Learning Outcomes based Curriculum Framework

(LOCF)

For

B.Sc. (Hons.)

(Environmental Science)

2019

UNIVERSITY GRANTS COMMISSION
BAHADUR SHAH ZAFAR MARG
NEW DELHI – 110 002

Foreword

UGC has been taking several initiatives for quality improvement in higher education system in the country. Curriculum revision is one of the focus areas of these initiatives. Curriculum development is defined as planned, a purposeful, progressive, and systematic process to create positive improvements in the higher educational system. The ever evolving and fast changing educational technology have posed various challenges as far as curriculum in the Higher Educational Institutions (HEIs) is concerned. The curriculum requires to be updated more often keeping in view the latest developments in the society and to address the society's needs from time to time.

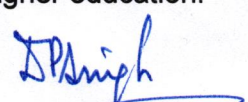
The Quality Mandate notified by UGC was discussed in the Conference of Vice-Chancellors and Directors of HEIs during 26-28th July, 2018; wherein it was inter-alia resolved to revise the curriculum based on Learning Outcome Curriculum Framework (LOCF).

Learning Outcome Curriculum Framework (LOCF) aims to equip students with knowledge, skills, values, attitudes, leadership readiness/qualities and lifelong learning. The fundamental premise of LOCF is to specify what graduates completing a particular programme of study are expected to know, understand and be able to do at the end of their programme of study. Besides this, students will attain various 21st century skills like critical thinking, problem solving, analytic reasoning, cognitive skills, self directed learning etc.. A note on LOCF for undergraduate education is available on the UGC website www.ugc.ac.in. It can serve as guiding documents for all Universities undertaking the task of curriculum revision and adoption of outcome based approach.

To facilitate the process of curriculum based on LOCF approach, UGC had constituted subject specific Expert Committees to develop model curriculum. I feel happy to present the model curriculum to all the HEIs. Universities may revise the curriculum as per their requirement based on this suggestive model within the overall frame work of Choice Based Credit System (CBCS) and LOCF.

I express my gratitude and appreciation for the efforts put in by the Chairperson/Member/Co-opted members/experts of the committees for developing model curriculum. I also take the opportunity to thank Prof. Bhushan Patwardhan, Vice-Chairman, UGC for providing guidance to carry forward this task. My sincere acknowledgement to Prof. Rajnish Jain, Secretary, UGC for all the Administrative support. I also acknowledge the work done by Dr. (Mrs.) Renu Batra, Additional Secretary, UGC for coordinating this important exercise.

All the esteemed Vice-Chancellors are requested to take necessary steps in consultation with the Statutory Authorities of the Universities to revise and implement the curriculum based on the learning outcome based approach to further improve the quality of higher education.



New Delhi
30th July, 2019

(Prof. D. P. Singh)
Chairman
University Grants Commission

Table of Contents

Preamble

Historically environment and conservation have been an integral part of India's ethical and spiritual values from ancient times. This is evident from the importance given to nature in the Vedic literature and epics the Ramayana and Mahabharata. Buddhism and Jainism have also given great importance to the conservation of natural resources and biodiversity. In more recent times, the value of flora and fauna has been documented by regimes of the Mughals and the British. The exploitation of our resources during British India required the introduction of formal educational processes to document India's biological resources. This tradition continued after independence as nature studies in school and college education.

The world got together to ensure preservation and enhancement of the human environment in Stockholm in 1972. Nations, irrespective of their economic status, have been facing newer environmental challenges of local, regional and global nature. Therefore, human beings needed to continue learning about the environment to appreciate the challenges and to find solutions. India has been quick to respond to the need and carefully added clauses in the Constitution of India to address the environmental concerns. Laws have been enacted as a commitment to the international community and to address Indian national concerns, and institutions like the Pollution Control Boards have been constituted. Consequently, over the years, Environmental Science has developed as an academic discipline and the need to create research base and technical manpower in the areas of Environmental Science has been felt world over.

By the 1970s it was observed that current patterns of development and our population growth placed enormous impacts on natural resources. The degradation of our environment such as deforestation, pollution, the spread of wasteland etc. led to the need for placing environment education in curricula. The Honorable Supreme Court, in response to MC Mehta's PIL, introduced formal environment education as an infusion into school curricula in different subjects. In 1991, the UGC created a compulsory Core Module Undergraduate Course on Environmental Studies to be implemented in all subjects at the undergraduate level. This is now referred to as 'Ability Enhancement Compulsory Course (AECC)'. During the last few years, several universities have initiated their courses on the environment in response to growing societal and industrial needs. As these provide disparate inputs, it is difficult for job opportunity providers to judge the competence level of job seekers on a single platform. Thus there is a growing felt need for a standardize honours programme on the environment at the bachelor's level.

The B.Sc. (Hon) Environmental Science programme and its LOCF curriculum have been designed to attract young minds to choose a career in broad areas of Environmental Science and applications. This programme has also been envisaged to fill the requirement of technical manpower in various sectors in India and elsewhere.

1. Introduction

Environmental Science has developed as a discipline of interdisciplinary nature. Therefore, explicit learning outcomes against the courses would provide a direction to the students and teachers to focus effectively on the subject. The recruiters would find it easier to visualize their internal needs and relate them to the available expertise of the graduates seeking jobs in this field. Thus, the learning outcomes based curriculum framework (LOCF) for B.Sc.(Hon.) Environmental Science has been envisaged to fill the gap that existed between the recruiters and academic institution, besides maintaining the standards of teaching-learning in the competitive world of today. The framework intends to bring in innovation in curriculum design and syllabus development, teaching-learning, and rational assessment of the students.

Since Environmental Science is an interdisciplinary subject, the candidates are expected to acquire skills in natural resource management, pollution control and social issues related to equitable use of resources.

Some topics in the Core courses may overlap with a similar Discipline Specific Elective (DSE) courses. However, the DSE courses in greater detail provide with opportunities for hands-on relevant training, exposure visits, skill development and project work.

Several courses may be supplemented by creating MOOCs through the e-Pathshala programme of the UGC.

As the environment and its studies are based on current and past scenarios, spatial and temporal aspects should become a part of a students' knowledge domain and acquired skills. This requires the student to have passed through a personal learning adventure into her/his environment and experiential learning, which is the foundation for critical and reflective learning.

The LOCF for B.Sc. (Hon.) Environmental Science has been prepared as per the structure provided by the UGC, however, the multidisciplinary nature of the subject and the field application of knowledge has been emphasized. Environmental Science is (also) an emerging discipline and so revision and amendments are inevitable, however, any modification must keep the spirit of CBCS and LOCF intact.

2. Learning outcomes based approach to Curriculum Planning

Domain knowledge, academic outlook, critical approach and thinking, ethical attitude, professional aptitude, adaptability, self-learning, problem solving ability, teamwork performances, and employability are the basis of the learning outcomes based curriculum. The learning outcomes are the ingredients based on which the graduate attributes, qualification descriptors, programme learning outcomes are determined. This also facilitates in curriculum planning and development as well as in the delivery and review of academic programmes.

2.1 Nature and extent of B.Sc. (Hon.) Environmental Science

B.Sc. (Hon.) Environmental Science is a natural science programme. This programme will make graduates ready to take up higher studies in environmental sciences and to take up careers in the fields of environmental research and learning. The environmental commitments of the society have grown since Stockholm 1972 and, therefore, all organisations have the immediate need of technical manpower and the knowhow to handle the environmental needs of different sorts of today of the nature of scientific, technological, remedial and socioeconomic types. This programme would deal with the topics that will cover issues from all attributes of the environment; issues from physical environment to socioeconomic and cultural environment. This learning outcomes based curriculum for this programme would have definite goals to be achieved to keep the students, teachers and the offering institutions stay focused on the primary objectives of the programme. The detailed programme learning outcomes are listed in the later sections.

This is a job oriented programme and relevant to the current needs of the society. The extent (scope, depth, and outcomes) of B.Sc. (Hon) Environment Sciences programme has taken into account the extent of the knowledge provided at school level in 10^{th}, 11^{th} and 12^{th} standard according to syllabi of NCERT and state boards. It has been designed to bridge the gap between the school level and M.Sc. programme on environment and its management offered by various universities. This is essential because of the interdisciplinary nature of the subject. More so, there is a current trend to look at the environment through a trans-disciplinary approach which is relevant by the nature of the subject and the socio-economic fabric of India.

2.2 **Aim of B.Sc. (Hon.) Environmental Science**

The aims of the B.Sc. (Hon) Environmental Science are to:

- Provide students with the scope to develop knowledge base covering all attributes of the environment and enable them to attain scientific/technological capabilities to find answers to the fundamental questions before the society with regards to human action and environmental effects with due diligence.
- Enhance the ability to apply this knowledge and proficiency to find solutions relating to environmental concerns of varied dimensions of today
- Provide with a direction and technical capability to carry on lifelong learning and show teamwork and collaborative endeavour, and decision making
- Improve the employability of the graduates including the enhancement of self- employment and entrepreneurial aptitude, and fill the technical resource gap especially in the Indian context
- Help graduates appreciate environmental needs to frame policy guidelines.
- Motivate graduates to appreciate that they are an integral stakeholder in the environmental management of India irrespective of their future jobs or working environments in accordance of the provisions vide Article 48A (Directive Principles of State Policy) and Article 51A(g) (Fundamental Duties) of the Constitution of India.
- Help graduates to understand the concerns related to Sustainable Development Goals (SDGs) and the Indian obligations

3. Qualification descriptors for B.Sc. (Hon.) Environmental Science

The qualification descriptors for the B.Sc. (Hon.) programme in Environmental Science shall be five learning attributes such as disciplined knowledge & understanding; skills & techniques; national and global competencies; communication; and application. The key qualification descriptor for Environmental Honours shall be the strong foothold of the basic scientific theories and principles as well as critical thinking and decision making. The major expected learning outcomes of the B.Sc. (Hon.) programme in Environmental Science should include the following:

Knowledge & Understanding

- *Demonstrate* extensive and systematic acquaintance of the disciplinary foundation in the various areas of Environmental Science.
- *Insightfully* address the contemporary research and development at both national and international arena.
- *Understand and engage* in the field of Environmental Sciences and its allied areas.

Skills & Techniques

- *Show* the ability to apply scientific knowledge & experimental skills in a critical and organized manner for evaluation and elucidation of complex environmental problems and issues related to terrestrial ecosystems; physical environment; air, water, and soil
- *Contamination*; human health hazards; biodiversity loss; food security and agricultural issues; solid waste management; and other specialized areas of electronics.
- *Demonstrate* the ability to identify the role of the scientific knowledge, experimental skills, scientific methods & tool in dealing with real-life case-specific issues and formulate sustainable solutions.
- *Exhibit* efficiency to model, simulates, and assesses the regional and global phenomenon and systems with both primary and secondary data sources.
- *Demonstrate* the ability to facilitate technocrats and manufacturers to design and develop eco-friendly products and processes towards accomplishment of the sustainable development goals.

Competence

- *Communicate* heterogeneous audience through his or her information, knowledge, and arguments effectively and professionally with write-ups and presentations in both national and international perspectives.
- *Ability* to work as a proactive and supportive member in a team through substantial contributions towards effective planning, management, and implementations of projects and/or tasks.
- *Exhibit* capability to think and execute independent research ventures/projects, interpret changes and fluctuations in the natural environment, predict or estimate probable environmental consequences of any process, evaluate research outcomes, and report in a conclusive and convincing manner.
- *Capability* to identify his or her strengths and limitations; develop an attitude to learn more; inculcate a lifelong learning practice; and grow as pragmatic knowledge seekers as well as knowledge creators.

4. Graduates Attributes

Graduates Attributes (GAs) are composed of independently measurable outcomes that signify the capabilities and potentials of the graduate to attain accomplishment and perform in adequate manner at appropriate situations. The Graduate Attributes of B.Sc (Honours) environmental Science are given as below:

GA1. Erudition of acquaintance: Gain in-depth knowledge and understandings of each discipline or professional area across boundaries of nations with an aptitude to identify, access, analyze and synthesize existing and new knowledge, and integrate them for the enrichment of knowledge.

GA2. Analytical Thinking: Critically to address multifaceted scientific issues and environmental phenomenon; pertain independent decision for synchronizing information to formulate innovative and intellectual advances towards focused research over wider theoretical and practical domains.

GA3. Problem Solving: Address and solve scientific vis-a-vis environmental problems via rational and original thinking; keep updates of different solution avenues and select appropriate options considering public health, cultural, and societal factors.

GA4. Application of modern tools: Select, learn and apply appropriate techniques, resources, sophisticated instruments, models for explaining different environmental consequences and mitigation activities with a thorough understanding of drawbacks.

GA5. Mutual and Multidisciplinary competence: Develop sound knowledge and perception about group dynamics, recognize role of individuals in a group, take initiatives and leadership in collaborative-multidisciplinary and trans-disciplinary scientific research, demonstrate a capacity for self-management and teamwork, timely decision-making through openness and flexibility, constructive arguments and rational analysis for achieving common goals and objectives; motivate group members to address environmental issues with a scientific outlook and mitigation approach.

GA6. Communication skill: Communicate scientific/technological knowhow and new learning to the scientific community and the society at large with strong conviction and confidence so that humanity benefit from the knowledge and technological development. This can be achieved through sound technical proficiency of graphics, software, writing skill, in-depth subject

specifics knowledge, by maintaining appropriate standards, by the ability to render as well as receive comprehensible instructions.

GA7. Life-long Learning: Distinguish the importance and possess the ability to prepare and engage in the life-long learning process; also have the ability to transfer the acquired skills in other domains of science; which can be achieved through enthusiasm and commitment to improving knowledge and competence in a continuous manner.

GA8. Ethical values and Social Responsibility: Attain strong academic integrity, professional code of conduct, ethics of experimental research and scientific writings, contemplation of the impact of research findings on conventional practices, and a clear sense of responsibility towards societal needs and reaching the targets for attaining inclusive and sustainable development.

GA9. Futuristic attitude: Ability to recognize and address current environmental scenarios, scientific and technological progress, lifestyle change, and biophysical evolutions with a futuristic view; practicing intuitiveness and interest towards scientific prediction via application of basic knowledge of science especially with regard to India's SDGs in terms of economic welfare, social equity and proactive long-term environment management.

