Ph.D. Courses

Environmental Science and Engineering

SRM UNIVERSITY *AP*

Andhra Pradesh

SRM University-*AP*, Andhra Pradesh

S.No	Course Category	Course Code	Course Title	L	T	P	C
1	Core	EVS 701	Physico-chemical wastewater treatment	3	0	0	4
2	Core	EVS 702	Biological wastewater treatment	3	0	0	4
3	Core	EVS 703	Special topics on sustainability analysis	1	0	0	1
4	Core	EVS 704	Advanced Biofuels	1	0	0	1
5	Core	EVS 705	Decarbonisation of heavy industries	3	1	0	4
6	Core	EVS 706	Environment, Social and Governance	3	1	0	4
7	Core	EVS 707	E-waste Recycling: Technology and Challenge	1	1	0	2
8	Core	EVS 708	Forest Ecology	3	1	0	4
9	Core	EVS 709	Biomass and Carbon Sequestration	3	1	0	4
10	Core	EVS 710	Aquatic Biogeochemistry	3	1	0	4
11	Core	EVS 711	Fundamentals of Limnology	3	1	0	4

Physico-chemical wastewater treatment								
Course Code	CE 301	Course Category	Elective	L-T-P-C	3	0	0	4
Pre-Requisite Course(s)	-	Co-Requisite Course(s)	-	Progressive Course(s)	-			
Course Offering Department	Environmental Science and Engineering	Professional / Licensing Standards	-					
Board of Studies Approval Date		Academic Council Approval Date						

Unit No.	Unit Name
Unit 1	**Overview**
	Wastewater characteristics – wastewater management in India – wastewater collection and systems design – factor involved in waste treatment methods
Unit 2	**Types of processes and selection**
	Types of processes & reactors – mass balance – reactions and mechanisms – mass transfer – optimization of a treatment process
Unit 3	**Unit operations**
	Screens – solids reduction – mixing and flocculation – mixing – sedimentation – floatation - aeration
Unit 4	**Advanced treatment systems**
	Membrane filtration – Types & process – Adsorption – Gas stripping – Ion exchange – Distillation
Unit 5	**Designing of treatment plants**
	Overall planning – Plant design – STP & CEPT – Commissioning – Operation of plant – Cost analysis

References:

1. Wastewater Engineering Treatment and Reuse, authored by Metcalf & Eddy, McGraw Hill Education; 4th edition, 2017.
2. Wastewater Treatment for Pollution Control and Reuse, 3rd edition, authored by Arceivala & Asolekar, Mc Graw hill Education, 2006.

Course Designers

Dr. Karthik Rajendran, Assistant Professor, Department of Environmental Science and Engineering, SRM University AP.

Biological wastewater treatment								
Course Code	CE 303	Course Category	Elective	L-T-P-C	3	0	0	4
Pre-Requisite Course(s)	-	Co-Requisite Course(s)	-	Progressive Course(s)	-			
Course Offering Department	Environmental Science and Engineering	Professional / Licensing Standards	-					
Board of Studies Approval Date		Academic Council Approval Date						

Unit No.	Unit Name
Unit 1	**Fundamentals of biological treatment**
	Overview – Introduction to microbial metabolism – Bacterial growth – Microbial growth – Modelling suspended growth treatment process
Unit 2	**Basic treatment processes**
	Aerobic biological oxidation – Nitrification – Denitrification – Biological phosphorus removal – Anaerobic fermentation and oxidation – Removal of toxic and recalcitrant organic compounds
Unit 3	**Advanced treatment processes**
	Suspended & attached growth biological processes – Process analysis – Nitrogen removal – Phosphorus removal
Unit 4	**Natural systems**
	Algae ponds – factors affecting natural systems - growth dynamics – pond design – NPS removal – fishponds – construction, operation, and maintenance of ponds
Unit 5	**Water reuse and sludge management**
	Sludge thickening – anaerobic digestion – aerobic digestion – drying beds – settling tanks – sludge dewatering – sludge disposal – water reclamation technologies – reusing wastewater

References:

1. Wastewater Engineering Treatment and Reuse, authored by Metcalf & Eddy, McGraw Hill Education; 4th edition, 2017.
2. Wastewater Treatment for Pollution Control and Reuse, 3rd edition, authored by Arceivala & Asolekar, Mc Graw hill Education, 2006.

Course Designers

Dr. Karthik Rajendran, Assistant Professor, Department of Environmental Science and Engineering, SRM University AP.

Special topics on techno-economic and Life Cycle Systems Analysis								
Course Code		Course Category	Core/Audit	L-T-P-C	1	0	0	1
Pre-Requisite Course(s)	Process Design and Systems Analysis	Co-Requisite Course(s)		Progressive Course(s)				
Course Offering Department		Professional / Licensing Standards						
Board of Studies Approval Date		Academic Council Approval Date						

Course Objectives / Course Learning Rationales (CLRs)

Objective 1: To evaluate the process system using sensitivity and uncertainty methods.
Objective 2: To estimate the financial risk associated with the system using Monte Carlo methods.
Objective 3: To assess the environmental impact caused by the process system during its lifespan.

Course Outcomes / Course Learning Outcomes (CLOs)

Outcomes	At the end of the course, the learner will be able to	Bloom's Level	Expected Proficiency Percentage	Expected Attainment Percentage
Outcome 1	Conduct sensitivity and uncertainty analysis for different processes systems.	4	80%	70%
Outcome 2	Conduct financial risk assessment of the process system using Monte Carlo methods	4	80%	70%
Outcome 3	Understand the concept of Life cycle analysis.	2	80%	70%
Outcome 4	Know about data collection, inventory data, and LCA methodology	2	80%	70%
Outcome 5	Design the boundary of process system and interpret LCA results.	4	80%	70%

Course Articulation Matrix (CLO) to Program Learning Outcomes (PLO)

CLOs	**Program Learning Outcomes (PLO)**														
	Engineering Knowledge	Problem Analysis	Design and Development	Analysis, Design and Research	Modern Tool and ICT Usage	Society and multicultural skills	Environment and Sustainability	Moral, Multicultural and Ethical Awareness	Individual and Teamwork Skills	Communication Skills	Leadership Readiness Skills	Self-Directed and Lifelong Learning	PSO1	PSO2	PSO3
Outcome 1	2	3	2	2	3	-	-	-	-	-	-	-	2	1	1
Outcome 2	2	3	2	2	3	-	-	-	-	-	-	-	2	1	1
Outcome 3	1	1	1	2	3	-	3	1	-	-	-	-	1	1	1
Outcome 4	1	2	2	1	3	-	3	1	-	-	-	-	3	2	1
Outcome 5	2	3	3	3	3	-	3	1	-	-	-		3	3	1

