NATIONAL INSTITUTE OF TECHNOLOGY WARANGAL

SCHEME OF INSTRUCTION AND SYLLABI

FOR

M.TECH PROGRAM IN WASTE MANAGEMENT

Effective from 2020-21

DEPARTMENT OF CIVIL ENGINEERING

NATIONAL INSTITUTE OF TECHNOLOGY WARANGAL

VISION

Towards a Global Knowledge Hub, striving continuously in pursuit of excellence in Education, Research, Entrepreneurship and Technological services to the society

MISSION

- Imparting total quality education to develop innovative, entrepreneurial and ethical future professionals fit for globally competitive environment.

- Allowing stake holders to share our reservoir of experience in education and knowledge for mutual enrichment in the field of technical education.

- Fostering product oriented research for establishing a self-sustaining and wealth creating centre to serve the societal needs.

DEPARTMENT OF CIVIL ENGINEERING

VISION

To be a knowledge nerve centre in civil engineering education, research, entrepreneurship and industry outreach services for creating sustainable infrastructure and enhancing quality of life.

MISSION

- Generating a specialized cadre of civil engineers by imparting quality education and training.

- Attain international standards in teaching, research and consultancy with global linkages.

DEPARTMENT OF CIVIL ENGINEERING
M.TECH. WASTE MANAGEMENT

PROGRAM EDUCATIONAL OBJECTIVES

PEO1	Apply knowledge of basic science and engineering to achieve waste management hierarchy and its significance in the socio-economic development
PEO2	Identify, formulate and design engineered solutions to waste management problems to cater needs of society
PEO3	Apply best waste management practices for securing ecologically sustainable development while promoting justifiable economic and social development
PEO4	Communicate and manage interdisciplinary teams in solving waste management problems.
PEO5	Demonstrate leadership qualities and exhibit professional ethics.

Mapping of Mission statements with program educational objectives

Mission Statement	PEO1	PEO2	PEO3	PE04	PEO5
MS1	3	3	3	2	2
MS2	2	3	2	3	3

PROGRAM OUTCOMES: At the end of the program the student will be able to:

PO1	Engage in critical thinking and pursue investigations/research and development to solve waste management problems.
PO2	Communicate effectively, write and present technical reports on complex engineering activities by interacting with the engineering fraternity and with society at large.
PO3	Demonstrate higher level of professional skills to tackle multidisciplinary and complex problems related to waste management
PO4	Analyze and predict waste management parameters /variables to ensure effective delivery of waste management services
PO5	Design feasible solutions for waste management which are legally, ethically, socially and economically acceptable
PO6	To develop waste management strategies for tackling problems at local, regional and global scales

Mapping of program outcomes with program educational objectives

Programme Outcomes	PEO1	PEO2	PEO3	PEO4	PEO5
PO1	2	3	2	3	-
PO2	2	2	2	3	3
PO3	2	3	2	3	3
PO4	2	3	1	2	1
PO5	2	3	1	3	1
PO6	1	3	2	3	1

CURRICULAR COMPONENTS

The total course package M.Tech. Degree program will typically consist of the following components.

a) Core Courses ≥ 24 Credits
b) Elective Courses ≥ 15 Credits
c) Dissertation = 27 Credits

Degree Requirements for M. Tech in Waste Management

Category of Courses	Credits Offered	Min. credits to be earned
Program Core Courses (PCC)	30	30
Departmental Elective Courses (DEC)	18	18
Dissertation	27	27
Total	75	75

SCHEME OF INSTRUCTION

M.Tech. (Waste Management) Course Structure

M. Tech. I - Year I - Semester

S No	Course Code	Course Title	L	T	P	Credits	Cat. Code
1	CE5301	Environmental Chemistry and Microbiology	3	0	0	3	PCC
2	CE5801	Solid Waste Management	3	0	0	3	PCC
3	SM5006	Strategic Management	3	0	0	3	PCC
4		Elective – I	3	0	0	3	DEC
5		Elective - II	3	0	0	3	DEC
6		Elective – III	3	0	0	3	DEC
7	CE5802	Environmental Monitoring Laboratory	0	1	2	2	PCC
8	CE5803	Waste Characterization and Analysis Lab	0	1	2	2	PCC
9	CE5841	Seminar – I	0	0	2	1	PCC
		TOTAL	**18**	**2**	**6**	**23**	

M. Tech. I - Year II - Semester

S No	Course Code	Course Title	L	T	P	Credits	Cat. Code
1	CE5851	Waste Processing Technologies	3	0	0	3	PCC
2	CE5852	Hazardous Waste Management	3	0	0	3	PCC
3	CE5353	Environmental Impact Assessment and Management	3	0	0	3	PCC
4		Elective – IV	3	0	0	3	DEC
5		Elective – V	3	0	0	3	DEC
6		Elective – VI	3	0	0	3	DEC
7	CE5853	Waste Management Design Lab	0	1	2	2	PCC
	CE5854	GIS Laboratory	0	1	2	2	PCC
8	CE5891	Seminar – II	0	0	2	1	PCC
		TOTAL	**20**	**2**	**6**	**23**	

M. Tech. II - Year I - Semester

S No	Course Code	Course Title	Credits	Cat. Code
		Industrial Training (8-10 Weeks) – Optional		
1	CE6842	Comprehensive Viva Voce	2	PCC
2	CE6849	Dissertation Part A	9	PCC
		Total	11	

M. Tech. II - Year II - Semester

S No	Course Code	Course Title	Credits	Cat. Code
1	CE6899	Dissertation Part B	18	PCC
		Total	18	

List of Electives

I Year I Semester

S.No	Course Code	Course Title
1.	CE5811	Logistics in Waste Collection and Disposal
2.	CE5812	Environmental Health and Safety
3.	SM5071	Entrepreneurship in Waste Management
4.	CH5121	Waste to Energy
5.	CH5122	Green & Cleaner Technology
6.	BT5125	Biotechnological Approaches for Waste Management
7.	CE5302	Water and Wastewater Treatment
8.	CE5312	Life Cycle Analysis
9.	CE5315	Environmental Systems Engineering

I Year II Semester

S.No.	Course Code	Course Title
1.	CE5861	Operational Research
2.	CE5862	Regulatory and Legal Framework for Waste Management
3.	CE5863	Bioremediation
4.	CE5864	Industrial Waste Management and Audit
5.	CE5865	Geospatial Technologies in Environmental Management
6.	CE5866	Landfill Design and Operation
7.	SM5051	Operations and Maintenance
8.	SM5031	Marketing Management for Waste
9.	CH5169	Energy Audit and Conservation

Note: In addition to the above listed electives, a student can also register one elective per semester from other departments and two electives per semester from other specializations of the same department, based on suitability of timetable.

DETAILED SYLLABUS

CE5301	ENVIRONMENTAL CHEMISTRY AND MICROBIOLOGY	PCC	3 – 0 – 0	3 Credits

Pre-requisites: NONE

Course Outcomes: At the end of the course the student will be able to:

CO1	Develop an understanding of the fundamental aspects of chemistry valuable for solving environmental problems
CO2	Apply the principles of chemistry in the treatment processes of water and wastewater
CO3	Classify and analyze the microorganisms
CO4	Understand the processes in biological treatment systems

Detailed Syllabus:

General Chemistry:-Basic principles – chemical equations – types of chemical reactions - calculations from chemical equations; gas laws; Equilibrium and Le Chatelier's Principle – factors affecting chemical equilibrium - activity and activity coefficient - ionic strength.

Physical Chemistry:- Thermodynamics – heat and work – enthalpy – entropy – free energy – temperature dependence of equilibrium constant; membrane processes; principles of solvent extraction; electrochemistry; chemical kinetics; adsorption.

Equilibrium Chemistry:- Variations of Equilibrium relationships; ways of shifting chemical equilibrium; solutions to equilibrium problems -acid base equilibrium – solubility equilibrium – oxidation reduction equilibrium.

Organic Chemistry and Biochemistry:- Organic compounds of interest to environmental engineers, general properties of the functional groups of organic compounds; Enzymes, classification enzymes catalyzed reaction, energy considerations coupling of reaction; Breakdown and synthesis of carbohydrates, fats, proteins under aerobic and anaerobic reactions; CNP cycles under aerobic and anaerobic reactions; Concepts of BOD, COD, TOC.

Environmental Chemistry:- Fundamentals of surface and colloidal chemistry; chemistry involved in water treatment; Atmospheric chemistry; soil chemistry; emerging pollutants and sources of pollution for water, air and soil

Environmental Microbiology:- Introduction of microbiology, classification and characterization of microorganisms, viruses; Morphology and structure of bacteria, nutrient requirement, growth of bacteria; Basic microbiology of water and sewage; Basic principals involved in the analysis of fecal indicator bacteria – coli forms and streptococci, plankton analysis, analysis of pseudomonas & streptococci; Pathways of aerobic and anaerobic metabolism, Energy transfer in metabolism; Kinetics of microbial growth. Microbiology of water, wastewater, soil and air.

