Walchand College of Engineering, Sangli

(Government Aided Autonomous Institute)

Course Contents (Syllabus) for

First Year M. Tech.
Civil
(Environmental Engineering)
Sem – I to II

AY 2020-21

Title of the Course:
Research Methodology (4IC501)

L	T	P	Cr
2	-	-	2

Pre-Requisite Courses: Nil

Textbooks:
1. Wayne Goddard and Stuart Melville, "Research Methodology: An Introduction" , 2nd Ed.-2004, Juta and Company Ltd.
2. Ranjit Kumar, "Research Methodology: A Step by Step Guide for beginners" , 4th Ed.-2014, SAGE Publications.
3. Stuart Melville and Wayne Goddard, "Research Methodology: An Introduction for Science & Engineering Students", 2000 , Juta and Company Ltd.

References:
1. Halbert, "Resisting Intellectual Property", Taylor & Francis Ltd ,2007.
2. Mayall, "Industrial Design", McGraw Hill, 1992.
3. Niebel, "Product Design", McGraw Hill, 1974.
4. T. Ramappa, "Intellectual Property Rights Under WTO", S. Chand, 2008

Course Objectives:
1. To prepare students for undergoing research, identify and formulate the research problems, state the hypothesis, design a research layout, set a research process and methodology.
2. To enable students to investigate the problem, interpret the results, propose theories, suggest possible/alternative solutions, solve and prove the solution adapted–logically and analytically, conclude the research findings.
3. To impart knowledge to review the literature and publish research in conference and journals.
4. To expose students to research ethics, IPR and patents.

Course Learning Outcomes:

CO	After the completion of the course the student should be able to	Bloom's Cognitive	
		Level	**Descriptor**
CO1	**Analyze** research and its significance in economic, social and legal aspects.	IV	Analyzing
CO2	**Evaluate** research problem and its design for solution logically and critically.	V	Evaluating
CO3	**Produce** research solution, publication, Dissertation, IPR and patent.	VI	Creating

CO-PO Mapping:

PO	1	2	3	4	5	6
CO1	3				1	
CO2	3			2		
CO3	3	3		2		

Assessments:
Teacher Assessment:

Two components of In Semester Evaluation (ISE), One Mid Semester Examination (MSE) and one End Semester Examination (ESE) having 20%, 30% and 50% weights respectively.

Assessment	Marks
ISE 1	10
MSE	30
ISE 2	10
ESE	50

ISE 1 and ISE 2 are based on assignment/declared test/quiz/seminar etc.
MSE: Assessment is based on 50% of course content (Normally first three modules)

ESE: Assessment is based on 100% course content with 60-70% weightage for course content (normally last three modules) covered after MSE.	
Course Contents:	
Module 1: Engineering Research Process	**6 Hrs.**
Meaning of research problem, Sources of research problem, Criteria and Characteristics of a good research problem, Errors in selecting a research problem, Definition, scope and objectives of research problem. Approaches of investigation of solutions for research problem, data collection, analysis, interpretation, Necessary instrumentations.	
Module 2: Research Methodology Tools	**7 Hrs.**
Problem statement formulation, resources identification for solution, Experimental and Analytical modelling, Numerical and Statistical methods in engineering research, Software tools like spread sheets.	
Module 3: Research Ethics and Report Writing	**6 Hrs.**
Effective literature studies approaches, critical analysis, Plagiarism, Research ethics, Effective technical writing, how to write report, Paper. Presentation of paper/report/seminar.	
Module 4: Introduction to IPR and Patents	**7 Hrs.**
Nature of Intellectual Property: Patents, Designs, Trade and Copyright. Process of Patenting and Development: technological research, innovation, patenting, development. International Scenario: International cooperation on Intellectual Property. Procedure for grants of patents, Patenting under PCT. Patent Rights: Scope of Patent Rights. Licensing and transfer of technology. New Developments in IPR: Administration of Patent System. New developments in IPR; IPR of Biological Systems, Computer Software etc. Traditional knowledge Case Studies	
Module wise Outcomes: At end of each module students will be able to: 1. Identify and formulate the research problems, state the hypothesis, design a research layout, set a research process and methodology. 2. Apply research tools to obtain solution to research problem. 3. Analyze critically existing literature and prepare seminar, write research article and report. 4. Create IPR in his domain of research and produce patent.	

Title of the Course: Physico-Chemical Methods for Water and Wastewater Treatment (4EV501)	L	T	P	Cr
	3	-	-	3

Pre-Requisite Courses: A course on Environmental Engineering at graduate level

Textbooks:

1. Peavy H, S, Rowe D, R, and Tchobanoglous G, *"Environmental Engineering",* McGraw-Hill Book Company, Indian edition 2017.
2. Metcalf and Eddy *"Wastewater Engineering Treatment and Reuse",* Tata McGraw Hill Publication, Indian Edition 2017.
3. Davis, M, L, and Cornwell, D, A, *"Introduction to Environmental Engineering",* Tata McGraw Hill Publishing Company, Special Indian Edition, 2010.
4. Unit Operations and Processes in Environmental Engineering, 2nd Edition, by Tom D. Reynolds and Paul A. Richards, PWS Publishing Company, 1995.

References:

1. Droste, Ronald L *"Theory and Practice of Water and Wastewater Treatment",* Wiley student Edition, 2009.
2. Weber W, J, "*Physico-Chemical Processes of Water quality control",* Wiley-Interscience, 1994.
3. Sincero A, P and Sincero G, A, *"Environmental Engineering A Design approach",* PHI learning private limited, 2004.
4. Quasim, S. R., Motley E, M and Zhu G, *"Water works engineering",* PHI learning private limited, 2000.

Course Objectives:

1. To provide in-depth knowledge of unit operations and processes for the treatment of water and wastewater.
2. To impart technical competency for analysis, evaluation and design of physical and chemical treatment systems for water and wastewater.
3. To inculcate aptitude for research, and consultancy.

Course Learning Outcomes:

CO	After the completion of the course the student should be able to	Bloom's Cognitive	
		Level	**Descriptor**
CO1	**Explain and Apply** the concepts of unit operations and processes for physical and chemical treatment of water and wastewater.	II III	Understanding Applying
CO2	**Analyze** and **evaluate** the physical and chemical treatment systems used in water and wastewater.	IV V	Analyzing Evaluating
CO3	**Design** physical and chemical treatment systems for water and wastewater.	VI	Creating

CO-PO Mapping:

PO	1	2	3	4	5	6
CO1			3			
CO2				3		
CO3						3

Assessments:
Teacher Assessment:

Two components of In Semester Evaluation (ISE), One Mid Semester Examination (MSE) and one End Semester Examination (ESE) having 20%, 30% and 50% weights respectively.

Assessment	Marks
ISE 1	10

MSE	30
ISE 2	10
ESE	50

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MSE: Assessment is based on 50% of course content (Normally first three modules)
ESE: Assessment is based on 100% course content with 60-70% weightage for course content (normally last three modules) covered after MSE.

Course Contents:

Module 1: Transport Phenomena and Reaction Kinetics	**7 Hrs.**
Review of conventional unit operations and processes in water and wastewater treatment Transport processes, Kinetics and Reaction rates, System material balance, Hydraulic transport flow regimes, Reactor Engineering (CMBR, CMFR, CMFRS, PFR, PFRD), Processes and rates of gas transfer	
Module 2: Aeration and Mixing	**8 Hrs.**
Types of aerator, Design of gravity aerators Coagulation and flocculation, Stability and destabilization of colloids, Transport of colloidal particles, Design of rapid and slow mix units Types of settling, Design of sedimentation tanks, Tube settler, Grit chamber (horizontal flow and aerated)	
Module 3: Filtration	**5 Hrs.**
Gravity and pressure filtration, filter hydraulics, Analysis of filtration process, Backwash hydraulics, Rate control patterns and methods, Design of dual media and pressure filter	
Module 4: Adsorption and Ion Exchange	**8 Hrs.**
Causes and Types of adsorption, Adsorption equilibria and adsorption isotherm, Process, Analysis and design of batch and continuous flow activated carbon adsorber Ion Exchange process, Exchange materials and capacity, Exchange reactions, Design and operation of softener for hardness and TDS removal	
Module 5: Membrane Filtration	**7 Hrs.**
Membrane separation processes, Design and operation of Reverse osmosis, Ultrafiltration, and Electrodialysis. Membrane fouling: Causes, and Control.	
Module 6: Disinfection	**5 Hrs.**
Kinetics of disinfection Ozone disinfection: Chemistry, System components, Modeling. UV disinfection: Source, System components, Estimation of UV dose. Principles and theories of Chemical oxidation.	

Module wise Outcomes:
At end of each module students will be able to:

1. **Apply** the concepts of transport and transformation models for the **analysis** and **evaluation** of various types of reactors.
2. **Apply** the acquired knowledge on solids separation for the **analysis** and **design** of rapid mixer, slow mixer and clarifier.
3. **Analyze, Evaluate** and **Design** single and dual media depth filtration systems.
4. **Apply** the knowledge of adsorption and ion exchange processes for the **analysis** and **design** of adsorption column and softener.
5. **Apply and Design** membrane filtration system for water and wastewater treatment.
6. **Analyze and evaluate** appropriate system of disinfection.

Title of the Course: Municipal Solid Waste Management (4EV502)	L	T	P	Cr
	3	-	-	3

Pre-Requisite Courses: Environmental Engineering

Textbooks:

1. Bhide. A. D. and Sundaresan. B. B., “Solid Waste Management”, Indian National Scientific Documentation Centre, 1st Edition, 1983.
2. CPHEEO, "Manual on Municipal Solid waste management”, Central Public Health and Environmental Engineering Organization, Government of India, New Delhi, 2000
3. Tchobanoglous G., “Integrated Solid Waste Management”, Tata McGraw-Hill Publishing Company Limited, 1st Edition, 1993.

