Department of
Environmental Science & Engineering

Syllabus and Course Content of 4-Year B. Tech Programme in Environmental Engineering

INDIAN INSTITUTE OF TECHNOLOGY (INDIAN SCHOOL OF MINES)
DHANBAD, JHARKHAND 826004

COURSE STRUCTURE
B.Tech. in Environmental Engineering

SEMESTER: 3

Course Type	Course Code	Name of the Courses	L	T	P	Credit Hrs.
DC1	ESC201	Drinking Water Supply and Treatment	3	0	0	9
DC2	ESC202	Air Pollution	3	0	0	9
DC3	ESC203	Noise Pollution and Control	3	0	0	9
E/SO1		ESO/SO1 Select any one from E/SO	3	0	0	9
E/SO2	MCE 201	Probability & Statistics	3	0	0	9
DP1	ESC251	Water Pollution Practical	0	0	2	2
DP2	ESC252	Air and Noise Pollution Practical	0	0	2	2
Total						**49**
Contact Hrs.			**15**	**0**	**4**	**19**

SEMESTER: 4

Course Type	Course Code	Name of the Courses	L	T	P	Credit Hrs.
E/SO3	CEE 201	Fluid Mechanics and Machines	3	0	0	9
DC4	ESC204	Geology and Land Use Planning	3	0	0	9
DC5	ESC205	Ecology and Environmental Microbiology	3	0	0	9
DC6	ESC206	Environmental Policy and Legislation	3	0	0	9
DC7	ESC207	Air Pollution Control	3	0	0	9
DP3	ESC253	Geology Practical	0	0	2	2
DP4	ESC254	Soil and Environmental Microbiology Practical	0	0	2	2
						49
Contact Hrs.			**15**	**0**	**4**	**19**

SEMESTER: 5

Course Type	Course Code	Name of the Courses	L	T	P	Credit Hrs.
DC8	ESC308	Environmental Geotechnology	3	0	0	9
DC9	ESC309	Wastewater Engineering	3	0	0	9
DC10/OE1	ESC310	Environmental Impact Assessment	3	0	0	9
HSS1/MS1	HSS1/MS1	HSS/MS1	3	0	0	9
E/SO4		ESO/SO4 Select any one from E/SO	3	0	0	9
DP5	ESC355	Environmental Geotechnology Practical	0	0	2	2
DP6	ESC356	Wastewater Engineering Practical	0	0	2	2
						49
Contact Hrs.			**15**	**0**	**4**	**19**

SEMESTER: 6

Course Type	Course Code	Name of the Courses	L	T	P	Credit Hrs.
DC11	ESC311	Solid Waste Management	3	0	0	9
DC12/DE1	ESC312	Geoinformatics	3	0	0	9
MS2/HSS2	MS2/HSS2	MS2/HSS2	3	0	0	9
OE2		Open Elective 2 (OE2) Any one from series 3 of ESE or other department	3	0	0	9
OE3		Open Elective 3 (OE3) Any one from series 3 of ESE or other department	3	0	0	9
DP7	ESC357	Solid Waste Management Practical	0	0	2	2
DP8	ESC358	Geoinformatics Practical	0	0	2	2
						49
Contact Hrs.			**15**	**0**	**4**	**19**

SEMESTER: 7

Course Type	Course Code	Name of the Courses	L	T	P	Credit Hrs.
DE1		Departmental Elective 1 (DE1) Any one from Series 1	3	0	0	9
DE2		Departmental Elective 2 (DE2) Any one from Series 1	3	0	0	9
OE4		Open Elective 4 (OE4) Any one from series 4 of ESE or other department	3	0	0	9
OE5		Open Elective 5 (OE5) Any one from series 4 of ESE or other department	3	0	0	9
OE6		Open Elective 6 (OE6) Any one from series 4 of ESE or other department	3	0	0	9
UGP*	ESC412	UGP-1 (Zero-Credit Compulsory)	0	0	0	6
DC13*	ESS001	Internship/Training/Seminar/Field-Excursion	0	0	0	9
						45
Contact Hrs.			**15**	**0**	**0**	**15+6*= 21**

SEMESTER: 8

Course Type	Course Code	Name of the Courses	L	T	P	Credit Hrs.
DE3		Departmental Elective 3 (DE3) Any one from Series 2	3	0	0	9
DE4		Departmental Elective 4 (DE4) Any one from Series 2	3	0	0	9
OE7		Open Elective 7 (OE7) Any one from series 4 of ESE or other department	3	0	0	9
HSS/OE			3	0	0	9
UGP-2	ESC413	UGP-2	0	0	0	6
						42
Contact Hrs.			**12**	**0**	**0**	**9+3*= 12**

LIST OF DEPARTMENTAL ELECTIVES (DE)

Course No.	Name	L	T	P	Credit Hrs.
ESD401	Biodiversity Conservation	3	0	0	9
ESD402	Industrial Waste Water Engineering	3	0	0	9
ESD403	Environmental Modelling	3	0	0	9
ESD404	Water Resource Planning and Management	3	0	0	9
ESD405	Environmental Biotechnology	3	0	0	9
ESD406	Environmental Nano Technology	3	0	0	9
ESD407	Hazardous and Biomedical waste Management	3	0	0	9
ESD408	Soil System and Ecological Restoration	3	0	0	9

LIST OF SO/ESO COURSES (DE)

SUBJECTS PROPOSED TO OFFER UNDER SO/ESO			
Course No.	**Name**	**Offering Semester**	**Mandatory for Departmental Students**
ESE 201	Pollution Control and Management	Monsoon	No
ESE 202	Atmospheric Science and Climate Change	Winter	No

LIST OF OPEN ELECTIVES (OE)

Course No.	Name	L	T	P	Credit Hrs.
Series 3					
ESO301	Life Cycle Assessment	3	0	0	9
ESO502	Environmental Aspects of Industries	3	0	0	9
ESO303	Occupational Health, safety and Risk Assessment	3	0	0	9
Series 4					
ESO404	Sustainability Engineering	3	0	0	9
ESO405	Cleaner Energy	3	0	0	9
ESO406	Environmental Management System and Auditing	3	0	0	9
ESO407	Climate Change and Modelling				

B.Tech- Common (First year)

S. No.	Course ID	Course Name	Lecture (L)	Tutorial (T)	Practical (P)	Credit Hours	Contact Hours
1	ESI101	Environmental Sciences (Modular)	1	0	0	3	1

Course Type	Course Code	Name of Course	L	T	P	Credit
DC	ESC 201	Drinking Water Supply and Treatment	3	0	0	9

Course Objective

The objective of the course is to present Understanding the water chemistry and principles of water treatment processes and its design and transportation.

Learning Outcomes

Upon successful completion of this course, students will:

- An insight into the structure of drinking water supply systems, water collection, water purification and water supply scheme for drinking water.
- An understanding of water quality criteria and standards, and their relation to public health.
- Student can apply knowledge of basic water chemistry to solve problems associated with drinking water treatment.

Unit No.	Topics to be Covered	Lecture Hours	Learning Outcome
1	**UNIT-I:** Drinking Water chemistry: Acids and Bases, titrations, buffers and buffer intensity, chemical equilibrium calculations, Langelier index, Oxidation and reduction reaction, stoichiometry, Redox couples, pE-pH diagrams. Basic concepts of organic chemistry, behaviour and fate of organics in the environment.	5	Understanding the role of water chemistry for selection of suitable method for treatment of surface and groundwater.
2	**UNIT-II:** Water requirements, Types of water demands, Water demand forecasting, Surface water and ground water sources, Water quality and drinking water standards, conventional contaminants and emerging contaminants; Water treatment: Source selection process, selection of treatment chain, plant siting.	5	To understand the criteria for planning of water supply system including the identification of degree of treatment.
3	**UNIT-III:** Physico-chemical processes (Process, Mechanism and Design): Sedimentation, Coagulation and Flocculation processes, Granular media filtration, Disinfection, Water softening, Adsorption and ion exchange processes, Desalination, Membrane filtration, Reverse osmosis, electrodialysis, Treatment of specific contaminants: Fluoride, Nitrate, Iron, Manganese and Arsenic etc.	18	This unit will help to understand the design component of each water treatment unit including conventional and advanced method.
4	**UNIT-IV** Determination of reservoir capacity, Gravitational, pumping and combined water supply schemes, Water-lifting arrangements, Distribution reservoirs and service storage, Pumping and design considerations for pumps, Design and hydraulic analysis of water distribution system, Distribution system components, Aqueducts, Hydraulics of conduits, Appurtenances and valves, water pipes, Storage tanks, Optimization of pipe network systems, Planning of urban and metropolitan water supply project and its implementation.	10	Understanding the layout and design of different unit of distribution network.

Recommended Text Books:

1. Environmental Engineering (2013 ed.)-Peavy and Rowe, McGraw Hill India.
2. Chemistry for Environmental Engineering and Science, (2003)-Sawyer, Clair N., Perry L. McCarty, and Gene F. Parkin. Boston: McGraw-Hill.

Recommended References:

1. Environmental Engineering-I, (33rd ed.)- S K Garg, Khanna Publishers Delhi.
2. Theory and practice of water and wastewater treatment (2009)-Textbook by Ronald L. Droste, Willey.

Course Type	Course Code	Name of Course	L	T	P	Credit
DC	ESC 202	Air Pollution	3	0	0	9

Course Objective
The objective of the course is to comprehend the essential concepts of Air pollution
Learning Outcomes
The students should be able to: • Explain basic principles on various aspects of atmospheric chemistry • Identify the major sources, effects and monitoring of air pollutants. • Understand the key transformations and meteorological influence on air • Relate and analyse the pollution regulation on its scientific basis

Unit No.	Topics to be Covered	Lecture Hours	Learning Outcome
1	Fundamentals of air pollution: Composition and physics of atmosphere, Stationary and mobile sources; combustion process, fugitive emission; primary and secondary pollutants; POPs, Effects of air pollution on human being, animals, plants; Air pollution episodes – causes and consequences; indoor air quality	10	Understanding the role of air chemistry and effect on human beings, animals and plants.
2	Atmospheric meteorology: Wind profiles, Global circulation, determination of atmospheric stability and mixing height using temperature gradient and effect of topography on atmospheric turbulence , inversions, mixing heights, plume behavior , ventilation co-efficient, theory and application of acoustic sounding (SODAR) technique	10	To understand the atmospheric metrology
3	Air quality monitoring: Air quality sampling network design; analysis and interpretation of data. Air pollution standards and indices, emission factor, emission inventory and emission standards, Prediction of effective stack height- plume rise concept and algorithm, e.g., Holland's equation, Briggs equation, etc.	10	To understand monitoring and analysis of air pollutants
4	Dispersion of air pollutants and modelling: Box model and Gaussian model with derivation and numerical with respect to point, line and area sources, Features and application of regulatory models, e.g., screening model, FDM, ISCST-3, Caline-4 and AERMOD models	10	To Understand the dispersion of air pollutant and prediction through various pollutants

Text Books:

1. 1.Boubel, R. W., Vallero, D., Fox, D. L., Turner, B., & Stern, A. C. Fundamentals of air pollution 4th edition Elsevier, 2008
2. Arthur C. Stern Fundamentals of air pollution 2nd edition, Elsevier, 1984
3. CS Rao, Environmental Pollution Control Engineering- Wiley Eastern Ltd., New Delhi, Latest Edition

Reference Books

1. De Nevers, N., Air Pollution Control Engineering, 3rd edition Waveland Press Inc 2016.
2. Peterson, A.P.G., Handbook of Noise Measurement General Radio Inc 1980.

Course Type	Course Code	Name of Course	L	T	P	Credit
DC	ESC 203	Noise Pollution and Control	3	0	0	9

Course Objective

- To impart knowledge on the sources, effects and control techniques of noise pollution.
- To impart knowledge about the preventive measures against noise pollution.

Learning Outcomes

Upon successful completion of this course, students will:

- To understand the nature and characteristics of noise pollution and basic concepts of noise control management.
- The students will able to identify, formulate and solve noise pollution problems.