Readings:

1. Sawyer, C.N., McCarty, P.L., Perkin, G.F. (2017). *Chemistry for Environmental Engineering and Science*, 5th Ed., McGraw-Hill India
2. Benefield D. L., Judkins F. J., Weand L. B. (1982). *Process Chemistry for Water and Wastewater Treatment*, 1st Ed., Prentice Hall, USA
3. Bitton G. (2011). *Wastewater Microbiology*, 4th Ed., Wiley India Pvt Ltd.
4. Mitchell R., Gu J.D. (2009). *Environmental Microbiology*, 2nd Ed., Wiley-Blackwell, USA
5. Weiner, E.R. (2010). *Applications of Environmental Chemistry - A Practical Guide for Environmental Professionals*, 1st Ed., CRC Press, USA

CE5801	SOLID WASTE MANAGEMENT	PCC	3 – 0 – 0	3 Credits

Pre-requisites: NONE

Course Outcomes: At the end of the course the student will be able to:

CO1	Sample and analyse physical, chemical and biological composition of wastes
CO2	Plan suitable storage, collection, transfer and transfer strategies for MSW management
CO3	Formulate 3Rs approach for processing and recovery of MSW
CO4	Plan and design facilities for engineered disposal of MSW

Detailed Syllabus:

Solid Waste: Definitions, Characteristics, and Perspectives
Types of solid wastes, sources of solid wastes, properties of solid wastes, solid waste management: an overview

Engineering Systems for Solid Waste Management
Solid waste generation; on-site handling, storage and processing; collection of solid wastes; transfer and transport; processing techniques; ultimate disposal; Integrated SW Management concepts

Engineering Systems for Resource and Energy Recovery
Processing techniques-biological and chemical conversion technologies – composting and its methods, Vermi-composting, mechanical composting, In vessel composting, incineration, pyrolysis, gasification; RRR approach, materials-recovery systems; recovery of biological conversion products; recovery of thermal conversion products; recovery of energy from conversion products; materials and energy recovery systems.

Engineering Disposal of SW
Dumping of solid waste; sanitary land fills – site selection, design and operation of sanitary landfills – Leachate collection & treatment. Identify methods of solid waste disposal during a site visit and follow safety precautions.

Readings:

1. Tchobanoglous G., Theisen H., Vigil S.A. (2014*). Integrated Solid Waste Management, Engineering Principles and Management Issues,* 2nd Ed., McGraw-Hill, USA
2. Vesilind, P.A., and Worrell W. A. (2016) *Solid Waste Engineering*, 2nd Ed., Cengage India
3. Peavy, H.S., Rowe, D.R., and Tchobanoglous, G. (2017). *Environmental Engineering*, 1st Ed., McGraw Hill Education,USA
4. John Pichtel (2014). *Waste Management Practices: Municipal, Hazardous and Industrial*, 2nd Ed., CRC Press, USA
5. Tchobanoglous G., Frank Kreith., (2002). *Hand Book of Solid Waste Management*, 2nd Ed., McGraw Hill, USA.
6. Qian X, Koerner RM and Gray DH. (2002). *Geotechnical Aspects of Landfill Design and Construction*, 1st Ed., Prentice Hall, USA.
7. CPHEEO (2016). *Manual on Municipal Solid Waste Management*, Ministry of Urban Development, India.

SM5006	STRATEGIC MANAGEMENT	PCC	3 – 0 – 0	3 Credits

Pre-requisites: NONE

Course Outcomes: At the end of the course the student will be able to:

CO1	Apply conceptual, diagnostic and analytical skills in strategy formulation, implementation and control
CO2	Analyze the suitability of strategies to achieve valuable outcomes.
CO3	Appraise the resources and capabilities of the organization
CO4	Demonstrate the ability to think critically in relation to a particular problem or strategic decision through real-world scenarios.
CO5	Analyze the best practices in strategic waste management and relate to sustainable development goals

Detailed Syllabus:

Introduction to Strategic Management: Concepts of Strategic management, strategic management process, vision, mission, objectives, goals, strategy; Environmental Appraisal-external, internal; resources & capabilities – SWOT analysis, concept of core competence and value chain analysis, PESTEL Analysis, Industry analysis; strategic issues of waste management.

Formulation of Strategy: Level of strategy formulation, Generic competitive strategies: cost leadership, and differentiation, framework for analyzing competition, competitive positioning of a firm.

Strategic alternatives and Choices: Grand strategies, business level strategies, horizontal, vertical integration, diversification. Strategic Choices- BCG matrix, G.E matrix portfolio analysis - Technology based versus mature industries, External growth strategy – Strategic Alliances, merger-acquisition, collaborative partnerships.

Implementation of Strategy: Elements of strategy implementation, structure, McKinsey's 7s framework Resources allocation, corporate leadership, personal values, organizational culture, Strategy evaluation and control – Balanced Scorecard.

Strategic waste management: Alignment with Sustainable Development goals; best practices in strategic waste management; challenges in strategic waste management.

(Case studies of related topics have to be discussed)

Readings:

1. Fred R.D., Forest R.D., (2016). *Strategic Management concepts,* 16th Ed, Pearson Education, USA..
2. Hitt, M.A., Hoskisson, R.E., Ireland, R.D., (2016). *Strategic Management*, Cengage Learning, India.
3. IGES, UNEP, CCET. (2018), *Phnom Penh Waste Management Strategy and Action Plan 2018-2035.* Phnom Penh, Cambodia.
4. Kobus, Dariusz. (2003) *Practical Guidebook on Strategic Planning in Municipal Waste Management*, Washington, D.C.: World Bank.

CE5802	ENVIRONMENTAL MONITORING LAB	PCC	0 – 1 – 2	2 Credits

Pre-requisites: NONE

Course Outcomes: At the end of the course the student will be able to:

CO1	Sample and store water, wastewater and soil samples
CO2	Analyse samples using appropriate techniques and instruments
CO3	Determine pollutant concentrations in air samples.
CO4	Perform microscopic examination of microbes

Detailed Syllabus:

Experiment No.1: Estimation of Solids (TDS, TSS, VS), Acidity, Alkalinity, Hardness, Chlorides and Fluorides
Experiment No.2: Estimation of Dissolved Oxygen and Biochemical Oxygen Demand
Experiment No.3: Estimation of Chemical Oxygen Demand
Experiment No.4: Estimation of Nitrogen, Phosphates and Sulphates
Experiment No.5: Determination of Available Chlorine in bleaching powder
Experiment No.6: Conducting Break Point Chlorination Test
Experiment No.7: Conducting Jar test for determining optimum dosage of coagulant
Experiment No.8: Plate count test and MPN test
Experiment No.9: Estimation of Organic Compounds Using HPLC
Experiment No.10: Analysis of samples using Gas Chromatograph
Experiment No.11: Determination of Heavy metals using spectrophotometer
Experiment No.12: Estimation of suspended particulate matter, SO_x, NO_x and VOC in air
Experiment No.13: Estimation of Bioaerosols present in the ambient air/indoor air

Readings:

1. *Standard methods for the examination of water and wastewater*, 23rd Ed, American Public Health Association, (2017) USA.
2. Sawyer, C. N., McCarty, P. L., and Parkin, G.F., (2003) *Chemistry for Environmental Engineering and Science*, 5th edition McGraw-Hill Education, USA.
3. Kotaiah, B., Kumara Swamy, N., (1994) *Environmental Engineering Laboratory Manual*, 1st Ed., Charotar Books Distributors, India.
4. EPA (2000). *A Guide to the Sampling and Analysis of Waters, Wastewaters, Soils and Wastes*, 7th Ed, Environment Protection Authority, Seychelles.
5. USEPA (2015). *Handbook for sampling and sample preservation of water and wastewater-scholar's choice edition*. Creative Media Partners, England.
6. EPA (2009). *Industrial Waste Resource Guidelines: Sampling and Analysis of Waters, Wastewaters, Soils and Wastes*, Environment Protection Authority, Seychelles.

CE5803	WASTE CHARACTERIZATION AND ANALYSIS LAB	PCC	0 – 1 – 2	2 Credits

Pre-requisites: NONE

Course Outcomes: At the end of the course the student will be able to:

CO1	Characterize waste quantity and composition for the design of suitable treatment facility.
CO2	Classify waste as hazardous or non-hazardous waste according to regulations
CO3	Plan appropriate treatment facility for the waste

Detailed Syllabus:

1. Sampling of a solid waste
2. Physical analysis of the waste material
    a. Picking analysis/quantifying material fractions as identifiable items.
    b. Particle size distribution.
    c. Moisture content.
    d. Densities. and chemical analysis
3. Chemical analysis of the waste material
    a. pH and alkalinity.
    b. Organic matter.
    c. Inorganics.
    d. Heating value/calorific value
4. Compressibility tests
5. Leaching tests
6. Respiration tests
7. Biochemical methane potential tests

Readings:

1. Thomas Christensen, (2011). *Solid Waste Technology & Management*, John wiley & sons, USA.
2. Metcalf & Eddy, (2017), *Waste water Engineering Treatment and Reuse*, 4th Ed, McGraw Hill Inc, India.
3. Peavy, H.S, Rowe, D.R., and Tchobanoglous, G., (2017). *Environmental Engineering*, Indian ED, McGraw Hill Inc., India.