References:

1. Vesilind, Worrell and Reinhart, “Solid Waste Engineering”, Cengage Learning India Pvt. Ltd.,
2. Masters G., “Introduction to Environmental Engineering and Science”, Pearson Education, 2004
3. Peavy, Rowe and Tchobanoglous, “Environmental Engineering”, Tata McGraw-Hill Publishing Company Limited, 1st Edition, 1985.
4. “MSW Rules 2016”, Swachh Bharat Mission and Smart Cities Program of India.

Course Objectives:

1. Provide knowledge on functional elements of MSWM.
2. Impart basic skills for design and operation of MSWM systems.
3. Have overview of MSW rules and Government initiatives.

Course Learning Outcomes:

CO	After the completion of the course the student should be able to	Bloom's Cognitive	
		Level	**Descriptor**
CO1	**Recognize** fundamental elements of MSW and **summarize** practices for effective MSW management.	I II	Remembering Understanding
CO2	**Apply** the fundamental elements of MSWM to **analyze** collection, transportation, and processing of MSW.	III IV	Applying Analyzing
CO3	**Evaluate** processing and disposal system; and to **devise** suitable plans for rehabilitation of existing MSWM	V	Evaluating

CO-PO Mapping:

PO	1	2	3	4	5	6
CO1			3			
CO2				3		3
CO3				3		

Assessments:
Teacher Assessment:

Two components of In Semester Evaluation (ISE), One Mid Semester Examination (MSE) and one End Semester Examination (ESE) having 20%, 30% and 50% weights respectively.

Assessment	Marks
ISE 1	10
MSE	30
ISE 2	10
ESE	50

ISE 1 and ISE 2 are based on assignment/declared test/quiz/seminar etc.
MSE: Assessment is based on 50% of course content (Normally first three modules)
ESE: Assessment is based on 100% course content with 60-70% weightage for course content

(normally last three modules) covered after MSE.	
Course Contents:	
Module 1: Municipal Solid Waste Sources and Characterization	**7 Hrs.**
Sources, Types, Composition, Physical, Chemical and Biological properties. Solid Waste Management: Objectives, Functional elements, Environmental impact of mismanagement,: Present Indian Scenario and scope to improve system for different functional elements of solid waste management system.	
Module 2: Solid Waste Generation Rate & Transfer Station	**6 Hrs.**
Solid Waste Generation Rate: Definition, Typical values for Indian cities, Factors affecting. Storage and collection: General considerations for waste storage at source, Collection components, Types of collection systems and its design, Transportation of solid waste: Means and methods, Routing of vehicles. Transfer station: Need, Types, factors affecting Capacity, Location and economic Viability.	
Module 3: Waste Processing Techniques & Material Recovery and Recycling	**7 Hrs.**
Waste Processing Techniques: Purpose, Mechanical volume and size reduction, component separation techniques. Material Recovery and Recycling: Objectives, Recycling program elements, Commonly recycled materials and processes. Energy recovery from solid waste: Parameters affecting, Fundamentals of thermal processing, Pyrolysis, Incineration, Refuse derived fuels, Energy recovery, case studies under Indian conditions.	
Module 4: Recovery of Biological Conversion Products: Compost and Biogas	**6 Hrs.**
Composting: Benefits, Processes, Stages, Technologies, Factors affecting, Properties of compost. Vermicomposting and Biomethanation.	
Module 5: Landfills	**7 Hrs.**
Site selection, Types, Principle, Processes, Land filling methods, Leachate and landfill gas management, Design of a landfill facility, closure, post-closure plans, and rehabilitation of dumpsites.	
Module 6: Overview of Municipal Solid Waste Rules and Government Initiatives	**7 Hrs.**
Waste Management legislation in India, integrated management-Public awareness; Role of NGO's; Introduction to various initiatives of the Govt. of India such as Swachh Bharat Mission, Smart Cities as well as Make in India; Biomedical; C and D waste Generation, identification, storage, collection, transport, treatment, and disposal, occupational hazards and safety measures.	
Module wise Outcomes: At end of each module students will be able to: 1. **Recognize** source and type of SW, and **to summarize** measures to improve the management practices. 2. **Explain** methodologies for the control on SW generation; **to evaluate** equipment and methods of SW collection, storage, and conveyance; and **to devise** economical solution for the transport of SW. 3. **Compare** SW processing techniques for resource recovery and recycling; evaluate energy recovery alternatives. 4. **Apply** biological techniques for the recovery conversion products such as compost and biogas 5. **Evaluate** site topography for design of sanitary landfills and decide closure and post-closure plans, suggest suitable methods for the rehabilitation of dumpsites. 6. **Recall** legislative background of MSWM according to nature of SW and devise public awareness program in line with Indian government initiatives.	

Title of the Course: **Environmental Chemistry and Microbiology Laboratory (4EV551)**	L	T	P	Cr
	-	-	4	2

Pre-Requisite Courses: Engineering Chemistry

Textbooks:

1. Peavy H. S., Rowe D. R. and Tchobanoglous G, *"Environmental Engineering",* McGraw-Hill book company, 1st Edition, 2013.
2. Pelczar Jr., M.J.E.C.S. Krieg, R. Noel., and Pelczar M. F., "Microbiology", Tata McGraw Hill Publishing Company Limited, 5th Edition, 1996.
3. Sawyer C.N. and McCarty P. L., *"Chemistry for Environmental Engineers",* Tata McGraw-Hill Publishing Company Limited, 5th Edition, 2003.

References:

1. American Public Health Association (APHA), "*Standard Methods for the Examination of Water and Wastewater",* 23rd Edition, 2017.
2. Metcalf and Eddy "Wastewater Engineering Treatment and Reuse", Tata McGraw Hill Publication, 6th Reprint. 2003.

Course Objectives :

1. To provide hands-on practice for analyzing the water and wastewater by physical, chemical and instrumental methods.
2. To provide fundamental knowledge of laboratory skills.
3. To impart knowledge of microbiology and bacterial identification.

Course Learning Outcomes:

CO	After the completion of the course the student should be able to	**Bloom's Cognitive**	
		Level	**Descriptor**
CO1	**Experiment** water/wastewater quality analysis through physical, chemical, biological and advanced instrumental methods.	III	Applying
CO2	**Analyze** and **interpret** data acquired from the experiments.	III IV	Applying Analyzing
CO3	**Identify** types of cells, bacteria by using proper staining methods.	IV	Analyzing

CO-PO Mapping:

PO	**1**	**2**	**3**	**4**	**5**	**6**
CO1			2	3		
CO2			2	2		
CO3			2	1		

Assessments:

Teacher Assessment:

In Semester Evaluations (ISE 1 & ISE 2), Mid Semester Evaluation (MSE) and End Semester Examination (ESE) have 25% weights each.

Assessment	Marks
ISE 1	25
MSE	25
ISE 2	25
ESE	25

ISE 1, ISE 2 and MSE are based on experimental work/performance in laboratory/assignment/declared test/etc.

ESE assessment is based on performance and oral.

Course Contents:

List of Experiments:

1. **Physical and bio-chemical analysis of water:**
   a. pH
   b. Acidity and Alkalinity
   c. Electrical conductivity
   d. Solids
   e. Hardness (Total, Ca and Mg, Temporary and Permanent)
   f. Dissolved oxygen
   g. Chloride content
   h. Residual chlorine in water
   i. Dissolved organic matter by BOD and COD
   j. Nitrate
   k. Sulphate
   l. Fluoride
   m. Iron and Manganese (Spectrophotometer)
2. **Microbiology:**
   a. Cell Types: Eukaryotic and Prokaryotic
   b. Gram staining
   c. Bacterial cultures
   d. Most Probable Number (MPN)
3. **Instrumental Methods:**
   Study and use of
   a. Flame photometer
   b. Spectrophotometer
   c. TOC Analyzer
   d. Gas Chromatograph
   e. Atomic Absorption Spectrophotometer
   f. Zeta meter
   g. CHNS Analyzer

Title of the Course: Water Treatability Studies Laboratory (4EV552)	L	T	P	Cr
	-	-	4	2

Pre-Requisite Courses: Physico-Chemical Methods for Water and Wastewater Treatment

Textbooks:

1. Peavy H, S, Rowe D, R, and Tchobanoglous G, "Environmental Engineering", McGraw-Hill Book Company, International edition, 1985.
2. Metcalf and Eddy "Wastewater Engineering Treatment and Reuse", Tata McGraw Hill Publication, 6th Reprint, 2003.
3. "Manual on water supply and Treatment", CPHEEO, Ministry of Urban Development, GoI, New Delhi, 1999.

References:

1. Sincero A, P and Sincero G, A, "Environmental Engineering A Design approach", PHI learning private limited, 2004.
2. Sawyer and McCarty, "Chemistry for Environmental Engineers", Tata McGraw Hill, Edition 5, 2003.
3. Clesceri, L. S., Greenberg, A. E. and Eaton, A. D. (Eds), Standard Methods for the Examination of Water and Wastewater, Washington, D.C., 21st Ed., 2001.
4. Quasim, S. R., "Water treatment plants planning, design and operation", CRC Press, 2nd Edition, 2010.

Course Objectives:

1. To provide exposure to the techniques and tools for the design and conduct of the experiments.
2. To provide an opportunity to contribute individually/ in groups to the development of experimental set ups by applying the acquired technological knowledge.