Unit No.	Topics to be Covered	Lecture Hours	Learning Outcome
1	Fundamentals of Noise: Sound power, Sound intensity and Sound pressure levels. Effects of noise - Presbycusis, Acoustic Trauma. Characterization of Noise from Construction, Mining, Transportation and Industrial Activities. Permissible noise levels in different zones, Noise standards and indices.	12	The knowledge of concepts of fundamental noise and its characterization.
2	Noise monitoring: ambient and road traffic noise monitoring, Noise Control measures, Design of Sound Absorption, Acoustic Barrier, Vibration Isolation, Vibration Damping, Muffling, Personal Protector and Green Belt for noise attenuation.	05	The knowledge regarding noise monitoring of ambient and traffic noise and its control measures.
3	Whole Body Vibration problems in surface mines and control measures. Ground Vibration and Air Blast - Environmental impacts, strategic planning and abatement.Environmental noise modeling: Important conditions, its scope and limitation , Noise assessment and purposes.	12	The information regarding different types of environmental impacts due to noise and its strategic planning and management.
4	Assessment of atmospheric attenuation with respect to enclosures, barrier, geometric spreading, air absorption, wind & temperature gradient, Ground effect, shielding by vegetation/greenbelt; and projections of noise contouring of the concerned area. Noise mapping and applications of salient noise models, eg. ENM, Sound PLAN etc.	10	The knowledge about Noise mapping and its applications in noise modeling for assessment of atmospheric attenuation.

Text Book

1. Environmental Noise Pollution – PE Cunniff, McGraw Hill, New York.
2. Noise Control: Principles and Practices - Bruel & Kjaer, 2nd ed. B & K Pub., Denmark.

Reference Book :

1. Engineering Noise Control: Theory and Practice – David Bies et. al., Routledge Publishers.

Course Type	Course Code	Name of Course	L	T	P	Credit
DC	ESC204	Geology and Landuse Planning	3	0	0	9

Course Objective

- To understand the geological concepts for interpreting the environmental problems.
- To learn natural environment that may be regarded as the sum of interaction between geology and land-use planning

Learning Outcomes

Upon successful completion of this course, students will:

- The students will learn the structures thoroughly investigated geologically for which engineering geology prepares the significant background.
- The students will be able to find out the causes of environmental pollution based on geological information.

Unit No.	Topics to be Covered	Lecture Hours	Learning Outcome
1	Branches of Geology: Earth's - its internal constitution, Lithosphere Hydrosphere and their constitutions, Geological work of River and Wind, Folds & Faults, Geological Hazards.	12	The knowledge regarding concepts of geological study of the earth surface.
2	Crystals system, Minerals-its properties, properties of common silicate minerals (Quartz, Feldspar, Pyroxene, Mica),Sulphide (Pyrite, Chalcopyrite, Galena, Sphalerite) and Oxides (Haematite, Magnetite, Chromite, Pyrolusite, Psilomelane).	05	The knowledge regarding different crystals system and type of mineral along with its properties.
3	Magma-its composition and constitution, description of some common Igneous rocks (Peridotite, Dolerite, Basalt, Granite, Rhyolite),Sedimentary rocks (Conglomerate, Sandstone, Shale, Limestone),description of some common Metamorphic rocks (Slate, Schist, Gneiss, Quartzite, Marble).. Aquifer-its types; Porosity and Permeability, delineation of watershed and its characteristics, Total Annual Replenishable Recharge and Pumping test studies.	10	The information regarding different types of rocks and its applications and also learn about the aquifer and its charactertics.
4	Coal- its composition and origin; Distribution of Indian coals, Geological time scale, Various Stratigraphic units of India, Fossils, their mode of preservation and uses. Land use Planning: Objective and importance; Land use and capability classification systems, Land use Planning models and their limitations. Impacts of natural and man-made activities on land characteristics. Impact of soil erosion.	12	The knowledge about coal, its composition and distribution in Indian aspects. Impact of landuse pattern on the environment.

Textbooks:

1. Textbook of Geology- P. K. Mukerjee.
2. Textbook of Engineering & General Geology- Parbin Singh.

Reference Books:

1. Environmental Land Use Planning and Management - John Randoloh (2003).
2. Landuse Planning for Sustainable Development – Jane Silberstein, M.A, Chris Maser.

Course Type	Course Code	Name of Course	L	T	P	Credit
DC	ESC 205	**Ecology and Environmental Microbiology**	3	0	0	9

Course Objective
To understand the Fundamentals of Ecology and Microbiology and Importance of Microbiology in the Environment
Learning Outcomes
Upon successful completion of this course, students will: • Understand the fundamentals and importance of ecology and microbiology in the environment • Understand the application of microbial remediation in the environment

Unit No.	Topics to be Covered	Lecture Hours	Learning Outcome
1	**UNIT-I** *Fundamentals of Ecology and Ecosystem* – Structural and Functional Components. Food chain & Food webs. Ecological pyramids; Energy flow. *Ecosystem Stability*- Inertia & Resilience, fragile ecosystem, Hot Spots; Aichi Target 15 & REDD+, Ecosystem services; NPV Ecosystems, and the Millennium Development Goals, Landscape ecology.	5	To understand the Fundamentals of Ecology
2	**UNIT-II** *Population and Community Ecology*- Characteristics and Structure, Population interaction; Population growth; Habitat; ecological niches and Ecotone. *Ecological Successions*- Trends of ecosystem development (structural and functional). Succession in land and water. System ecology; Energy flow in ecosystem- recycled pathway. Biogeochemical cycles; Nutrient cycling in tropics. Limiting factors- Liebig's law, Shelford's laws, Steno and Eury species. Bio-monitoring, pollution tolerant& sensitive species; Indicator species. *Biological diversity*-red data book species. Biodiversity indices; biodiversity conservation.	8	To understand the behavior of living organisms in the environment and also biodiversity amongst the living organism
3	**UNIT-III** *Aquatic ecology*- stratification, productivity, life forms, impacts of thermal discharge and reservoir de-watering. Marine and Estuarine ecosystem; Wetland ecosystem, Ecotoxicology- toxicity testing system, LC50, EC50, NOEC, LOEC, Eutrophication kinetics, phosphorus model. Pesticide and bioaccumulation.	4	To understand the behavior of aquatic organisms in the environment
4	**UNIT-IV** *Environmental importance of microbiology*- Classification, distribution of microbes, Nutrition, Enumeration of microbes, Bacterial growth curve, Batch culture, continuous culture, Effects of environmental factors on growth, Control of Microbes. Microbial Metabolism- Glycolysis, TCA, and ETC, Fermentation, Energy balance-Growth, Enzymes, metabolic pathways and intermediate products, Different kinetics model.	8	To understand the importance of microorganisms in the environment
5	**UNIT-V** *Water microbiology*-Analysis, waterborne diseases and pathogens, MPN and MFT test; fecal coliform and fecal streptococci; IMVIC test. Air microbiology- Microorganisms of air, Air-borne diseases and pathogens. *Soil Microbiology*-Microbial flora, soil borne pathogens, Bio-fertilizers, N-fixation, root nodule formation, VAM fungi, Bio-pesticides.	8	To understand the importance and behavior of microorganisms in the water, Air and soil environment
6	**UNIT-VI]** Concept of microbial remediation- Degradation of natural substances, Mechanism and Application; Microbial composting; Vermicomposting; Microbial applications for Bioenergy from waste.	6	To understand the application of microorganisms in the various pollutant removal

Recommended Text Books:

1. Fundamentals of Ecology (latest ed). Eugene P. Odum. WB Sunders Company, Philadelphia.
2. Fundamentals of Ecology- MC Dash. Tata-McGraw Hill, New Delhi.

Recommended References:

1. Microbiology - Michael J.Pelzer et.al., (latest ed.), Tata McGraw Hill, New Delhi.
2. Introduction to Environmental Engg. G.M.Masters. Prentice Hall of India

Course type	Course Code	Name of Course	L	T	P	Credit
DC	ESC 206	Environmental Policy and Legislation	3	0	0	9

Course Objective(s)

The objective(s) of the course is to present an introduction to environmental policies, evolution of environmental legislation in India, environmental standards etc. with an emphasis on how to understand relationship between environmental policy and environmental acts for sustainable management of environmental resources.

Learning Outcome(s)

Upon successful completion of this course, students will have:

- fundamental knowledge of environmental policy and legislation.
- broad understanding of environmental importance of environmental movements for restoration and conservation of natural resources.
- Knowledge of legal aspects relating to hazardous and toxic substances management, handling rules etc.

Unit No.	Topics to be Covered	Lecture hour(s)	Learning Outcome(s)
1	Environmental Policies; National and International trends, Changes in global perspective, International treaties. National Policies: National Environmental Policy, National Forest Policy, National Water Policy, Rehabilitation and Resettlement Policy, CSR policy	14	Students will have foundation of environmental improvements made through implementation of environmental policy and how draft policy becomes act when international treatises and national movements define the direction and commitment of government for the sustainable use of natural resources etc.
2	Evolution of environmental legislation in India, Legal provisions for environmental protection; various Acts, Rules and Regulations. Notifications issued under various Acts and Rules	14	Students will have fundamental knowledge of past-present-future course of legal system for environment protection and conservation of natural resources; consequences of legislations as well as the judicial interpretations on various environmental issues; role of Citizen, Panchayat, Municipality, State, and Union in protection of environment etc.
3	Environmental standards; Criteria for standards setting.	4	Students will learn decision-making process for the development of environmental standards; knowledge of technical and economic ramifications, as well as social and public health implications associated with criteria used in setting of environmental standards etc.
4	Public Liability Insurance Act and legal aspects relating to hazardous and toxic substances.	7	Students will gain knowledge about aim and objectives of the Public Liability Insurance Act providing immediate relief to the persons affected by accident occurring while handling any hazardous substance and for matters connected therewith or incidental thereto; scope of Environmental Relief Fund etc.
	Total	39	

Text Book:

1. Environmental Legislation in India, Ulla Roiha, Finpro, Region Asia
2. Environmental Law of India, S.K. Choudhuri, Oxford & IBH Publishers

Reference Books:

1. Pollution control acts, rules and notifications issued thereunder, CPCB-India
2. Handbook of Environmental laws, Acts, Guidelines, Compliances & Standards Policy, Trivedy, BS Publishers

Course Type	Course Code	Name of Course	L	T	P	Credit
DC	ESC 207	Air Pollution Control	3	0	0	9

Course Objective

The objective of the course is to understand and evaluate the behavior of air pollutants and the strategies to control their presence in the ambient atmosphere.

Learning Outcomes

Upon successful completion of this course, students will be able to:

- Brief on the behaviour of air pollutants in atmosphere.
- Design different types of control equipment's for the abatement.
- Evaluate the engineering solutions for industrial and vehicular air pollution problems.

Unit No.	Topics to be Covered	Lecture Hours	Learning Outcome
1	General properties of flue gas and particle dynamics.	04	To learn application of mass and energy balance to the calculations involving flue gas and particle
2	Design of control device for gaseous pollutant-absorption-adsorption-incineration-condensation.	12	To design numerically a control device for gaseous pollutants depending on type of originating source.
3	Design of control device for particulate pollutant- Gravity settler- Cyclone separators- fabric filters-Electrostatic Precipitator -wet scrubber.	12	To design numerically a control device for particulate pollutant based on their size and removal efficiency.
4	Industrial Air Pollution Control: Dust control and abatement measures in mines; role of green belts. Thermal power plants: Control principle to improve overall thermal efficiency, Fuel and flue gas desulphurization, FBC, control of NO_x, control of mercury, concept of Integrated Gasification Combined Cycle (IGCC) and Carbon Capture and Storage (CCS). Control of motor vehicle emissions.	05	Develop an understanding of the concepts for Industrial Air Pollution Control for power sector and automobiles.
5	Indoor air pollution control, auxiliary equipment's design for air pollution control such as hoods, fans and ducts, calculation to estimate pressure drop due to air pollution control device and total cost estimation procedure including operating cost.	06	Get the knowledge for indoor air pollution control equipment.

Text Books:

1. Cooper, C.D., Alley, F.C. Air pollution control: A design approach, 2. baskı, Waveland Press, Inc., ABD.
2. Theodore, L. Air pollution control equipment calculations, John Wiley & Sons, Inc., ABD.

Reference Books:

1. Spellman, F. R., Whiting, N. E., (2004). ENVIRONMENTAL ENGINEER'S MATHEMATICS HANDBOOK by CRC Press.

Course Type	Course Code	Name of Course	L	T	P	Credit
DC	ESC 251	Water Pollution	0	0	2	2

Course Objective

1. Impart the practical knowledge about water quality parameters.
2. Impart the knowledge to understand the degree of treatment based on water quality parameters.

Learning Outcomes

Upon successful completion of this course, students will:

- Plan and conduct an experiment for physico-chemical properties of water
- Understanding the role of water quality parameters for water suplly and treatment.