Course Average	2	2	2	2	3	-	2	1	-	-	-	-	2	2	1

Course Unitization Plan

Unit No.	Unit Name	Required Contact Hours	CLOs Addressed	References Used
Unit 1	**Modern TEA tools**	5	1,2	1
	Uncertainty analysis - Types	1		
	Sensitivity analysis – Qualitative and quantitative test	2		
	Monte Carlo methods in financial engineering	2		
Unit 2	**Introduction to Life cycle assessment (LCA)**	5	3,4,5	2,3
	LCA Overview – Types - Methodology	3		
	Uncertainty and sensitivity analysis of LCA	2		
Unit 3	**Life cycle inventory and impact assessment**	5	3,4,5	2,3
	LCA Inventory analysis – Purpose and scope	2		
	Identify and set boundaries - Life cycle impact assessment (LCIA)	3		

References:

1. Engineering economy, 6th edition,by Leland Blank, Anthony Tarquin. Tata Mc-Graw Hill, 2020.
2. Handbook on Life Cycle Assessment: Operational guide to the ISO standards by Jeroen Guinee, Springer, USA, 2014.

Other References

1. SuperPro Designer User Guide, intelligen.com/wp-content/uploads/2020/05/SuperPro_ManualForPrinting_v11.pdf
2. SimaPro database manual, https://simapro.com/wp-content/uploads/2022/06/DatabaseManualMethods940Superseded.pdf
3. www.openlca.org
4. www.ecoinvent.org

Learning Assessment

Bloom's Level of Cognitive Task		Continuous Learning Assessments (60%)								End Semester Exam (40%)	
		CLA-1 (10%)		Mid-1 (15%)		CLA-2 (10%)		Mid-2 (15%)			
		Th	Prac	Th	Prac	Th	Prac	Th	Prac	Th	Prac
Level 1	Remember	30%	-	30%	-	30%	-	30%	-	60%	-
	Understand										
Level 2	Apply	50%		50%		50%		50%		40%	
	Analyse										
Level 3	Evaluate	20%		20%		20%		20%			
	Create										
Total		100%		100%		100%		100%		100%	

Course Designers

Dr. Karthik Rajendran, Associate Professor, Department of Environmental Science and Engineering, SRM University AP.

Biomass Energy

Course Code	ES 520	Course Category	Elective	L-T-P-C	2	1	0	3
Pre-Requisite Course(s)	-	Co-Requisite Course(s)	-	Progressive Course(s)	-			
Course Offering Department	Environmental Science	Professional / Licensing Standards	-					
Board of Studies Approval Date		Academic Council Approval Date						

Course Objectives / Course Learning Rationales (CLRs)

Objective 1: To understand the concept of various waste to energy conversion (biochemical and thermochemical) technologies.

Objective 2: Concept of bioenergy system analysis and knowledge of basic aspects of life cycle assessment (LCA).

Course Outcomes / Course Learning Outcomes (CLOs)

Outcomes	At the end of the course, the learner will be able to	Bloom's Level	Expected Proficiency Percentage	Expected Attainment Percentage
Outcome 1	Analyze the biomass resource assessment and get knowledge about bioreactors with its kinetic models	3	80%	70%
Outcome 2	Understand the various conversion technologies to generate energy from biomass	3	80%	70%
Outcome 3	Apply the subject knowledge to address the environmental problems	4	80%	70%
Outcome 4	Able to evaluate the technical, economical and life cycle assessment of bioenergy plant	4, 5	80%	70%

Course Articulation Matrix (CLO) to Program Learning Outcomes (PLO)

CLOs	**Program Learning Outcomes (PLO)**														
	Engineering Knowledge	Problem Analysis	Design and Development	Analysis, Design and Research	Modern Tool and ICT Usage	Society and Multicultural Skills	Environment and Sustainability	Moral, and Ethical Awareness	Individual and Teamwork Skills	Communication Skills	Project Management and Finance	Self-Directed and Life Long Learning	PSO1	PSO2	PSO3
Outcome 1	3	3	2	1	2	2	2	3	2	-	2	3	1	2	3
Outcome 2	2	1	1	2	-	2	2	-	3	-	3	3	1	1	2
Outcome 3	2	1	-	2	2	1	1	2	3	-	3	3	1	1	2
Outcome 4	2	1	1	3	2	3	1	3	-	-	3	2	1	1	2
Course Average	2	1	1	2	2	2	2	3	3	-	3	3	1	1	2

Course Unitization Plan

Unit No.	Unit Name	Required Contact Hours	CLOs Addressed	References Used
Unit 1	**Bioenergy Fundamentals**	9	1,2	2,3,4
	Mass and Energy Balances - Reaction Thermodynamics - Reaction Kinetics -Microbial Metabolisms -Metabolic Models--	2		
	Microbial Growth in Batch Culture - Monod Equation for Microbial Growth	3		
	Mass Balances and Reactions in Fed-Batch and Continuous-Stirred Tank Bioreactors -Elemental Balance and Stoichiometric Models	4		
Unit 2	**Bioenergy Feedstocks**	9	1,2	1,2,4
	Lignocellulose-Based Feedstocks - Feedstock	2		
	Availability and Production -Harvesting and Collection of Crop Residues and Energy Crops	3		
	Algae-Based Feedstocks -Algal Growth Conditions -Steps in Algal-Biodiesel Production	4		
Unit 3	**Biological Conversion Technologies**	9	1,2,3	1,2,3,4
	Pre-treatment of Lignocellulosic Feedstocks -Enzymatic Hydrolysis	2		
	Ethanol Fermentation -Fundamentals of Anaerobic Digestion -Anaerobic Digestion Model No. 1 (ADM1)	4		
	Biogas Production and Applications - Microbial Fuel Cells	3		
Unit 4	**Thermal Conversion Technologies**	9	1,2,3	1,4
	Fundamentals of Biomass Combustion -Biomass Properties and Pre-processing - Biomass Furnaces	3		
	Environmental Impact and Emissions of Biomass Combustion	2		
	Gasification -Gasifiers -Gasification Mass and Energy Balance -Applications of Biomass Gasification	4		
Unit 5	**Bioenergy System Analysis**	9	4	1,4
	Techno-Economic Assessment Basic Steps in TEA	3		
	Tools, Software, and Data Sources for Performing TEA	3		
	Life-Cycle Assessment -Procedure for LCA -Tools Available to Perform LCA	3		

References:

1. Bioenergy :Principles and applications by Yebo Li Smair Kumar Khanal. John Wiley &Sons, 2017.
2. Anaerobic Biotechnology for Bioenergy Production: Principles and Applications by S. Harikishan. Wiley-Blackwell, 2008.