Course Learning Outcomes:

CO	After the completion of the course the student should be able to	Bloom's Cognitive	
		Level	Descriptor
CO1	**Design** experiments by applying the acquired knowledge on techniques and tools.	VI	Creating
CO2	**Carry out** experimental studies for characterization, parameter estimation, and performance evaluation independently and in teams.	III	Applying
CO3	**Analyze, critique, and interpret** experimental results through application of modern engineering tools and **conclude** based on the results.	IV V	Analyzing Evaluating

CO-PO Mapping:

PO	1	2	3	4	5	6
CO1			3			
CO2			3			
CO3				3		

Assessments:

Teacher Assessment:

In Semester Evaluations (ISE 1 & ISE 2), Mid Semester Evaluation (MSE) and End Semester Examination (ESE) have 25% weights each.

Assessment	Marks
ISE 1	25

MSE	25
ISE 2	25
ESE	25

ISE 1, ISE 2 and MSE are based on experimental work/performance in laboratory/assignment/declared test/etc.

ESE assessment is based on performance and oral.

Course Contents:

List of Experiments:

1. Determination of order and rate of reaction/mass transfer parameter using CMBR
2. Flow measurement by ultrasonic flow meter
3. Use of natural and chemical coagulant/s for the turbidity, and color removal
4. Settling column studies for discrete and flocculent dilute suspensions
5. Physical and chemical characteristics of sand as filter media
6. Determination of head loss in depth filter
7. Development of adsorption isotherm with activated carbon
8. Determination of exchange capacity of resin
9. Use of resin for hardness removal
10. Chlorination study on raw, filtered and distributed water

Title of the Course: Professional Elective 1 Environmental Chemistry and Microbiology (4EV511)	L	T	P	Cr
	3	-	-	3

Pre-Requisite Courses: A course on chemistry at graduate level

Textbooks:

1. Sawyer C.N. and McCarty P.L., "Chemistry for Environmental Engineers", Tata McGraw-Hill Publishing Company Limited, 5th Edition, 2003.
2. Holler F. J. and Crouch S. R., "Skoog and West's Fundamentals of analytical Chemistry", Cengage Learning, 9th Edition, 2012.
3. Mohapatra P. K., "Textbook of Environmental Microbiology", I. K. International Publishing House Pvt. Ltd., Reprint 2013.

References:

1. VanLoon G. W. and Duffy S. J., "Environmental Chemistry: A Global Perspective", Oxford University Press, Indian Edition, Reprint 2011.
2. Pelczar Jr., M. J. E. C. S. Krieg, R. Noel., and Pelczar M. F., "Microbiology", Tata McGraw Hill Publishing Company Limited, Reprint 2012.
3. Madigan, M., Bender K. S., Buckley D.H., Sattley W. M., and Stahl D.A., "Brock Biology of Microorganisms", 15th Edition New York: Pearson, 2017.

Course Objectives:

1. To provide in-depth knowledge of environmental chemistry and microbiology for the treatment of water, wastewater and solid waste.

Course Learning Outcomes:

CO	After the completion of the course the student should be able to	Bloom's Cognitive	
		Level	**Descriptor**
CO1	**Explain** the basic concepts of environmental chemistry and microbiology of water and wastewater.	II	Understanding
CO2	**Summarize** environmental significance of organic compounds and microorganisms.	II	Understanding
CO3	**Apply** instrumental and microbiological methods for water and wastewater analysis.	III	Applying

CO-PO Mapping:

PO	1	2	3	4	5	6
CO1			2			
CO2			2			
CO3			3	1		1

Assessments:

Teacher Assessment:

Two components of In Semester Evaluation (ISE), One Mid Semester Examination (MSE) and one End Semester Examination (ESE) having 20%, 30% and 50% weights respectively.

Assessment	Marks
ISE 1	10
MSE	30
ISE 2	10
ESE	50

ISE 1 and ISE 2 are based on assignment/declared test/quiz/seminar etc.
MSE: Assessment is based on 50% of course content (Normally first three modules)
ESE: Assessment is based on 100% course content with 60-70% weightage for course content (normally last three modules) covered after MSE.

Course Contents:	
Module 1: Introduction to General Chemistry and Physical Chemistry	**6 Hrs.**
General chemistry: Nomenclature, Valency, Oxidation-reduction equations, pH-pE diagrams, Ionization, Solubility Product, Common ion effect. **Physical chemistry:** Enthalpy, Entropy, Vapour pressure, Solvent extraction	
Module 2: Introduction to Organic Chemistry and Biochemistry	**6 Hrs.**
Organic chemistry: Environmental significance of different organic compounds viz. Aliphatic Compounds: Alcohols, Aldehydes and Ketones, Acids, Esters, Ethers, Halogenated aliphatic compounds, Compounds containing nitrogen. Aromatic Compounds: Hydrocarbons, Phenols, Alcohols, Aldehydes, Ketones and Acids, Compounds containing nitrogen, Heterocyclic compounds, Dyes, Detergents and Pesticides. **Biochemistry:** Biochemistry of carbohydrates and Proteins, General biochemical pathways.	
Module 3: Instrumental Methods	**8 Hrs.**
Instrumental Methods: UV- visible, atomic absorption spectroscopy, flame photometry with reference to principle, instrumentation, calibration, working and applications in environmental analysis. Chromatography and its types. Mass spectroscopy and Gas chromatography with reference to principle, instrumentation, calibration, working and applications in environmental analysis.	
Module 4: Colloidal Chemistry	**4 Hrs.**
Colloidal Chemistry: General Properties, Brownian movement, Tyndall effect, Environmental significance of colloids. Colloidal dispersion in liquids: Solid-in-liquid, liquid-in-liquid, gas-in-liquid. Colloidal dispersions in air: Fog and Smog, Smoke and other particulate aerosols.	
Module 5: Introduction to Environmental Microbiology	**8 Hrs.**
Introduction to microbiology: Groups of microorganisms, Major characteristics of microorganisms, Microbial classification, nomenclature and identification, Cell elements and composition, Cell and its composition, Cytoplasmic membrane, Prokaryotic cell division, Growth curve of bacteria, Enzymes and their regulation, Energy production by aerobic and anaerobic processes, Transport of nutrients by bacteria, Synthesis of amino acids, Process of protein synthesis. Control of microorganisms by physical and chemical agents.	
Module 6: Water, Wastewater and Solid Waste Treatment Using Microbiome	**8 Hrs.**
Drinking water microbiology, Drinking water microbiome and treatment, Microbial instability, Water borne microbial diseases. Bioremediation and wastewater microbiology, Bioremediation examples, Acid mine drainage, Enhanced metal recovery. Solid waste microbiology, Landfills, Leachate anaerobic degradation phases.	
Module wise Outcomes: At end of each module students will be able to: 1. **Explain** the basic concepts of general and physical chemistry. 2. **State** the environmental significance of organic compounds and **explain** basic concepts of biochemistry. 3. **Apply** the acquired knowledge on instrumental methods for the analysis of contaminants in water and wastewater. 4. **Explain** the significance of colloidal chemistry for solving environmental engineering related problems. 5. **Explain** the basic concepts of microbiology. 6. **Apply** appropriate system for water/wastewater/MSW treatment using microbiome.	

Title of the Course: Professional Elective 1 Geo-Environmental Engineering (4EV512)	L	T	P	Cr
	3	-	-	3

Pre-Requisite Courses: Soil Mechanics

Textbooks:

1. G L SivakumarBabu, “Soil Reinforcement and Geosynthetics”, Universities Press (India) Pvt. Ltd. Hyderabad, 2006.
2. S. K. Gulhati, Manoj Datta, “Geotechnical Engineering”, Tata McGraw Hill, New Delhi, 2005.
3. Braja Das, “Principles of Geotech. Engg”, Thomson Asia Pvt. Ltd, 5th Edition, 2002.
4. Fang, H.Y, “Introduction to Environmental Geotechnology”, CRC Press, 1997.

References:

1. Donald Coduto, “Geotechnical Engineering Principles and Practices Prentice Hall of India Pvt. Ltd, New Delhi, 2002.
2. Daniel, D. E, “Geotechnical Practice for Waste Disposal”, Chapman and Hall, 1993.
3. Koerner, R.M., “Designing with Geosynthetics”, Fifth Edition, Prentice Hall, New Jersey, 2005.

Course Objectives:

1. To provide students the necessary knowledge and concepts in the field of Subsurface Contamination, their effects, detection and remedial measures.
2. To familiarize the students with types and properties of geosynthetic materials, their use for various Civil engineering functions in general and for solid/slurry waste containment in particular.