CE5851	WASTE PROCESSING TECHNOLOGIES	PCC	3 – 0 – 0	3 Credits

Pre-requisites: NONE

Course Outcomes: At the end of the course the student will be able to:

CO1	Identify waste processing methods for different types of wastes.
CO2	Plan recovery of materials and energy from solid wastes
CO3	Design waste processing systems as per regulatory standards
CO4	Integrate emerging technologies in waste Management

Detailed Syllabus:

Waste Generation and Characterization
Types and sources of solid wastes: Residential Waste, Commercial and Institutional Waste, Industrial Waste, Construction and Demolition Waste, an overview of various techniques for evaluation of parameters, Selection of Appropriate Technologies for waste treatment, legislations for waste management

Processing and Treatment of Solid Waste: Mechanical Treatment
Material Recovery Facility, Recycling and Recovery, Types of Material Recovery Facilities Design of Material Recovery Facilities.

Processing and Treatment of Solid Waste: Biological Treatment
Biological methods for waste processing: Composting, Biomethanation, Biodeisel, Biohydrogen, Mechanical Biological Stabilization

Processing and Treatment of Solid Waste: Thermal Treatment
Incineration, Residues and its utilisation, co-combustion, Pyrolysis, Gasification, Refuse Derived Fuel, solid recovered fuel

Emerging Technologies in Waste Management
Technologies Under Development, Bio-fuels and bio-chemicals, Technologies for Smart Waste Collection, use of SCADA systems for waste management, technical options for Construction and Demolition Waste Management

Readings:

1. Thomas Christensen, (2011). *Solid Waste Technology & Management*, John wiley & sons, USA.
2. John Pichtel (2014). *Waste Management Practices: Municipal, Hazardous and Industrial*, 2nd Ed., CRC Press, USA
3. Tchobanoglous G., Frank Kreith., (2002). *Hand Book of Solid Waste Management*, 2nd Ed., McGraw Hill, USA.
4. Tchobanoglous G., Theisen H., and Vigil S.A. (2014*). Integrated Solid Waste Management, Engineering Principles and Management Issues,* 2nd Ed., McGraw-Hill, USA
5. Vesilind, P.A., and Worrell W. A. (2016) *Solid Waste Engineering*, 2nd Ed., Cengage India.
6. Peavy, H.S, Rowe, D.R., and Tchobanoglous, G., (2017). *Environmental Engineering*, Indian ED, McGraw Hill Inc., India.
7. Qian X, Koerner RM and Gray DH. (2002). *Geotechnical Aspects of Landfill Design and Construction*, 1st Ed., Prentice Hall, USA.
8. CPHEEO (2016). *Manual on Municipal Solid Waste Management*, Ministry of Urban Development, India.

CE5852	HAZARDOUS WASTE MANAGEMENT	PCC	3 – 0 – 0	3 Credits

Pre-requisites: NONE

Course Outcomes: At the end of the course the student will be able to:

CO1	Examine physical, chemical and biological characteristics of hazardous wastes
CO2	Analyze activities associated with the management of Hazardous wastes.
CO3	Formulate and plan suitable disposal facility for handling hazardous wastes
CO4	Design and locate waste containment systems as per regulatory standards.

Detailed Syllabus:

Introduction to Hazardous waste:
Hazardous waste definition, sources, identification and classification; Hazardous waste management in developing countries- Collection, handling, storage and transport, TSDF concept; Hazardous waste management rules and regulations

Hazardous waste treatment and disposal:
Hazardous waste treatment technologies: Physical, chemical, physico-chemical treatment, and thermal treatment;-Solidification, chemical fixation, encapsulation, pyrolysis and incineration.
Hazardous waste disposal: Hazardous waste landfills- Site selections, design and operation. Hazardous waste reduction, recycling and reuse, remediation of hazardous waste contaminated sites

Management of different Hazardous wastes:
Nuclear waste: Characteristics – Types – Nuclear waste – Uranium mining and processing – Power reactors – Refinery and fuel fabrication wastes – spent fuel – Management of nuclear wastes – Decommissioning of Nuclear power reactors – Health and environmental effects,
Biomedical waste: Introduction to biomedical wastes, sources, classification, collection, segregation, treatment and disposal. Biomedical waste management rules
E-waste: introduction, e-waste characteristics; e-waste generation, collection, transport, recycling and disposal methods; Effects of e-wastes on the society and environment. E-waste waste management rules
Plastic waste: Plastic Waste – Sources, Production, Global and Indian Context; Plastic Waste Management Practices – Plastic management- recycling, energy production, landfilling, other application.

Readings:

1. Tchobanoglous G., Theisen H., and Vigil S.A. (2014*). Integrated Solid Waste Management, Engineering Principles and Management Issues,* 2nd Ed., McGraw-Hill, USA
2. John Pichtel (2014). *Waste Management Practices: Municipal, Hazardous and Industrial*, 2nd Ed., CRC Press, USA
3. Vesilind, P.A., and Worrell W. A. (2016) *Solid Waste Engineering*, 2nd Ed., Cengage India
4. Peavy, H.S, Rowe, D.R., and Tchobanoglous, G., (2017). *Environmental Engineering*, Indian ED, McGraw Hill Inc., India
5. Tchobanoglous G., Frank Kreith., (2002). *Hand Book of Solid Waste Management*, 2nd Ed., McGraw Hill, USA.
6. Qian X., Koerner R.M., and Gray D.H., (2002). *Geotechnical Aspects of Landfill Design and Construction*, 1st Ed., Prentice Hall, USA.
7. CPHEEO (2016). *Manual on Municipal Solid Waste Management*, Ministry of Urban Development, India.

CE5353	ENVIRONMENTAL IMPACT ASSESSMENT AND MANAGEMENT	PCC	3 – 0 – 0	3 Credits

Pre-requisites: NONE

Course Outcomes: At the end of the course the student will be able to:

CO1	Identify environmental attributes for the EIA study.
CO2	Identify methodology and prepare EIA reports.
CO3	Specify methods for prediction of the impacts.
CO4	Formulate environmental management plans.

Detailed syllabus:

Introduction: Definitions - Environmental Inventory, Standards, Indices - Environmental attributes— Air, Water Noise, Land Economic; Cultural and detailed discussions of individual parameters of each attributes; methods for Prediction and assessment of impacts air - water - soil - noise - biological - cultural - social - economic environments - Standards and guidelines for evaluation, EIA notification.

EIA - EIA Terminology - Need for EIA - Evolution of EIA - Concepts of EIA - Merits and demerits of EIA - Procedures - Screening, Scoping baseline data, Impact prediction - Stake holders of EIA - Public Participation in Decision making - Projects requiring Environmental Clearance.

EIA methodologies - Criteria for Selection -Impact identification, measurement, interpretation and Evaluation - Impact Communication - Adhoc Methods, Checklists Methods, matrices , Networks and Overlays Methods - Cost-Benefit Analysis - Rapid EIA and Comprehensive EIA - General Framework for Environmental Impact Assessment, Characterization and site assessment.

EMP and Monitoring - Document Planning - Scope and Baseline conditions - Construction Stage Impacts - Environmental Management Plan - Identification of significant or Unacceptable Impacts - Environmental Mitigation Plans - Relief and rehabilitation - Environmental Legislation and Audit - Concept of Environmental Risk Analysis and Life Cycle Assessment - Legal and regulatory Aspects in India.

EIA Case Studies of Developmental Projects : Preparation of EIA for developmental projects - Factors to be considered in making assessment decisions, Water Resources Project, Pharmaceutical industry, thermal plant, Mining, Nuclear fuel complex, Highway project, Sewage treatment plant, CETP, Treatment Storage Disposal Facility, Municipal Solid waste processing plant, Tannery industry. Software for rapid EIA.

Readings:

1. Canter, L.W., (1982). Environmental Impact Assessment, McGraw Hill Pub. Co., USA.
2. Lawrence, D.P., (2003). *Environmental Impact Assessment: Practical Solutions to Recurrent Problems*, John Wiley & Sons, Canada.
3. Hosetti, B. B., Kumar, A., (1998). *Environmental Impact Assessment & Management*, Daya Books, India.
4. Hartman, L., (1987). *Methodological Guidelines for the Integrated Environmental Evaluation of Water Resources Development*, UNEP, France.
5. Anjaneyulu, Y., Manickam, V., (2007). *Environmental Impact Assessment Methodologies*, B.S. Publications, India.
6. Wathern, P., (2015). *Environmental Impact Assessment- Theory and Practice*, Taylor and Francis Group, U.K.

