ROYAL GLOBAL UNIVERSITY
GUWAHATI

Royal School of Environmental & Earth Sciences

(RSEES)

Department of Environmental Science

Learning Outcomes based Curriculum Framework (LOCF)

For Postgraduate Programme

M.Sc. Environmental Science

w.e.f. 2022-23

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Preamble

Environment is defined as the human surrounding and the discipline – Environmental Science – examines the role of human beings in shaping its surrounding and provides with the scope of research to find ways to attain sustainability. The human surrounding being so diverse, the scope of Environmental Science is wide, and the approach is multidisciplinary. The Stockholm Conference in 1972 provided with the direction to the nations to focus on protecting the environment from degradation. India realized the international commitment and made important amendments in the Constitution of India to accommodate environmental responsibilities and duties - the inclusion of Article 48A and 51A(g). In the later years the environmental concerns grew with the growing pollution of air and water in the cities and water bodies, degradation of forests and land. It is now explicit that interventions are needed to understand the environmental effects of pollution, biodiversity loss, climate change and its impacts on the hydrological regime and consequently on the agriculture, livelihood, and the economy. Thus, Environmental Science education has become pertinent in the national and global context. The M.Sc. in Environmental Science programme envisages to address the need for creating informed scientific manpower to engage with the environmental issues of local, regional, and global nature. The multidisciplinary approach of the discipline is reflected in the curriculum and research and learning have been kept central throughout the programme.

1. Introduction

The multidisciplinary nature of Environmental Science as a discipline demands an approach which connects the dots from the life sciences to physical sciences and pure sciences. Therefore, it is important to visualize the level of accomplishment expected in the Environmental Science Post-graduates. So, a learning outcome-based approach (LOBA) was taken while developing the curriculum. A set of learning outcomes of the M.Sc. programme in Environmental Science and programme outcomes (POs) were worked out to set the standard and level of accomplishments in terms of knowledge and skill gained. Similar learning outcomes were worked out for the individual courses and the course outcomes (COs) were then mapped with the learning outcomes of the

programme. The mapping helped to keep the focus on the programme outcomes. This will also help recruiters to appreciate their need vis-à-vis the expertise of the graduates just looking at the POs and the COs. The wide scope of Environmental Science has been addressed in the curriculum. The fundamental issues that are a must for the graduates were adjusted in the Core courses, which are mandatory for the students. Some courses were regarded as Elective courses, which were to be chosen by the students as per their interests and future career plan. Provisions are also kept open for the students to earn credits from other departments from the Open elective courses. There is a mandatory Project Dissertation of 12credits, which would empower the graduates to make decisions in systematic studies. This will also motivate them to choose a career in research and life-long learning. The level of understanding of the subject and domain knowledge, critical thinking, moral and ethical foundation, professional aptitude, ability to adapt, self-learning, problem solving ability, teamwork, and employability are the basis of the curriculum.

2. Nature and extent of M.Sc. Environmental Science

M.Sc. 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 organizations have the necessity of technical manpower and the knowhow to handle the environmental needs of different sorts of today which are 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 and biological 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 our society. The extent (scope, depth and outcomes) of M.Sc. Environment Sciences programme has taken into account the extent of the knowledge provided at school level in 10th, 11thand 12th standard according to syllabi of NCERT and state boards and the knowledge from B.Sc course in Environmental Science or from Chemistry, Physics, Botany, zoology or life sciences. It has been designed to bridge the gap between the school level and M.Sc. programmes 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 transdisciplinary approach which is relevant by the nature of the subject and the socio-economic fabric of India.

2.2 **Aim of the program (M.Sc. Environmental Science)**

- 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.
- To enhance the ability to apply this knowledge and proficiency to find solutions relating to environmental concerns of varied dimensions of present times.
- To provide with a direction and technical capability to carry on lifelong learning and show teamwork and collaborative endeavour, and decision making.
- To improve the employability of the graduates including the enhancement of self- employment potential and entrepreneurial aptitude, and fill the technical resource gap especially in the global context.
- To help the graduates appreciate the requirement of framing environmental policy guidelines.
- To 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 of Article 48A (Directive Principles of State Policy) and Article 51A(g) (Fundamental Duties) of the Constitution of India.

3. Qualification descriptors for the graduates

A graduate in M.Sc. in Environmental Science is expected to have the following attributes: Discipline knowledge & understanding, skills and technical hand, competence, communication and application. These attributes, Qualification descriptors, shall be the basis of scientific theories and principles, critical thinking, and decision making. The major expected learning outcomes of the M.Sc. programme in Environmental Science shall include the following:

Knowledge & Understanding:

- Demonstrate extensive and systematic knowledge of Environmental Science.

- Insightfully address the contemporary questions pertaining to the environment of both national and global importance.
- Engage in the field of Environmental Sciences and its allied areas.

Skills & Techniques:

- Show the ability to apply the knowledge in a critical and organized manner for the evaluation and elucidation of complex environmental problems e.g. issues related to ecosystems, air, water, and soil pollution, human health hazards; biodiversity loss, food security and agricultural issues.
- Demonstrate the ability to identify the role of Environmental Science in formulating sustainable solutions to the environmental problems.
- Demonstrate the ability design and develop eco-friendly products and processes towards accomplishment of the sustainable development goals.
- Exhibit efficiency to model, simulate, and assess environmental conditions based to the available data.

Competence:

- Communicate effectively
- Ability to work as a team and contributions towards effective planning, management, and implementations of projects/programme
- Exhibit capability to think and execute independent research projects/programme and evaluate the outcomes, and make a conclusive and comprehensive report
- Capability to identify his or her strengths and limitations; develop a lifelong learning attitude

4. Graduate Attributes

Graduate Attributes (GAs) are independently measurable outcomes that signify the capabilities of the graduates given as below:

GA1. Disciplinary knowledge: In-depth knowledge and understandings of the discipline or professional area across boundaries of nations with an aptitude to identify, access, analyze and synthesize existing and new knowledge, and integrate them.

GA2. Critical thinking: Critically address the 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. Research-related skills: A sense of inquiry and capability for asking relevant/ appropriate questions and problems; Ability to recognize cause-and-effect relationships, define problems, formulate hypotheses, test hypotheses, analyze, interpret and draw conclusions from data, establish hypotheses, predict cause-and-effect relationships; ability to plan, execute and report the results of an experiment or investigation.

GA5. 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.

GA6.**Scientific reasoning**: Ability to analyze, interpret and draw conclusions from quantitative/qualitative data; and critically evaluate ideas, evidence and experiences from an open-minded and reasoned perspective.

GA7. 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.

GA8. 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.

GA9. Lifelong learning: Distinguish the importance and possess the ability to prepare and engage in 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 improve knowledge and competence in a continued manner.

5. Programme Outcomes (POs)

PO1: Knowledge of Environmental Science (*Disciplinary Knowledge*) Graduate will gain thorough understanding of Environmental Science as collated in the curriculum and developed the capability of self-learning to continue the search for knowledge

PO2: Problem analysis (*Critical thinking*) Graduate will gain research acumen and developed critical thinking to carry out research in the domain, and continue learning

PO3: Development of solutions (***Problem solving***) Graduates will develop solutions for shaping strategies (scientific, social, economic and legal) for environmental protection and conservation of biodiversity, social equity and sustainable development.

PO4: Conduct investigations of complex problems (***Research related skills***) Graduate will contribute to and facilitate interdisciplinary research and problem solving, through independent and collaborative research work

PO5: Communication (***Communication skills***) Graduate will design and execute project, write scientific reports, develop research and communication skills.

PO6: Scientific tool usage (*Scientific reasoning*) Graduate will use quantitative and qualitative research tools and techniques to analyze, implement, envision, assess, and report sustainability efforts

PO7: Ethics (*Ethical values and social responsibility*) Graduate will acquire the sense of responsibility to safeguard the environment as a constitutional duty.

PO6: Environment and sustainability (*Futuristic attitude*) Graduate will gain skills to apply the knowledge to the environmental challenges before the society of the nature of local, regional, or global dimensions aligned with the economy and sustainability.

PO9: Pursuit of Knowledge (*Lifelong learning*) Graduate will acquire values and attitudes towards understanding complex environmental- economic-social challenges, and participating actively in solving current environmental problems and preventing the future ones.

6. Program Specific Outcomes (PSOs)

PSO1 **Academic competence:** Understand fundamental concepts, principles and processes underlying environmental problems at local, regional and global scale, and demonstrate an understanding of a wide range of environmental techniques (theoretical and analytical).

PSO2 **Personal and Professional Competence:** Apply environmental data analysis methodology in order to conduct research and demonstrate appropriate skill to seek innovative solutions to problems that emerge in various fields of Environmental Science and interdisciplinary fields like Green Technology, Biotechnology etc.

PSO3 **Research Competence:** Formulate ideas, write scientific reports, demonstrate effective presentation, communication skill and standard research practices.

PSO4 **Entrepreneurial and Social competence:** Demonstrate capability for developing sustainable societies and exhibit awareness of environmental and ethical issues: emphasizing on academic and research ethics, scientific misconduct, intellectual property rights and issues of plagiarism.

7. Teaching Learning Process

Teaching and learning in this programme involve classroom lectures, computer lab and tutorials.

It allows-

- The tutorials allow a closer interaction between the students and the teacher as each student gets individual attention.
- Written assignments and projects submitted by students
- Project-based learning
- Group discussion
- Home assignments
- Class tests
- Quizzes
- PPT presentations, Seminars, interactive sessions
- Co-curricular activity etc.
- Industrial Tour or Field visit

8. Programme Evaluation

8.1. The programme structures and examinations shall normally be based on Semester System. However, the Academic Council may approve Trimester/Annual System for specified programmes.

8.2. In addition to end term examinations, student shall be evaluated for his/her academic performance in a programme through, presentations, analysis, homework assignments, term papers, projects, field work, seminars, quizzes, class tests or any other mode as may be prescribed in the syllabi. The basic structure of each programme shall be prescribed by the Board of Studies and approved by the Academic Council.

8.3. Each programme shall have a number of credits assigned to it depending upon the academic load of the programme which shall be assessed on the basis of weekly contact hours of lecture, tutorial and laboratory classes, self-study. The credits for the project and the dissertation shall be based on the quantum of work expected.

8.4. Depending upon the nature of the programme, the components of internal assessment may vary. However, the following suggestive table indicates the distribution of marks for various components in a semester: -

Component of Evaluation	**Marks**	**Frequency**	**Code**	**Weigh tage (%)**
Continuous Evaluation				
Analysis/Class test	Combination of any three from (i) to (v) with 5 marks each	1-3	C	**25 %**
Home Assignment		1-3	H	
Project		1	P	
Seminar		1-2	S	
Viva-Voce/Presentation		1-2	V	
MSE	MSE shall be of 10 marks	1-3	Q/CT	
Attendance	Attendance shall be of 5 marks	100%	A	**5 %**
Semester End Examination		1	SEE	**70 %**
Project				**100 %**

COURSE STRUCTURE & SYLLABUS

DEPARTMENT OF ENVIRONMENTAL SCIENCE

M.Sc. Environmental Science

Programme Structure

M.Sc Environmental Science Course Structure (With subject codes)

Course structure and Credit Summary

S.No	Credit Assigned in each semester					
	Courses	**1st**	**2nd**	**3rd**	**4th**	**Total Credit**
1	**Core Paper**	16	16	12	4	48
2	**DSE**	4	4	12	12	32
3	**AECC**	2	2	1	1	6
4	**AEEC**	0	2	2	0	4
5	**Industrial visit/ Internship (summer or winter)**	0	0	2	0	2
6	**Project**	0	0	0	10	10
Total Credit		**22**	**24**	**29**	**27**	**102**

1st SEMESTER							
Sl. No	**Subject Code**	**Names of subjects**	**L**	**T**	**P**	**C**	**TCP**
1	ENV164C101	Fundamental of Environmental Science	4	0	0	4	4
2	ENV164C102	Environmental Chemistry and Toxicology	4	0	0	4	4
3	ENV164C103	Environmental Biology and Ecology	4	0	0	4	4
4	ENV164C114	Practical-I	0	0	8	4	8

		Ability Enhancement Compulsory Courses (AECC)					
6	CEN984A101	Communicative English-I	1	0	0	1	1
7	BHS984A103	Behavioural Science-I	1	0	0	1	1
		Discipline Specific Elective (DSE): Any One to be selected					
8	ENV164D101	Climatology and Meteorology	4	0	0	4	4
9	ENV164D102	Environmental Economics	4	0	0	4	4
TOTAL CREDITS (C) AND TOTAL CONTACT PERIODS (TCP)			**19**	**0**	**8**	**22**	**27**

2nd SEMESTER

Sl. No	**Subject Code**	**Names of subjects**	**L**	**T**	**P**	**C**	**TCP**
1	ENV164C201	Statistical methods in Environmental Application	4	0	0	4	4
2	ENV164C202	Environmental Pollution and Control	4	0	0	4	4
3	ENV164C203	Natural Hazards and Disaster Management	4	0	0	4	4
4	ENV164C214	Practical - II	0	0	8	4	8
		Ability Enhancement Compulsory Courses (AECC)					
5	CEN984A201	Communicative English-II	1	0	0	1	1
6	BHS984A203	Behavioural Science-II	1	0	0	1	1
		Ability Enhancement Elective Courses (AEEC / SEC-1*)					
7	AEEC/SEC/-1		2	0	0	2	2
		Discipline Specific Elective (DSE): Any One to be selected					
8	ENV164D201	Remote Sensing and GIS	4	0	0	4	4
9	ENV164D202	Atmospheric Science	4	0	0	4	4
TOTAL CREDITS (C) AND TOTAL CONTACT PERIODS (TCP)			**20**	**0**	**8**	**24**	**28**

3rd SEMESTER

Sl. No	**Subject Code**	**Names of subjects**	**L**	**T**	**P**	**C**	**TCP**

1	ENV164C301	Environmental Geoscience	4	0	0	4	4
2	ENV164C302	Energy and Environment	4	0	0	4	4
3	ENV164C303	Solid and Hazardous Waste Management	4	0	1	4	4
4	ENV164C321	Industrial visit/ Internship (summer or winter)	0	0	0	2	0
		Ability Enhancement Compulsory Courses (AECC)					
5	CEN984A301	Communicative English-II	1	0	0	1	1
		Ability Enhancement Elective Courses (AEEC / SEC-2*)					
6	**AEEC / SEC-2**		2	0	0	2	2
		Discipline Specific Elective (DSE): Any three to be selected					
7	ENV164D301	Climate change and its Impact	4	0	0	4	4
8	ENV164D302	Environmental Impact Assessment and Legislation	4	0	0	4	4
9	ENV164D303	Instrumental Methods and Analysis	4	0	0	4	4
10	ENV164D304	Ecology and Aquatic Environment	4	0	0	4	4
TOTAL CREDITS (C) AND TOTAL CONTACT PERIODS (TCP)			**27**	**0**	**15**	**29**	**36**

4th SEMESTER

Sl. No	**Subject Code**	**Names of subjects**	**L**	**T**	**P**	**C**	**TCP**
1	ENV164C401	Soil Science	4	0	0	4	4
2	ENV164C422**	Major Project	0	0	24	10	24
		Ability Enhancement Compulsory Courses (AECC)					
3	CEN984A401	Communicative English-II	1	0	0	1	1
		Discipline Specific Elective (DSE): Any three to be selected					
4	ENV164D401	Ecosystem and Biodiversity Conservation	4	0	0	4	4
5	ENV164D402	Contemporary Environmental Issues	4	0	0	4	4
6	ENV164D403	Natural Resources and Management	4	0	0	4	4

7	ENV164D404	Environmental Plant Physiology and Biochemistry	4	0	0	4	4
TOTAL CREDITS (C) AND TOTAL CONTACT PERIODS (TCP)			**17**	**0**	**30**	**27**	**41**
Total Credit=22+24+29+27=102							

M. Sc. Course in Environmental Science: Semester-I

Paper I Core Course	Fundamentals of Environmental Science	Subject Code:
	L-T-P-C: 3-1-0-4 Credit Units: 4 Scheme of Evaluation: (T)	ENV164C101

Course Objectives:
The paper will provide the students with fundamental concept of different segments of environment and knowledge related to different types of natural resources, biodiversity and its conservation and population growth and its impact on environment.

