GONDWANA UNIVERSITY,

GADCHIROLI

National Education Policy 2020

FACULTY OF SCIENCE AND TECHNOLOGY

Syllabus B.Sc. Semester V

Program: TYUGP

Major Course: Environmental Science

With effect from Session: 2026-2027

BACHELOR OF SCIENCE

(Honours / Research)

ENVIRONMENTAL SCIENCE - MAJOR

Environment Science deals with the study and processes in water, air, land, soil and organisms which leads to pollute or degrade environment. It helps us for establishing standard for safe, clean and healthy natural ecosystem. It also deals with important issues like safe and clean drinking water, hygienic living conditions and clean and fresh air, fertility of land, healthy food and development.

Programs Outcomes:

Knowledge

Students can learn about environmental issues at local, regional, and global scales.

Skills

Students can learn how to use modern instruments and analytical techniques for environmental analysis. They can also learn to apply scientific methods and quantitative techniques to understand environmental systems.

Awareness

Students can become more aware of environmental concerns, climate change, and related mitigation strategies. They can also learn to appreciate the ethical, cross-cultural, and historical context of environmental issues.

Decision-making

Students can learn how to apply their knowledge to make efficient environmental decisions, management, and sustainable development.

Programme Outcomes for Environmental Science (Minor Subjects)

1. Environmental Awareness and Sensitization

i. Students gain basic understanding of environmental and ecological principles, biodiversity, and sustainability.

ii. Builds awareness about climate change, pollution, and conservation issues.

iii. Encourages responsible citizenship and sustainable lifestyle choices.

2. Interdisciplinary Knowledge

i. Integrates science to address environmental challenges.

ii. Promotes holistic thinking in line with NEP 2020's vision of multidisciplinary education.

3. Practical and Analytical Skills

i. Exposure to laboratory methods, fieldwork, and data analysis for environmental monitoring.

ii. Skills in water/soil testing, pollution measurement, GIS mapping, and ecological surveys.

iii. Ability to interpret environmental data and propose solutions.

4. Sustainable Development Understanding

i. Knowledge of environmental laws and international conventions.

ii. Understanding of Sustainable Development Goals (SDGs) and India's environmental commitments.

iii. The ability to acquire scientific knowledge and understand the practical applications of community action.

5. Problem-Solving and Critical Thinking

i. Students learn to identify, analyze, and propose solutions to environmental problems.

ii. Encourages innovation in waste management, renewable energy, and conservation practices.

iii. Develops capacity for research-oriented thinking even in minor subject streams.

6. Employability and Career Readiness

i. Enhances career prospects in environmental consultancy, NGOs, corporate education.

ii. Provides supplementary exposure that enriches the main subject and strengthens the student's credentials.

iii. This training component successfully provides students with highly valuable transferable skills.

GENERAL INSTRUCTIONS:

1. Theory examination for all Semesters will be at university level.
2. The Semester V examination will consist of theory papers, each of three hours' duration. The major theory paper will carry 40 marks, while the minor paper will be of 80 marks. In addition, internal assessment will account for 10 marks in the major paper and 20 marks in the minor paper.
3. The Semester VI examination will consist of theory papers, each of three hours' duration. The major theory paper will carry 40 marks, while the minor paper will be of 80 marks. In addition, internal assessment will account for 10 marks in the major paper and 20 marks in the minor paper.
4. The question paper will consist of five questions, each carrying 8 marks, with 16 marks allotted for each question in the minor paper.
5. Five questions will be based on four units with internal choice.
6. Fifth question will be compulsory with questions from each of the four units having equal weightage and there will be no internal choice.
7. Practical examination will be of 4 hours duration and separately for each semester having 30 marks each.
8. The marks will be given for all examinations and they will be converted into grade points. The final grade card will have marks, credits, grades, grade points, SGPA and CGPA.

