hence, students must complete minimum of two actives as part of NCrF. These learning activities shall be considered as CCA components of CIE. The evaluation activities will be done using set of rubrics developed for each activity. The following sample activities are listed below. The sample activities are given below. The course coordinator can also give their own TW/SL activities as per the course outcomes.*		
Sl. No.	**Term Work (TW) Activity**	**Number of Hours / Semester**
1	*TW1: Prepare a hazard, vulnerability, and risk assessment for a selected water-supply or wastewater utility using a risk matrix and GIS-based asset mapping.*	*24*
2	*TW2: Develop an Emergency Response Plan, including incident command, communication protocols, emergency water supply, service-priority matrix, and recovery actions for a selected disaster scenario.*	*24*
SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.		
Sl. No.	**Self-Learning (SL) Activity**	**Number of Hours / Semester**
1	*SL1: Study a documented disaster or emergency involving a water utility and analyse its causes, impacts, response, and recovery measures.*	*24*
2	*SL2: Review water-utility resilience measures such as backup power, emergency storage, network redundancy, flood protection, or drought management.*	*24*
3	*SL3: Complete a MOOC, spoken tutorial, webinar, or online technical module related to disaster management, GIS, SCADA, water safety, or critical-infrastructure resilience and submit a learning summary.*	*24*

Sample rubrics for TW activities:

Criterion	*4 – Excellent*	*3 – Good*	*2 – Satisfactory*	*1 – Needs Improvement*
Problem understanding	*Problem is clearly defined with strong justification and clear objectives.*	*Problem is mostly clear with minor gaps in framing or justification.*	*Problem is stated but lacks clarity or detailed justification.*	*Problem is poorly defined or unclear.*
Data and method	*Data collected/used is appropriate and sufficient; methods/tools are well chosen and logically applied.*	*Data and methods are generally appropriate with minor issues or omissions.*	*Limited or partially relevant data; methods are basic or inconsistently applied.*	*Data is inadequate/irrelevant; methods are inappropriate or missing.*
Analysis	*Analysis is thorough; interpretations are logically argued and results are valid.*	*Analysis is generally sound with minor errors or missing details.*	*Analysis is partial; contains gaps or superficial interpretation.*	*Analysis is weak, incorrect, or largely missing.*
Recommendations	*Recommendations are feasible, context-*	*Recommendations are relevant but*	*Recommendations are generic or*	*Recommendations are incomplete,*

Criterion	*4 – Excellent*	*3 – Good*	*2 – Satisfactory*	*1 – Needs Improvement*
	specific, and clearly derived from analysis.	*may have minor limitations or lack detail.*	*only loosely connected to analysis.*	*unrealistic, or absent.*
Presentation	*Work is very well organized, neat, and professionally presented.*	*Work is well organized with minor issues in formatting or clarity.*	*Presentation is acceptable but uneven.*	*Work is poorly organized, difficult to follow, or untidy.*

WASTEWATER & SAFETY SIMULATION LABORATORY			
Course Code	**1MCWHL207**	*Scheme*	*2026*
Type of course	*Professional Core Course Lab*	*Semester*	*II*
Teaching Hours/Week (L:T:P)	*2(0: 0: 2)*	*CIE Marks*	*50*
Total Hours of Pedagogy L:T:P:SL:TW	*30(0: 0:28:2)*	*SEE Marks*	*50*
Credits	*1*	*Total Marks*	*100*
Type of Examination	**Practical**	*Exam Hours*	*3*

Course outcome (Course Skill Set)

At the end of the course, the student will be able to:

1. *CO1 — L3: Operate wastewater-treatment and safety-simulation tools to configure process, hydraulic and occupational-safety scenarios.*
2. *CO2 — L4: Analyse wastewater quantity and quality data and simulate unit processes such as screening, grit removal, primary clarification, biological treatment and disinfection.*
3. *CO3 — L4: Evaluate treatment efficiency, mass balance, energy use, sludge generation and compliance indicators under different operating conditions.*
4. *CO4 — L5: Design and compare process-control, risk-reduction and emergency-response strategies for wastewater treatment facilities.*
5. *CO5 — L6: Develop an integrated digital decision-support model/dashboard for resilient, safe and sustainable wastewater-treatment operation.*