CE5853	WASTE MANAGEMENT DESIGN LAB	PCC	0 – 1 – 2	2 Credits

Pre-requisites: NONE

Course Outcomes: At the end of the course the student will be able to:

CO1	Estimate the physical and chemical composition of solid waste
CO2	Analyze the waste collection system
CO3	Design waste transformation processes
CO4	Design waste containment systems as per regulatory standards

Detailed Syllabus:

1. Estimate the moisture content and specific weight of solid waste sample
2. Determine the approximate chemical composition of a solid waste sample and estimate the energy content
3. Assess the solid waste quantities using material-balance analysis
4. Statistical analysis of solid waste collected data
5. Selection of container size for use at a commercial facility
6. Analysis of waste collection systems
7. Layout of collection route for a given area
8. Design of composting plants
    - Estimate the oxygen requirements for the aerobic conversion of solid waste
9. Design of Biogas plant
    - Estimate the amount of gas produced from the organic fraction of soli waste under anaerobic conditions
10. Design of an incinerator for the treatment of solid waste
    - Determination of the effects of excess air on temperature and composition of flue gases
    - Determine the heat available in the exhaust gases from the combustion of solid waste
    - Estimate the amount of energy produced from a solid waste energy conversion system
11. Design of sanitary landfill design
    - Estimate the chemical composition and the amount of gas that can be derived from the organic constituents of solid waste
12. Secured landfill design
13. Design of a combination of compost plant and landfill for municipal solid waste management for a city

Readings:

1. Tchobanoglous G., Theisen H., and Vigil S.A. (2014*). Integrated Solid Waste Management, Engineering Principles and Management Issues,* 2nd Ed., McGraw-Hill, USA.
2. Peavy, H.S, Rowe, D.R., and Tchobanoglous, G., (2017). *Environmental Engineering*, Indian ED, McGraw Hill Inc., India.
3. John Pichtel (2014). *Waste Management Practices: Municipal, Hazardous and Industrial*, 2nd Ed., CRC Press, USA
4. Qian X., Koerner R.M., and Gray D.H., (2002). *Geotechnical Aspects of Landfill Design and Construction*, 1st Ed., Prentice Hall, USA.
5. CPHEEO (2016). *Manual on Municipal Solid Waste Management*, Ministry of Urban Development, India.

CE 5854	GIS LABORATORY	PCC	0-1-2	2 Credits

Prerequisites: None

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

CO1	Prepare different geospatial layers
CO2	Compute geometric measurements and perform spatial analysis
CO3	Create high-quality maps and associated graphics

Detailed Syllabus:

1. Digitization of Points and Lines
2. Editing Map Elements
3. Attribute Data Entry and Manipulation
4. Cleaning, Building and Transformation
5. Data Analysis – Overlay, Buffer
6. Map Generation with Patterns and Legends
7. Buffer Analysis
8. Network Analysis

Reading:

1. ArcGIS 10.1 user manuals, 2013
2. ERDAS Imagine 2013 user manual

CE5811	LOGISTICS IN WASTE COLLECTION AND DISPOSAL	DEC	3 – 0 – 0	3 Credits

Pre-requisites: NONE

Course Outcomes: At the end of the course the student will be able to:

CO1	Plan logistics for waste collection and disposal
CO2	Formulate strategies for segregation of waste and waste reduction
CO3	Plan appropriate recycle facility for heterogeneous wastes
CO4	Plan and design waste collection systems

Detailed Syllabus:

Introduction to waste management logistics, importance, methods of logistics, human components, technological components- waste handling equipment and technology, and managerial goals, steps in waste management logistics.
Basics of GPS & GIS - introduction, importance; GPS aided vehicle; GPS in India, US, Russia. variable cycle (multi-day, weekly, bi-weekly, monthly, quarterly),variable route start location, route optimization, scheduling, GPS tracking, mobile communications.
Waste collection system and organization: Environmental aspects of waste collection, role of public authority and private sector in waste collection, organizing collection of residential waste, fee schemes, public awareness programs.
Source segregation and collection of source-segregated waste: Purpose of source segregation, segregation criteria and guidance, segregation potential and efficiencies, systems for collecting segregated fraction
Waste transfer stations: waste delivery, waste transfer, transportation of the reloaded waste, siting and Design of waste transfer station, economical considerations, recycling solid wastes, materials recovery facilities

Readings:

1. Tchobanoglous G., Theisen H., and Vigil S.A. (2014*). Integrated Solid Waste Management, Engineering Principles and Management Issues,* 2nd Ed., McGraw-Hill, USA.
2. Vesilind, P.A., and Worrell W. A. (2016) *Solid Waste Engineering*, 2nd Ed., Cengage India.
3. Tchobanoglous G., Frank Kreith., (2002). *Hand Book of Solid Waste Management*, 2nd Ed., McGraw Hill, USA.
4. Thomas Christensen, (2011). *Solid Waste Technology & Management*, John wiley & sons, USA.
5. Letcher, T.M., Vallero, D.A. (2011). *Waste: A Handbook for Management*, 1st Ed, Academic Press, USA.
6. John Pichtel (2014). *Waste Management Practices: Municipal, Hazardous and Industrial*, 2nd Ed., CRC Press, USA.
7. Ajith, P.S., Hari Kumar, P.N., (2016). *Solid Waste Management of Municipalities*, Abhijeet Publications, India.
8. Jagbir Singh, Ramanathan, AL., (2019). *Solid Waste Management - Present and Future Challenges*, I.K. International publishing House Pvt.Ltd., India.
9. Rama Chandra, T.V., (2016). *Environmental Engineering Series Management of Municipal Solid Waste*, TERI Press, India.
10. Ahmed El Rabbany (2002): *Introduction to GPS- The Global Positioning System, Second Edition*, Artech House Publishers, India.

CE5812	ENVIRONMENTAL HEALTH AND SAFETY	DEC	3 – 0 – 0	3 Credits

Pre-requisites: NONE

Course Outcomes: At the end of the course the student will be able to:

CO1	Understand salient aspects of environment health and safety
CO2	Implement safety protocols related to environment health and safety
CO3	Identify various activities in a working environment that affect health and safety
CO4	Implement occupational safety policies

Detailed Syllabus:

EHS Management System
Purpose and responsibility, EHS Program Goals and Objectives, EHS Program, EHS Committees, Workplace Inspections, EHS Self-Inspection Checklists, Introduction to Environmental Compliance

Injury, Illness, and Near Miss
Reporting Incidents, Personal Injuries, and Near Misses, Incident Investigation of Injuries, Illnesses, and Near Misses Workers, Lost-Time Injuries and Illnesses, Return to Work Program, First Aid, Travel Immunization Program

Fire Safety
Emergency Planning and Evacuation, Fire Emergency Procedure, Reporting Fires, Life Safety: Exitways, Life Safety Policy, Life Safety: Public Assemblies, Portable Fire Extinguishers, Storage and Use of Flammable and Combustible Liquids, Sign and Tag Requirements for Accident Prevention, Fire and Life Safety Coordination, Managing Fire Alarms, Life Safety: Electrical Equipment, Exterior Open Flame, Policy on Fire Protection System Impairments, False Alarm Ordinance, Building Emergency Coordinators

Occupational Safety Policies
Industrial Hygiene Program Requirements, Medical Surveillance, Hearing Conservation Program, Use of Chemical Carcinogens, Chemical Waste Disposal, OSHA Bloodborne Pathogens Standard, OSHA Laboratory Standard, Use of Biohazardous Agents, Product or Device Alert/Recall, Personal Protective Equipment, Eye and Face Protection, Eye Protection for Chemistry Lab Courses, Foot Protection, Compliance with Laboratory Safety Standards, Respiratory Protection Program, Laboratory Ventilation Policy, Clearance of Laboratories Where Hazardous Materials Have Been Used, Indoor Air Quality Policy

Readings:

1. National Research Council (US), Committee on Prudent Practices in the Laboratory (2011). *Prudent Practices in the Laboratory: Handling and Management of Chemical Hazards, updated version*, National Academies Press, USA.
2. *Environment, Health and Safety Manual* (2020), The university of North Carolina at chapel hill, North Carolina, USA.

SM5071	ENTREPRENEURSHIP IN WASTE MANAGEMENT	DEC	3 – 0 – 0	3 Credits

Pre-requisites: NONE

Course Outcomes: At the end of the course the student will be able to:

CO1	Assimilate the attitudes, values, characteristics, behaviour, and processes associated with possessing an entrepreneurial mindset and engaging in successful appropriate entrepreneurial behaviour.
CO2	Develop entrepreneurial opportunities & recognize the entrepreneurial potential within yourself, whether you want to start your own business or act as an entrepreneur within an existing organization
CO3	Understand how to turn a new business concept into a sustainable business venture
CO4	Explore entrepreneurial leadership and management style.

Detailed Syllabus:

Introduction to Entrepreneurship, Practicing Entrepreneurship and its significance and contribution to the economy
Entrepreneurial Mindset, Supporting Social Entrepreneurship, Entrepreneurship and opportunities in Waste Management, Generating New Ideas, Using Design Thinking
Building Business Models, Planning a Waste Managing Enterprise, Human Resources and Infrastructure, Arranging and Managing Finance, Marketing and Pitching the idea
Government rules, Navigating Legal & IP Issues involved in Waste Management, Role of financial institutions
Innovations in waste management, Revenue models, Developing Networks, Challenges in Entrepreneurship, Learning from Failure
Case studies: Wealth from waste and entrepreneurs in India and other countries

Readings:

1. Hisrich, R.D., and Peters, M.P., Shepherd A.D., (2013). *Entrepreneurship*, 9th Ed., McGraw Hill, USA.
2. Kuratko, D.F., (2017) *Entrepreneurship: Theory, Process, Practice*, 10th Ed., Cengage Learning Publishing, India.
3. Peter Drucker, (2012). *Innovation and Entrepreneurship*, Routledge Publishers, England UK.