DISTRIBUTION OF PRACTICAL MARKS (Semester V and VI each):

Total marks: 30

1. Two experiments	**- 20 marks (10 marks each)**
2. Certified practical record book	**- 04 marks**
3. Certified tour report/field diary	**- 03 marks**
4. Viva-voce	**- 03 marks Total**

THE DISTRIBUTION OF MARKS FOR THE FIELD PROJECT (Semester V)

STUG03ENVS009

Total marks: 30

1. **Understanding the topic - 10 Marks**
2. **Method and analysis - 10 Marks**
3. **Teamwork / collaboration - 05 Marks**
4. **Submission of the report - 05 Marks**

THE DISTRIBUTION OF MARKS FOR THE WORK ON COMMUNITY ENGAGEMENT PROGRAMME (Semester V)

STUG04ENVS009

Total marks: 30

1. **Understanding community needs - 10 Marks**
2. **Implementation and execution - 10 Marks**
3. **Teamwork /collaboration - 05 Marks**
4. **Submission of the report - 05 Marks**

Gondwana University, Gadchiroli
NEP 2020 U.G. PROGRAMME SESSION 2026-27
Faculty of Science and Technology
Programme Name - B.Sc. Sem V (Environmental Science) (Level-5.5) **Revised Scheme**

Sr. No.	Course Category	Subject name	Total Credit	Teaching Scheme (Hrs)			Examination Scheme									Total Marks
							Theory					Practical				
				Theory	Practical	Total Hrs.	UA	CA	Total Marks	Min. Passing	Duration of Exam (Hrs.)	UA	CA	Total Mark	Min. Passing	
1.	Major Subject (Core Subject) Annexure-I	Paper V: Environmental engineering	2+2=4	02	04	06	40	10	50	20	03	30	20	50	25	100
		Paper VI: Environmental Innovation	2+2=4	02	04	06	40	10	50	20	03	30	20	50	25	100
2.	Major Subject (Elective) Annexure-II	Paper DSE- I Any one from Major elective subject basket- 1. Industrial ecology 2. Industrial safety, health and environmental management 3. Industrial processes and pollution control	2+2=4	02	04	06	40	10	50	20	03	30	20	50	25	100
3.	Minor Subject (Core Subject) Annexure-III	Paper III Natural resource management	2+2=4	02	04	06	40	10	50	20	03	30	20	50	25	100
4.	VSC Annexure-IV	Based on Major subject: Components of Environmental Science	02	--	04	04	--	--	--	--	--	30	20	50	25	50
5.	FP/CEP Annexure-V	Based on Major Subject (30 hrs/credit)	02	--	04	04	--	--	--	--	--	30	20	50	25	50
6.	IKS(SS) Annexure-VI	IKS in Environmental Science-I	02	02	-	02	40	10	50	20	02	--	--	--	--	50
Total			22	10	24	34	200	50	250	100	14	180	120	300	150	550

B.Sc. Semester V (Environmental Science)				
Sr. No.	**Course Code**	**Course Title**	**Paper Title**	**Credits**
1.	**STUG05ENVS001**	Major subject – P V (Theory)	Environmental engineering	**2**
	STUG05ENVS002	Major subject – P V (Practical)	Practical based on - Environmental Engineering	**2**
	STUG05ENVS003	Major subject – P VI (Theory)	Environmental Innovation	**2**
	STUG05ENVS004	Major subject – P VI (Practical)	Practical based on - Environmental Innovation	**2**
2.	**STUG05ENVS005**	Major (Elective) (T)	1. Industrial ecology	**2**
	STUG05ENVS006	Major (Elective) (P)	Practical based on: Industrial ecology	**2**
	STUG05ENVS007	Major (Elective)(T)	2. Industrial safety, health and environmental management	**2**
	STUG05ENVS008	Major (Elective)(P)	Practical based on: Industrial safety, health and environmental management	**2**
	STUG05ENVS009	Major (Elective)(T)	3. Industrial processes and pollution control	**2**
	STUG05ENVS0010	Major (Elective)(P)	Practical based on: Industrial processes and pollution control	**2**
3.	**STUG05ENVS0011**	Minor Course (T)	Natural resource management	**2**
	STUG05ENVS0012	Minor Course (P)	Practical based on: Natural resource management	**2**
4.	**STUG05ENVS0013**	Vocational Skill Course (VSC)	Components of Environmental Science	**2**
5.	**STUG05ENVS0014**	FP/CEP	Field Project/ Community Engagement Program	**2**
6.	**STUG05ENVS0015**	IKS (SS)	IKS in Environmental Science-I	**2**