5. Program Learning Outcomes of B.Sc. (Hon.) Environmental Science

The following program outcomes have been identified for B.Sc. (Hon.) Environmental Science

PLO1	Ability to recognize the need for learning the topic and develop foundational knowledge on the topic
PLO2	Ability to develop critical thinking and problem solving skills to solve interdisciplinary issues related to the topic
PLO3	Ability to understand the relationships between natural and man-made systems
PLO4	Ability to apply statistical methods, ICT and innovative techniques in classroom, field and laboratory to analyze scientific data
PLO5	Ability to develop lifelong learning and professional skills
PLO6	Ability to design and execute a scientific project, write scientific reports, develop research and communication skills
PLO7	Ability to spread awareness about the environment around us, sustainable development and conduct outreach activities
PLO8	Ability to gain empirical knowledge on the topic and contribute in decision making processes

Semester	Course title	C1: Introduction to the environment	C2: Natural Resource Management and Sustainable Development	C3: Introduction to Biological Environment	C4: Introduction to the Physical Environment	C5: Fundamentals of Ecology	C6: Biodiversity and Conservation	C7: Water Resources	C8: Solid Waste Management
I	PLO1: Ability to recognize the need for learning the topic and develop foundational knowledge on the topic	x	x	x			x	x	x
I	PLO2: Ability to develop critical thinking and problem solving skills to solve interdisciplinary issues related to the topic	x	x	x		x	x	x	x
II	PLO3: Ability to understand the relationships between natural and man-made systems	x	x	x		x	x		x
II	PLO4: Ability to apply statistical methods, ICT and innovative techniques in classroom, field and laboratory to analyze scientific data	x	x	x			x		x
III	PLO5: Ability to develop lifelong learning and professional skills	x	x	x			x	x	x
III	PLO6: Ability to design and execute a scientific project, write scientific reports, develop research and communication skills	x	x	x			x	x	x
III	PLO7: Ability to spread awareness about the environment around us, sustainable development and conduct outreach activities	x	x	x			x		x
IV	PLO8: Ability to gain empirical knowledge on the	x	x			x	x	x	x

	topic and contribute in decision making processes								
IV	C9: Environmental Chemistry	x	x	x	x		x		x
IV	C10: Basics of Environmental Statistics and Computer Application				x	x	x		
V	C11: Environmental Pollution and Human Health	x	x	x			x	x	x
V	C12:Environment al Instrumentation				x	x			
VI	C13:Environmental legislation and policy	x	x	x		x		x	x
VI	C14: Atmospheric Processes	x	x	x	x		x	x	x
	DSE1:Energy and Environment	x	x	x		x	x	x	x
	DSE2: Natural Hazards and disaster management	x	x	x		x	x	x	x
	DSE3:Environment al Economics	x	x			x	x	x	x
	DSE4:Land and Soil Conservation and management	x	x	x		x	x	x	x
	DSE5: Soil Remediation and Restoration	x	x	x		x	x	x	x
	DSE 5A: Environmental modelling	x	x		x	x	x	x	x
	DSE 6: Water Treatment Technology	x	x	x		x	x	x	x
	DSE6A:Air Pollution Monitoring and Control	x	x	x		x	x	x	x
	DSE7:Environmental Biotechnology	x	x	x	x		x		x
	DSE8 : Industrial health and safety	x	x	x	x		x		x
	DSE20: Project/Dissertation	x	x	x	x	x	x	x	x

6. Programme structure of B.Sc. (Hon.) Environmental Science

Total Credits: 148 credits

Structure of B.Sc. (Hon) Environmental Science

Course category	No of courses	Credits per course	Total Credits
I. Core courses	14	6	14x6=84
II. Elective courses			
A. Discipline specific courses (DSE)** (Optional *Dissertation or project* work in place of one DSE paper of 6 Credits in the 6th Semester)	4	6	24
B. Generic elective courses (GE)	4	6	24
III. Ability enhancement courses (AECC) English/ Hindi/MIL/communication	2	4	8
IV. Skill Enhancement courses (SEC)**	2	4	8
Total			148

6.1 Semester-Wise Schedule

SEMESTER I

Course type	Course title	Credits
Core	C1:Introduction to the Environment	6
	C2: Natural Resource Management and Sustainable Development	6
GE	GE paper 1	6
AECC	AECC1 : English	4
	Total	22

SEMESTER II

Course type	Course title	Credits
Core	C3: Introduction to the Biological Environment	6
	C4 Introduction to the Physical Environment	6
GE	GE paper 2	6
AECC	AECC2/Hindi/MIL/Communication	4
	Total	22

SEMESTER III

Course type	Course title	Credits
Core	C5: Fundamentals of Ecology	6
	C6: Biodiversity and Conservation	6
	C7: Water Resources	6
GE	GE paper 3	6
SEC	SEC paper1	4
	Total	28

SEMESTER IV

Course type	Course title	Credits
Core	C8: Solid Waste Management	6
	C9 Environmental Chemistry	6
	C10: Basics of Environmental Statistics and Computer Application	6
GE	GE paper 4	6
SEC	SEC paper 2	4
	Total	28

SEMESTER V

Course type	Course title	Credits
Core	C11: Environmental Pollution and Human Health	6
	C12: Environmental Instrumentation	6
	DSE paper 1	6
	DSE paper 2	6
	Total credits	24

SEMESTER VI

Course type	Course title	Credits
Core	C13: Environmental legislation and policy	6
	C14: Atmospheric processes	6
DSE	DSE paper 3	6
	DSE paper 4 /or Project dissertation	6
	Total credits	24

6.2 List of Courses

A. Core courses

Semester	Course title	Lecture (L)	Tutorial (T)	Practical (P)*	Contact Hour	Credits
I	C1: Introduction to the Environment	5	1	0	6	6
I	C2: Natural Resource Management and Sustainable Development	5	1	0	6	6
II	C3: Introduction to the Biological Environment	4	0	2	8	6

II	C4: Introduction to the Physical Environment	5	1	0	6	6
III	C5: Fundamentals of Ecology	4	0	2	8	6
III	C6: Biodiversity and Conservation	5	1	0	6	6
III	C7: Water Resources	5	1	0	6	6
IV	C8: Solid Waste Management	4	0	2	8	6
IV	C9: Environmental Chemistry	4	0	2	8	6
IV	C10:Basics of Environmental Statistics and Computer Application	4	0	2	8	6
V	C11 Environmental Pollution and Human Health	4	0	2	8	6
V	C12: Environmental Instrumentation	4	0	2	8	6
VI	C13: Environmental legislation and policy	5	1	0	6	6
VI	C14: Atmospheric Processes	5	1	0	6	6

A. Discipline specific courses (DSE)

Course title	Lecture (L)	Tutorial (T)	Practical (P)*	Contact Hour	Credits
DSE1: Energy and Environment	5	1	0	6	6
DSE2: Natural Hazards and disaster management	5	1	0	6	6
DSE3: Environmental Economics	5	1	0	6	6
DSE4: Land and Soil Conservation and Management	5	1	0	6	6
DSE5: Soil Remediation and Restoration or	5	1	0	6	6
DSE 5A: Environmental modelling	4	0	2	8	6
DSE 6: Water Treatment Technology	4	0	2	8	6

or					
DSE 6A: Air Pollution Monitoring and Control	4	0	2	8	6
DSE 7: Environmental Biotechnology	4	0	2	8	6
DSE8 : Industrial health and safety	5	1	0	6	6
DSE20: Project/Dissertation (Optional: May be offered in lieu of a DSE course)	0	0	8	16	8

B. Skill Enhancement courses (SEC)

Course title	Lecture (L)	Tutorial (T)	Practical (P)*	Contact Hour	Credits
SEC1: Remote sensing and geographic information system and modelling	4	0	0	4	4
SEC2: Environmental impact assessment (EIA)	4	0	0	4	4

C. General Elective courses (students from other disciplines can opt)

Course title	Lecture (L)	Tutorial (T)	Practical (P)*	Contact Hour	Credits
GE1: Wildlife Conservation and Management	5	1	0	6	6
GE2: ENVIRONMENT AND GENDER	5	1	0	6	6
GE3: Green Technologies	5	1	0	6	6
GE4: Environment and society	5	1	0	6	6
GE5: Fundamentals of Ecotourism	4	0	2	8	6
GE6: Folk culture and traditional communities of India	5	1	0	6	6

Note:

- *Institutes may offer more courses for C, D and E category of courses without compromising the philosophy of LOCF*
- *The core courses are mandatory courses listed as 'A' category.*
- *The B, C, D and E category of courses may not necessarily be from the parent department/institute/college as they are courses of CBCS nature*

6.3 Assessment Implementation Plan

Stage wise assessment plan will be adopted through a repetitive and systematic approach. The main purpose of planning the assessment process is to evaluate that methods of assessing the learners are suitable with respect to each program learning outcome. This will also help the respective faculty/school to analyze the performance of the students to the desired standards; to revise vis-à-vis refine the assessment criteria; and also to make necessary alterations in the programme in a liberal manner. It is also expected that the respective faculty would adopt rubrics as part of the appraisal process. The rubrics would define what is expected and what will be assessed, and would detail the criteria; creating a simpler, fairer, transparent, and yet accomplished grading and ranking system. Overall, the evaluation criteria will be established for each of the five student learning outcomes. A five-point rubric rating scales may be developed by the faculty/school/department as shown in the following example:

5 points = Exceeds expectations
4 points = Meeting expectations
3 points = Fairly competent
2 point = Approaching
1 point = Not there yet

Similar type of rubric scaling may be framed from the given structure encompassing the local factors and average student characteristics of the region or state.

6.4 Graduate Program Learning Outcomes Assessment Matrix

Student Learning Outcomes: The expected ability of students after completion of the B.Sc.(Hon.) Environmental Science programme	Assessment: How we will assess how well students are learning this
Ability to recognize the need for learning the topic and develop foundational knowledge on the topic	*Over a period of 3 years* Interview Internal review External review
Ability to develop critical thinking and problem solving skills to solve interdisciplinary issues related to the topic	*Over a period of 3 years* Project/practical Interview Internal review External review
Ability to understand the relationships between natural and man-made systems	*Over a period of 3 years* Writing skill Presentation Internal review
Ability to apply statistical methods, ICT and innovative techniques in classroom, field and laboratory to analyze scientific data	*Over a period of 3 years* Writing skill Presentation Interview Internal review
Ability to develop lifelong learning and professional skills	*Over a period of 3 years* Writing skill Presentation Interview Internal review
Ability to design and execute a scientific project, write scientific reports, develop research and communication skills	*Over a period of 3 years* Experimentation skill Presentation

	Interview External review
Ability to spread awareness about the environment around us, sustainable development and conduct outreach activities	*Over a period of 3 years* Writing skill Interview Internal review External review
Ability to gain empirical knowledge on the topic and contribute in decision making processes	*Over a period of 3 years* Writing skill Interview Internal review External review

6.5 DETAILED SYLLABUS

C1: Introduction to the Environment

L5 T1 P0 CH6 Cr6

Course outcomes:

CO1 Knowledge of the environment and the role of human beings in shaping the environment

CO2 Understand various components of the environment and interfaces

CO3 Critically appreciate the environmental concerns of today

Course content:

- Multidisciplinary nature of Environmental Science
- Environment – Definition and the components – the physical components, socio-economic and cultural component
- Natural resources – definition and types, renewable and non-renewable resources, resource use and depletion
- The atmosphere – structure and composition, physicochemical role of the atmosphere, radiative balance and earth's temperature regime
- Rocks and minerals, the rock cycle, biogeochemical cycles, soil- structure and types, land resources, and landforms
- Water resources, water bodies and water use, issues with water and conservation
- Ecosystems – concepts and structure, diversity and stability, concepts of biomes, biodiversity
- The Urban environment and issues – internal migration, waste generation and management, vehicular traffic, air and water pollution, urban heat island, future of cities, urban green space and aesthetics, Concept of smart cities, sustainable cities
- Environmental issues – local, regional, and global. Concepts of pollution of air, water, and land, urbanization and solid wastes, biodiversity loss, land degradation and desertification, biodiversity loss, ozone layer depletion, climate change
- Environmental concerns – historical development of environmentalism and conservation on Indian perspective

Textbooks:

- Cunningham W.P., Cunningham M.A., Saigo B.W., Environmental Science: A global concern, McGrawHill 2003
- Cunningham W.P., Cunningham M.A, Principles of Environmental Science: Seventh Edition, McGrawHill 2014
- Rogers P.P., Jalal, K.F., Boyd J.A., An introduction to sustainable development, Earthscan

Reference books:

- Roosa S.A., Sustainable Development Handbook, CRC Press 2008
- Atkinson G., Dietz S., Neumayer E., Agarwala M, Handbook of Sustainable Development, Edward Elger, 2014
- Robbins P., Hintz J., Moore S.A., Environment and Society: A critical introduction, Wiley Blackwel 2014

***

C2: Natural Resource Management and Sustainable Development

L5 T1 P0 CH6 CR6

Course outcomes :

CO1 Appreciate attributes of natural resource use and management

CO2 Understand the complexity of natural resource and issues, and sustainability

CO3 Apply theories and methods with interdisciplinary approach towards natural resource management

CO4 Critically examine the gap in the resource availability, use, and conservation

CO5 Appreciate ideas of sustainable development and application

CO6 Critically examine the interlink between development and the environment

Course content:

- Natural resource

  Introduction to earth's natural resources

  Occurrence, formation and distribution.

