MASTER OF TECHNOLOGY

ENVIRONMENTAL ENGINEERING

CURRICULUM

[EFFECTIVE FROM 2024 – 25 ONWARDS]

DEPARTMENT OF CIVIL ENGINEERING
NATIONAL INSTITUTE OF TECHNOLOGY
TIRUCHIRAPPALLI – 620 015

Master of Technology
(Environmental Engineering)

CURRICULUM

(Effective from 2024 - 25 Onwards)

DEPARTMENT OF CIVIL ENGINEERING
NATIONAL INSTITUTE OF TECHNOLOGY
TIRUCHIRAPPALLI - 620 015, INDIA.

VISION OF THE INSTITUTE

- To be a university globally trusted for technical excellence where learning and research integrate to sustain society and industry.

MISSION OF THE INSTITUTE

- To offer undergraduate, postgraduate, doctoral and modular programmes in multi-disciplinary / inter-disciplinary and emerging areas.
- To create a converging learning environment to serve a dynamically evolving society.
- To promote innovation for sustainable solutions by forging global collaborations with academia and industry in cutting-edge research.
- To be an intellectual ecosystem where human capabilities can develop holistically.

VISION OF THE DEPARTMENT

Shaping infrastructure development with societal focus

MISSION OF THE DEPARTMENT

Achieve International Recognition by:

- *Developing Professional Civil Engineers*
- *Offering Continuing Education*
- *Interacting with Industry with emphasis on R&D*

PROGRAMME EDUCATIONAL OBJECTIVES (PEOs)

PEO 1	Graduates of the programme will become effectively as environmental engineers in government, industry, or other organizations; designing, improving, and implementing efficient environmental engineering practices that is sustainable.
PEO 2	Graduates of the programme will provide solutions to environmental engineering problems that account for economical, societal, ethical, as well as with standards both as individuals and in team environments, by applying acquired engineering knowledge.
PEO 3	Graduates of the programme will continue their lifelong learning to remain effective professionals to maintain and enhance technical and professional growth.

PROGRAMME OUTCOMES (POs)

PO1	An ability to independently carry out research / investigation and development work to solve practical problems
PO2	An ability to write and present a substantial technical report / document
PO3	Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program

CURRICULUM STRUCTURE

M. Tech. (ENVIRONMENTAL ENGINEERING)

Components	Number of Courses	Credits	Total Credits
Programme Core (PC)	3 / Semester (6 / Year)	24	**42**
Programme Elective (PE)*	3 / Semester (6 / Year)	18	
Essential Laboratory Requirements (ELR)	3 / Year	6	**6**
Internship/Industrial Training/ Academic Attachment (I/A)	1	2	**2**
Open Elective (OE) / Online Course (OC)#@	2 (I – IV Semester)	6	**6**
Project Phase-I	1	12	**12**
Project Phase-II	1	12	**12**
Total	**20**	**80**	**80**

Note:

* ***ONLINE COURSES EQUIVALENT TO PROGRAMME ELECTIVES (Optional):*** *Out of 6 programme electives, students have the option to study two online courses (Maximum of 1 per semester in the 1st year of Study) equivalent to programme elective courses through NPTEL / Swayam.*

\# ***OPEN ELECTIVES (OE) / ONLINE COURSE (OC) (Compulsory):*** *Students must complete 6 credits between I and IV semester either through online courses of their choice from NPTEL / Swayam (discipline electives / other electives) or through open electives offered by the PG programmes of the institute other than the progamme specialization.*

@ ***MICROCREDITS (Optional):*** *Students may opt 3 courses of 1 credit (4-week duration) each as microcredits or 2 courses (2 credits (8-week duration) & 1 credit (4-week duration) instead of 1 OE/OC.*

CURRICULUM

SEMESTER I

Code	Course of Study	Credit
MA601	Numerical Methods and Applied Statistics	4
CE701	Environmental Process Chemistry and Microbiology	4
CE703	Physico-chemical Processes for Water and Wastewater Treatment	4
	Programme Elective I	3
	Programme Elective II	3
	Programme Elective III / Online (NPTEL)	3
CE707	Environmental Quality Measurements Laboratory	2
		23

SEMESTER II

Code	Course of Study	Credit
CE702	Biological Process Design for Wastewater Treatment	4
CE704	Solid and Hazardous Waste Management	4
CE706	Air Pollution and Control Engineering	4
	Programme Elective IV	3
	Programme Elective V	3
	Programme Elective VI / Online (NPTEL)	3
CE708	Environmental Engineering Processes Laboratory	2
CE710	Environmental Computation Laboratory	2
		25

SUMMER TERM (evaluation in the III semester)

Code	Course of Study	Credit
CE746	Internship / Industrial Training / Academic Attachment (I/A) (6 weeks to 8 weeks)	2

SEMESTER III

Code	Course of Study	Credit
CE747	Project Work (Phase I)	12

SEMESTER IV

Code	Course of Study	Credit
CE748	Project Work (Phase II)	12

OPEN ELECTIVES (OE) / ONLINE COURSE (OC)

Code	Course of Study	Credit
	# (To be completed between I to IV semester)	6

PROGRAMME ELECTIVES

Sl. No.	Code	Course of Study	Credit
1.	CE711	Transport of Water and Wastewater	3
2.	CE712	Membrane Technologies for Water and Wastewater Treatment	3
3.	CE713	Industrial Wastewater Management	3
4.	CE714	Modeling of Natural Systems	3
5.	CE715	Groundwater Flow and Contaminant Transport Through Porous Media	3
6.	CE716	Indoor Environmental Quality	3
7.	CE717	Aerosol Science and Engineering	3
8.	CE718	Analytical Methods for Environmental Monitoring	3
9.	CE719	Landfill Design and Operation	3
10.	CE720	Environmental Impact Assessment	3
11.	CE721	Environmental Laws	3
12.	CE722	Environmental Nanotechnology	3
13.	CE723	Cleaner Production and Environmental Sustainable Management	3
14.	CE724	Environmental Biotechnology	3
15.	CE725	Remote Sensing and GIS for Environmental Applications	3
16.	CE726	Climate Variability, Mitigation and Adaptation	3
17.	CE727	Environmental Systems Analysis	3
18.	CE728	Environmental Social Governance	3
19.	CE729	Ecological and Ecosystem Engineering	3

OPEN ELECTIVES (OE) (List of some courses from Programme Electives, that will be Open Electives for other PG Specialization, if it is offered as Programme Elective for the respective specialization)

Sl. No.	Code	Course of Study	Credit
1.	CE711	Transport of Water and Wastewater	3
2.	CE712	Membrane Technologies for Water and Wastewater Treatment	3
3.	CE718	Analytical Methods for Environmental Monitoring	3
4.	CE720	Environmental Impact Assessment	3
5.	CE723	Cleaner Production and Environmental Sustainable Management	3

(For OE courses refer the curriculum of other PG specializations)

MICROCREDITS (MC) [Students can opt 3 courses of 1 credit (4-week duration) each as microcredits or 2 courses (2 credits (8-week duration) & 1 credit (4-week duration) instead of 1 OE/OC]

Sl. No.	Code	Course of Study	Credit
1.		Equivalent to OC (May be completed between Semester I to Semester IV)	3

Electives [Choices]

1. Program Elective (PE) Courses

Option 1:

Semester	No. of Programme Electives	No. of Online Programme Electives	Credits for Programme Elective Courses
I	3	0	9
II	3	0	9

Option 2:

Semester	No. of Programme Electives	No. of Online Programme Electives	Credits for Programme Elective Courses
I	2	1	9
II	3	0	9

Option 3:

Semester	No. of Programme Electives	No. of Online Programme Electives	Credits for Programme Elective Courses
I	3	0	9
II	2	1	9

Option 4:

Semester	No. of Programme Electives	No. of Online Programme Electives	Credits for Programme Elective Courses
I	2	1	9
II	2	1	9

2. Online Courses (OC) / Open Elective (OE) Courses

Option 1:

Semester	No. of Open Elective Courses	No. of online Courses		
		3 Credit courses	2 credit courses	1 credit course
I - IV	-	2	-	-
	-	1	1	1
	-	1	-	1+1+1

Option 2:

Semester	No. of Open elective Courses	No. of online Courses		
		3 credit courses	2 credit courses	1 credit course
I - IV	1	1	-	-
	1	-	1	1
	1	-	-	1+1+1

Option 3:

Semester	Open elective Courses	No. of online Courses		
		3 credit courses	2 credit courses	1 credit course
I - IV	2	-	-	-

COURSE OUTCOME AND PO MAPPING

PROGRAMME CORE

Course Outcomes: On successful completion of the course, students will be able to:

Course Code	Course Name	CO	Course outcomes Students will be able to:	PO1	PO2	PO3
MA601	Numerical Methods and Applied Statistics	CO1	compute solution for linear, non-linear and system of equations	2	1	2
		CO2	solve the mathematical problems through linear programming approaches	2	1	2
		CO3	utilize the knowledge of standard distributions for solving real life case studies	2	2	3
		CO4	use statistical knowledge in testing hypotheses on large and small samples	2	2	3
		CO5	compute and interpret relationship between parameters in the design of experiments	3	3	3
CE701	Environmental Process Chemistry and Microbiology	CO1	infer the chemical reactions involved in the treatment of water and wastewater	1	2	2
		CO2	utilize the acid base equilibria concept in design of water and wastewater treatment systems	2	3	3
		CO3	apply the concepts of solubility equilibria and redox chemistry for treatment of water and wastewater	3	3	3
		CO4	quantify the dosage of chemicals requirement based on chemical reactions in water treatment	3	3	3
		CO5	differentiate between different microbial species and their growth kinetics	2	2	3
CE703	Physico Chemical Processes for Water and Wastewater Treatment	CO1	differentiate the physical, chemical and biological characteristics of water and wastewater	2	2	3
		CO2	evaluate various physical and chemical treatment options for treatment of water and wastewater	2	3	3
		CO3	explain the mechanism behind the treatment processes and their advantages and disadvantages	2	3	3
		CO4	design various physico- chemical units for the treatment of water and wastewater	3	3	3

Course Code	Course Name	CO	Course outcomes Students will be able to:	PO1	PO2	PO3
		CO5	analyze and design the advanced treatment systems for the removal of specific constituents	3	3	3
CE702	Biological Process Design for Wastewater Treatment	CO1	describe the range of conventional treatment processes for the treatment of organics	1	1	2
		CO2	execute and assess the performance of bioreactors	3	3	3
		CO3	design the biological reactors based on biokinetic parameters	3	3	3
		CO4	perform and design the advanced biological treatment processes for the removal of nutrients and micro pollutants	3	3	3
		CO5	select appropriate processes for the treatment of specific wastewater, and its design considerations	3	3	3
CE704	Solid and Hazardous Waste Management	CO1	quantify and characterize solid wastes for any region	1	2	2
		CO2	evaluate different functional elements involved in solid waste management system	1	2	2
		CO3	design and implement effective solid waste management strategies	3	3	3
		CO4	suggest suitable technologies for hazardous waste management	2	3	3
		CO5	investigate the impacts of improper disposal of electronic and biomedical waste	2	3	3
CE706	Air Pollution and Control Engineering	CO1	classify the types and sources of air pollutants and to understand their effects on human health and the broader environment	1	2	2
		CO2	apply iso-kinetic sampling procedure for determining air pollutant concentration	2	2	2
		CO3	build air quality management plan for any given location	3	3	3
		CO4	select appropriate technologies for particulate and gaseous pollutant control	3	3	3
		CO5	identify causes of indoor air pollution and select suitable air purification technology	2	2	2

ESSENTIAL LABORATORY REQUIREMENTS (ELR)