Other Resources:

1. Engineering and technical aspects of anaerobic digestion by Flotats, X., Bonmatí, A., Fernández, B., Sales, D., Aymerich, E., Irizar, I., Palatsi, J., Romero, LI, Pérez, M., Vicent, T., Font, X. Mundi-Prensa Libros, 2016.
2. Bioenergy and Biofuels from Biowastes and Biomass by Khanal, S.K.; Surampalli, R.Y.; Zhang, T.C.; Lamsal, B.P.; Tyagi, R.D.; Kao, C.M. Virginia, USA: American Society of Civil Engineers, 2010.

Learning Assessment

Bloom's Level of Cognitive Task		Continuous Learning Assessments (50%)								End Semester Exam (50%)	
		CLA-1 (10%)		Mid-1 (15%)		CLA-2 (10%)		Mid-2 (15%)			
		Th	Prac	Th	Prac	Th	Prac	Th	Prac	Th	Prac
Level 1	Remember	30%	-	30%	-	30%	-	30%	-	60%	-
	Understand										
Level 2	Apply	50%		50%		50%		50%		40%	
	Analyse										
Level 3	Evaluate	20%		20%		20%		20%			
	Create										
Total		100%		100%		100%		100%		100%	

Course Designers

Dr. Karthik Rajendran, Assistant Professor, Department of Environmental Science and Engineering, SRM University AP.

Decarbonisation of Heavy Industries								
Course Code		Course Category	Core	L-T-P-C	3	1	0	4
Pre-Requisite Course(s)	-	Co-Requisite Course(s)	-	Progressive Course(s)	-			
Course Offering Department	Environmental Science and Engineering	Professional / Licensing Standards	-					
Board of Studies Approval Date		Academic Council Approval Date						

Course Objectives / Course Learning Rationales (CLRs)

Objective 1: To understand unit operations, mass balance, and energy balance in the manufacturing process of heavy industries.

Objective 2: This course teaches concepts about carbon mitigation techniques and various policies associated with it.

Course Outcomes / Course Learning Outcomes (CLOs)

Outcomes	At the end of the course, the learner will be able to	Bloom's Level	Expected Proficiency Percentage	Expected Attainment Percentage
Outcome 1	Understanding the unit processes and source of CO_2 involved in heavy industries	2	80%	70%
Outcome 2	Understand the pathways to carbon emission reduction	4	80%	70%
Outcome 3	Analysing carbon capture and storage systems	4	80%	70%
Outcome 4	Concepts about carbon credit, tax, and pricing.	4	80%	70%

Course Articulation Matrix (CLO) to Program Learning Outcomes (PLO)

CLOs	Program Learning Outcomes (PLO)														
	Engineering Knowledge	Problem Analysis	Design and Development	Analysis, Design and Research	Modern Tool and ICT Usage	Society and Multicultural Skills	Environment and Sustainability	Moral, and Ethical Awareness	Individual and Teamwork Skills	Communication Skills	Project Management and Finance	Self-Directed and Lifelong Learning	PSO1	PSO2	PSO3
Outcome 1	1	1	1	1	-	-	-	-	-	-	3	-	1	1	3
Outcome 2	1	1	1	2	3	-	-	-	-	-	3	-	2	1	3
Outcome 3	1	1	2	1	3	-	-	2	3	-	-	-	3	1	2
Outcome 4	1	1	2	1	3	-	-	2	3	-	-	-	3	1	2
Course Average	1	1	1	1	3	-	-	2	3	-	3	-	2	1	3

Course Unitization Plan

Unit No.	Unit Name	Required Contact Hours	CLOs Addre ssed	Refe rences Used
Unit 1	**Heavy Industry in India**	12	1	1
	Introduction to heavy industry – power – steel – chemical – cement – gasification – annual production capacity – demand	4		
	Unit operations of the process for each industry – description – material and energy flow study	4		
	Analysis of industrial CO_2 sources – power – steel – chemical –cement – gasification – emission global and Indian scenario – emission rates – future projections	4		
Unit 2	**Carbon emission reduction levers**	12	2	2
	Decarbonisation – major categories of reduction opportunities – energy efficiency – low carbon energy supply – terrestrial carbon – best available technique	6		
	Business as usual pathways – suitable key levers – Power – steel – chemical – cement – gasification	6		
Unit 3	**Carbon Capture and Utilisation**	12	3	2, 3
	Carbon capture – different methods of carbon capture – pre-combustion methods – oxygen-combustion method – post-combustion methods – chemical-looping combustion and algae species – carbon negative technologies	6		
	Carbon utilisation – CO_2-based chemical products, including polymers – CO_2-based fuels – microalgae fuels – concrete building materials – bio-energy with carbon capture and storage (BECCS) – biochar.	6		
Unit 4	**Carbon storage**	12	3	2
	Carbon storage – transport of carbon dioxide – geological carbon Storage – Reservoirs, seals, and traps – oil fields – carbon sequestration – mineral carbonation – Leakage and monitoring	6		
	Global Storage capacity – storage clusters in India – Numerical calculations for energy input requirement for CCS system – Future developments – Role of CCS in decarbonisation of heavy industries	6		
Unit 5	**Policies, finance, investment, and international collaboration**	12	4	2
	Policy Instruments and Strategies – carbon credits – carbon tax – countries and Institutions – policy framework for India	4		
	Economic and business rationale for CCUS hubs and clusters – hub and cluster framework for India	4		
	Estimation of capital costs and cash costs for demo scale CCUS projects – financing mechanisms – various funding sources Socio – Economic Impact of CCUS	4		

References:

1. Malti Goel, M Sudhakar and R V Shahi, Carbon capture, storage and, utilization: A possible climate change solution for energy industry, TERI, 2018
2. Carbon Capture Utilization and Storage (CCUS), Policy Framework and its Deployment Mechanism in India, NITI Aayog 2022
3. Cameron Hepburn et al., The technological and economic prospects for CO2 utilization and removal, Nature 2019.

Learning Assessment

Bloom's Level of Cognitive Task		Continuous Learning Assessments (60%)								End Semester Exam (40%)	
		CLA-1 (10%)		Mid-1 (20%)		CLA-2 (10%)		Mid-2 (20%)			
		Th	Prac	Th	Prac	Th	Prac	Th	Prac	Th	Prac
Level 1	Remember	30%	-	30%	-	30%	-	30%	-	60%	-
	Understand										
Level 2	Apply	50%		50%		50%		50%		40%	
	Analyse										
Level 3	Evaluate	20%		20%		20%		20%			
	Create										
Total		100%		100%		100%		100%		100%	

Course Designers

Dr. Karthik Rajendran, Associate Professor, Department of Environmental Science, SRM University AP.