  Types of natural resources-

  Renewable and non-renewable resources

  Conventional and non-conventional

  Values: economic, societal. Environmental, spiritual, optional and aesthetic values

- Natural resources, values and environmental concerns

  Land resources: forest land, agricultural land, grassland, semi-arid, desert; land use classification, overutilization and land degradation

  Forest resources: Major forest types and their characteristics, distribution, forest crops and wild animals, utilization of forest resources, issues related to resources harvesting, utilization and degradation

  Water resources: Fresh and marine water; surface water and ground water, wetlands, rivers, lakes, mangroves, overexploitation, sustainable harnessing of water, rain water harvesting, conflicts, water wars

  Energy resources: Fossil fuels, nuclear fuels and hydroelectric energy, alternative source of energy (wind, solar), Increasing demand, efficient use of energy,

  Food resources: Food security, food problems across globe, agriculture and effects of

modern agriculture, case-studies, traditional farming methods

Mineral resources: metallic and non-metallic, mining, extraction, utilization, and environmental effects

- Resources extraction, processing and utilization

  Labour, raw materials and energy

  Mining and its consequences and affects

  Extraction and challenges of processing

  Chain of processes from ore to manufactured object – Life Cycle Assessment (LCA)

  Use to reuse and recycling –Several newer aspects have been suggested for resource use management7R's (Recycle, Refuse, Reduce, Reuse, Repair, Recover, Regift)

- Conservation and management of natural resources

  Waste matter: a new source of wealth

  Humans and conservation

  Conservation and protection

  Sustainable use of natural resources

  Natural resource management Approaches-Community based natural resource management (CBNRM), Integrated natural resource management (INRM)

  Natural resources governance and policy

- Sustainable development - What is unsustainable development and what is sustainable development. Definition and concept, The Brundtland commission and later developments, Determinants of sustainable development, Indicators of sustainable development, Sustainable society, societal prerequisites of sustainable development, International cooperation, Sustainable development goals. Millennium development goals
- What is the role of ESD (Education for Sustainable Development)

Reference books:

- Klee G.A., Conservation of Natural Resources. Prentice Hall College Div., 1991.
- Rai G. D., Non-conventional Energy sources. Khanna Publishers, New Delhi.
- Lynch D.R., Sustainable Natural Resource Management: For Scientists and Engineers,

***

C3: Introduction to the Biological Environment

L4 T0 P2 CH8 CR6

Course outcomes:

CO1 Understand the biosphere and biotic community

CO2 Appreciate physiology of plants and animals, and relation with environment

CO3 Appreciate the Climatic factors, stress and physiology

CO4 Critically examine the impact of human action on the biological environment

Course content:

- Biosphere: Deals with the living species of the Earth. Interactions of living species and their changes with the present environmental modifications
- Understanding Bio complexity: Biological complexity of life. Problems faced by living organisms residing at different habitats and their way of interactions with the environment, India's common flora and fauna. Strategies adopted by plants, animals, fungi, bacteria and archaea to cope with their habitat.
- Animal behaviour and Physiology: Understanding how animals behave and adapt to external environments, adaptive responses that enable species to survive and reproduce. Environmental change that favours or disfavours behaviours and physiologies of animals.
- Plant Physiology and Ecophysiology: Key concepts on how plants capture energy and transform it to the ecosystems. The productivity of plants and plants in the field (ecophysiology); their influence on water, carbon, nutrient and energy cycles is central to the functioning of landscapes. Long-distance transport in the phloem; uptake, movement and control of water fluxes in the soil-plant-atmosphere continuum; landscape carbon and water budgets; behavior and physiology of stomata; ion uptake by plant roots; comparative ecophysiology of plants in contrasting environments; the ecophysiology of global forest mortality in response to drought; and the physiology of plants exposed to stress.
- Ecology and Ecosystem structures, composition and function: Ecological patterns and functions of ecosystems. Interactions of biotic and abiotic factors on determining the

functions and structures of ecosystem. Introduction to wildlife ecology, Forest and Mountain ecology, Aquatic ecology, Semi-arid ecology, Alpine and lowland ecology.

Practical:

Basic understanding on plant and animal physiology- Growth, development and metabolism: Measuring growth parameters - plants and animals; Biological Imaging and photography; Influence of Acid rain on ecosystem- plants, microbes and aquatic ecosystem; Responses of plant to environment- light, nutrient, CO_2;

Field visit and reporting: Recording bio-complexity at field level (Relationships within plants, animals and between plants and animals in the ecosystem.

Textbooks:

- Bhatia A. L., Text book of Environmental Biology, I K International Publishing House (March 27, 2010)
- Saradhi P.P., Biophysical processes in living systems, Oxford & IBH Publishing, 2008.
- Krishnamurthy K.V., An Advanced Text Book on Biodiversity- Principle and Practices, Oxford & IBH Publishing., 2004

Reference Books:

- Hock B. and Elstner E. F. F., (eds). Plant Toxicology, Fourth Editon, CRC Press., 2004.
- Ladd P. C., (Ed.) Comparative Animal Physiology, fourth edition, WileyLiss, New York, 1991.
- Calver M., et al (Eds) , Environmental Biology, Cambridge University Press.

***

C4: Introduction to the Physical Environment

L5 T1 P0 CH6 CR6

Course outcomes:

CO1 Should be able to describe the composition and vertical structure of atmosphere.

CO2 Should have understanding of the clear distinction between adiabatic lapse rate and the environmental lapse rate and be able to work out temperatures at higher altitudes based on the lapse rate.

CO3 Should have an understanding of how aerosols impact climate through processes of scattering and absorption of radiations.

CO4 Should be able to describe types of clouds and their structure.

CO5 Should know how geostrophic winds and cyclones are caused in the earth atmospheric system.

CO6 Should be able to appreciate the impact of human activity on the energy balance in the earth atmospheric system.

Course content:

- Forces of nature, states of matter-solid, liquid and gas. Structure of earth, origin and composition of atmosphere, atmospheric mass, gaseous constituents, trace gases, vertical profile of atmosphere, scale height, thermodynamic properties of atmosphere, gas laws, first and second laws of thermodynamics, isothermal and adiabatic processes, latent heat, sensible heat, virtual temperature, dew point, vapour pressure, saturated vapour pressure, RH, Hydrostatic equation, lapse rates-adiabatic and environmental, mixing height, atmospheric stability classes. Weather and climate.
- Atmospheric aerosols, types and examples, inorganic and organic aerosols, mass transfer, diffusion and transport, particle impaction, sedimentation velocity, relaxation time, stopping distance.
- Transfer of heat, conduction, convection, radiative transfer, radiation laws, solar and terrestrial radiations, Stefan Boltzman law, Wien's law and Planck's law, irradiance, absorption, transmission, reflection, emission and scattering of radiations, Rayleigh and Mie scattering, diffraction. Role of aerosols in climate.
- Clouds microphysical processes, nucleation of water vapour and condensation, structure

and types of clouds.

- Atmospheric dynamics, steady and non-steady motion, Geostrophic winds, cyclones, hurricanes and thunderstorms. General circulation, global energy balance, global atmospheric change, simple global temperature models.
- Water budget of the earth atmospheric system, soil resources.

Reference Books:

- Wallace J. M. and Hobbs P.V., Atmospheric science, (Academic Press) 2006.
- Monteith J.L. and Unsworth M.H., Principle of Environmental Physics, (Academic Press), 2008.
- Smith C., Environmental Physics (Routledge), 2004.
- Mason N. and Huges P., Introduction to Environmental Physics (Taylor and Francis), 2001.
- Gilbert M., Masters., Introduction to Environmental Engineering and Sciences, (prentice Hall of India), 2008.
- Andrew R. W. and Jackson J. M., Environmental Science- The Natural Environment and Human Impact (Longmon), 1996.

***

C5: Fundamentals of Ecology

L4 T0 P2 CH8 CR6

Course Outcomes:

CO1 Knowledge on ecology, and ecological dynamics

CO2 Ability to correlate ecological dynamics and regulation of vital processes on earth as biogeochemical cycles

CO3 Ability to interpret ecosystem services, ecological resilience, ecological economics, and landscape ecology

CO4 Set up experiments to appreciate concepts of Ecology

CO5 Critically examine the forces impacting ecosystems like climate change, stress, population, consumerism, globalization, and land use

Course content:

- Introduction, foundational concept of ecology and environment, Biotic and abiotic components, ecological dynamics
- Ecosystem (types and components), ecosystem ecology, ecosystem diversity, niche, habitat, biomes, bioregions, and Eco regions; ecological dynamics in regulating vital processes on the planet earth as biogeochemical cycles
- Hierarchy and levels of organization, ecological genetics, population dynamics, interactions among living organisms or ecological communities (interspecific, intraspecific, predation, commensalism, mutualism, symbiosis, coevolution), ecological succession, Invasive species and the threats.
- Ecosystem productivity, energy flow in ecosystems, food chain, food web, food pyramid and nutrient cycling
- Ecosystem services, ecological resilience, ecological economics, and landscape ecology
- Urban Ecology, Urban landscape planning and green architecture
- Ecology and climate change; current issues in ecology (ecological stress)

Practical:

Assessment of abiotic components in an ecosystem as physicochemical properties in – Atmosphere, Hydrosphere, Lithosphere

Assessment of biotic components in an ecosystem primarily pattern of organisms and habitat

exposure

Assessment of biodiversity in a given geographical area – floristic diversity (citing categories of different life forms based on morphological features only)

Quadrat study for plants (1m× 1m), involving random sampling to random sampling to measure the abundance, density and frequency of various species in an ecosystem

Field visit and reporting: Forest/desert/aquatic ecosystem – record biotic and abiotic components and interactions

Textbooks:

- Kormondy E.J., Concepts of Ecology, Pearson, 2017.
- Odum, E.P. and Barrett, G.W., Fundamentals of ecology (Vol. 3, p. 5). Philadelphia: Saunders, 1971.
- Dash M. C. and Dash S.P., Fundamentals of Ecology, Mcgraw Hill, 2009.
- Ricklefs, R.E. and Miller, G.L., Ecology. W. H. Freeman & Co. 2000.
- Smith, R.L., Smith, T.M., Hickman, G.C. and Hickman, S.M., Elements of ecology. Pearson Benjamin Cummings, San Francisco, CA, 1998

Reference Books:

- Krebs C.J. Ecology: The experimental Analysis of Distribution and Abundance, Pearson, 2016.
- Chew S.C., The recurring dark ages: ecological stress, climate changes, and system transformation. Rowman Altamira, 2006.
- Bharucha E.. Changing Landscapes, The Cultural Ecology of India. Harper Collins Publishers, India, 2017.

***

C6: Biodiversity and Conservation

L5 T1 P0 CH6 CR6

Course outcomes:

CO1 Systematically understand biodiversity and its vital role in ecosystem functions

CO2 Appreciate the need of biodiversity conservation in the context of various developmental pathways and policy framework that the mankind has been undergoing

CO3 Identify the importance of biodiversity in natural environments

CO4 Critically examine biodiversity and human linkages, and help policy formulating for conservation

CO5 Application of knowledge in general communication for public extension

Course content:

- Diversity in living world: Evolution of biodiversity, Properties of life, Organization of life, The biosphere: Life on earth
- Concept of Biodiversity: Concept and definition, Levels of organization, Dimension of biodiversity, Global biodiversity gradient. List of common flora and fauna of India, endangered and endemic species Extinction and evolution of species
- Values of Biodiversity and ecosystem services: Importance of biodiversity, Direct and indirect used value, Ecosystem Services, Ecosystem Stability
- Biodiversity threats, conservation approaches and management: Decline of biodiversity-causes and consequences, Direct and indirect threats; Reason of conservation and conservation approaches, Ecoregions, Megadiverse countries, Biodiversity hotspots, The spread and threats of invasive species
- National Parks, Wildlife Sanctuary, Conservation reserves, Community Reserves, Protected areas; Conservation and management practices, *In situ* and *ex situ* strategy, Advantages, risks and opportunities; Traditional ecological knowledge, Traditionally conserved areas in India : Sacred Groves, Rivers, Mountains etc. *Case studies*
- Biodiversity and climate changes: Impacts of climate change on biodiversity, Climate change and threats to species and ecosystems, Distribution and adaptation pattern of plants and animals, Vulnerability to climate change, Migration/shifting toward higher latitudes
- Biodiversity conservation and human health: Direct and indirect linkages, Biodiversity and rural livelihoods, Poverty, Development and Biodiversity, Conflicts between Human

Health and Biodiversity Conservation, *Case studies*

- Biodiversity conservation: Legal aspects: Legal Instruments Relevant to Biological Diversity in India, Endangered Species Act, Federal Role in Wildlife Preservation
  Major International Conventions: Convention on Biological Diversity, Convention on Migratory Species, Convention on International Trade in Endangered Species of WildFauna and Flora, Ramsar Convention, World Heritage Convention.
- Role of Corporate Social Responsibility (CSR) in Environment and Biodiversity Management

Textbooks:

- Gaston K.J. and Spicer Biodiversity – An Introduction, Blackwell Publishing, 2004.
- Krishnamurthy K. V. Textbook of Biodiversity, CRC Press. 2003.
- Krishnamurthy K. V. An Advanced Textbook on Biodiversity: principles and Practice, Oxford & IBH Pub. Co. Pvt. Ltd. 2008.

Reference Books:

- Schulze E-D., Harold M., (Eds.) Biodiversity and Ecosystem Function. Springer-Verlag, London. (1994)
- Khan T. I., Global Biodiversity and environmental Conservation. Pointer Publisher. Jaipur. 2001.
- Magurran A. E., Measuring Biological Diversity. Wiley-Blackwell, Pp-264. 2003.
- Magurran A. E., and McGill B.J.(Eds.) Biological Diversity Frontiers in Measurement and Assessment. Oxford University Press(2010)
- Joshi P. C., Joshi N. Biodiversity and conservation. A.P.H. Pub(2004)
- Melchias G. Biodiversity and conservation. Science, University of Michigan(2001)
- Pandey. B.N. Biodiversity Issues Threats and Conservation. Narendra Publishing(2012)
- Sodhi N. S., and Ehrlich P. R., (Eds.) Conservation Biology for All.Oxford University Press. 2010.
- Maiti P. K. and Maiti P., Biodiversity: Perception, Peril and Preservation, PHI, New Delhi, 2001.
- Bharucha, E. Wonders of Indian Wilderness, Abbeville Press Pub., 2008

***

C7 Water Resources

L5 T1 P0 CH6 CR6

Course Outcomes:

CO1 Knowledge of water sources and processes involved

CO2 Identify the data requirements for water resources and interpret the analysis of the same

CO3 Estimate the design parameters of a water resources system using elementary methods

CO4Critically examine water resource management systems interaction and significance with respect to the environment

CO5 Application of knowledge on water resource technology

Course content:

- Water Availability around the globe: Forms of water available in earth, Surface, ground and atmospheric water, Salt water and fresh water.
- Hydrologic Cycle and Processes: Precipitation – types and forms, Infiltration, Evaporation, Interception, Runoff. Global atmospheric and oceanic circulation and their impact on weather and climate.
- Measurement techniques: Use of Rain-gauges, RADAR and satellites for rainfall measurement, Hyetograph and Mass curve of rainfall, Isohyetal maps, Mean precipitation over an area, Measurement of Evaporation, Infiltration and Riverflow.
- Storm Hydrology: Introduction to Catchment area, Runoff generation process and governing factors, Hydrograph, Separation of baseflow and surface runoff, Unit Hydrograph and its uses, Flood – causes and effects,
- Ground Water Hydrology: Aquifers and its types, Flow of groundwater in aquifers, Surface and Groundwater interaction.
- Statistical Analysis of Hydrological Processes: Frequency and Return period of hydrologic variables, Probability Analysis, Depth-Area-Duration-Frequency relationship of Rainfall.
- Water Resources Engineering: Types of Water Resources Projects, Objectives and principles, Irrigation and water supply, Power Generation, Flood Control, Navigation, Recreation, Reservoir projects and their components, Dams, Types of dams, Diversion headworks, Components and their functions, Run of river projects, Multipurpose projects, Advantage and disadvantages of water resource projects.
- Water scarcity, Water sensitization and management

Textbooks:

- Modi P. N., “Irrigation Water Resources and Water Power Engineering”, Standard Book House
- Subramanya, K., “Engineering Hydrology”, McGraw Hill Education

Reference Books:

- Chow V. T., Maidment D. R., Mays L. W., “Applied hydrology”, McGraw Hill Education
- Garg S. K., “Hydrology and Water Resources Engineering”, Khanna Publishers

***

C8: Solid Waste Management

L4 T0 P2 CH8 CR6

Course outcomes:

CO1 Understand the characteristic of wastes and the systems, and processes of waste management.