Course Code	Course Name	CO	Course outcomes Students will be able to:	PO1	PO2	PO3
CE707	Environmental Quality Measurements Laboratory	CO1	apply different analysis techniques for the measurement of physical and chemical parameters of water and wastewater	2	3	3
		CO2	classify the nature / type of wastewater and its treatment on the basis of the organic strength of wastewater	2	3	3
		CO3	identify and differentiate the classifications of microorganisms through microscopic examination study	2	3	3
		CO4	monitor the ambient air quality in terms of particulate and gaseous pollutant concentration	2	3	3
		CO5	estimate the level of contamination in the soil through chemical analysis	2	3	3
CE708	Environmental Engineering Processes Laboratory	CO1	estimate the dosage requirement of chemicals for the removal of suspended and dissolved inorganic constituents from water	3	3	3
		CO2	predict the settling characteristics of suspended impurities present in water	3	3	3
		CO3	model the column sorption process and design the reactor for field applications	3	3	3
		CO4	design suitable processes for treatment of specific contaminants	3	3	3
		CO5	evaluate the performance of various biological processes in wastewater treatment	3	3	3
CE710	Environmental Computation Laboratory	CO1	apply appropriate statistical tools in environmental studies	1	2	2
		CO2	develop models relevant to environmental systems	3	3	3
		CO3	use software/tools to design water and wastewater networks	3	3	3
		CO4	predict environmental hazards and suggest mitigation measures	3	3	3
		CO5	understand the fundamentals of artificial intelligence in solving environmental problems.	1	2	2

PROGRAMME ELECTIVES

Course Code	Course Name	CO	Course outcomes	PO1	PO2	PO3
CE711	Transport of Water and Wastewater	CO1	select appropriate pipe designs for water supply mains and distribution networks	3	3	3
		CO2	design sewer networks and water supply distribution networks for various field conditions	3	3	3
		CO3	analyze and solve complex problems in water and sewage transmission systems	3	3	3
		CO4	use various computer software tools for the design and analysis of water and sewage networks	3	3	3
		CO5	evaluate and optimize hydraulic systems for improved efficiency and effectiveness	3	3	3
CE712	Membrane Technologies for Water and Wastewater Treatment	CO1	understand principles and separation mechanisms in membrane processes	1	1	2
		CO2	fabricate and characterize synthetic membranes	2	2	2
		CO3	select appropriate membrane processes for water treatment	2	2	3
		CO4	design membrane bioreactors for wastewater treatment applications	3	3	3
		CO5	suggest suitable remediation techniques for membrane fouling	2	2	3
CE713	Industrial Wastewater Management	CO1	understand the environmental impacts associated with industrial effluent disposal	1	1	2
		CO2	assess the pollution prevention alternatives adopted by industries	2	2	2
		CO3	design advanced wastewater treatment technologies	3	3	3
		CO4	recommend the pollution control methods for specific industries	3	3	3
		CO5	suggest suitable options for practicing zero liquid discharges	3	3	3

Course Code	Course Name	CO	Course outcomes	PO1	PO2	PO3
CE714	Modeling of Natural Systems	CO1	utilize the mass balance approach for the prediction of air and water quality	3	3	3
		CO2	develop contaminant transport model for natural systems	3	3	3
		CO3	predict the quality of water in river, lakes and estuaries using specific models	3	3	3
		CO4	solve the transport equation using numerical techniques	3	3	3
		CO5	estimate the concentration of pollutant in ambient air using dispersion models	3	3	3
CE715	Groundwater Flow and Contaminant Transport through Porous Media	CO1	understand contaminant transport mechanisms in aquifers	1	2	3
		CO2	develop flow and transport model for contaminant-soil interactions in groundwater	2	3	3
		CO3	differentiate various numerical techniques for solving flow and transport equations	2	3	3
		CO4	build a contaminant transport model for real field applications	3	3	3
		CO5	apply the software packages for modeling of groundwater pollution	3	3	3
CE716	Fundamentals of Indoor Environmental Quality	CO1	understand the parameters affecting indoor environmental quality (IEQ)	1	2	2
		CO2	measure the various IEQ parameters	2	2	2
		CO3	assess the impact of poor IEQ on human health and comfort	2	2	2
		CO4	design sustainable buildings as per the standards and guidelines	3	3	3
		CO5	understand the applications of CFD modelling in indoor air quality study	1	2	2
CE717	Aerosol Science and Engineering	CO1	understand the fundamental principles of atmospheric aerosols	1	1	2
		CO2	evaluate particle formation and dynamics in the atmosphere	2	2	3

Course Code	Course Name	CO	Course outcomes	PO1	PO2	PO3
		CO3	monitor atmospheric aerosols and understand its chemical composition	2	2	3
		CO4	assess the impacts of aerosols on atmospheric processes, climate, and air quality	3	3	3
		CO5	apply aerosol reactor design concepts in various engineering applications	3	3	3
CE718	Analytical Methods for Environmental Monitoring	CO1	understand the principles of analytical instruments in environmental monitoring	1	1	2
		CO2	select suitable ion selective electrodes for water and wastewater quality analysis	2	2	2
		CO3	evaluate the level of pollution using sophisticated instruments	3	3	3
		CO4	utilize appropriate electrochemical methods for industrial applications	3	3	3
		CO5	summarize various material characterization techniques and its principles	1	2	2
CE719	Landfill Design and Operation	CO1	identify salient aspects of landfills and suggest suitable site and configuration for landfills	2	2	3
		CO2	understand the landfill gas components and to classify the nature of landfill leachate based on reactions in the landfills	2	2	3
		CO3	design the major components of landfill as per regulatory standards	3	3	3
		CO4	execute landfill operations and plan the post closure monitoring systems for landfills	3	3	3
		CO5	apply the theoretical knowledge for the landfill reclamation projects in real world	3	3	3
CE720	Environmental Impact Assessment	CO1	analyse the environmental impacts of proposed projects	2	3	3
		CO2	predict the magnitude of an impact using mathematical tools	3	3	3

Course Code	Course Name	CO	Course outcomes	PO1	PO2	PO3
		CO3	propose proper mitigation measures to avoid environmental impacts	3	3	3
		CO4	summarise the EIA report with a suitable environmental management plan	2	3	3
		CO5	develop and apply post-project monitoring and environmental audit programs for compliance and improvement	3	3	3
CE721	Environmental Laws	CO1	understand fundamental concepts and importance of environmental laws at National/International level	1	1	1
		CO2	recognize constitutional and legal provisions related to environmental protection	1	2	2
		CO3	evaluate the effectiveness of current practices in controlling pollution as per environmental laws	3	3	3
		CO4	engage with public and non-governmental organizations to promote environmental awareness	1	2	2
		CO5	understand the role of judiciary in implementing environmental laws	1	1	2
CE722	Environmental Nanotechnology	CO1	understand the nanoscale phenomena and principles of nanotechnology	1	1	2
		CO2	fabricate various synthetic nanocomposites	2	3	3
		CO3	characterize and interpret the fabricated nanocomposites	2	3	3
		CO4	apply the knowledge of nanotechnology in water and wastewater treatment	3	3	3
		CO5	assess potential impacts associated with nanomaterials	3	3	3
CE723	Cleaner Production and Environmental Sustainable Management	CO1	modify schemes applied at different governance levels to achieve sustainable innovation	2	2	3
		CO2	prepare process flow diagram and material balance for various industrial processes	3	3	3

Course Code	Course Name	CO	Course outcomes	PO1	PO2	PO3
		CO3	summarize various techniques for cleaner production and to apply environmental sustainable management concepts in industries	3	3	3
		CO4	prepare detailed environmental statements on organization's performance and improvement plans	3	3	3
		CO5	examine the toxicological and ecological aspects of ecotoxicology and to transfer knowledge of ecotoxicological theory to new environmental situations	2	3	3
CE724	Environmental Biotechnology	CO1	explain the mechanisms of detoxification and biodegradation of solid wastes	1	1	2
		CO2	list out the different methods for bioremediation of environment	1	2	2
		CO3	evaluate the benefit of microorganisms in degrading organic contaminants	2	2	3
		CO4	design biological system for the removal of biodegradable compounds	3	3	3
		CO5	select suitable assessment methods for bioremediation	3	3	3
CE725	Remote Sensing and GIS for Environmental Engineering Applications	CO1	understand the basic concept of satellite image processing	1	1	2
		CO2	perform pre and post processing of satellite images	2	2	2
		CO3	comprehend about geographic information system	1	1	2
		CO4	select appropriate geospatial operations	2	2	3
		CO5	apply the geospatial and image processing techniques for environmental problems	3	3	3
CE726	Climate Variability, Mitigation and Adaptation	CO1	demonstrate a thorough understanding of climate systems, including the drivers of climate variability	1	1	2
		CO2	assess various mitigation technologies and strategies for	2	2	2

Course Code	Course Name	CO	Course outcomes	PO1	PO2	PO3
			their feasibility and effectiveness			
		CO3	develop and propose effective adaptation strategies for different sectors impacted by climate change	3	3	3
		CO4	analyze and interpret international and national climate policies and assess their implications for climate action	3	3	3
		CO5	utilize climate models and analytical tools to simulate climate scenarios and evaluate potential outcomes of mitigation and adaptation strategies	3	3	3
CE727	Environmental Systems Analysis	CO1	analyse the system performance using simulation models	3	3	3
		CO2	optimize environmental engineering Systems using optimization models	3	3	3
		CO3	use the concepts of probabilistic and fuzzy models for improving management processes	3	3	3
		CO4	employ model-based environmental analysis in decision-making	3	3	3
		CO5	choose a suitable Systems analysis method and tool for a given decision situation	3	3	3
CE728	Environmental Social Governance	CO1	identify the need of ESG and contribute towards improvement of company's ESG ratings	1	1	2
		CO2	assess the role of Corporate Social Responsibility in ESG	1	2	2
		CO3	estimate the scope 1,2 & 3 GHG emissions as per GHG protocol and device decarbonization strategy	2	3	3
		CO4	develop various reporting frameworks and assist in developing sustainability reports and BRSR reporting	3	3	3

Course Code	Course Name	CO	Course outcomes	PO1	PO2	PO3
		CO5	carry out materiality assessment and identify long term risks	3	3	3
CE729	Ecological and Ecosystem Engineering	CO1	to identify the interrelationship of ecology, ecotechnology, and ecological engineering	1	2	2
		CO2	to classify, evaluate and design interface ecosystems	2	2	3
		CO3	to design sustainable loading of eco systems	3	3	3
		CO4	to develop model in different ecological scenarios and applications in real field	3	3	3
		CO5	to expertise on eco sanitation regarding different ecosystem	3	3	3

3 - High; 2 - Medium; 1 – Low

PROGRAMME CORE

Course Code	:	MA601
Course Title		**NUMERICAL METHODS AND APPLIED STATISTICS**
Type of Course	:	Programme Core
Prerequisites	:	Basic knowledge in Mathematics
Contact Hours	:	45
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives

1. To familiarize with various numerical methods for solving linear, non-linear and system of linear equations
2. To learn linear and integer programming
3. To recall the basic probability concepts, introduce random variables and some of the special distributions
4. To impart knowledge on hypothesis testing for large and small sample
5. To discuss about experimental design and time series analysis

Course Content

Linear System - Gaussian Elimination and Gauss - Jordan Methods - Matrix Inversion - Gauss Seidel Method - Nonlinear Equations - Regula Falsi and Newton - Raphson Methods - Interpolation - Newton's and Lagrange's Interpolation; Linear Programming - Graphical and Simplex methods - Big-M method - Two phase method - Dual simplex method - Dual theory - Sensitivity analysis - Integer programming - applications; Random Variable - Two Dimensional Random Variables - Standard Probability Distributions - Binomial Poisson and Normal Distributions - Moment Generating Function; Sampling Distributions - Confidence Interval Estimation of Population Parameters - Testing of Hypotheses - Large Sample Tests for Mean and Proportion - t-Test - F-Test and Chi-Square Test- Curve Fitting - Method of Least Squares - Regression and Correlation - Rank Correlation - Multiple and Partial Correlation - Analysis of Variance - One Way and Two Way Classifications -Experimental Design - Latin Square Design - Time Series Analysis; Introduction and hands-on practice on popular / available tools in the context of engineering applications.