CH5121	WASTE TO ENERGY	DEC	3 – 0 – 0	3 Credits

Pre-requisites: NONE

Course Outcomes: At the end of the course the student will be able to:

CO1	Understand technologies for generation of energy from solid waste
CO2	Study various energy generation methods
CO3	Identify sources of energy from bio-chemical conversion
CO4	Analyse the environmental and health impact of waste to energy conversion

Detailed Syllabus:

Characterization of wastes, agricultural residues and wastes including animal wastes; industrial wastes; municipal solid wastes. Waste processing types and composition of various types of wastes; Characterization of Municipal Solid Waste, Industrial waste and Biomedical Waste, waste collection and transportation; waste processing-size reduction, separation; waste management hierarchy, waste minimization and recycling of Municipal solid waste.
Thermo chemical conversion: incineration, pyrolysis, gasification of waste using gasifiers, environmental and health impacts of incineration; strategies for reducing environmental impacts. Energy production from wastes through incineration, energy production through gasification of wastes. Energy production through pyrolysis and gasification of wastes, syngas utilization.
Bio-chemical Conversion: Anaerobic digestion of sewage and municipal wastes, direct combustion of MSW-refuse derived solid fuel, industrial waste, agro residues, anaerobic digestion biogas production, and present status of technologies for conversion of waste into energy, design of waste to energy plants for cities, small townships and villages. Energy production from wastes through fermentation and trans esterification. Cultivation of algal biomass from wastewater and energy production from algae. Energy production from organic wastes through anaerobic digestion and fermentation, introduction to microbial fuel cells. Process analysis and reactor configurations for Methane production, Energy assessment, Bio-methanation from sludge digestion.
Energy production from waste plastics, gas cleanup Waste, Heat Recovery: Concept of conversion efficiency, energy waste, waste heat recovery classification, advantages and applications, commercially viable waste heat recovery devices
Environmental and health impacts-case studies: Environmental and health impacts of waste to energy conversion, case studies of commercial waste to energy plants, waste to energy- potentials and constraints in India, eco-technological alternatives for waste to energy conversions.

Readings:

1. Robert C. Brown, (2019). *Thermo-chemical Processing of Biomass: Conversion into Fuels, Chemicals and Power,* John Wiley and Sons, USA.
2. Sergio Capareda, (2013). *Introduction to Biomass Energy Conversions,* CRC Press, USA.
3. Krzysztof J Ptasinski, (2016). *Efficiency of Biomass Energy: An Exergy Approach to Biofuels, Power, and Biorefineries*, John Wiley & Sons, USA.
4. Vesilind, P.A., and Worrell W. A. (2016) *Solid Waste Engineering*, 2nd Ed., Cengage India.

CH5122	GREEN AND CLEANER TECHNOLOGIES	DEC	3 – 0 – 0	3 Credits

Pre-requisites: NONE

Course Outcomes: At the end of the course the student will be able to:

CO1	Estimate the carbon credits of various activities
CO2	Acquire principles of Energy efficient technologies.
CO3	Learn the importance of green fuels and its impact on environment.
CO4	Identify the importance of life cycle assessment

Detailed Syllabus:

Greenhouse emissions, Climate change and role of green and cleaner technologies, causes and effects. Diagnostics and baseline determination, Climate change mitigation and adaptation strategy. Risk assessments & mitigation. Carbon accounting, Carbon Market. Carbon capture and storage Potential Carbon sequestration (forest sinks); Green Technology – definition- Importance – Historical evolution – advantages and disadvantages of green technologies-factors affecting green technologies- Role of Industry, Government and Institutions – Industrial Ecology – role of industrial ecology in green technology. Principles of Green Technologies, Reasons for Green Technology, resource minimization, waste minimization, concepts, Green reactions solvent free reactions, Catalyzed (heterogeneous/homogeneous) reactions, Ultrasound mediated reactions, Bio catalysts etc. Materials for "Green" Systems: Green materials, including biomaterials, biopolymers, bioplastics, and composites. Green Technologies for Energy, Green Fuels– Definition-benefits and challenges – comparison of green fuels with conventional fossil fuels with reference to environmental, economical and social impacts. Various Technologies Available for Energy Production: Wind, Solar biofuels etc. Principles of Cleaner production, barriers, role of Industry, clean development mechanism, reuse, recovery, recycle, raw material substitution-Wealth from waste, case studies. Overview of Cleaner Production Assessment Steps and Skills, Process Flow Diagram, Material Balance, Cleaner Production, Option Generation – Technical and Environmental Feasibility analysis Economic valuation of alternatives.

Readings:

1. Clark, J.H., and Macquarrie, D.J., (2002). *Handbook of Green Chemistry and Technology,* John Wiley and Sons, USA.
2. Paul Anastas, and John Warner, (2000). *Green Chemistry: Theory and Practice,* Oxford University Press, USA.
3. Mike Lancaster, (2016). *Green Chemistry- An introductory Text,* 3rd Ed, Royal Society of Chemistry, UK.
4. Matthew N. O. Sadiku, (2020). *Emerging green technologies*, CRC Press, USA.
5. Pradeep Tomar, and Gurjit Kaur, (2019). *Green and Smart Technologies for Smart Cities*, CRC Press, USA.

BT5125	BIOTECHNOLOGICAL APPROACHES FOR WASTE MANAGEMENT	DEC	3 – 0 – 0	3 Credits

Pre-requisites: NONE

Course Outcomes: At the end of the course the student will be able to:

CO1	Identify salient aspects of biological processes for waste management
CO2	Design of bioreactors for waste treatment
CO3	Apply principles of bioremediation for handling waste
CO4	Plan suitable biotechnological process for hazardous waste management

Detailed Syllabus:

Introduction to waste management. Introduction to bioreactor, Microbial growth kinetics, Design of a bioreactors, Instrumentation and control, Aeration and agitation, Effluent treatment. Bio-industrial waste management. Strategies for sustainable waste management.

Bioreactors for wastewater treatment: – Aerobic System Biological processes for domestic and industrial wastewater treatments; Aerobic systems - activated sludge process, trickling filters, biological filters, rotating biological contractors (RBC), Fluidized bed reactor (FBR), expanded bed reactor, Inverse fluidized bed biofilm reactor (IFBBR) packed bed reactors air- sparged reactors. Biological Treatment of Wastewater, Anaerobic System Anaerobic biological treatment – contact digesters, packed column reactors, UASB. Case studies on biological wastewater treatments.

Bioremediation:- Introduction, constraints and priorities of Bioremediation, Biostimulation of Naturally occurring microbial activities, Bioaugmentation, in situ, ex situ, intrinsic & engineered bioremediation. Solid phase bioremediation - land farming, prepared beds, soil piles, Phytoremediation. Composting, Bioventing & Biosparging; Liquid phase bioremediation - suspended bioreactors, fixed biofilm reactors. Metal Biotechnology Mining and Metal biotechnology – with special reference to Copper & Iron. Microbial transformation, accumulation and concentration of metals, metal leaching, extraction and future prospects. Case studies on Bioleaching.

Hazardous Waste Management: Introduction - Xenobiotic compounds, recalcitrance. hazardous wastes - biodegradation of Xenobiotics . Biological detoxification - market for hazardous waste management, biotechnology application to hazardous waste management - examples of biotechnological applications to hazardous waste management – cyanide detoxification - detoxification of oxalate, urea etc. - toxic organics – phenols, STP, antibiotic treatment. Case studies on Bioremediation of Xenobiotic compounds

Readings:

1. Surajit Das, (2014). *Microbial biodegradation and bioremediation*. Elsevier.
2. Stanbury, P. F., Whitaker, A., & Hall, S. J. (2016). *Principles of fermentation technology*. 3rd Ed, Butterworth-Heinemann, UK.
3. Doran, P. M., Fell J.M.G., (1995). *Bioprocess engineering principles*. Academic Press USA.
4. Mohapatra, P. K. (2010). *Textbook of environmental biotechnology*, I.K. International Pvt Ltd. India.
5. Metcalf & Eddy, (2017), *Waste water Engineering Treatment and Reuse*, 4th Ed, McGraw Hill Inc, India.
6. Rittmann, B. E., & McCarty, P. L. (2020). *Environmental biotechnology: principles and applications*. 2ndEd, Tata McGraw-Hill Education. India.
7. Singh, A., Kuhad, R.C., (2013). *Biotechnology for environmental management and resource recovery*, Springer, India.

CE5302	WATER AND WASTEWATER TREATMENT	DEC	3 – 0 – 0	3 Credits

Pre-requisites: NONE

Course Outcomes: At the end of the course the student will be able to:

CO1	Design the components of water treatment plant
CO2	Design the components of wastewater treatment plant
CO3	Design the low cost sanitation systems
CO4	Design sludge treatment and disposal methods.