B.Sc. Part III Semester V

Major Subject

STUG05ENVS001

Paper V

Environmental Engineering

Unit I: Environmental Sampling

1. **Air Sampling:** Ambient air sampling site selection criteria. Duration of sampling period. Location of sampling sites. Gaseous and particulate air sampling. National Ambient Air Quality Standards (2009). Significance of stack sampling, Components and working of (PM,2.5+PM10 Dichotomous Sampler, Respirable Dust Sampler (PM10 Sampler), Fine Particulate Sampler (PM,2.5) Sampler), Continuous Ambient Air Quality Monitoring Systems (CAAQMS), Dust fall jar.

2. **Water Sampling:** Objectives. Types of water samples (Grab, Composite, Integrated). Devices used to collect water sample. Indian standards drinking water-specification (IS10500:2012).

3. **Noise, Soil and Solid Waste Sampling:** Sampling devices used for noise sampling. National Ambient Air Quality Standard w.r.t. noise. Soil sampling: Soil sampling by quartering method. Collection, Preparation and physicochemical analysis of soil sample. Solid waste sampling, Sample preparation and estimation of different parameters.

Unit II: Instrumentation and Errors

1. **Principles of Analytical Methods**: Titrimetry, Gravimetry, Colorimetry, Spectrophotometry. Spectroscopy: Definition. Classification of instrumental methods based on physical properties measurements. Atomic spectroscopy and molecular spectroscopy.

2. Instrumentation: Ultra violet-visible (UV-Vis) spectrophotometer. Atomic absorption spectrophotometer. Flame photometer. Gas chromatography: Principle, components and applications in environmental analysis.

3. Errors in Environmental Analysis: Definition. Importance of errors in environmental measurements. Determinate and in-determinate errors. Sources of errors, Types of Errors, Methods of minimization. Accuracy and precision. Measures of central tendency: Mean mode, median, range, average deviation, standard deviation, confidence limit and numerical problems.

Unit III: Operation and Maintenance of Pollution Treatment Units

1. Wastewater Treatment Units: Operation and maintenance procedure of screen, grit chamber, oil and grease trap, equalisation tank, agitator and dosing tanks and clarifloculator.

2. Aeration Tanks: Operation start up procedure, aeration tank start up with seed, seedling and culture transfer, normal operating procedure, determination of sludge age, wasting activated sludge, effluent characteristics, troubleshoot mechanism.

a. Settling tank- Operation, operation troubles, prevention and cure.
b. Sludge drying bed-Operation troubles, prevention and cure.
c. Operation and maintenance of aerators and pumps.

3. Air Pollution Control Units: Operational problems and maintenance procedure-Fabric filters and electrostatic precipitators.

Unit IV: Corporate Management

1. Principles of Management: Need for management principles. Functions of management, Concept of management principle. Objectives and components of environmental management. Principle of environmental management. Corporate social responsibility (CSR). Industrial safety and security for environmental management.

2. General aspects of Planning: Meaning of planning. Structure of planning. Evaluation of planning: advantages and limitations. Steps in planning. Characteristics of a sound plan. Making planning effective. Corporate environmental planning.

3. Foundations of Environmental Decision Making: Features of decision making. Significance of decision making in sustainability, Types of Decisions in Environmental Management, Role of science, policy, and economics in decision making, Process of decision making. Decision Making in Resource Management.