References

1. *Bowker, A.H., and Lieberman, G. J., Engineering Statistics. Prentice Hall, 1972.*
2. *Venkatraman, M. K., Numerical Methods in Science and Engineering. National Publisher Company, 5th Edition, 1999.*
3. *Jain, M. K.; Iyengar, S. R. K.; Jain, R. K., Numerical Methods for scientific and engineering computation. 6th edition, New Age International (p) Limited, 2012.*
4. *Hamdy A.T., Operations Research: An introduction. 10th edition Pearson Prentice Hall, 2007.*
5. *Gupta, S.C., Fundamentals of Statistics. Himalaya Publishing House, 7th Revised and Enlarged Edition, 2014.*
6. *Gupta, S.C., and Kapoor, V.K., Fundamentals of Mathematical Statistics. Sultan Chand and Sons, 2014.*

Course Outcomes

At the end of the course student will be able

1. to compute solution for linear, non-linear and system of equations
2. to solve the mathematical problems through linear programming approaches
3. to utilize the knowledge of standard distributions for solving real life case studies
4. to use statistical knowledge in testing hypotheses on large and small samples
5. to compute and interpret relationship between parameters in the design of experiments

Course Code	:	CE701
Course Title	:	**ENVIRONMENTAL PROCESS CHEMISTRY AND MICROBIOLOGY**
Type of Course	:	Programme Core
Prerequisites	:	Basic knowledge in Chemistry and Microbiology
Contact Hours	:	45
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives

1. To study the basic concepts of environmental chemistry and acid base equilibria
2. To learn the solubility equilibria approach for the removal of heavy metals from water and wastewater
3. To understand the application of redox chemistry in water and wastewater treatment
4. To discuss the concepts of chemical precipitation in water softening
5. To describe the characteristics and growth kinetics of microbial populations

Course Content

Environmental Chemistry - Chemical Equilibria and Kinetics fundamentals – Chemical thermodynamics - Gas Laws; Acid Base Equilibria - Equilibrium Diagrams - Alkalinity and Acidity - Carbonic Acid System - Buffer and buffer intensity; Solubility Equilibria - Removal of Heavy Metals from Complex Water and Wastewater Systems; Oxidation Reduction Equlilibria - Stability Diagrams - Application of Redox Chemistry; Water Stabilization - Langelier Saturation Index - Caldwell Lawrence Diagrams; Water Softening and Neutralization - Chemical Precipitation; Microbiological concepts – characteristics and classification of microorganisms – Prokaryotic and Eukaryotic Cell structure - Growth curve-measurement of microbial growth - enzyme kinetics – bio kinetics - Microbial metabolism - respiration and energy generation - Microbiology of wastewater Treatment.

References

1. *Benfield, L.D.; Weand, B.L.; Judkins, J.F., Process chemistry for water and wastewater. Prentice Hall Inc, Englewood Cliffs, New Jersey, 1982.*
2. *Weber Jr, W.J., Physico-chemical Process for Water Quality Control. Wiley Inc. Newyork, 1972.*
3. *Tortora, G.J.; Furke, B. R.; Case, C. L., Microbiology- An introduction (11th Ed.). Benjammin /Cummings publ Co, Inc, California, 2013.*

4. *Pelczar, M.J.; Chan, E.C.S.; Krieg, N. R., Microbiology. 5th Edition, Tata McGraw Hill, New Delhi, 2001.*
5. *Benjamin, M.M., Water Chemistry. Waveland Press, 2014*
6. *Stumm, W., and Morgan, J.J., Aquatic Chemistry: Chemical Equilibria and Rates in Natural Waters. Wiley 2013.*
7. *Brezonik, P.; Arnold, W., Water Chemistry: An Introduction to the Chemistry of Natural and Engineered Aquatic Systems. Oxford University Press, USA, 2011.*

Course Outcomes

At the end of the course student will be able

1. to infer the chemical reactions involved in the treatment of water and wastewater
2. to utilize the acid base equilibria concept in design of water and wastewater treatment systems
3. to apply the concepts of solubility equilibria and redox chemistry for treatment of water and wastewater
4. to quantify the dosage of chemicals requirement based on chemical reactions in water treatment
5. to differentiate between different microbial species and their growth kinetics

Course Code	:	CE703
Course Title	:	**PHYSICO-CHEMICAL PROCESSES FOR WATER AND WASTEWATER TREATMENT**
Type of Course	:	Programme Core
Prerequisites	:	Basic knowledge in water and wastewater
Contact Hours	:	45
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives

1. To learn the physical, chemical and biological characteristics of water and wastewater
2. To provide an understanding of various physicochemical methods for treatment of water and wastewater
3. To explain the limitations, advantages and disadvantages of each unit operations and processes
4. To study the principle and design of the physical and chemical treatment units used for the removal of undesirable constituents (contaminants) from water and wastewater
5. To describe the various advanced treatment systems for the removal of specific constituents and its limitations

Course Content

Water Quality - Physical, Chemical and Biological Parameters of Water - Water Quality Requirement - Potable Water quality Standards - Wastewater Effluent Standards - Water Quality Indices; Water Purification in Natural Systems; Primary, Secondary and Tertiary Treatment - Unit Operations - Unit Processes; Particle Separation Processes - Coagulation and Flocculation Processes - Particle Surface Charge - Surface Potential and Stability of Colloidal

Dispersions; Sedimentation and Flotation Processes - Gravity Thickeners - Clarifiers and Flotation Systems - Filtration and Ultrafiltration Processes - Modeling Approaches for Rapid Sand Filters - Solute Separation Processes - Gas Transfer Processes - Diffused and Surface Aeration and Air Stripping of Volatile Contaminants in Packed Tower - Adsorption and Ion Exchange Processes - Sorption Isotherm Models and Rates Considerations - Sorption in Completely Mixed and Packed Bed Reactors - Precipitation Processes - Reverse Osmosis and Electro dialysis - Species Transformation Processes - Chemical Oxidation / Reduction Processes - Disinfection using Chlorine and UV - Advanced Oxidation Process.

References

1. *Weber, W.J., Physicochemical processes for water quality control. John Wiley and sons, Newyork. 2003.*
2. *Peavy, H.S.; Rowe, D.R.; Tchobanoglous, G., Environmental Engineering. McGraw Hills, New York, 2017.*
3. *Metcalf, L., and Eddy, H.P., Wastewater Engineering, Treatment and Reuse. 5th Edition, Tata McGraw-Hill, New Delhi, 2013.*

Course Outcomes

At the end of the course student will be able

1. to differentiate the physical, chemical and biological characteristics of water and wastewater
2. to evaluate various physical and chemical treatment options for treatment of water and wastewater
3. to explain the mechanism behind the treatment processes and their advantages and disadvantages
4. to design various physico- chemical units for the treatment of water and wastewater
5. to analyze and design the advanced treatment systems for the removal of specific constituents

Course Code	:	CE702
Course Title	:	**BIOLOGICAL PROCESS DESIGN FOR WASTEWATER TREATMENT**
Type of Course	:	Programme Core
Prerequisites	:	Basic knowledge in wastewater and its treatment
Contact Hours	:	45
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives

1. To learn the fundamentals of process kinetics and enzyme reactions
2. To know the concepts of various bioreactors and its application in biological treatment of wastewater
3. To study about various biological treatment processes and its operations for the wastewater treatment

4. To provide the knowledge about the kinetics of biological growth and its application i n the design of biological reactors
5. To explain the design principles and operational problems involved in various biological treatment processes

Course Content

Constituents of Wastewaters - Sources - Significant Parameter - Fundamentals of Process Kinetics - Zero Order - First Order - Second Order Reactions - Enzyme Reactions - Bio Reactors - Types - Classification - Design Principles - Design of Wastewater Treatment Systems - Primary - Secondary and Tertiary Treatments - Evaluation of Biokinetic Parameters - Activated Sludge and its Process - Modifications - Biological Nitrification and Denitrification — Attached Growth Biological Treatment Systems -Trickling Filters - Rotating Biological Contactors - Waste Stabilization Ponds and Lagoons- Algae and Bacteria Symbiosis - Aerobic Pond - Facultative Pond - Anaerobic Ponds - Polishing Ponds - Aerated Lagoons - Anaerobic Processes - Process Fundamentals - Standard, High Rate and Hybrid Reactors - Anaerobic Filters-Expanded / Fluidized Bed Reactors - Upflow Anaerobic Sludge Blanket Reactors - Expanded Granular Bed Reactors - Two Stage / Phase Anaerobic Reactors -Membrane Bioreactors – Sludge Digestion - Sludge Disposal.

References

1. *Benefield, L.D., and Randall C.W., Biological Process Design for Wastewater Treatment. Prentice-Hall, Inc. Eaglewood Cliffs, 1989.*
2. *Grady Jr, C.P.L., and Lin H.C., Biological wastewater treatment: Theory and Applications. Marcel Dekker, Inc New York, 1980.*
3. *Metcalf, L., and Eddy, H.P., Wastewater Engineering, Treatment and Reuse. 5th Edition, Tata McGraw-Hill, New Delhi, 2013.*
4. *Arceivala, S. J., and Asolekar, S.R., Wastewater Treatment for Pollution Control. 3rd Edition, McGraw-Hill Education (India) Pvt. Ltd., New Delhi, 2006.*

Course Outcomes

At the end of the course student will be able
1. to describe the range of conventional treatment processes for the treatment of organics
2. to execute and assess the performance of bioreactors
3. to design the biological reactors based on biokinetic parameters
4. to perform and design the advanced biological treatment processes for the removal of nutrients and micro pollutants
5. to select appropriate processes for the treatment of specific wastewater, and its design considerations

Course Code	:	CE704
Course Title	:	**SOLID AND HAZARDOUS WASTE MANAGEMENT**
Type of Course	:	Programme Core
Prerequisites	:	Fundamental knowledge in Waste management
Contact Hours	:	45
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives

1. To provide comprehensive understanding of Municipal Solid Waste (MSW) and its properties
2. To describe the importance of understanding interrelationship between the functional elements
3. To enumerate engineering principles and technological solutions in MSW management
4. To provide knowledge on management of hazardous, biomedical and electronic waste
5. To brief the regulatory framework and compliance in Solid Waste Management

Course Content

Municipal Solid Waste (MSW): Sources - Composition and Properties - Quantitative & Qualitative Analysis; Generation rates - Onsite Handling - Storage - Source Segregation - Collection - Transfer & Transport - Waste Processing – Recovery & Recycling - Biological & Thermal Conversion Technologies; Sanitary Landfill: Leachate - Landfill Gas - Closure and Post-Closure Monitoring; Hazardous Waste: Sources - Characteristics - Classification - Impact on Human Health & Environment - Environmental Regulations - Waste Minimization & Resource Recovery - Storage & Transportation – Treatment - Landfill Disposal & Land Storage; Electronic Waste: Composition – Characteristics – Environmental and Health Implications – Storage & On-site Handling - Recycling E-Waste - Extended Producer Responsibility (EPR) - Treatment and Disposal; Biomedical waste: Source – Classifications – Health Hazards – Waste Collection - Segregation & Labelling – Handling – Onsite/Off Site Transportation – Treatment & Disposal of Biomedical Waste; Status of Waste Management - Rules and Regulations Governing Waste Management.