Detailed Syllabus:

Water transmission main design- Gravity and pumping main; Design of pump house; – Storage reservoirs- Water treatment Plant Design: Screening – Aeration- Sedimentation – Coagulation, Flocculation- Slow sand Filtration–Rapid Sand Filtration- Back washing –Membrane Processes- --Disinfection-

Design of Preliminary and Primary Treatment Operations for wastewater: Screening, Comminuting, Grit removal, Skimming Tank, Primary sedimentation.

Design of Suspended Growth Processes, Modifications, Process Design Criteria, Oxygen and Nutrient Requirements- Design of Attached Growth Processes: Trickling Filters (Standard Rate, High Rate), Biofilters, Rotating Biological Contactors.

Design of Waste stabilisation Ponds, Lagoons, Root Zone Treatment Systems, Membrane bioreactors, fluidized bed reactors, Hybrid Systems, Anaerobic systems for wastewater treatment, Design of Septic tank, Sludge Treatment and Disposal, Design of Digester Tank, Sludge Dewatering and Ultimate Disposal.

Readings:

1. Mackenzie L. Davis, (2017). Water and Wastewater Engineering: Design Principles and Practice, McGraw Hill, India.
2. Peavy, H.S, Rowe, D.R., and Tchobanoglous, G., (2017). *Environmental Engineering*, Indian ED, McGraw Hill Inc., India.
3. Shammas, N.K., and Wang, N.K., (2018) *Lawrence K. Wang, Water Supply and Wastewater Removal*, 3rd Edition, John Wiley & Sons, Inc, India.
4. David Hendricks, (2010). *Fundamentals of Water Treatment Unit Processes - Physical, Chemical, and Biological,* CRC Press, USA.
5. Metcalf & Eddy, (2017), *Waste water Engineering Treatment and Reuse*, 4th Ed, McGraw Hill Inc, India.
6. CPHEEO, (1999). *Manual on Water Supply and Treatment*, 3rd Ed., Ministry of Urban Development, India.
7. CPHEEO, (2013). *Manual on Sewerage and Sewage Treatment,* 3rd Ed., Ministry of Urban Development, India.

CE5312	LIFE CYCLE ANALYSIS	DEC	3 – 0 – 0	3 Credits

Pre-requisites: NONE

Course Outcomes: At the end of the course the student will be able to:

CO1	Understand the concept of Life cycle thinking and framework of Life cycle assessment.
CO2	Understand the computational structure behind LCA software packages
CO3	Write report/paper based on a LCA study

Detailed Syllabus:

Introduction, Life Cycle Assessment concepts.

A brief history of Life-cycle Inventory analysis, overview of methodology, Three components, Indentifying and setting boundaries for life-cycle stages, issues that apply to all stages, Applications of inventory analysis

Procedural framework of Life-cycle inventory: Introduction, define the purpose and scope of inventory

General issues in Inventory analysis: Introduction, Using Templates, Data issues, special case boundary issues

Issues Applicable to specific life cycle stages: Introduction, Raw Material acquisition stage, Manufacturing stage, Use/Reuse/Maintenance stage, Recycle/Waste Management stage.

Term Project Proposal, Process Based LCA, Software Demo: SimaPro Part-1, LCA Software Demo: SimaPro Part 2, LCA Software Demo: GREET, LCA Software Demo: BEES (Construction Materials)

Readings:

1. Ciambrone , D.F., (2019). *Environmental Life Cycle Analysis*, Taylor and Francis Group, UK.
2. Jeroen Guinee, (2014). *Handbook on Life Cycle Assessment: Operational guide to the ISO standards,* Springer, USA.

CE5315	ENVIRONMENTAL SYSTEMS ENGINEERING	DEC	3 – 0 – 0	3 Credits

Pre-requisites: NONE

Course Outcomes: At the end of the course the student will be able to:

CO1	Analyze physical, chemical and biological processes in environmental systems
CO2	Formulate and solve governing equations for pollutant transport
CO3	Analyze engineered transport system
CO4	Plan and analyze treatment systems

Detailed syllabus:

Basic concepts of mole and mass concentration: notations and conventions, Review of mass balance concepts.

Diffusive transport: Diffusion and Fick's first law, Calculation of molecular diffusion coefficients in air and water

The constitutive transport equation: Derivation of general transport equation and special forms ie continuity and NS equations and similarity between equations of mass momentum and heat dispersion laws.

Theories of mass transport: two film theory, penetration and surface renewal theory, Boundary layer theory. Mass transport correlations

Transport in sheared reactors: Fluid shear and turbulence, transport in steady sheared fluids, turbulent sheared fluids, shear rates in mixed reactors

Particles and fractals: Introductions, particle size spectra, solid particles and fractal aggregate geometries, measuring and calculating fractal dimensions from particle size distributions.

Coagulation in natural and engineered systems: Introduction, general coagulation equations, factors affecting the stability of aquasols, coagulation kinetics, fractal coagulation models.

Finite difference and Finite volume procedures for solutions of partial differential equations of Mass, Momentum and Energy transport phenomenon

Readings:

1. Bruce E. Logan,(2012). *Environmental Transport Processes*, 2nd Ed., John Wiley and Sons, USA.
2. Cussler, E.L., (2009). *Diffusion: Mass transfer in fluid systems,* 3rd Ed., Cambridge University Press, UK.
3. John S. Gulliver, (2012). *Introduction to chemical transport in the environment*, Cambridge University Press, UK.

CE5861	OPERATIONAL RESEARCH	DEC	3 – 0 – 0	3 Credits

Pre-requisites: None

Course Outcomes: At the end of the course the student will be able to:

CO1	Formulate and solve deterministic optimization models
CO2	Apply deterministic optimization techniques for resource allocation, scheduling, inventory control
CO3	Apply decision theory and stochastic optimization techniques for decision making under uncertainty
CO4	Formulate and solve optimization models for planning and design of waste management systems

Detailed syllabus

Modeling Techniques: Concepts of Systems Engineering, Types of mathematical models, Formulation of a prescriptive model, Overview of optimization techniques

Linear Programming, Graphical method, Simplex method, Sensitivity analysis, Dual LP, Transportation problem, Assignment problem, Integer Linear Programming

Dynamic Programming: Concepts of dynamic programming, Formulation of recursive equation, Resource allocation using DP, Capacity expansion, Inventory control

Nonlinear Optimization, Classical optimization techniques, Lagrange methods, Kuhn-Tucker conditions, steepest gradient technique and other gradient based search techniques, Overview of genetic algorithm

Decision Theory: Decision analysis, Decision making under risk and uncertainty, Markovian decision process, stochastic inventory control

Simulation: Types of simulation models, Monte-Carlo simulation, Applications of simulation

Other Optimization Techniques, Overview of Multi Objective Optimization Techniques, Fuzzy Optimization and Fuzzy Decision Making

Reading:

1. Taha, H. A. (2017), *Operations Research,* 10th Ed, Pearson Higher Education, USA.
2. Hiller, F. S., Lieberman, G. J., Nag, B., Basu, P., (2017), *Introduction to Operations Research*, McGraw Hill Publications, USA.
3. Revelle, C.S., Whitlatch, E.E., and Wright, J.R. (2013), *Civil and Environmental Systems Engineering*, Pearson Education Inc., USA.
4. Daellenbach, H. G. and George, J. A. (1978), *Introduction to Operations Research Techniques*, Allyn and Bacon Inc., Boston.
5. Gillett, B. E. (1989), *Introduction to Operations Research – A Computer Oriented Algorithmic Approach*, Tata McGraw Hill Publishers, India.

CE5862	REGULATORY AND LEGAL FRAMEWORK FOR WASTE MANAGEMENT	DEC	3 – 0 – 0	3 Credits

Pre-requisites: None

Course Outcomes: At the end of the course the student will be able to:

CO1	Understand the Regulatory and legal frameworks in waste management
CO2	Identify various components of Regulatory and legal frameworks in WM
CO3	Assess the challenges in the Regulatory and legal frameworks in WM
CO4	Formulate the frameworks for legal and regulatory requirements for emerging waste management scenarios

Detailed syllabus

Introduction
Overview of waste management in India, importance of legal and regulatory frameworks, Difference between Regulatory and Legal frameworks, Legal Landmarks in the History of Waste management in India, Institutional framework on solid waste management in India.

Waste Management Laws in India
The Environmental Protection Act, The Hazardous Wastes (Management, Handling and Transboundary Movement) Rules, 2008, The Plastic Waste (Management and Handling) Rules, 2011, Bio-Medical Waste (Management and Handling) Rules, 1998, The E- Waste (Management and Handling) Rules, 2011, The Batteries (Management and Handling) Rules, 2001.