Course Outcome:

On completion of the course, the students will able to:		Bloom's cognitive Level
CO1	Define principles of environmental science and concept of structure and function of different compartments of the Environment	**1**
CO2	Illustrate the mechanisms of interactions between different spheres of environment	**2**
CO3	Develop scientific perspective of the issues confronting our present-day environment	**3**
CO4	Analyze the national and global environmental issues relating to atmosphere, water, soil and land use, biodiversity, and natural resources	**4**

Detailed Syllabus:

Modules	Topics (if applicable) & Course Contents	Periods
I.	Introduction- Definition, concepts and scope of Environmental Science; Global environment and its segments: **Biosphere- D**istribution on land, water and air **Atmosphere** (Structure and composition of atmosphere; radiative & heat balance; earth's temperature regime; weather (Weather elements and their variations) and climate (Major climatic zones of the world; Climates of India, climate and vegetation; Climatic extremes-environmental implications, Global climate change and its impact on environment); albedo **Hydrosphere** (Hydrological Cycle, vertical profile and stratification) **Lithosphere** Environmental systems: Biogeographical cycles- water, carbon, nitrogen, phosphorus and sulphur cycles.	**12**
II.	Man and Environment: Man-environment relationship, concept of sustainable development, EIA (Definition and Concept) Population growth- biological growth curves and carrying capacity, human population growth and environmental constrains; distribution of world's population, age-sex composition; literacy of India's population; Impact of growing population (global and Indian Issues); Effects of environment on human culture and livelihood.	**12**
III.	Fundamentals of Ecology: meaning and scope; Ecosystems - types, structural and functional aspects; Energy flow in ecosystems, food chain, food web, trophic levels, ecological pyramids, ecotone, ecological niche. Structure and functions of ecosystem, human impact on ecosystems;	**12**

	Biodiversity, loss of biodiversity, threats to biodiversity (biotic and abiotic stress), strategies for conservation	
IV	Natural Resources: renewable and non-renewable resources: Water, forests, minerals, food and land; water resources, water bodies and water use, issues with water conservation; Concept of reserve and resources. Energy and growing energy needs, energy sources (conventional and alternative) Common property resources (CPRs).	**12**
TOTAL		**48**

Text Books:

1.Allaby, Michael. *Basics of environmental science*. Routledge, 2002.
2.Wright, Richard T., Dorothy Boorse, and Dorothy T. Boorse. *Environmental science: toward a sustainable future*. Pearson/Prentice Hall, 2005.
3.Manahan S. E., Environmental Science & Technology – A sustainable approach to Green Science and Technology, Taylor & Francis, 2006
4.Zhang, Chunlong. *Fundamentals of environmental sampling and analysis*. John Wiley & Sons, 2007.

Reference Books:

1. Manahan, Stanley E. "Environmental science and technology." (1997).
2. Atkinson, Giles, et al., eds. *Handbook of sustainable development*. Edward Elgar Publishing, 2014.
3. Roosa, Stephen A. *Sustainable development handbook*. CRC Press, 2020.
4. Weathers, Kathleen C., David L. Strayer, and Gene E. Likens, eds. *Fundamentals of ecosystem science*. Academic Press, 2021.
5. Robbins, Paul, John G. Hintz, and Sarah A. Moore. *Environment and society: a critical introduction*. John Wiley & Sons, 2022.

Reading Materials:

1. Cockerham, Lorris G., and Barbara S. Shane. *Basic environmental toxicology*. Routledge, 2019.
2. Doyle, Michael P., Francisco Diez-Gonzalez, and Colin Hill, eds. *Food microbiology: fundamentals and frontiers*. John Wiley & Sons, 2020.
3. Olatunde-Aiyedun, Tope Gloria. "Fundamentals of Environmental Education." *Olatunde-Aiyedun, TG (2021). Fundamentals of Environmental Education. LAP LAMBERT Academic Publishing, Mauritius. https://www. researchgate. net/publication/349573767_Fundamentals_of_Environmental_Education* (2021).
4. Saravanan, K. *Principles of environmental science and technology*. New Age International, 2004.
5. Weathers, Kathleen C., David L. Strayer, and Gene E. Likens, eds. *Fundamentals of ecosystem science*. Academic Press, 2021.

Paper II Core Course	**Environmental Chemistry and Toxicology** **L-T-P-C: 3-1-0-4** **Credit Units: 4** **Scheme of Evaluation: (T)**	**Subject Code: ENV164C102**

Course Objectives:

The paper will provide the students with the knowledge of important chemical reactions in air, water and soil, and the reactions associated with smog formation, ozone and acid rain chemistry. The objective is also to inculcate the pesticide and heavy metal chemistry and their transport mechanism in the food chain.

Course outcomes:

On completion of the course, the students will able to:		**Bloom's cognitive Level**
CO1	Define the concepts, principles, and methods of environmental chemistry and environmental toxicology	**1**
CO2	Compare and demonstrate different techniques used for analysis of hazardous substances	**2**
CO3	Identify and examine the movement of toxicants in both biotic and abiotic components of the environment	**3, 4**

Detailed Syllabus:

Modules	**Topics (if applicable) & Course Contents**	**Periods**
I.	Environmental Chemistry: Concept and scope of Environmental Chemistry, acid base reactions, pH and pOH, common ion effect, buffer solutions, solubility, hydrolysis, chemical equilibrium, chemical speciation, catalysis, Adsorption. Chemistry of Cleaning Agents: Soap and detergents; Chemistry of colloids Chemistry of Fuels: Gasoline and additives, antiknock compounds Concept of green chemistry.	**12**
II.	Atmospheric Chemistry: Chemical composition of the atmosphere; Chemical and photochemical reactions in the atmosphere- formation of smog, PAN, atmospheric aerosol chemistry, hydrocarbons, PAH, PCBs, CFCs (Organic compounds) Water Chemistry: Physical and chemical properties of water and their environmental significance; Water quality parameters- physical, chemical and biological. Distribution of chemical species in water, solubility of gases in water, carbonate system.	**12**
III.	Soil Chemistry: Soil and sub-soil definition, difference between soil and sub soil, chemical & mineralogical composition of soil; Physical properties of soil- colour, texture, bulk density, permeability; Chemical properties- soil acidity, alkalinity, macro and micro nutrients; Chemistry of Pesticides; Chemistry of Environmental Trace Elements: Fluoride (F^-), Arsenic (As), Mercury (Hg) and Cadmium (Cd)	**12**
IV	Environmental Toxicology: Introduction to Environmental toxicology, concepts of toxicology, dose-response relationships, absorption of toxicants. Toxic substances in the environment, biochemical impacts of toxic substances, their sources and entry routes; Transport of toxicants by air and water; Transport through food chain - bio-transformation and biomagnification.	**12**
TOTAL		**48**

Text Books:

1. De, A.K. *Environmental Chemistry*: 9th Edition, New Age International Publishers, 2019.

2. Sharma, B.K. and Kaur, H. *Environmental Chemistry*: 9th Edition, Meerut: Goel Publishing House, 2016.
3. Manahan, S.E. *Environmental Chemistry*: 8th Edition, CRC Press 2004.
4. Giraid, G. *Principles of Environmental Chemistry*: 3rd Edition, Prentice Hall International, 2013.

Reference Book:

1. Alloway, Brian, and David C. Ayres. *Chemical principles of environmental pollution*. CRC press, 1997.
2. Fifield, Frederick William, and Peter J. Haines, eds. *Environmental analytical chemistry*. Vol. 2. London: Blackwell science, 2000.
3. Lodge, James P. *Methods of air sampling and analysis*. Routledge, 2017.

Reading Materials:

1. Ali, Hazrat, Ezzat Khan, and Ikram Ilahi. "Environmental chemistry and ecotoxicology of hazardous heavy metals: environmental persistence, toxicity, and bioaccumulation." *Journal of chemistry*, 2019.
2. Connell, Des W., et al. *Basic concepts of environmental chemistry*. CRC/Taylor & Francis, 2005.
3. Jiang, Guibin, and Xiangdong Li. *A new paradigm for environmental chemistry and toxicology*. Springer Singapore, 2020.
4. Manahan, Stanley. *Environmental chemistry*. CRC press, 2017.
5. Nadarajan, Stalin, and Surya Sukumaran. "Chemistry and toxicology behind chemical fertilizers." *Controlled Release Fertilizers for Sustainable Agriculture*. Academic Press, 2021. 195-229.
6. Roberts, Stephen M., Robert C. James, and Phillip L. Williams, eds. *Principles of toxicology: environmental and industrial applications*. John Wiley & Sons, 2022.
7. Spurgeon, David J., et al. "Systems toxicology approaches for understanding the joint effects of environmental chemical mixtures." *Science of the total environment* 408.18 (2010): 3725-3734.

Paper III Core Course	Environmental Biology and Ecology L-T-P-C: 3-1-0-4 Credit Units: 4 Scheme of Evaluation: (T)	Subject Code: ENV164C103

Course Objectives:

To impart knowledge on population ecology (flora and fauna), their physiological and morphological traits so as to make the students understand the mode of action of pollutants on plant and animal system.

Course Outcomes:

On completion of the course, the students will able to:		Bloom's cognitive Level
CO1	Relate how both plants and animals respond to pollutants and their tolerance mechanism	**1**
CO2	Demonstrate comprehensive understanding of the pollution damage to flora and fauna	**2**
CO3	Apply and inspect the different control measures and environmental techniques for the remediation of environmental pollution	**3, 4**
CO4	Propose some ecofriendly and traditional techniques for the remediation/reclamation of degraded environment	**5**

Detailed Syllabus:

Modules	Topics (if applicable) & Course Contents	Periods
I.	Major environmental pollutants and their impact on plant and animal system. Damage of cell, tissues, cell organelles and cell ultrastructure due to atmospheric pollution, Mode of action of atmospheric pollutant in cellular system, impact of gaseous air pollution on photosynthesis Visible symptoms of air pollution damage caused by different pollutants in plants, Plant tolerance of pollutants and mechanism	**12**
II.	Air pollutant transmission in animal body; Gaseous pollutants and their impact on birds and mammals; Heavy metal and trace elements toxicity in animal body; Acid rain injury in aquatic fauna. Pollution hazard of nitrate, chlorine, arsenic and polycyclic aromatic hydrocarbon (PAH) on human health.	**12**
III.	Scope of ecology, autecology, synecology, population, community, biome, tolerance range and limiting factors. Distinguishing characters of forests, grasslands, arid lands and wetlands; Community organization- concept of habitat, ecological succession. Fundamentals of microbial ecology; Xenobiotics and microbial transformation of pollutants in soil; Soil microbes and their function in rhizosphere; Microbial metabolism in soil, biological nitrogen fixation.	**12**
IV	Environmental Biotechnology: Traditional and Modern Concepts of biotechnology; Basic concept of genetic engineering and its applications Application of Environmental biotechnology in-Biological monitoring, bioindicators, bioremediation and phytoremediation as control measures of environmental pollution (land, air and gases); waste degradation and removal; Ecofriendly techniques- fermentation technology, vermiculture technology & biofertilizer technology, biopesticide	**12**
TOTAL		**48**

Text Books:

1. Saradhi, P.P. *Biophysical processes in living systems*, Oxford & IBH Publishing, 2008
2. Bhatia, A.L. *Text book of Environmental Biology*, I K International Publishing House, 2010.
3. Krishnamurthy, K. V. *An advanced textbook on biodiversity: Principles and practice*. Oxford and IBH Publishing, 2018.

Reference Books:

1. Prosser, C. Ladd. *Comparative animal physiology*. Wiley-Liss,1991
2. Bertold, H., and Erich, F. F. E. *Plant Toxicology*, Fourth Edition, CRC Press, 2004.
3. Calver, M. *Environmental Biology*, Cambridge University Press, 2009.

Reading Materials:

1. Carpenter, Stephen R., et al. "Accelerate synthesis in ecology and environmental sciences." *BioScience* 59.8 (2009): 699-701.
2. Lion, Sébastien. "Theoretical approaches in evolutionary ecology: environmental feedback as a unifying perspective." *The American Naturalist* 191.1 (2018): 21-44.
3. Nelson, Melissa K., and Daniel Shilling, eds. *Traditional ecological knowledge: Learning from Indigenous practices for environmental sustainability*. Cambridge University Press, 2018.
4. Rittmann, Bruce E., et al. "A vista for microbial ecology and environmental biotechnology." (2006): 1096-1103.
5. Singh, Anita, and Madhoolika Agrawal. "Acid rain and its ecological consequences." *Journal of Environmental Biology* 29.1 (2007): 15.
6. Suthers, Iain, David Rissik, and Anthony Richardson, eds. *Plankton: A guide to their ecology and monitoring for water quality*. CSIRO publishing, 2019.
7. Urbanska, Krystyna M., Nigel R. Webb, and Peter J. Edwards, eds. *Restoration ecology and sustainable development*. Cambridge University Press, 1997.

Paper IV Core Course	**Practical-I**			**Subject Code: ENV164C114**
	L-T-P-C: 0-0-8-4	**Credit Units: 4**	**Scheme of Evaluation: (P)**	

Course Objectives:

The practical paper will provide an understanding on different analytical techniques for the analysis of soil and water physical parameters. It will also provide hands on training on experiments such as turbidimetric and potentiometric that will help develop expertise on analysis of various environmental samples and sampling techniques.

Course Outcomes:

On completion of the course, the students will able to:		**Bloom's cognitive Level**
CO1	Identify different analytical techniques of physico-chemical parameters of soil and water	**3**
CO2	Distinguish and evaluate different tests to understand the validation of the techniques for soil and water	**4, 5**
CO3	Develop skills to create awareness to the community at the regional level on the impact of soil and water pollution	**6**

Modules	**Topics (if applicable) & Course Contents**	**Periods**
I.	Analysis of Physical parameters of soil: Texture, Bulk density (core cutter method), particle density (picnometer method and density bottle method), porosity, soil moisture (Infra red moisture method and Oven dry method), Water holding capacity	**12**
II	Analysis of chemical properties of soil: pH, electrical conductivity, Soil organic carbon (SOC), soil organic matter (SOM), Soil microbial biomass carbon estimation, soil nutrient analysis (N, P, K, Ca, Mg, etc) Soil heavy metals.	**12**
III	Soil heavy metals analysis: Cd, Cr, Cu, Co, Fe, Mn, Mg, Ni, Pb, Zn (Diacid digestion method and sequential extraction method)	**12**
IV	Potentiometric Experiments: Estimation of pH, Electrical conductivity, Estimation of Temperature in water Titrimetric Experiments: Determination of Hardness, Alkalinity, Acidity in water	**12**
TOTAL		**48**

Text Books:

1. Hesse, Peter Ralston, and P. R. Hesse. "A textbook of soil chemical analysis." (1971).
2. Karia, G. L., and R. A. Christian. *Wastewater treatment: Concepts and design approach*. PHI Learning Pvt. Ltd., 2013.
3. Methods manual –Soil Testing in India, Department of Agriculture & Cooperation Ministry of Agriculture, GOI, New Delhi, 2011.