B.Sc. Part III Semester V
Major Subject
STUG05ENVS002
Practical: Environmental Engineering

A. Practical: Particulate Sampling

1. Studies on operation and maintenance of various particulate samplers.
2. Studies on separation and measurement of fractions (PM 2.5/PM 10) by Dichotomous sampler.
3. Measurement of settleable particulates by the Dust fall Jar Method.
4. Measurement of respirable suspended particulate matter (RSPM) by Respirable Dust Sampler.
5. Measurement of particulate fractions by Fine Particulate Sampler (FPS).
6. Collection, measurement, and analysis of airborne dust deposited on leaf surfaces

   (Gravimetric Method, Leaf Washing Method).

   i. Determination of dust load per unit leaf area (mg/cm^2).

   ii. Chemical analysis of washed-off dust for:

   - pH and conductivity of wash water.
   - Heavy metals (Zn, Cr)
   - Sulphate and chloride.

B. Practical: Gaseous Sampling by Impingers/Bubblers Containing Absorbing Solutions

1. SO_2 Sampling and Analysis: Using West-Gaeke method.
2. NOx Sampling and Analysis: Using Jacob & Hochheiser method.
3. CO Sampling: Collection using gas sampling bags and analysis by non-dispersive infrared (NDIR) spectroscopy.
4. O_3 Sampling: Absorption in buffered KI solution and iodometric titration.
5. H_2S Sampling: Absorption in cadmium acetate solution and colorimetric analysis.
6. Ammonia Sampling: Absorption in boric acid and titration with standard acid.
7. Studies on Volatile Organic Compounds (VOCs): Sampling using activated charcoal tubes and analysis by GC.

C. Water Quality Parameters: Physical

1. Measurement of temperature, color, odour, and turbidity.
2. Measurement of electrical conductivity (EC).
3. Determination of total dissolved solids (TDS).

D. Analysis of Water Quality Parameters: Chemical

1. Determination of dissolved oxygen by Winkler's Method
2. Determination of biochemical oxygen demand (BOD) by 5-day incubation method.
3. Determination of chemical oxygen demand (COD) by Dichromate reflux method.
4. Determination of chloride content by Argentometric titration.

5. Determination of total hardness by EDTA titration method.
6. Estimation of alkalinity and acidity by titrimetric methods.
7. Determination of nitrate by colorimetric methods.
8. Determination of phosphate by stannous chloride or molybdenum blue method.
9. Determination of sulphate by gravimetric or turbidimetric method.

Books for Reference

1. Air Pollution, M. N. Rao. Tata McGraw Hill Publishing Company, New Delhi
2. Environmental Analysis (1994), M.M. Saxena, Agro Botanical Publishers (India)
3. Environmental Chemistry and Pollution Control (1993), S.S. Dara, S. Chand and Company, New Delhi.
4. Environmental Chemistry (2000), B. K. Sharma, Goel Publication House, Meerut
5. Environmental Sanitation (2001), Baljeet Kapoor, S. Chand and Company, New Delhi
6. Soil Science (2002), M.M. Rai, McMillan India, Limited
7. Text Book of Environment, K.M. Agrawal, McMillan India Limited
8. Instrumental Method of Chemical Analysis (2012), G.R. Chatwal, Himalaya Publishing House, Mumbai
9. Chemical Methods for Environmental Analysis (1996), R. Ramesh & M. Anbu, MacMillan India Ltd., Mumbai
10. A Manual of Practical Methods in Environmental Science (1998), Environmental Research Academy, Visakhapatnam, India.

B.Sc. Part III Semester V
Major Subject
STUG05ENVS003
Paper VI: Environmental Innovation

Unit I: Foundations of Innovation

1. Fundamentals of Innovation: Definition and concept of innovation, eco-innovation and environmental innovation, importance of innovation in business and society, waves of innovation, characteristic features of invention and innovation, types of innovation (Product, process, technological innovation, business innovation, marketing, organizational, and social innovation).