Solid waste management rules 2016
Source segregation of waste and Duties of waste generator, Introduction of the concept of partnership in Swachh Bharat, Collection and disposal of sanitary waste, Collect back scheme for packaging waste, User fee and spot fine, Promotion of marketing and utilization of compost, Promotion of waste to energy, Criteria and standards for waste treatment facility and pollution control, Management of waste in hilly areas, Duties of constitutional bodies and Ministries

Regulatory and Legal policy making in Waste Management
Waste management protocol during epidemics, Circular economy in waste management, Role of global economy, Stake holder engagement, Best practices in India and Abroad- Case studies

Reading:

1. “National Environment Policy, 2006”, Ministry of Environment and Forests, Government of India, Approved by the Union Cabinet on 18 May, 2006
2. “Municipal solid waste management Manual Part 1,2 & 3”(2016), Central public health and environmental engineering organization, Ministry of Urban Development, Government of India.

CE5863	BIOREMEDIATION	DEC	3 – 0 – 0	3 Credits

Pre-requisites: NONE

Course Outcomes: At the end of the course the student will be able to:

CO1	Apply fundamental principles of bioremediation processes
CO2	Identify bioremediation processes for different pollutants
CO3	Design processes for enhancing biodegradation.
CO4	Identify ethical, environmental, societal and safety issues related to bioremediation

Detailed Syllabus:

Fundamental aspects of environmental microbiology
Structure and Functions of Procaryotic Cells -Structure and Functions of Eucaryotic Cells
Taxonomy of Microorganisms: Bacteria- Algae, Fungi and Protozoa -Study of Microbial Structure - Light Microscopy -Dark-field and Phase-contrast Microscopy -Electron Microscopy -Environmental Significance of Bacteria, Fungi, and Algae -Microbial Metabolism, Growth and Biokinetics - Microbial Nutrition and Metabolism - Microbial Growth and Energy - Enzymes and Their structures - Biokinetic Models - Batch and Continuous Chemostat Studies - Determination of Biokinetic Parameters
Microbiology reactions
Suspended Growth Reactors - Biofilm Reactors - Batch Reactors - Completely Stirred Tank Reactors - Plug Flow Reactors - Reactors in Series - Engineering Design of Reactors
Bioflim processes
Trickling Filters and Biological Towers -Rotating Biological Contactors - Granular Media Filters - Fluidized-bed Reactors -Hybrid Biofllm Processes
Bioremediation for soil environment
Environment of Soil Microorganisms -Soil Organic Matter and Characteristics -Soil Microorganisms Association with Plants - Pesticides and Microorganisms -Petroleum Hydrocarbons and Microorganisms -Industrial solvents and Microorganisms -Biotechnologies for Ex-Situ Remediation of Soil - Biotechnologies for in-Situ Remediation of Soil - Phytoremediation Technology for Soil Decontamination
Biotreatment of metals
Microbial Transformation of Metals -Biological Treatment Technologies for Metals Remediation - Bioleaching and Biobenificiation -Bioaccumulation -Oxidation/Reduction Processes -Biological Methylation -Case studies
Emerging environmental biotechnologies
Phytoremediation -Sequestering Carbon Dioxide -Biomonitoring -Application of Microbial Enzymes - Biomembrane Reactors

Readings:

1. Ergas, S.J., Chang, D.P.Y., Schreoder, E.D., and Eweis J.B., (1998). *Bioremediation Principles*, WCB/McGraw-Hill, USA.
2. Rittmann, B. E., & McCarty, P. L. (2020). *Environmental biotechnology: principles and applications*. 2nd Ed, Tata McGraw-Hill Education. India.

CE5864	INDUSTRIAL WASTE MANAGEMENT AND AUDIT	DEC	3 – 0 – 0	3 Credits

Pre-requisites: NONE

Course Outcomes: At the end of the course the student will be able to:

CO1	Implement fundamental concepts of industrial waste management
CO2	Analyze the effects of disposal of industrial wastes
CO3	Design system or process to meet desired needs and imposed constraints
CO4	Prepare documentation for waste management auditing

Detailed syllabus:

Introduction:
Impact of Industrial Waste on the society and environment. Environmental standards applicable to industrial units. Segregation and classification of waste from the industries**.** Treatment and disposal methods.

Construction and Demolition Waste (C&D waste):
Introduction, characteristic, Storage of C&D waste, collection and transportation, 3R concept, Disposal**.**

Residual waste management from industries and treatment plants:
Physical, chemical and biological characteristics of residues from industries and treatment plants; Treatment methods- physical, chemical and biological treatment methods; Disposal methods

Hotel waste management:
Characterization of waste, Energy content of the waste, treatment and disposal of the hotel waste.

Waste export procedure and documentation:
Export regulations, classification of the waste, export compliance, export documentation procedures, recordkeeping requirements.

Waste management audit:
Necessity for internal audit, standards for audits, audit planning, materiality and sampling, internal control overview of compliance, Evaluate the Economics of Pollution Prevention, Environmental Audit, understanding of rules and regulations, documentation procedures, recordkeeping requirements.

Readings:

1. Tchobanoglous G., Frank Kreith., (2002). *Hand Book of Solid Waste Management*, 2nd Ed., McGraw Hill, USA.
2. Keith Waldron, (2009). *Handbook of waste management and co-product recovery in food processing*, Vol 2, CRC Press, USA
3. Thomas Christensen, (2011). *Solid Waste Technology & Management*, John wiley & sons, USA.
4. Chandrappa, R., Das, D.B., (2012). *Solid waste management: Principles and practic*e, Springer, USA.
5. Torgal, F.P., Ding, Y., Colangelo, F., Koutamanis, A., Tuladhar, R., (2020).*Advances in Construction and Demolition Waste Recycling: Management, Processing and Environmental Assessment*, Elsevier, USA.
6. Johnson, T.E., Bade, D.L., (2010). *Export/Import Procedures and Documentation.* 4th Ed, AMACOM, USA.
7. Senthilvelmurugan, J., Mahalakshmi, S.,(2019). *Export and Import Documentation and Procedures*
8. Frank Woodard, (2001). *Industrial Waste Treatment Handbook.* Elsevier, USA.

CE5865	GEOSPATIAL TECHNOLOGIES IN ENVIRONMENTAL MANAGEMENT	DEC	3 – 0 – 0	3 Credits

Pre-requisites: NONE

Course Outcomes: At the end of the course the student will be able to:

CO1	Apply fundamental aspects of Geographical Information System and Remote Sensing
CO2	Conceptualize the geospatial applications for environmental management
CO3	Implement geospatial technologies for environmental management

Detailed Syllabus:

Fundamentals of GIS –Modeling Real World Features Data, Data Models – Spatial and Non-spatial, Components, Data Collection and Input,

Topology – Types of Errors, Editing and Error Rectification, Types of Topology, Modeling topological Relationships, Tolerances.

Spatial Analysis and Map Composition – Proximity Analysis, Overlay Analysis, Buffer Analysis, Network Analysis, Digital Elevation Models, Preparation of qualitative and quantitative maps, levels of maps.

Remote Sensing Principles: Active and Passive Radiation, Electromagnetic Radiation - Reflectance, Transmission, Absorption, Thermal Emissions, Spectral reflectance of Earth's surface features, Platforms and Sensors, Drone based surveys

Geospatial based project planning and Implementation for environmental issues and waste management– Understanding the Requirements, Phases of Planning, Specifications, Procedure for analysis projects and design projects, Optimised route planning for waste management, Landfill/Solid waste management site selection, Spatial modelling aspects for public health and environmental management

Readings:

1. Kang Tsung Chang.,(2019). *Introduction to Geographic Information Systems*,9th Ed, Mc Graw Hill Publishing Company Ltd, USA.
2. Lillesand T.M & Kiefer R.W., Chipman, J.W.,(2011). *Remote Sensing and Image Interpretation*, John Wiely India Pvt Ltd.
3. William Bajjali, (2018). *ArcGIS for Environmental and Water Issues,* Springer, USA.
4. Allan Brimicombe, (2009). *GIS, Environmental Modeling and Engineering*, 2nd Edition, CRC Press, 2009.
5. Andrew Skidmore, (2017). *Environmental Modelling with GIS and Remote Sensing*, CRC Press, USA.