Environmental, social, and governance								
Course Code		Course Category	Core	L-T-P-C	3	1	0	4
Pre-Requisite Course(s)	-	Co-Requisite Course(s)	-	Progressive Course(s)	-			
Course Offering Department	Environmental science and engineering	Professional / Licensing Standards	-					
Board of Studies Approval Date		Academic Council Approval Date						

Course Objectives / Course Learning Rationales (CLRs)

Objective 1: Aims to provide an overview of the competing theories and empirical evidence underlying Environmental, Social, and Governance (ESG) investment.

Objective 2: To understand and summarize the most interesting forms of ESG investment vehicles and modalities themselves.

Course Outcomes / Course Learning Outcomes (CLOs)

Outcomes	At the end of the course, the learner will be able to	Bloom's Level	Expected Proficiency Percentage	Expected Attainment Percentage
Outcome 1	Define ESG investing	1	80%	70%
Outcome 2	Ability to understand ESG investment concepts and challenges	2	75%	60%
Outcome 3	Understand ESG consideration in investment decision with emphasis on portfolio construction	3	80%	65%
Outcome 4	Illustrate case studies in managing ESG	4	70%	60%

Course Unitization Plan

Unit No.	Unit Name	Required Contact Hours	References Used
Unit 1	**Introduction**	9	1, 2, 3
	Principles for responsible investing	3	
	Sustainable Development Goals	1	
	Identifying key trends in ESG investing	1	
	Overview on carbon tax, carbon credit, subsidies and green initiative practices	4	
Unit 2	**ESG, SRI, and impact investing**	9	1
	Environmental, Social, and Governance Investing	1	
	Socially Responsible Investment	1	
	Divestment: South Africa and sin stocks	1	
	Impact Investing, Mission Investing, United Nations principles for responsible investing, United Nations Sustainable Development Goals	4	
	Financial returns versus social and environmental returns	1	
	Global sustainable investment	1	
Unit 3	**Defining and measuring ESG Performance**	9	1
	ESG factors in portfolio construction	1	
	Standards for companies to report their ESG Impacts	3	
	Quality issues and corporate reporting findings in ESG reporting	2	

	Services providing an assessment of corporate ESG	3	
Unit 4	**Overview of financial institutions**	9	1
	Information asymmetries, moral hazard, and adverse selection	1	
	Commercial banks, Credit unions	2	
	Investment banks, Central banks, Insurance companies, Pension funds	4	
	Asset managers, Hedge funds, Private equity	2	
Unit 5	**ESG: Managing Institutional investor funds and endowments**	9	1, 2
	Institutions: Black Rock, Fidelity, PIMCO, Goldman Sachs, J.P. Morgan, Betterment, JUST Capital	3	
	Colleges & University: Hampshire College, Yale University, University of California, Brown University, Harvard, Columbia University	3	
	Organisations providing analysis, support, consulting and investing services for endowment management	3	

Recommended resource:

1. Hill, J. (2022). *Environmental, social, and governance (ESG) investing: A balanced analysis of the theory and practice of sustainable portfolio*. Academic Press, an imprint of Elsevier.

Other resource:

2. Ditlev-Simonsen, C. D. (2022). *A guide to sustainable corporate responsibility: From theory to action*. Palgrave Macmillan.
3. Carbon Capture Utilization and Storage (CCUS), *Policy Framework and its Deployment Mechanism in India*, NITI Aayog 2022.

Learning Assessment

Bloom's Level of Cognitive Task		**Continuous Learning Assessments (60%)**								**End Semester Exam (40%)**	
		CLA-1 (10%)		**Mid-I (25%)**		**CLA-2 (10%)**		**CLA-3 (15%)**			
		Th	**Prac**	**Th**	**Prac**	**Th**	**Prac**	**Th**	**Prac**	**Th**	**Prac**
Level 1	Remember	30%	-	50%	-	30%	-	50%	-	70%	-
	Understand										
Level 2	Apply	20%	-	20%	-	20%	-	20%			
	Analyse										
Level 3	Evaluate	50%	-	30%	-	50%	-	30%		30	
	Create										
Total		100%		100%				100%		100%	

Course Designers

Dr. Karthik Rajendran, Associate Professor, Department of Environmental Science and Engineering, SRM University AP.

E-waste Recycling: Technology and Challenges								
Course Code		Course Category	Core	L-T-P-C	1	1	0	2
Pre-Requisite Course(s)		Co-Requisite Course(s)	-	Progressive Course(s)				
Course Offering Department	ESE	Professional / Licensing Standards						
Board of Studies Approval Date		Academic Council Approval Date						

Course Objectives / Course Learning Rationales (CLRs)

Objective 1: Estimate the quality and quantity of e-waste.
Objective 2: Evaluate different technologies for managing e-waste.
Objective 3: Selecting different tools for managing and recycling e-waste.
Objective 4: Assessing policies on e-waste management.

Course Articulation Matrix (CLO) to (PLO)

CLOs	Program Learning Outcomes (PLO)														
	Scientific and Disciplinary Knowledge	Analytical Reasoning and Problem Solving	Critical and Reflective Thinking	Scientific Reasoning and Design Thinking	Research Related Skills	Modern Tools and ICT Usage	Environment and Sustainability	Moral, Multicultural and Ethical Awareness	Individual and Teamwork Skills	Communication Skills	Leadership Readiness Skills	Self-Directed and Lifelong Learning	PSO 1	PSO 2	PSO 3
Outcome 1	2	2	2	2	2	2	3	-	2	-	-	2	3	3	3
Outcome 2	2	2	2	2	-	2	3	-	2	-	-	2	3	3	3
Outcome 3	2	2	2	2	2	2	3	-	2	-	-	2	3	3	3
Outcome 4	2	2	-	2	-	-	3	-	2	-	-	2	3	3	3
Course Average	**2**	**2**	**2**	**2**	**2**	**2**	**3**	**-**	**2**	**-**	**-**	**2**	**3**	**3**	**3**