Course Learning Outcomes:

CO	After the completion of the course the student should be able to	Bloom’s Cognitive	
		Level	**Descriptor**
CO1	**Describe** and **Differentiate** various engineering properties of soils, available geosynthetic materials, their properties and suitability.	II IV	Understanding Analyzing
CO2	**Calculate** area requirement of landfill site, **Evaluate** compaction quality using field tests.	IV V	Analyzing Evaluating
CO3	**Describe** components of sanitary landfill sites, **Analyze** stability of landfill embankments, liners and covers.	II IV	Understanding Analyzing

CO-PO Mapping:

PO	1	2	3	4	5	6
CO1			3			
CO2				2		3
CO3				2		3

Assessments:

Teacher Assessment:

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Assessment	Marks
ISE 1	10
MSE	30
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MSE: Assessment is based on 50% of course content (Normally first three modules)

ESE: Assessment is based on 100% course content with 60-70% weightage for course content (normally last three modules) covered after MSE.	
Course Contents:	
Module 1: Introduction to Geo-environmental Engineering	**7 Hrs.**
Introduction, overview of pollution, control and remediation, Case histories on Geo-environmental Engineering, Soils- Soil as 'Phased System', Soil classification, Various Soil Types with important engineering properties, their suitability for intended purpose, Clay Mineralogy.	
Module 2: Contaminant Transport in Soil	**5 Hrs.**
Soil-water-contaminant interaction; Contaminant Transport, Geochemical Attenuation and attenuation capacity of soils. Zones of contaminant plume. Introduction to Detection of polluted zones and Monitoring designed system.	
Module 3: Introduction to Geosynthetic Materials	**6 Hrs.**
Various forms of Geosynthetic material (GM, GT, GN, GG, GCL, GP, Geofoam), Their general applications for various engineering functions. Various Geosynthetic material properties. Use of Geosynthetic material in waste containment. Concerns about use.	
Module 4: Solid Waste Containment	**12 Hrs.**
Site selection, Typical cross sections of landfills, merits and demerits. Area calculation of landfill site. EPA (MoEF and CPCB) Guidelines. CCL, GCL and composite liners. Compaction quality control for CC liners. Stability analysis of Landfills: Conventional Slope Stability analysis by method of slices, stability number concept. Stability against sliding of geomembrane over clay (liner stability) and sliding of soil over geomembrane (Cover stability). Assessment of anchorage requirement of GM.	
Module 5: Slurry Waste Containment	**5 Hrs.**
Slurry Waste Containment: Slurry transported wastes, pond layouts, components of pond, embankment construction, staged raising of embankment, Design aspects, environmental impact and control. **Vertical Barriers for Containment**: Various types of Cutoff Walls, Requirements of good vertical barriers, Slurry trench walls using Bentonite and Cement-bentonite slurry, material and construction aspects.	
Module 6: Geotechnical Reuse of Waste Material	**5 Hrs.**
Waste reduction, use of waste in geotechnical construction, Waste characteristics for soil replacement, Transport considerations, and engineering properties of waste.	
Module wise Outcomes: At end of each module students will be able to: 1. **Explain and appraise** the environmental and health related risks, **describe** soil properties and behavior, understand soil-water-contaminant interaction. 2. **Describe and compare** plume transport. 3. **Describe and differentiate** various available geosynthetic materials. **Compare** their suitability for general engineering functions. 4. **Design** liner and cover system, **Perform** area calculations for landfill site, slope stability analysis and stability of liner-cover system. 5. **Explain** methods of slurry waste containment, vertical barriers. 6. **Explain and examine** reuse of waste material.	

Title of the Course: Professional Elective 2 Computational Methods and Optimization Techniques (4EV515)	L	T	P	Cr
	3	-	-	3

Pre-Requisite Courses: All Courses in Mathematics for UG

Textbooks:

1. Chapra S.C. and Canale R.P., "Numerical Methods for Engineers", Tata McGraw Hill Publications, 4th Edition, 2002.
2. Babu Ram "Numerical Methods", Pearson, 1st Edition, 2010.
3. Hamdy A. Taha, "Introduction to O.R.", 6th edition, (PHI)

References:

1. Balguruswamy, E. "Numerical Methods", Tata McGraw-Hill Publishing Co. Ltd., 2nd Edition, 2009.
2. Jain M.K., Iyengar S. R., Jain R. K., "Numerical Methods", New Age International (P) limited, 5th Edition, 2007.
3. N.D. Vora, "Quantitative Techniques in Management", 2nd edition (TMH).

Course Objectives:

1. To provide knowledge of numerical approach and significance of error analysis.
2. To provide necessary knowledge of numerical tools required for analyzing and solving problems in the field of engineering.
3. To provide pre-requisite statistical knowledge to the students for analyzing the data/results.
4. To deliver know-how of typical optimization techniques applicable to engineering problems.

Course Learning Outcomes:

CO	After the completion of the course the student should be able to	Bloom's Cognitive	
		Level	**Descriptor**
CO1	**Solve** linear, nonlinear equations, ODE and PDE by numerical methods.	III	Applying
CO2	**Analyze** data using various methods of regression and interpolation.	IV	Analyzing
CO3	**Propose** optimal solution using appropriate techniques.	V	Evaluating

CO-PO Mapping:

PO	1	2	3	4	5	6
CO1				1		
CO2				2		
CO3				1		

Assessments:

Teacher Assessment:

Two components of In Semester Evaluation (ISE), One Mid Semester Examination (MSE) and one End Semester Examination (ESE) having 20%, 30% and 50% weights respectively.

Assessment	Marks
ISE 1	10
MSE	30
ISE 2	10
ESE	50

ISE 1 and ISE 2 are based on assignment/declared test/quiz/seminar etc.

MSE: Assessment is based on 50% of course content (Normally first three modules)

ESE: Assessment is based on 100% course content with 60-70% weightage for course content (normally last three modules) covered after MSE.

Course Contents:	
Module 1: Introduction to Optimization Techniques	**6 Hrs.**
Introduction O. R., Problem Formulation, Classification of optimization problems. Unconstrained optimization, constrained optimization, Optimization of Linear P. P. using Simplex method, Duality and sensitivity analysis.	
Module 2: Optimization Problems and Solutions	**7 Hrs.**
Typical optimization problems in engineering and their solutions such as Assignment Problem, Transportation Problem, Shortest path, Minimal Spanning tree, Maximum flow Problem.	
Module 3: Dynamic Programming	**7 Hrs.**
Dynamic Programming: Multistage decision process, recursive relationships, Principle of optimality, Computational procedure in DP, DP applications, Problem of dimensionality. Game theory, Introduction to genetic algorithm and Simulation.	
Module 4: Introduction to Computational Methods	**6 Hrs.**
Introduction to Computational Methods, Accuracy & Precision, Error in Computational Methods, Significance of error computation. Revision of computational methods for solving linear and non-linear equations, Gauss Seidel Method, one point iteration method, Multiple Roots, Polynomial equations, Descartes' rule, Strum theorem.	
Module 5: Interpolation and Regression Methods	**6 Hrs.**
Difference between regression and interpolation, Linear interpolation, quadratic interpolation, General form of Newton's Interpolating Polynomial, Newton's divided difference interpolation polynomials, Lagrange's Interpolating Polynomials. Linear Regression, Least Squares Method, Polynomial Regression, Nonlinear Regression: Power fit, Parabola of Best fit.	
Module 6: Numerical Differentiation and Integration	**8 Hrs.**
Numerical Differentiation and integration, Numerical Quadrature, Cote's formula, Difference Equations, Solutions of Ordinary Differential Equations, Initial value and boundary value problems, Classification of methods of solution. Runge-Kutta Method, Solutions of B.V. Problems by Finite Difference methods. Classification of Partial Differential Equations, Formation of difference equations, Solution of Laplace's and Poisson's equations.	
Module wise Outcomes: At end of each module students will be able to: 1. **Apply** the concepts of optimization techniques to solve LPP. 2. **Optimize** typical engineering models. 3. **Evaluate** multi-stage decision process and decisions under uncertainty. 4. **Explain** elements of computational methods and **solve** linear as well as nonlinear equations. 5. **Apply** knowledge of computational methods for interpolation and regression of data. 6. **Employ** computational methods for solutions of ODEs and PDEs.	

Title of the Course: Professional Elective 2 Water Quality Modeling (4EV516)	L	T	P	Cr
	3	-	-	3

Pre-Requisite Courses: Basics of hydraulics and water quality

Textbooks:

1. Tchobanoglous G. and Schroeder E. D., "Water Quality: Characteristics, Modeling and Modifications", Addison-Wesley publishing company, Reprint 1987.
2. Chapra S., "Surface Water Quality Modeling", Tata Mc-Graw Hill, 1997.
3. Walski, Chase and Savic, "Water Distribution Modeling", Haestad Press, First edition, 2007.

References:

1. Lee C. C and Lin S. D., "Hand book of environmental engineering calculations", McGraw Hill Publication, 2nd Edition 2007.
2. Todd D. K., "Groundwater Hydrology", John Wiley & Sons, Second Edition, 2007.
3. Metcalf and Eddy, "Wastewater Engineering Treatment and Reuse", Tata McGraw Hill Publication, 6th Reprint. 2003.

Course Objectives:

1. Impart in-depth knowledge of modeling/simulation of water quality in surface, and sub-surface sources.
2. Enhance technical competency to deal with water quality issues in real life cases through modeling.

Course Learning Outcomes:

CO	After the completion of the course the student should be able to	Bloom's Cognitive	
		Level	**Descriptor**
CO1	**Explain** and **apply** concepts of simulation/modeling for pollutant transport in surface and sub-surface sources of water.	II III	Understanding Applying
CO2	**Analyze** and **evaluate** the processes contributing to water quality variations.	IV V	Analyzing Evaluating
CO3	**Apply** the modern tools of engineering for the analysis and design of environmental systems.	III	Applying

CO-PO Mapping:

PO	1	2	3	4	5	6
CO1			3			
CO2				3		
CO3						3

Assessments:
Teacher Assessment:

Two components of In Semester Evaluation (ISE), One Mid Semester Examination (MSE) and one End Semester Examination (ESE) having 20%, 30% and 50% weights respectively.

Assessment	Marks
ISE 1	10
MSE	30
ISE 2	10
ESE	50

ISE 1 and ISE 2 are based on assignment/declared test/quiz/seminar etc.
MSE: Assessment is based on 50% of course content (Normally first three modules)
ESE: Assessment is based on 100% course content with 60-70% weightage for course content (normally last three modules) covered after MSE.