CE5866	LANDFILL DESIGN AND OPERATION	PCC	3 – 0 – 0	3 Credits

Pre-requisites: NONE

Course Outcomes: At the end of the course the student will be able to:

CO1	Identify salient aspects of landfills
CO2	Suggest suitable site and configuration for landfills
CO3	Plan and design the major components of landfill as per regulatory standards
CO4	Operate and monitor landfills

Detailed syllabus

Introduction: Landfill principle, Landfill classification, types and methods, Lanfill's role in sustainable waste management, Waste and landfill fundamentals.
Siting and regulatory requirements: Size of the landfill, Traffic and Access, Site-specific Information, Site Hydrology, Permits, Other Regulatory Issues, Additional Regulatory Requirements for Bioreactor Landfills and secured Landfill
Typical landfill configurations: Cell Layout, Water Table, Aquifers, and Bedrock, Landfill foundation and slope stability, Site development plan
Key aspects of design and construction: Preparation of landfill sub-base, Liner design, Leachate management, Landfill gas management, daily, intermediate and final cover design, Stormwater management, Bioreactor landfill design, Secured landfill design, Landfill Construction
Landfill operation: Waste acceptance at landfills, Waste filling and compaction, Bioreactor Landfill Operations, Tools and Techniques for Landfill Monitoring
Post-construction monitoring: Leachate monitoring and leakage detection, Groundwater monitoring, Landfill gas migration, Stability of the final cover
Landfill Closure and Post Closure: Elements of closure and Post-closure process, Closure considerations for sustainable landfills, Determination of End of post-closure care, Landfill reclamation and reuse, Final site use and configuration

Readings:

1. Townsend, T.G., Powell, J., Jain, P., Xu, Q., Tolaymat, T., and Reinhart, D. (2015) *Sustainable Practices for Landfill Design and Operation*, Springer, USA.
2. Tchobanoglous G., Theisen H., and Vigil S.A. (2014*). Integrated Solid Waste Management, Engineering Principles and Management Issues,* 2nd Ed., McGraw-Hill, USA.
3. John Pichtel (2014). *Waste Management Practices: Municipal, Hazardous and Industrial*, 2nd Ed., CRC Press, USA
4. Qian X., Koerner R.M., and Gray D.H., (2002). *Geotechnical Aspects of Landfill Design and Construction*, 1st Ed., Prentice Hall, USA.
5. CPHEEO,(2016). *Manual on Municipal Solid Waste Management*, Ministry of Urban Development, India.

SM5051	OPERATIONS AND MAINTENANCE	DEC	3 – 0 – 0	3 Credits

Pre-requisites: None

Course Outcomes: At the end of the course the student will be able to**:**

CO1	Understand the operations involved in waste management methods and techniques.
CO2	Examine the government regulations and initiatives in waste maintenance.
CO3	Explain the importance of hygiene and safety in waste management.
CO4	Identifying various operational maintenance issues of waste management and its ‘solutions.

Detailed syllabus:

Fundamental principles, operating strategy, responsibilities of waste generators, responsibilities of the municipality, NGOs, municipal collection of solid wastes and special wastes, political will, community mobilization, resolving bottlenecks, addressing environmental hygiene and safety.
Waste **c**ollection routes, mode of transportations, vehicles used for collecting waste, economy in transportation, waste optimization of transport routes, routing and scheduling, Replacing, repairing, track recording of vehicles, machinery, safety of transport workers. Maintenance of vehicles.
Operation and maintenance of waste transfer stations: role of transfer stations, transfer station design, site design plan, transfer technology, transfer station operations, operations and maintenance plans, facility operating hours, interacting with the public, waste screening. Emergency situations, record keeping. Environmental issues, safety issues.
Role of community landfill site, daily operations, access control, control of windblown debris, control of fire. Release to the receiving environment, troubleshooting and resolving safety, service, and operational issues maintain and distribute waste management related information on a daily basis.
Waste management equipments, life cycles, Types of maintenances, maintenance of equipment, plant, life cycle. Application of software for Operational activities of procurement, time and attendance. Importance of data collection for maintenance, employee assignment and scheduling problems, facility maintenance & Renovation, Inspection and Monitoring, Odor management methods, decommissioning of waste management facilities, usage of data science for maintenance activities.

Readings:

1. Central Pollution Control Board,(2016). *Management of Municipal Solid Wastes*, India,
2. Central Pollution Control Board,(2014) *Management of Municipal Solid Waste*. Ministry of Environment and Forests, New Delhi, India.
3. Rajaram, V., Siddiqui F. Z., & Agrawal, S., Khan, M.E., (2016). *Solid and Liquid Waste Management,* PHI learning Pvt Ltd, India.
4. Tchobanoglous G., Frank Kreith., (2002). *Hand Book of Solid Waste Management*, 2nd Ed., McGraw Hill, USA.

SM5031	MARKETING MANAGEMENT FOR WASTE	DEC	3 – 0 – 0	3 Credits

Pre-requisites: NONE

Course Outcomes: At the end of the course the student will be able to:

CO1	Understand the concepts and issues of waste marketing
CO2	Apply contemporary marketing theories to the demands of business
CO3	Demonstrate the ability to analyze marketing problems and opportunities using a variety of strategies and tactics
CO4	Create an understanding on the importance of integrated marketing communication and its elements

Detailed syllabus:

Introduction to Marketing Management, Core Concepts of Marketing, Marketing Orientations, Meaning and definition of Solid Waste Markets, Issues in Waste Marketing
Marketing Environment, Marketing Research, Marketing Mix, Marketing Strategy: evolving Waste Marketing Strategy
Product Life Cycle, Pricing of the Product / Service, Pricing Strategies, Determinants of Price, Branding the product, Product features, Types or levels of products, Value creation in product, Value chain analysis
Consumer Behaviour, Segmentation, Targeting and Positioning, Solid Waste Distribution systems, Channels of distribution
Sales teams and targets, Integrated Marketing communications, Role of Social Media, Promotion mix elements, Role of contemporary modes of marketing communications, CRM and International Marketing.

Readings:

1. Kotler, P., Keller, K.L., (2011). *Marketing Management,* 14th Ed, Pearson, USA.
2. Philip T. Kotler, Gary Armstrong, Prafulla Agnihotri, (2018) *Principles of Marketing,* Pearson Education, USA.
3. Ramaswamy and Namakumari,(2018) *Marketing Management*, Sage Publishing,USA.

CH5169	ENERGY AUDIT AND CONSERVATION	DEC	3 – 0 – 0	3 Credits

Pre-requisites: NONE

Course Outcomes: At the end of the course the student will be able to:

CO1	Implement energy audit for a chemical plant
CO2	Plan energy conserving strategies
CO3	Evaluate the suitability of renewable energy resources
CO4	Analyze the energy utilization of a process equipment

Detailed syllabus

Energy Scenario: Energy use patterns, energy resources, Oil a critical resource, economic and environmental consideration, Future scenario

Heat & work: First & second law of thermodynamics, Heat Engines.

Energy Audit: Energy conversion, Energy index, Energy consumption representation - pie chart, Sankey diagram & load profile, general audit, detailed audit, waste heat recovery.

Targeting and Conservation: Energy utilization and conversion – thermal efficiency, Heat Exchangers – heat recovery , Air conditioners – supply and removal of heat.

Use of alternate energy: Solar energy, Wind energy, Nuclear energy, Biomass, Geothermal energy, Future Energy Alternatives.

Pinch Analysis and Process Heat Integration

Energy Management Key Performance Indicators and Energy Dashboards

Case Studies: Energy conservation in alcohol industry, fertilizer industry, and pulp and paper industry, Energy conservation in different units of refinery like FCCU, HCU and ADU.

Reading:

1. Murphy W.R. and Mckay G., (2007) *Energy Management,* Elsevier, USA.
2. Hinrichs, R., and Kleinbach M.H.,(2013) *Energy: Its Use and the Environment*, 9th Ed, Cengage Learning, USA.
3. Capehart B. L., Turner W. C. and Kennedy W. J.,(2012). *Guide to Energy Management*, 7th Ed, The Fairmont Press, USA.
4. Rai G. D., (2010) *Non-conventional Energy Sources,* 6th Ed, Khanna Publishers, India.
5. Rossiter, A.P., Jones, B.P., (2015). *Energy Management and Efficiency for the process industries*, Wiley, USA.ss

CE5841	Seminar – I	PCC	0 – 0 – 2	1 Credits

Pre-requisite: NONE

Course Outcomes: At the end of the course the student will be able to:

CO1	Select a topic relevant to planning, analysis and design of a Waste Management systems
CO2	Undertake a critical review of the literature on the chosen topic
CO3	Prepare and present a technical report

CE5891	Seminar – II	PCC	0 – 0 – 2	1 Credits

Pre-requisite: NONE

Course Outcomes: At the end of the course the student will be able to:

CO1	Select a topic relevant to planning, analysis and design of a Waste Management systems
CO2	Undertake a critical review of the literature on the chosen topic
CO3	Prepare and present a technical report

CE6842	Comprehensive Viva	PCC	0 – 0 – 0	2 Credits

Pre-requisite: NONE

Course Outcomes: At the end of the course the student will be able to:

CO1	Assimilate knowledge of different courses studied
CO2	Develop overall comprehension about Environmental Engineering
CO3	Analyze real life environmental problems with theoretical knowledge learned
CO4	Interpret and articulate solutions to real life environmental problems

CE6849	Dissertation Part – A	PCC	0 – 0 – 0	9 Credits

Course Outcomes: At the end of the course the student will be able to:

CO1	Identify and define a topic relevant to planning, analysis and design of a waste management systems based on the social, economical and environmental considerations
CO2	Make a critical review of the available literature on the topic
CO3	Conduct independent research to formulate and solve the chosen problem
CO4	Prepare technical report on the study carried out and publish the results

CE6899	Dissertation Part – B	PCC	0 – 0 – 0	18 Credits

Course Outcomes: At the end of the course the student will be able to:

CO1	Identify and define a topic relevant to planning, analysis and design of a waste management systems based on the social, economical and environmental considerations
CO2	Make a critical review of the available literature on the topic
CO3	Conduct independent research to formulate and solve the chosen problem
CO4	Prepare technical report on the study carried out and publish the results