Note:

1. *The laboratory syllabus consists of PART-A and PART-B. While PART-A has 6-8 conventional experiments, PART-B has 6 typical open-ended experiments. The maximum marks for the laboratory course are 100.*
2. *Both PART-A and PART-B are considered for CIE and SEE.*
3. *Students have answer 1(one) question from PART-A and 1(one) question from PART-B.*
   a. *The questions set for SEE shall be from among the experiments under PART-A. It is evaluated for* **80 marks** *out of the maximum 100 marks.*
   b. *The open-ended question set for SEE shall be any other open-ended question and not selected from the experiments under PART-A. It shall be evaluated for* **20 marks.**

For Continuous Internal Evaluation (CIE) during the semester, classwork shall typically include open-ended questions from **Part-B**, *along with other similar questions designed to enhance the students' skills.*

PART – A
FIXED EXPERIMENTS

2. **Introduction to wastewater and safety simulation environment:** *Configure a representative municipal wastewater-treatment plant, define influent flow and pollutant characteristics, establish process units, set operating parameters and generate a baseline model. CO1*
3. **Wastewater flow and pollutant-load analysis:** *Analyse diurnal flow variation and influent BOD, COD, TSS, nitrogen and phosphorus data; calculate pollutant loads, variability and design/operating scenarios using Excel, Python, MATLAB or equivalent. CO1, CO2*
4. **Primary treatment simulation:** *Simulate screening, grit removal and primary sedimentation; determine removal efficiencies, overflow rate, detention time, solids capture and the effect of flow and settling-velocity changes. CO2, CO3*
5. **Biological treatment simulation:** *Model an activated-sludge or equivalent biological process; examine aeration demand, dissolved oxygen, sludge age/SRT, F/M ratio, biomass concentration, ammonia oxidation and effluent quality. CO2, CO3*
6. **Tertiary treatment and disinfection***: Simulate filtration, nutrient removal and disinfection; evaluate*

contact time, disinfectant dose, residual, pathogen-control indicators and the effect of peak flow or impaired operation. CO2, CO3

7. **Mass balance, sludge production and energy analysis:** *Prepare a process-wide mass balance and estimate sludge generation, recycle streams, aeration energy and pumping energy; compare baseline and improved operating conditions. CO3, CO4*
8. **Hydraulic and process-failure simulation:** *Introduce pump failure, power interruption, bypass, shock load, low dissolved oxygen, toxic influent or clarifier overload; assess hydraulic/process consequences and propose recovery actions. CO3, CO4*
9. **Occupational safety risk assessment:** *Prepare a process-area risk register for confined spaces, toxic gases, biological exposure, chemical handling, electrical hazards, slips/falls and rotating equipment using a risk matrix or equivalent simulation tool. CO1, CO4*
10. **Emergency-response and safety-barrier simulation:** *Develop a scenario for hydrogen-sulphide release, chlorine/hypochlorite exposure, confined-space rescue, chemical spill or electrical incident; simulate alarm, isolation, evacuation, communication, PPE and recovery actions. CO4, CO5*
11. **Integrated monitoring dashboard:** *Develop a dashboard showing flow, loading, treatment efficiency, effluent indicators, energy use, alarms, risk level and compliance trends; interpret the dashboard for operational decision-making. CO4, CO5*

PART – B

OPEN ENDED EXPERIMENTS

Open-ended experiments are laboratory activities in which the outcome is not predetermined. Students are given a problem statement and are encouraged to select suitable data, assumptions, software, modelling approach and performance indicators. The work shall include problem definition, model/data preparation, analysis, validation or sensitivity assessment, interpretation and recommendations.