Course Contents:	
Module 1: Fundamentals of Water Quality Modeling	**5 Hrs.**
Fundamentals: Concept of modeling, Model development, Types of models, Model sensitivity, Assessment of model performance, Movement of the contaminants in the environment Water quality in distribution system, Causes of variation, transport of constituents in pipe, chemical reactions, water quality simulations for source trace and water age.	
Module 2: Streams/Rivers and Estuaries	**6 Hrs.**
Streams/Rivers and Estuaries: Dispersion and Mixing of pollutants, Estuary transport, Point and non-point/distributed sources of pollution, Application plug and mixed flow reactors (MFR) to streams with point and distributed sources, Spill models for plug and mixed flow system, Application of MFR model to estuaries.	
Module 3: Process of Water Quality Modeling	**9 Hrs.**
Water quality modeling process, Modeling of organic pollution of stream, Streeter-Phelps equation for point, multiple point and distributed sources, Calibration, Modified/Total Streeter-Phelps equation, Anaerobic condition, Estuary Streeter-Phelps equation.	
Module 4: Groundwater Pollution and Control	**8 Hrs.**
Sources of groundwater pollution, Groundwater movement, Cone of Depression, Capture zone curve, Immiscible compounds, Processes in solute migration through porous media, Solute transport equation, Chemical reaction during transport, Sorption and retardation, Dupuit-Forchheimer theory of free surface flow, Control measures for contaminant plume, Hydrodynamic, physical, conventional pump and treat system, Soil vapour extraction with and without air sparging, In-situ bioremediation.	
Module 5: Lakes and Rivers	**7 Hrs.**
Eutrophication problem in lakes and flowing water, Role of Carbon, Nitrogen and phosphorous, Phosphorous loading concept, Thermal stratification, Stratification and dissolved oxygen, Hydraulic behavior of lakes, Effects of physical processes on water quality, Modeling of lakes and reservoirs.	
Module 6: Introduction to Water Quality Modeling Softwares	**5 Hrs.**
Study of modeling with EPANET, Qual2e and MODFLOW: Model conceptual basis, Modeling environment, Capabilities, Applications.	
Module wise Outcomes: At end of each module students will be able to: 1. **Explain** the concepts of modeling and **apply** it for the study of water quality variation in water distribution system. 2. **Apply** and evaluate pollutant transport processes in streams and estuaries. 3. **Explain**, and **apply** the concepts of modeling and calibration for point and distributed sources of pollution. 4. **Explain** and **apply** modeling concepts of pollutant transport in groundwater systems. 5. **Analyze** and **apply** the concepts of eutrophication problem in lakes. 6. **Evaluate** water distribution, groundwater and surface water systems using modern tools of engineering for pollutant transport.	

Title of the Course: **Biological Methods for Wastewater Treatment (4EV521)**	L	T	P	Cr
	3	-	-	3

Pre-Requisite Courses: A course on Wastewater Treatment at graduate level and Physico-Chemical Methods for Water and Wastewater Treatment

Textbooks:

1. Peavy H, S, Rowe D, R, and Tchobanoglous G, "Environmental Engineering", McGraw-Hill Book Company, Indian edition 2017.
2. Metcalf and Eddy "Wastewater Engineering Treatment and Reuse", Tata McGraw Hill Publication, Indian Edition 2017.
3. Unit Operations and Processes in Environmental Engineering, 2nd Edition, by Tom D. Reynolds and Paul A. Richards, PWS Publishing Company, 1995.

References:

1. Droste, Ronald L "Theory and Practice of Water and Wastewater Treatment", Wiley student Edition, 2009.
2. Crites Ron and Tchobanoglous George, "*Small and Decentralized Wastewater Management Systems*", McGraw-Hill Book Company, International edition, 1998.
3. Sincero A, P and Sincero G, A, *"Environmental Engineering A Design approach",* PHI learning private limited, 2004.
4. Quasim, S. R., "Wastewater treatment plants planning, design and operation", CRC Press, 2nd Edition, 2010.

Course Objectives :

1. To provide conceptual and field knowledge for the analysis, design and evaluation of biological processes of wastewater treatment.
2. To enhance the technical competency to conduct research and address the problems of industry/society related to wastewater treatment.
3. To inculcate the qualities of critical thinking.

Course Learning Outcomes:

CO	After the completion of the course the student should be able to	**Bloom's Cognitive**	
		Level	**Descriptor**
CO1	**Explain and Apply** the acquired knowledge on biological wastewater treatment.	II III	Understanding Applying
CO2	**Analyze** and **evaluate** the suspended and attached growth, aerobic and anaerobic biological wastewater treatment systems at secondary and tertiary levels.	IV V	Analyzing Evaluating
CO3	**Design** wastewater treatment and sludge processing facilities.	VI	Creating

CO-PO Mapping:

PO	**1**	**2**	**3**	**4**	**5**	**6**
CO1			3			
CO2				3		
CO3						3

Assessments:

Teacher Assessment:

Two components of In Semester Evaluation (ISE), One Mid Semester Examination (MSE) and one End Semester Examination (ESE) having 20%, 30% and 50% weights respectively.

Assessment	**Marks**
ISE 1	10
MSE	30
ISE 2	10
ESE	50

ISE 1 and ISE 2 are based on assignment/declared test/quiz/seminar etc. MSE: Assessment is based on 50% of course content (Normally first three modules) ESE: Assessment is based on 100% course content with 60-70% weightage for course content (normally last three modules) covered after MSE.	
Course Contents:	
Module 1: Biochemical Processes	**6 Hrs.**
Fundamentals: Measurement of organic pollutant, Biochemical transformation, Bioreactor configuration, Aerobic, Anoxic and Anaerobic Biochemical operations Kinetics of Bio-chemical operations: Biomass growth, Substrate utilization, Yield Kinetics of (Aerobic/Anoxic, Anaerobic) biomass growth	
Module 2: Suspended and Attached Growth Systems for Carbon Oxidation	**9 Hrs.**
Review of conventional activated sludge process (ASP), aerated lagoon and waste stabilization ponds Modeling aerobic suspended growth in complete-mix and plug flow reactor with and without recycle Design and operation of sequential batch/cyclic ASP and membrane bioreactor Biological filtration, Eckenfelder model for performance of packed tower with and without recirculation Design and operation of rotating biological contactor	
Module 3: Biological Nitrogen and Phosphorous Removal	**5 Hrs.**
Biological nitrogen and phosphorous removal, Kinetics of nitrification and denitrification Process design of ASP, SBR and RBC for carbon oxidation – nitrification and denitrification	
Module 4: Sludge Processing	**9 Hrs.**
Design and operation of Upflow Anaerobic Sludge Blanket system Sludge processing: Sludge mass-volume relationship, Process fundamentals of Thickening, Stabilization, Conditioning, and Dewatering Design and operation of gravity thickener, dissolved air flotation tank, anaerobic digester, belt press and sludge drying bed	
Module 5: Onsite Treatment and Constructed Wetland	**7 Hrs.**
Design and operation of decentralized wastewater treatment systems Moving Bed Bio reactor, Anaerobic filter, Modified septic tank Constructed Wetland (CW): Classification and application, Design and operation of horizontal flow subsurface, Vertical flow systems Emerging concepts in CW, Sludge treatment constructed wetland Design and operation of Water hyacinth system	
Module 6: Land Treatment Processes	**4 Hrs.**
Land treatment systems: Processes, Removal mechanisms, Design and operation of slow rate, rapid infiltration and overland flow systems	
Module wise Outcomes: At end of each module students will be able to 1. **Explain** concepts of biological wastewater treatment. 2. **Explain,** and **apply** the concepts of suspended and attached growth for the **design** of aerobic treatment systems. 3. **Apply** and **analyze** the concepts of biological nutrient removal for the design of nitrogen and phosphorous removal systems. 4. **Apply** the knowledge of anaerobic treatment to **Design** anaerobic systems for wastewater and sludge treatment. 5. **Apply and Design** constructed wetland system for wastewater and sludge treatment. 6. **Identify and Apply** appropriate system of wastewater reclamation and reuse.	

Title of the Course: **Air Pollution and Control (4EV522)**	L	T	P	Cr
	3	-	-	3

Pre-Requisite Courses: Environmental Engineering

Textbooks:

1. Wark and Warner, "Air Pollution", C.F., H.R. Publication, 1st Edition, 1978.
2. Nevers N., "Air Pollution control Engineering" McGraw-Hill, New York, 2nd edition, 1995.
3. Martin Crawford, "Air Pollution and Control", Tata McGraw Hill Publication, 1st Edition, 1976.

References:

1. Richard W. Boubel and Bruce Turner, "Fundamentals of Air Pollution", Academic Press, New York, Third edition, 1994.
2. Stern A. C., "Air Pollution Vol. I and II", Allied Publishers Limited, 1st Edition, 1994.
3. Rao H.V.N. and Rao M. N., "Air Pollution", Tata McGraw Hill, 1st Edition, 1989.

Course Objectives :

1. To provide knowledge on physics of atmosphere, meteorology and its relation to air pollution, different types of air pollution control equipment.