Reference Books:

1. Nielsen, David M., ed. *Practical handbook of ground-water monitoring*. CRC Press, 1991.
2. Basu, P. K. "Methods manual: soil testing in India." *Department of Agriculture & Cooperation, Ministry of Agriculture Government of India New Delhi. Krishi Bhawan, New Delhi* 110001 (2011).

3. Manual of Methods of Analysis of Water, Food Safety and Standards Authority of India Ministry of Health and Family Welfare Government of India, New Delhi, 2016

Reading materials:

1. Collins, William Dennis, and Geological survey (États-Unis). *Notes on practical water analysis*. US Government Printing Office, 1928.
2. Barcelona, Michael J. *Practical guide for ground-water sampling*. Vol. 600. No. 2-104. Robert S. Kerr Environmental Research Laboratory, Office of Research and Development, US Environmental Protection Agency, 1985.
3. Jiménez, Blanca, and Takashi Asano. "Water reuse: An international survey of current practice, issues and needs." (2008).

Paper I DSE	**Climatology and Meteorology** **L-T-P-C: 3-1-0-4** **Credit Units: 4** **Scheme of Evaluation: (T)**	**Subject Code: ENV164D101**

Course Objectives:

The paper aims to provide an understanding of the earth's climate and the factors responsible for its change. It will focus on the physical principles governing the global energy budget, the role of the circulation of the atmosphere and oceans, and interactions between different components of the climate system. Also, it will provide insights about the climate variability that results from interactions within the climate system (e.g., El Nino-Southern Oscillation (ENSO).

Course outcomes:

On completion of the course, the students will able to:		**Bloom's cognitive Level**
CO1	Define and demonstrate sound understanding of the atmosphere and climate as integral part of the physical environment	**1, 2**
CO2	Utilize and explain meteorological knowledge in the matrices of environmental research	**3**
CO3	Examine the interaction between earth and atmospheric system, and explain their mechanisms particularly the microclimate	**4, 5**

Detailed Syllabus:

Modules	**Topics (if applicable) & Course Contents**	**Periods**
I.	The earth and the atmospheric system: Overview of the structure and composition of the atmosphere; Energy for the earth-atmosphere system- its relation with the sun; rotation, revolution, and variation of energy received; radiation and atmospheric interaction	**12**
II.	Fundamentals of Meteorology: pressure, pressure belts, temperature, wind and atmospheric circulation; atmospheric moisture: condensation, formation of precipitation, dew, fog and clouds; atmospheric stability: lapse rate, adiabatic process, mixing height	**12**
III.	Micrometeorology: Definition of microclimate, introduction to ABL, microclimate of vegetated surface, urban microclimate- factors that modifies meteorological process in urban area, modified process and observed results, UHI, thermal comfort.	**12**
IV	Weather system: Weather systems associated with fronts, extra-tropical cyclones, anticyclones and blockings; Tropical system- equatorial trough, ITCZ, jet streams, vortices; monsoon, El Nino-Southern Oscillation (ENSO) Climate: elements of climate, climate control, degree days, thermal comfort. Climate classification: Determining factors of climate, effect of topography, climatic classification Climate of India: spatial and temporal patterns of climatic parameters- temperature, rainfall and its variability in India with special reference to N.E.	**12**
Total		**48**

Text books:

1. Oliver J.E. and. Hidore J.J., Climatology: An atmospheric science, Second Edition, Pearson Education, 2003.
2. Oliver, John E., ed. Encyclopedia of world climatology. Springer Science & Business Media, 2008.
3. Miller, Austin A. Climatology. Methuen & Co. Ltd, London, 2012
4. Ahrensand R C. D., Hensen. Meteorology Today: An Introduction to weather climate and the Environment. 10th Edition. Brookes/ Cole Cengage Learning Learning, 2013

5. Perry, Allen, and Russell Thompson. Applied climatology: principles and practice. Routledge, 2013.
6. Rohli, Robert V., and Anthony J. Vega. Climatology. Jones & Bartlett Learning, 2017.

Reference books:

1. Christopherson RW, Geosystems: An introduction to physical geography, 7th edition, Prentice Hall, 2008.
2. Kale V.S., Flood studies in India, Geological Society of India,1998.
3. Hartmann, Dennis L. *Global physical climatology*. Vol. 103. Newnes, 2015.
4. Rohli, Robert V., and Anthony J. Vega. *Climatology*. Jones & Bartlett Learning, 2017.
5. Heymann, Matthias, and Dania Achermann. "From climatology to climate science in the twentieth century." The Palgrave handbook of climate history. Palgrave Macmillan, London, 2018. 605-632.

Reading Materials:

1. Adler, Robert F., et al. "The Global Precipitation Climatology Project (GPCP) monthly analysis (new version 2.3) and a review of 2017 global precipitation." *Atmosphere* 9.4 (2018): 138.
2. Ahmadi, Mohsen, et al. "Investigation of effective climatology parameters on COVID-19 outbreak in Iran." *Science of the total environment* 729 (2020): 138705.
3. Camargo, Suzana J., et al. "Characteristics of model tropical cyclone climatology and the large-scale environment." *Journal of Climate* 33.11 (2020): 4463-4487.
4. Griffiths, John F. "Applied climatology: an introduction." *Applied climatology: an introduction.* (1966).
5. Nishi, Akifumi, Hiroyuki Kusaka, and Shingo Nakamura. "Mesoscale and local-scale climatology of extreme temperature events in Niigata, Japan." *International Journal of Climatology* (2022).
6. Wille, Jonathan D., et al. "Antarctic atmospheric river climatology and precipitation impacts." *Journal of Geophysical Research: Atmospheres* 126.8 (2021): e2020JD033788.

Paper 2 DSE	Environmental Economics	Subject Code:
	L-T-P-C: 3-1-0-4 Credit Units: 4 Scheme of Evaluation: (T)	ENV164D102

Course Objectives:

To impart the basic and key knowledge of scope and importance of ecological economics. This will help in enhancing the knowledge of cost & benefit analysis, economics in sustainability, global sustainability and economic solutions to environmental problems.

Course Outcomes:

On completion of the course, the students will able to:		**Bloom's cognitive Level**
CO1	Define and explain the concept of sustainability from economic and environmental frontage	**1, 2**
CO2	Identify the fundamentals of environmental economics and examine its application on human welfare	**3, 4**
CO3	Prioritize the best environmental regulation practices gained through case studies	**5**

Detailed Syllabus:

Modules	**Topics (if applicable) & Course Contents**	**Periods**
I.	Fundamental Concepts in welfare economics, Economic theory of a common – property resource, Problem of social cost, Divergence between social cost and private cost.	**12**
II.	Concept of market, market failure; Economics of resources and resources of economics, Environmental quality, Valuation of Environmental Goods and Services: Compensating Variations and Surplus, Equivalent Variations and Surplus, Willingness to pay or accept for improvement or loss of environmental goods and services Concepts of Sustainable Development, Risk assessment, Risk Management.	**12**
III.	Solutions to Environmental Problems: Conventional Solution – Command and Control approach, Economic Solution- Environmental Subsidies, Relation between Development Environmental Quality: Environmental Kuznets Curve, Deposit Refund System and Pollution permit Trading System, Costs and Benefit analysis of Environmental Decisions.	**12**
IV	Case study from Air quality regulations, Water Quality regulations, Solid and Toxic waste regulation policy. Strategic planning for sustainable development, International agreements.	**12**
TOTAL		**48**

Text Books:

1. Munasinghe, Mohan. *Environmental economics and sustainable development*. Vol. 3. World Bank Publications, 1993.
2. Callan and Thomas, Environmental Economics and management: Theory Policy and management. Dryden Press, USA ed., 1996.
3. Marshall, G.R. Economics of Collaborative Environmental Management. ISBN: 1844070948 –Earth scan , 2005.

Reference Books:

1. Chary, S. N and Yasulu, V. Environmental Management, 2000.
2. Negi, J. S. Environmental Policy Studies, 2006.
3. Hanley, Nick, Jason Shogren, and Ben White. *Introduction to environmental economics*. Oxford University Press, 2019.
4. Lewis, Lynne, and Thomas H. Tietenberg. *Environmental economics and policy*. Routledge, 2019.

Reading Materials:

1. Cao, XingHua, et al. "Does sustainable environmental agenda matter in the era of globalization? The relationship among financial development, energy consumption, and sustainable environmental-economic growth." *Environmental Science and Pollution Research* (2022): 1-11.
2. Cropper, Maureen L., and Wallace E. Oates. "Environmental economics: a survey." *Journal of economic literature* 30.2 (1992): 675-740.
3. Haram, Mohammed Hussein Saleh Mohammed, et al. "Feasibility of utilising second life EV batteries: Applications, lifespan, economics, environmental impact, assessment, and challenges." *Alexandria Engineering Journal* 60.5 (2021): 4517-4536.
4. Khan, Syed Abdul Rehman, et al. "Industry 4.0 and circular economy practices: A new era business strategies for environmental sustainability." *Business Strategy and the Environment* 30.8 (2021): 4001-4014.
5. Marcus, Michelle, and Pedro HC Sant'Anna. "The role of parallel trends in event study settings: an application to environmental economics." *Journal of the Association of Environmental and Resource Economists* 8.2 (2021): 235-275.
6. Stavins, Robert. "Environmental economics." (2007).
7. Štreimikienė, Dalia, et al. "Multiplexing efficiency of environmental taxes in ensuring environmental, energy, and economic security." *Environmental Science and Pollution Research* 29.5 (2022): 7917-7935.

M. Sc. Course in Environmental Science: Semester-II

Paper I **Core Course**	**Statistical methods in Environmental Application**	**Subject Code: ENV164C201**
	L-T-P-C: 3-1-0-4 **Credit Units: 4** **Scheme of Evaluation: (T)**	

Course Objectives:

This paper will introduce the basic concepts useful for environmental data analysis. It will help the students to be aware of a wide range of statistical applications in environmental management and decision making so that they can develop technical skills to use statistical tools and software for real time environmental data analysis.

Course Outcomes:

On completion of the course, the students will able to:		**Bloom's cognitive Level**
CO1	Understanding on concept of population and sample in environmental statistics (descriptive and analytical)	**1, 2**
CO2	Apply one or more of the standard statistical software (Microsoft excel, SPSS, R, Minitab, etc.)	**3**
CO3	Apply the knowledge on probability and other forms of distributions (Normal, Poisson etc.) for data-analysis and evaluation	**3, 4, 5**

Detailed Syllabus:

Modules	**Topics (if applicable) & Course Contents**	**Periods**
I.	Environmental Variables-Discrete and continuous; Data collection - primary and secondary; Presentation of data - spatial and non-spatial data; Basic Statistics - frequency distribution, measures of central tendency and dispersion, moments, skewness and kurtosis. Probability Rules and Theoretical Distributions: Basic probability rules, expectation, conditional probability; Probability distributions – binomial, Poisson, normal and Log-normal distributions; Fitting of probability distributions to environmental data.	**12**
II.	Design of Sample Survey: Population and sample, advantages of sampling over complete census and its limitations; Different techniques of sampling –simple random sampling, stratified random sampling, systematic sampling. Correlation and Regression: Bi-variate data and scatter diagram; Simple (linear) correlation and regression; Coefficient of correlation and regression and their properties; Fitting of regression line; Multiple and partial correlations and regressions.	**12**
III.	Sampling distribution and test of significance: Parameter and statistics; Sampling distribution, standard error and its uses; Concept of t-distribution, F-distributions, Chi Square distribution without derivation and their applications; Null hypothesis and uses of t- test, F-test, X^2-tests; Test of significance of large samples	**12**
IV	Analysis of Variance: Different types of models used in AOV; Basic assumptions and its violation; One and two way classified data; Application of AOV to environmental data Time series analysis: Components of time series, models, measurement of	**12**

	trend, seasonal movements, cyclical movements.	
TOTAL		**48**

Text Books:

1. Gupta, S. C. Kapoor VK, Fundamentals of Mathematical Statistics, 10th Edition, S. Chand & Sons, 2000.
2. Scott, Marian, and Richard Chandler. *Statistical methods for trend detection and analysis in the environmental sciences*. John Wiley & Sons, 2011.
3. Meeker, William Q., Luis A. Escobar, and Francis G. Pascual. *Statistical methods for reliability data*. John Wiley & Sons, 2022.

Reference Books:

1. Green, Roger H. *Sampling design and statistical methods for environmental biologists*. John Wiley & Sons, 1979.
2. Mahmood, A. Statistical Methods in Geographical Studies, Student Edition, Rajesh Publications, 1999.
3. Barnett, Vic. *Environmental statistics: methods and applications*. John Wiley & Sons, 2005.
4. Medhi, J. Statistical Methods: An Introductory Text *(*2nd Edition). New Age International Ltd. Publishers, 2006.
5. Hoshmand, A. Reza. *Statistical methods for environmental & agricultural sciences*. CRC press, 2017.
6. Shrestha, Anil. *Application of Geodetector Method and Other Statistical Methods to Study Groundwater Vulnerability to Nitrate Contamination in The Central Valley Aquifer, California*. Northern Illinois University, 2019.

Reading Materials:

1. Clark, James S., and Alan E. Gelfand, eds. *Hierarchical modelling for the environmental sciences: statistical methods and applications*. OUP Oxford, 2006.
2. Gilbert, Richard O. *Statistical methods for environmental pollution monitoring*. John Wiley & Sons, 1987.
3. Mecozzi, Mauro, et al. "Uncommon multivariate statistical methods for environmental studies: a review." *Trends in Environmental Analytical Chemistry* 6 (2015): 31-38.
4. Tomy, Lishamol, Christophe Chesneau, and Amritha K. Madhav. "Statistical Techniques for Environmental Sciences: A Review." *Mathematical and Computational Applications* 26.4 (2021): 74.

Paper II Core Course	**Environmental Pollution and Control**			**Subject Code: ENV164C202**
	L-T-P-C: 3-1-0-4	**Credit Units: 4**	**Scheme of Evaluation: (T)**	

Course Objectives

To impart the knowledge of pollution and environmental degradation so that the students acquire a set of values for environmental protection. This paper also aims at providing the students with the knowledge on various environmental policies and guidelines related to environmental pollution and its control.