Course Unitization Plan

Unit No.	Unit Name	Required Contact Hours	CLOs Addressed	References Used
Unit 1	E-waste and their chemical content	**6**	**1,2**	**1,2**
	Global e-waste generation and management, Types of e-waste, Challenges in the collection of e-waste, urban mining: resources and recycling technology	4		
	Tutorials	2		
Unit 2	**Industrial recycling and thermal methods of recycling**	**6**	**1,2,3**	**1,2,3**
	Mechanical processing and sorting on the industrial scale	2		
	Pyrometallurgical processing theory and recycling process	2		
	Tutorials	2		
Unit 3	**Hydrometallurgical operation for metal recycling**	**8**	**2,3,4**	**1,2,3**
	Introduction to hydrometallurgy: theory and types of hydrometallurgical operations	2		
	Leaching, precipitations, solvent extraction, ion exchange	4		
	Tutorials	2		
Unit 4	**Emergent recycling methods**	**4**	**2,3,4**	**1,2,3**
	Challenges around rare and strategic raw materials, integrating new green emerging solvents (non-aqueous, supercritical fluids)	2		
	Tutorials	2		
Unit 5	**Policies and Rules on Solid Waste Management**	**6**	**3,4**	**4,5**
	E-waste management rules: globally, national, green deal	3		
	Tutorials	3		
Total Contact Hours		**30**		

References:

1. Electronic Waste Management and Treatment Technology by MNV Prasad and Meththika Vithanage, Elsevier (2019).
2. Urban Mining for Waste Management and Resource Recovery: Sustainable Approaches by Pankaj Pathak and Prangya Rout, CRC Press Taylor & Francis (2021).
3. Sustainable Urban Mining of Precious Metals by Sadia Ilyas, Hyunjung Kim, Rajiv Ranjan Srivastava, CRC Press Taylor & Francis (2021).
4. Ewaste (Management) -Rules (2022), https://cpcb.nic.in/uploads/Projects/E-Waste/e-waste_rules_2022.pdf.
5. Green deal, https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en.

Learning Assessment (Theory)

Bloom's Level of Cognitive Task		Continuous Learning Assessments (50%)				End Semester Exam (50%)
		CLA-1 (10%)	Mid-1 (15%)	CLA-2 (10%)	Mid-2 (15%)	
Level 1	Remember	30	30	20	20	20
	Understand					
Level 2	Apply	60	60	70	70	70
	Analyse					
Level 3	Evaluate	10	10	10	10	10
	Create					
Total		**100%**	**100%**	**100%**	**100%**	**100%**

Course Designers

1. Pankaj Pathak, Assistant Professor, Department of Environmental Science, SRM University AP.

Forest Ecology								
Course Code		Course Category	Core	L-T-P-C	3	1	0	4
Pre-Requisite Course(s)		Co-Requisite Course(s)	Core	Progressive Course(s)				
Course Offering Department	ESE	Professional / Licensing Standards						
Board of Studies Approval Date		Academic Council Approval Date						

Course Objectives / Course Learning Rationales (CLRs)

Objective 1: To understand the fundamental concepts of forest ecology

Objective 2: To **a**nalyse the various structural and functional aspects of forest ecology

Objective 3: Analyse the importance of ecology in biodiversity conservation and climate change

Course Outcomes / Course Learning Outcomes (CLOs)

Outcomes	At the end of the course, the learner will be able to	Bloom's Level	Expected Proficiency Percentage	Expected Attainment Percentage
Outcome 1	Understand the fundamentals of forest ecology of different forest types	2	80%	70%
Outcome 2	Understand the structural and compositional drivers of forest ecology	2	80%	70%
Outcome 3	Analyse the functional traits and their link in functional ecology	4	80%	70%
Outcome 4	Evaluate the role forest ecology in species conservation, management and sustainability.	4	80%	70%

Course Articulation Matrix (CLO) to Program Learning Outcomes (PLO)

CLOs	**Program Learning Outcomes (PLO)**													
	Engineering Knowledge	Problem Analysis	Design and Development	Analysis, Design and Research	Modern Tool and ICT Usage	Society and multicultural skills	Environment and Sustainability	Moral, Multicultural and Ethical Awareness	Individual and Teamwork Skills	Communication Skills	Leadership Readiness Skills	Self-Directed and Lifelong Learning	PSO1	PSO2	PSO3
Outcome 1	-	2	-	2	1	1	3	1	1	1	1	2	2	2	1

Outcome 2	-	2	-	2	1	1	3	1	1	1	1	2	2	2	1
Outcome 3	-	2	-	2	1	1	3	1	1	1	1	2	2	2	1
Outcome 4	-	2	-	2	1	1	3	1	1	1	1	2	2	2	1
Course Average	-	2	-	2	1	1	3	1	1	1	1	2	2	2	1

Course Unitization Plan - Theory

Unit No.	Unit Name	Required Contact Hours	CLOs Addressed	References Used
Unit 1	**Forest and Forest Environment**	**8**	**1,2**	**1,2,3,4**
	Forest, Structure of forest ecosystem, Forest microclimate.	2	1,2	1,2
	Forest types and their classification.	1	1	3,4
	Forest types of India with special reference to Central India	3	1,2	3,4
	Forest and Tree cover of India.	2	1,2	
Unit 2	**Community Forest Ecology**	**10**	**1,2**	**1,2,5,7**
	Forest community concepts; vegetation concepts, ecological succession, and climax.	3	1,2	2,5,7
	Qualitative and quantitative characters of community, Ecological niche	4	1,2	2,5
	Methods of studying vegetation	3	2	2,5
	Species diversity and its measurement.	2	1,2	2,5
Unit 3	**Forest Ecosystem Function**	**14**	**2,3**	**1,2,5,6,7**
	Concept of ecosystem, types, structure and functional aspects of major ecosystem, productivity and food web and food chain in the forest.	3	2,3	2,5,6
	Methods of measurement; Productivity patterns; Litter production and decomposition, Nutrient cycling in forest, Element cycling- Canopy leaching and Nitrogen fixation, Decomposition-Nitrification and Mycorrhizae in the forest.	7	2,3	1,5,6
	Tropical scrubs and thorn forests – distribution, species composition, structure and functioning.	2	2,3	2,5,6,7
	land use change for different tropical forest.	2	3	2,5,6,7
Unit 4	**Ecophysiology and Regeneration of Forest Trees**	**12**	**3,4**	**1,2,5,7**
	Characteristic of tropical trees; Shoot growth and leafing pattern of trees; Growth pattern in plants.	3	3,4	1,5,7
	Phenology of trees; Seed dispersal patterns; Forest seed dormancy and germination.	3	3,4	1,5,7
	Growth, structure of forest tree	2	3	1,5,7
	Regeneration ecology of forest trees, types, Regeneration sampling pattern and intensity of different	4	3,4	1,2,5,7

	tree species. regeneration restoration and reproduction, ‘r’ and ‘k’ selection			
Unit 5	**Biodiversity and Conservation**	**14**	**1,3,4**	**2,5,6,7**
	Biodiversity (Concept, definition, level), types, importance, forest diversity indices (alpha, beta and gamma diversity), threats and its conservation.	3	1,3,4	2,5,6,7
	Biogeographic zones, Endangered and endemic species of India. Threats to biodiversity, biological invasions, Biodiversity resources of tropical forest in India.	4	3,4	2,5,6,7
	Conservation of biodiversity- In-situ and Ex-situ conservation of biodiversity.	4	1,3,4	2,5,6
	Ecosystem and biodiversity services: Ecological, economic, social, ethical, aesthetic and Informational value	3	1,3,4	2,5
Total Contact Hours		**60**		