Course Learning Outcomes:

CO	After the completion of the course the student should be able to	**Bloom's Cognitive**	
		Level	**Descriptor**
CO1	**Recognize, and summarize** scientific and engineering principles for air pollution studies.	I II	Remembering Understanding
CO2	**Apply** appropriate dispersion models **estimate** air pollutant concentrations	III V	Applying Evaluating
CO3	**Analyze** situations leading to air pollution and **design** air pollution control strategies with due consideration to technical, environmental, health, safety and social considerations	IV V	Analyzing Evaluating

CO-PO Mapping:

PO	**1**	**2**	**3**	**4**	**5**	**6**
CO1			3			
CO2			3			3
CO3				3		3

Assessments:
Teacher Assessment:

Two components of In Semester Evaluation (ISE), One Mid Semester Examination (MSE) and one End Semester Examination (ESE) having 20%, 30% and 50% weights respectively.

Assessment	**Marks**
ISE 1	10
MSE	30
ISE 2	10
ESE	50

ISE 1 and ISE 2 are based on assignment/declared test/quiz/seminar etc.
MSE: Assessment is based on 50% of course content (Normally first three modules)
ESE: Assessment is based on 100% course content with 60-70% weightage for course content (normally last three modules) covered after MSE.

Course Contents:

Module 1: Air pollution: A retrospective	**7 Hrs.**
Air pollution: sources and types and effects on biosphere, National and international air emission standards; air pollution emission inventory; emission factor; air quality index; Strategy for effective control of air pollution in India, Introduction to air pollution control	

act, and international agreements for mitigating global air pollution effects.	
Module 2: Meteorology	**7 Hrs.**
Physics of atmosphere, Solar radiation, Wind circulation, Lapse rate, Inversion, Stability conditions, Pasquil stability model, Maximum mixing depth, Wind rose, Plume behavior, Global effects of air pollution: Green house effects, acid rain and ozone layer depletion, Heat island effect, Visibility, Photochemical reaction	
Module 3: Dispersion of pollutants in the atmosphere	**6 Hrs.**
Eddy diffusion model, the Gaussian dispersion model, Point source, Line source, Maximum ground level concentration, Determination of stack height, Sampling time corrections, Effects of inversion trap Definition, Distribution and source of different particulate matter, Terminal settling velocity, Basics of hood and duct design for particulate collection	
Module 4: Control Equipment for Particulate Matter	**7 Hrs.**
Operation design and component detailing of Settling chamber, Cyclone, Wet collectors, Fabric filter, and Electrostatic precipitator	
Module 5: General control of Gaseous pollutants	**7 Hrs.**
Principles of absorption, Adsorption, Basic design of absorption and adsorption units, Incineration and after burner, Control of SO_2, NOx	
Module 6: Motor Vehicle Emissions	**6 Hrs.**
Automobile Source Emission of pollutants from automobiles, Photochemical smog, Reduction of emissions by different methods, Alternative fuels and their utilizations.	
Module wise Outcomes: At end of each module students will be able to 1. **Recognize** the elements of air pollution scenario and **summarize** effects on human health, welfare and the environment. They will also be able to **state** emission standards and provisions made in act and international agreements for mitigating global air pollution effects. 2. **Explain** meteorological aspects leading to air pollution hazards. 3. **Apply** mathematical models to **estimate** emission, distribution, dispersion, settling and collection of air pollutants. 4. **Implement** appropriate air pollution control technique to **design** relevant instrumentation. 5. **Describe** principle of gaseous pollutants control and to **design** absorption and adsorption units. 6. **Identify** sources of air pollution from automobile and to **discuss** reduction of emissions by different methods, and utilization of alternative fuels.	

Title of the Course: MSW Characterization and Air Quality Monitoring Laboratory (4EV571)	L	T	P	Cr
	-	-	4	2

Pre-Requisite Courses: Solid Waste Management & Air Pollution and Control

Textbooks:

1. Wayne T. D., Air Pollution Engineering Manual, John Wiley & Sons, 2000.
2. Rao C. S., Environmental Pollution Control Engineering, New Age Int. Pubs, 2005.
3. "Manual for wet and dry depositing", CPCB Methods, Central Lab test methods, 2001.

References:

1. Sincero A. P. and Sincero G, A, "Environmental Engineering A Design approach", PHI learning Private limited, 2004.
2. Nathanson J. A. "Basic Environmental technology for water supply, waste management and Pollution control", PHI Publishing Company, 5th Edition, 2009.
3. Wark K. and Warner C.F., "Air Pollution", C.F., H.R. Publication, 1st Edition, 1978.

Course Objectives:

1. To provide hands on practice to analyze quality of ambient air, noise levels, stack emissions and MSW.
2. To provide knowledge to analyze environmental condition.

Course Learning Outcomes:

CO	After the completion of the course the student should be able to	Bloom's Cognitive	
		Level	**Descriptor**
CO1	**Recognize** and **explain** use of instrumentation for air, and noise monitoring and MSW Characterization.	I II	Remembering Understanding
CO2	**Use** instrumentation for air, and noise monitoring and MSW Characterization.	III	Applying
CO3	**Assess** environmental condition by using results obtained through experimentation	V	Evaluating

CO-PO Mapping:

PO	1	2	3	4	5	6
CO1			2	3		
CO2				3		2
CO3				3		2

Assessments:

Teacher Assessment:

In Semester Evaluations (ISE 1 & ISE 2), Mid Semester Evaluation (MSE) and End Semester Examination (ESE) have 25% weights each.

Assessment	Marks
ISE 1	25
MSE	25
ISE 2	25
ESE	25

ISE 1, ISE 2 and MSE are based on experimental work/performance in laboratory/assignment/declared test/etc.

ESE assessment is based on performance and oral.

Course Contents:

List of Experiments:

Part A:

1. Sampling of Municipal Solid Waste (MSW)
2. Proximate analysis of Municipal Solid Waste (MSW).
3. Ultimate analysis of Municipal Solid Waste (MSW).
4. Study of air samplers for ambient air quality monitoring.
5. Study of air samplers for indoor air quality monitoring.
6. Study of stack monitoring kit.
7. Study of automobile exhaust analyzer.
8. Study of weather monitoring station.
9. Study of noise level meter and ambient noise level measurements.

Part B:

1. Mini Project 1: Municipal Solid Waste Management for small locality/society/colony/village.
2. Mini Project 2: Indoor/Outdoor air quality monitoring of enclosed/open area.

Title of the Course: Wastewater Treatability Studies Laboratory (4EV572)	L	T	P	Cr
	-	-	4	2

Pre-Requisite Courses: Physico-Chemical Methods for Water and Wastewater Treatment and Biological Methods for Wastewater Treatment

Textbooks:

1. Hammer M, J and Hammer M, J, "Water and Wastewater Technology", PHI learning private limited, 6th Edition, 2008.
2. Metcalf and Eddy "Wastewater Engineering Treatment and Reuse", Tata McGraw Hill Publication, 6^{th} Reprint. 2003.
3. Lee C, C and Lin S, D, "Hand book of environmental engineering calculations", McGraw Hill Publication, 2nd Edition. 2007.

References:

1. Sawyer and McCarty, "Chemistry for Environmental Engineers", Tata McGraw Hill, Edition 5, 2003.
2. Clesceri, L. S., Greenberg, A. E. and Eaton, A. D. (Eds), Standard Methods for the Examination of Water and Wastewater, Washington, D.C., 21st Ed., 2001.
3. Quasim, S. R., "Wastewater treatment plants planning, design and operation", CRC Press, 2^{nd} Edition, 2010.

Course Objectives :

1. To provide hands-on practice to plan, design and conduct experiments.

Course Learning Outcomes:

CO	After the completion of the course the student should be able to	Bloom's Cognitive	
		Level	Descriptor
CO1	**Design** and **conduct** experiments using appropriate techniques and tools to demonstrate research skill individually/groups.	VI	Creating
CO2	**Analyze, critique,** and **interpret** results of experimental studies on performance evaluation and characterization studies.	IV V	Analyzing Evaluating

CO-PO Mapping:

PO	1	2	3	4	5	6
CO1			3			
CO2				3		

Assessments:

Teacher Assessment:

In Semester Evaluations (ISE 1 & ISE 2), Mid Semester Evaluation (MSE) and End Semester Examination (ESE) have 25% weights each.

Assessment	Marks
ISE 1	25
MSE	25
ISE 2	25
ESE	25

ISE 1, ISE 2 and MSE are based on experimental work/performance in laboratory/assignment/declared test/etc.

ESE assessment is based on performance and oral.

Course Contents:

List of Experiments:

1. Determination of BOD rate constant for domestic and industrial wastewater
2. Development of laboratory scale Activated Sludge Process (ASP) and Determination of MLSS, MLVSS, sludge volume index and sludge density index
3. Evaluation of bio-kinetic parameters for aerobic treatment
4. Performance evaluation of aerobic sequential batch reactor for treating domestic wastewater
5. Study on characterization of raw and processed (thickened/stabilized/dewatered) sludge
6. Development and operation of anaerobic reactor for wastewater/sludge treatment
7. Evaluation of effluent quality for land application
8. Evaluation of impact of effluent disposal on soil
9. Study of Activated Sludge Models (ASM)

Title of the Course: Professional Elective 3 Environmental Management Systems (4EV531)	L	T	P	Cr
	3	-	-	3

Pre-Requisite Courses: Environmental Engineering Course at Graduate Level

Textbooks:

1. Canter, L. W., Environmental Impact Assessment, McGraw-Hill, 2nd Edition, 1997.
2. Agarwal, N. P., Environmental Reporting and Auditing, Raj Pub., 1st Edition, 2002.
3. Judith, P. and Eduljee, G., Environmental Impact Assessment for Waste Treatment and Disposal Facilities, John Wiley & Sons, 1st Edition, 1994.