Unit No.	Topics to be Covered	Practical Hours	Learning Outcome
1	Calibration of pH meter, TDS and conductivity meter and determination of pH, TDS and conductivity of a given water sample.	2	Understanding the operation and calibration of most common equipments in field of water quality measurement
2	Determination of different component of NOM by TOC analyzer and spectrophotometer	2	To understand the role of NOM during water treatment
3	Determination of acidity and alkalinity of given water sample.	2	Undestanding the role of acidity and alkalinity in drinking water quality and its role during water treatment.
4	Determination of hardness of given water sample.	2	Understanding the measurement of different component of hardness and its role in water quality management.
5	Determination of nitrate of given water sample.	2	Understanding the measurement of nitrate and its role in water quality management.
6	Determination of sulphate of given water sample.	2	Understanding the measurement of sulphate and its role in water quality management.
7	Determination of chloride of given water sample.	2	Understanding the measurement of chloride and its role in water quality management.
8	Determination of chlorine demand, residual chlorine and breakpoint.	2	Understanding the disinfection requirement for drinking water
9	Calibration and standardization of Nephelometer and Determination of optimum coagulant dose using jar test and turbidity meter	2	Understanding the removal mechanisim of colloidal particles from water source.
10	Determination of optimum lime soda dose for hardness removal	2	Understanding the lime and soda chemistry for hardness removal.
11	Determination of sodium and potassium by flame photometer	2	Understanding the determination of selected ions by flame photometer

Course Type	Course Code	Name of Course	L	T	P	Credit
DC	ESC 252	Air and Noise Practical	0	0	2	2

Course Objective

- To learn assessment of ambient air and noise quality

Learning Outcomes

Upon successful completion of this course, students will:

- The students will learn various analytical and sampling protocols to monitor and analyze various ambient air and noise quality parameter.

Unit No.	Topics to be Covered	Lecture Hours	Learning Outcome
1.	Calibration of orifice of the Respirable Dust Sampler (RDS) and Determination of PM_{10} & $PM_{2.5}$ in ambient air	2	Students will understand principal of RDS and estimation Particulate matter.
2.	Determination of SO_2 in ambient air	2	Students will learn analysis of sulphur di oxide and use of titration and spectrophotometer.
3.	Determination of NO_x in ambient air	2	Students will learn analysis of Nitrogen oxides and use of spectrophotometer.
4.	Determination of CO and Ozone in ambient air.	2	Students will get exposer to CO and Ozone analyser.
5.	Elementary analysis of Particulate matter for heavy metals and PAHs.	2	Student will get Exposure of GC and HPLC.
6.	Determination of Ammonia in Ambient Air.	2	Students will get exposure of ammonia analyais.
7.	Construction of Wind rose diagram & Demonstration of Stack Monitoring Kit	2	Will learn metrological aspects.
8.	Ambient noise monitoring	2	Will learn concept of noise measurement.
9.	Frequency spectrum analysis of machine noise	2	Will learn importance and analysis of frequency wise noise level.
10.	Traffic noise monitoring	2	Will learn importance and procedure for traffic noise monitoring.
11.	Audiometry survey for assessing hearing acuity	2	Will learn occupational effect of noise and its assessment.

Reference book

1. Guidelines for measurement of Ambient air Pollutants, Volume 1, CPCB 2011.
2. IS 5182 (Part 14): Methods for Measurement of Air Pollution, Part 14: Guidelines for Planning the Sampling of Atmosphere (Second Revision) by Bureau of Indian Standards (BIS).

Course Type	Course Code	Name of Course	L	T	P	Credit
DC	ESC 253	Geology Practical	0	0	2	2

Course Objective

- The identification of different types of rocks and understanding their behavior.
- To apply geologic concepts and approaches on environmental engineering projects.

Learning Outcomes

Upon successful completion of this course, students will:

- The student will be able to demonstrate the basic lab skills: identifying minerals and rocks; inferring rock origin from examination of specimens; reading, drawing and interpreting contour maps and profiles; using terrestrial coordinates.

Unit No.	Topics to be Covered	Lecture Hours	Learning Outcome
1.	Topsheet Analysis,: Their Number, Scale and Index and Physiographical parameters analysis through Toposheet.	2	The knowledge regarding concepts of Topsheet analysis and information regarding physiographical features and tools of the toposheet.
2.	Preparation of Contour line map (choose one suitable sector of toposheet) and demarcation of higher and lower landmarks with direction.	2	The knowledge regarding different contour map.
3.	Preparation of Drainage map and drainage density of a given watershed area.	2	The information regarding different types of drainage pattern in the given watershed area.
4.	Preparation of watershed map and analysis of slope of sub watershed area.	2	The knowledge about watershed map and its use in watershed management and planning.
5.	Calculation of TARR value.	2	To understand the importance of total annual replenishable recharge and for assessment of groundwater utilization and its stage of groundwater development.
6.	To draw the profile/section of different beds in the given geological map.	2	To understand and to identify regions of groundwater movement, evaluate potential sites for economic mineral deposits, and locate oil and gas reservoirs.
7.	Drawing of strike line & determination of true dip & apparent dip.	2	To understand the attitude of rock layers or other planar geologic features) in constructing of accurate geologic maps and geologic cross-sections.
8.	Laboratory Study and Observations of Physical Properties of Minerals.	2	To understand the behaviour and characteristics of minerals for remediation of contaminated soils and groundwater.
9.	Study of rock specimens and its physical properties (Igneous, Sedimentary and Metamorphic rocks).	2	The knowledge about the important rocks and give idea about what the Earth was like in the past.
1o.	Study through GPS- Latitude, Longitude, Elevation etc.	2	The knowledge about the latitude and longitude of any location can easily be determined.
11.	Study of Water table fluctuation through secondary data.	2	To estimate the groundwater recharge by analysis of water-level fluctuations from the observation wells.

TextBook

1. Textbook of Geology; G.B. Mahapatra, CBS.
2. Textbook of Geology; P. K. Mukherjee, World Press.

Reference book

1. Practical Geology; Dr. Harish Kapasya, Himanshu Publications.

Course Type	Course Code	Name of Course	L	T	P	Credit
DC	ESC 254	**Soil and Environmental Microbiology Practical**	0	0	2	2

Course Objective

3. Impart the practical knowledge about soil properties.
4. Develop idea about culture media and staining techniques.
5. Develop understanding about the microbiology of air, water and soil environment

Learning Outcomes

Upon successful completion of this course, students will:

- Plan and conduct an experiment for physico-chemical properties of soil
- Understand the preparation of culture media and staining techniques.
- Learn methods for enumeration of microbes from air, water and soil.

Unit No.	Topics to be Covered	Practical Hours	Learning Outcome
1	Estimation of physical parameters of soil	2	To understand the physical parameters of soil
2	Estimation of chemical parameters of soil	2	To understand the chemical parameters of soil
3	Estimation of heavy metals concentration from soil	2	To learn the process of heavy metal detection from the soil
4	Quantitative and qualitative characters of plant communities Ecological sampling of an area (line transect and quadrate method) "species-area" curve method	2	To understand the Quantitative and qualitative characters of plant communities
5	Study of vegetation of pond ecosystem. Study of fresh water and polluted water algae – (Blue green algae, Green algae and Diatoms).	2	To understand the importance of microorganisms in the environment
6	Culture media preparation– Semi-synthetic and Synthetic media. Liquid, Solid and semisolid media, Nutrient agar, PDA media	2	To understand the culture media preparation
7	Gram staining techniques for detection of gram positive and gram negative bacteria. Study of fungi (medium – Rose Bengal agar).	2	To see the shape, size an arrangement for bacteria and fungi
8	Bacteriology of drinking water and domestic sewage -MPN techniques for total coliform, Faecal coliform and Faecal Streptococci (FS), Membrane filtration techniques for faecal coliform and total coliform. IMViC test	2	To understand the microorganisms in the water environment
9	Microbiology of Air: Enumeration of microbes by exposure plate method.	2	To understand the microorganisms in the ar environment
10	Microbiology of soil: Isolation of microbes by serial dilution methods and colony count by colony counter.	2	To understand the microorganisms in the soil environment

Recommended manuals:

1. Handbook of instrumental techniques for analytical chemistry, Frank A. Settle, 1stEdition, Prentice Hall.
2. Microbiology: a laboratory manual. Cappuccino J C, Sherman N, 3rd edn. Benjamin/cummings Pub, New York.

Course Type	Course Code	Name of Course	L	T	P	Credit
DC	ESC 308	Environmental Geotechnology	3	0	0	9

Course Objective

- To learn various soil engineering for land reclamation purposes, conversion of degraded waste land in new landuse, creation of new lands.
- To learn the application of soil mechanics in soil improvement, soil remediation, subgrade-drainage system, enhancing slope stability in mining areas, hilly regions, etc.

Learning Outcomes

Upon successful completion of this course, the students will :-

- learn about various kind of soil and environmental geotechniques to reclaim degraded land for conversion into various land-uses like construction, infrastructure, plantation, agriculture, forestry or development of aesthetics.
- be able to stabilize erosion prone land, unstable hill and mine slopes; understand flow of contaminants in soil; conduct polluted soil remediation.

Unit No.	Topics to be Covered	Lecture Hours	Learning Outcome
1	Geotechnology and environment ; Basics of soil materials, Physical Characterisation of soil, Solids-water-air relationships, Consistency, Index properties, Classification	10	The unit will provide an overview of different types of soil, its index properties, classification and their physical characteristics.
2	**Soil Compaction:** Factors affecting compaction, Optimum moisture content. Engineering Behaviour. **Compressibility and Consolidation:** Primary and Secondary Consolidation, Consolidation of disturbed soil, Ground improvement techniques.	05	This unit will help student in understanding various soil compaction and consolidation techniques for improving the engineering behavior of different soils.
3	**Shear strength of soils:** Shear strength of soils and its application in waste dumps, reclaimed sites, hill slopes, etc. Stability analysis. Stability of Slopes	04	This unit will help the students in understanding the shear strength of soil for determination of stability conditions.
4	**Effective Stress, Capillarity and Permeability of soil:** Effective Stress, Capillarity and Permeability of soil Hydrodynamic Case-Flow Condition.	05	This unit provides a detailed overview of permeability of soil for ground water movement, rainwater harvesting, flow of contaminants, etc.
5	**Seepage Through Soils:** Flow nets through a pervious medium, Two Dimensional Flow-Laplace's Equation, Steady State Flow, Flowlines, Equipotential Lines. Prevention of erosion, protective filters.	05	This unit will help the students in understanding the flow conditions and simulating techniques.
6	Soil Exploration, waste materials in geotechnical construction, application of geotextiles, Instrumentation in Environmental Geotechnology, case studies, Issues in soil degradation and remediation..	10	This unit will help the students in exploration of soil and utilization of waste for geotechnical applications as replacement of natural soil.

Text Books:

1. Environmental Geotechniques - R Sarsby, Thomas Telford Publishing, London, 2000.
2.. Basic and Applied Soil Mechanics (2nd ed.) – G Ranjan & ASR Rao, New Age Publ. 2008.

Reference Books:

1. Geotechnical Engineering – SK Gulhati and M Datta, Tata McGraw Hill, New Delhi, 2005.
2. Hydrology – HM Ragunath, Wiley Eastern Limited,1990

Course Type	Course Code	Name of Course	L	T	P	Credit
DC	ESC 309	Wastewater Engineering	3	0	0	9

Course Objective
To describe the objective, principles and design of effluent treatment processes and sewerage system for higher discharge standards and effluent re-use.
Learning Outcomes
• Understand the role of each unit process within typical treatment process trains, their interaction and the context of when they are applied. • Appreciate the advantages, disadvantages and limitations of the technologies and new developments

Unit No.	Topics to be Covered	Lecture Hours	Learning Outcome
1	**Wastewater Engineering-**An Overview, wastewater characteristics and concern , wastewater treatment new directions and concerns ,Analysis of flow rate ,mass loading, process analysis and selection, reactor, types of reactor ,mass balance analysis, types of reactions, analysis of reaction rate & order, flow sheets for wastewater treatment plant	6	The unit will provide an overview of sources, characteristics and understand the basic engineering concepts of designing an ETP
2	**Sewerage:** Types & sources of sewage ,sewerage system, hydraulic design of sewer, selection Types of sewer, construction laying and testing of sewer lines design of Sewage Pumping Station, Maintenance of sewerage system, introduction to sewer CAD.	8	This unit will help student in understanding the engineering principles & design of various types of sewerage system.
3	**Preliminary& primary treatment processes-** design and operation of approach channel, screening , gravity separation theory, grit removal system , design and operation of type –II settling, flow equalization, Coagulation & flocculation, design of clari-flocculator, dissolved air floatation and aeration system	10	This unit will help the students in understanding the design and operation of physico-chemical process used in STP.
4	**Fundamentals of biological system:** derivation of bacterial growth kinetics. Process design and operation of attached growth, suspended growth and hybrid process: activated sludge process - its modifications, oxidation ditch, aerated lagoon; Waste stabilization pond; Biofilter, trickling filter, RBC; Anaerobic treatment - reactors, UASB reactor, Design and operation of biological nitrification and de-nitrification system. Floating aquatic plant system	8	This unit provides a detailed overview of biological treatment technologies used for wastewater treatment.
5	**Design of sludge disposal facility:** Gravity Thickener, Anaerobic digester, and Sludge drying bed. Disposal and Reuse of Treated effluent, Effluent Standards	7	This unit will provide and understanding on sludge treatment design facilities used in STP.