Learning Assessment

Bloom’s Level of Cognitive Task		**Continuous Learning Assessments (50%)**								**End Semester Exam (50%)**	
		CLA-1 (10%)		**Mid-1 (15%)**		**CLA-2 (10%)**		**Mid-2 (15%)**			
		Th	**Prac**	**Th**	**Prac**	**Th**	**Prac**	**Th**	**Prac**	**Th**	**Prac**
Level 1	Remember	30%	-	30%	-	20%	-	20%	-	60%	-
	Understand										
Level 2	Apply	50%		50%		60%		60%		40%	
	Analyse										
Level 3	Evaluate	20%		20%		20%		20%			
	Create										
Total		100%		100%		100%		100%		100%	

References:

1. Elements of Ecology, Pearson Education, India. Smith T.M. and Smith R.L. (2015).
2. Biodiversity Perception, Peril and Preservation. PHI Learning Private Limited, New Delhi. Maiti P.K. and Maiti P. (2011).

Other References:

3. Forest Survey of India, Dehradun. FSI State of Forest Report (2021).
4. Champion, H.G. and Seth, S.K. (1968). A revised survey of the forest types of India (Reprinted 2004). Natraj Publication, Dehradun.
5. Community Ecology. Sinauer Associates, Inc.; 1 edition. Gary G. Mittelbach (2012). ISBN: 978-0878935093.
6. Environmental Science. 14th Edition, Thomson, California. Miller G.T. Jr. (2014)
7. Ecology, Environmental Science and Conservation. S. Chand & Company Pvt. Ltd., New Delhi. 929p. Singh J.S. Singh S.P. & Gupta S.R. (2014).

Biomass and Carbon Sequestration								
Course Code	**ENV-504**	Course Category	Core	L-T-P-C	3	1	0	4
Pre-Requisite Course(s)	Biomass and Carbon Sequestration	Co-Requisite Course(s)	Core	Progressive Course(s)				
Course Offering Department	ESE	Professional / Licensing Standards						
Board of Studies Approval Date		Academic Council Approval Date						

Course Objectives / Course Learning Rationales (CLRs)

Objective 1: To understand the fundamental concepts of carbon dynamics in various ecosystems.
Objective 2: To **a**nalyse the role of various drivers in carbon sequestration and its dynamics.
Objective 3: Analyze the importance ecosystems in biodiversity conservation and global carbon cycle in changing climate.

Course Outcomes / Course Learning Outcomes (CLOs)

Outcomes	At the end of the course, the learner will be able to	Bloom's Level	Expected Proficiency Percentage	Expected Attainment Percentage
Outcome 1	Understand the fundamentals of the carbon sequestration of different ecosystems	2	80%	70%
Outcome 2	Understand the drivers of biomass & carbon sequestration	2	80%	70%
Outcome 3	Analyse the role of different species & ecosystems in biomass accumulation and carbon storage	4	80%	70%
Outcome 4	Evaluate their role in local, regional & global carbon cycle, mapping and climate change	4	80%	70%

Course Articulation Matrix (CLO) to Program Learning Outcomes (PLO)

CLOs	**Program Learning Outcomes (PLO)**														
	Engineering Knowledge	Problem Analysis	Design and Development	Analysis, Design and Research	Modern Tool and ICT Usage	Society and multicultural skills	Environment and Sustainability	Moral, Multicultural and Ethical Awareness	Individual and Teamwork Skills	Communication Skills	Leadership Readiness Skills	Self-Directed and Lifelong Learning	PSO1	PSO2	PSO3
Outcome 1	1	2	-	2	1	2	3	2	1	1	1	2	2	2	1
Outcome 2	1	2	-	2	1	2	3	2	1	1	1	2	2	2	1
Outcome 3	1	2	-	2	1	2	3	2	1	1	1	2	2	2	1
Outcome 4	1	2	-	2	1	2	3	2	1	1	1	2	2	2	1

Course Average	1	2	-	2	1	2	3	2	1	1	1	2	2	2	1

Course Unitization Plan - Theory

Unit No.	Unit Name	Required Contact Hours	CLOs Addressed	References Used
Unit 1	**Introduction**	**10**	**1,2**	**1,2,3**
	Carbon sequestration, Carbon capture and storage, types (Terrestrial, Biological, Geologic, Ocean, Carbon Sequestration).	4	1	1,2
	Natural and artificial carbon sequestration	3	1,2	1,2
	Carbon sink and carbon source, Carbon footprint, Carbon accounting, Carbon Market, carbon credit, carbon trading.	3	1,2	1,2,3
Unit 2	**Assessment of Biomass and Carbon Stocks**	**12**	**1,2**	**1,2,3,4,5**
	Assessment of carbon stock, Forest biomass and carbon, measures forest biomass.	2	1,2	2,4,5
	Method- direct (destructive method) and indirect (non-destructive, remote sensing regression models, conversion from forest parameters), Methods of developing allometric equations relating girth and biomass of trees.	6	1,2	1,2,3,5
	Sampling designs in forest inventory	2	1,2	2,5
	Estimation of aboveground biomass, belowground biomass and detritus.	2	1,2	2,4,5
Unit 3	**Carbon Dynamics of Tropical Forests**	**12**	**2,3**	**2,4,5,6**
	Introduction, Tropical Forest Systems - Forest type descriptions.	4	2,3	2,4,6
	Carbon pools in tropical forest- Aboveground Biomass, Belowground Biomass, Epiphytes, Litter and Logs, Soil Carbon.	6	2,3	2,4,5,6
	Climate Change Impacts on Tropical Forest Dynamics.	2	2,3	2,4
Unit 4	**Forest Inventory/Mensuration**	**12**	**2,3,4**	**1,2,3,6**
	Methods of measuring – diameter, girth, height and volume of trees; form-factor; volume estimation of stand, current annual increment; mean annual increment.	6	2,3,4	1,2,3,6
	Sampling methods and sample plots.	4	3,4	1,2,6
	Yield calculation, yield and stand tables.	2	3	1,2,6
Unit 5	**Concepts of Remote Sensing and GIS**	**14**	**1,2,3,4**	**7,8,9**
	Concepts of Remote Sensing and GIS, spectral characteristics of surface features (soil, vegetation, water), Satellite and Sensors, Geographical Information System (GIS).	6	1,2,3,4	7,8,9
	Applications of Remote Sensing and GIS, Remote sensing-based forest biomass and carbon stock maps.	4	3,4	7,8,9
	Forest resources- forest type mapping, forest density mapping, change analysis, matrix analysis; water	4	2,3,4	7,8,9

	resources- mapping surface waterbody, land use and land cover mapping.			
Total Contact Hours		**60**		