References

1. *CPHEEO, Manual on Municipal Solid waste management, Central Public Health and Environmental Engineering Organization, Government of India, New Delhi, 2016.*
2. *Kreith, F., and Tchobanoglous, G., Handbook of Solid Waste Management. McGraw Hill LLC, 2002.*
3. *Tchobanoglous, G.; Theisen, H.; Vigil, S.A., Integrated solid waste management: engineering principles and management issues. McGraw-Hill, New York, 1993.*
4. *Pichtel, J., Waste Management Practices: Municipal, Hazardous, And Industrial. CRC press, 2014*
5. *LaGrega, M.D.; Buckingham, P.L.; Evans, J.C., Hazardous Waste Management. Waveland Press, 2010*

Course Outcomes

At the end of the course student will be able
1. to quantify and characterize solid wastes for any region
2. to evaluate different functional elements involved in solid waste management system
3. to design and implement effective solid waste management strategies
4. to suggest suitable technologies for hazardous waste management
5. to investigate the impacts of improper disposal of electronic and biomedical waste

Course Code	:	CE706
Course Title	:	**AIR POLLUTION AND CONTROL ENGINEERING**
Type of Course	:	Programme Core
Prerequisites	:	Basic knowledge in Air pollution
Contact Hours	:	45
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives

1. To provide an understanding of the sources, pathways and receptors in air quality management
2. To study the sampling and measurement techniques for air pollution monitoring
3. To know the fundamental concepts of air quality management
4. To learn the design principles for gaseous and particulate control devices
5. To discuss the importance of indoor air quality and its effect on occupant health and productivity

Course Content

Introduction to air pollution – Historic perspective – Definition – Pollution Systems – Sources – Classification of Air Pollutants – Reactions of Pollutants in the Atmosphere – Effect of air pollution on human health – Vegetation and property; Monitoring of Air Pollutants: Sampling of particulate and gaseous pollutants – Continuous monitoring systems – Stack emission – Personal exposure – Analysis and measurement of particulate and gaseous pollutants – Real-time – Vehicular exhaust – On-board measurements – Low-cost sensors; Air Pollution Meteorology; Air Quality Management: Scales of air pollution – Urban hotspots – Emission inventory – Source apportionment – Carrying capacity of airsheds – Air quality indices – Case studies; Air Pollution Control: Philosophy – Principles and methods for particulate and gaseous pollutants control – Selection of control equipment – Design of control equipment – Settling chamber – Cyclone separators – Scrubbers – Bag filters – Electrostatic precipitators – Vehicular emissions control – Catalytic converters and filters; Air quality standards – Norms – Rules and regulations – National Clean Air Programme; Indoor Air Pollution: Sources – Types of pollutants – Effects – Indoor air quality instrumentation and measurement – Air purification technologies and materials.

References

1. *Boubel, R.W.; Fox, D.L.; Turner, D.B.; Stern, A.C., Fundamentals of Air Pollution. 3rd Edition, Academic Press, New York, 2005.*
2. *Kenneth, W., and Warner, C.F., Air pollution its origin and control. Harper and Row Publishers, New York, 1997.*
3. De Nevers, N., Air Pollution Control Engineering. McGraw Hill, New Delhi, 2016.
4. *Theodore, L., Air Pollution Control Equipment Calculations. John Wiley & Sons Inc Publication, New Jersey, 2008.*
5. *Peavy, H. S.; Rowe, D. R.; Tchobanoglous, G., Environmental Engineering. McGraw Hills, New York, 2017.*
6. *Rao, C.S., Environmental pollution control Engineering. New age international Ltd, New Delhi, 2007.*

Course Outcomes

At the end of the course student will be able

1. to classify the types and sources of air pollutants and to understand their effects on human health and the broader environment
2. to apply iso-kinetic sampling procedure for determining air pollutant concentration
3. to build air quality management plan for any given location
4. to select appropriate technologies for particulate and gaseous pollutant control
5. to identify causes of indoor air pollution and select suitable air purification technology

ESSENTIAL LABORATORY REQUIREMENTS (ELR)

Course Code	:	CE707
Course Title	:	**ENVIRONMENTAL QUALITY MEASUREMENTS LABORATORY**
Type of Course	:	Laboratory
Prerequisites	:	Basic knowledge in water and wastewater analysis
Contact Hours	:	36
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives

1. To give students theoretical understanding and hands on experience with physical and chemical characteristics of water and wastewater
2. To familiarize the methods to estimate the organic strength of wastewater
3. To study the various techniques for the examination of microorganisms
4. To measure the particulate and gaseous pollutant concentration in ambient air
5. To determine the contamination of soil through various chemical analysis

Course Content

Physical and Chemical Characteristics of Water: pH - Electrical Conductivity - Turbidity - Alkalinity - Acidity - Hardness - Sulphates - Fluorides - Nitrates - Analysis of Solids Content of Water: Total Solids - Suspended Solids - Volatile Solids - Non Volatile Solids - Residual Chlorine Analysis - Test on Dissolved Oxygen - BOD and COD - Metal Analysis; Microscopic Examination of Microorganisms: Preparation of Bacterial Smear - Staining - Basic Pure Culture Techniques - Bacteriological examination of water: Standard Plate Count Test - MPN Tests and MFT Tests; Ambient Air Quality Analysis: Determination of SPM - PM_{10} - $PM_{2.5}$ - CO - NO_X and SO_X - Stack emission monitoring; Soil Analysis: pH - Conductivity - Cation Exchange Capacity - Sodium Adsorption Ratio.

References

1. *Standard Methods for the Examination of Water and Wastewater, 23rd Edition, 2017*
2. *Manual on water supply and Treatment, CPHEEO, Ministry of Urban Development, GOI, New Delhi, 2000.*
3. *Pepper, I. L.; Gerba, C. P.; Brendecke, J. W., Environmental Microbiology A Laboratory Manual. Academic Press Inc., San Diego, USA, 1995.*

Course outcomes

At the end of the course student will be able

1. to apply different analysis techniques for the measurement of physical and chemical parameters of water and wastewater
2. to classify the nature / type of wastewater and its treatment on the basis of the organic strength of wastewater
3. to identify and differentiate the classifications of microorganisms through microscopic examination study

4. to monitor the ambient air quality in terms of particulate and gaseous pollutant concentration
5. to estimate the level of contamination in the soil through chemical analysis

Course Code	:	CE708
Course Title	:	**ENVIRONMENTAL ENGINEERING PROCESSES LABORATORY**
Type of Course	:	Laboratory
Prerequisites	:	Basic knowledge in water and wastewater treatment
Contact Hours	:	36
Course Assessment Methods		Continuous Assessment, End Assessment

Course Learning Objectives

1. To learn the principles of estimation of chemical dosage for the removal of suspended and dissolved inorganic constituents from water
2. To impart the knowledge on the settling behaviour of suspended impurities, present in water
3. To familiarise the kinetics and isotherm models of sorption processes for dissolved solids separation from water and wastewater
4. To provide the basic understanding of heavy metal removal through chemical unit processes
5. To study the biokinetics of biological processes and its application in design of biological systems

Course Content

Water Softening - Lime and Caustic Soda Process - Coagulation and Flocculation of Water - Optimization of Dose, pH and Time of Flocculation - Sedimentation - Settling Column Analysis of Flocculating Particles - Filtration - Chlorination - Adsorption - Colour Removal by Adsorption - Heavy Metal Precipitation – Membrane Distillation - Kinetics of Activated Sludge Process - anaerobic digestion - biogas potential - Specific methanogenic activity.

References

1. *Benfield, L.D.; Weand, B.L.; Judkins, J.F., Process chemistry for water and wastewater. Prentice Hall Inc Englewood Cliffs New Jersey, 1982.*
2. *Weber, W.J., Physico-chemical Process for Water Quality Control. Wiley Inc., New York, 1972.*
3. *Peavy, H.S.; Rowe, D. R.; Tchobanoglous, G., Environmental Engineering. McGraw Hills, New York, 2017.*
4. *Benefield, L.D., and Randall, C.W., Biological Processes Design for wastewaters. Prentice-Hall, Inc. Eaglewood Cliffs, 1989.*

Course Outcomes

At the end of the course student will be able

1. to estimate the dosage requirement of chemicals for the removal of suspended and dissolved inorganic constituents from water
2. to understand the settling characteristics of suspended impurities, present in water
3. to model the column sorption process and design the reactor for field applications
4. to design suitable processes for treatment of specific contaminants
5. to evaluate the performance of various biological processes in wastewater treatment

Course Code	:	CE710
Course Title	:	**ENVIRONMENTAL COMPUTATION LABORATORY**
Type of Course	:	Laboratory
Prerequisites	:	Basic knowledge in Statistics
Contact Hours	:	36
Course Assessment Methods		Continuous Assessment, End Assessment

Course Learning Objectives

1. To learn statistical tools for analysis and interpretation
2. To know the application of various software/tools in the field of environmental Engineering
3. To gain proficiency in design, visualization and solving environmental problems using different software
4. To understand and apply various tools in environmental impact assessment
5. To acquires skills in application of Artificial Intelligence (AI) Techniques for environmental applications

Course Content

Applications of spreadsheets and Statistical tools for solving environmental problems; Hands-on practice on standard software in environmental engineering field: Surface Water Quality – Water Distribution Network - Groundwater Quality – Sewerage Network– Analysis and Design of Wastewater treatment systems- Air Quality - Solid Waste management – Environmental Impact Assessment – Risk Management - Life Cycle Assessment; Application of Artificial Intelligence in solving Environmental Problems.

References

1. *Getting Started with MATLAB 7: A Quick Introduction for Scientists and Engineers. Oxford University Press, 2005.*
2. *Mathews, J.H., and Fink, K.D., Numerical methods using MATLAB, 4th edition Pearson Education, 2015.*
3. *Zheng, C., and Bennett, G.D., Applied contaminant Transport Modeling. A John wiley& sons, inc., publication, New York, 2002.*
4. *The United States Agency for International development, "WaterGEMS Training Manual" November, 2014.*

5. *Rossman, L.; Woo, H.; Tryby, M.; Shang, F.; Janke, R.; Haxton, T., EPANET 2.2 User Manual. U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-20/133, 2020.*
6. *Sopariya, H., Design of Sewer Network Using SewerGEMS Software (1st ed.). LAP LAMBERT Academic Publishing, 2018.*
7. *Di Noi, C.; Ciroth, A.; Srocka, M., OpenLCA 1.7. Comprehensive User Manual for Life Cycle Assessment, GreenDelta GmbH, Berlin, Germany, 2017.*
8. *Alexander, A.; Burklin, C.; Singleton, A., Landfill Gas Emissions Model (LandGEM) Version 3.02 User's Guide, Eastern Research Group, Morrisville, NC, 2005.,*
9. *Visual MODFLOW Flex 8.0, Integrated Conceptual & Numerical Groundwater Modeling Software- User manual. Waterloo Hydrogeologic, Inc., 2022*
10. *BioWin - a comprehensive simulation tool for biological wastewater treatment plant design, analysis and training: http://www.envirosim.com/downloads/BW5Manual.pdf*

Course Outcomes

At the end of the course student will be able
1. to apply appropriate statistical tools in environmental studies
2. to develop models relevant to environmental systems
3. to use software/tools to design water and wastewater networks
4. to predict environmental hazards and suggest mitigation measures
5. to understand the fundamentals of artificial intelligence in solving environmental Problems

PROGRAMME ELECTIVES

Course Code	:	CE711
Course Title	:	**TRANSPORT OF WATER AND WASTEWATER**
Type of Course	:	Program Elective
Prerequisites	:	Basic knowledge in transport of water and wastewater
Contact Hours	:	36
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives

1. To learn the principles and applications of water transmission mains
2. To study the various components and design considerations of water distribution systems
3. To design sewer networks and storm water drains effectively
4. To utilize computer applications in the design and analysis of water distribution and sewer networks
5. To understand and apply principles of hydraulic design and analysis for optimizing water and sewer systems

Course Content

Fluid properties - fluid flow - continuity principle, energy principle and momentum principle - frictional head loss in free and pressure flow - minor heads losses - Carrying Capacity - Flow measurement - Estimation of storage capacity - impounding reservoirs - intakes - gravity and pressure conduits - hydraulics of fluid flow - pumps and accessories - capacity of pumps - selection of pumps - maintenance - economic design of pumps and pumping mains - Jointing - laying and maintenance - water hammer analysis - water distribution pipe networks Design, analysis and optimization – appurtenances - corrosion prevention - minimization of water losses - leak detection - storage reservoirs- Strom water Drainage - Necessity - combined and separate system - Estimation of storm water runoff - Formulation of rainfall intensity duration and frequency relationships - Rational methods - Planning factors - Design of sanitary sewer - partial flow in sewers - economics of sewer design - Wastewater pumps and pumping stations - sewer appurtenances - material, construction - inspection and maintenance of sewers - Design of sewer outfalls - mixing conditions; Transition flow critical depth in sewers - draw down curves and hydraulic jump - Use of computer software in water transmission - water distribution - sewer and storm water design – EPANET 2.0 - SEWER - BRANCH and Canal ++.