Text Book

1. Wastewater Engineering: Treatment and Reuse (4th ed.)-Metcalf and Eddy
2. Wastewater Treatment for Pollution Control (3rd ed.) - SJ Arceivala, Tata McGraw Hill,1998.

Reference Book

1. Wastewater Treatment Plants: Planning, Design and Operation Holt - SR Qasim, Rinehart & Winston, NY, 1985
2. Environmental Engineering-II, S K Garg, Khanna Publishers, India

Course Type	Course Code	Name of Course	L	T	P	Credit
DC	ESC 310	**Environmental Impact Assessment**	3	0	0	9

Course Objective
To develop the skills in the EIA so that the development projects with EC can realize real life environmental sustainability.
Learning Outcomes
• Understanding the significant and importance of carrying out EIA • Understanding of EIA process • The students will come out with skills in EIA /EMP formulation with follow-up EC practices of various development projects

Unit No.	Topics to be Covered	Lecture Hours	Learning Outcome
1	**Evolution of EIA Process,** National environmental policy act and its implementation;	04	Appreciation of the significance & importance of EIA
2	Planning and management of impact Assessment studies, EIA Process – Screening, Scoping, EIA EMP Preparation, Public Consultation. Decision Making, Post Monitoring and Auditing	08	Understanding the stages of EIA process
3	Methodologies for EIA – Impact identification checklists, matrices etc. , Environmental indices and indicators for describing the affected environment;	06	Help in understanding why and how EIA is carried out
4	Assessment , Prediction and Mitigation aspects in EIA, Air and Water Impact Assessment, Ecological Impact Assessment, social Impact Assessment.	10	Understanding how the specific individual specific environmental attribute is assessed & mitigated
5	Risk and Uncertainty in EIA. Documentation of EIA and EMP NABET accreditation aspects of EIA/EMP Preparation	06	Help in understanding the NABET accreditation aspects of carrying out EIA
6	Regional Environmental Impact Assessment(REIA), Strategic Environmental Assessment(SEA),	05	Understanding how EIA is carried out at regional as well national levels

Books :

1. Environmental Impact Assessment -Larry, W. Canter (latest ed), McGraw Hill Inc. Singapore,
2. Environmental Assessment – Ravi Jain/L. V. Urban, McGraw-Hill, Latest Edition

Reference:

1. Environmental and Social Impact Assessment – C. J. Barrow, Arnold Publication, Latest Edition
2. EIA Notification 1994, 2006 and amendments

Course Type	Course Code	Name of Course	L	T	P	Credit
DC	ESC 311	Solid Waste Management	3	0	0	9

Course Objective

To provide a comprehensive insights of the types, sources, generation, storage, collection, transport, processing and disposal of municipal solid waste. The student is expected to know about the regulatory framework for the municipal solid waste management.

Learning Outcomes

Upon successful completion of this course, students will:

- Understand the fundamental principles of existing and emerging technologies for the treatment of waste and recovery of materials and energy from waste.
- Have an overview of the Indian and international waste management regulations and guidelines for the design, construction, operation and management of waste treatment facilities.
- To have an overview of management of waste from industrial and agricultural sector.

Unit No.	Topics to be Covered	Lecture Hours	Learning Outcome
1	**Introduction to Solid Waste:** Sources, types, composition, physical, chemical and biological characteristics of municipal solid waste, properties and classification of hazardous solid waste, problems related to solid waste management, Agricultural, Domestic (urban) wastes, Biomedical waste, E-waste, Plastic Waste and Construction Waste, Management of lead acid battery.	6	The unit will provide an overview of different types of solid wastes and their characteristics.
2	**Engineering principles:** Generation and collection rates, separation, storage and processing at source, collection of solid waste, transfer and transport, hauled container system and stationary container system, analysis of collection systems, optimization of routes, transfer stations, need and types of transfer station, location of transfer station.	10	This unit will help student in understanding the engineering principles of different solid waste management systems.
3	**Solid waste disposal:** Landfill classification, types and methods, siting considerations, stages of landfill. Composition, characteristics, generation, movement and control of landfill gas. Composition, formation, movement and control of leachate in landfills. Layout and preliminary design of landfills, landfill operation and closure, final cover.	10	This unit will help the students in understanding the design and operation of solid waste landfill.
4	**Material separation and processing technologies:** Thermal conversion technologies, combustion, pyrolysis and gasification, combustion calculations, Environmental control, biological and chemical conversion technologies, Aerobic and Anaerobic Composting, energy recovery, recycling, waste minimization and utilization.	8	This unit provides a detailed overview of thermal treatment technologies along with the recycling and anaerobic digestion options.
5	**Source specific solid waste management:** Agriculture, Process industry, Mineral and Metallurgical industry, Disposal of industrial and mill tailings etc. Regulatory aspects of solid waste management.	5	To understand the management strategy of some specific types of wastes. The unit will also give an insight of regulatory framework.

Text Books:

1. Tchobanoglous, G., Theisen, H., and Vigil, S. A. (2014). Integrated Solid Waste Management: Engineering Principles and Management Issues. New Delhi: McGraw-Hill Education (India) Private Limited.
2. Peavy, H. S., Rowe, D. R., & Tchobanoglous, G. (2010). Environmental Engineering. New York: McGraw-Hill.
3. Khan, I. H., and Ahsan, N. (2012). Textbook of solid waste management. New Delhi: Satish Kumar Jain for CBS Publisher and Distributors.

Reference Books:

1. Tchobanoglous, G., and Kreith, F. (2002). Handbook of Solid Waste Management-Second Edition. New York: McGraw-Hill.
2. CPHEEO (2000). Manual on Municipal Solid Waste Management, Central Public Health and Environmental Engineering Organisation, Ministry of Urban Development, Govt. of India, New Delhi.
3. Williams, P. T. (2005). Waste treatment and disposal-Second Edition. London: John Wiley and Sons.

Course Type	Course Code	Name of Course	L	T	P	Credit
DC	ESC312	Geoinformatics	3	0	0	9

Course Objective

Understanding of the fundamental concepts of Remote Sensing and Geographic Information System and the understanding of the wide applications of Remote Sensing and GIS in Environmental Management.

Learning Outcomes

Upon successful completion of this course, students will develop:

- Understanding of the fundamental concepts of Remote Sensing and Geographic Information System.
- Understanding of the wide applications of Remote Sensing and GIS in Environmental Management.

Unit No.	Topics to be Covered	Lecture Hours	Learning Outcome
1	Introduction, Types of Remote Sensing, Application and importance of Remote Sensing; Physics of Remote Sensing; The Electromagnetic spectrum; Spectral Reflectance Curves; Spectral Signatures; Types of Resolution. Remote Sensing Platforms: Ground, airborne and satellite-based platforms; Some important Remote Sensing Satellites.	10	This unit will help the students to develop an elementary idea on origin of remote sensing and important fundamental concepts related to EM spectrum.
2	Aerial Photography and Photogrammetry: aerial and terrestrial photogrammetry, applications of photogrammetry, types and geometry of aerial photograph, flying height and scale, relief (elevation) displacement, Stereoscopy and Orthophotography, Aerial Photo Interpretation, LiDAR.	8	This unit will help the students to learn the various types of sensors involved in RS techniques and the image components
3	Digital Image Processing: Pixels and Digital Number; Digital Image Structure; Format of Remote Sensing Data; Concept of False Color and True Color Imagery; Image Processing functions: Image Restoration, Image Enhancement, Image Transformation, Image Fusion, Image Classification and Analysis; Image interpretation strategies.	10	This unit will help the students to develop the fundamental concepts of digital image processing techniques.
4	Geographic Information System: Introduction; Preparation of thematic map from remote sensing data; Co-ordinate systems; Concept of Datum; GIS components: Hardware, software and infrastructures; GIS data types: Data Input and Data Processing; DEM/ DTM generation. Integration of GIS and Remote Sensing. Application of Remote Sensing and GIS in Environmental Management: Case Studies; An introduction Global Positioning System.	11	Students will have a vivid knowledge on the concepts of GIS and its applications to real environmental case studies.

Text Books

1. Remote Sensing & GIS - by Basudeb Bhatta, Oxford University Press (OUP) Higher Education Division, (Second Edition), 2011.
2. Introduction to Remote Sensing - by James B. Campbell and Randolph H.Wynne, (Fifth Edition), The Guiford Press, 2011
3. Concepts and Techniques of Geographic Information Systems by Chor Pang Lo, Albert K. W. Yeung, Prentice Hall, 2002.

Reference Books

1. Principles of Geographical Information Systems - P A Burrough and R. A. McDonnell, OUP,Oxford 1998.
2. Geographic Information System- Kang Tsung Chang, Tata Mc Graw Hill, Publication Edition, 2007.

Course Type	Course Code	Name of Course	L	T	P	Credit
DC	ESC 355	Environmental Geotechnology (P)	0	0	2	2

Course Objective
• To learn the application of soil mechanics in soil improvement, soil remediation, subgrade-drainage system, enhancing slope stability in mining areas, hilly regions, etc.
Learning Outcomes
Upon successful completion of this practical course, the students will learn about various methods for determining physical parameters of soil.

Unit No.	Experiments	Lecture Hours	Learning Outcome
1	Identification of Soil	2	Identification of different types of soil.
2	Sampling and Grain Size Distribution	2	The students will learn to separate various coarse size fraction of the soil for geotechnical analysis.
3	Distribution of Specific Gravity of Soil	2	This unit will help the students in determining the sp.gr of various kinds of soils
4	Atterberg Limits	2	The students will be able to learn about the consistency of soil with various moisture conditions.
4.1	Plastic Limit		
4.2	Liquid Limit		
4.3	Shrinkage Limit		
5	Determination of Density of Soil	2	Determination of bulk and dry density
6	Determination of Relative Density & Void Ratio of Soil	2	Determination of relative density and void ratio with change in various loads
7	Sedimentation Analysis	2	The students will learn to separate various fine size fraction of the soil for geotechnical analysis.
8	Determination of Permeability of Soil	2	The students will learn to determine permeability of soil in constant head and falling head conditions.
8.1	Falling Head Permeability Test		
8.2	Constant Head Permeability Test		
9	Compaction Test (Standard & Modified)	2	The students will learn to compact the soil by mechanical means.
10	Consolidation Test	2	The students will learn to consolidate a fully saturated soil sample by application of load
11	Triaxial Test	2	The students will learn to shearing strength of soil under undrained condition
12	Direct Shear Test	2	The students will learn to shearing strength of soil under drained condition
13	Free Swell & Swelling Pressure of Soil	2	The students will learn the Free Swell & Swelling Pressure of expansive soil

Text Books:

1. Soil Mechanics Laboratory Manual by B.M.Das, Oxford University Press.

Reference Books:

1. IS 2720 , Indian Standards for Soil Testing

Course Type	Course Code	Name of Course	L	T	P	Credit
DC	ESC 356	Wastewater Engineering	3	0	0	9

Course Objective
To understand various physico-chemical and biological parameters used in design and operation of wastewater treatment plants.
Learning Outcomes
Hands on experience on various methods used for analysis of wastewater.