CO2 Identify the case specific issues related to pollution potentials of solid wastes

CO3 Address solid waste management practices through a cradle-to-grave approach

CO4 Apply understanding to generate recourses from wastes

CO5 Make appropriate decisions through application of waste management principles

Course content:

- Introduction: Definitions, sources, composition; and generation of - municipal solid wastes (MSW); biomedical wastes; e-waste; and hazardous wastes at national and global scale.
- Environmental impacts: Major pollutants; human health effects; ecosystem damage; air quality; water quality; and soil quality.
- Scientific Management: Principles of solid management; UN conventions (e.g Basel Convention); Collection & transportation measures; Segregation techniques; Pre- cautions; physico-chemical characterization (density, field capacity, particle size, field capacity, pH, organic C, NPK, heat value etc.).
- Techniques of resource recovery: Composting; Microbial decay; Anaerobic digestion; Incineration; Pyrolysis, Landfill gas recovery.
- Environmental regulations: Eco-mark & ISO 14000; symbols & color codes; Solid Waste Management Rules, 2016; Plastic Waste Management Rules 2016
- Practical: Proximate analysis; Density & Porosity; pH; Organic C estimation; Visit to Landfills & enumeration of waste composition

Recommended books:

- White P.R. et al, Integrated Solid Waste Management, Lewis Publisher, 1989.
- Manual on Municipal Solid Waste Management, CPHEEO, Ministry of Urban Development, Govt. of India, New Delhi, 2000.
- David L.H.F. and Liptak D. G., Hazardous waste and solid waste, Lewis Publisher, 2000
- Oberoi N.K, Environmental Management, (2nd Edition) Excel Books, New Delhi, 2003.

Practical:

Laboratory experiments: Proximate analysis, Density, Total Organic Carbon, Total Nitrogen, Coliform count

Field visit: Visit to solid-waste and waste-water management sites, sampling, analysis and reporting

***

C9: Environmental Chemistry

L4 T0 P2 CH8 CR6

Course outcomes:

CO1 Comprehensive understanding of the concept of atom, electronic configuration, periodic properties and bonding

CO2 Appreciation of the fundamental of thermodynamics, chemical equilibrium and chemical kinetics and a comprehensive understanding of the chemistry of water, air and soil, and how human activities pose to alter the chemistry

CO3 Comprehensive understanding acid-base concepts, neutralization, and buffer and buffer capacity

CO4 Functional knowledge application on controlling toxic chemicals in the environment, including POPs and emerging pollutants

CO5 Setting up and conducting experiments

Course content:

- Atomic structure, electronic configuration, periodic properties of elements (ionization potential, electron affinity and electronegativity), types of chemical bonds (ionic, covalent, coordinate and hydrogen bonds); mole concept, molarity and normality, quantitative volumetric analysis.
- Thermodynamic system; types of chemical reactions; chemical equilibrium -type and principles, acids, bases and salts, solubility products; solutes and solvents; redox reactions, concepts of pH and pE, Acid-baseequilibria, Acid-base titrations, electrochemistry, Nernst equation, electrochemical cells.
- Basic concepts of organic chemistry, hydrocarbons, aliphatic and aromatic compounds, organic functional groups, polarity of the functional groups, and synthesis of xenobiotic compounds like pesticides and dyes, synthetic polymers.
- Composition of atmosphere; measurement of composition, atmospheric particles – chemistry and sources, carbonaceous nature of aerosol, chemistry of and trace gases, reactions of SOx, NO_x,Hydrocarbon and surface ozone, Acid rain and case studies; free radicals chemistry, photochemical reactions in atmosphere
- Fundamentals of Air pollution, smog, types of smog (London smog and photochemical

smog), and their chemistry. Chemistry of stratospheric ozone and depletion

- Chemical and physical properties of water; alkalinity and acidity of water, hardness of water, calculation of total hardness; solubility of metals, complex formation and chelation; colloidal particles
- Fundamentals of Water pollution – organic matter, oxidation, aquatic microbial/biochemical processes, Acid mine waters, heavy metals, emerging water pollutants, Antibiotic load.
- Fundamentals of soil pollution, POPs, Pesticides, PAHs and PCBs.
- Fundamentals of Green chemistry

Practical:

Analysis of organic carbon, dissolved oxygen (DO), chemical oxygen demand of water samples of a pond.

Analysis of nitrate , sulphate in samples

Measurement of acidity and alkalinity, hardness of water

Separation of organic mixture by distillation

Separation of compounds by chromatography – paper /thin layer

Field visit: sampling of wastewater/soil/sediment; characterization in the laboratory and reporting

Textbooks:

- Manahan S. E, Environmental Chemistry, CRC Press2010
- Girard J., Principles of Environmental Chemistry, Jones Bartlett Learning, 2014

Reference books:

- Harrison R., Principles of Environmental Chemistry, RSC 2007
- Hanrahan G., Key concepts of Environmental Chemistry, Elsevier Inc. 2012

***

C10: Basics of Environmental Statistics and Computer Application

L4 T0 P2 CH8 CR6

Course Outcomes:

CO1 Knowledge of basic statistical parameters CO2

Understand R statistical software

CO3 Able to perform statistical estimation through R Statistical software

CO4 Able to perform data processing and visual presentation using R statistical software CO5

Able to estimate Probability and probability distribution fitting on R

Course Content:

- Introduction, Data presentation, Frequency, Histogram, Basic Statistics (Mean Median, Mode, Standard Deviation, Skewness, Kurtosis), Quantiles, Box, Whisker Plots
- Concept of population, sample, Sample design, Sample size for data analysis, data quality, Quality control
- Probability, Probability distribution, cumulative distribution function, parametric distributions and non-parametric distributions, Estimating distribution parameters, Ordinary least square technique, Maximum likelihood estimates,
- Test of Hypothesis, Goodness of fit test, correlation, covariance, cross correlation,
- Test for stochastic trend, Auto correlation function, partial auto correlation function, Bivariate Regression, Multi variate regression, collinearity, Auto regression, Moving average, Auto Regressive Integrated Moving Average model.

Practical:

R software Introduction, software Module download, Data entry into R Work station, Matrix operation, Statistical Plots generation, Simple statistical analysis in R, Small programme development in R, Test of Hypothesis, Case studies from Different domain of Environment such as air, water, soil and Biodiversity etc.

Textbooks:

- Spiegel M., Stephens LJ, Schaum's Outline of Statistics, McGraw Hill
- Forsyth D., Probability and Statistics for Computer Science, Springer

***

C11 Environmental Pollution and Human Health

L4 T0 P2 CH8 CR6

Course outcomes:

CO1 Knowledge on the types and the science of environmental pollution

CO2 Appreciation of the effect of polluting on human health

CO3 Analytical ability to link cause and effect of pollution CO4

Critical issues of handling pollution vis a vis human being CO5

Ability to develop pollution mitigation/abetment strategies

Course content:

- Environmental pollution – definition, local, regional and global implications, effects of environmental pollution
- Air Pollution: Introduction, air pollutants, types and sources, history of air pollution episodes, air pollution and effects on human health, health effects of Particulate matter, heavy metals (Pb in particular), sulphur dioxide (SO_2), nitrogen dioxide (NO_2), volatile organics, surface ozone and PAHs. Air pollution and physical and psychological wellbeing.
- Respiratory diseases, Cardiovascular damage, Fatigue, headaches and anxiety Irritation of the eyes, nose and throat Damage to reproductive organs, Harm to the liver, spleen and blood Nervous system damage. Air pollution Public health matters, Air pollution source apportionment, regulation, and mitigation.
- Water pollution-introduction, sources of water pollutants, organic matter, organic micro pollutants, microbial pollution, Agriculture and Water pollution, Problems of pesticides and chemical fertilizers, Geogenic Contamination – problems of As and F^- in ground water and human health, Case of As and F^- , Groundwater Contamination by Hazardous Wastes leaching. Industrial and Mining Operations and water pollution, Sewage and waste water, Pharmaceuticals in Wastewater, Sanitation and Drinking Water, waterborne diseases, Wastewater Treatment and Water Reuse, Implications on health – appreciation of Minamata disease, *itai itai* disease, blue baby syndrome.

- Noise pollution: Introduction, noise categories, Noise effects - hearing loss, Cardiovascular effects, Psychological impacts, Stress, Annoyance, effects on Child development Cognitive development, control of noise pollution and regulation
- Land pollution: causes and consequences, MSW – characterization, and impact on public health, emission from waste dumping sites, leaching, biomagnification, Agriculture and land pollution, mitigation measures, Land management through phytoremediation and bio-remediation; Biological mediated pollution control

Practical:

Measurement of particulate matter in air by grab sampling and gravimetric method.

Understanding levels of SOx and NOx in ambient air

Sampling and analysis of organic matter, nitrate, sulphate, TDS and COD of waste water/ contaminated soil

Understanding and comparing noise levels of localities

Field visit: Visit to a local polluted site-Urban/Rural/Industrial/Agricultural, sampling, analysis and reporting, Visit to industry having air-pollution control measures and reporting

Reference books:

- Shaw I.C. and Chadwick J., Principles of Environmental Toxicology, Taylor& Francis, 2008
- Manahan S.E., Environmental Chemistry, Lewis, 1994
- De A. K., Environmental Chemistry, Wiley Eastern Limited, 2000
- Moore J. W., Inorganic Contaminants of Surface Water, Springer-Verlag
- Gurjar B. R., Molina L.T., Ojha C.S.P. (Eds.), Air Pollution: Health and Environmental Impacts, CRC Press
- Elaine M.A. and Bugyi G.(Eds.), Impact of Water Pollution on Human Health and Environmental Sustainability, Information Science Ref.

***

C12: Environmental Instrumentation

L4 T0 P2 CH8 CR6

Course outcomes:

CO1 Knowledge of analytical instrumentations

CO2 Appreciate outputs of analytical data

CO3 Skill developed in the field of environmental instrumentation and analyses CO4

Application of knowledge in setting up and conducting experiments

Course content:

- Basics principles of analytical instruments - spectroscope, diffraction, chromatography, electronic transition, fundamentals of optics and photometry, principles of microscopy
- Spectroscopy: Introduction, basic principles, Electromagnetic radiations and interactions with matters: Define Spectroscopy, Types of spectroscopy, Absorption spectrum, Emission spectra, Wave length and Wave number, Electromagnetic radiation, Quantisation of energy, Electronic, vibrational and rotational spectroscopy. Franck– Condon principle, Jablonski diagram, radiative, non-radiative pathways, fluorescence and phosphorescence. Absorption of radiation, Beer-Lambert's law, deviation of Beer- Lambert's equation and its limitations. UV-Visible spectroscopy, Fluorescence spectroscopy, IR/Raman spectroscopy, Flame Photometry, Atomic Absorption Spectroscopy, NMR Spectroscopy and Mass spectroscopy.
- Principle of diffraction and X-ray diffraction: X- ray spectra, Bragg's law and intensity of X- rays, Mosley's law, XRD techniques
- Introduction to Chromatography: Classification – Theory – distribution coefficient, rate of travel, retention time, retention volume, adjusted retention volume, specific retention volume, column capacity, separation number, peak capacity, shapes of chromatic peak, column efficiency, resolution,
- Gas Chromatography: Principle, carrier gas, stationery phase, instrumentation, sample injection, column detectors (TCD, FID, ECD), effect of temperature on retention, qualitative and quantitative analysis
- High Performance Liquid Chromatography: Principle, instrumentation, column, sample injection, detectors (absorbance, refractive index, electrochemical), mobile phase selection, ion pair chromatography.
- Introduction to sampling techniques and analytical methods to measure environmental

contamination in air, water, soils, and food. Safe Laboratory Practices, Quality assurance and Quality control

Practical:

Measurement of ambient noise

Measurement of atmospheric dust

Calibration and measurement of pH, Conductivity Measurement

light absorbance Vs concentration (Beer's law)

Constructing a calibration curve from chromatograms of calibration standards

Analysis of IR spectra of simple compound

Analysis of NMR simple compounds

Analysis of Mass spectra of simple compounds

Microscopy of environmental samples

Field visit: Visit to a national laboratory (CSIR Lab) to see sophisticated instrumentation facilities. Demonstrations for the students may be organized on request.