References

1. *Manual on water supply and Treatment. CPHEEO, Ministry of Urban Development, GoI, New Delhi, 2013.*
2. *Bajwa, G.S., Practical Handbook on Public Health Engineering. Deep Publishers, Shimla, 3rd edition, 2011.*
3. *Hammer, M.J., Water and Wastewater Technology, Prentice Hall, New Jercy, 7th edition, 2012.*

Course Outcomes

At the end of the course student will be able

1. to select appropriate pipe designs for water supply mains and distribution networks
2. to design sewer networks and water supply distribution networks for various field conditions
3. to analyze and solve complex problems in water and sewage transmission systems
4. to apply computer software tools for the analysis and design of water distribution and sewer system
5. To evaluate and optimize hydraulic systems for improved efficiency and effectiveness

Course Code	:	CE712
Course Title	:	**MEMBRANE TECHNOLOGIES FOR WATER AND WASTEWATER TREATMENT**
Type of Course	:	Program Elective
Prerequisites	:	Basic knowledge in water and wastewater treatment
Contact Hours	:	36
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives

1. To provide the knowledge of nanoscale phenomenon and governing principles
2. To learn membrane materials, modules, and contaminant transport phenomena
3. To focus on the recent development in membrane processes for water purification
4. To study the role of membrane bioreactors for the treatment of wastewater
5. To brief the membrane fouling and its mitigation strategies

Course Content

Principles of Membrane Processes - Types and Classification - Theory of Membrane Separation - Types and Choice of Membranes - Liquid Membranes - Synthetic Membranes - Composite Membranes - Preparation, Characterization of Membranes - Recent Development in Membranes; Modules and Washing Process; Membrane Distillation; Electrodialysis: Principles - Electrodialysis Stack and its Various Components; Ion Exchange process - Electrical Resistance of Ion Exchange Membrane - Donnan Dialysis; Reverse Osmosis - Theory and Principle - Materials - Design Considerations; Filtration: Theory - Nanofiltration - Ultrafiltration - Microfiltration; Membrane Bioreactors - Biomass Separation - Design Principles - Submerged Anaerobic Membrane Bioreactors; Fouling: Types of fouling - Fouling Mechanism and Identification - Strategies to Monitor the Fouling Potential of Membrane - Pretreatment Options to Mitigate Fouling.

References

1. *Marcel, M., Basic Principles of Membrane Technology, Springer Netherlands, 1996.*
2. *Heinrich, S., Introduction to Membrane Science and Technology, Wiley, 2011.*
3. *Alfredo, C.; Angelo B.; Navin K. R., (Eds) Advances in Membrane Technologies for Water Treatment: Materials, Processes and Applications. Elsevier Science, 2015.*

4. *Kaushik, N., Membrane Separation Processes, PHI Learning Pvt. Ltd., 2017.*
5. *Crespo, J.G., and Boddekes, K.W., Membrane Processes in Separation and Purification, Kluwer Academic Publications, 1994.*
6. *Rautanbach, R., and Albrecht, R., Membrane Process, John Wiley & Sons, 1989.*

Course Outcomes

At the end of the course student will be able
1. to understand principles and separation mechanisms in membrane processes
2. to fabricate and characterize synthetic membranes
3. to select appropriate membrane processes for water treatment
4. to design membrane bioreactors for wastewater treatment applications
5. to suggest suitable remediation techniques for membrane fouling

Course Code	:	CE713
Course Title	:	**INDUSTRIAL WASTEWATER MANAGEMENT**
Type of Course	:	Program Elective
Prerequisites	:	Basic knowledge in water and wastewater treatment
Contact Hours	:	36
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives

1. To study the sources and characteristics of industrial wastewater
2. To learn the toxicity and bioassay tests for wastewater
3. To focus on pollution prevention options
4. To comprehend various industrial wastewater treatment techniques
5. To discuss effluent treatment and disposal in various industries

Course Content

Industrial Wastewater - Sources - Types - Environmental Impacts - Regulatory Requirements - Generation Rates - Characterization - Toxicity and Bioassay Tests - Prevention vs Control of Industrial Pollution - hierarchy of priorities for industrial waste management - Source Reduction Techniques - Waste Audit - Evaluation of Pollution Prevention Options - Waste Minimization - Equalization - Neutralization - Floatation - Precipitation - Aerobic and Anaerobic Biological Treatment - Sequencing Batch Reactors - High-Rate Reactors - Chemical Oxidation processes - Adsorption - Ion Exchange - Membrane Technologies; Case studies from various industries; Zero Effluent Discharge Systems; Effluent disposal standards; Wastewater Reuse - Disposal of effluent on Land.

References

1. *Lawrence, K.W.; Yung-T, H.; Howard, H.L.; Constantine, Y., Handbook of Industrial and Hazardous Wastes Treatment. Taylor & Francis, 2004.*

2. *Franklin, L.B.; George, T.; Ryujiro, T.; Stensel, H.D., Wastewater Engineering: Treatment and Resource Recovery. McGraw-Hill Education, 2014.*
3. *Qasim, S.R., Wastewater Treatment Plants Planning, Design, and Operation. Second Edition, CRC Press, 2017*
4. *Eckenfelder, W.W., Industrial Water Pollution Control. 3rd Edition, McGraw-Hill, 1999.*
5. *Arceivala, S.J., Wastewater Treatment for Pollution Control. 3rd Edition, McGraw-Hill, 2006.*
6. *Woodard, F., Industrial waste treatment Handbook. Butterworth Heinemann, 2nd Edition, New Delhi, 2006.*

Course Outcomes

At the end of the course student will be able

1. to understand the environmental impacts associated with industrial effluent disposal
2. to assess the pollution prevention alternatives adopted by industries
3. to design advanced wastewater treatment technologies
4. to recommend the pollution control methods for specific industries
5. to suggest suitable options for practicing zero liquid discharges

Course Code	:	CE714
Course Title	:	**MODELING OF NATURAL SYSTEMS**
Type of Course	:	Program Elective
Prerequisites	:	Basic Knowledge in water, wastewater and air quality parameters
Contact Hours	:	36
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives

1. To provide an understanding of mass balance approach for the prediction of air and water quality
2. To learn the mathematical model development for natural systems
3. To study the transport and fate of pollutant in surface water bodies
4. To familiarize the numerical techniques for solving the system equations
5. To brief the atmospheric dispersion models

Course Content

Definition - Classification - Examples of Models for Environmental Systems - Concepts of Scale in Natural Systems - Brief Review of Mass, Momentum and Energy Balance - steady state system – time variable response systems – Model formulation; Transport and fate of pollutant in aquatic systems: Rivers - Dissolved oxygen model for streams - Estuaries – Lakes; Finite Difference and Linear Algebraic Methods to Solve the System Equations - Some Special

Models; Introduction to Air Quality Models: Meteorology - Atmospheric Stability and Turbulence - Gaussian Plume Model and Modifications - Line source models.

References

1. *Chapra, S.C., Surface water quality modeling. McGraw Hill International Edition, 1997.*
2. *Davis, M.L., and Cornell, D.A., Introduction to Environmental Engineering. McGraw Hill International Editions, 1998.*
3. *Peavy, H.S.; Rowe, D.R.; Tchobanoglous, G., Environmental Engineering. McGraw Hills, New York, 2017.*
4. *Gilbert, M.M., Introduction to Environmental Engineering and Science. Prentice- Hall of India Pvt. Ltd., Newdelhi, 3rd Edition, 2007.*
5. *Martin, L.J., and McCucheon, S.C., Hydrodynamics of transport for water quality modeling. Lewis Publishers, Boca Raton, 1999.*

Course Outcomes

At the end of the course student will be able

1. to utilize the mass balance approach for the prediction of air and water quality
2. to develop contaminant transport model for natural systems
3. to predict the quality of water in river, lakes and estuaries using specific models
4. to solve the transport equation using numerical techniques
5. to estimate the concentration of pollutant in ambient air using dispersion models

Course Code	:	CE715
Course Title	:	**GROUNDWATER FLOW AND CONTAMINANT TRANSPORT THROUGH POROUS MEDIA**
Type of Course	:	Program Elective
Prerequisites	:	Basic knowledge in Modeling of natural systems
Contact Hours	:	36
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives

1. To provide an understanding of water movement in subsurface environment
2. To study the transport of contaminants through porous media
3. To know the fate of contaminants and its interactions with porous media
4. To familiarize the application of various analytical solutions and numerical models in groundwater systems
5. To learn the groundwater modeling tools for model development and prediction

Course Content

Water Movement in the Subsurface - Groundwater Environment - Types of Aquifers - Sources of Contamination - Saturated Flow - Continuity Equation - Darcy's Law - Equation of Flow - Transport of Contaminants - Transport Equation - Dispersion and Diffusion in Porous Media – Reaction Terms: Adsorption and Surface Complexation - Soil Chemical Kinetics – Monod

Kinetic Reactions; Coupling of Contaminant - Soil Interactions with Transport - Reaction and Transport of Trace Metals, Ligands and Non-polar Organic Solutes - Analytical Solutions and Numerical Modeling Modelling; Modeling of Groundwater Pollution: Model development - Model Input Parameters – Initial and Boundary Conditions - Calibration - Sensitivity Analysis - Groundwater Transport Modelling Using VISUAL MODFLOW.

References

1. Zheng, C., and Bennett, G.D., Applied contaminant Transport Modeling. A John wiley & sons, inc, publication, Newyork, 2002.
2. *Freeze, R.A., and Cherry, J.A., Groundwater, Prentice Hall, 1979.*
3. *Sun, N.Z., Mathematical modelling of groundwater Pollution. Springer, Verlac Newyork Inc., and Geological publishing house, 1996.*
4. *Grathwohl, P., Diffusion in Natural Porous Media: Contaminant Transport. Sorption, desorption and Dissolution Kinetics, Kluwer Academic, Boston, 1998.*

Course Outcomes

At the end of the course student will be able
1. to understand contaminant transport mechanisms in aquifers
2. to develop flow and transport model for contaminant-soil interactions in groundwater
3. to differentiate various numerical techniques for solving flow and transport equations
4. to build a contaminant transport model for real field applications
5. to apply the software packages for modeling of groundwater pollution

Course Code	:	CE716
Course Title	:	**INDOOR ENVIRONMENTAL QUALITY**
Type of Course	:	Program Elective
Prerequisites	:	Fundamental Knowledge in indoor environment
Contact Hours	:	36
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives

1. To study the key factors influencing indoor environmental quality (IEQ) in buildings
2. To learn the consequences of inadequate indoor environmental quality
3. To know the analytical and instrumental methods to measure various IEQ parameters
4. To familiarize the regulations, standards and guidelines of IEQ
5. To learn the fundamentals of computational fluid dynamics (CFD)

Course Content

Introduction to indoor environmental quality – Parameters: Thermal Comfort - thermal balance of human body – instrumentation and measurement - impact of thermal comfort on human productivity and health; Indoor air quality (IAQ): Pollutants – carbon dioxide, volatile organic compounds (VOCs), formaldehyde and bioaerosols – sources – moisture - mold damage and ventilation – IAQ measurement and instrumentation; Building acoustics: Basics of acoustics and specification of Sound – Sound power – Sound intensity and Sound Pressure levels – Indoor Noise Propagation – Noise criteria – Effects of noise on health – Annoyance rating schemes – Special noise environments – Noise standards and limits – Instrumentation and monitoring – Noise indices; Illumination: Daylighting and Artificial lighting – impact on health – measurement; Occupant surveys – Evaluation, feedback and review; Standards and regulations; Sensors for IEQ monitoring; Fundamentals of Computational Fluid Dynamics in indoor air quality modeling.