Sl. No.	Name of the Experiment	Lecture hr	Learning Outcome
1.	Determination of acidity, alkalinity & CO_2 (free) of wastewater sample	2	Student will learn on the concept behind acidic /alkaline characteristics and types of acidity/ alkalinity present in wastewater
2.	Determination of BOD & COD in municipal wastewater and confer on the biodegradability of wastewater	2	The student will learn and understand the biodegradability and organic strength of the wastewater.
3.	Demonstration of Nitrate-nitrogen (NO_3-N) Ammonical Nitrogen (NH_4-N) & TKN of given wastewater sample	2	The student will learn on various forms of nitrogen, i.e. TKN, Ammonia Nitrogen & Nitrate present in wastewater.
4.	Determine TSS, TDS, TVS & TS of given wastewater sample. Also determine the settleable solids & non-settleable SS in given wastewater sample	2	The student will learn on various types of solids and their significance in design of ETP.
5.	Determination of Phenol & SO_4 in municipal wastewater	2	The student will learn on the impact of Phenol & Sulphate present in wastewater.
6.	Determine MLSS, MLVSS concentration, sludge volume index (SVI) of sludge sample	2	The student will learn on concepts of sludge characterization and their role in design of biological treatment system
7.	Determination of TOC, DOC, UV_{254} & SUVA of given wastewater sample	2	The student will learn on concepts of Natural organic Matter (NOM) and their analysis protocol through TOC analyzer.
8.	Determination of heavy metals such as Zn, Ni, Fe, Pb and Cr by Atomic absorption spectroscopy (AAS) in municipal wastewater	2	The student will learn on concepts of determination of heavy metals by atomic absorption spectrophotometry (AAS).
9.	Determination of organic pollutant by High Performance Liquid Chromatography (HPLC)	2	The student will learn on principle and operation of HPLC.
10.	Determination of VFA using of given wastewater sample by Gas Chromatography (GC)	2	The student will learn chromatographic separation and isolation of individual VFAs by Gas Chromatography (GC)
11.	Determination of dye concentration in given wastewater sample	2	The student will learn spectrophotometric determination of dyes present in wastewater.

Reference book:

1. APHA, 2012. Standard Methods for the Examination of Water and Wastewater. 22nd edition. (Washington D.C.).

Course Type	Course Code	Name of Course	L	T	P	Credit
DC	ESC357	**Solid Waste Management Practical**	0	0	2	2

Course Objective
6. To provide comprehensive insights about the solid waste characteristics, transportation, safe disposal and management
Learning Outcomes
➢ Able to address the issues like transportation optimization, sanitary landfill design, hazardous waste disposal etc.

Unit No.	Topics to be Covered	Practical Hours	Learning Outcome
1.	Solid waste collection techniques	2	Students will know how to collect representative sample of solid waste dump
2.	Solid waste segregation techniques	2	To differentiate and quantify various SW components
3.	Proximate Analysis of solid waste	2	To determine moisture content, volatile combustible matter, Fixed Carbon and ash content
4.	Ultimate Analysis of solid waste	2	To determine CHNS & O content of SW
5.	Determination of Calorific Value	2	To determine energy content of SW by Bomb Calorimeter
6.	Determination of coarse fraction	2	Segregation of solid waste
7.	Determination of EC & CEC of solid waste	2	To determine the cation exchange capacity
8.	Determination of exchangeable Na & K; non-exchangeable K & HNO_3-soluble-K.	2	To determine the nutrient exchange capacity for SW
9.	Determination of organic matter and organic carbon C:N ratio	2	To determine the feasibility of SW for composting
10.	DTPA -extractable micronutrients and trace elements in OB samples	2	To determine the feasibility of plantation in waste like OB dumps
11.	Toxicity Characteristics Leaching Procedure	2	To understand the leaching behaviour of SW
12.	CHNS analysis and calculation of energy and gas generation	2	To calculate amount of energy and gas generated from SW

Text Books:

1. Peavy, H. S., Rowe, D. R., & Tchobanoglous, G. (2010). Environmental Engineering. New York: McGraw-Hill.

Course Type	Course Code	Name of Course	L	T	P	Credit
DC	ESC358	**Geoinformatics Practical**	0	0	2	2

Course Objective
2. Hands on training on Remote Sensing and GIS applications
Learning Outcomes
Upon successful completion of this course, students will: • Learn to use Remote Sensing and GIS data handling. • Learn the application of RS & GIS for pratical environmental problem solving.

Unit No.	Topics to be Covered	Practical Hours	Learning Outcome
1	Operational introduction to RS & GIS Software; Concept of Database Management System in GIS	2	Students will have a preliminary idea of working in RS & GIS data and useful softwere functions.
2	Georeferencing and Projection with Toposheet and Satellite Imagery	2	Students will learn how to associate geographical signature to a ordinary image data or even hardcopy data and how to operate those data in a geographical space.
3	Raster and Vector Data operations	2	Students will learn the basics of satellite image correction operation and vector data handling.
4	Vector Data Operation using Geoprocessing Tools	2	Students will learn how to integrate and disintegrate vector data for practical problem solving in GIS.
5	Image Correction, Enhancement, Mosaic and Subset.	2	Students will learn the intermediate level opration of satellite images.
6	Image Classification and Accuracy Assessment.	2	Students will learn the advanced level opration of satellite image for feature extraction.
7	Analysis of Digital Elevation Model (Slope and Aspect Map Generation).	2	Students will learn basic operations of Digital Elevation Model (DEM).
8	Watershed Delineation with Hydrology Tool.	2	Students will learn to use DEM for hydrological feature extraction.
9	RS & GIS based suitability analysis.	2	Students will learn to integrate various remote sensing data for GIS based suitability analysis.
10	RS & GIS based risk mapping.	2	Students will learn to map the environmental risk and vulnerability.
11	RS & GIS based geostatistical analysis.	2	Students will learn to use geostatistical analysis in GIS environment.
12	Hands on training on GPS Survey and Plotting	2	Students will learn to use GPS for Geographical data collection.

Course Type	Course Code	Name of Course	L	T	P	Credit
DE	ESD401	Biodiversity Conservation	3	0	0	9

Course Objective

The identification of different aspects of biological diversity and conservation techniques.

Learning Outcomes

Upon successful completion of this course, students will:

- An insight into the structure and function of diversity for ecosystem stability.
- An understanding of biodiversity in community resource management.
- Student can apply fundamental knowledge of biodiversity conservation to solve problems associated with infrastructure development.

Unit No.	Topics to be Covered	Lecture Hours	Learning Outcome
UNIT-I	Introduction: Concept of Species, Variation; Introduction to Major Plant Groups; Evolutionary relationships between Plant Groups; Nomenclature and History of plant taxonomy; Systems of Classification and their Application; Study of Plant Groups; Study of Identification Characters; Study of important families of Angiosperms; Plant Diversity Application.	6	Understanding the role of plant diversity at population, community, ecosystem and biome levels.
UNIT-II	Introduction to Animal Diversity and Taxonomy; Principles and Rules of Taxonomy; ICZN Rules, Animal Study Techniques; Concepts of Taxon, Categories, Holotype, Paratype, Topotype etc; Classification of Animal kingdom, Invertebrates, Vertebrates, Evolutionary relationships between Animal Groups.	6	Understanding the role of animal diversity at population, community, ecosystem and biome levels.
UNIT-III	Microbial Diversity; Microbes and Earth History, Magnitude, Occurrence and Distribution. Concept of Species, Criteria for Classification, Outline Classification of Microorganisms (Bacteria, Viruses and Protozoa); Criteria for Classification and Identification of Fungi; Chemical and Biochemical Methods of Microbial Diversity Analysis	6	Understanding the role of microbial diversity at population, community, ecosystem and biome levels.
UNIT-IV	Mega diversity; Biodiversity Hot-spots, Floristic and Faunal Regions in India and World; IUCN Red List; Factors affecting Diversity, Impact of Exotic Species and Human Disturbance on Diversity, Dispersal, Diversity-Stability Relationship; Socio-economic Issues of Biodiversity; Sustainable Utilization of Bioresources; National Movements and International Convention/Treaties on Biodiversity.	6	Understanding the concept of biodiversity terminologies; policy of biodiversity conservation; national and international scenario of past, present and future trends of biodiversity issues.
UNIT-V	Conservations of Biodiversity: In-Situ Conservation- National parks, Wildlife sanctuaries, Biosphere reserves; Ex-situ conservation- Gene bank, Cryopreservation, Tissue culture bank; Long term captive breeding, Botanical gardens, Animal Translocation, Zoological Gardens; Concept of Keystone Species, Endangered Species, Threatened Species, Rare Species, Extinct Species	6	Understanding of biodiversity conservation methods.
UNIT-VI	Introduction to Biodiversity Sampling and Sample Size; Sampling units- Quadrats & Transects, Study of SOI Toposheets, Compass and GPS for making Field Maps; Sampling of various life forms (Flora: herbs, shrubs, trees, lianas etc.; Fauna: bird, insects, mammal etc.); Qualitative and Quantitative Characteristics of Diversity; Species Area Curve, Species Abundance Distribution; Girth Class Distribution, Estimation of Regeneration Potential; Estimation of Ecological Indices, Application of Statistics in Biodiversity Conservation	9	Understanding of biodiversity conservation methods.

Recommended Text Books:

1. A textbook of Botany: Angiosperms- Taxonomy, Anatomy, Economic Botany & Embryology. S. Chand, Limited, Pandey, B. P.
2. Principles of Systematic Zoology, Mcgraw-Hill College, Ashlock, P.D., Latest Edition.
3. Microbiology, MacGraw Hill Companies Inc, Prescott, L.M., Harley, J.P., and Klein D.A. (2005).

Recommended References:

1. Ecological Census Technique: A Handbook, Cambridge University Press, Sutherland, W.
2. Encyclopaedia of Biodiversity, Academic Press, Simonson Asher Levin.

Course Type	Course Code	Name of Course	L	T	P	Credit
DE	ESD402	Industrial Wastewater Engineering	3	0	0	9

Course Objective

Course Objective

To comprehend the significance of water efficiency and waste minimization in industrial sectors.

Learning Outcomes

Upon successful completion of this course, students will be able:
Identify industrial waste stream characteristics from major industrial categories
Understand the significance of these characteristics for design of unit processes
Develop an overall treatment strategy for any industrial waste stream

Unit No.	Topics to be Covered	Lecture Hours	Learning Outcome
1	Sources and characteristics of industrial wastewater: management of Industrial wastewater, volume reduction, neutralization, equalization and proportioning, treatment and disposal	6	To understand fundamentals of wastewater operation
2	Advanced treatment process: Chemical Precipitation, Ion exchange, Adsorption, Membrane Filtration, Air Stripping, Electro-dialysis, Chemical Oxidation Processes, Advanced Oxidation processes.	9	To get familiarise with various unit operations in water and waste water treatment
3	Environmental issues for specific industries: Chlor-alkali, electroplating, distillery, dairy, tannery, paper & pulp, textile, dye, fertilizer, refinery, pharmaceutical, iron & steel, coke ovens, coal washeries, mining.	18	To demonstrate the real-world challenges
4	Design, operation and maintenance aspects of Industrial complexing for zero pollution attainment and Common effluent treatment plant (CETP)	6	To understand the need and importance of Zero Discharge

Recommended Text Book

1. W.W. Eckenfelder, Jr., Industrial Water Pollution Control 3rd Edition, McGraw-Hill, 1999.
2. Water Environment Federation(WEF), Industrial Wastewater Management, Treatment, and Disposal, 3rd Edition, WEP press, 2008.
3. Metcalf and Eddy, Inc, T. Asano, F.L. Burton, H. Leverenz, R. Tsuchihashi,G. Tchobanoglous. Water reuse Issues, Technologies and Applications McGraw-Hill 2007.

Recommended Reference Book

1. N. L. Nemerow, Industrial Waste Treatment: Contemporary Practice and Vision for the Future, Butterworth-Heinemann, 2006.

Course Type	Course Code	Name of Course	L	T	P	Credit
DE	ESD403	Environmental Modelling	3	0	0	9

Course Objective
The objective of the course is to provide basic knowledge on mathematical model construction and analyze environmental problems mathematically.
Learning Outcomes
Upon successful completion of this course, students will be able to: • Describe the transport of water and air contaminants. • Description of naturally occurring process to released pollutants in mathematical form to develop models. • Use of regulatory models for the purpose of impact study and to device control management plan.

Unit No.	Topics to be Covered	Lecture Hours	Learning Outcome
1	Introduction, Water Quality, Development of Mathematical Models, Reaction Kinetics, Mass Balance, Steady state solutions, Types of loadings, Types of Reactors, Incompletely mixed systems, Advection, Diffusion, Dispersion, Distributed systems (steady state and Time variable), Control Volume approach (Steady state solutions).	08	Get the idea of water quality modelling.
2	River Quality modelling, Streeter Phelps model, Fate and transport of pollutants in rivers and streams, Pulse and step inputs, transport in estuaries, Fate and transport of pollutants in lakes, step and pulse input models, Fate and transport of pollutants in subsurface systems, Step and pulse input models.	10	Understand development and application of surface water quality models.
3	**Meteorological modelling:** Comparison of boundary layer (BL) and free atmosphere characteristics, diurnal cycle of the ABL, convective BL, potential temperature, degree of turbulence, variance of the vertical and horizontal velocity, comparison between day time and night time BL, prediction of CBL height and Monin-Obukhov length (L).	10	To understand the behavior of atmosphere with respect to turbulence and thereby mixing strength to disperse pollutants
4	**Air quality modelling (AQM):** Major AQM types & scales, steps in model formulation, types of input required for dispersion modelling, Preparation of meteorological data for air quality models (surface and upper air data). Emission quantification for point, area and line sources. The box model, Gaussian plume and puff model, Receptor Models such as Chemical Mass Balance (CMB) and Positive Matrix Factorization (PMF). **Performance evaluation of models**: Model parameterization, calibration and validation, sensitivity analysis and its role, errors and uncertainty analysis. Application of commonly used regulatory models (AERMOD, CALPUFF and CALRoads) and their applications to industrial problems.	10	Use of regulatory air quality models such as screen and refined one for different case studies including input preparation.