References:

1. "Environmental Auditing", Published by CPCB, Govt. of India Publication, New Delhi.
2. Mhaskar, A.K., Environmental Audit", Media Enviro Publications, 2002.
3. K. Whitelaw and Butterworth, ISO 14001: Environmental System Handbook, 1997.

Course Objectives :

1. To provide knowledge of ecological aspects.
2. To provide knowledge of Environmental Ethics.
3. To provide knowledge of environmental legislation.
4. To provide necessary knowledge of managerial tools required for assessing, analyzing and solving problems in the field of environmental management.

Course Learning Outcomes:

CO	After the completion of the course the student should be able to	Bloom's Cognitive	
		Level	**Descriptor**
CO1	Explain ecological imbalance due to various types of pollution and perceive environmental ethics and legislation.	II	Understanding
CO2	Choose appropriate methodology for EIA and auditing and assess the impacts.	III IV	Applying Analyzing
CO3	Justify EMS and Environmental Management Plan for infrastructural facilities.	V	Evaluating

CO-PO Mapping:

PO	1	2	3	4	5	6
CO1			1		2	
CO2			2	2		
CO3		1	3	3		

Assessments:

Teacher Assessment:

Two components of In Semester Evaluation (ISE), One Mid Semester Examination (MSE) and one End Semester Examination (ESE) having 20%, 30% and 50% weights respectively.

Assessment	Marks
ISE 1	10
MSE	30
ISE 2	10
ESE	50

ISE 1 and ISE 2 are based on assignment/declared test/quiz/seminar etc.
MSE: Assessment is based on 50% of course content (Normally first three modules)
ESE: Assessment is based on 100% course content with 60-70% weightage for course content (normally last three modules) covered after MSE.

Course Contents:

Module 1: Ecological Aspects and Noise Pollution	**7 Hrs.**
Ecological aspects: Salient features of major Eco Systems, Energy Transfer, Population Dynamics, Ecological imbalance, Preservation of Biodiversity. Land Pollution, Water	

Pollution due to sewage, industrial effluents and leachate, Pollution due to Nuclear Power Plants, Radioactive Waste, Thermal pollution, causes and control. **Noise Pollution:** Decibel Levels, Monitoring, Hazards, Control measures.	
Module 2: Environmental Ethics and Legislation	**7 Hrs.**
Environmental Ethics: Ethics in society, Environmental consequences, Responsibility for environmental degradation, Ethical theories and codes of Ethics, Changing attitudes, Sustainable development. **Environmental Legislation:** Water (prevention and control of pollution) act 1974, The environmental act 1986, The Noise Pollution (Regulation and Control) Rules, 2000. Environmental economics.	
Module 3: Environmental Impact Assessment (EIA)	**7 Hrs.**
Definitions and Concept, Scope, Objectives, Types of impacts, Elements of EIA, Baseline studies. Methodologies of EIA, Prediction of impacts and its methodology, Uncertainties in EIA, Status of EIAs in India.	
Module 4: Environmental Auditing	**6 Hrs.**
Definitions and concepts, Scope and Objectives, Types of audit, Accounts audit, Environmental audit statement, Qualities of environment auditor. Environmental Impact Statement (EIS).	
Module 5: ISO Standards	**7 Hrs.**
ISO and ISO 14000 Series: Introduction, Areas covered in the series of standards, Necessity of ISO certification. **Environmental management system:** Evolution, Need, Elements, Benefits, ISO 14001 requirements, Steps in ISO 14001 certification, ISO 14001 and sustainable development, Integration with other systems (ISO 9000, TQM, Six Sigma), Benefits of integration.	
Module 6: Environmental Management Plan	**6 Hrs.**
Definition, Importance, Development, Structuring, Monitoring, Cost aspects. Strategy for siting of Industries, Environmental Labeling, Life-Cycle Assessment.	
Module wise Outcomes: At end of each module students will be able to 1. **Explain** concepts of biological wastewater treatment. 2. **Explain,** and **apply** the concepts of suspended and attached growth for the **design** of aerobic treatment systems. 3. **Apply** and **analyze** the concepts of biological nutrient removal for the design of nitrogen and phosphorous removal systems. 4. **Apply** the knowledge of anaerobic treatment to **Design** anaerobic systems for wastewater and sludge treatment. 5. **Apply and Design** constructed wetland system for wastewater and sludge treatment. 6. **Identify and Apply** appropriate system of wastewater reclamation and reuse.	

Title of the Course: Professional Elective 3 Hazardous Waste Management (4EV532)	L	T	P	Cr
	3	-	-	3

Pre-Requisite Courses: Wastewater and Industrial Waste treatment

Textbooks:
1. LaGrega, M. D., Buckingham, P. L. and Evans, J. C., Hazardous Waste Management, 2nd Edition, McGraw Hill, 2001.
2. Metcalf and Eddy "Wastewater Engineering Treatment and Reuse", Tata McGraw Hill Publication, 6th Reprint, 2003.

References:
1. Sincero A, P and Sincero G, A, "Environmental Engineering A Design approach", PHI learning private limited, 2004.
2. Wentz, C. A., Hazardous Waste Management, 2nd Ed., McGraw Hill, 1995.
3. Lewandowski G.A. and DeFilippi L.J., Biological Treatment of Hazardous Wastes, John Wiley & Sons, 1998.

Course Objectives :
1. Provide in-depth knowledge of hazardous waste management.
2. To enhance the technical competency and apply the acquired knowledge for research and development, industry, and consultancy activities.

Course Learning Outcomes:

CO	After the completion of the course the student should be able to	Bloom's Cognitive	
		Level	**Descriptor**
CO1	**Explain** characterization, waste minimization, transportation, site remediation, and risk associated with hazardous waste.	II	Understanding
CO2	**Explain** and **Apply** the physical, chemical, and biological methods of treating hazardous waste.	II III	Understanding Applying
CO3	**Design** treatment and disposal facilities for hazardous waste.	VI	Creating

CO-PO Mapping:

PO	1	2	3	4	5	6
CO1			2			
CO2				2		
CO3				2		2

Assessments:
Teacher Assessment:

Two components of In Semester Evaluation (ISE), One Mid Semester Examination (MSE) and one End Semester Examination (ESE) having 20%, 30% and 50% weights respectively.

Assessment	Marks
ISE 1	10
MSE	30
ISE 2	10
ESE	50

ISE 1 and ISE 2 are based on assignment/declared test/quiz/seminar etc.
MSE: Assessment is based on 50% of course content (Normally first three modules)
ESE: Assessment is based on 100% course content with 60-70% weightage for course content (normally last three modules) covered after MSE.

Course Contents:

Module 1: Introduction to hazardous Waste Management	**5 Hrs.**
Hazardous waste: Definition, Sources, Characterization, Classification, Magnitude of problem, Concept of toxicity, Assessment of sites.	

Module 2: Waste minimization and Treatment	8 Hrs.
Waste minimization: Benefits, Approaches, Priorities in hazardous waste management, Resources recovery, Case studies. Treatment: Physical, Chemical and Biological treatment systems applicable for hazardous waste, Hazard in processing, Case studies of treatment.	
Module 3: Transportation of Hazardous Waste	**7 Hrs.**
Transportation: Storage of hazardous waste, Regulations governing transporters, Containers, Bulk transport, Non-bulk transport, Hazardous substances emergency response.	
Module 4: Disposal of Hazardous Waste	**8 Hrs.**
Land fill disposal: Land fill as disposal sites, Siting, Designing, Closure, Case studies Injection well disposal: Classifications, Deep well injection, Case studies.	
Module 5: Site Remediation	**7 Hrs.**
Site remediation: Site assessment and inspection, Hazard ranking system, Containment and treatment technologies, financial considerations, Case studies.	
Module 6: Risk Assessment	**5 Hrs.**
Risk Assessment: Process, Risk management, Hazardous waste management rules.	
Module wise Outcomes: At end of each module students will be able to 1. **Explain** concepts of hazardous waste and toxicity. 2. **Explain,** and **apply** waste minimization and treatment as referred to hazardous waste. 3. **Explain** the requirements of storage and transportation of hazardous waste. 4. **Design** landfill sites for hazardous waste disposal. 5. **Explain and Apply** techniques of site remediation and assessment. 6. **Explain** risk management and hazardous waste rules.	

Title of the Course: Professional Elective 4 Energy and Buildings (4EV536)	L	T	P	Cr
	3	-	-	3

Pre-Requisite Courses: Building Materials and Construction, Building Planning and Design

Textbooks:

1. Renewable Energy: Power for Sustainable Future, Ed. By Godfrey Boyle, Oxford Univ. Press, Third Edition.
2. Manual of tropical Housing and Building- Climatic Design by Koenigsberger, Ingersoll, Mayhew, Szokolay.
3. Alternative Building materials and Technologies by K.S. Jagadish, B.V.Venkatarama Reddy, K. S. Nanjunda Rao.

References:

1. Passive and Low Energy Building Design for Tropical Island Climates- by N. V. Baker, Published by Commonwealth Science Council, May 1987.
2. Energy Policy in the Greenhouse, Florentin Krause, Earthscan Pub. Ltd. London.
3. World Energy Investment Outlook- Special Report, International Energy Agency, London, 2014.

Course Objectives :

1. To introduce the PG students, the scientific and engineering principles of energy
2. To impress upon the integration of new materials and traditional techniques to bring about cost effectiveness, energy efficiency and environmental friendly technologies in construction industry.
3. Imparting the objective of environmental friendly building concepts during the construction and operational phases.