References

1. *Nazaroff,* W.W., and *Alvarez-Cohen, L., Environmental Engineering Science. Wiley sons, Newyork, 2001.*
2. *Pengler, J.D.; McCarthy, J.F.; Same, J.M., Indoor Air Quality Handbook. McGraw Hill, 2000.*
3. *Maroni, M.; Seifert, B.; Lindvall, T., Indoor Air Quality: A Comprehensive Reference Book. Elsevier Science Ltd, 1996.*

Course Outcomes

At the end of the course student will be able
1. to understand the parameters affecting indoor environmental quality (IEQ)
2. to measure the various IEQ parameters
3. to assess the impact of poor IEQ on human health and comfort
4. to design sustainable buildings as per the standards and guidelines
5. to understand the applications of CFD modelling in indoor air quality study

Course Code	:	CE717
Course Title	:	**AEROSOL SCIENCE AND ENGINEERING**
Type of Course	:	Program Elective
Prerequisites	:	Fundamental Knowledge in atmospheric chemistry
Contact Hours	:	36
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives

1. To learn the basics of aerosol physics
2. To study aerosol formation and transformation in atmosphere
3. To gain proficiency in aerosol measurement and characterization methods
4. To know the health impacts due to atmospheric aerosols
5. To familiarize the fundamentals of aerosol reactor design for real life applications

Course Content

Atmosphere - Composition of air; Aerosols- Physics of aerosols - Size distributions – Mechanics of motion – Agglomeration –Diffusion – Electrical effects and Light scattering; Particle formation and Growth dynamics; Sampling – Iso-kinetic sampling – Aerosol Measurement and Instrumentation; Chemical composition; Aerosol-Water interactions –

Cloud Condensation Nuclei – Aerosol transport and deposition – Visibility – Global effects; Biological Aerosols – Respiratory deposition; Aerosol reactor design engineering and Applications: Environmental Aerosols – Catalysis – Combustion – Instrumentation – Pharmaceuticals – Powder production.

References

1. *Friedlander, S.K., and Smoke, D., Smoke, Dust, and Haze: Fundamentals of Aerosol Dynamics. Oxford University Press, New York, 2000.*
2. *Hinds, W.C., Aerosol Technology: Properties, Behavior and Measurement of Airborne Particles. Wiley-Interscience, New York., 1999*
3. *Seinfeld, J.H., and Pandis, S.N., Atmospheric Chemistry and Physics: from Air Pollution to Climate Change. John Wiley, New York, 1998*

Course Outcomes

At the end of the course student will be able
1. to understand the fundamental principles of atmospheric aerosols
2. to evaluate particle formation and dynamics in the atmosphere
3. to monitor atmospheric aerosols and understand its chemical composition
4. to assess the impacts of aerosols on atmospheric processes, climate, and air quality
5. to apply aerosol reactor design concepts in various engineering applications

Course Code	:	CE718
Course Title	:	**ANALYTICAL METHODS FOR ENVIRONMENTAL MONITORING**
Type of Course	:	Program Elective
Prerequisites	:	Basic knowledge of water and wastewater quality
Contact Hours	:	36
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives

1. To learn the various instrumental methods for environmental monitoring
2. To list the types of instrumental errors and calibration methods
3. To study the principle of spectrophotometry, chromatography, and their applications
4. To familiarize the working principle of air samplers
5. To provide the information about various material characterization techniques

Course Content

Classification of Instrumental Methods; Performance Characteristics of Instruments – Errors and Uncertainties - Types of errors – Noise Reduction – Sensitivity and Detection limit – precision and accuracy – calibration; Ion Selective Electrodes - Conductometry - Electrolytic Conductivity - Specific Equivalent and Molar Conductance – Working Principles of pH, EC, TDS Meters; Principles - Instrumentation and Applications: Turbidimetry - Flame Photometer - Spectrophotometry – Atomic Absorption and Emission Spectrometry – Inductively Coupled

Plasma and its types – Chromatography – column efficiency and resolution - Column Chromatography – Thin Layer Chromatography – Ion chromatography – Gas Chromatography (GC) – High Precision Liquid Chromatography (HPLC) – Ion Chromatography Mass Spectroscopy – Gas Chromatography Mass Spectroscopy (GCMS) – Electrochemical methods – Electrochemical Cell – Cyclic Voltammetry - Total Organic Carbon Analyser - Air samplers; Material Characterization Techniques: SEM – TEM – XRD – FTIR – Thermal Analysis – Working Principles and Applications.

References

1. *Skoog, D. A.; West, D.M.; Nieman T.A., Principles of Instrumental Analysis. Thomson Asion (P) Ltd. Singapore, 2004.*
2. *Willard, H.H.; Merit, L.L.; Dean, J.A.; Settle, F.A., Instrumental Methods of Analysis, CBP Publishers and Distributors. New Delhi, 1988.*
3. *Douglas, A.S.; Holler, F.J.; Timothy, A.N., Principles of Instrumental Analysis. 6th Edition Thomson Brooks/Cole, 2007.*

Course Outcome

At the end of the course student will be able

1. to understand the principles of analytical instruments in environmental monitoring
2. to select suitable ion selective electrodes for water and wastewater quality analysis
3. to evaluate the level of pollution using sophisticated instruments
4. to utilize appropriate electrochemical methods for industrial applications
5. to summarize various material characterization techniques and its principles

Course Code	:	CE719
Course Title	:	**LANDFILL DESIGN AND OPERATION**
Type of Course	:	Program Elective
Prerequisites	:	Basic knowledge in solid waste management
Contact Hours	:	36
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives

1. to familiarize with landfill components and legal frameworks for landfilling
2. to impart knowledge on reactions in landfills and their impacts on environment
3. to learn the design principles of landfill components as per the guidelines and regulatory compliances
4. to understand the landfill operation and safety control procedures
5. to provide ideas for landfill reclamation, resource recovery and reuse

Course Content

Concepts of Integrated SWM – Landfills: Components - Legal framework for landfilling – Landfill siting considerations; Reactions in Landfills: Leachate – Landfill water balance - Hydrologic Evaluation of Landfill Performance (HELP) model – leachate quality - landfill gas

(LFG) – Gas quantity and quality - Landfill fire and Fire control - Landfill Design: Liners - Leachate collection system (LCS) – leachate treatment and disposal – Leachate re-circulation - bioreactor landfills – Landfill Gas Collection – Landfill Gas use – Geotechnical aspects of landfill design – Landfill stability and settlement – Landfill Cap – landfill Economics; Landfill Operations: Equipments – filling sequence – Daily cover – Monitoring and control- Post Closure care and use of landfills; Impacts of legacy waste: Fate and behavior of toxics and persistent substances in the environment; Remediation Principles: Rehabilitation of Open dumps - Bioremediation and Biomining of legacy waste – case studies.

References

1. *Pichtel, J., Waste management practices: municipal, hazardous, and industrial. CRC press, 2005.*
2. *Worrell, W.A., and Vesilind, P.A., Solid waste engineering, 2012.*
3. *Tchobanoglous, G., Solid waste management. Environmental engineering: environmental health and safety for municipal infrastructure, land use and planning, and industry. Wiley, New Jersey, pp.177-307, 2009.*
4. *CPHEEO. Manual on Solid Waste Management. Ministry of Urban Development, 2016.*
5. *Townsend, T.G.; Powell, J.; Jain, P.; Xu, Q.; Tolaymat, T.; Reinhart, D., Sustainable practices for landfill design and operation. Springer, 2015.*
6. *Bagchi, A., Design of landfills and integrated solid waste management. John Wiley & Sons, 2004.*
7. *Qian, X.; Koerner, R.M.; Gray, D.H., Geotechnical aspects of landfill construction and design. Prentice Hall, 2001.*

Course Outcomes

At the end of the course student will be able

1. to identify salient aspects of landfills and suggest suitable site and configuration for landfills
2. to understand the landfill gas components and to classify the nature of landfill leachate based on reactions in the landfills
3. to design the major components of landfill as per regulatory standards
4. to execute landfill operations and plan the post closure monitoring systems for landfills
5. to apply the theoretical knowledge for the landfill reclamation projects in real world

Course Code	:	CE720
Course Title	:	**ENVIRONMENTAL IMPACT ASSESSMENT**
Type of Course	:	Program Elective
Prerequisites	:	Basic knowledge in Impact Assessment
Contact Hours	:	36
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives

1. To learn the importance of environmental impact assessment in various engineering projects
2. To brief the various methodologies involved in environmental impact assessment

3. To identify the prediction tools for the assessment of different environmental impacts
4. To describe the concepts of environmental management systems
5. To understand the principles and practices of post-project monitoring and environmental auditing

Course Content

Evolution of EIA - Concepts - Rapid and Comprehensive EIA - EIA notifications and its amendments - Legislative and Environmental Clearance Procedures in India - Introduction to PARIVESH; QCI-NABET accreditation system; Different FORMs in EIA; Screening - Scoping – Role of specific conditions- general conditions- ESZ notifications - Functions of Appraisal committees - Standard ToR and Specific ToR - Base Line Studies -Role of EIA coordinator and functional area experts - Methodologies - Check List - Matrices - Mitigation - Prediction Tools for EIA - Assessment of Impacts- Risk Assessment and disaster management plan- Public Participation - Resettlement and Rehabilitation - Documentation of EIA - Environmental Management Plan - Post Project Monitoring; Case Studies in EIA; Environmental Audit - Life Cycle Assessment – Environmental Management Systems.

References

1. *Canter, R. L., Environmental Impact Assessment. Mc Graw Hill International Edition, 1997.*
2. *John, G.R., and David, C.W., Environmental Impact Analysis Handbook. McGraw Hill Book Company, 1980.*
3. *Underwood, J.G.; James, R.C.; Beanlands, M.L., Cumulative Environmental Impacts: A Primer for Scientists and Policy Makers. Lewis Publishers, 1996.*
4. *Ramachandra, T.V., Cumulative Environmental Impact Assessment. Nova Science Publishers, 2006.*
5. *Guidelines from the Ministry of Environment, Forest and Climate Change (Government of India) for Environmental Impact Assessments (EIAs).*

Course Outcomes

At the end of the course student will be able
1. to analyse the environmental impacts of proposed projects
2. to predict the magnitude of an impact using mathematical tools
3. to propose proper mitigation measures to avoid environmental impacts
4. to summarise the EIA report with a suitable environmental management plan
5. to develop and apply post-project monitoring and environmental audit programs for compliance and improvement

Course Code	:	CE721
Course Title	:	**ENVIRONMENTAL LAWS**
Type of Course	:	Program Elective
Prerequisites	:	Basic knowledge in environmental studies
Contact Hours	:	36
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives

1. To realize the fundamental principles of environmental laws and their importance
2. To study the status and effectiveness of environmental laws
3. To familiarize with constitutional and legal provisions related to environmental protection
4. To explore the role of government institutions in shaping and enforcing environmental law and policy
5. To know the contributions of NGOs and public participation in environmental law implementation

Course Content

Basic Principles of Environmental Laws - Introduction of International Environmental Laws - Status of Environmental Laws in India; Sources of Environmental Laws: Constitutional Provisions - Legal Provisions - Role of Government Institutions in Shaping and Administration of Environmental Law and Policy; Laws related to: Water Pollution - Solid and liquid Waste management - Air Pollution; Implementing Environmental Law: Administrative policy and Process - Procedural Aspects of Environmental Law - Functioning of Central & State Pollution Control Boards (PCBs) - Environmental Monitoring by the Agency - Industrial Pollution Control - Occupational Safety and Health - Role of Courts in Implementing Environmental Laws - Role of People and NGOs; Case Studies.