Text Books:

1. Stull, R.. "Practical Meteorology: An algebra-based survey of atmospheric science" – version 1.02b. Univ. of British Columbia. 940 pages. ISBN 978-0-88865-283-6.
2. Surface Water-Quality Modelling by Steven C. Chapra, Medtech.

Reference Books:

1. First principles of meteorology and air pollution by Mihalis Lazaridis . Springer.
2. Air pollution modelling by Zannetti paolo, 2013,Springer.
3. A Basic Introduction to Pollutant Fate and Transport by Frank M. Dunnivant and Elliot Anders, John Wiley & Sons, NY.

Course Type	Course Code	Name of Course	L	T	P	Credit
DE	ESD404	Water Resource Planning and Management	3	0	0	9

Course Objective

- The objective of the course is to understanding of the engineering of water resource systems in general and urban hydrologic systems in particular.
- To incorporate analytical abilities into the planning and design of water resource systems.

Learning Outcomes

Upon successful completion of this course, students will:

- The students will be able to understand the water resources planning and design problems with an emphasis on intelligent engineering decision making.
- The students will learn about different types of Hydraulic structures like spillways, dams, diversion head works, regulator.

Unit No.	Topics to be Covered	Lecture Hours	Learning Outcome
1	Water Resources: Introduction, hydrological cycle, World water distribution, need for conservation & development of water resources. Precipitation: measurement of rainfall, Index of wetness, Design of rain gauge network, Probable maximum precipitation curve.	12	The knowledge of concepts of hydrological study and water resource conservation and development.
2	Infiltration: Infiltration Capacity Curve, Measurement & estimation of water losses, Runoff cycle, Runoff coefficients, Computation of runoff: unit hydrograph, Bernard`s distribution, Unit Storm Method, Evapotranspiration.	3	The knowledge regarding infiltration behaviour and its uses in estimation of water losses runoff,percolation and evapotranspiration.
3	Stream: Stream Flow Measurement, Notches, Weirs, control meters, Venture-Flames, Velocity area method, Slope area method. Reservoir-Types of reservoirs, Storage zones, Catchment yield & reservoir yield, Reservoir capacity, mass curve of inflow and outflow. Reservoir sedimentations and losses, Selection of sites for a reservoir, economic height of dam, Hydrological reservoir routing-Trial and Error method, Modified Pu's method and Goodrich method.	10	The information regarding stream measurement, reservoir and different hydrological reservoir method.
4	Recharging of underground storage, infiltration galleries, infiltration wells, springs, Floods flows and management; Definition and causes of flood, estimation of design flood and flood flows for design of hydraulic structures, Flood control measures,Flood routing.. Groundwater hydrology.	7	The knowledge about recharging of groundwater through rechargng structureand its management aspects.
5	Aquifer; porosity, permeability, measurement of yield, Laws of groundwater movement: Darcy`s law, Thiems equilibrium formula, Duipuits formula etc. Water resources planning & management: Impact of climate change on water resources.	6	The information regarding aquifer and its characterstics along with its planning and management.

Text Books

1. Water Resources Engineering- Larry W. Mays, John Wiley and Sons, Mc Graw Hill.
2. Hydrology and Water Resources Engineering- S.K. Garg, Khanna Publishers

Reference Books

1. Water Resources Engineering - Ray K Linsley, Joseph B Franzini, David L Freyberg, George Tchobanoglous, Mc Graw Hill.
2. Hydrology- M.M. Das, M.D. Saikia, PHI Learning Pvt Ltd., New Delhi.

ESD 405	Environmental Biotechnology	(3-0-0)

Course Philosophy:
Provides comprehensive knowledge of state-of-the-art biotechnological processes for bioremediation, bioenergy production and metal recovery.

Learning Outcome:
After studying this course, students should be able to:

- Describe biotechnological solutions to address environmental issues including pollution, recovery of mineral resource, renewable energy and water recycling.

Contents	No of Lectures	Learning outcomes
Unit I Introduction to environmental biotechnology; Nucleic acids, polymerase chain reaction (PCR); reverse transcription PCR (RT-PCR) and its applications; Bacterial genetic recombination; Recombinant DNA technology and its applications in environmental engineering; Environmental monitoring- bioreporter, biomarker and biosensor technology.	[**12L**]	An elementary idea about key molecular biology tools such as PCR.
Unit II Overview of microbial transformations; Bioremediation of petroleum hydrocarbons, radionuclei, dyes and lignin removal; phytoremediation; biomass for removal and biosorption of heavy metals; removal of volatile organic compounds from waste gas.	[**10L**]	Concepts of popular biotechnological processes such as bio-remediation and microbial degradation.
UNIT III Clean technologies: biofertilizers, bio-pesticides, microbial polymer production and bio plastic technology; Biotechnology of fossil fuels: desulfurization of coal, microbial enhanced oil recovery (MEOR); Biofuels: biogas, biohydrogen, bioethanol production. Biotechnology of mineral processing.	**[14L]**	Clear understanding of the applications of biotechnology for solving real life environmental problems
UNIT IV Intellectual Properties rights; Copyright; Biosafety regulations; Ethical issues in environmental biotechnology.	[**3L**]	An understanding of IPR and ethical issues in environmental biotechnology

Recommended Text Books:

1. B. E. Rittmann and P. L. McCarty, Environmental Biotechnology: Principles and Applications, 2001.
2. B. Bhattacharya and R. Banerjee, Environmental Biotechnology, 2008.

Recommended References:

1. Smith, J.E. (2004) Biotechnology, 3rd Edition, Cambridge University Press, UK.
2. Brown T. A. Gene Cloning and DNA analysis. Sixth Edition, Wiley-Blackwell publication

Course Type	Course Code	Name of Course	L	T	P	Credit
DE	ESD406	Environmental Nanotechnology	3	0	0	9

Course Objective
To gain fundamental knowledge on nanotechnology for environmental engineering applications
Learning Outcomes
Upon successful completion of this course, students will be able: To explain the fundamentals behind synthesis and characterisation instrumentals of materials at the nanometre scale To understand the nanomaterials role in water treatment and its toxicology impact on human

Unit No.	Topics to be Covered	Lecture Hours	Learning Outcome
1	Nanotechnology and the environment, nanotechnology and our energy challenge nanomaterials fabrication top down and bottom up approaches	18	To understand Fundamentals behind synthesis
2	Methods and analytical tools for structural characterization of nanomaterials: X-ray Diffraction, Electron Microscope, Scanning Probe Microscopy	9	To understand Fundamentals behind of characterisation tools
3	Applications of nanomaterials for environmental clean-up: Membranes, Adsorption, photocatalysis	9	To perceive the importance of nanomaterials on environmental clean
4	Nanomaterial exposure, toxicity, and impact on human health.	3	To get awareness on the health impact of nano materials

Recommended Text Book

1. T. Pradeep, A Textbook of Nanoscience and Nanotechnology, Tata McGraw-Hill, 2003
2. J.W. Steed, D.R. Turner and K. J. Wallace, Core Concepts in Supramolecular Chemistry and Nanochemistry, John Wiley & Sons, Ltd, 2007.
3. P. Balaz, Mechanochemistry in Nanoscience and Minerals Engineering, Springer-Verlag Berlin Heidelberg, 2008.

Recommended Reference Book

1. M.Wiesner, J.Y. Bottero, Environmental Nanotechnology: Applications and Impacts of Nanomaterials 2nd edition, McGraw Hill, 2016

Course Type	Course Code	Name of Course	L	T	P	Credit
DE	ESD 407	Hazardous and Biomedical Waste Management	3	0	0	9

Course Objective

To provide in depth understanding of Hazardous and Biomedical Waste characteristics and management. The course covers the planning and engineering principles needed to address the Hazardous and Biomedical Waste Management.

Learning Outcomes

Upon successful completion of this course, students will:

- A comprehensive overview of hazardous and biomedical wastes management from both scientific and engineering principles point of view.
- Understanding of the fundamental principles of existing and emerging technologies for the treatment of hazardous and biomedical wastes.
- Understanding of the legislative and regulatory framework related to the generation, treatment, storage, and disposal of hazardous and biomedical wastes.

Unit No.	Topics to be Covered	Lecture Hours	Learning Outcome
1	Hazardous Wastes: Definition, Sources and Classification; Characteristics of Hazardous wastes: Ignitability, Corrosivity, Reactivity, Toxicity, Generation of Hazardous Waste, Guidelines of Hazardous Waste Management, Basel Convention, Regulatory frame work: Hazardous and Other Wastes (Management and Transboundary Movement) Rules, 2016; Monitoring of critical parameters/risk-analysis. HAZAN, HAZOP; Environmental Impacts of Hazardous Wastes; Emergency Management: Indian and foreign legislation in respect of the above.	10	This unit will provide an overview of generation, characteristics and classification of hazardous wastes. It also covers the prevailing regulatory framework for its effective management.
2	Storage, Collection and Transport of Hazardous Waste; Processing and Disposal of Hazardous Wastes; Treatment, Storage and Disposal Facility; Hazardous Waste Reduction; Hazardous Waste Treatment, Physical and Chemical Treatment, Thermal Treatment, Incineration, Combustion Calculation and Air requirements, Environmental Control Measures, Pyrolysis, Biological Treatment, Hazardous Waste Landfills, Secure Landfill, Site Selection, Component of Landfill, Landfill Design and Operation, Deep Well Injection.	15	This unit will help student in understanding the engineering principles of hazardous waste management systems and different treatment techniques.
3	Hazardous Chemicals: Toxic chemicals, Flammable Chemicals, Pesticides, Explosives, Reactive Substances, Cyanide Wastes, Water-soluble Chemical Compounds of Heavy Metals, & Toxic Metals; Hydrocarbons, Point Pigment Dyes, Oil Emulsion Tars, Phenols, Asbestos, Acid/Alkaline Slurry, Physical Properties, Chemical Composition; Lethal Dose and Concentration on Human Life, Flora and Fauna; Case studies, Leakages, Explosion, Oil-spills, Fire of Hazardous Chemical Storage.	6	A detailed overview of different types of hazardous chemicals, and its effect on health and environment. Explanation of case studies of hazardous wastes accidents.
4	Biomedical Waste: Definition, Characteristics and Categorization; Handling and Storage, Treatment and Disposal; Biomedical Waste Management; Biomedical Waste Management Rules, 2016. Radioactive wastes, Generation and Processing of Atomic Minerals, Disposal of Fuel rods, Leakage in atomic reactor plants, Remediation of contaminated sites.	8	The student will learn the basic principles of biomedical and radioactive waste management as per the prevailing laws and regulations.

Text Books:

1. Pichtel, J. (2014). Waste Management Practices: Municipal, Hazardous and Industrial. CRC Press New York: 2nd Edition.
2. VanGuilder, C. (2008). Hazardous Waste Management: An Introduction. New Delhi: Mercury Learning and Information (Second Edition).
3. Rao, M. N., Sultana, R., & Kota, S. H. (2017). Solid and Hazardous Waste Management: Science and Engineering. India: BS Publications.

Reference Books:

1. Tchobanoglous, G., Theisen, H., & Vigil, S. A. (2014). Integrated Solid Waste Management: Engineering Principles and Management Issues. New Delhi: McGraw-Hill Education (India) Private Limited.
2. CPHEEO (2000). Manual on Municipal Solid Waste Management, Central Public Health and Environmental Engineering Organisation, Ministry of Urban Development, Govt. of India, New Delhi.

Course Type	Course Code	Name of Course	L	T	P	Credit
DE	ESD408	**Soil System and Ecological Restoration**	3	0	0	9

Course Objective
The objective of the course is to learn different techniques and methods of restoration of mine degraded land and to understand soil – plant systems and their disturbance due to mining activities.
Learning outcomes
Upon successful completion of his course, student will: • Knowledge of soil assessment in the context of land restoration. • Understanding principles underlying restoration ecology and ecological restoration. • Design and implement ecorestoration practices successfully • Assessment of loss of ecosystem goods and services due soil pollution and after restoration.