Learning Assessment

Bloom's Level of Cognitive Task		**Continuous Learning Assessments (50%)**								**End Semester Exam (50%)**	
		CLA-1 (10%)		**Mid-1 (15%)**		**CLA-2 (10%)**		**Mid-2 (15%)**			
		Th	**Prac**	**Th**	**Prac**	**Th**	**Prac**	**Th**	**Prac**	**Th**	**Prac**
Level 1	Remember	30%	-	30%	-	20%	-	20%	-	60%	-
	Understand										
Level 2	Apply	50%		50%		60%		60%		40%	
	Analyse										
Level 3	Evaluate	20%		20%		20%		20%			
	Create										
Total		100%		100%		100%		100%		100%	

References

1. Carbon Dynamics in Tropical Forest Ecosystems. Viswanathl S. Sandeep S. (2019).
2. Carbon sequestration in forest ecosystems. Springer Science & Business Media. Lorenz K. & Lal R. (2011).

Other References:

3. Indirect methods of tree biomass estimation and their uncertainties. Southern Forests: a Journal of Forest Science, 79(1), 41-49. Njana M.A. (2017).
4. The biomass assessment handbook: Energy for a sustainable environment. Routledge. Rosillo-Calle F. De Groot P. Hemstock S.L. & Woods J. (Eds.). (2015).
5. Carbon Dynamics of Tropical Forests. Springer Science+Business Media B.V. Ashton M.S. Craven D. Griscom H.P. (2012).
6. Biomass volume estimation and valorization for energy. BoD–Books on Demand. Tumuluru J.S. (Ed.). (2017).
7. Remote Sensing of Biomass: Principles and Applications. BoD–Books on Demand Fatoyinbo L. (Ed.). (2012).
8. Advances in Passive Microwave Remote Sensing of Oceans 1stEdition CRC Press. Raizer V. (2017).
9. Understanding Earth Observation: The Electromagnetic Foundation of Remote Sensing (Remote Sensing and Digital Image Processing) 1st Edition, Springer. Solimini D. (2016).

Aquatic Biogeochemistry								
Course Code		Course Category	Core	L-T-P-C	3	1	0	4
Pre-Requisite Course(s)		Co-Requisite Course(s)	Core	Progressive Course(s)				
Course Offering Department	ESE	Professional / Licensing Standards						
Board of Studies Approval Date		Academic Council Approval Date						

Course Objectives / Course Learning Rationales (CLRs)

Objective 1: To understand the fundamental concepts of aquatic biogeochemical cycling
Objective 2: Analyse various factors regulating the carbon cycling in aquatic ecosystems
Objective 3: Analyse the importance of aquatic biogeochemistry in global carbon cycle

Course Outcomes / Course Learning Outcomes (CLOs)

Outcomes	At the end of the course, the learner will be able to	Bloom's Level	Expected Proficiency Percentage	Expected Attainment Percentage
Outcome 1	Understand the fundamentals of the biogeochemistry of aquatic systems	2	80%	70%
Outcome 2	Understand various drivers of aquatic carbon cycling	2	80%	70%
Outcome 3	Analyse the links between various pools (dissolved, particulate, and gases) aquatic ecosystem components	4	80%	70%
Outcome 4	Evaluate the role of aquatic biogeochemistry in the global carbon cycling	4, 5	80%	70%

Course Articulation Matrix (CLO) to Program Learning Outcomes (PLO)

CLOs	Program Learning Outcomes (PLO)														
	Engineering Knowledge	Problem Analysis	Design and Development	Analysis, Design and Research	Modern Tool and ICT Usage	Society and multicultural skills	Environment and Sustainability	Moral, Multicultural and Ethical Awareness	Individual and Teamwork Skills	Communication Skills	Leadership Readiness Skills	Self-Directed and Lifelong Learning	PSO1	PSO2	PSO3
Outcome 1	-	2	-	2	1	1	3	1	1	1	-	2	2	2	1
Outcome 2	-	2	-	2	1	1	3	1	1	1	-	2	2	2	1
Outcome 3	-	2	-	2	1	1	3	1	1	1	-	2	2	2	1
Outcome 4	-	2	-	2	1	1	3	1	1	1	-	2	2	2	1
Course Average	-	2	-	2	1	1	3	1	1	1	-	2	2	2	1

Course Utilization Plan

Unit No.	Unit Name	Required Contact Hours	CLOs Addressed	References Used
Unit 1	**Introduction to Aquatic Biogeochemistry**	**10**	**1**	**1**
	Movement, storage, and transformation of elements (C, N, P) across hydrosphere and other earth systems	6	1	1
	Human impacts on the cycling of carbon with an emphasis and global change.	4	1	1
Unit 2	**Cycling of dissolved organic matter in aquatic systems**	**12**	**2**	**1**
	Composition and reactivity of DOM;	4	2	1
	DOM Production and Consumption processes;	4	2	1
	Chromophoric DOM: from soil to streams to open ocean;	3	2	1
	DOM and global carbon cycle	3	2	1
Unit 3	**Aquatic Respiration, Production, and Microbial Loop**	**14**	**2,3**	**1,2**
	Aquatic respiration; Respiration at organism (bacteria, plankton, etc.) to ecosystem system level (lakes, coastal, and oceanic systems)	6	2	2
	Bacterial production and respiration; Top-down and bottom-up controls;	4	3	2
	Microbial Loop in aquatic systems, Role of microbial loop in aquatic carbon cycling	4	3	1,2
Unit 4	**Aquatic Greenhouse gas emissions**	**12**	**3,4**	**2**
	Emissions of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O).	4	3	2
	Production and consumption processes of GHGs, Bio-physical controls on GHG emissions.	4	23	2
	Anthropogenic alteration of aquatic GHG emissions.	4	3,4	2
Unit 5	**Aquatic ecosystem's response to global environmental changes**	**12**	**4**	**1**
	Aquatic biogeochemistry and global carbon cycling, Climate change: Impact & response of aquatic ecosystems	4	4	1
	Human alteration of aquatic carbon cycling: Eutrophication, Pollution, flow diversion (dams) impacts on carbon cycling	4	4	1
	Land-scape change impact on aquatic carbon processing	4	4	1
Total contact hours		**60**		