Course Learning Outcomes:

CO	After the completion of the course the student should be able to	Bloom's Cognitive	
		Level	**Descriptor**
CO1	***Grasp*** the language of energy in context to energy policies and ***interpret*** the relevance of environment and energy efficiency in context to nonrenewable and renewable energy resources.	II	Understanding
CO2	***Estimate*** the energy contribution of various materials and components in buildings and develop an ability to ***justify*** appropriate/environmental friendly/energy efficient building systems.	IV	Analyzing
CO3	***Apply*** the concept of heat exchange in buildings and adopt passive and active design strategies to maximize human comfort in buildings for tropical regions.	III	Applying

CO-PO Mapping:

PO	1	2	3	4	5	6
CO1	2		2			
CO2	2			3		
CO3	2			3		

Assessments:

Teacher Assessment:

Two components of In Semester Evaluation (ISE), One Mid Semester Examination (MSE) and one End Semester Examination (ESE) having 20%, 30% and 50% weights respectively.

Assessment	Marks
ISE 1	10
MSE	30
ISE 2	10
ESE	50

ISE 1 and ISE 2 are based on assignment/declared test/quiz/seminar etc. MSE: Assessment is based on 50% of course content (Normally first three modules) ESE: Assessment is based on 100% course content with 60-70% weightage for course content (normally last three modules) covered after MSE.	
Course Contents:	
Module 1: Introduction to Energy	**7 Hrs.**
Global warming, causes, energy considerations, energy conservation and energy efficiency, energy systems and spatial structures, Classification of energy, primary and secondary energy, commercial and non-commercial energy, renewable and nonrenewable energy, Global primary energy reserves and consumption, energy distribution, Units of Energy with examples	
Module 2: Conventional Materials and Techniques in Buildings	**6 Hrs.**
Constraints in Choice of building systems, Pre & post construction performance, Properties of materials, Types of Physical, Mechanical, Chemical and Thermal characteristics, Introduction to structural and physical aspects of buildings, Conventional materials used in construction, Case studies of various building materials, Energy consumption in various building materials, Sustainability considerations	
Module 3: Energy and Environmental issues in Buildings	**6 Hrs.**
General facts, energy resources and their impacts on environment, energy in context to built-environment, Sustainable buildings, sustainability and objectives of Green buildings, LEED & Griha, planning aspects of sustainable buildings, energy consumption and efficiency in buildings, Design strategies, Material strategies, Parametric assessment, Env. Issues related to buildings materials.	
Module 4: Sustainable Materials and Techniques for Masonry	**7 Hrs.**
Felt requirements and real objectives of Green towns, Energy scenario in pre and post independent India, Need and approach to sustainability, Green building materials, Design constraints. Appropriate materials and techniques in construction: Relevance of building blocks, mortars. Stabilized mud blocks, FAL-G blocks, Hollow concrete blocks, Calcium silicate bricks, Hourdi blocks, Relevance of Lime, Lime pozollona and combination mortars for masonry, Energy consumption and comparison in building blocks, energy estimates in masonry components.	
Module 5: Roofing Concepts in Green Buildings	**7 Hrs.**
Structural inefficiencies in Conventional roofing systems, Concepts in roofing alternatives, Thatch roofs, Filler slab roofs, Filler materials, Composite beam-panel roofs / floors, hollow hourdi/concrete block roofs / floors, Ferrocement roofing systems, Masonry Domes and Vaults, Rain water harvesting, Energy consumption in different roofing systems, Overall embodied energy comparisons in buildings.	
Module 6: Energy Systems in Building Maintenance	**7 Hrs.**
Elements of climate, Factors influencing climate, Climate and human comfort, Orientation of buildings, Comfort criteria, Heat exchange in buildings, Concepts of Active and Passive Energy systems in Buildings, Use of modern gadgets leading to energy efficiency.	
Module wise Outcomes: At end of each module students will be able to 1. **Recognize** the various forms of energy resources/reserves available in context to the world and country and i**dentify** issues in construction industry in context to the environmental impacts. They will be able to **comprehend** the necessity of bringing in a new parameter of energy efficiency in construction activities. 2. **Identify** the building materials and **generalize** their strengths and constraints while making a choice for a particular building system. They will have a better **understanding** of the various conventional materials used in the building industry and their energy consumption.	

3. **Apply** the usage of modern materials based on their properties, the sustainability issues due to the usage of such materials, adopt the concepts of sustainability planning in buildings. 4. **Analyze** the energy consumed in masonry for different building units and mortar combinations and **judge** the cost and energy economics for making appropriate choices in a building system. 5. **Evaluate** the embodied energy of different roofing systems, **generalize** the current lacunae in RC roofs and can **define** the energy efficient measures to be inducted in the conventional roofs. 6. **Appraise** their knowledge of efficient passive and active energy systems by **understanding** the applications of renewable energy resources like wind and solar energy and plan for adaption of efficient electrical gadgets in buildings to achieve thermal comfort and visual efficiency.	

Title of the Course: Professional Elective 4 **Industrial Wastewater Pollution and Control (4EV537)**	L	T	P	Cr
	3	-	-	3

Pre-Requisite Courses: A course on Wastewater Treatment at graduate level and Physico-Chemical Methods for Water and Wastewater Treatment

Textbooks:

1. Peavy H, S, Rowe D, R, and Tchobanoglous G, "Environmental Engineering", McGraw-Hill Book Company, Indian edition 2017.
2. Metcalf and Eddy "Wastewater Engineering Treatment and Reuse", Tata McGraw Hill Publication, Indian Edition 2017.
3. Unit Operations and Processes in Environmental Engineering, 2nd Edition, by Tom D. Reynolds and Paul A. Richards, PWS Publishing Company, 1995.

References:

1. Droste, Ronald L "Theory and Practice of Water and Wastewater Treatment", Wiley student Edition, 2009.
2. Crites Ron and Tchobanoglous George, "*Small and Decentralized Wastewater Management Systems*", McGraw-Hill Book Company, International edition, 1998.
3. Sincero A, P and Sincero G, A, *"Environmental Engineering A Design approach",* PHI learning private limited, 2004.
4. Quasim, S. R., "Wastewater treatment plants planning, design and operation", CRC Press, 2nd Edition, 2010.

Course Objectives :

1. To provide conceptual and field knowledge for the analysis, design and evaluation of biological processes of wastewater treatment.
2. To enhance the technical competency to conduct research and address the problems of industry/society related to wastewater treatment.
3. To inculcate the qualities of critical thinking.

Course Learning Outcomes:

CO	After the completion of the course the student should be able to	**Bloom's Cognitive**	
		Level	**Descriptor**
CO1	**Explain** and **apply** concepts of industrial wastewater treatment.	II III	Understanding Applying
CO2	**Analyze** and **evaluate** the physical and chemical treatment systems used in water and wastewater.	IV V	Analyzing Evaluating
CO3	**Design** physical and chemical treatment systems for water and wastewater.	VI	Creating

CO-PO Mapping:

PO	**1**	**2**	**3**	**4**	**5**	**6**
CO1			2			
CO2				3		
CO3				2		3

Assessments:

Teacher Assessment:

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MSE: Assessment is based on 50% of course content (Normally first three modules)

ESE: Assessment is based on 100% course content with 60-70% weightage for course content (normally last three modules) covered after MSE.	
Course Contents:	
Module 1: Classification of Industries and Cooling Tower	**4 Hrs.**
Classification of Industries, General water requirements in industry, Industrial water reuse, Cooling tower make up water, Water and salt balances in cooling tower, Common water quality problems in cooling water tower systems, Estimation of blow-down water composition, Analysis of scaling potential by Langlier and Ryzner indices.	
Module 2: Waste Minimization Techniques	**5 Hrs.**
Waste audit, Concept of waste minimization and Techniques of volume and strength reduction. Equalization: Process, Flow and quality, Location, Volume requirement and Design considerations. Reuse and recycling concepts, Process description, Objectives and Methods of Neutralization and Proportioning.	
Module 3: Agro Based Industries	**12 Hrs.**
Manufacturing processes, Water usage, Sources, Quantities and characteristics of effluents (process stream and combined), Pollution effects, Waste Reduction/ Reclamation/Byproduct recovery, Utilization, Alternative methods of treatment and disposal for Agro-based industries: Sugar, Distillery, Dairy, Pulp and paper mill and Textile.	
Module 4: Chemical and Engineering Industries	**12 Hrs.**
Manufacturing processes, Water usage, Sources, Quantities and characteristics of effluents (process stream and combined), Pollution effects, Waste Reduction /Reclamation/Byproduct recovery, Utilization, Alternative methods of treatment and disposal for a. Chemical industries: Pharmaceutical, Petroleum and refineries, Fertilizer and Tannery b. Engineering industries: Steel, Electroplating, Foundries c. Thermal power plants.	
Module 5: Common Effluent Treatment Plant	**4 Hrs.**
Concept, Objectives, Methodology, Cost benefit analysis, Design, Operation and maintenance.	
Module 6: Detailed Project Report for Waste Treatment Facilities	**3 Hrs.**
Project report preparation for waste treatment and disposal system of industries, Pre-feasibility, feasibility and detailed project reports, Project financial appraisal.	
Module wise Outcomes: At end of each module students will be able to 1. **Explain** and **Evaluate** water requirements and reuse options in different industries. 2. **Apply** waste minimization techniques in industrial waste management. 3. **Design and Evaluate** treatment system for agro based industrial wastewater. 4. **Design and Evaluate** treatment system for chemical and engineering industrial wastewater. 5. **Explain, Design and Inspect** common effluent treatment plants. 6. **Apply** knowledge for feasibility study and report preparation of waste treatment and disposal.	