Unit No	Topics to be Covered	Lecture Hours	Learning Outcome
1	**Introduction:** Development of soil; causes of land degradation and productivity; Soil physico-chemical & biological properties; soil water, Soil organic matter, soil fertility and plant nutrition, soil aggregates.	6	Understanding of process of land degradation, basic properties of soil and process of restoration of fertility
2	Ecological degradation and disturbance; Soil functions, Plant responses environmental stress.. Development processes in disturbed ecosystem.	3	Understanding development of soil quality index and how plants responses to environmental stress
3	Principles of ecological restoration. SERI guidelines; Abiotic and biotic controls on community composition. Engineering reclamation: estimation of soil erosion and control; sedimentation ponds. Topsoil management. Soil amendments and biofertilizer	4	To understand principles of ecological restoration and techniques of engineering restoration of degraded sites
4	Benefits of reclamation – background, establishment of ecological succession, macro-aggregate formation, soil fertility, carbon sequestration, rebuilding soil structure.	3	Acquainted with topsoil management and use of amendments.
5	Vegetation establishment & selection of plant species*: C*over development technique; Miwayanki methods. Hydroseeding, development of grass-legume cover, Habitat management for faunal conservation. Practical techniques for effective habitat creation and restoration. Green belt development plan	4	To familiarized with different techniques of vegetation cover development
6	Soil pollution. Contaminated land and remediation technologies. Dynamics and management of soil carbon nitrogen, phosphorus, potassium and other nutrients in the context of effective land restoration and reclamation.	5	To understand causes of soil pollution, and remediation of land.
7	Mine Tailings Management: Reclamation of tailings impoundments etc. Principles of Phytoremediation. Current bioremediation practice and application.	5	To familiarize with mine tailings management and remediation practices of tailings impoundments.
8	Evaluation of reclamation success and Soil quality indices. Forest ecosystem services; Economic valuation of forest goods and services; Millennium ecosystem assessment, calculation of NPV and IRR.	4	To understand how to evaluate reclamation success & evaluate economics of reclamation.
9	Best reclamation practices. Mine closure activities. Mine pit limnology. Monitoring and aftercare of restored sites	4	To know best reclamation practices and mine closure activities.

Text Books:

1. Ecorestoration of the Coalmine degraded lands - Subodh Kumar Maiti, SPRINGER, 2013

Reference Books:

1. Biogeotechnologies of Mine site Rehabilitaion – MNV Prasad, P Favas, SK Maiti, Elsevier (2018)
2. Quarry Reclamation - NJ Coppin & AD.Bradshaw, Mining Journal Books, London,1982
3. Soil pollution a reality – FAO, United Nation, Rome, 2018

Course Type	Course Code	Name of Course	L	T	P	Credit
E/ SO	ESE 201	Pollution Control and Management	3	0	0	9

Course Objective
• To develop understanding of atmospheric science including quantifying climate sensitivity to changes in greenhouse gases and interrelation between the various components of the climate system
Learning Outcomes
• The students will be able to know the basics of atmospheric science and climate change. • They will develop a broader awareness of current methods and areas of research in climatology. • They will also assess current and future climatic risks.

Unit No.	Topics to be Covered	Lecture Hours	Learning Outcome
1	**Air pollution:** Fundamentals of air pollutants and impact, ambient air monitoring, emission factors; overview of prediction models, air pollution control techniques, suppression and consolidation of dust **Noise Pollution:** Fundamentals of Noise Pollution and Impact, monitoring and control measures.	12	The students will be able to learn about air and noise issues with respect to the industries, they will serve. They will also learn how to improve the environmental conditions.
2	**Water pollution:** Global hydrological cycle: self-purification mechanism, sources of water pollution, water quality parameters and standards, Eutrophication, acid mine drainage and heavy metal pollution- preventive and control measures. Design and operation of wastewater treatment plant	11	The will be able to learn about the water pollution and treatment methodologies.
3	**Solid waste Management and** Land **degradation** due to industrial activities, physical and biological reclamation.	04	The will be able to learn about the solid waste management and land degradation arising out of such industrial activities
4	**Land Acquisition & Revenue**: Concepts, Related laws and regulations **Corporate Social Responsibility:** Concepts and principles, Rehabilitation and Resettlement issues, Social Impact Assessment.	04	The will be able to learn about the Land acquisition methods, the Corporate Social Responsibility of the industries.
5	**Environmental Laws and administration**; Overview of Environmental Laws, Environmental clearance procedures and Environmental Impact Assessment process, Environmental Audit, Sustainable development, environmental carrying capacity- concepts & principles.	08	The will be able to learn about Environmental Laws and administration applicable in India and other countries**.**

Text Books

1. Introduction to environmental engineering (5th edition) by Mackenzie L Davis and avid A Cornwell (2014). Mc Graw Hillpublishers.
2. S.C.Bhatia (2001), Environmental Pollution and Control in Chemical Process Industries, Khanna Publishers, New Delhi.

Reference Books

1. R.C Gupta (2012), Energy and Environmental Management in Metallurgical Industries, PHI Learning Pvt. Ltd.

Course Type	Course Code	Name of Course	L	T	P	Credit
E/ SO	ESE 202	Atmospheric Science and Climate Change	3	0	0	9

Course Objective

The objective of the course is to develop understanding of atmospheric science including quantifying climate sensitivity to changes in greenhouse gases and interrelation between the various components of the climate system.

Learning Outcomes

Upon successful completion of this course, students will be able to:

- The students will be able to know the basics of atmospheric science and climate change.
- They will develop a broader awareness of current methods and areas of research in climatology.
- They will also assess current and future climatic risks.

Unit No.	Topics to be Covered	Lecture Hours	Learning Outcome
1	Course overview; Structure and Composition of the Atmosphere, Components of the climate system.	03	To introduce components of climate system
2	Global energy balance and Radiative transfer in the atmosphere, global climate models, Climate sensitivity to changes in greenhouse gases and feedback mechanisms between the components.	10	To learn radiative budget applicable to Earths surface solar system
3	Global temperature distributions, greenhouse effect, influences on temperature, daily and seasonal variations, Heat index.	05	To understand the impact of GHG on temperature distribution
4	Concept of pressure, ideal gas law, pressure gradient, hydrostatic equilibrium, wind forces: Coriolis force, Cloud formation (lifting mechanism, stability, lapse rates), cloud types, growth of cloud droplets, forms of precipitation, measuring precipitation., environmental lapse rate, adiabatic processes and stability.	10	To understand atmospheric stability and cloud physics
5	Atmospheric circulation; single cell model, three-cell model, semi-permanent pressure cells, polar fronts & jet streams, troughs, ridges and wind systems, air-sea interactions.	06	To learn global circulation and wind pattern
6	Strategies for reducing emissions: The Kyoto Protocol, reports of IPCC, the Clean Air Act and the EPA.	05	Policies and acts to reduce GHG emission

Reference Books:

1. Introduction to Atmospheric Chemistry, by Daniel J. Jacob, Princeton University Press, (2004)
2. First principles of meteorology and air pollution by Mihalis Lazaridis (2010). Springer.
3. Goosse H., P.Y. Barriat, W. Lefebvre, M.F. Loutre, and V. Zunz (2010). Introduction to climate dynamics and climate modelling.

Course Type	Course Code	Name of Course	L	T	P	Credit
OE	ESO 301	Life Cycle Assessment	3	0	0	9

Course Objective

Enable the students to acquire the knowledge and skills needed to address concepts of sustainability and cleaner production. To understand the concept of life cycle analysis (LCA) and the basic principles of the methods.

Learning Outcomes

Upon successful completion of this course, students will:

- Thorough understanding of the concepts of sustainability and cleaner production, and the challenges that engineers face in applying these concepts in an industrial and societal context.
- Detail training on how to use LCA.
- Critically analyse environmental emissions and develop simple methodologies to reduce these emissions.

Unit No.	Topics to be Covered	Lecture Hours	Learning Outcome
1	**Introduction of LCA:** An Introduction to Sustainability Concepts and Life Cycle Analysis, Risk and Life Cycle Framework for Sustainability, Introduction to Environmental Risk Assessment, Historical Development of LCA, Components of LCA.	8	The unit deals with introduction of life cycle analysis for sustainability assessment and environmental management. .
2	**LCA Methodologies:** Introduction to Goal and Scope Definition, Life Cycle Inventory, Life Cycle Impact Assessment, Life Cycle Interpretation, Introduction to commercially available LCA Software tools. ISO Framework for LCA.	9	This unit will showcase the different stages of life cycle assessment as per ISO standards.
3	Life Cycle Inventory and Impact Assessments; Functional Units and System Boundary; Data Quality; Procedure for Life Cycle Impact Assessment; Impact Category definition; Impact category classification, characterization, and weighting. Interpretation of LCIA Results; Sensitivity Analysis; LCIA Practices. Factors for Good LCA Study. Benefits and Drawbacks LCA.	14	This unit will make the students learn in conducting LCA analysis for products or services.
4	Economic, Environmental, and Social Performance Indicators, Environmental Cost Analysis. Case Studies of LCA applications.	8	Environmental, economic and social LCA analysis of any products and services with some cased studies.

Text Books:

1. Life Cycle Assessment Handbook-A Guide for Environmentally Sustainable Products- Mary Ann Curran, John Wiley and Sons, Inc. Hoboken, New Jersey, 2012.
2. Life cycle Assessment Inventory Guidelines and Principles-B.W. Vigon, C.L. Harrison and U.S.E.P.A. Risk Reduction Engineering Laboratory, Lewis Publishers, 1994.
3. Environmental Life- Cycle Assessment- Marry Ann Curran, McGraw Hill, 1996.

Reference Books:

1. The Computational Structure of Life Cycle Assessment- Reinout Heijungs and Sangwon Suh, Springer Science+Business Media, B.V., 2002.
2. Background and Future Prospects in Life cycle Assessment-Walter Klopffer, Springer, 2014.

ESO 502	Environmental Aspects of Industries	L	T	P	C
		3	0	0	9

Course Objectives:

- To learn various process engineering, unit operations of Mining, Metallurgical, Thermal Power, Cement and Petroleum Industries.
- Application of Air-Water-Soil Pollution Control Mechanism in these Industries

Learning Outcomes:

- Understanding the environmental aspects and impacts of each unit operations of the polluting industries.
- The students will be able to understand and orient themselves with the industry before they undergo summer training, internship, interview or job.
- The students will be able to conceive and prepare Environmental Management Plan of these industries.

Unit I	Environmental laws related to Various Industries. **Mining Industry**: Mineral production, history of environmental problems. Mining Methods- Opencast and underground mining. Unit operations: Site clearance, drilling, blasting, transportation, reclamation, R&R, mine closure, etc. Mineral beneficiation and their environmental impacts. **Metallurgical Industry**: Unit operations, sources and management of pollution in integrated steel plants, DRI plants, Aluminium Plants, Copper, Lead, etc. Metallurgical Plant Location and Layout.	**20 L**
Unit II	**Thermal Power Plants & Cement Industries**: Introduction: site selection, layout and unit operations; Fuel and fuel handling -types of fuels, solid, liquid and gaseous. Fuel burning equipment; Pollution control devices- ash handling, management and its utilisation. Environmental management for captive power plants. Environmental problems in cement industries. Co-Processing	**6 L**
Unit III	**Petroleum Industry:** Production and consumption of the oil and gas, unit operations involved in exploration and production of petroleum and natural gas; Major environmental problems in On-Shore and off-shore exploration	**6 L**
Unit IV	**Chemical Industry:** Petrochemical, Paint, Chemical Fertilizer, Pesticides, Distilleries, Pharmaceuticals, Pulp & Paper, Sugar Industries, etc.	**7L**

Books and References:

Text Books

1. Sustainable Mining Practices: A global Perspective (2005) V.Rajaram, S.Dutta, K Parameswaran. A.A. Balkema Publishers.
2. Environmental Management in Mining Areas - NC Saxena, Gurdeep Singh and R Ghosh (Ed.), Scientific Publishers (India), Jodhpur 2003.
3. Environmental Control in Petroleum Engineering, John C Reis, Elsevier Science & Technology Books, 1996.

Reference Books

1. R.C Gupta (2012), Energy and Environmental Management in Metallurgical Industries, PHI Learning Pvt. Ltd.
2. Environmental Impact of Mining - CG Down & J Stocks, Applied Sc. Pub, London, 1978**.**
3. Environmental Impacts of Mining: Monitoring, Restoration and Control – M Sengupta, Lewis Publishers, Boca Raton, 1993.
4. S.C.Bhatia (2001), Environmental Pollution and Control in Chemical Process Industries, Khanna Publishers, New Delhi.