Textbooks:

- Skoog D. A. and Crouch S. R., Principles of Instrumental Analysis (7th Edition)
- Ewing G. R., Instrumental Methods of Chemical Analysis (5th Ed.), McGraw Hill.
- Rouessac F. , Rouessac A., Chemical Analysis: Modern Instrumentation Methods and Techniques, Wiley
- Kemp W., Organic Spectroscopy, Palgrave Macmillan, 1991

***

C13: Environmental legislation and policy

L5 T1 P0 CH6 CR6

Course outcomes:

CO1 Understand the Indian constitutional provisions with respect to the environmental protection, division of powers, and fundamental rights

CO2 Appreciation of forest and wildlife laws and environmental laws relating to social justice (Forest Dwellers' Act of 2006; The Biodiversity Act of 2002)

CO3 Comprehensive understanding of pollution control laws (The Water Act, The Air Act and the Environment (Protection) Act of 1986), and rules

CO4 Functional understanding of international Environmental laws (Treaties and Protocols), and Indian commitments

CO5 Appreciate some case studies of environmental litigation

Course content:

- The Constitution of India and provisions – Article 48A (The protection and improvement of environment and safeguarding of forests and wildlife); Article 51 A(g) (Fundamental duties), The right to livelihood, The right to a Wholesome Environment, The Right to Intergenerational Equity, Division of power between the Centre and the States in matters of forest and wildlife, and water
- Forest and Wildlife laws: The Indian Forest Act 1927; The Wildlife (Protection) Act 1972; The Forests (Conservation) Act 1980, National Forest Policy
- Laws for pollution control and Environmental Protection: The Water (Prevention and Control of Pollution) Act 1974; The Air (Prevention and Control of Pollution) Act 1981; The Environment (Protection) Act 1986 and the Rules there after; Initiatives like Ecomarks, ; Noise Pollution (Regulation and Control) Rules 2000, The National Green Tribunal Act 2010
- Laws for social equity and justice: ; The Biological Diversity Act 2002 –National Biodiversity Authority (NBA), State Biodiversity Boards(SBBs), Biodiversity Management Committee (BMC), Public Biodiversity Register (PBR), Access and Benefit Sharing (ABS), Biodiversity Heritage Site (BHS) ideas of patents, Geographical Indicators, Bio-piracy; The Schedule Tribes and other Traditional

Dwellers (Recognition of Forests Rights) Act 2006;The Public Liability Insurance Act 1991;

- International environmental laws, sources of international law, Major conventions and treaties: The Stockholm Declaration of 1972; United Nations Conference on Environment and Development 1992; Rio de Janeiro (Rio Declaration, Agenda 21); Montreal Protocol 1987; Kyoto Protocol 1997; Copenhagen and Paris summits; Ramsar convention: CITES 1973;Convention on Biological Diversity
- Case studies of environmental litigation (case studies that have given new directions and those are from institute's geographical area)

Suggested Readings:

- Divan S. &Rosencranz A., Environmental Law and Policy in India. OUP, 2001.
- Naseem M., Environmental Law in India Mohammad. Kluwer Law, 2011 International.
- Venkat A. Environmental Law and Policy. PHI, 2011
- Sands P., Peel J., Principles of International Environmental Law, CUP 2018
- Abraham C.M. Environmental Jurisprudence in India. Kluwer Law International. 1999.

***

C14: Atmospheric Processes

L5 T1 P0 CH6 CR6

Course outcomes:

CO1 Knowledge of structure and composition of the atmosphere and explain global atmospheric circulation

CO2 Understand the processes involved in the mixing and transport of constitutes against varied stability conditions

CO3 Recognise major geochemical processes involving cycling of constituents

CO4 Recognise major chemical/ photochemical pathways of organic and inorganic gases and their implications including acid rain, smog, ozone depletion, visibility impartment

CO5 Application of knowledge in appreciating the atmosphere of large cities and global atmospheric issues

Course content:

- Atmosphere: composition and structure, mass, Atmospheric pressure, vertical profile of temperature and pressure
- Atmospheric transport, geostrophic flow- Coriolis force, Geostrophic balance, circulation, Vertical transport –temperature lapse rates, Stability, types of stability, latent heat and cloud formation, concept of PBL,
- Turbulence – Definition, Turbulent flux, Parameterization of turbulence,
- Concepts of diffusion, dispersion, Ideas of Eulerian approach, Langrangian approach, The Gaussian plume equation,
- Geochemical Cycles, The Carbon, nitrogen and oxygen cycles, Mass balance of atmospheric CO_2
- Chemical Kinetics – principles of gas phase reactions, rate expressions, Bimolecular reactions, Three-body reactions, reversible reactions and equilibria, Photolysis, free radical reactions
- The stratosphere – the ozone layer, the Chapman mechanism, catalytic ozone loss, agents of loss process, mechanisms, Polar ozone loss- mechanism, PSC formation, The ozone hole
- The greenhouse effect- fundamental of radiation, Solar and terrestrial emission spectra, Radiative balance of the Earth, behaviour of gas molecules- CO_2, H_2O, Methane, etc. and particles,
- Concepts of atmospheric scattering and diffraction, radiative forcing - definition and

application, effect temperature, water vapour and cloud feedbacks, Optical depths, Weather and Climate- tropical weathers and extreme weathers

- Climate change- causes, effects and mitigation/ adaption

Textbooks:

- Jacob D. J, Introduction to Atmospheric Chemistry, Princeton, 2004
- Seinfeld J. H. and Pandis S.N., Atmospheric Chemistry and Physics. Wiley 2006
- Hobbs P. V., Introduction to Atmospheric Chemistry, CUP 2000

Reference books:

- Finlayson-Pitts and Pitts, Chemistry of the Upper and Lower Atmosphere, Academic Press, 2000
- Wallace J. M. and Hobbs P. V., Atmospheric Science: An Introductory Survey, Academic Press, 2006
- Barker J. R., Steiner A. L, Wallington T. J (Eds.), Advances In Atmospheric Chemistry Vol-1, World Scientific 2017
- Jacob D. J. and Brasseur G., Modelling Atmospheric Chemistry, CUP 2017

***

DSE1: Energy and Environment

L5 T1 P0 CH6 CR6

Course outcomes:

CO1 Understanding of solar radiation's spectrum and the energy available from solar radiations

CO2 Should be able to make a distinction between conventional and renewable energy sources

CO3 Understanding of the principles of energy conversion in case of each of the energy sources.

CO4 Should be able to state how the consumption of fossil fuels and biomass leads to adverse impact on health and climate.

CO5 Should have an understanding of the implications of large scale production of power from sources such as hydro, solar, wind etc.

CO6 Should become aware of the government's energy policy

Course content:

- Introduction: concepts of energy, power, heat and work, potential energy, kinetic energy, conservation of energy; energy conversion factors, global energy flows, sun's radiations, energy budget of earth atmospheric system, energy in biosphere, photosynthesis, energy flow in an ecosystem, human influence on energy flows.
- History of energy use sectorial consumption of energy, energy consumption with time, population growth and projections for future.
- Sources of energy: Conventional and nonconventional sources, fossil fuels-coal, gas and oil and their properties, renewable sources-solar (flat plate and Photovoltaic), wind, hydro, ocean thermal, geothermal, tidal, biomass, nuclear, biofuels and the principles of energy generation, fuel cells, hydrogen energy.
- Environmental implications of energy use: air pollution from fossil fuels and biomass, impacts on climate change and health, impacts of large scale use of energy from solar, wind, hydro, ocean thermal energy, geothermal sources and nuclear energy. Thermal pollution-cooling towers, cooling by river water, lakes and ocean, radioactive waste, oil spills. CO2 emission reduction potential from use of renewable energy.
- Energy storage devices, efficiency of energy use and energy policy of the country. Current status of installed capacity and potential of renewable energy sources.

Reference Books:

- Thorndike E. H., Energy and Environment- A Primer for Scientists and Engineers (Addison Wesley, Publishing) 1976.
- Devins D. W., Energy and its Physical Impact on Environment (John Wiley & Sons) 1982.
- Raven P. H. and Berg L. R. Environment (John Wiley & Sons)
- Gilbert M. Masters, Introduction to Environmental Engineering and Sciences (prentice Hall of India) 2008.
- Tindell J. W. and Weir A. D., Renewable Energy Resources (ELBS)
- Shonley J. I. Environmental Applications of General Physics V(Addison Wesley, Publishing)
- Andrew R. W. and Jackson J. M., Environmental Science- The Natural Environment and Human Impact (Longmon) 1996.
- Boyles D. T., Bio Energy: Technology, Thermodynamics and Costs (Ellis Horwood Ltd, John Wiley and Sons) 1984.
- Wilson R. and Jones W., Energy, Ecology and Environment (Academic Press, Inc) 1974.
- Dunderdale J., Energy and Environment (Royal Society of Chemistry) 1990.

***

DSE2: Natural Hazards and disaster management

L5 T1 P0 CH6 CR6

Course outcomes:

CO1 Understand the different types of natural hazard, their major driving forces/factor, and the causes.

CO2 Understand the relationship/interface between geophysical processes and human activities in causing natural hazard

CO3 Hazards Scenario at the global as well as National level

CO4 Understand the mitigation approaches, their choices and alternatives CO5

Develop foundations for hazard, risk and vulnerability assessment

Course content:

- Earth and atmospheric process: basics of plate-tectonic, hydro-geomorphic and atmospheric (energy atmospheric circulation) processes.
- Definitions and associated concepts: natural hazards, risk, vulnerability; Hazards and risk assessment.
- Floods: floods as physical process (river systems, runoff, river activities); causes and factors of flooding, effects of /hazards associated with flooding; response to flood hazards; global and India scenario.
- Earthquake: origin of earthquakes; seismic waves; world's seismicity with emphasis on Indo-Burma region; hazards associated with earthquakes; response to earthquake hazards
- Drought: Cause and impact; types of draughts (meteorological, hydrological, agricultural and socio-economic) response to hazards- mitigation and adaptation; droughts in India
- Cyclones: Genesis; tropical cyclones- formation, frequency and trajectory; impact of cyclones, mitigation and adaptation.
- Landslides: Genesis (slope failure mechanism); causes of landslides, prevention and correction methods; Global and Indian scenario.
- Disaster: definition, causes, natural and man-made, effects- immediate and delayed, disaster management and case studies

Textbooks:

- Bell F.G., Geological Hazards: Their Assessment, Avoidance & Mitigation, Taylor and Francis, 2003.
- Alexander D., Natural Disasters, ULC press Ltd, London, 1993.
- Bryant E., Natural Hazards, 2nd Edition, Cambridge University Press

Reference:

- National Policy on Disaster Management, NDMA, New Delhi, 2009.
- A Global Report - Reducing Disaster Risk, A Challenge for Development; UNDP Publication, 2004

***

DSE3: Environmental Economics

L5 T1 P0 CH6 CR6

Course Outcomes:

CO1 Know the concepts of market and the economics of the environment

CO2 Identify economic solutions to environmental problems and the role of environmental market based instruments

CO3 Apply of economic theories to analyze environmental problems and solutions

CO4 Appreciate risk analysis in providing economic solutions to environmental problems

CO5 Apply economic analysis in environmental decision making process

Course contents:

- Introduction: History and fundamental concept of environmental economics; introduction to economic theories and economic approach to real world environmental problems
- Depletion of natural resources, climate change impacts, degradation of environmental quality, solid and toxic wastes, best management practice and sustainable development, national and international agreements
- Environmental goods, public goods, private goods, common property resources, economic valuation, concept of market, market failure, social costs, private costs, externalities
- Economic Solution, policy instruments and environmental markets, environmental market based instruments: pollution charge, subsidy, deposit refund system and pollution permit trading system; scenario of environmental market worldwide
- Economic analysis vis-à-vis benefit-cost analysis in environmental decision making – present value, future value, inflation correction; comparing environmental benefits and costs
- Risk analysis: risk assessment and risk management
- Case studies: air quality regulation, water quality regulation, solid and toxic waste regulation
- Economic issues of ABS(Access Benefit Sharing) as per Biodiversity Act 2002
- Concepts related to Life Cycle Assessment of products and economic concerns
- Methods of assessing Natural Capital of economic terms

Textbooks:

- Field, B.C. and Field, M.K., Environmental economics: an introduction. Sustainable Human Development Review, 105, 1997.
- Singh, K. and Shishodia, A., Environmental economics: Theory and applications. SAGE Publications India, 2007.
- Andersen, M.S. and Sprenger, R.U. eds., Market-based instruments for environmental management: politics and institutions. Edward Elgar Publishing, 2000.

Reference Books:

- Quah, E. and Haldane, J.B.S., Cost-benefit analysis. Routledge, 2007.

Suggested Readings:

- Willis, G. and Garrod, K.G., Economic valuation of the environment. Methods and case studies. Environ Res Econ, 21, pp.101-102, 1999.

***

DSE4: Land and Soil Conservation and Management

L5 T1 P0 CH6 CR6

Course Outcomes:

CO1 Understand principles of water and land management

CO2 Describe the basics of hydrology, soil conservation, groundwater, irrigation and drainage, and watershed

CO3 Understand impact of human action on soil and land

CO4 Critically examine the issues of Soil and Land in the environmental perspectives

CO5 Apply knowledge in water and land conservation projects

CO6 Natural forest, grassland, wetland etc. Eco restoration techniques and case

Course content:

- Introduction: Engineering in land and water management, land and water management and agricultural production, soil and water conservation, groundwater and wells, irrigation and drainage management, watershed management, environmental management, concept of sustainable development.
- Land resources for agriculture: Land classification, land capability classification, USDA system, land evaluation (US system of soil taxonomy), FAO framework for land evaluation, land degradation, land improvement, agro climatic zoning.
- Hydrologic cycle: Components, precipitation, rainfall-rain gauges, analysis of rainfall data, frequency, average depth, runoff-factors affecting, methods for estimation, runoff hydrograph, unit hydrograph.
- Water measurement: Fundamental equations, measurement of flow in open channels-velocity area methods, direct methods, measurement of flow in pipes- volumetric measurement, flow rate measurement, water level recording equipment.
- Basic soil water relations: Volume and mass relations, soil texture, soil structure, soil water, energy concept of soil water, soil moisture characteristics and it's measurement, available water, soil sampling devices, dynamics of soil water- Darcy's law, permeability and hydraulic conductivity, lab. determination of hydraulic conductivity. Infiltration-equations, drainable pore volume.
- Crop water requirements: Methods- energy balance, climatological approaches,

evaporation pans, Evapotranspiration- estimation, crop coefficient, water balance method, lysimeters and evaporimeters, irrigation requirements of crops, irrigation scheduling, duty and delta of water

- Land grading and layout: Factors affecting, planning and survey, calculations- various methods, equipment.
- Conveyance and application of irrigation water:

  Types of channels, design of open channels, velocity and discharge, most economical channel section, lining, structures, water diversion and control, water application appliances, underground pipeline systems, ancillary structures and devices, surface irrigation methods-border, check basin, furrow, drip, sprinkler, irrigation efficiencies.
- Agricultural Drainage:

  Salt affected soils- classification, irrigation water quality, reclamation. Causes of waterlogging, surface drainage- systems, design discharge and drainage coefficient, sub-surface drainage methods, tile and mole drains.
- Soil erosion principles:

  Soil erosion- effects, causes, types, factors affecting, measurement of soil loss and sediment yield, USLE. Soil erosion control- agronomical and structural measures- contour cultivation, strip cropping, contour trenching, bunding, bench terracing. Wind erosion and its control, stream bank erosion and its control, gully erosion and its control.
- Integrated Watershed management:

  Definition, strategies, socio-economic issues, objectives, selection of priority area, micro planning, Public participation in watershed management, sedimentation of reservoirs and its control, watershed work plans. Farm ponds- types, components and design.
- Ecorestoration:

  Basic concepts, Methods for restoring naturalness in forests, grasslands, wetlands etc (degraded forests, drained wetlands, polluted rivers, grassland restoration, mangrove afforestation, coral reef restoration)

Textbooks:

- Moorthy V. V. N., Land and water management, Kalyani, 2006

Reference books:

- Larsson G. , Land Management as Public Policy, University Press of America 2010
- Howell E. A., Harrington J. A., Glass S. B., Introduction to Restoration Ecology , Island Press, Washington, United States, 2011.