2. Innovation Process: Definition, Stage-Gate, Lean Innovation models, Stages of the Innovation Process (Idea Generation, development of concept, Prototyping & Experimentation, Implementation, Diffusion & Adoption, Evaluation & Feedback, Iteration & Continuous Improvement), Innovation Management Frameworks-Scanning, searching, strategic selection, resourcing), Innovation ecosystem, barriers and drivers of innovation.

3. Foundations of Ethics in Innovation: Meaning and importance of ethics in innovation, Ethical theories applied to innovation (utilitarianism, deontology, virtue ethics), features of responsible research and innovation **(RRI),** Stakeholder participation in ethical decision-making, Environmental impact of technological innovations.

Unit II: Sustainable Innovations

1. Physical Innovations: Free public transport, solar panels with advanced efficiency (e.g., perovskite solar cells), Flexible solar panels, eco-friendly smartphones, Waste-to-energy plants converting trash into electricity, Smart recycling bins with AI sorting technology, Air-purifying towers and smog-free innovations. The Seabin: Cleaning the Oceans Safely.

2. Chemical Innovations: Hydrogen fuel cells as clean energy alternatives, Plastic-to-fuel conversion innovations, Atmospheric water generators (extracting water from air), Nanotechnology-based water filters, Washing whiter without water, carbon capture and storage (CCS) technologies.

3. Biological Innovations: Biodegradable plastics and compostable packaging, Smart irrigation systems for agriculture, Second generation bio-fuels for commercial flights, Innovative waste water recycling, The Veganbottle: An all-natural alternative to plastic bottles, Vertical farming and hydroponics systems, Biodegradable ink, bio CNG plant.

Unit III: Innovations in Agriculture and Ecology

1. Agriculture and Food: Innovation in soil management, Smart irrigation systems for agriculture, Beej Bachao Andolan (Seed conservation movement), Innovations in organic fertilizers and bio-pesticides, Magnetized fly ash for agriculture: methods of manufacturing, results on crops, Ecological principle for pest management, value addition for agricultural products, use of GPS, drones, and IoT sensors to monitor soil, crops, and weather.

2. Forestry: Community forest management in Orissa and Uttarkhand, Natural resource conservation: Mendha Lekha, Makkuu van Panchayats in Uttarkhand, Smart Forest management systems (Fire Management, pest and disease control, joint forest management (JFM), green India mission, sustainable harvesting, bio-economy Innovations)**,** India state of forest report (ISFR).

3. **Biodiversity:** IoT and sensor networks, Environmental DNA (eDNA), traditional ecological knowledge (TEK) alongside scientific methods for resource management, conservation of mangroves, conservation of olive-green turtles in Orissa.

Unit IV: Environmental Innovations in Water,Energy and Education

1. Water: Digital Paani - IoT-powered water management, Swajal- Clean drinking water initiatives, Indra Water: an electrochemical technology, Water source management in Bhandara and Hiwre Bazar. Water management– Pani Panchyat. Tank restoration- water women in Karnataka

2. Energy: Decentralized energy in India: Solar-powered livelihood tools, Microgrids & mini-grids deployment, Green energy business models in India, Electricity from rice husk and algae, Biogas units in Karnataka, Solar lighting for energy poor by SELCO India.

3. Education for Innovations: Innovations in environmental education, Bare foot college, Tilhona, Rajasthan (solar equipment training, construction of low cost solar equipments), Vigyan Ashram: low-cost equipment for energy production and conservation, Centre for environmental education (CEE), Ahmedabad, National innovation foundation, India. IISc (Centre for Ecological Science), The energy and resource institute (TERI). CEPT University (formerly the Centre for Environmental Planning and Technology) Ahmedabad, Centre of science for village, Wardha. Patent: Procedure in India and world.