References

1. *Divan, S., and Rosencranz, A., Environmental Law and Policy in India Cases and Materials. Oxford University Press, 2022.*
2. *Percival, R.V.; Christopher, H.; Schroeder, A.S.; Leape, P., Environmental Regulation: Law, Science, and Policy. Aspen Publishing, 2024*
3. *Asolekar. S.R., and Gopichandran, R., Preventive Environmental Management. Foundation Books, 2005.*
4. *Johnson, B.L., and Lichtveld, M.Y., Environmental Policy and Public Health. CRC Press, 2022*

Course Outcomes

At the end of the course student will be able

1. to understand fundamental concepts and importance of environmental laws at National/International level
2. to recognize constitutional and legal provisions related to environmental protection
3. to evaluate the effectiveness of current practices in controlling pollution as per environmental laws
4. to engage with public and non-governmental organizations to promote environmental awareness
5. to understand the role of judiciary in implementing environmental laws

Course Code	:	CE722
Course Title	:	**ENVIRONMENTAL NANOTECHNOLOGY**
Type of Course	:	Program Elective
Prerequisites	:	Basic knowledge in water & wastewater treatments
Contact Hours	:	36
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives

1. To brief the fundamental principles of nanotechnology
2. To provide comprehensive understanding of nanomaterial fabrication techniques
3. To learn surface morphology and chemical characterization of nanomaterials
4. To explore the use of nanomaterials in environmental applications
5. To brief the potential toxicological and ecotoxicological impacts of nanomaterials

Course Content

Overview of nanomaterials in the environment – fundamental principles - natural nanomaterials – Synthetic Nanomaterial fabrication: Chemical, and Biological Synthesis; Structural and Chemical characterization - Surface chemistry and colloidal aspects of Nanomaterial; Environmental Applications: Nanomaterial for groundwater remediation - membrane process - nano based water & wastewater treatments - nanomaterial for air pollution control; Potential impact of nanomaterials - toxicological impact - ecotoxicological impact - life cycle risk assessment of nanomaterial.

References

1. *Wiesner, M.R., and Botter, J.Y., Environmental Nanotechnology: Applications and Impacts of Nanomaterials. McGraw-Hill, New York, 2007.*
2. *Fulekar, M. H., and Pathak, B., Environmental Nanotechnology. CRC Press., 2018.*
3. *Rao, C.N.R.; Müller, A.; Cheentham, A.K., Chemistry of Nanomaterials. Wiley – VCH, 2008.*
4. *Mamadou, D.; Jeremiah, D.; Nora, S.; Anita, S.; Richard, S., Nanotechnology Applications for Clean Water. Elsevier Science, 2009.*

Course Outcomes

At the end of the course student will be able
1. to understand the nanoscale phenomena and principles of nanotechnology
2. to fabricate various synthetic nanocomposites
3. to characterize and interpret the fabricated nanocomposites
4. to apply the knowledge of nanotechnology in water and wastewater treatment
5. to assess potential impacts associated with nanomaterials

Course Code	:	CE723
Course Title	:	**CLEANER PRODUCTION AND ENVIRONMENTAL SUSTAINABLE MANAGEMENT**
Type of Course	:	Program Elective
Prerequisites	:	Basic knowledge in Solid and Hazardous Waste Management
Contact Hours	:	36
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives

1. To provide the concept of sustainable development and to discuss the strategies and barriers of sustainability
2. To deliberate the principles and concepts of cleaner production and its importance
3. To discuss the green processes and green energy management in various industrial processes
4. To discuss the interrelationship between Industrialization and Sustainable Development
5. To learn the principles and methods of occupational safety and health, risk assessment and its management

Course Content

Concepts of Sustainable Development - Indicators of Sustainability - Sustainability Strategies, Barriers to Sustainability - Resource Degradation - Industrialization and Sustainable Development – Sustainable Engineering - Industrial Ecology - Socio Economic Policies for Sustainable Development - Clean Development Mechanism: Principles and Concepts of Cleaner Production - Definition - Importance - Historical Evolution - Benefits - Promotion - Barriers - Regulatory versus Market Based Approaches - Environmental Management Hierarchy - Source Reduction Techniques - Process and Equipment Optimization - Reuse - Recovery - Recycle - Raw Material Substitution - Overview of CP Assessment Steps and Skills - Process Flow Diagram - Material Balance - CP Option Generation - Technical and Environmental Feasibility Analysis - Economic Valuation of Alternatives - Total Cost Analysis - Pollution Prevention and Cleaner Production Awareness Plan - Waste Audit - Environmental Statement - Green House Gases and Carbon Credit - Carbon Sequestration - Sustainable Development through Trade - Carbon Trading - Ecotoxicology - Hazards by Industry and its Environmental Effects - Relationship of Occupational Hygiene / Safety and Disease - Overview, Planning, Hazard Identification and Risk Assessment – Pesticides and Environment - Response to Toxic Exposures - Dose Response, Frequency Response and Cumulative Response - Lethal and Sub-Lethal Doses - Dose - Response Relationships between Chemical and Biological Reactions - Detoxification in Human Body - Detoxification Mechanisms, Organs of Detoxification - Green Energy and Green Process Management in Pharmaceutical, Construction, Textiles, Petroleum Refineries, Iron and Steel Industries.

References

1. *Kirkby, J.,and O'Keefe, P.; Timberlake, Sustainable Development. Earthscan Publication, 1999.*
2. *Bishop, P. L., Pollution Prevention: Fundamentals and Practice. McGraw Hill International, 2004.*
3. *Modak, P.; Visvanathan, C.; Parasnis, M., Cleaner Production Audit. Environmental System Reviews, Asian Institute of Technology, Bangkok, 1995.*
4. *Koren, H.; Handbook of Environmental Health and Safety - Principle and Practices (3rd Rdition). Lewis Publishers, 1995.*
5. *Shaw, I.C., and Chadwick, J., Principles of Environmental Toxicology. Taylor & Francis ltd, 2000.*

Course Outcomes

At the end of the course student will be able

1. to modify schemes applied at different governance levels to achieve sustainable innovation
2. to prepare process flow diagram and material balance for various industrial processes
3. to summarize various techniques for cleaner production and to apply environmental sustainable management concepts in industries
4. to prepare detailed environmental statements on organization's performance and improvement plans
5. to examine the toxicological and ecological aspects of ecotoxicology and to transfer knowledge of ecotoxicological theory to new environmental situations

Course Code	:	CE724
Course Title	:	**ENVIRONMENTAL BIOTECHNOLOGY**
Type of Course	:	Program Elective
Prerequisites	:	Basic knowledge in microbiology
Contact Hours	:	36
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives

1. To study the principles and concepts of environmental biotechnology
2. To familiarize the biodegradation mechanism of solid wastes
3. To learn the applications of various biotechnological tools for the treatment and betterment of environment
4. To enumerate the various biotechnological remedies for environmental pollution
5. To brief the environmental effects and ethics of microbial technology

Course Content

Environmental Biotechnology - Principles and Concepts - Usefulness to Mankind - Degradation of High Concentrated Toxic Pollutants - Halogenated, Non Halogenated, Petroleum Hydrocarbons, Metals - Mechanisms of Detoxification - Oxidation - Dehalogenation - Biotransformation of Metals - Biodegradation of Solid Wastes - Biotechnological Remedies for Environmental Pollution - Decontamination of Groundwater - Bioremediation - Production of Proteins - Biofertilizers - Physical, Chemical and Microbiological Factors of Composting - Health Risk - Pathogens - Odor Management - Microbial Cell / Enzyme Technology - Adapted Microorganisms - Biological Removal of Nutrients - Algal Biotechnology - Extra Cellular Polymers - Biogas Technology - Applications - Environmental Effects and Ethics of Microbial Technology - Genetically Engineered Organisms - Microbial Containment - Risk Assessment; Bioremediation and Biodegradation - Microbial Catabolism of Organic Pollutant - Catabolic Enzymes - Biodegradation Detoxication Reactions - Biodegradation Kinetics - Requirements of Biodegradation – Nutritional, Environmental and Biological Factors - Monitoring and Assessment Methods - Soil Enzyme Assay - Bacterial

Biosensors - Toxicological Risk Assessments - Improved Bioremediation by Engineering Microbes - Bioadsorbents - Metal Precipitation - Enzymatic Transformation of Metals.

References

1. *Chaudhury, G.R., Biological Degradation and Bioremediation of Toxic chemicals. Dioscorides Press, 1994.*
2. *Bhattacharya, B.C., and Banerjee, R., Environmental Biotechnology. Oxford University Press, 2007.*
3. *Martin, A.M., Biological Degradation of Wastes. Elsevier Applied Science, 1991.*
4. *Blaine, M.F., Soil Microbiology Ecology. Marcel Dekker Inc, 1993.*

Course Outcomes

At the end of the course student will be able
1. to explain the mechanisms of detoxification and biodegradation of solid wastes
2. to list out the different methods for bioremediation of environment
3. to evaluate the benefit of microorganisms in degrading organic contaminants
4. to design biological system for the removal of biodegradable compounds
5. to select suitable assessment methods for bioremediation

Course Code	:	CE725
Course Title	:	**REMOTE SENSING AND GIS FOR ENVIRONMENTAL ENGINEERING APPLICATIONS**
Type of Course	:	Program Elective
Prerequisites	:	Basic knowledge in environmental engineering
Contact Hours	:	36
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives

1. To learn the potential applications of remote sensing in environmental engineering
2. To familiarize various satellite's data products and image classification algorithms
3. To introduce GIS data structures, data input and data pre and post processing
4. To give an idea about the various geospatial operations
5. To provide exposure on applicability of geo-spatial data products and methods to deal with environmental applications

Course content

Introduction to Remote sensing - Active, Passive, Optical Remote sensing - Electro Magnetic Radiation - EM spectrum - EMR interaction with atmosphere - Scattering - Atmospheric Windows and its Significance – EMR interaction with Earth Surface Materials - EMR interaction with atmosphere, water, soil and Earth surface – imaging spectrometry - Atmospheric windows - Spectral signature; Types of Platforms - orbit of Satellites - Satellite characteristics - types and classification of sensors - imaging modes - characteristics of optical sensors - sensor resolution-spectral - radiometric and temporal - characteristics of detectors; Introduction to image processing - pre-processing - geometric corrections – image enhancement - spatial filtering technique - image classification techniques - visual and digital interpretation of Satellite Images - Environmental Satellites: GOES - NOAA - AVHRR - CZCR - OCM - OCEANSAT - Sentinel - LandSat - MODIS; Fundamentals of Geographic Information System - Geodata - type - Input Sources - Raster and Vector data model - Comparison of Raster and Vector data - errors in data – Geospatial analysis using Raster and Vector data – File format - Data conversion between Raster and vector Projection and transformation - Reclassification - Neighbourhood and Regional Operations – Map Algebra – Vector Data Analysis - Proximity analysis - Attribute data Analysis - concepts of SQL; Tools for map Analysis: Weighted overlay - Boolean logic models – Index overlay models – Fuzzy logic method - Monitor and mapping of atmosphere constituents - Spectral responses of clear and contaminated water - Site suitability analysis for disposal of solid waste using Multi Criterion Analysis - GIS for groundwater vulnerability for pollution - Seawater intrusion modeling - Oil spill detection - satellite mapping of Chlorophyll - suspended sediment concentration inland and coastal waterbodies - Remote Sensing application on soil degradation assessment - soil erosion - soil salinity mapping - air quality Mapping - Eutrophication and reservoir sedimentation.