***

DSE5: Soil Remediation and Restoration

L5 T1 P0 CH6 CR6

Course outcomes:

- Ability to think and function as a prudent professional soil scientist.
- Generate and analyze soil quality data towards sustainable solutions.
- Apply the gained knowledge to practical situations.
- Ability to respond flexibly towards restoration of problematic soils of specific areas.
- Demonstrate and train farmers/growers to establish sound soil quality maintenance practices.

Course content:

- Soil Formation: Weathering and Soil formation; Profile development; Soil composition; Soil forming rocks and minerals; Classification
- Soil physico-chemical properties: Soil texture and structure; Soil separates and particle size distribution; Bulk density, particle density, pore space, soil water; Soil colloids; pH, Eh, CEC, base saturation
- Problem soils: Nature and extent of problem soils in India; Physico-chemical properties of acid soils, saline soils, alkaline soils, acid-sulfate soils
- Soil pollution: Heavy metal pollution; organic pollutants in soil; impacts on soil micro-organisms; bio-indicators of soil pollution
- Soil erosion and desertification: Soil erosion (definition, mechanism of water and wind erosion); Nature and extent of desertification in India; cause and effects on agriculture and sustainability issues
- Soil & Plant relations: Soil organic matter; Decomposition; Humus formation; Significance on soil fertility, nutrient availability
- Remediation measures: Treatment of problem soils (liming, salt eradication, treatment of saline and alkaline soils); heavy metal removal/localization.
- Restoration: Vegetation recovery (tolerant species, using hyper accumulators, etc.); soil organic matter application; mulching; mechanical measures (contour trenching, contour mulching, drainage, etc.)

Recommended books:

- Arakeri H.R. and Roy D.; Principles of Soil Conservation and Water Management; Oxford IBH Pub. Co. Pvt. Ltd.; 2000
- Brady N.C., and Weil R.R. Elements of the Nature and Properties of Soils, 3rd Ed. Prentice Hall, 2010.
- Stewart B.A., Advances in soil sciences, Lewis Publisher, 2000.
- Biswas T.D. and Mukherjee S.K., Textbook of Soil Sciences, Publisher: McGraw-Hill
    - Inc., US, 2nd edition, 1995.

***

DSE 5A: Environmental modelling

L4 T0 P2 CH8 CR6

Course outcomes:

- Understand mathematical and statistical concepts required for model development.
- Understand different environmental systems, their components, processes and their interconnections.
- Perform data exploration and visualization
- Understand the importance and implications of quantifying uncertainty in environmental assessment, modelling
- Test model performance in terms of statistical error estimation

Course content:

- Introduction: Principles of model development, Types of models, Physical models, Statistical Models, Conceptual models, basic elements of Model building.
- Mathematical Concepts: Matrices, system of linear equations, Series and sequences, Difference Equations, Differential and partial differential equations, Integrals (Line, area and volume), Permutations, Combinations, Simple Probability, Conditional probability, Probability distributions,
- Environmental System and Processes: Natural and artificial systems, characters and components of the system, measures and concentrations, processes categories, transport process, transformation processes.
- Model Framework: Stochastic Models, Dynamic models, Approaches to modelling, Uncertainty measurement, Model Verification and validation, Model feedback systems

Practical:

Simulation Model: Simile Simulation model operation and testing

Environmental System Equations: Case study for Water Pollution, Air Pollution, Soil Pollution, Water Biodiversity

Statistical Modelling: Simple Stochastic Models: Auto Regressive Model, Moving

Average Model, Multivariate Regression Model.

Recommended books:

- William G. Gray W.G. and, Gray G.A., Introduction to Environmental Modeling, CUP
- Holzbecher E., Environmental Modeling: Using MATLAB, Springer
- Wainwright J., Mulligan M (Ed) Environmental Modelling: Finding Simplicity in Complexity, Wiley

***

DSE 6: Water Treatment Technology

L4 T0 P2 CH8 CR6

Course Outcomes:

CO1 Select the sources of water for various water uses.

CO2 Explain unit operations and processes of water treatment systems.

CO3 Apply the principles and design water treatment units.

CO4 Apply concepts and will be able to design the water treatment plant.

Course contents:

- Introduction, Population Forecasting and Water Demand
- Water Quality: Definitions, Characteristics and Perspectives
- Physical water quality parameters, Chemical water quality parameters, Biological water quality parameters, water quality requirement, water quality guidelines and standards for various water uses.
- Water Purification process in Natural system
- Physical process, Chemical process, Biochemical processes, response of stream to biodegradable organic waste, application of natural processes in engineered system
- Engineered systems of water purification
- Overview of water treatment, water treatment process
- Aeration: Principles and design of aeration systems –two film theory, water in air system, air in water system.
- Solid Separation and settling operations: principles of sedimentation –types of settling and settling equations, design criteria and design of settling tanks.
- Coagulation and Flocculation: Principle of Coagulation and Flocculation –types of coagulants, coagulant aids, coagulation theory, optimum dose of coagulant, design criteria
- Filtration: Types, hydraulics of filter bed, design criteria and design of filters, filter backwash, operational problems and trouble shooting.
- Disinfection: Types of disinfectants, factors affecting disinfection, methods of disinfection, chemistry of chlorination.
- Water Softening

Practical:

Laboratory experiments: Alkalinity Test; Turbidity Test; pH and Conductivity Test; Estimation of Hardness; Estimation of BoD and CoD; Estimation of residual chlorine

Field Visit: Visit to a water treatment site, sampling, analysis, and reporting on the same; Visit to a STP or ETP site and reporting

Textbooks:

- Garg S.K., Water Supply Engineering (Vol-I & II), Khanna Publishers
- Peavy H.S., Rowe D.R. & Tchobanoglous G., "Environmental Engineering". McGraw Hill International Edition.
- Karia G.L., Wastewater Treatment: Concepts and Design Approach, PHI, 2013.

Reference books:

- McGhee T. J., "Water Supply and Sewerage", McGraw-Hill, Inc., 1991.
- Davis M. L. & Cornwell D. A., "Introduction to Environmental Engineering", McGraw- Hill, Inc.,1991.
- Metcalf & Eddy, "Wastewater Engineering- Treatment and Reuse," Tata McGraw Hill, 4thEdn., 2003.
- Sawyer C. N., McCarty P. L., Parkin G. F., "Chemistry for Environmental Engineers", McGraw-Hill, 1994.
- Punmia B.C., Environmental Engineering (Vol-I & II), Laxmi Publishers.

***

DSE 6A: Air Pollution Monitoring and Control

L4 T0 P2 CH8 CR6

Course Outcomes:

CO1 Able to differentiate between primary and secondary pollutants

CO2 Familiarise with different sources and sinks of common air pollutants

CO3 Develop understanding about different types of monitoring techniques available for gaseous and particulate matter.

CO4 Able to do sampling and analysis of air pollutant

CO5 Develop an understanding of working of air pollution control devices

Course Content:

- Introduction: Definitions, types of air pollutants, Sources of air pollution: Point source, area source, Volume source; criteria pollutant, Air Quality Index, Ambient air quality standards, Vehicle emission standards.
- Air pollution meteorology, Atmospheric Reactions and Scavenging processes.
- Effect of Air pollution on plants, animals, humans, biodiversity, agriculture etc,
- Air pollution sampling methods: Sampling from point sources (Stack Monitoring, vehicles), ambient sampling methods. Online and offline sampling instruments for gaseous and particulate air pollutants.
- Air pollution control methods: industrial source control technology: Cyclone, Electrostatic Precipitator, Baghouse Filter, Venturi Scrubber – principle and use, its limitations.

Practical:

Monitoring of Total Suspended Particulate Matter (TSPM); monitoring of SO_2, NO_2, NH_3, CO and O_3, Exposure analysis of SO_2, NO_2 and CO, to plants leaves; Field Visit to nearby industries for studding different control technology

Suggested books:

- Allegrini I, DeSantis F. (Ed), Urban Air Pollution: Monitoring and Control Strategies, Springer
- Clarke A.G., Industrial Air Pollution Monitoring, Springer

***

DSE7: Environmental Biotechnology

L4 T0 P2 CH8 CR6

Course Outcomes:

CO1 Knowledge on scope of biotechnology in environmental applications

CO2 Knowledge of microbiology and biochemistry

CO3 Ability to perform various molecular biological applications, and knowledge of equipment used in molecular biological techniques

CO4 Ability to apply molecular biological techniques in pollution management and industrial applications

CO5 Knowledge of advanced biotechnological applications, and biosafety in analytical procedures

Course content:

- Introduction: Introduction and history, scope of environmental biotechnology
- Biochemistry and molecular biology: Cell as a unit of life, cellular components, biomolecules, enzymes, molecular genetics – nuclear material, central dogma, replication, repair and recombination of genetic material, translation, transcription, mutation
- Molecular biological techniques: DNA and RNA purification; isolation of plasmid; polymerase chain reaction; cloning and recombinant technology; enzyme assays; biochemical assays (identification of microbes); enzyme-linked immunosorbent assay (ELISA); instrumentation-UV-visible and fluorescence spectroscopy), electron microscopy techniques (SEM and TEM), high performance liquid chromatography(HPLC), laminar air flow, hot air oven, microwave, incubator, gel electrophoresis, pH meter, Fourier-transform infrared spectroscopy (FTIR) and X-ray diffraction (XRD)
- Microbiology and industrial applications: classification of microorganisms, microorganisms in extreme environment, pathogenic and useful microorganisms, microbial enzymes in industrial applications; involvement of microorganisms in fermentation; production of biofertilizers, biogas, bioethanol and biopolymers; and food industry
- Biotechnological applications in pollution management: solid waste management and

waste water treatment; role of microorganisms in sewage treatment and degradation of municipal solid waste; degradation of plastics and polymers using microorganisms

- Environmental remediation: Bioremediation-remediation of toxic compounds using plants and microorganisms; Nanobiotechnology – green synthesis of nanomaterials, application of nanomaterials in combating environmental pollution
- Advanced environmental biotechnology applications: biofilms, biosensors and genetically engineered microorganisms in environmental applications; significance and importance of biocorrosion and bioleaching in environmental pollution
- Biosafety in analytical procedures

Practical:

Study laboratory equipment – Compound Microscope; Laminar Air Flow, Autoclave, Spectrophotometer and other basic equipment used in the laboratory

Preparation of different culture media, sterilization of media, pour plate techniques, solid media in test tubes; microbial culture, inoculation techniques, streaking, spreading and replication; microbial cell counting by serial dilution technique and pour plate technique

Identification of microorganisms through biochemical tests (bacteria/fungi/virus); screening of useful microorganisms from several hosts/extreme environment (example – cellulose producing microorganism)

DNA extraction and purification techniques

Study of alcoholic and mixed acid fermentation techniques

Textbooks:

- Jördening, H.J. and Winter, J. eds., Environmental biotechnology: concepts and applications. John Wiley & Sons, 2005.
- Singh, B.D. and Singh, B.D., Biotechnology expanding horizons. Kalyani publishers. 2007.
- Lehninger, A.L., Nelson, D.L., Cox, M.M., Lehninger principles of biochemistry. Macmillan, 2005.
- Elliott, W.H., Elliott, D.C. and Jefferson, J.R., Biochemistry and molecular biology (Vol. 2001, p. 586). Oxford: Oxford University Press, 1997.

- Wang, L.K., Ivanov, V., Tay, J.H. and Hung, Y.T. eds., Environmental biotechnology (Vol. 10). Springer Science & Business Media, 2010.
- Rittmann, B.E. and McCarty, P.L., Environmental biotechnology: principles and applications. Tata McGraw-Hill Education, 2012.

Reference Books:

- Patel A.H., Industrial microbiology. Macillan India Ltd, 2000.
- Nalwa, H.S. ed., Nanostructured materials and nanotechnology: concise edition. Elsevier, 2001.
- Doble, M., Kruthiventi, A.K. and Gaikar, V.G., Biotransformations and bioprocesses. CRC Press, 2004.
- Hambleton, P., Melling, J. and Salusbury, T.T. eds., Biosafety in industrial biotechnology. Glasgow: Blackie Academic & Professional, 1994.

***

DSE 8: Industrial Health and Safety

L5 T1 P0 CH6 CR

Course Outcomes:

CO1 Ability to provide industry with inputs on health and safety.

CO2 Internalize ISO 14001 and its implications for an industry.

CO3 Learn and disseminate issues related to occupational health and hazards.

CO4 Protocol development for an industry on disaster prevention, health issues, safety measures and environment management.

Course Content:

- Generate material, courses for workers and sensitization of industry managers.
- Be able to design and help recognition of an industry for IS014001.
- Work out measures for an industrial campus on all situations that could lead to a disaster, or a gradual degradation of the environment.
- Test and monitor industrial health and safety of an industry, and suggest remedies to fill gaps in implementation.
- Strategic management and planning and tools for implementing health and safety measures.
- Management of communicable diseases.
- Principles of accident prevention.
- Set up measures for altering organisational behaviour and risk management

References:

- Reese C.D. (Occupational Health and Safety Management: A Practical Approach, Third Edition, CRC Press, 2017
- Smedley J., Dick F., and Sadhra S. (Eds), Oxford Handbook of Occupational Health (2 ed.), Oxford University Press, 2013
- Dentch M.P., The ISO 14001:2015 Implementation Handbook: Using the Process Approach to Build an Environmental Management System , ASQ, 2016.