Course Outcomes:

On completion of the course, the students will able to:		Bloom's cognitive Level
CO1	Define the different sources of environmental pollution and demonstrate various remedial/control measures	**1, 2**
CO2	Identify the magnitude and intensity of environmental pollution and relate with real-time ground problems	**3**
CO3	Analyze different types of pollution and the guidelines for their control in the context of public health	**4**
CO4	Undertake environmental sampling and estimate data with respect to air, soil, water and noise pollution	**5**

Detailed Syllabus:

Modules	Topics (if applicable) & Course Contents	Periods
I.	Introduction: Definition and sources of pollution; Different types of pollution and their global, regional and local aspects. Air Pollution: Types and sources of air pollutants; Reaction of pollutants in air forming smog, atmospheric diffusion and stack performance; Environmental Lapse rate, temperature inversion, mixing height, transport of pollutants; Plume behaviour, sinks of atmospheric gases.	**12**
II.	Water Pollution :Sources of water and their contamination; Types of pollutants, various industrial effluents such as pulp and paper mills, oil exploration and refinery, petrochemicals, domestic wastes, agricultural wastes; Groundwater pollution by arsenic, fluoride and other metals; Treatment of water and wastewater; Eutrophication – causes and effects and control measures. Thermal pollution: Definition and sources; Chemical and biological effects of thermal pollution, effect on marine life, bacteria and water quality and other aquatic biota; Thermal pollution from power plants and their control. Oil pollution : Oil pollution and marine ecology, sources of oil pollution, factors effecting fate of oil after spillage movement, spreading, evaporation, emulsification, dispersion	**12**
III.	Soil pollution and agrochemicals: Causes of soil pollution; Effects of pesticides and weedicides on soil components and soil health, pesticide residues, residual toxicity; Different kinds of synthetic fertilizers (N, P,K), and their impact on soil physicochemical properties, toxicity on plants due to overdose of fertilizer, pollution caused by fertilizers in soil; Industrial effluents and their impact on soil components; Contamination by radio-nuclides.	**12**
IV	Radiation Pollution: Radioactive decay; Interaction of radiation with matter; Biological impact and health hazards associated with radiation; Units of radioactivity and radiation dose; Radioactive waste disposal. Noise Pollution: Basic properties of sound waves – plane and spherical waves,	**12**

	sound pressure, loudness and intensity levels, decibel; Sources of Noise Pollution- measurement and analysis of sound, measures to control noise pollution	
TOTAL		**48**

Text Books:

1. De, A. K. Environmental Chemistry, 9th Edition, New Delhi: ISBN 978-93-87477-24-7, New Age International Publishers, 2008.
2. Sharma, B.K. and Kaur, H. Environmental Chemistry, Meerut: Goel Publishing House, 1996.
3. Koren, H and Bisesi, M. Handbook of Environmental Health and Safety – principle and practices, (Vol. I and II), 3rd Edition, Florida: Lewis Publishers, 1996.

Reference Books:

1. Manahan S.E., Environmental Chemistry, Lewis, 1994.
2. Manahan, S.E. Environmental Chemistry, 8thEdition, Florida, CRC Press, 2004.
3. Shaw I.C. and Chadwick J., Principles of Environmental Toxicology, Taylor & Francis, 2008.
4. Peirce, J. Jeffrey, P. Aarne Vesilind, and Ruth Weiner. *Environmental pollution and control*. Butterworth-Heinemann, 1998.
5. Farmer, Andrew. *Managing environmental pollution*. Routledge, 2002.
6. Vesilind, P. Aarne, J. Jeffrey Peirce, and Ruth F. Weiner. *Environmental pollution and control*. Elsevier, 2013.

Reading Materials:

1. Ajibade, Fidelis O., et al. "Environmental pollution and their socioeconomic impacts." *Microbe mediated remediation of environmental contaminants*. Woodhead Publishing, 2021. 321-354.
2. Chen, Yi-Gong, et al. "Impacts of heavy metals and medicinal crops on ecological systems, environmental pollution, cultivation, and production processes in China." *Ecotoxicology and Environmental Safety* 219 (2021): 112336.
3. Choudhury, A. T. M. A., and I. R. Kennedy. "Nitrogen fertilizer losses from rice soils and control of environmental pollution problems." *Communications in soil science and plant analysis* 36.11-12 (2005): 1625-1639.
4. Long, Caicheng, et al. "Applications of carbon dots in environmental pollution control: A review." *Chemical Engineering Journal* 406 (2021): 126848.
5. Yusuf, Ahmed, et al. "Updated review on microplastics in water, their occurrence, detection, measurement, environmental pollution, and the need for regulatory standards." *Environmental Pollution* 292 (2022): 118421.
6. Zhou, Kan, et al. "Drivers of regional environmental pollution load and zoning control: a case study of the Yangtze River economic Belt, China." *Chinese Geographical Science* 32.1 (2022): 31-48.

Paper III Core Course	Natural Hazards and Disaster Management L-T-P-C: 3-1-0-4 Credit Units: 4 Scheme of Evaluation: (T)	Subject Code: ENV164C203

Course Objectives:

The aim of this paper is to provide insights into various environmental hazards, their causes, nature, preparedness and assessment of loss so that the students can estimate how human activities interfere with the geophysical processes in causing and/or accentuating natural hazard.

Course Outcomes:

On completion of the course, the students will able to:		Bloom's cognitive Level
CO1	Understand the concepts of environmental hazard, vulnerability and risk	**1, 2**
CO2	Identify different types of hazards (natural and man-made) and compare their management strategies and practicability	**3, 4**
CO3	Assess the mitigation approaches and develop a foundation for hazard, risk and vulnerability assessment	**5**

Detailed Syllabus:

Modules	Topics (if applicable) & Course Contents	Periods
I.	Definition - Hazard, vulnerability and risk; Environmental hazards: Natural (Geophysical, hydrological, climatological, meteorological and biological) and man-made hazards (Hazards due to dams and reservoirs, hazards due to nuclear power plant, industrial hazards, occupational hazards, Chemical hazards) , mitigation measures. Environmental Risk and Hazards: Identification of hazard prone belts, hazard zonation and risk assessment, developing warning system, risk assessment and reduction in vulnerable areas Hazard Mitigation: Strategies for mitigation – warning system, forecasting, emergency preparedness, education and training activities, Basics of hazard management and mitigation	**12**
II.	Earthquake and Volcanic Hazards: Origin and severity of earthquakes, effects of earthquakes, risk evaluation, seismic hazards and its zonation in India with special reference to North East India, coping with seismic hazards; Origin and types of volcanic activities; Volcanic belts, nature of volcanic hazards, mitigation of volcanic hazard vulnerability. Slope Instability and Landslide Hazard: Causes - destabilizing forces; mass movement types; Human use and landslides, strength of materials and instability of slopes, subsidence and swelling of ground.	**12**
III.	Flood hazard and its management: Definition - floods, floodplains and flood-prone areas; Causes, nature and frequency of flooding; Urbanization and flooding; Flood Hazard Assessment – environmental effects of flooding, flood prone areas of India and associated hazards, flood mitigation and management in Northeast India.	**12**
IV	Desertification and Drought: Causes of desertification; Evaluation of desertification hazard – potential and zoning; Drought - causes, types, distribution and management Cyclones and Tsunami: Cyclones – their nature and genesis; Nor'westers; Weather associated with cyclones; Tsunami – their origin, nature and impact on coastal areas; Tidal waves	**12**
TOTAL		**48**

Textbooks:

1. Bell, F.G. *Geological Hazards: Their Assessment, Avoidance & Mitigation*, Taylor and Francis,2003.
2. Bell, F.G. *Environmental Geology* - Principles and Practice, Blackwell Science,1998.
3. Anderson, D. L. *Theory of the Earth.* Blackwell Scientific Publications, 1989.
4. Krauskopf, K.B. and Bird, D.K., *Introduction to Geochemistry*. McGraw-Hill,1994.

Reference Books:

1. National Policy on Disaster Management, NDMA, New Delhi, 2009.
2. A Global Report - *Reducing Disaster Risk, A Challenge for Development*; UNDP Publication, 2004.
3. Saxena, H.M. *Environmental Geography*, 2nd Edition, Jaipur, Rawat Publications, 2007.

Reading Materials:

1. Cui, Peng, et al. "Scientific challenges of research on natural hazards and disaster risk." *Geography and Sustainability* 2.3 (2021): 216-223.
2. Katoch, Sheetal. "Disaster management: Proactive approach in reducing vulnerability to natural disasters by managing disaster risks."
3. Oktari, Rina Suryani, et al. "Knowledge management practices in disaster management: Systematic review." *International Journal of Disaster Risk Reduction* 51 (2020): 101881.
4. Pearce, Laurie. "Disaster management and community planning, and public participation: how to achieve sustainable hazard mitigation." *Natural hazards* 28.2 (2003): 211-228.
5. Singh, Garima, Rakshit Jakhar, and Preeti Sachar. "Impact on people's lives and livelihoods in Gujarat due to Natural hazards." *International Journal* 10.4 (2022).
6. Tang, Rumei, et al. "Impact of economic development levels and disaster types on the short-term macroeconomic consequences of natural hazard-induced disasters in China." *International Journal of Disaster Risk Science* 10.3 (2019): 371-385.
7. Yu, Manzhu, Chaowei Yang, and Yun Li. "Big data in natural disaster management: a review." *Geosciences* 8.5 (2018): 165.

Paper IV Core Course	**Practical II**			**Subject Code: ENV164C214**
	L-T-P-C: 0-0-8-4	**Credit Units: 4**	**Scheme of Evaluation: (P)**	

Course Objectives

The paper will provide the students with appropriate analytical procedures and techniques to help them acquaint with hands on experience on analysis of various environmental parameters involving air, water and soil, followed by application of right statistical tools and techniques for resulting into meaningful scientific information. In addition, the students will be able to map and interpret the different environmental degradation in both space and time using geo-spatial technology.

Course Outcomes

On completion of the course, the students will able to:		Bloom's cognitive Level
CO1	Apply suitable statistical tools and techniques for the assessment and evaluation of different environmental variables	**3**
CO2	Analyze different datasets/satellite products for geo-spatial mapping, and interpret the spatial data visually and digitally using GIS software	**4, 5**
CO3	Assess different environmental parameter (soil, water, air, noise) data on field using scientific devices/tools	**5**
CO4	Compile analyzed data, prepare scientific reports and design field projects independently	**6**

Detailed Syllabus:

Modules	Topics (if applicable) & Course Contents	Periods
I.	Computer analysis of environmental data: Regression analysis, trend analysis, error analysis and application of statistical tests in Environmental problems; Fitting of polynomials to environmental data; Analysis of time series of environmental variable; Use of Chi-square, F-test and t- test; Principle component analysis of environmental variable.	**12**
II.	Measurement of noise in silent, industrial, residential and commercial zones. Determination of (i) SPM in ambient air by high volume sampler and their analysis; Determination of PM10, PM 2.5; Analysis of SO_2, NO_2, by wet chemistry method in ambient air.	**12**
III.	Gravimetric Analysis: Estimation of Total Dissolved Solids (TDS), Total Suspended Solids (TSS), Total Solids (TS) in water samples. Estimation of turbidity of water using Nephelometer Titrimetric Experiments: Estimation of Ca, Mg, Cl^- in water samples. Estimation of dissolved oxygen(DO), Biological Oxygen Demand(BOD), Chemical Oxygen Demand (COD) in different types of water samples Volumetric analysis of water and soil samples by EDTA titration. Spectrophotometric determination of Iron, Nitrate and phosphates in water samples Experiments related to Microbiological analysis of waste water. Estimation of contaminants in water: Fluorides and arsenic in ground water.	**12**
IV	Introduction to open source and professional GIS software system Georeferencing of maps by using Open Source GIS; Map digitization and creation of points, lines and polygons; Preparation of thematic maps Digital Image processing: Unsupervised classification and Supervised classification; Preparation of maps by using GPS data	**12**
TOTAL		**48**

Textbooks:

1. Garg S.K., Water Supply Engineering (Vol-I & II), Khanna Publishers, 1999.
2. Biswas T.D. and Mukherjee S.K., Textbook of Soil Sciences, Publisher: McGraw- Hill Inc., US, 2nd edition,1995.
3. Karia G.L., Wastewater Treatment: Concepts and Design Approach, PHI, 2013.
4. Stewart B.A., Advances in soil sciences, Lewis Publisher,2000.
5. Brady N.C., and R.R. Weil. 2010. Elements of the Nature and Properties of Soils, 3rd Ed. PrenticeHall, 2010.

Reference Books:

1. Quattrochi, Dale A., and Michael F. Goodchild, eds. *Scale in remote sensing and GIS*. CRC press, 1997.
2. Wallace, J.M., Hobbs, P.V. *Water quality sampling and analysis* (Academic Press), 2006.
3. Gorr, Wilpen L., and Kristen Seamens Kurland. *GIS tutorial: workbook for ArcView* 9. ESRI, Inc., 2008.
4. Law, Michael, and Amy Collins. *Getting to know ArcGIS for desktop*. Redlands, CA, USA: ESRI press, 2013. Farkas G. *Practical GIS* (Packt Publishing), 2017.

Reading Materials:

1. Alshari, Eman A., and Bharti W. Gawali. "Development of classification system for LULC using remote sensing and GIS." Global Transitions Proceedings 2.1 (2021): 8-17.
2. Kim, Min-Kook. "Continuity of Instruction: Hands-on Exercise in GIS Course." SCHOLE: A Journal of Leisure Studies and Recreation Education (2021): 1-2.
3. Walsh, Stephen J. "Spatial education and integrated hands-on training: Essential foundations of GIS instruction." Journal of Geography 91.2 (1992): 54-61.

Paper IV DSE	**Remote Sensing and GIS**			**Subject Code: ENV164D201**
	L-T-P-C: 3-1-0-4	**Credit Units: 4**	**Scheme of Evaluation: (T)**	

Course Objectives:

The aim is to make the students understand about space and ground data/sources/products and GIS tools so as to make them acquire soft-technical skills and functional knowledge to carry out GIS (RS-GIS) based projects.

Course outcomes:

On completion of the course, the students will able to:		**Bloom's cognitive Level**
CO1	Understand remote sensing and geographic information system (RS- GIS) as a powerful tool for geospatial analysis	**1**
CO2	Explain satellite data in space and relate to actual ground features for different application	**2**
CO3	Apply RS-GIS to address real life field issues using different techniques	**3**
CO4	Examine one or more GIS techniques and compare for various resource management applications	**4, 5**

Detailed Syllabus:

Modules	Topics (if applicable) & Course Contents	Periods
I.	Introduction to Remote sensing: Concept, Definitions and Scope of Remote Sensing, Process and Characteristics of Remote Sensing System. Concept of Electromagnetic Radiation (EMR): Wavelength-frequency-energy EMR Spectrum and its properties, EMR wavelength regions and their application, Atmospheric windows EMR Interaction in the atmosphere: Scattering, absorption, transmission, atmospheric windows, Reflectance curve, spectral signatures. EMR with Earth's Surface Features (ESF): Spectral Reflectance Curve, Concept of signatures, Wavelength-frequency-energy relationship of EMR Remote Sensing Scenario in Indian Context	**12**
II	Data products and Data sources: Satellite imagery, aerial photographs (IRS-LISS-I, II, III, IV Data; CARTOSAT, LANDSAT, SENTINEL). Digital Image Processing: principles, image pre-processing , scale, coordinate systems, Image interpretation- manual and digital, classification- training set manipulation, ground truth Accuracy assessment	**12**
III	Introduction to GIS: Basic Concepts: definition of GIS, Components of GIS, Variables - points, lines, polygon Georeferncing: Map projection, coordinate system, datum, scale Introduction to GPS; Concept of Map Scales: Defining Map, Projection Systems, Categories of maps, Map Scales Measurement of Geographic Variables: Nominal, Ordinal, Interval and Ratio Scales, Qualitative vs. Quantitative data, Discrete vs. Continuous data GIS Data: Spatial and Attribute Data; Raster and Vector data structures	**12**
IV	Application of remote sensing and GIS: land use land cover (LULC), forestry, water resources, agriculture, biodiversity assessment, urban planning, climate change and environmental monitoring and assessment	**12**
TOTAL		**48**

Text Books:

1. Davis, S. M., Landgrebe, D. A., Phillips, T. L., Swain, P. H., Hoffer, R. M., Lindenlaub, J. C., & Silva, L. F. Remote sensing: the quantitative approach. New York, 1978.
2. Lillesand, T. and Kiefer, R.W. Remote Sensing and Image Interpretation, 7th edition, New York John Wiley & Sons, 1979.
3. Burrough, Peter A. "Principles of geographical." Information systems for land resource assessment. Clarendon Press, Oxford, 1986.
4. Ustin, Susan L., ed. Manual of remote sensing, remote sensing for natural resource management and environmental monitoring. Vol. 4. John Wiley & Sons, 2004.
5. Varshney, Pramod K., and Manoj K. Arora. Advanced image processing techniques for remotely sensed hyperspectral data. Springer Science & Business Media, 2004.
6. Jense, J.R. Remote Sensing of the Environment – An earth resource perspective. Pearson Education 2009.
7. Jones, Chris B. Geographical information systems and computer cartography. Routledge, 2014.
8. Lillesand, Thomas, Ralph W. Kiefer, and Jonathan Chipman. Remote sensing and image interpretation. John Wiley & Sons, 2015.
9. Liu, Jian Guo, and Philippa J. Mason. Image processing and GIS for remote sensing: techniques and

applications. John Wiley & Sons, 2016.
10. Pandey, Shivam. Basic Concept of Remote Sensing, GPS, and GIS. Sankalp Publication, 2020

Reference Books:

1. Burrough, P.A. and McDonnell, R. A. Principles of Geographical Information Systems. 7th Edition, Oxford University Press, 2018.
2. Thenkabail, Prasad S., John G. Lyon, and Alfredo Huete, eds. *Hyperspectral Remote Sensing of Vegetation, Four Volume Set*. CRC Press, 2022.
3. Zhang, Ke, Yang Hong, and Amir AghaKouchak. "Interdisciplinary Perspectives on Remote Sensing for Monitoring and Predicting Water-Related Hazards." *Remote Sensing of Water-Related Hazards* (2022): 1-9.