2. *Develop and calibrate a digital wastewater-treatment model for a selected municipal or institutional plant using measured, published or simulated data; report calibration limitations and improvement measures. CO2, CO3, CO5*
3. *Compare alternative treatment trains for a specified influent and reuse objective, considering removal performance, land, energy, sludge, chemical consumption, resilience and indicative life-cycle implications. CO2, CO3, CO4, CO5*
4. *Analyse the effect of climate- or operation-related variability, such as rainfall-derived inflow, drought, temperature change, power interruption or shock loading, and prepare an adaptation and recovery plan. CO3, CO4, CO5*
5. *Prepare a quantitative risk assessment and emergency-response plan for a selected wastewater-treatment facility, integrating bow-tie analysis, risk ranking, safety barriers, alarm logic, communication and post-incident review. CO1, CO4, CO5*
6. *Develop a predictive or rule-based control strategy for aeration, pumping, chemical dosing or sludge wasting to reduce energy/chemical use while maintaining effluent performance and operational safety. CO3, CO4, CO5*
7. *Prepare an integrated wastewater and safety simulation report for a real or hypothetical facility, including process flow diagram, assumptions, data analysis, model outputs, risk register, emergency plan,*

dashboard and sustainability recommendations. CO2, CO4, CO5

Suggested Learning Resources

Textbooks:

1. *Metcalf & Eddy/AECOM, Wastewater Engineering: Treatment and Resource Recovery, McGraw-Hill.*
2. *Henze, M., van Loosdrecht, M. C. M., Ekama, G. A. and Brdjanovic, D., Biological Wastewater Treatment: Principles, Modelling and Design, IWA Publishing.*
3. *Tchobanoglous, G., Burton, F. L., Stensel, H. D. and Tsuchihashi, R., Wastewater Engineering: Treatment and Resource Recovery, McGraw-Hill.*
4. *Spellman, F. R., Handbook of Water and Wastewater Treatment Plant Operations, CRC Press.*

Reference books / Manuals:

1. *Grady, C. P. L., Daigger, G. T., Love, N. G. and Filipe, C. D. M., Biological Wastewater Treatment, CRC Press.*
2. *Crites, R. and Tchobanoglous, G., Small and Decentralized Wastewater Management Systems, McGraw-Hill.*
3. *World Health Organization, Sanitation Safety Planning: Manual for Safe Use and Disposal of Wastewater, Greywater and Excreta.*
4. *International Water Association, manuals on wastewater-process modelling, resource recovery and treatment-plant operation.*
5. *Relevant BIS standards, CPCB/SPCB guidelines, National Building Code provisions, institutional laboratory safety manuals and applicable occupational-health and emergency-response procedures.*

Software tools:

1. *BioWin, GPS-X, WEST, SUMO, MATLAB/Simulink or equivalent wastewater-process simulation software.*
2. *EPANET, SWMM or equivalent tools for hydraulic, sewer-network and stormwater/inflow simulation where relevant.*
3. *Excel, Python or MATLAB for mass balance, calibration, sensitivity analysis, risk scoring, optimisation and data visualisation.*
4. *QGIS, AutoCAD or equivalent for plant layout, hazard zoning, emergency access and evacuation mapping.*
5. *Power BI, Tableau, Grafana or equivalent for process and safety dashboards.*
6. *Any equivalent open-source or licensed software approved by the Department..*

Assessment Structure (both CIE and SEE)

The weightage assigned to Continuous Internal Evaluation (CIE) and Semester End Examination (SEE) shall be 50% each. A student shall secure a minimum of 50% of the maximum marks prescribed for CIE and a minimum of 40% of the maximum marks prescribed for SEE to be eligible for a pass in the course.

A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to a subject /course only if he/she secures not less than 50% of the aggregate marks obtained in CIE and SEE taken together.

Continuous Internal Evaluation (CIE):

For the Professional Core Course Laboratory, the maximum marks prescribed are 100. Out of these, 50 marks are allotted for Continuous Internal Evaluation (CIE) and 100 marks for the Semester End Examination (SEE). The SEE marks obtained out of 100 shall be proportionately scaled down to 50 marks. The final result shall be declared based on the aggregate of the CIE marks (50) and the scaled-down SEE marks (50), totalling 100 marks."

Out of 50 marks, 40 marks shall be assigned for assessment of regular laboratory PART -A classwork, and 10 marks for Part – B. (Table 1)

Out of 40 marks, 25 marks shall be based on the regular classwork and allotment of marks shall be as per rubrics listed in Table 1.