***

SEC1: Remote sensing and geographic information system and modelling

L4 T0 P0 CH4 CR4

Course outcomes:

CO1 Building a foundation for understanding Remote Sensing and Geographic Information System (RS-GIS) as a powerful tool for geospatial analysis.
CO2 Build the foundation of understating of cartography, digital image, spatial and non-spatial data and geospatial terminology.
CO3 Learn about data and sources (RS based and other sources, field data collection) and integrate those into GIS environment for analysis.
CO4 Appreciate the application of RS-GIS techniques to the matrices of environment and Resource management.
CO5 Obtain Basic competence in skills with functional knowledge of the fundamentals to carry out GIS (RS-GIS) based project.

Course content:

- Remote Sensing: definitions and principles; electromagnetic (EME) spectrum; interaction of EMR with Earth's surface; spectral signature; satellites and sensors; aerial photography and image interpretation.
- Geographical Information Systems: definitions and components; spatial and non-spatial data; raster and vector data; database generation; database management system; land use/ land cover mapping; overview of GIS software packages; GPS survey, data import, processing, and mapping.
- Applications and case studies of remote sensing and GIS in geosciences, water resource management, landuse planning, forest resources, agriculture, marine and atmospheric studies.
- Basic elements of statistical analyses: sampling; types of distribution – normal, binomial, poisson; measurements of central tendency and dispersion; skewness; kurtosis; hypothesis testing; parametric and non-parametric tests; correlation and regression; curve fitting; analysis of variance; ordination.
- Hands-on: Based on the theory.

Textbooks:

- Lillesand T. M., Remote Sensing and Image Interpretation. John Wiley, 7th Edition, 2015
- Burrough P.A. and McDonnell R.A., Principles of Geographical Information Systems. 2nd Edition, Oxford University Press, 2006.

Reference books:

- Jense J. R., Remote Sensing of the Environment – An earth resource perspective. Pearson Education, 2nd Edition, 2013

***

SEC2: Environmental impact assessment (EIA)

L4 T0 P0 CH4 CR4

Course outcomes:

CO1 Explain the environment and its natural, and socio-economic and cultural components, and its temporal and spatial dimensions

CO2 Comprehensively understand of the origin and development of EIA and the developments in India

CO3 Appreciate the EIA process

CO4 Define impact and identify, and predict impacts

CO5 Understand the Indian EIA process and clearance regime and functional knowledge of environmental management plan (EMP), and environmental audit

Course content:

- Define Environment and its components, characteristics of Impact, and Projects and stages. Environmental impact assessment (EIA): definitions, introduction and concepts; rationale and historical development of EIA; Components and EIA
- The EIA Process, scope and methodologies; role of project proponents, project developers and consultants; Terms of Reference; impact identification and prediction; baseline data collection; Public consultation in EIA.
- Environmental Impact Statement (EIS), Environmental Management Plan (EMP).
- EIA regulations in India; status of EIA in India; current issues in EIA; case study of hydropower projects/ thermal projects.
- Rapid EIA; Strategic Environmental Assessment; Social Impact Assessment; Biodiversity Impact Assessment; Cost-Benefit analysis; Life cycle assessment; environmental appraisal; environmental management - principles, problems and strategies; environmental planning; environmental audit
- Risk assessment: introduction and scope; project planning; exposure assessment; toxicity assessment; hazard identification and assessment; risk characterization; risk communication; environmental monitoring; community involvement; legal and regulatory framework; human and ecological risk assessment.

Textbooks:

- Barrow, C.J. Social Impact Assessment: An Introduction. Oxford University Press. 2000.
- Glasson, J., Therivel, R., Chadwick, A. Introduction to Environmental Impact Assessment. London, Research Press, UK. 1994.

Reference books:

- Judith, P. Handbook of Environmental Impact Assessment. Blackwell Science. 1999.
- Marriott, B. Environmental Impact Assessment: A Practical Guide. McGraw-Hill, New York, USA. 1997.

Suggested readings:

- The environment (Projection) Act 1986
- The Environmental Impact Assessment Notification, 1994, GoI
- Environmental Impact Assessment Notification, 2006

***

GE1: Wildlife Conservation and Management

L5 T1 P0 CH6 CR6

Course outcomes:

CO1 Understand basic ecological principles (the interconnectedness of organisms to each other and their environment) to environmental problems and sustainability issues.

CO2 Articulate fundamental concepts in wildlife conservation and management.

CO3 Apply understanding of cultural, historical, and current perspectives on the human-wildlife relationship to effectively address wildlife issues.

CO4 Identify the primary international, national, and state agencies and scientific organizations, responsible for conservation and management of wildlife, and understand the role of private citizens in decision-making at all levels.

CO5 Make informed decisions about wildlife conservation and management by critically evaluating information sources.

CO6 Appreciate current threats to biodiversity.

CO7 Be capable of assessing status of wildlife and biodiversity.

Course content:

- Introduction: Definition of wildlife (instrumental, intrinsic, ecocentric, religious, conservational); Aldo-Leopold's land ethics; Indian wildlife; Protected areas in India; Legal instruments (Wildlife Protection Act, 1972; Forest Dwellers Act, 2006; Biodiversity Conservation Act, 2002); Threats to wildlife; Wildlife trade and role of CITES,
- Overview of protected areas in India: Biodiversity within an outside protected areas and in protected areas
- Threats to wildlife– extinction , island biogeography, endemic and endangered species and vulnerability to extinction , habitat destruction, fragmentation, exotic species and invasive, lots of biodiversity
- Wildlife behaviour: Group living; Migration patterns; Predation behaviour; Selfishness and altruism; Evolutionary stable strategies; Concept of optimality in animal decision making; Optimal foraging theory
- Conflicts between man and wildlife: Elephant-man conflict; Rhino-man conflict; River dolphin-man conflict; Tiger-man conflict; Leopard-man conflict; Conflict management

and shifting from extraction to preservation; Response system between human-wildlife conflict

- Conservation measures: Man and Biosphere program (MAB); Resource portioning and niche theory; Issue of food and water scarcity; Conservation and reconstruction of forest landscape; Captive breeding, relocation and rehabilitation of fauna, corridors for protected areas and significance of landscape management, buffer management , fire control, poaching and illegal activities.
- Wetland management: structure, function, food chains, food webs, threats and conservation. Eco restoration of wetland
- Management of coastal and marine ecosystem: coral reefs, distribution, structure, function, threats and conservation
- Wildlife heath monitoring: Rescue measures for wounded animals; First aid for animal injuries; Animal health management; Population viability and habitat analysis (PVHA); National and International organizations involved in wildlife health management
- Current issue in wildlife conservation: Community based conservation vs. rare species conservation; Climate change and wildlife movement; Ecological services of wildlife; Ecotourism and wildlife; Habitat fragmentation and wildlife corridors
- Sustainability in wildlife management: Collaborative partnership for sustainable wildlife management; Voluntary relocation of local communities; Use of barriers, deterrents, and alternative cropping on wildlife management; Land-use planning; Shared governance, education and awareness-raising; Zoonotic disease management

Self-learning:

- Orientation to field biology and natural history
- Observations and collection of study material, wildlife signs and evidences.
- Exercise on wildlife population parameters and census methods for various species.
- Types of sampling- quantitative , qualitative for flora and fauna
- Estimation of frequency, density, abundance of species.
- Field tour designed to examine wildlife conservation issues in a variety of ecological situations in a bio-geographic zone of India.
- Assignments, seminars, and report at the end of the course.
- Current tools in the wildlife management:

- Tiger census using Mstripes and radio collaring, satellites and camera traps

Recommended books:

- Saha, G.K., and Majumdar, S. Wildlife Biology: An Indian Perspective, Prentice Hall of India. 2017.
- Kaushik, A., and Garg, G. Perspectives in Environmental Studies, New Age Publishers. 2018.
- Rangaraj, M. India's Wildlife History: An Introduction, Oxford Press, 2006.
- Rangaraj, M. and Sivaramakrishna, K. Shifting Ground: People, Animals and Mobility in India's Environmental History, Oxford Press, 2014.
- Bindra, P.S. The Vanishing: India's Wildlife Crisis, Penguin Books. 2017.
- Sinha, S. Handbook on Wildlife Law Enforcement in India, WWF Press. 2011.
- Reidinger, R. F. and J. E. Miller. Wildlife Damage Management: Prevention, Problem Solving and Conflict Resolution. The John Hopkins University Press. 243pp. 2013.
- Conover, M. R. Resolving Human-Wildlife Conflicts: The Science of Wildlife Damage Management. CRC Press. 418 pp. 2001.
- Woodroffe, R. et al. People and Wildlife, Conflict or Co-existence? Cambridge University Press. 516 pp. 2005.
- Caughley, G., and A.R.E. Sinclair, editors. Wildlife Ecology and Management, Blackwell Science. 1994.
- Sutherland, W.J. The Conservation Handbook: Research, Management and Policy. Blackwell Sciences. 2000.

***

GE2: ENVIRONMENT AND GENDER

L5 T1 P0 CH6 CR6

Course outcomes:

CO1 Understand the relation between gender and environment

CO2 Understand environmental issues through the perspective of gender

CO3 Develop a critical understanding of the physical environment and social environment

Course content:

This course will begin with a brief introduction to theme of gender in society. It will introduce students to the social, political and economic status of women in society with special reference to their marginalized position. Some of the basic concepts used to address gender inequality will be introduced. The course will map the trajectory of feminist movements over the years along with the major theoretical debates in feminism. Along the course the students will be exposed to the vital relation between gender and environment. It will help them understand environment from a more sensitive and informed perspective.

Outline:

- GENDER INEQUALITY: Difference between sex and gender; Social construction of gender; Gender discrimination; Patriarchy.
- FEMINIST THEORIES: Definition of feminism; Basic types of Feminism: Liberal Feminism, Socialist Feminism, Radical Feminism.
- FEMINIST MOVEMENTS: First wave; Second Wave; Third Wave
- GENDER AND ENVIRONMENT: Women and agriculture; Women and their relationship to land; Nature-nurture debate.
- ECOFEMINISM: Definition; Types of ecofeminism; Ecofeminism and sustainable development; Deep Ecology
- ETHICS OF CARE: Women as care givers; relation between women and their caring nature
- WOMEN AND ENVIRONMENTAL MOVEMENTS: Contribution of women in various environmental movements.
- GENDER AND SUSTAINABLE DEVELOPMENT: Androcentric development and gender inequality; Gender equality as a route to sustainable development.

RECOMMENDED READINGS:

- Cheney J. 'Eco-Feminism and Deep Ecology', *Environmental Ethics*, 9 (2): 115-145, 1987
- Gilligan C. *In a Different Voice: Psychological Theory and Women's Development*, Cambridge: Harvard University Press, 1982.
- Mies, Maria &Vandana Shiva, *Ecofeminism*, Jaipur: Rawat Publications. 2010
- Noddings, N. *Caring: A Feminine Approach to Ethics and Moral Education*, Berkeley: University of California Press.1984
- Tong R. *Feminist Thought: A Comprehensive Introduction*, Oxfordshire: Routledge.1997
- Warren, K. J. "Feminism and Ecology: Making Connections", *Environmental Ethics*, 9 (1): 3-20, 1987
- Warren, K. J. *Ecofeminism: Women, Culture, Nature*, Jaipur: Rawat Publications. 2018

***

GE3: Green Technologies

L5 T1 P0 CH6 CR6

Course Outcomes:

CO1 Knowledge on importance and significance of green technology

CO2 Knowledge on development and application of innovative technologies in conversion natural forms energy to economically and environmentally feasible forms

CO3 Ability to develop, fabricate and utilize eco-friendly and cost-effective products in a variety of applications, and green design in building and infrastructure

CO4 Ability to understand the role of green technology in resource generation, employment and improvement of livelihood standards

CO5 Knowledge of various environmental monitoring and assessment tools, and industrial safety and hazard analysis

Course content:

- Introduction: History, concept and current scenario of green technology; green technology and sustainability
- Development and application of innovative technologies in conversion natural forms of energy such as hydro-energy, solar energy, wind energy, tidal energy and geo-thermal energy to economically and environmentally feasible forms
- Development, fabrication and various applications of eco-friendly biosensors, nanomaterials, biopolymers, biogas, bioethanol and biofuel
- Development and application of eco-friendly and cost-effective tools in environmental pollution management and agricultural activities
- Green design, building and infrastructure
- Role of green technologies in resource generation, employment and improvement of livelihood standards
- Life cycle assessment (LCA), life cycle costing (LCC), material flow analysis (MFA), cost benefit analysis (CBA), cost-effective analysis (CEA), carbon footprint, ecological footprint, and eco-labelling
- Environmental management system (EMS), and industrial safety and hazard analysis

Textbooks:

- Bewick, M.W., Handbook of organic waste conversion. Van Nostrand Reinhold Co. 1980
- Rai, G.D., Non-conventional sources of energy. Khanna Publishers, 2013
- Kiang, Y.H., Waste energy utilization technology. United States, 1981.
- Sanghi, R. and Srivastava, M.M., Green Chemistry: Environment Friendly Alternatives. Alpha Science Int'l Ltd. 2003.

Reference Books:

- Abele, E., Anderl, R. and Birkhofer, H., Environmentally-friendly product development. Springer-Verlag London Limited, 2005.
- Moss, T. and Marvin, S., Urban infrastructure in transition: networks, buildings and plans. Routledge, 2016.
- Green, L., Communication, technology and society. Sage, 2002.