Reading materials:

1. Abid, Sheikh Kamran, et al. "A review on the application of remote sensing and geographic information system in flood crisis management." *Conference on Broad Exposure to Science and Technology.—2022*.
2. Dandge, K. P., and S. S. Patil. "Spatial distribution of ground water quality index using remote sensing and growth using remote sensing and GIS techniques: A micro-level study." *GeoJournal* 87.3 (2022): 2101-2123GIS techniques." *Applied Water Science* 12.1 (2022): 1-18.
3. Das, Sandipta, and Dasharatha P. Angadi. "Land use land cover change detection and monitoring of urban 5.Chandrasekar, A. *Basics of atmospheric science*. PHI Learning Pvt. Ltd., 2022.
4. Foody, Giles M., and Peter M. Atkinson. "Current status of uncertainty issues in remote sensing and GIS." *Uncertainty in remote sensing and GIS* (2002): 287-302.
5. Rajesh, H. M. "Application of remote sensing and GIS in mineral resource mapping-An overview." *Journal of mineralogical and Petrological Sciences* 99.3 (2004): 83-103.
6. Singh, Ajay. "Remote sensing and GIS applications for municipal waste management." *Journal of environmental management* 243 (2019): 22-29.
7. Taloor, Ajay Kumar, Praveen K. Thakur, and Md Jakariya. "Remote sensing and GIS applications in water science." *Groundwater for Sustainable Development* (2022): 100817.
8. Walsh, Stephen J., David R. Butler, and George P. Malanson. "An overview of scale, pattern, process relationships in geomorphology: a remote sensing and GIS perspective." *Geomorphology* 21.3-4 (1998): 183-205.

Paper II	Atmospheric Science			Subject Code:
DSE	L-T-P-C: 3-1-0-4	Credit Units: 4	Scheme of Evaluation: (T)	ENV164D202

Course Objectives:

This paper will impart the basic knowledge and concepts of various processes and phenomena in the field of atmospheric science. Also, it will train the students with quantitative and scientific reasoning skills so that they can be well acquainted with probable solutions to various challenges and issues related to atmospheric sciences.

Course outcomes:

On completion of the course, the students will able to:		Bloom's cognitive Level
CO1	Understand the concepts, processes and mechanisms of changes in the atmosphere	**1, 2**
CO2	Identify the processes of atmospheric transport and deposition	**3**
CO3	Compare the atmospheric processes and interpret the role of atmospheric concepts towards specific functions of earth as a system	**4, 5**

Detailed Syllabus:

Modules	Topics (if applicable) & Course Contents	Periods
I.	Elementary concepts of atmospheric sciences: atmosphere and its composition, pressure and its variation with height, variation of temperature with height, definition of wind, squall, gustiness, gale, Beaufort scale, land and sea breeze, katabatic and anabatic winds, Buys-Ballot's law, geostrophic wind, visibility, causes of poor visibility, haze, mist, fog,	**12**

	tropical depression and storm, diurnal variation of surface pressure, surface and air temperature, wind, rainfall, humidity and cloudiness, basic ideas of general circulation	
II.	Transport of Heat, Mass and Momentum: Transport of heat, mass, and momentum in the atmosphere across different interface such as soil, vegetation, water; Mass transfer by Gases, water vapour and particles; Mass diffusion, Mass exchange between air, plants and animals. Properties of turbulance, Roughness parameters, Aerodynamic resistance, Bowen ratio, flux gradients, wind speed gradients; Turbulent transfer, profiles and fluxes across vegetation canopies. General equation for transport within a gas. Verticle fluxes, Eddy Covariance, Conduction, Convection and Advection in gases, liquids and solids. Diffusion coefficients for momentum, heat, water vapor, and other gases and dependence on temperature. Transient heat balance. Sensible heat flux, latent heatflux.	**12**
III.	Atmospheric aerosols: Continental and Marine (Origin, Physical and Chemical characteristics), Cloud Morphology, Warm Cloud Microphysics (Nucleation and Condensation), Growth of cloud droplets by collision and coalescence, Cold Cloud Microphysics (Nucleation and growth of ice), Ice in the atmosphere.	**12**
IV	Radiation Environment: Properties of Electromagnetic radiation, Principles of radiation absorption and emission, Concepts of Black Body, Wein's law, Kirchoff's law, Planck's law, Stefan-Boltzman's law; Radiative exchange between layers and surfaces, radiative resistance; Cosine law, Spectral reflectivity and absorptivity, Beer's law, Kubelka-Munk Equations. Irradiance and radiance; Principle of scattering and absorption of shortwave and long wave radiation, Aerosol Optical depth, Single scattering Albedo, Radiation balance, Role of atmospheric dust in radiation balance, concept of radiative forcing, Terrestrial radiation and its passage through the atmosphere. Raleigh and Mie scattering.	**12**
TOTAL		**48**

Textbooks

1. Iqbal M. Introduction to solar Radiation, Academic press, 1983
2. Rogers , R. R. and Yau, M.K. A Short course in cloud physics" 3rd Edition, Butterworth - Heinemann Publications, 1996.
3. Campbell G.S., Norman, J.M. An Introduction to Environmental Biophysics, 2e, Springer-Verlag, New York,1997.
4. Barry, R.J. and Chorley, R.G. Atmosphere, Weather and Climate (Methuen Publication), 2009.
5. Monteith J. and Unsworth, M. Principles of Environmental Physics: Plants, Animals, and the Atmosphere, 4e, Academic Press, 2013.

Reference books

1. Jacobson, Mark Z. Fundamentals of Atmospheric Modelling, Cambridge UniversityPress, 2005.
2. Wallace, John M., and Peter V. Hobbs. *Atmospheric science: an introductory survey*. Vol.

92. Elsevier, 2006.
3. Petty, G.W. A First Course in Atmospheric Radiation, second ed. Sundog Publishing, 2006.
4. Foken, T. Micrometeorology. Springer-Verlag, Berlin,Heidelberg, 2008.
5. Hewitt, C. Nick, and Andrea V. Jackson, eds. *Handbook of atmospheric science: principles and applications*. John Wiley & Sons, 2008.
6. Chandrasekar, A. *Basics of atmospheric science*. PHI Learning Pvt. Ltd., 2022.

Reading materials

1. Pye, Havala OT, et al. "The acidity of atmospheric particles and clouds." *Atmospheric chemistry and physics* 20.8 (2020): 4809-4888.
2. Ram, Kirpa, et al. "Why airborne transmission hasn't been conclusive in case of COVID-19? An atmospheric science perspective." *Science of The Total Environment* 773 (2021): 145525.
3. Schiffer, Jamie M., et al. "Sea spray aerosol: where marine biology meets atmospheric chemistry." *ACS central science* 4.12 (2018): 1617-1623.
4. Yang, Dazhi, Wenting Wang, and Xiang'ao Xia. "A concise overview on solar resource assessment and forecasting." *Advances in Atmospheric Sciences* (2022): 1-13.

M. Sc. Course in Environmental Science: Semester-III

Paper I Core Course	**Environmental Geoscience**			**Subject Code: ENV164C301**
	L-T-P-C: 3-1-0-4	**Credit Units: 4**	**Scheme of Evaluation: (T)**	

Course Objectives:

The paper will help in understanding the Earth surface processes that can be used in determining the cause and nature of past and future climate. It will also develop key observational and analytical skills that enable them to address fundamental questions about the functioning of geoscience systems, especially in relation to hydrology and water quality, soils, mineral resources, and climate change.

Course Outcomes:

On completion of the course, the students will able to:		**Bloom's cognitive Level**
CO1	Understand the major geological processes occurring in the Earth's crust	**1, 2**
CO2	Utilize geological methods for minimizing the destructive potential of natural processes for sustainable biosphere on earth	**3**
CO3	Examine earth as a system of interlinked spheres (geosphere, hydrosphere, biosphere, atmosphere), and explain the unifying paradigms associated with geological time and plate tectonic	**4, 5**

Detailed Syllabus:

Modules	Topics (if applicable) & Course Contents	Periods

I	Earth's Origin: Origin of the earth, evolution of the earth's atmosphere, origin of heat, geological history of earth. Geological time scale evolution of continents and ocean basins. Continental drift, plate tectonics, seismic waves, plate boundaries; Earth's interior	**12**
II.	Concept of minerals and rocks. Rocks and their classification, formation of igneous and metamorphic rocks; Minerals and their classification; Weathering and soil formation, soil profile, soil classification, soils of India	**12**
III.	Geochemical Classification of elements, abundance of elements in bulk earth, crust, hydrosphere and biosphere; Geochemical recycling of elements Environmental Geochemistry: Concepts of major, trace and REE. Classification of trace elements, mobility of trace elements; Geochemical cycles, Paleoclimate	**12**
IV.	Distribution of water in earth- hydrology and hydrogeology; Major basins and groundwater provinces of India, groundwater fluctuations, hydraulic conductivity, groundwater quality and over exploitation of groundwater	**12**
TOTAL		48

Text Books:

1. Zektser, Igor S., et al., eds. Geology and ecosystems. Springer Science & Business Media, 2007.
2. Rafferty, John P., ed. Geological Sciences. Britannica Educational Publishing, 2011.
3. Howie, R. A. Introduction to rock forming minerals, 3rd Edition, Mineralogical Society of Great Britain, 2013.
4. Revil, André, and Abderrahim Jardani. The self-potential method: Theory and applications in environmental geosciences. Cambridge University Press, 2013.
5. Gill, Robin. Chemical fundamentals of geology and environmental geoscience. John Wiley & Sons, 2014.
6. Chenchouni, Haroun, et al., eds. New Prospects in Environmental Geosciences and Hydrogeosciences: Proceedings of the 2nd Springer Conference of the Arabian Journal of Geosciences (CAJG-2), Tunisia 2019. Springer Nature, 2022.

Reference Books:

1. Goff, Fraser, and K. S. Lackner. "Carbon dioxide sequestering using ultramafic rocks." *Environmental Geosciences* 5.3 (1998): 89-101.
2. Saxena, Gaurav, R. Kishor, and R. N. Bharagava. *Bioremediation of industrial waste for environmental safety*. Springer Singapore, 2020.
3. Gill, Joel C., and Martin Smith, eds. *Geosciences and the sustainable development goals*. Springer Nature, 2021.
4. Camps-Valls, Gustau, et al., eds. *Deep learning for the Earth Sciences: A comprehensive approach to remote sensing, climate science and geosciences*. John Wiley & Sons, 2021.

Reading Materials:

1. Gill, Robin. *Chemical fundamentals of geology and environmental geoscience*. John Wiley & Sons, 2014.
2. Gorody, Anthony W. "Factors affecting the variability of stray gas concentration and composition in

groundwater." *Environmental Geosciences* 19.1 (2012): 17-31.
3. Lakshmanan, E., R. Kannan, and M. Senthil Kumar. "Major ion chemistry and identification of hydrogeochemical processes of ground water in a part of Kancheepuram district, Tamil Nadu, India." *Environmental geosciences* 10.4 (2003): 157-166.
4. Liverman, Dave, Christopher PG Pereira, and Brian Marker. "Communicating environmental geoscience: introduction." *Geological Society, London, Special Publications* 305.1 (2008): 1-4.
5. Papazotos, Panagiotis. "Potentially toxic elements in groundwater: a hotspot research topic in environmental science and pollution research." *Environmental Science and Pollution Research* 28.35 (2021): 47825-47837.
6. Pereira, Joy Jacqueline. "Environmental geoscience in Southeast Asia: Current trends and future challenges." *Episodes Journal of International Geoscience* 24.2 (2001): 115-117.
7. Soeder, Daniel J. "Greenhouse gas sources and mitigation strategies from a geosciences perspective." *Advances in Geo-Energy Research* 5.3 (2021): 274.

Paper II Core Course	**Energy and Environment**			**Subject Code: ENV164C302**
	L-T-P-C: 3-1-0-4	**Credit Units: 4**	**Scheme of Evaluation: (T)**	

Course Objectives:

The aim is to give the concept of different energy sources and processes of energy conversion for various uses. Also, it will give an idea about the generation principal of thermal, hydroelectric, geothermal, nuclear etc. energy and the various problems and issues associated with it.

Course Outcomes:

On completion of the course, the students will able to:		**Bloom's cognitive Level**
CO1	Understand the concept, working principles, transformation and generation of different forms of energy and their sources	**1, 2**
CO2	Identify the different initiatives for energy conservation and examine the sustainable use at the global, regional and local scale	**3, 4**
CO3	Judge the most suitable energy forms to be applied in different environmental conditions in a sustainable manner	**5**

Detailed Syllabus:

Modules	**Topics (if applicable) & Course Contents**	**Periods**
I.	Energy sources, forms, significance and its ultimate fate. Sun as source of energy; Solar radiation and its spectral characteristics; Energy flow patterns. Effects of energy use on the environment and analyses of current energy	**12**

	related problems.; Energy production and consumption pattern –World and India.	
II.	Principles of generation of thermal, hydroelectric, Wave, Tidal, OTEC, wind, geothermal, and solar power. Hazards related of hydropower. Bioenergy: methods to produce energy from biomass; Bio-energy and biofuels. Nuclear reactors-principles and types; Promise and problems of Nuclear energy-fission an fusion,	**12**
III.	Fossil fuels-classification, composition, physicochemical characteristics and energy content of coal, petroleum and natural gases. Air pollution and thermal pollution from fossil fuels. Radioactive wastes from nuclear power plants, Emission of CO_2 in developed and developing countries	**12**
IV	Thermochemical conversion technology, Wind Energy Conversion Technology and Energy Storage, Biomass Power Generation Technologies, Energy conservation, substitution and management.	**12**
TOTAL		**48**

Textbooks:

1. Culp, Jr, A W. Principles of energy conversion, second edition. United States, 1991.
2. Sorensen, Bent. Renewable energy conversion, transmission, and storage. Elsevier, 2007.
3. Ristinen R. A. and Kraushaar J.J. Energy and the Environment, 5th Edition, John Wiley and Sons, 2008.
4. Bostan, Ion, et al. Resilient energy systems: renewables: wind, solar, hydro. Vol. 19. Springer Science & Business Media, 2012.
5. Klinghoffer, Naomi B., and Marco J. Castaldi, eds. Waste to energy conversion technology. Elsevier, 2013.
6. Ristinen, R. Energy and the Environment, 3rd Edition, John Wiley and Sons, 2015.
7. Patel, Mukund R., and Omid Beik. Wind and solar power systems: design, analysis, and operation. CRC press, 2021.