B.Sc. Part III Semester V
Major Subject
STUG05ENVS004
Practical: Environmental Innovation

A. Environment and Innovations

1. Analysis of fly ash for physical and chemical parameters.
2. Determination of organic farming soil for organic carbon.
3. Estimation of vermicompost sample for pH,acidity and chloride.
4. Analysis of cowdung cake/slurry for physical and chemical parameters.
5. Determination of water holding capacity of soil.

B. Technological Innovation for Water Analysis

1. Sensor-Based Monitoring: i) Use of electrochemical sensors for estimation of dissolved oxygen, pH, and conductivity.
2. Biosensor Applications: Determination of biochemical oxygen demand (BOD) by using enzyme-based biosensors
3. Remote Sensing & Imaging: Assessment of turbidity and algal blooms by using spectral imaging devices to assess turbidity and algal blooms.
4. Portable Field Kits: On-site determination of potable water quality parameters with digital handheld kits.

C. Practicals for Waste-to-Energy

1. **Characterization of Municipal Solid Waste (MSW):** Determining moisture content and calorific value of waste.
2. Pilot plant experimentation on anaerobic digestion of organic waste (food, agricultural residues).
3. Determination of biogas composition (CH_4 and CO_2) using Orsat Apparatus.

D. Digital Environmental Monitoring

1. Noise levels analysis using digital sensors.
2. Studies on use of GIS and remote sensing tools to assess land use change.

E. Experimentation on Innovations in Organic Fertilizers

1. Establish the physical and chemical profile of innovative organic fertilizers.
   i. Proximate analysis of organic fertilizers for moisture, ash and volatile matter.
   ii. Nutrient analysis of organic fertilizers for total N–P–K.
   iii. Estimation of organic carbon in organic fertilizers by the Walkley–Black Method.

Books for Reference

1. Ecosystem approach to disaster risk reduction-Anil K Gupta, Sreja S Nair, National institute of Disaster Management, New Delhi.
2. Wetland restoration: A handbook for New Zealand freshwater systems hydrology- Dave Campbell.
3. Ecologically based stream restoration in New York Coastal Watersheds-Any B Filipowicz, New York State Department, July 2006.
4. Ecological restoration for protected areas, principles, guidelines and best practices, IUCN.
5. Sea grass habitat restoration management plan, Dept. of Interior, Florida.
6. Eco-Innovation final Report for Sectoral Innovation Watchalasdair Reid Michal Miedzinski
7. Measuring eco-innovation, Rene Kemp, United Nations University 2008 European Journal of Sustainable Development (2013), 2, 1, 171-224
8. Promoting Eco-Innovations to Leverage Sustainable development of Eco-Industry and Green Growthby1dr. A.N. Sarkar, Published By Ecsdev, Via Deifiori, 34, 00172, Rome, Italy
9. Sustainable Innovation Exploring A New Innovation Paradigm by Dorothea Seebodegraphic Design Link Ontwerpers dorothea Seebode, June 2011
10. Innovative River Management– Combining ecology, Institute of management, Viena
11. Chemical Methods for Environmental Analysis (1996), R. Ramesh & M. Anbu, MacMillan India Ltd., Mumbai
12. Environmental Analysis (1994), M.M. Saxena, Agro Botanical Publishers (India)
13. Chemical Methods for Environmental Analysis (1996), R. Ramesh & M. Anbu, MacMillan India

Ltd., Mumbai.
14. Handbook of Water and Wastewater Analysis" by Kanwaljit Kaur. Atlantic; Edition (2007); Atlantic Publishers and Distributors (P) Ltd.
15. Chemistry for Environmental Engineering and Science" by Clair N. Sawyer, Perry L. McCarty, and Gene F. Parkin.