References

1. *Agarwal, C.S., and Garg, P.K., Remote Sensing in Natural Resources Monitoring and Management. Wheeler & Co, 2000.*
2. *Gibson, P.J., Introductory Remote Sensing-Principles and Concepts. Taylor and Francis Press, 2000.*
3. *Gibson, P.J., and Power, C.H., Introductory Remote Sensing-Digital Image Processing and Application. Taylor and Francis Press, 2000.*
4. *Lillesand, T., and Kiefer, W.K., Remote Sensing and Image Interpretation 4th Edition. Wiley, 2015.*
5. *Ramkumar, M., Geological Hazards: Causes, Consequences and Methods of Containment. New India Publishing Agency, 2009.*

Course Outcomes

At the end of the course student will be able

1. to understand the basic concept of satellite image processing
2. to perform pre and post processing of satellite images
3. to comprehend about geographic information system
4. to select appropriate geospatial operations
5. to apply the geospatial and image processing techniques for environmental problems

Course Code	:	CE726
Course Title	:	**CLIMATE VARIABILITY, MITIGATION AND ADAPTATION**
Type of Course	:	Program Elective
Prerequisites	:	Basic knowledge in environmental science
Contact Hours	:	36
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives

1. To provide a comprehensive understanding of the fundamental principles of climate science, including the causes and effects of climate variability and change
2. To explore and evaluate various climate change mitigation strategies aimed at reducing greenhouse gas emissions and their effectiveness in different contexts
3. To study methods and technologies for adapting to climate change impacts, focusing on resilience and sustainability in both urban and rural settings
4. To examine climate policies, international agreements, and governance frameworks that influence climate action at the global, national, and local levels
5. To develop analytical skills for assessing climate data, modeling climate scenarios, and designing mitigation and adaptation projects

Course content

Introduction to Climate Science - Climate System Basics: Atmosphere, Hydrosphere, Lithosphere, and Biosphere; Climate vs. Weather: Definitions and Differences; Climate change as a problem - Impacts of climate change - Historical Climate Change: Natural and Anthropogenic Factors; Climate Change Mitigation: Greenhouse Gases: Sources - Sinks - Impacts - Global warming; Mitigation and policy evaluation - Strategies and technology options; Mitigation Strategies: Renewable Energy - Energy Efficiency - Carbon Sequestration; Climate Change Mitigation Policies: Kyoto Protocol - Paris Agreement; Climate change case studies; Climate Change Adaptation: Vulnerability and Risk Assessment; Adaptation Strategies: Infrastructure - Agriculture - Water Resources - Urban Planning; Evaluation of the effectiveness of approaches in managing climate change risk; Case Studies of Adaptation Projects; Climate Policy and Governance - International Climate Agreements: United Nations Framework Convention on Climate Change (UNFCCC) - Overview and significance of the Convention - COP Meetings; National Climate Policies: India's National Action Plan on Climate Change; Governance Frameworks: Institutions - Stakeholders - Policy Implementation; Effectiveness of policy approaches in reducing climate change and variability risk; Climate Data Analysis and Modeling - Climate Data Sources: Observations - and Climate Models - Scenario Analysis - Impact Assessment.

References

1. *Boylr, G.; Everest, B.; Ramage, J., Energy Systems and Sustainability: Power for a Sustainable Future 2nd Edition. Oxford University Press, 2012.*
2. *Stokke, O.S., Implementing the Climate Regime 1st Edition. Taylor & francis, 2005.*
3. *Hovi, J.; Stokke, O.; Ulfstein, G., Implementing the Climate Regime: International Compliance. Earthscan, 2005.*
4. *Yamin, F., Climate Change and Carbon Markets: A Handbook of Emission Reduction Mechanisms. Earthscan, 2005.*
5. *Edmond, A., and Jason, E., Climate Change: The Science of Global Warming and Our Energy Future 2nd Edition. Columbia University Press, 2018.*
6. *Dessler, A.E., Introduction to Modern Climate Change 2nd Edition. Cambridge University Press, 2018.*
7. *Gidens, A., The Politics of Climate Change: National Response to the challenge of global warming. Policy Network, 2008.*

8. *Bodansky, D.; Brunnie, J.; Rajamani, L., International Climate Change Law. Oxford University Press, 2017.*

Course Outcomes

At the end of the course student will be able

1. to demonstrate a thorough understanding of climate systems, including the drivers of climate variability
2. to assess various mitigation technologies and strategies for their feasibility and effectiveness
3. to develop and propose effective adaptation strategies for different sectors impacted by climate change
4. to analyze and interpret international and national climate policies, and assess their implications for climate action
5. to utilize climate models and analytical tools to simulate climate scenarios and evaluate potential outcomes of mitigation and adaptation strategies

Course Code	:	CE727
Course Title	:	**ENVIRONMENTAL SYSTEMS ANALYSIS**
Type of Course	:	Program Elective
Prerequisites	:	Fundamental Knowledge in Environmental Systems
Contact Hours	:	36
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives

1. To brief the role of optimization models in planning and design of environmental engineering projects
2. To list out various optimization models and its limitations
3. To learn the application of simulation models in environmental projects
4. To know the fundamental principles of systems engineering, including analysis and design
5. To provide an understanding of application of modern tools in different case studies

Course Content

Systems Engineering - Analysis - Design - Synthesis - Applications to Environmental Engineering Systems - Role of Optimization Models - Deterministic Models / Linear Programming - Dynamic Programming - Separable and Nonlinear Programming Models - Formulation of Objective Functions and Constraints for Environmental Engineering Planning and Design - Probabilistic Models - Fuzzy Models - Simulation Models - Modern Tools - Expert Systems - Neural Networks - Genetic Algorithm - Case Studies - Applications.

References

1. *Rich, L. G., Environmental Systems Engineering. McGraw Hill, 1973.*
2. *Thoman, R.V., Systems Analysis & water Quality Control. McGraw Hill, 1994.*
3. *McConnell, D., and Lambert, S.M., Environmental Engineering: Fundamentals, Sustainability, Design. People Education Limited, 2005.*

Course Outcomes

At the end of the course student will be able
1. to analyse the system performance using simulation models
2. to optimize environmental engineering Systems using optimization models
3. to use the concepts of probabilistic and fuzzy models for improving management processes
4. to employ model-based environmental analysis in decision-making
5. to choose a suitable Systems analysis method and tool for a given decision situation

Course Code	**:**	CE728
Course Title	**:**	**ENVIRONMENTAL SOCIAL GOVERNANCE**
Type of Course	**:**	Program Elective
Prerequisites	**:**	Basic knowledge in air pollution and sustainability
Contact Hours	**:**	36
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives

1. To learn Environmental, Social, and Governance (ESG) and its basic principles
2. To describe global warming and climate change and to discuss the strategies for decarbonization
3. To gain knowledge in greenhouse gas (GHG) protocol and to calculate scope 1, 2 & 3 GHG emissions
4. To understand various sustainability reporting and various reporting frameworks
5. To recognize the materiality assessment

Course Content

Fundamentals of ESG – Industrial aspects of environment – Basics of Corporate Social Responsibility (CSR) – Role of CSR in ESG – Basics of corporate governance – role of Human Resource (HR) in ESG – Principles of Sustainable Management – Global warming and climate change – GHG protocol – Intergovernmental Panel on Climate Change (IPCC) – Calculating Scope 1 emissions – Scope 2 emissions – Scope 3 emissions – Sustainability reporting – Global Reporting Initiative (GRI) – Business Responsibility and Sustainability Reporting (BRSR) – Sustainability assurance – ESG rating agencies – S&P Global – MSCI – Renewable energy – Solar energy – Wind energy – Energy efficiency – Climate scenario analysis – GHG Target setting – Decarbonization – Science Based Targets initiative (SBTi) alignment – Materiality assessment – Single materiality – Double materiality – Circular Economy.

References

1. *Tracy Dathe; René Dathe; Isabel Dathe; Marc Helmold., Corporate Social Responsibility (CSR), Sustainability and Environmental Social Governance (ESG), Springer International Publishing, 2022.*
2. *Ranganathan, J.; Corbier, L.; Bhatia, P.; Schmitz, S.; Gage, P.; Oren, K., The Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard. World Resources Institute, 2004.*

3. *Bhatia, P.; Cummins, C.; Brown, A.; David, R.; Holly, H., The Greenhouse Gas Protocol: Corporate Value Chain (Scope 3) Accounting and Reporting Standard. World Resources Institute, 2011.*
4. *Kelly, L.; Finnegan, J.; David, R.; Bhatia, P., The Greenhouse Gas Protocol: Mitigation Goal Standard. World Resources Institute, 2014.*

Course Outcomes

At the end of the course student will be able

1. to identify the need of ESG and contribute towards improvement of company's ESG ratings
2. to assess the role of Corporate Social Responsibility in ESG
3. to estimate the scope 1,2 & 3 GHG emissions as per GHG protocol and device decarbonization strategy
4. to develop various reporting frameworks and assist in developing sustainability reports and BRSR reporting
5. to carry out materiality assessment and identify long term risks

Course Code	:	CE729
Course Title	:	**ECOLOGICAL AND ECOSYSTEM ENGINEERING**
Type of Course	:	Program Elective
Prerequisites	:	Basic knowledge in air pollution and sustainability
Contact Hours	:	36
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives

1. To understand the principles and concepts of terrestrial, freshwater, and marine ecology
2. To explore threats to biodiversity and conservation strategies.
3. To learn the development and evolution of ecosystems.
4. To differentiate the structural and functional interactions of environmental systems
5. To understand the principles of ecological economics and sustainable development

Course Content

Ecology - Terrestrial ecology - Fresh water ecology - Marine ecology; Biodiversity: Indices - Assessment methods – Threats – Conservation; Development and Evolution of Ecosystems: Principles and Concepts - Energy Flow and Material Cycling – Productivity; Classification of Ecotechnology; Ecological Engineering: Classification of Systems - Structural and Functional Interactions of Environmental Systems - Mechanisms of Steady State Maintenance in Open and Closed Systems; Modeling of Ecotechnology: Classification of Ecological Models – Applications; Ecological Economics; Self Organizing Design and Processes - Multi Seeded Microcosms - Interface Coupling in Ecological Systems - Concept of Energy - Determination of Sustainable Loading of Ecosystems - Eco sanitation - Soil Infiltration Systems - Wetlands and Ponds – Source Separation Systems - Aqua Cultural Systems - Agro Ecosystems - Detritus Based Treatment for Solid Wastes - Marine Systems - Case Studies.

References

1. *Chapman, J.L., and Reiss., M.J., Ecology: Principles and Applications. Cambridge Univ. press, 2nd edition, 2018.*
2. *Singh, J.S.; Singh, J.P.; Gupta, S.R., Ecology, Environment and Resource conservation. Anamaya Publ., New Delhi, 5th edition, 2017.*
3. *Hunter Jr, M.L., and Gibbs, J.P., Fundamentals of Conservation Biology. Wiley, 2009.*
4. *Kangas, P.C., and Kangas, P., Ecological Engineering: Principles and Practice, Lewis Publishers, New York, 2004.*
5. *Etnier, C., and Guterstam, B., Ecological Engineering for Wastewater Treatment, Lewis Publishers, New York, 2nd edition, 1997.*

Course Outcomes

At the end of the course student will be able

1. to identify the interrelationship of ecology, ecotechnology, and ecological engineering
2. to classify, evaluate and design interface ecosystems
3. to design sustainable loading of eco systems
4. to develop model in different ecological scenarios and applications in real field
5. to expertise on eco sanitation regarding different ecosystem