Reference Books:

1. Fowler, J.M. Energy and Environment, McGraw Hill, 2004
2. Rai, G.D., Non–Conventional Sources of Enegry, Khanna Publishers, 2007.
3. Energy and the Challenge of Sustainability, World Energy Assessment, UNDP, 2000.

Reading materials:

1. Danish, Mir Sayed Shah, et al. "A systematic review of metal oxide applications for energy and environmental sustainability." *Metals* 10.12 (2020): 1604.
2. Klemeš, Jiří Jaromír, et al. "Minimising the present and future plastic waste, energy and environmental footprints related to COVID-19." *Renewable and Sustainable Energy Reviews* 127 (2020): 109883.
3. Xiao, Xiao, Yang Lan, and Jun Chen. "Learning from nature for healthcare, energy, and environment." *The Innovation* 2.3 (2021).

Paper III Core Course	Solid and Hazardous Waste Management L-T-P-C: 3-1-0-4 Credit Units: 4 Scheme of Evaluation: (T)	Subject Code: ENV164C303

Course Objectives:

The aim is to acquaint students with the ability to select the most suitable solid waste management (SWM) options in a specific local context so as to assess the environmental impact of SWM. It will also help the students to assess the economic impact of SWM options and to develop innovative solutions of urban SWM.

Course Outcomes:

On completion of the course, the students will able to:		Bloom's cognitive Level
CO1	Demonstrate sound understanding of the waste generation process and characteristics of different types of solid wastes	**1, 2**
CO2	Classify the waste management processes through cradle-to-grave perspectives	**2**
CO3	Apply recycling vis-à-vis resource recovery technologies for useful conversion of specific waste type to eco-friendly products	**3**
CO4	Discover some alternate solutions and recommend possible implementable SWM plan for urban and peri-urban areas	**4, 5**

Detailed Syllabus:

Modules	Topics (if applicable) & Course Contents	Periods
I.	Solid waste-types and sources. Solid waste characteristics, generation rates, solid waste components, proximate and ultimate analyses of solid wastes. Solid waste collection and transportation: container systems-hauled and stationary, layout of collection routes, transfer stations and transportation.	**12**

II.	Solid waste processing and recovery: Recycling, recovery of materials for recycling; Composting and vermicomposting, biomethanation of solid waste, disposal of solid waste- sanitary land filling and its management, incineration of solid waste. Plastic waste: sources, consequences and management	**12**
III.	Municipal Solid waste –Definitions, sources, generation, segregation, classification and physico-chemical characterization; principles of solid waste management Hazardous wastes: definition, source, effects and management; Biomedical wastes: definition, source, effects and management; E-waste generation & management; Eco friendly disposal methods of solid wastes. Fly ash: definition, source, composition, effects, utilization and management	**12**
IV	Waste treatment technologies for resource and energy recovery- basic principles; techniques of resource& energy recovery; microbial decay, anaerobic digestion, incineration, pyrolysis.; landfill engineering and leachate management; mining of old landfills. Practical: Field visit to different solid wastes dumping sites. Preparation of vermicompost	**12**
TOTAL		**48**

Text Books:

1. White, P.R et al., Integrated Solid Waste Management, Lewis Publisher, 1989.
2. Manual on Municipal Solid Waste Management, CPHEEO, Ministry of Urban Development, Govt. of India, New Delhi, 2000.

Reference Books:

1. David, H.F. L., Liptak, B.G., Bouis, P.A., Hazardous waste and solid waste, Lewis Publisher, 2000.
2. Oberoi, N.K., Environmental Management, 2nd Edition, Excel Books, New Delhi, 2003.
3. Gottinger, Hans-Werner. *Economic models and applications of solid waste management*. Routledge, 2018.

Reading Materials:

1. Das, Atanu Kumar, et al. "COVID-19 pandemic and healthcare solid waste management strategy–A mini-review." *Science of the Total Environment* 778 (2021): 146220.
2. Gautam, Pratibha, Sunil Kumar, and Snehal Lokhandwala. "Advanced oxidation processes for treatment of leachate from hazardous waste landfill: A critical review." *Journal of Cleaner Production* 237 (2019): 117639.
3. Liu, Jianguo, Shuyao Yu, and Yixuan Shang. "Toward separation at source: Evolution of Municipal Solid Waste management in China." *Frontiers of Environmental Science & Engineering* 14.2 (2020): 1-3.
4. Lu, Jia-Wei, Ni-Bin Chang, and Li Liao. "Environmental informatics for solid and hazardous waste management: advances, challenges, and perspectives." *Critical reviews in environmental science and technology* 43.15 (2013): 1557-1656.
5. Srinilta, Chutimet, and Sivakorn Kanharattanachai. "Municipal solid waste segregation with CNN." *2019 5th International conference on engineering, applied sciences and technology (ICEAST)*. IEEE, 2019.
6. Tadesse, Takele. "Solid and Hazardous Waste Management." *Waste Manag* 120 (2004): 50017-8.

Paper I DSE	Climate Change and Its Impact			Subject Code
	L-T-P-C: 3-1-0-4	Credit Units: 4	Scheme of Evaluation: (T)	ENV164D301

Course Objectives:

To impart basic and key knowledge of the Global Climate Change which will help the students in enhancing knowledge on contribution of greenhouse gases (GHGs)in -global warming, remedial measures against global warming and climate change and policies, global and national action plan related to climate change mitigation.

Course outcomes:

On completion of the course, the students will able to:		Bloom's cognitive Level
CO1	Define and illustrate the elements of climate (Global warming, greenhouse effect, GHGs, sources, sinks, GWP) and climate change	**1, 2**
CO2	Choose the different drivers (anthropogenic and natural) of climate change and outline the impacts on different ecosystems and their sustainability	**3**
CO3	Compare different policies and agreements regarding climate change and sustainable development goals	**4**
CO4	Assess the adaptation and mitigation approaches in combating climate change and propose the best suitable strategies for combating through site-specific adaptation	**5, 6**

Detailed Syllabus:

Modules	Topics (if applicable) & Course Contents	Periods
I.	Climate change: Global warming and greenhouse effect, sources and sinks of greenhouse gases, major GHGs and their Global Warming Potential (GWP), analytical techniques of monitoring greenhouse gases Global climate change- its history. Impact of climate change on agriculture, forestry, water resources, sea level rise, coastal ecosystem and pests and diseases. Climate change and food security	**12**

II.	CO_2-global carbon deposits, sinks and sources, carbon sequestration, terrestrial carbon sequestration and carbon footprint. Effect of elevated CO_2 on growth and productivity of agricultural crops Methane- sources and sinks, methane emission from wetlands Nitrous oxide- its chemistry, sources and sinks; Nitrous oxide emission from agricultural soil	**12**
III.	Mitigation of GHGs in relation to climate change. Climate change and impact on horticultural and plantation crops and impact on human health; Adaptation and mitigation strategies of climate change and future climate change scenario	**12**
IV	Contribution of agriculture and forestry to climate change; Stratospheric ozone layer depletion-effect of UV radiation on plants and human health; International environmental conventions and agreements on climate change: Stockholm conference on Human Environment 1972, Montreal Protocol 1987, Earth Summit at Rio de Janeiro 1992, Agenda-21, Kyoto Protocol 1997, Earth Summit at Johannesburg 2002, Conference of Parties (COPs), recent UNFCCC meetings, Clean Development Mechanism (CDM)	**12**
TOTAL		**48**

Text Books:

1. Berdowski, J., Guichert, R., Heil, B. The Climate System, A.A. Blakema Publisher, 2000.
2. Bengtsson, F.O., Geosphere Biosphere Interaction and Climate, 1st Edition, Cambridge University Press, 2001.
3. Hardy, J.T. Climate Change: Causes, effects and solutions, John Wiley and Sons, 2003.

ReferenceBooks:

1. Horel, J. and Geisler, J. Global Environmental Change: An atmospheric perspective, John Wiley and Sons, 1997.
2. Bernstein, Lenny. *Climate change 2007*. desLibris, 2013.
3. Uprety, D.C. Global Warming and Agriculture, Springer, 2018.

Reading Materials:

1. Abid, Muhammad, Uwe A. Schneider, and Juergen Scheffran. "Adaptation to climate change and its impacts on food productivity and crop income: Perspectives of farmers in rural Pakistan." *Journal of Rural Studies* 47 (2016): 254-266.
2. Campbell, Bruce M., et al. "Urgent action to combat climate change and its impacts (SDG 13): transforming agriculture and food systems." *Current opinion in environmental sustainability* 34 (2018): 13-20.
3. Kumar, C. P. "Climate change and its impact on groundwater resources." *International Journal of Engineering and Science* 1.5 (2012): 43-60.
4. Kumar, Rohitashw, and Harender Raj Gautam. "Climate change and its impact on agricultural productivity in India." *Journal of Climatology & Weather Forecasting* (2014).
5. Mahato, Anupama. "Climate change and its impact on agriculture." *International Journal of Scientific and Research Publications* 4.4 (2014): 1-6.
6. Sivakumar, Bellie. "Global climate change and its impacts on water resources planning and

management: assessment and challenges." *Stochastic Environmental Research and Risk Assessment* 25.4 (2011): 583-600.
7. IPCC reports

Paper II	Environmental Impact Assessment and Legislation	Subject Code:
DSE	L-T-P-C: 3-1-0-4 Credit Units: 4 Scheme of Evaluation: (T)	ENV164D302

Course Objectives:

The paper aims to introduce the concepts, procedures and methodology of Environmental Impact Assessment (EIA), to develop a critical awareness of factors which affect the use of EIA as part of project management in the legislative and regulatory context of proposed and already existing projects, and to expose the students to the need for EIA and how to prepare the various documents required by state and federal regulations.

Course outcomes:

On completion of the course, the students will able to:		Bloom's cognitive Level
CO1	Define and summarize the concepts and components of environmental impact assessment	**1, 2**
CO2	Develop sound understanding of the EIA process and the methodologies to individually prepare the EMPs	**2**
CO3	Analyze the developmental actions with the fundamental understanding of EIA and sustainable development.	**4**
CO4	Interpret EIA that examines the environmental consequences of developmental actions	**5**

Detailed Syllabus:

Modules	Topics (if applicable) & Course Contents	Periods
I.	Aims and objectives of Environmental Impact Assessment (EIA), EIA notification 1994, 2006 and subsequent amendment; Environmental Impact Statement (EIS) and Environmental Management Plan (EMP). EIA guidelines; Impact assessment methodologies, procedure for reviewing EIA of developmental projects. Environmental planning as part of EIA and Environmental Audit. Environmental management system standards (ISO 14000 series); Eco-labelling schemes.	**12**

II.	International Environmental Laws: Evolution and development of International Environmental laws with reference to Stockholm Conference, Nairobi Declaration, and Rio Conference etc.	**12**
III.	National Environmental Policy: National Policy on EIA and Regulatory Framework: Rule & regulations of central & state Government and Central & State pollution control boards for Safeguard for Environmental Protection. Environment Audit	**12**
IV	EIA case studies: River Valley project, Township, oil refinery, highway, developmental issues in NE India.	**12**
TOTAL		**48**

Text Books:

1. Divan, S. Rosencranz A. Environmental Law and Policy in India, OUP, 2001.
2. Glasson, J, The rival and Chadwick, Introduction to Environmental Impact Assessment, Routledge, 2005.
3. Morgan, R.K. Environmental Impact Assessment - A Methodological Approach, 3rd Edition, Springer, 2008.

Reference Books:

1. Carter E.L., Environmental Impact Assessment, McGraw-Hill Education,1996
2. Morris, Peter, and Riki Therivel, eds. *Methods of environmental impact assessment*. Vol. 2. Taylor & Francis, 2001.
3. Glasson, John, and Riki Therivel. *Introduction to environmental impact assessment*. Routledge, 2013.
4. Wood, Chris. *Environmental impact assessment: a comparative review*. Routledge, 2014.
5. Naseem, M. and Naseem, S. Environmental Law in India Mohammad. Kluwer Law, International, 2020
6. Divan, Shyam, and Armin Rosencranz. *Environmental Law and Policy in India: Cases and Materials*. Oxford University Press, 2022.

Reading Materials:

1. Basavalingaiah, K., et al. "Energy flow and life cycle impact assessment of coffee-pepper production systems: An evaluation of conventional, integrated and organic farms in India." *Environmental Impact Assessment Review* 92 (2022): 106687.
2. Debnath, Biswajit, Ankita Das, and Abhijit Das. "Towards circular economy in e-waste management in India: Issues, challenges, and solutions." *Circular Economy and Sustainability*. Elsevier, 2022. 523-543.
3. Murshed, Muntasir, et al. "The nexus between environmental regulations, economic growth, and environmental sustainability: linking environmental patents to ecological footprint reduction in South Asia." *Environmental Science and Pollution Research* 28.36 (2021): 49967-49988.
4. Shammi, Mashura, Arvind Behal, and Shafi M. Tareq. "The escalating biomedical waste management to control the environmental transmission of COVID-19 pandemic: A perspective from two south Asian countries." *Environmental science & technology* 55.7 (2021): 4087-4093.
5. Shammi, Mashura, et al. "Application of short and rapid strategic environmental assessment (SEA) for biomedical waste management in Bangladesh." *Case Studies in Chemical and Environmental Engineering* 5 (2022): 100177.

6. Verheem, R. A. A., and J. A. M. N. Tonk. "Strategic environmental assessment: one concept, multiple forms." *Impact Assessment and Project Appraisal* 18.3 (2000): 177-182.

Paper III DSE	Instrumental Methods and Analysis L-T-P-C: 3-1-0-4 Credit Units: 4 Scheme of Evaluation: (T)	Subject Code: ENV164D303

Course Objectives:

The aim is to provide adequate knowledge of the principles, instrumentation and applications of common analytical techniques, including atomic and molecular absorption spectroscopy, electrochemical and separation methods (chromatographic and electrophoretic). Furthermore, the course will help acquire practical command over the extraction processes and handling of solid, liquid and gaseous samples.

Course outcome:

On completion of the course, the students will able to:		Bloom's cognitive Level
CO1	Define and demonstrate the analytical principles and techniques applied in environmental analysis	**1, 2**
CO2	Apply QA/QC analytical protocols	**3**
CO3	Assess different instrumentation techniques to estimate environmental parameters and identify the better methods for analysis for environmental contaminants	**4, 5**

Detailed Syllabus:

Modules	Topics (if applicable) & Course Contents	Periods
I.	Principles of analytical methods: Titrimetry, gravimetry, bomb calorimetry; Potentiometric analysis: pH measurement method, Ion Selective Electrode (ISE); Chromatography techniques: paper chromatography and column chromatography, Thin layer chromatography (TLC), Gas chromatography (GC), High-performance liquid chromatography (HPLC); Electrophoresis,	**12**
II.	Emission spectroscopy and analytical emission Spectrophotometry: Flame photometry, Atomic absorption spectroscopy (AAS), Inductively coupled plasma atomic emission spectroscopy (ICP-AES), Inductively coupled plasma optical emission spectroscopy (ICP-OES), Inductively coupled plasma mass spectroscopy (ICP-MS),	**12**

III.	Microscopy: Transmission Electron Microscopy (TEM), Scanning Electron Microscopy (SEM). Anode Stripping Voltametry (ASV)	**12**
IV	X-ray methods: X-ray diffraction, X-ray fluorescence and X-ray absorption and X-ray emission spectroscopy Demonstration of the instruments: AAS, ICP-OES, HPLC and GC	**12**
TOTAL		**48**

Text Books:

1. Hollas, J. M. Modern Spectroscopy, 4th edition, John Wiley & Sons, Ltd., Chichester,2004
2. Banwell C. N. and McCash E. M. Fundamentals of Molecular Spectroscopy 5th ed, McGraw-Hill,2013.
3. De, A.K. Environmental Chemistry. (9th Edition), New Age International, New Delhi, 2019.
4. Santra, S.C. Environmental Science, 9th Edition, New Central Book Agency (P) Ltd, New Delhi, 2019.