The remaining 15 marks shall be based on the practical test conducted by two Internal examiners appointed by the HoD. The allotment of marks shall be as per the rubrics defined for the practical test as indicated in the Table 1.

The open-ended question set for CIE shall be any other open-ended question and not selected from the experiments

under PART-A. It shall be evaluated for 10 marks. The allotment of marks shall be as per rubrics listed in Table 2.

Table – 1 Distribution of marks corresponding to laboratory component

Component	Description	Marks
Allotment of marks for regular classwork		
Ability in Conducting Experiments	*Initiative, skill, safety practices, teamwork, and independent handling of equipment during regular lab sessions.*	*10 marks*
Laboratory Record / Journal	*Regular and neat maintenance of lab record, accuracy of results, and timely submission.*	*15 marks*
	Subtotal	**25**
Allotment of marks for CIE practical test		
Laboratory Test / Experiment Performance	*Ability to set up apparatus, follow procedure, take observations, and obtain correct results in the test experiment.*	*5 marks*
Viva-Voce	*Understanding of theory, concepts, and experimental procedure; ability to explain results and answer related questions.*	*10marks*
	Subtotal	**15**
	Total	**40**

Table 2 Distribution of marks corresponding to PART -B of the laboratory component

Evaluation Rubrics for continuous internal evaluation CIE). Maximum marks:10

Criteria and Guiding factors	Students' Level and Rubrics Excellent: E, Good: G, Fair: F Needs Improvements: NI			
	E	**G**	**F**	**NI**
(1) *Problem Understanding* **Criteria:** *Is the problem understood correctly and framed appropriately?* *(i)Clarity in interpreting the given problem. (ii)Identification of relevant concepts and constraints.* *(iii) Ability to rephrase or model the problem logically.*	*2.0*	*1.5*	*1.0*	*0.5*
(2) *Conceptual Knowledge* **Criteria***: Are the chosen methods or concepts valid for this type of problem?* *(i) Application of appropriate theories, principles, or laws.* *(ii) Integration of multiple concepts where necessary.* *(iii)Accuracy in stating relevant equations or models.*	*2.0*	*1.5*	*1.0*	*0.5*
(3) *Approach and Strategy* **Criteria***: Is the approach well thought out and methodical?* *(i) Logical structure and progression.* *(ii) Use of diagrams, sketches, or flowcharts if applicable.* *(iii)Identification of assumptions and boundary conditions.*	*2.0*	*1.5*	*1.0*	*0.5*
(4) *Execution and Accuracy* **Criteria***: Are the calculations correct? Is the final solution reasonable?* *(i) Correct application of formulas/methods.* *(ii)Accuracy of calculations or simulations (if any).* *(iii)Unit consistency and result verification.*	*2.0*	*1.5*	*1.0*	*0.5*

(5) *Innovation or Depth* **Criteria***: Has the student shown original thinking or alternative methods?* *(i)Novel or efficient solutions. (ii)Consideration of alternate approaches.* *(iii)Interdisciplinary integration or practical extensions.*	*1*	*0.75*	*0.5*	*0.25*
(6) *Presentation and Clarity* **Criteria***: Is the answer easy to follow and professionally written?* *(i) Organization and neatness.* *(ii) Clarity of explanation, labelling, and steps.* *(iii) Use of proper technical terminology.*	*1*	*0.75*	*0.5*	*0.25*
Total	*10*	*7.5*	*5.0*	*2.5*

Note:

(i) The marks shown for Excellent, Good, Fair, Needs Improvement are indicative. The evaluator may also assign intermediate scores depending on the quality of work.

(ii) If the total score results in a fraction, it should be rounded off to the next higher integer.

(iii) The listed criteria are guidelines; evaluators may also consider other authentic dimensions (e.g., depth of insight, critical thinking, and practical awareness, recognition of limitations, or justified compromises.

(iv) To award the full10 marks in the excellent category, the student must demonstrate reasonably good performance across all six criteria; otherwise, proportionally lower marks may be given.