B.Sc. Part III Semester V
Major Subject (Elective)
STUG05ENVS005
1. Industrial Ecology

Unit I: Sustainable Development

1. Overview of Industrial Ecology: Definition, Origin of IE, the environment and the anthrosphere, industrial systems, material resources, societal factors and environmental equity. An overview of industrial ecology with a focus on complex systems and the scope of the field. Industrial Symbiosis: Key opportunities and challenges for increased symbiosis, including spatial aspects of systems and design of infrastructure for eco industrial parks. Industrial symbiosis-Kalundborg - a case study.

2. Sustainability and Circular Economy: Principles of sustainability and circular economy, Master equation for the estimation of total environmental impact, Technological evolution, Analogy of biological ecology and industrial ecology, Food webs and industrial ecoparks,

Unit II: Life Cycle Assessment (LCA)

1. Foundation of LCA: Definition of LCA, Components in a product's life cycle, Structure of LCA, Advantages of LCA, Case studies. Biomimicry/Biomimetics, levels of biomimetics.

2. LCA Process: LCA process (scoping, activity, and Life cycle inventory (LCI), Life cycle impact assessment, analytical tools-life cycle assessment (LCA): ISO 14000 guidelines, Material flow analysis (MFA), Energy flow analysis (EFA), Input–Output analysis, Environmental foot printing (carbon, water, ecological). Strategies of industrial ecology- Material substitution, De-materialization, Trans materialization-examples - Reuse and recycling, Case studies, Typical constraints on reuse and recycling. Delinking and decoupling,Eco-design and sustainable manufacturing.

Unit III: Design for the Environment

1. Sustainable Design and Industrial Ecology Practices: Relationship between DfE and Industrial ecology, Environmentally conscious product and facility design, Eco-design and sustainable manufacturing, Recycling, remanufacturing, and waste valorization, Industrial symbiosis and eco-industrial parks, Design for environmental practices, Aspects of lessening impacts-Zero emission system.

2. Green Chemistry and Clean Technologies: Principles of green chemistry and green engineering. Clean technology Centre, industrial services, barriers and conflicts. Industrial metabolism. Ecological foot print, Delinking and decoupling. Environmental considerations in Design: Minimizing resource use (energy, water, raw materials), Pollution prevention and waste minimization, Hazardous material substitution and safer alternatives, Designing for recyclability, reusability, and remanufacturing.

Unit IV: Societal relevance of Industrial Ecology

1. Industrial Ecology and Sustainable Development Perspectives: Historical evolution from environmental protection to sustainability science, Industrial ecology in developing vs. developed societies, Linking industry, environment, and society. Role of industrial ecology in achieving sustainable development goals (SDGs), Equity, ethics, and environmental justice in industrial

systems, Industrial symbiosis and community benefits, Urban metabolism: cities as socio-industrial ecosystems.

2. Social Dimensions of Circular Economy and Industrial Ecology: Social dimensions of circular economy (jobs, livelihoods, social innovation), Case studies of eco-industrial parks and their community integration, Role of governments, NGOs, and civil society in promoting industrial ecology, Green technologies and their social adoption, Role of education and awareness in advancing industrial ecology, Digital tools (AI, IoT, blockchain) for sustainable societal-industrial integration, analysis of social impacts of industrial systems.

B.Sc. Part III Semester V
Major Subject (Elective)
STUG05ENVS006
Practical: Industrial Ecology

A. Practical: Carbon Footprint

1. Determination of calorific value of coal and biomass.
2. Emission monitoring – Measurement of CO_2, CO, SO_2, NOx from combustion sources using gas analyzers.
3. Energy audit experiments – Recording electricity consumption of laboratory equipment and calculating CO_2 equivalents.
4. Carbon footprint calculation – Lab-based estimation of emissions from transport and industrial processes.
5. Life Cycle Assessment (LCA) – Software-based practical to quantify carbon emissions across product stages.

B. Practical: Water Footprint

1. Water quality analysis – pH, turbidity, hardness, alkalinity, chloride, residual chlorine.
2. Estimation of organic load in water samples- BOD (Biochemical Oxygen Demand) & COD (Chemical Oxygen Demand).
3. Rainwater harvesting design – Preparation of lab-scale models to measure collection efficiency.