Reference Books:

1. Willard, Hobart Hurd, et al. "Instrumental methods of analysis." (1988).
2. Sharma. B. K., Industrial Methods of Chemical Analysis, Krishna Prakashan, Meerut. Sareen K., Instrumental Methods of Environmental Analysis, DVSPublisher, 2001.
3. Wendell, G. M. and Ela, P. Introduction to Environmental Science and Engineering, Masters, 3rd Edition, New Delhi, Phi Learning Pvt Ltd, 2008.
4. Reineccius, Gary. "Instrumental methods of analysis." *Food flavour technology* (2010): 229-265.

Reading Materials:

1. Ramos-Vera, Cristian Antony. "Representation of exploratory graphical analysis: a contribution to clinical instrumental research." *Nutrición Hospitalaria* 39.1 (2022): 235-236.
2. Sarkar, Tanmay, et al. "A review on the commonly used methods for analysis of physical properties of food materials." *Applied Sciences* 12.4 (2022): 2004.
3. Sibirtsev, Vladimir S., Roman O. Olekhnovich, and Evgenia O. Samuylova. "Assessment of integral toxicity of water resources by instrumental methods of analysis." *International Multidisciplinary Scientific GeoConference: SGEM* 17 (2017): 507-514.
4. Widding-Havneraas, Tarjei, and Henrik Daae Zachrisson. "A Gentle Introduction to Instrumental Variables." *Journal of Clinical Epidemiology* 149 (2022): 203-205.

Paper IV	Ecology and Aquatic Environment			Subject Code:
DSE	L-T-P-C: 3-1-0-4	Credit Units: 4	Scheme of Evaluation: (T)	ENV164D304

Course Objectives:

To inculcate the behavioral and physiological mechanisms of organisms' interactions with biotic and abiotic environment. This paper will also provide the knowledge of different types of Ecology, the inter-relationship between organism in population and communities and the problems of niche segregation, speciation, etc.

Course Outcomes:

On completion of the course, the students will able to:		Bloom's cognitive Level
CO1	Define the ecology of aquatic systems - population, structure, functions and their importance at the system scale level	**1**
CO2	Summarize the origin and adaptation of aquatic organisms during the course of evolution	**2**
CO3	Identify the impacts of aquatic pollution and examine how to use the biological strategies to prevent the pollution.	**3, 4**

Detailed Syllabus:

Modules	Topics (if applicable) & Course Contents	Periods
I.	Fundamental concepts: Abiotic and biotic components; scales (population, species, community, ecosystems, biomes); niches and habitats Population ecology: Population growth rates (density dependent/independent); meta population ecology (colonization, persistence, extinction, patches, sources, sinks); age structured populations Interactions: Types (mutualism, symbiosis, commensalism, competition, parasitism, predation, etc); ecophysiology (physiological adaptations to abiotic environment); prey-predator interactions (Lotka-Voltera equation etc) Community ecology: Community assembly, organization and succession; species richness, evenness and diversity indices, species-area relationships; theory of island biogeography Ecosystems structure and function: trophic levels and their interactions; nutrient cycles; primary and secondary productivity	**12**

II.	History of Evolutionary thought: Lamarckism; Darwinism; Modern Synthesis Fundamentals: Variation; heritability; natural selection; fitness and adaptation; types of selection (stabilizing, directional, disruptive) Diversity of life: Origin and history of life on earth; diversity and classification of life; systems of classification (cladistics and phenetics) Life history strategies: Allocation of resources; tradeoffs; r/K selection Interactions: Co-evolution (co-adaptations, arms race, Red Queen hypothesis, cospeciation); prey-predator interactions (mimicry, crypsis, etc) Molecular evolution and phylogenetics: Neutral theory; molecular clocks; rates of evolution; phylogenetic reconstruction; molecular systematics Macroevolution: Species concepts and speciation; adaptive radiation; convergence; biogeography	**12**
III.	Diversity of aquatic habitats; hydrologic cycle Aquatic food webs including microbial loop; trophic cascade Measurement of aquatic primary productivity Lakes - Origin and classification, ecological zonation, thermal stratification, water circulation, physical and chemical characteristics Phytoplankton – diversity and models of nutrient-limited growth, paradox of plankton; a general account of zooplankton	**12**
IV	A general account of benthic and periphytic communities, Characteristics of running water habitats; river continuum concept Oceans Chemistry of seawater, circulation and ecological zonation in sea, marine biota, coral reefs A general account of estuaries and wetlands Eutrophication: Causes, consequences and control measures Responses to Stress, Toxic Chemicals, and Other Pollutants in Aquatic Ecosystems	**12**
TOTAL		**48**

Textbooks:

1. Odum, E.P. and Barett, G.W. Fundamentals of Ecology, 5th ed.: Saunders Comp., Philadelphia, London, Toronto, 1971.
2. Dobson, M. and Frid, C. Ecology of Aquatic Systems. Longman, 1998.
3. Talling, J.F. and Lemoalle, J. Ecological Dynamics of Topical Inland Waters. Cambridge University Press, 1998.
4. Wetzel, R.G. and Likens, G.E. Limnological Analysis. Springer-Verlag, 2000.
5. Adams, S.M. (Ed). Biological Indicators of Aquatic Ecosystem Stress. American Fisheries Society, Bethesda, 2002.
6. Dodson, S. Introduction to Limnology. McGraw-Hill, New York, 2005.
7. Hall, B.K. and Hallgrimsson, B. Strickberger's evolution. 4th ed. Sudbury: Jones and Bartlett; 2008.

Reference Books:

1. Gautam, Ashutosh. *Recent Researches in Aquatic Environment*. Daya Books, 1995.
2. Baird, Andrew J., Andrew J. Baird, and Robert L. Wilby, eds. *Eco-hydrology: plants and water in terrestrial and aquatic environments*. Psychology Press, 1999.
3. Barnabe, Gilbert, and Regine Barnabe-Quet, eds. *Ecology and management of coastal waters: the aquatic environment*. Springer Science & Business Media, 2000.
4. Sigee, David C. *Freshwater microbiology: biodiversity and dynamic interactions of microorganisms in the aquatic environment*. John Wiley & Sons, 2005.
5. Hauer, Christoph, et al. "The role of sediment and sediment dynamics in the aquatic environment." *Riverine ecosystem management*. Springer, Cham, 2018. 151-169.

Reading Materials:

1. Chen, Carl W., and Gerald T. Orlob. "Ecologic simulation for aquatic environments." *Systems analysis and simulation in ecology* 3 (1975): 475-588.
2. Hauer, Christoph, et al. "The role of sediment and sediment dynamics in the aquatic environment." *Riverine ecosystem management*. Springer, Cham, 2018. 151-169.
3. Jones, Oliver Andrzej Hodgson, Nikolaos Voulvoulis, and J. N. Lester. "Potential ecological and human health risks associated with the presence of pharmaceutically active compounds in the aquatic environment." *Critical reviews in toxicology* 34.4 (2004): 335-350.
4. Koblížek, Michal. "Ecology of aerobic anoxygenic phototrophs in aquatic environments." *FEMS Microbiology Reviews* 39.6 (2015): 854-870.
5. Labbate, Maurizio, et al. "Anthropogenic impacts on the microbial ecology and function of aquatic environments." *Frontiers in microbiology* 7 (2016): 1044.
6. Ma, Hui, et al. "Microplastics in aquatic environments: toxicity to trigger ecological consequences." *Environmental Pollution* 261 (2020): 114089.
7. Urakawa, Hidetoshi, and Irma Nelly G. Rivera. "Aquatic environment." *The biology of vibrios* (2006): 173-189.

M. Sc. Course in Environmental Science: Semester-IV

Paper I Core Course	Soil Science			Subject Code: ENV164C401
	L-T-P-C: 3-1-0-4	Credit Units: 4	Scheme of Evaluation: (T)	

Course Objectives:

To provide the fundamental knowledge of soil, its chemistry, land use pattern, pollution, degradation, role of microbes in its management, etc. Other objectivesare to provide a better appreciation of the distribution and variability of soils and their properties and knowledge about rational and scientific thinking about the measures to abate soil degradation.

Course Outcomes:

On completion of the course, the students will able to:		Bloom's cognitive Level
CO1	Understand the physical and chemical properties of soil and their effect on plant's health	**1, 2**
CO2	Make use of the knowledge on soil to rocks and minerals formation, their weathering and climatic factors affecting them	**3**
CO3	Analyze the causes, effects and conclude the remedies to prevent and mitigate soil/land degradation	**4, 5**

Detailed Syllabus:

Modules	Topics (if applicable) & Course Contents	Periods
I.	Fundamentals of Soil: Weathering and Soil formation- Profile development, soil composition; Soil forming rocks and minerals – Classification. Soil biology: Soil organic matter, decomposition, humus formation, significance on soil fertility, nutrient availability.	**12**
II.	Physical properties of soil: Soil texture and structure - Bulk density, particle density, pore space, soil air, soil temperature, soil colour, soil water, Significance of soil physical properties on plant growth.	**12**
III.	Soil chemistry: Soil colloids - Inorganic colloids, Clay minerals, Ion exchange reactions, Organic colloids. Saline and alkaline soil: problem soils (acid, alkaline and sodic soils); Reclamation of saline and alkaline soil. Transportation of pollutants in soil system. Soil erosion and conservation: Water erosion, wind erosion and its control; Water harvesting technique	**12**

IV	Soil microorganisms and their roles in soil quality.-C:N ratio. Soil and climate change: Effects of global warming on soils and its management. Soil classification: soil group of the world, soils of India.	**12**
TOTAL		**48**

Text Books:

1. Stewart, B. A. Advances in soil sciences, Lewis Publisher, 2000.
2. Lal, Rattan, ed. Encyclopedia of soil science. No. 11. CRC Press, 2006.
3. Tan, Kim H. Environmental soil science. CRC Press, 2009.
4. Brady, N.C. and Weil, R.R., Elements of the Nature and Properties of Soils, 3rd Edition, Prentice Hall, 2010.
5. Lal, Rattan, and Bobby Alton Stewart, eds. World soil resources and food security. Boca Raton, Fla, USA: CRC Press, 2012.
6. Plaster, Edward. Soil science and management. Cengage learning, 2013
7. Lal, Rattan, and Bobby Alton Stewart, eds. Principles of sustainable soil management in agroecosystems. CRC Press, 2013.
8. Lal, Rattan, and Bobby Alton Stewart, eds. Urban soils. CRC Press, 2017.
9. Coleman, David C., Mac Callaham, and D. A. Crossley Jr. Fundamentals of soil ecology. Academic press, 2017.

Reference Books:

1. Leeper, Geoffrey Winthrop, and Nicholas C. Uren. *Soil science: an introduction*. Melbourne University Press, 1993.
2. Biswas, T.D. and Mukherjee, S. K. Textbook of Soil Sciences, (2nd edition), US: Publisher: McGraw Hill Inc., 1995.
3. Sumner, Malcolm E., ed. *Handbook of soil science*. CRC press, 1999.
4. Tan, Kim H. *Environmental soil science*. CRC Press, 2009.
5. Plaster, Edward. *Soil science and management*. Cengage learning, 2013.
6. Rowell, David L. *Soil science: Methods & applications*. Routledge, 2014.

Reading materials:

1. Bellinaso, Henrique, José Alexandre Melo Demattê, and Suzana Araújo Romeiro. "Soil spectral library and its use in soil classification." Revista Brasileira de Ciência do Solo 34 (2010): 861-870.
2. Brevik, Eric C. "Soils and climate change: gas fluxes and soil processes." Soil Horizons 53.4 (2012): 12-23.
3. Dawud, Seid Muhie, et al. "Is tree species diversity or species identity the more important driver of soil carbon stocks, C/N ratio, and pH?." Ecosystems 19.4 (2016): 645-660.
4. Hurni, Hans, et al. "Soil erosion and conservation in global agriculture." Land use and soil resources. Springer, Dordrecht, 2008. 41-71.
5. Powlson, David. "Will soil amplify climate change?." Nature 433.7023 (2005): 204-205.
6. Saha, Jayanta K., et al. Soil pollution-an emerging threat to agriculture. Springer Singapore, 2017.
7. Smith, Pete. "Soils and climate change." Current opinion in environmental sustainability 4.5 (2012): 539-544.

Paper I DSE	Ecosystem and Biodiversity Conservation L-T-P-C: 3-1-0-4 Credit Units: 4 Scheme of Evaluation: (T)	Subject Code: ENV164D401

Course Objectives:

To acquaint students with the understanding on the biodiversity in the context of ecosystem-dynamics, functioning and services provisioning. Through the course, students will acquire practical ability to assess biodiversity with different methodologies and conduct critical measures of analysis to manage biodiversity.

Course Outcomes:

On completion of the course, the students will able to:		Bloom's cognitive Level
CO1	Define and extend the concept of ecosystems and their biodiversity at different levels; interpret the values of biodiversity and its conservation importance	**1, 2**
CO2	Identify the different Conventions and Acts related to biodiversity, and transfer the curated knowledge to local communities for real-time conservation awareness	**3**
CO3	Compare the different conservation techniques and practices, and relate the importance of people participation in protecting regional diversity	**4**
CO4	Evaluate the methods on biodiversity inventories and plan independent field-surveys	**5, 6**

Detailed Syllabus:

Modules	Topics (if applicable) & Course Contents	Periods
I.	Ecosystem: Concept, trophic structure, gradient and ecotones, ecosystem restoration Ecosystem diversity: Classification of ecosystems, major ecosystem types and biomes; Geochemical environment: Gaia Hypothesis Biodiversity concepts, levels and types, Genetic diversity, species diversity, exploration and collection of plant materials, land races; Crop domestication, origin and evolution of cultivated species, agrobiodiversity; Biogeography; Principles of conservation of biological diversity in-situ and ex-situ.	**12**
II.	Extinction of species, mass extinction events, measurement of biodiversity: diversity indices. IUCN clauses and concept of threatened and endangered species. Significance and values of biodiversity, threats to biodiversity, causes and consequences of biodiversity loss, impact of climate change on biodiversity.	**12**
III.	National and global conservation measures, institutions and conventions; Indian Biodiversity Act 2002; Biodiversity and economics with special reference to India; Biodiversity in relation to global environmental changes; Biodiversity hot spots in India and world Forest conservation-Chipko movement, Appiko movement, Silent valley movement, Gandhamardhan movement Wildlife conservation projects: Project tiger, Project elephant, Crocodile conservation,	**12**

	GOI-UNDP Turtle project, Indo-Rhino project	
IV	Conservation of biodiversity: Red Data book, ethics in conservation of biodiversity. Biodiversity related national and international conventions and organizations. Management of biodiversity - Sacred groves, Community reserve forest, Reserve forests, National Parks, Wildlife Sanctuary, Biosphere Reserve, Private/corporate forest. Constrains of conservation. **Visit to a nearby biodiversity rich area**	**12**
TOTAL		**48**

Text Books:

1. Joseph, B. Environmental Studies, Tata McGraw-Hill, 2006.
2. Abrol, Dharam P. *Pollination biology: biodiversity conservation and agricultural production*. New York: Springer, 2012.
3. Silk, Nicole, and Kristine Ciruna, eds. *A practitioner's guide to freshwater biodiversity conservation*. Island Press, 2013.
4. Drechsler, Martin. *Ecological-economic modelling for biodiversity conservation*. Cambridge University Press, 2020.