Course Type	Course Code	Name of Course	L	T	P	Credit
OE	ESO 303	Occupational Health and Safety	3	0	0	9

Course Objective
• To learn various Occupational Health, Risk and Safety issues in the industry. • To learn Ergonomics in the workplaces, workplace risk and international guidelines for mitigation of these risks
Learning Outcomes
• Understanding the Occupational Health, Risk and Safety unit operations of the polluting industries. • The students will be able to understand and orient themselves with the industry before they undergo summer training, internship, interview or job. • The students will be able to conceive and prepare Health, Safety and Risk Management Plan of the industries.

Unit No.	Topics to be Covered	Lecture Hours	Learning Outcome
1	**Occupational Health and Safety concern and problems**. National and International protocols and concerns, policies and legislation. **Introduction to Ergonomics:** Role of Ergonomics in improving Health of Workforce. Area of application in work system. Anatomy, posture and Body Mechanics, Anthropometric principles in workspace and equipment design; Work capacity, stress and fatigue; Impacts of temperature, illumination, noise in human behaviour; Human–machine interaction, human error and safety; Accidents and safety.	12	The students will be able to learn about the OHS concern and issues with respect to the industries, they will serve. They will also learn how a good working posture and environment can improve working efficiency as well as improve health.
2	**Occupational Health & Safety Management Systems: -** OHSAS 18001 /ISO 45001-2018 guidelines, Legal requirements; Occupation Health and Safety Policy; OH&S Documentation.	12	The will be able to learn about the International Guidelines and how to implement it in the industry they will serve.
3	**Safety at work place:** Managing health and safety in industries, slips and trips, general fire safety, work at height, building work, machinery safety, plant and equipment maintenance, gas and oil-fired equipment, flame-proof and intrinsically safe equipment, pressurized plant and equipment, workplace transport, lifting and handling, managing health, safe ways of working, selection and training; Special groups of workers, contractors and agency workers, personal protective equipment, useful contacts and information for safety, role of health and safety executives.	10	The will be able to learn about the safety requirement in various work places. They will be able to work as environment and safety officers in their work places.
4	**Risk Assessment and Management:** Perception of Risk in Industries: Theories and Human Adjustment. Environmental and Industrial Risk assessment: Introduction, identification of potential hazards, assessment of the risk, consequence analysis, hazard identification methods: check list, hazard and operability studies (HAZOP), hazard analysis methods, failure modes and effect analysis, hazard indices, models, regulatory priorities. Emergency preparedness and response. Disaster Management.	05	The will be able to learn the Risk assessment and management techniques.

Text Books

1. Fundamental Principles of Occupational Health and Safety, Benjamin O. Alli, The Synergist, , USA
2. Occupational Health and Safety Management: A Practical Approach, Charles D. Reese, CRC Press
3. Safety, Health and Environment Handbook, K.T.Narayanan, Mc Graw Hill.

Reference Books

1. Practical Guide to Occupational Health and Safety by Paul A Erickson, Academic Press, (Elsevier Science) USA, UK 5. OHSAS- 18001, Guidelines, British Standards Institute, 2007
2. Introduction to Ergonomics – R.S Bridger, 3rd Edition, Routledge

Course Type	Course Code	Name of Course	L	T	P	Credit
OE	ESO 404	Sustainability Engineering	3	0	0	9

Course Objective
Understanding on Various issues of sustainability Role of engineering and technology within sustainable development
Learning Outcomes
Upon successful completion of this course, students will : Learn the methods, tools, and incentives for sustainable product-service system development. Develop a broader perspective for adapting sustainable practices by utilizing the engineering knowledge and principles.

Unit No.	Topics to be Covered	Lecture Hours	Learning Outcome
1	Sustainability- need and concept and challenges, sustainable development framework, Environmental policies, acts and protocols, Global, Regional and Local environmental issues, Clean Development Mechanism, Circular Economy and its Implementation.	05	The students will be able to understand what is sustainable development framework and different governmental policies which aim for it. .
2	Natural resources and their pollution, Carbon credits, Zero waste.	04	The students will be able to understand about the natural resources, its exploitation, related pollution, Carbon credit and mitigation measures
3	Environmental Management System and its application, ISO 14001 Guidelines, Life Cycle Analysis, Inventory and Impact Assessment, Environmental Audits. An overview of Environmental Impact Assessment, Environmental Clearances, Public Consultations	10	The information regarding International Guidelines of Environmental Management.
4	Sustainable habitat, Green buildings, Green materials, Case studies. Energy, Conventional and renewable sources.	10	The students will be able to learn about energy efficient green building.
5	Technology and sustainable development, Sustainable urbanization, Industrial Ecology.	04	The students will be able to learn about sustainable development in cities and Industries.

Textbooks:

1. Sustainable Engineering: Concepts, Design and Case Studies, D.T. Allen, and D.R. Shonnard, Prentice Hall,(2011).

Reference Books:

1. Engineering applications in sustainable design and development, A.S. Bradley, A.O. Adebayo, P. Maria, Cengage learning.

Course Type	Course Code	Name of Course	L	T	P	Credit
OE	ESO405	Clean Energies	3	0	0	9

Course Objective
To gain fundamental knowledge on clean technologies for energy generation
Learning Outcomes
Upon successful completion of this course, students will be able: To understand role of alternative technologies for energy production To make interpretation about the energy sources and comprehend them with types

Unit No.	Topics to be Covered	Lecture Hours	Learning Outcome
1	Energy Alternatives and its Principles	6	To understand need of renewable energy
2	Solar Radiation, availability, measurement and estimation, Solar Thermal Conversion Devices, storage and applications	12	To understand Fundamentals solar energy conversion
3	Hydel power, Tidal Energy, Ocean Thermal Energy, Geothermal Energy, Molten salt energy storage	12	To understand fundamentals other means of Renewable sources
4	Wind Energy Conversion, Bioenergy Technologies, Fuel Cell	9	To understand fundamentals other means or of Renewable sources

Recommended Text Book

1. Vaughn C. Nelson, Kenneth L. Starcher, Introduction to Renewable Energy, 2nd Edition, CRC press 2015

Recommended Reference Book

1. J. Twidell and T. Weir, Renewable Energy Resources, 3rd edition, Routledge, London, 2015.
2. B. Viswanathan**,** M. Aulice Scibioh, Fuel Cells: Principles and Applications 1st Edition, CRC press 2006.

Course Type	Course Code	Name of Course	L	T	P	Credit
OE	ESO 406	Environmental Management System and Auditing	3	0	0	9

Course Objective

- To learn methodologies of Environmental Management System through ISO Guidelines, Life Cycle Assessment and Corporate Social Responsibility.
- To learn the implementation of Environmental Management System through Environmental Audit

Learning Outcomes

- The students will learn environmental management system and various auditing processes.
- The students will be able to prepare the statutory Environmental Statement for various industries.
- The students will be able to serve and guide the industrial sector as good corporate citizens.

Unit No.	Topics to be Covered	Lecture Hours	Learning Outcome
1	Environmental Audit: Objectives, Types of Audits, Features, Planning and Organising Audits; Pre-visit data collection, Audit Protocol; Onsite Audit; Data Sampling - Inspections - Evaluation and Presentation; Exit Interview; Audit Report - Action Plan - Management of Audits; Waste Management Contractor Audits; Environmental Statement**.**	12	The students will be able to learn about the Environmental Auditing and issues with respect to the industries, they will serve. They will also learn how to conduct environmental audits and improve the environmental conditions.
2	Life Cycle Approach (LCA). Inventory and Impact Assessment	05	The will be able to learn about the Life Cycle Assessment and how to the impact assessment in the industry they will serve.
3	Introduction and Formulation of ISO Guidelines in Environmental Management Systems; ISO 14000 Series, Principles; Accreditation Process, Environmental Auditor Criteria, Benefits of EMS; Aspect-Impact Analysis, Continual Improvement, Environmental Performance, Environmental Policy, Vision and Mission, Objective and Target, Environmental Management Planning, Implementing EMS, Plan-Do-Check-Act (PDCA), Preventive and Corrective Action, Internal and External Audits, Documentation, Roles and Responsibilities, Management Reviews & Improvements; Legal and Regulatory Concerns; Integrating ISO 9000 & ISO 14000, BS 7750, EMAS. Preparation of ISO Manuals	12	The will be able to learn about the International Guidelines and how to implement it in the industry they will serve.
4	Corporate Social Accountability: Requirements, Social Accountability (SA) 8000, Certification, Elements of Social Management System, Social policy, Planning, Implementation, Business Benefits, Corporate Social Responsibility (CSR), different Models.	10	The will be able to learn the Corporate Social Accountability and its implementation techniques.

Text Books

1. Planning and Implementation of ISO14001, Environmental Management System- Girdhar Gyani & Amit Lunia Raj Publishing House, Jaipur, 2000.
2. Introduction to Environmental Audit- R. D. Tripathi, Alfa Publication
3. ISO 14001 Auditing Manual – Gayle Woodside and Patrick Aurrichio, McGraw-Hill.

Reference Books

1. "The ISO: 14000 Handbook" - Joseph Caseio (Ed), Published - CEEM Information Services. 2000
2. INSIDE ISO: 14000 – The Competitive Advantage of Environmental Management - Don Sayre, Vinity Books International, New Delhi.
3. ISO 14001 Environmental Systems Handbook 2nd Revised Edition, Ken Whitelaw. A Butterworth-Heinemann Publication.

Course Type	Course Code	Name of Course	L	T	P	Credit
OE	ESO407	Climate Change and Modelling	3	0	0	9

Course Objective

The objective of the course is to explore the climate change on local, national and international prospect through specified models.

Learning Outcomes

Upon successful completion of this course, students will be able to:

- Explain and critically evaluate the current state of climate change science and relationship between Earth's climate system.
- Recognize the key factors influencing global and regional climate in the past, present, and future.
- Interpret, and critically evaluate different approaches to incorporate uncertainty into climate modelling.

Unit No.	Topics to be Covered	Lecture Hours	Learning Outcome
1	Description of the climate system and its components: Atmosphere, Ocean Composition and properties, The cryosphere and the land surface and the terrestrial biosphere. The Energy balance, hydrological and carbon cycles: The Earth's energy budget, The heat balance at the top of the atmosphere: a global view, Heat storage and transport, Heat balance at the surface, The hydrological cycle and The carbon cycle.	08	Understand the fundamental concepts of climate systems, its components and climate balance.
2	Modelling of the climate system: Introduction to a climate model, Types of models, A hierarchy of model, Energy balance models, Intermediate complexity models, General circulation models, Components of a climate model (Atmosphere, Ocean, Sea ice, Land surface, Marine biogeochemistry and Ice sheets), Testing the validity of models.	10	Develop the concepts necessary for modelling the earths climatic system.
3	The response of the climate system to a perturbation: Climate forcing and climate response, Notion of radiative forcing, Major radiative forcings, Equilibrium response of the climate system - a definition of feedback, Transient response of the climate system, Direct physical feedbacks, Water vapour feedback and lapse rate feedback, Cloud feedback, Cryospheric feedbacks, Geochemical, biogeochemical and biogeophysical feedbacks.	06	Develop the concepts of climate balance and various types of climate feedbacks.
4	Brief history of climate: causes and mechanisms, Internal climate variability, The climate since the Earth's formation, The last million years: glacial interglacial cycles.	05	Get the knowledge of past-climate history through the geological time scale.
5	Future climate changes: Emission scenarios, the purpose of the scenarios and scenario development, Special Report on Emission Scenarios (SRES), Representative concentration pathways (RCPs), Climate projections for the 21st century, Changes in global mean surface temperature, The spatial distribution of surface temperature and precipitation changes, Changes in the ocean and sea ice, Changes in the carbon cycle and climate-carbon feedbacks, Long-term climate changes, The carbon cycle and Sea level and ice sheets.	10	Develop the key concepts for future climate modeling and scenarios involved in future climate projection.

Reference Books:

1. Goosse H., P.Y. Barriat, W. Lefebvre, M.F. Loutre, and V. Zunz. Introduction to climate dynamics and climate modelling. Online textbook available at http://www.climate.be/textbook.
2. K. McGuffie and A. Henderson-Sellers. The Climate Modelling Primer, Wiley Blackwell
3. Stull, R.. "Practical Meteorology: An algebra-based survey of atmospheric science" – version 1.02b. Univ. of British Columbia. 940 pages. ISBN 978-0-88865-283-6
4. First principles of meteorology and air pollution by Mihalis Lazaridis. Springer.
5. Essentials of Meteorology: An Invitation to the Atmosphere by Ahrens, C. Donald & Robert Henson.