References:

Hansell DA & Carlson, CA (2014). Biogeochemistry of marine dissolved organic matter. 2nd edition. Academic Press. ISBN: 978-0-12-405940-5

Del Giorgio PA & Williams P.A (2005). Respiration in Aquatic Ecosystems. Oxford University Press ISBN: 0-19-852709- 8

Other Resources:

Marine Microbiology: Facets & Opportunities. Ramaih N. (2004). National Institute of Oceanography (CSIR), Goa

Learning Assessment

Bloom's Level of Cognitive Task		Continuous Learning Assessments (50%)								End Semester Exam (50%)	
		CLA-1 (10%)		Mid-1 (15%)		CLA-2 (10%)		CLA-3 (15%)			
		Th	Prac	Th	Prac	Th	Prac	Th	Prac	Th	Prac
Level 1	Remember	20%	-	20%	-	20%	-	20%	-	60%	-
	Understand										
Level 2	Apply	60%	-	50%	-	50%	-	50%	-	40%	-
	Analyse										
Level 3	Evaluate	20%	-	30%	-	30%	-	30%	-		-
	Create				-		-		-		-
Total		100%		100%		100%		100%		100%	

Fundamentals of Limnology								
Course Code		Course Category	Core	L-T-P-C	3	1	0	4
Pre-Requisite Course(s)		Co-Requisite Course(s)	Core	Progressive Course(s)				
Course Offering Department		Professional / Licensing Standards						
Board of Studies Approval Date		Academic Council Approval Date						

Course Objectives / Course Learning Rationales (CLRs)

Objective 1: To understand the fundamental concepts on freshwater aquatic systems and their physical and chemical processes.

Objective 2: Understand the importance of freshwater aquatic systems in global carbon cycling.

Objective 3: Examine the biogeochemistry and microbial ecology of freshwater systems.

Objective 4: Analyse the freshwater systems at a landscape perspective.

Course Outcomes / Course Learning Outcomes (CLOs)

Outcomes	At the end of the course, the learner will be able to	Bloom's Level	Expected Proficiency Percentage	Expected Attainment Percentage
Outcome 1	To understand the fundamental concepts on freshwater aquatic systems	2	80%	70%
Outcome 2	To examine freshwater aquatic systems in the context of global carbon cycling	2	80%	70%
Outcome 3	Analyze the carbon and microbial dynamics in freshwater environments	4	80%	70%
Outcome 4	Evaluate the freshwater systems at a landscape context	4, 5	80%	70%

Course Articulation Matrix (CLO) to Program Learning Outcomes (PLO)

CLOs	**Program Learning Outcomes (PLO)**														
	Engineering Knowledge	Problem Analysis	Design and Development	Analysis, Design and Research	Modern Tool and ICT Usage	Society and multicultural skills	Environment and Sustainability	Moral, Multicultural and Ethical Awareness	Individual and Teamwork Skills	Communication Skills	Leadership Readiness Skills	Self-Directed and Lifelong Learning	PSO1	PSO2	PSO3
Outcome 1	-	2	-	2	1	1	3	1	1	1	-	2	2	2	1
Outcome 2	-	2	-	2	1	1	3	1	1	1	-	2	2	2	1
Outcome 3	-	2	-	2	1	1	3	1	1	1	-	2	2	2	1

Outcome 4	-	2	-	2	1	1	3	1	1	1	-	2	2	2	1
Course Average	-	2	-	2	1	1	3	1	1	1	-	2	2	2	1

Course Utilization Plan

Unit No.	Unit Name	Required Contact Hours	CLOs Addressed	References Used
Unit 1	**Introduction to Limnology**	**10**	**1**	**1**
	Limnology as a Discipline; Aquatic ecosystem services, Origin, abundance, and size distribution of lakes, ponds, impoundments; Lakes and reservoirs of Asia. Formation, diversity and distribution of rivers and streams	4	1	1
	Morphology and Zonation; Temperature, stratification, and light; Hydrodynamics & mixing	4	1	1
	Anthropogenic impacts on Nutrients – phosphorus and nutrients	2	1	1
Unit 2	**Processes at air-water and land-water interfaces**	**12**	**2**	**2**
	Aquatic plants, Littoral zone dynamics, Terrestrial subsidies on aquatic metabolism	6	2	2
	Gas exchange at air-water interfaces, Measurement of gas exchange,	6	2	2
Unit 3	**Microbial Ecology of freshwater systems**	**14**	**3**	**1,2**
	Bacteria – distribution and diversity. Top-down and bottom-up controls, organic matter cycling.	6	3	1,2
	Role in nutrient (phosphorus and nitrogen) cycling. Microbial loop and food webs.	4	3	1.2
	Biogeographic patterns of bacterial communities	4	3	1,2
Unit 4	**Dissolved organic matter (DOM) cycling in lakes and rivers**	**12**	**3**	**2**
	Composition and reactivity of DOM across lakes, rivers, and streams; Terrestrial dissolved organic carbon in inland waters	4	3	2
	Coloured and fluorescent DOM: from soil to streams to open ocean	4	3	2
	DOM cycling and greenhouse gas production. Browning of inland waters	4	4	2
Unit 5	**Landscape Limnology**	**12**	**4**	**2**
	Principles of landscape limnology, integrating landscape terrestrial and aquatic carbon fluxes	6	4	2
	Landscape limnology framework to understand lake productivity, greenhouse gas emissions, and dissolved organic carbon (DOC) in inland waters.	6	4	2
Total contact hours		**60**		

References

1.Encyclopedia of Inland waters. Likens G.E. (2009). Academic Press, ISBN: 978-0-12-370626-3

2. Limnology: Lake and River Ecosystems, Wetzel, R.G. (2001). Third Edition. Academic Press

Other resources

3. Soranno et al (2010). Using Landscape Limnology to Classify Freshwater Ecosystems for Multi-Ecosystem Management and Conservation. BioScience 60:60(6), 440-454.

Learning Assessment

Bloom's Level of Cognitive Task		Continuous Learning Assessments (50%)								End Semester Exam (50%)	
		CLA-1 (10%)		Mid-1 (15%)		CLA-2 (10%)		CLA-3 (15%)			
		Th	Prac	Th	Prac	Th	Prac	Th	Prac	Th	Prac
Level 1	Remember	20%	-	20%	-	20%	-	20%	-	60%	-
	Understand										
Level 2	Apply	60%	-	50%	-	50%	-	50%	-	40%	-
	Analyse										
Level 3	Evaluate	20%	-	30%	-	30%	-	30%	-		-
	Create				-		-		-		-
Total		100%		100%		100%		100%		100%	