Reference Books:

1. Kramer, Randall, Carel van Schaik, and Julie Johnson, eds. *Last stand: protected areas and the defense of tropical biodiversity*. Oxford University Press, 1997.
2. Brady, N.C. Weil, R.R. Elements of the Nature and Properties of Soils, 3rd Ed. Prentice Hall, 2010.
3. Santra, S.C. Environmental Science, 6th Edition, New Central Book Agency (P) Ltd., 2011.
4. Garcia, Serge M., Jake Rice, and Anthony Charles, eds. *Governance of marine fisheries and biodiversity conservation: interaction and co-evolution*. John Wiley & Sons, 2014.
5. Nakano, Shin-ichi, Tetsukazu Yahara, and Tohru Nakashizuka, eds. *Aquatic biodiversity conservation and ecosystem services*. Springer Singapore, 2016.
6. Dudgeon, David. *Threatened Freshwater Animals of Tropical East Asia: Ecology and Conservation in a Rapidly Changing Environment*. Taylor & Francis, 2022.
7. Sher, Anna. *An introduction to conservation biology*. Oxford University Press, 2022.

Reading Materials:

1. Montagnini, Florencia, Brett Levin, and Kjell E. Berg. "Introduction. Biodiversity Islands: strategies for conservation in human-dominated environments." *Biodiversity Islands: Strategies for Conservation in Human-Dominated Environments*. Springer, Cham, 2022. 3-37.
2. Okaka, Wilson Truman. "Effectiveness of Local Community Policy Responses to Climate Change Impact on Ecosystem Services for Biodiversity Conservation in the Semi-Arid Zones." *Research Anthology on Environmental and Societal Impacts of Climate Change*. IGI Global, 2022. 218-229.
3. Wang, Wei, et al. "Biodiversity conservation in China: A review of recent studies and practices." *Environmental Science and Ecotechnology* 2 (2020): 100025.

Paper III	Contemporary Environmental Issues			Subject Code:
DSE	L-T-P-C: 3-1-0-4	Credit Units: 4	Scheme of Evaluation: (T)	ENV164D402

Course Objectives

To familiarize students with the scientific understanding of general ecological principles, current environmental issues, and ways that science and society are addressing contemporary environmental problems. Students will gain an understanding of community development, species interactions, and population dynamics, implications of human population growth and anthropogenic alterations to air, water, and land resources, including effects on global biodiversity and potential implications on human health.

Course Outcomes:

On completion of the course, the students will able to:		Bloom's cognitive Level
CO1	Define and demonstrate systematic knowledge of contemporary environmental issues at local, regional and global level	**1, 2**
CO2	Identify how the environmental crisis will greatly impact both current and future generations and all other species.	**3**
CO3	Examine over prioritizing among the three pillars of sustainable development for a given environment needs and/or problems.	**4, 5**

Detailed Syllabus:

Modules	Topics (if applicable) & Course Contents	Periods
I.	Current social issues related to environment: Population growth, urbanization, tragedy of commons, food security, carrying capacity; deforestation, acidification, desertification; control measures of desertification, social forestry, types of social forestry, agro forestry, water crisis, conservation of water, ecological footprints, carbon credits; Waste management: waste segregation, Issues related to waste management, Swachh Bharat Abhiyan	**12**
II.	Major environmental issues: Narmada dam, Tehri dam, Almatti dam, Cauvery and Mahanadi, Hydro power projects, Wetland conservation, Dams: Large dams and issues benefits and environmental impacts of dams. Climate change causes and consequences: Global perspective as well as Indian scenario; Global Warming and impacts of global warming, mitigation of greenhouse gas emission and climate change; Climate change and human health	**12**

III.	Sanitation and epidemiological issues: Goitre, Groundwater arsenic pollution, Arsenicosis, Groundwater fluoride pollution, Fluorosis, Issues of arsenicosis and fluorosis with special reference to North East India, Dengue, Air borne disease allergies, Epidemiology and sanitary action, Rainwater harvesting.	**12**
IV.	Modern Concepts of biotechnology: Traditional and Modern Biotechnology, Application of Environmental Biotechnology in Waste degradation and removal, soil and land treatment, Air and Waste gases, Enzyme application, Environmental detection and monitoring	**12**
TOTAL		**48**

Text Books:

1. S.E. Manahan, *Environmental Science & Technology – A sustainable approach to Green Science and Technology*, Taylor & Francis, 2006
2. Cuningham, W. P., and B. W. Saigo. 1999. *Environmental Science*: A Global Concern, 5th ed. New York: WCB/McGraw-Hill.
3. Pickering, K.T. and Owen, L.A. *An introduction to global environmental issues*, 2nd Edition, London: Routledge Publisher (Taylor & Francis group), 1995.
4. Santra, S.C. *Environmental Science*, (6th edition), Kolkata: ISBN 13: 978-8173814044.Central Book Agency, 2000.

Reference Books:

1. Santra, S.C. *Fundamentals of Ecology and Environmental Biology*, 3rd Edition, Central Book Agency, 2002.
2. Boyle, G., Everett, B., *Energy system and sustainability, power for sustainable future*, 2ndEdition, Oxford University Press, 2003.

Reading Materials:

1. Mehta, Meera. "Public finance at scale for rural sanitation–a case of Swachh Bharat Mission, India." Journal of Water, Sanitation and Hygiene for Development 8.3 (2018): 359-373.
2. Shyamsundar, Priya, et al. "Fields on fire: Alternatives to crop residue burning in India." Science 365.6453 (2019): 536-538
3. Smith, Jo, Bruce D. Pearce, and Martin S. Wolfe. "Reconciling productivity with protection of the environment: Is temperate agroforestry the answer?." Renewable Agriculture and Food Systems 28.1 (2013): 80-92.
4. Toenniessen, Gary H., John C. O'Toole, and Joseph DeVries. "Advances in plant biotechnology and its adoption in developing countries." Current opinion in plant biology 6.2 (2003): 191-198.

Paper III DSE	Natural Resources and Management L-T-P-C: 3-1-0-4 Credit Units: 4 Scheme of Evaluation: (T)	Subject Code: ENV164D403

Course Objectives:

To impart knowledge on different types of renewable and non-renewable energy resources and its conservation management techniques. Also, to instill among the students to use critical thinking skills to convey how society perceives natural resource management vs. the actual management/conservation of our natural resources.

Course outcome:

On completion of the course, the students will able to:		Bloom's cognitive Level
CO1	Define and outline systematically about the natural resources and its vital role	**1, 2**
CO2	Identify how and where the Earth's resources are generated, and list their extraction, utilization, and the consequences on natural environment	**3, 4**
CO3	Compare the different methods of biodiversity conservation and management and develop perspectives on ways to tackle the same sustainably	**5, 6**

Detailed Syllabus:

Modules	Topics (if applicable) & Course Contents	Periods
I.	Introduction to natural resources and their consumption patterns. Supply and demand of natural resources. Types of natural resources: renewable and non-renewable resources. Forest resources, mangroves, food resources, world food problems and environmental concerns; Approaches to natural resource management.	**12**
II.	Water resources: Surface water, groundwater, world distribution of water, over exploitation of groundwater, water conflicts; Major environmental issues related to dams; Sustainable water management. Traditional water management system. Soil resources: Land resources, land degradation: causes and mechanisms. Land use and environmental problems of soil. Soil surveys and Land use planning	**12**
III.	Mineral resources: uses and exploitation. Distribution and uses of some of the major metallic and nonmetallic minerals. Major minerals found in India. Environmental impact of mineral extraction and use. Case studies.	**12**
IV	Non-renewable energy resources: Patterns of consumption; Global energy source and overview. Fossil fuels: reserves of coal, its classification and basic geology, environmental impact of coal mining, reserves of oil and gas. Environmental impact of their production and consumption. Geothermal energy: sources and uses. Advantages and disadvantages of various energy types.	**12**
TOTAL		**48**

Text Books:

1. Utton, Albert E., W. RD Sewell, and Timothy O'Riordan. "Natural resources for a democratic society: public participation in decision-making.[Book: collection of 12 essays]." (1976).
2. Bohm, P., Russell, C. 'Comparative Analysis of Alternative Policy Instruments', in: Handbook of Natural Resource and Energy Economics, Vol.I Ed. A.V. Kneese and J.L. Sweeney, 1985.
3. Baland, Jean-Marie, and Jean-Philippe Platteau. *Halting degradation of natural resources: is there a role for rural communities?*. Food & Agriculture Org., 1996.
4. Grebner, Donald L., et al. *Introduction to forestry and natural resources*. Academic press, 2021.

Reference Books:

1. Kneese, A.V. Sweeney JL, Handbook of Natural Resource and Energy Economics, Chapters 2,12,14,17, North Holland, 1985.
2. Jhariya, Manoj Kumar, Ram Swaroop Meena, and Arnab Banerjee, eds. *Ecological intensification of natural resources for sustainable agriculture*. Singapore: Springer, 2021.
3. Wang, Lawrence K., et al., eds. *Integrated natural resources management*. Vol. 20. Switzerland: Springer Nature, 2021.
4. Banerjee, Arnab, et al., eds. *Agroecological footprints management for sustainable food system*. Singapore: Springer, 2021.

Reading materials:

1. Azam, Waseem, Irfan Khan, and Syed Ahtsham Ali. "Alternative energy and natural resources in determining environmental sustainability: a look at the role of government final consumption expenditures in France." *Environmental Science and Pollution Research* (2022): 1-17.
2. Erdoğan, Seyfettin, et al. "The role of natural resources abundance and dependence in achieving environmental sustainability: evidence from resource-based economies." *Sustainable Development* 29.1 (2021): 143-154.
3. Hossain, Akbar, et al. "Natural resources intensification and footprints management for sustainable food system." *Agroecological Footprints Management for Sustainable Food System*. Springer, Singapore, 2021. 25-68.
4. Jahanger, Atif, et al. "The linkages between natural resources, human capital, globalization, economic growth, financial development, and ecological footprint: The moderating role of technological innovations." *Resources Policy* 76 (2022): 102569.
5. Jhariya, Manoj Kumar, Ram Swaroop Meena, and Arnab Banerjee. "Ecological intensification of natural resources towards sustainable productive system." *Ecological intensification of natural resources for sustainable agriculture*. Springer, Singapore, 2021. 1-28.
6. Nassani, Abdelmohsen A., Abdullah Mohammed Aldakhil, and Khalid Zaman. "Ecological footprints jeopardy for mineral resource extraction: Efficient use of energy, financial development and insurance services to conserve natural resources." *Resources Policy* 74 (2021): 102271.
7. Yang, Xiyue, et al. "Natural resources, population aging, and environmental quality: analyzing the role of green technologies." *Environmental Science and Pollution Research* (2022): 1-15.

Paper IV DSE	Environmental Plant Physiology and Biochemistry			Subject Code: ENV164D404
	L-T-P-C: 3-1-0-4	Credit Units: 4	Scheme of Evaluation: (T)	

Course Objectives:

This paper will provide fundamental knowledge on the physiology of crops affected by physical, chemical, and biotic environment. It centers on developing an understanding of the relationships and interactions of species or crops within communities, and the physiological mechanisms involved in crop responses to environmental conditions and how plants/crops acquire the resources needed for establishing and building the canopies through the growth of various organs.

Course outcomes:

On completion of the course, the students will able to:		**Bloom's cognitive Level**
CO1	Define and demonstrate the physiological and biochemical responses of plants under changing environmental conditions	**1, 2**
CO2	Identify and distinguish the plant tolerance mechanism against various environmental pollutants at physiological and molecular level	**3, 4**
CO3	Explain the critical insights on the adaptive mechanisms of plants against stress	**5**

Detailed Syllabus:

Modules	**Topics (if applicable) & Course Contents**	**Periods**
I.	Plant growth and development in relation to environmental stress- water and temperature stress, drought stress and resistance. Anaerobiosis in soils, the effect of anoxia on plant metabolism, plant adaptation, survival and growth in waterlogged soils.	**12**
II.	UV radiation and its effect on cellular processes and metabolism. Effect of air pollutants in light reactions in chloroplasts, photosynthesis, photorespiration and dark respiration, membrane transport	**12**
III.	Physiological and molecular aspects of plant tolerance to atmospheric pollutants Oxyradicals and scavenging systems, enzyme system associated with plant defence mechanisms, superoxide dismutase, role of stomata in plant defence system	**12**
IV	Bioconversion of pollutants. Enzymatic degradation of pollutants by monooxygenase. Role of cytochrome P 450 and its multiple forms. Metal toxicity: metal bio macromolecule interaction. Practical: Analysis of pollution damage on plants morphology and physiology	**12**
TOTAL		**48**

Text Books:

1. Levitt, J, Responses of Plants to Environmental Stress, Volume-I, 2nd Edition, New York Academic Press, 1972.
2. Fitter, A.H., Hay, R, K ,M. Environmental Physiology of Plants, 3rd edition, Academic Press, 2001.
3. Park, N.S. Physicochemical & Environmental Plant Physiology, 3rd Edition, Academic Press, 2005.

Reference Books:

1. Brett, Christopher T., and Keith W. Waldron. *Physiology and biochemistry of plant cell walls*. Vol. 2. Springer Science & Business Media, 1996.
2. Taiz, L., Zeiger, E., Plant Physiology, Sinauer Associates, 1998.
3. Pintan, R., Varanini, Z., Nannipieri, P., The Rhizosphere-Biochemistry and Organic Substances at the Soil Plant interface, 2nd Edition, CRC Press, 2007.
4. Bala, Manju, Sunita Gupta, and N. K. Gupta. *Practicals in plant physiology and biochemistry*. Scientific Publishers, 2013.
5. Prasad, M. N., and Kazimierz Strzalka, eds. *Physiology and biochemistry of metal toxicity and tolerance in plants*. Springer Science & Business Media, 2013.

Reading Materials:

1. Ali, Qasim, et al. "Seed priming by sodium nitroprusside improves salt tolerance in wheat (Triticum aestivum L.) by enhancing physiological and biochemical parameters." *Plant physiology and biochemistry* 119 (2017): 50-58.
2. Bajguz, Andrzej, and Shamsul Hayat. "Effects of brassinosteroids on the plant responses to environmental stresses." *Plant physiology and biochemistry* 47.1 (2009): 1-8.
3. Barneix, Atilio J. "Physiology and biochemistry of source-regulated protein accumulation in the wheat grain." *Journal of plant physiology* 164.5 (2007): 581-590.
4. Li, Yanqun, et al. "The effect of developmental and environmental factors on secondary metabolites in medicinal plants." *Plant Physiology and Biochemistry* 148 (2020): 80-89.
5. Mirza, Hasanuzzaman, M. A. Hossain, and M. Fujita. "Physiological and biochemical mechanisms of nitric oxide induced abiotic stress tolerance in plants." *American Journal of Plant Physiology* 5.6 (2010): 295-324.