Suggested Readings:

- Murugesan, S., Harnessing green IT: Principles and practices. IT professional, 10(1), pp.24-33, 2008.
- Kumar, A., Bisht, B.S., Joshi, V.D. and Dhewa, T., Review on bioremediation of polluted environment: A management tool. International journal of environmental sciences, 1(6), p.1079, 2011.
- Soyez, K. and Plickert, S., Mechanical-biological pre-treatment of waste: State of the art and potentials of biotechnology. ActaBiotechnologica, 22(3-4), pp.271-284, 2002.
- Krass, D., Nedorezov, T. and Ovchinnikov, A., Environmental taxes and the choice of green technology. Production and operations management, 22(5), pp.1035-1055, 2013.
- Curran, M.A., Environmental life-cycle assessment. The International Journal of Life Cycle Assessment, 1(3), pp.179-179, 1996.
- Asiedu, Y. and Gu, P., Product life cycle cost analysis: state of the art review. International journal of production research, 36(4), pp.883-908, 1998.
- Darnall, N. and Edwards Jr, D., Predicting the cost of environmental management system adoption: the role of capabilities, resources and ownership structure. Strategic management journal, 27(4), pp.301-320, 2006.

***

GE4: Environment and Society

L5 T1 P0 CH6 CR6

Course outcomes:

CO1 Understand the human surrounding and the role of human being in shaping the surrounding

CO2 Ability to understand the need to address current environmental issues

CO3 Ability to draw conclusions form environmental movements, environmental legislations,

CO4 Knowledge on forest and environment, agriculture and environment, and institutional initiatives in the field of environment

CO5 Knowledge on the role of Indian traditions and culture in environment and its priorities

Course content:

- Human beings and environment: the competition within, environmental degradation, conservation
- Current environmental issues– pollution, trans boundary issues, biodiversity loss, climate change, urbanization, land degradation, Environmental issues of urban areas, solid wastes, e-wastes, hazardous wastes, The Bhopal gas tragedy
- Role of the society – interest groups, awareness and conservation, rights and duties, the constitutional provisions – Article 48A and Article 51A(g), environmental legislations, green benches, international cooperation, Indian commitments
- Economy of the environment, environmental good, Natural Resources, resource use and depletion, Common property resources, the tragedy of commons, sustainable development
- Environmentalism, Environmental movements – Chipko, Appiko, Narmada Bachao Andolan, Bishnoi movement
- Issues with Indian agriculture – modern Vs organic agriculture, crop biodiversity Vs monoculture, energy and water availability, agro-marketing, farmers' wellbeing and subsistence
- The Panchayati raj, participatory development, institutional initiatives for - resource development, sanitation and hygiene, social forestry, joint forest management, sacred groves

- Environmental issues of Indian villages, biomass mass burning, exposure risk and gender,

water availability, Water and gender, migration Indian traditions and conservation Indian environmental priorities

Reference books:

- Poulopoulos, S. G., and Inglezakis V.J., Eds. *Environment and Development: Basic Principles, Human Activities, and Environmental Implications*. Elsevier, 2016.
- Harper, C. and Snowden M. *Environment and society: Human perspectives on environmental issues*. Routledge, 2017.
- Barr, S. *Environment and society: Sustainability, policy and the citizen*. Routledge, 2016.

Suggested readings:

- Schumacher, E. F. *Small is beautiful: A study of economics as if people mattered*. Random House, 2011.
- Hardin, G.. "The tragedy of the commons." *science*162.3859 (1968): 1243-1248.
- Carson, R.. "Silent spring. 1962." (2009).
- Agarwal, A. and Narain, S. eds. *Dying Wisdom: Rise, fall and potential of India's traditional water harvesting systems*. Centre for Science and Environment, 1997.

***

GE5 Fundamentals of Ecotourism

L4 T0 P2 CH8 CR6

Course Outcomes:

CO1Appricate concepts of ecotourism and its management

CO2 Understand values of wildlife and minimizing impact on natural ecosystem due to tourism

CO3 Learn basic concepts of ecotourism facility management and hospitality needs.

CO4 Appreciate sustainability in ecotourism

Course content:

- Introduction Ecotourism: concepts and definitions; Evolution and characteristics of ecotourism;
- Ecotourism guidelines: National and State level ecotourism guidelines; Laws, Tourism bill of rights; code for environmentally responsible tourism; World Ecotourism Summit
- Tourism Impacts, Economic, social, political and environmental impacts, Sustainable Ecotourism – prospects and Challenges,
- Geography of India India's biodiversity, Parks and Sanctuaries, Environmental concerns
- Community based Ecotourism, Significance of ecotourism planning Carrying capacity and development Benefits of sustainable tourism; Peoples' initiatives on Ecotourism, Community Education and Public Awareness (CEPA)
- Case study- ecotourism development in a hill station (existing infrastructural development and alternative measures to be suggested)
- New avenues (Indian context)

Practical:

Field visit to Eco restoration sites.

Identification of tracks and sites, bird identification, bird calls

References:

- Holden A. Environment and Tourism, Routledge, London, 2008.
- Sharma S.P., Tourism and Environment, Kanishka, New Delhi, 2006
- Weaver D. Eco-Tourism, John Wiley and sons Australia Ltd, 2008.
- Wood M., Eco Tourism – Principles, Practices and Policies for Sustainability, UNEP and TIES
- Beddard F.E., A text book of Zoogeography, BiblioLife

***

GE 6: Folk cultures and traditional communities of India

L5 T1 P0 CH6 CR6

Course Outcomes:

CO1 Appreciation of mega diversity of cultures.
CO2 Value of India's heterogenecity in diverse cultures and their uniqueness. CO3
Importance of India's pluralistic, democratic and constitutional ethos.
CO4 Understanding folk traditions in agriculture, animal husbandry, fisheries, tribal foragers and their indigenous traditional knowledge systems (TKS).
CO5 Appreciation of maintenance of unique cultures in the vague of homogenization, globalization and urbanization.

Course Content:

- Diversity of traditional folk cultures.
- Lives and lifestyles of complex traditional communities.
- Linkage of biogeopgraphic zones to indigenous cultures.
- The "adivasi" their importance in futuristic India.
- Tribal art, handicraft, music, dance, folklore, mythology, dress codes, local food, etc.
- Communication, education and public awareness (CEPA) for long term preservation for traditional knowledge systems.
- Ethical issues in conservation of indigenous culture.

References:

- Basham, A.L., The Wonder That was India, Surjeet Publications, 2008
- Basham, A.L., The Illustrated Cultural History of India, OUP , 2007
- Patra, A., The Spiritual Life and Culture of India, Oxford University Press, England. 2012
- Henderson, C. E. Culture and Customs of India. Greenwood Publishing Group. 2002
- Husnain, N., Tribal India, Palaka Prakashan, 2001
- Husnain, N., Indian Society and Culture: Continuity and Change, 2010
- Ministry of Tribal affairs, Government of India (https://tribal.nic.in/)

***

7. Teaching-learning Process for B.Sc. (Hon) Environmental Science

It has been envisaged to impart of holistic knowledge and understanding of the various components of environmental Science and the interfaces and inter-linkages of all the aspects of local, regional, and global environment through the of B.Sc. (Hon) Environmental Science programme. The learning process is expected to lead to the development of academic and professional skills necessary for professionals dealing with environmental issues in varied sectors – industry, academic, and government and non-government organizations. Development of critical thinking and decision making, empowered with skill, would be the key emphasis of teaching-learning for this programme.

The approaches to teaching-learning process under this programme would include lectures, seminars, tutorials, workshops, field-based study, practical and project-based learning adequately substantiated with laboratory-based experiments, and industrial and field visits. The outcome-centric approach warrants promoting the transition from teacher-centric to learner-centric pedagogies. Adopted teaching strategies would encourage in developing problem-solving skills and higher-order skills of reasoning and analysis among the learners.

Teaching methods may include: lectures supported by group tutorial work; practical and field-based learning; utilization of prescribed textbooks and e-learning resources and other self-study materials; project work; and internship and visits to field sites, and industrial or other research facilities etc. The concerned faculty needs to stimulate the learning on a balanced apportionment of 30:30:40 norms. Here, lectures (listening/hearing) encompasses 30 percent of the delivery; audio-visuals (seeing/power point presentation/video/demonstrations) constitutes 30 percent of the learning mechanisms; and practice (doing/participating/discussion) 40 percent. However, the given ratio may be altered according to the specific needs of the respective Institution/University. The teacher may also have the freedom to develop or evolve any other knowledge transfer method for achieving the basic goals of focused learning and holistic development. The following broad approaches are suggested for comprehensive outcome oriented and participative learning.

Lectures: Lectures may be schemed to offer the learners the up-to-date contexts on the subject matter, which is interactive and involving students in joining hands with their teachers to get new insights of the subject. The teacher may postulate the lecture outcomes in the beginning of the lectures and subsequently summarize the major aspects covered during the lecture at the end to

keep the focus on the outcome.

Case Studies*:* As and when possible, case studies of real nature may be taken up to train the students in evolving creative solutions of multifaceted environmental problems faced by the society.

Field visits: Wherever there is scope, visit to nearby forest areas, gardens, agricultural lands, industrial units, industrial safety operational sites, urban green space, organic farming sites, water treatment plants, optional visits based o biogeographic locations (national parks, wildlife sanctuaries, zoos, mangroves for coastal areas, mountains),conservation based NGOs and research organization (BNHS.WWF, CEE , SACON, WII ,WTI ,IFAW, NGT,BVIEER), interpretation centre, research laboratory , rehabilitation centre, industrial CSR sites, SPCB (State Pollution Control Board)waste dumping sites, and factories may be undertaken and student may be asked to communicate findings of the field visit in the form of a report and seminar.

Laboratory Sessions: Laboratory sessions are important to train a student to follow specific procedures for obtaining scheduled outcome. This helps students gain confidence on the theoretical knowledge obtained from lectures and self-studies and adept them to handle equipment, learn standard techniques, collect and interpret data, and write reports. For the improvement of the lab experience of the students following should be implemented:

Simulations: Student may be given adequate hands on exposure to work some computational tools/software MATLAB, SPSS, Sigma-Plot, Scilab, labview, and GIS package(s) like QGIS.

Problem solving: Apart from the standardized procedure given in laboratory manuals, student could be assigned with a scientific problem for encouraging them in formulating their own way to solve the given problem.

Laboratory Report: The Laboratory report should clearly reflect the student's experience and their understanding on the science behind the experiments. Report writing helps students to collate the ideas and findings. In general, a laboratory report may be systematically organized in various sections as *Introduction, Procedure, Results, and Conclusion/Interpretation* of the obtained results. The *Introduction* section would define the problem statement, establish scientific concept, and provide logical reasoning. *Results* must begin with effective statements of overall findings and results must be presented visually, clearly and accurately. The *conclusion* section must reflect the intrinsic values of the results.

Project-based learning:

Project-based learning offers an opportunity to the students to work independently under guidance of a supervisor. Students may be assigned to the respective faculty members under whose guidance he or she would work on a problem keeping the focus to enhance their (students') ability to critical thinking, identification of research problems and research gaps, formulate research objectives, formulation of research plan, and problem solving via execution of specific experiments, and develop specialized skills to handle specific problems. This would train the students to nurture their creativity and innovative ideas, collaboration/teamwork and leadership, communications, learning self-reliance and project management. Adequate assessment requirements for individual marking are presentations with discussions and seminars on the working process and the results.

Summer training/internship: Students may be allowed to work as summer trainee or interns in other institutes/ laboratories/ industries depending upon the scopes and availability during summer/winter recess.

After the period of training, it is expected that students achieve the following:

- Recognize the duties, responsibilities and ethics at a professional position.
- Ability to apply knowledge learned to solve specific problems in relevant domain of science.
- Gain exposure and practical experience in the relevant field.
- Ability to prepare technical reports for the training.
- Ability to communicate effectively in the work environment.

8. Assessment Methods

Under the perspectives of the diversity in learning and pedagogical methods adopted by different universities and institutions, universities are expected to ensure that the assessment tools are satisfactorily rendering clear information about the attainment level of course outcomes and program outcomes for each and every student.

Assessment priorities*:* Institutions must prioritize formative assessments (in semester activities including tests done at the department or instructor level) rather than giving heavy and final weightage to summative assessments (end-semester). Progress of learners towards

achieving learning outcomes may be assessed making creative use of the following, either independently or in combination:

- Time-constrained examinations (say 1-hour or 2-hour tests)
- Closed-book and open-book tests (if applicable)
- Problem based assignments/ term papers
- Quizzes
- Lab reports
- Individual/Team assignments
- Oral presentations, including seminar presentation
- Viva voce
- Peer and self-assessment etc.
- Any other pedagogic approaches as may be relevant keeping in view the learner's level, credit load and class size.

Weightage Distribution: In view of the need for more activity centric evaluation, more marks may be assigned for in-semester i.e. internal evaluation. The distribution of marks in in-semester and end-semester examination should preferably be in the ratio of 40:60.

End Semester Examination: The semester end examination must focus on evaluating the problem solving, critical thinking and skill abilities of the students. The scope and priorities may be decided on the basis of the learning outcomes of the respective courses.

(*Institutions are expected to encourage instructors to bring in innovative and flexible methods to guarantee the fullest realization of Learning Outcomes outlined in the document. All such instructional and assessment requirements must be clearly communicated to all stakeholders at the time of course registration. Any subsequent change or minor modification necessary for fuller realization of learning outcomes must be arranged with due notice and institutional arrangement at the relevant level.*

Freedom and accountability of the stakeholder are key attributes that determine the success of the Learning Outcomes framework. The excellence of institutions will be increasingly determined by Learning Outcomes rather than programme or course objectives. Hence it is necessary to innovate continually in learning and assessment in order to ensure meaningful and socially relevant learning (with transparent Learning Outcomes indices) rather than rote learning.)

9. Key words:

Environment, atmosphere, lithosphere, hydrosphere, biosphere, pollution, remediation, physicochemical processes, modeling

***

Expert Committee Members of Learning Outcomes based Curriculum Framework (LOCF) Environmental Science

Professor V.K. Jain, Vice Chancellor, Tezpur University

Professor M. Krishnan, Vice Chancellor Madurai Kamaraj University (Formerly Professor of Biochemistry, School of Life Science at Central University of Rajasthan)

Professor A.S. Ragubanshi, Institute of Sustainable Development, BHU

Professor S. P. Singh, School of Energy and Environmental Studies, Devi Ahilya Vishwavidyalaya, Indore

Co-opted Members:

Professor Raza R. Hoque, Dr. Satya Sundar Bhattacharya, Dr. Amit Prakash, Dr.Nayanmoni Gogoi, and other faculty members of the Department of Environmental Science and Civil Engineering, Tezpur University

Professor Bharat Chandra Kusre, Central Agricultural, Imphal (Gangtok Campus)

Dr. Deepak Kumar, Department of Sociology, Punjabi University, Patiala