C. Practical: Ecological Footprint

1. Land use analysis – GIS-based mapping of land consumption for crop, housing, and industry.
2. Biocapacity estimation – Calculation of productivity of cropland, forest, grazing land, and fishing grounds.
3. Waste generation study – Per capita quantification of solid waste and its ecological impact.
4. Ecological footprint calculator – Lab exercise using software tools to estimate footprint of individuals/communities.

D. Practical: Industrial Process

1. Laboratory exercise on preparation of material flow diagrams for an industrial process.
2. Study of input–output analysis for raw materials and waste streams.

E. Waste Management

Analysis of raw waste water and treated waste water for different parameters

i. pH, acidity, and alkalinity.

ii. Total, suspended, dissolved solids and Volatile solids (VS).

iii. Nutrients Analysis of waste water: Ammonia nitrogen, Ammonium nitrogen, Nitrite nitrogen, Nitrate Nitrogen, Total Kjeldahl Nitrogen (TKN).

iv. Total Phosphorus (TP)
v. Microbial analysis: total plate count, coliform detection, yeast & mold counts.
vi. Measurement of residual chlorine from treated water.

F. Solid & Hazardous Waste Management:
i. laboratory-scale composting and anaerobic digestion.
ii. Hazardous waste leachate analysis for landfill design.

G. Carbon Footprint Calculation
i. Noise pollution measurement – decibel levels from transport vehicles
ii. Carbon footprint calculation – lab-based estimation of CO_2 emissions per km
iii. H. Life Cycle Stage: Studies on waste segregation, composting, biodegradability, leachate analysis, LCA models

Books for Reference

1. Allen, D., (1993) "Using Wastes as Raw Materials: Opportunities to Create an Industrial Ecology," Hazardous Waste & Hazardous Materials, 10(3):273-277.

2. Allen, D., and Behmanish, N. (1994), "Wastes as Raw Materials," in Allenby and Richards (eds.) The Greening of Industrial Ecosystems, National Academy of Engineering, pp.69-89.

3. Allenby, B.R., (1994a) "Industrial Ecology Gets Down to Earth," Circuits & Devices, January, 24-28.

4. Allenby, B.R., (1994b) "Integrating Environment and Technology: Design for Environment," in The Greening of Industrial Ecosystems, National Academy Press, Washington, D.C., pp. 137-148.

5. Allenby, B.R., (1992), "Industrial Ecology: The Materials Scientist in an Environmentally Constrained World," MRS Bulletin, March, pp.46-51.

6. Allenby, B.R. and Fullerton, A. (1991-92), "Design for Environment - A New Strategy for Environmental Management," Pollution Prevention Review Winter, pp.51-61.

7. Allenby, B.R. and Richards, D.J. (1994),The Greening of Industrial Ecosystems, National Academy of Engineering, Washington, D.C.

8. Ausubel, J.H. (1992), "Industrial ecology: Reflections on a colloquium," Proc. Natl. Acad. Sci. USA, 89:879-884.

9. Ayres, R.U. (1994), "Industrial Metabolism: Theory and Policy," in The Greening of Industrial Ecosystems, National Academy Press, Washington, D.C., pp. 23-37.

10. Ayres, R.U. (1991), "Industrial Metabolism: Closing The Materials Cycle," SEI Conference on Principles of Clean Production, Stockholm, April, 1991.

11. Ayres, R.U. (1989), "Industrial Metabolism," Technology and the Environment, National Academy Press, Washington, D.C., pp.23-49.

12. Brodyansky, V., Sorin, M., and Le Goff, P. (1994), "The Efficiency of Industrial Processes: Exergy Analysis and Optimization," Elsevier, New York.

13. Chiaro and Joklik (1994), "Industrial Ecology in Extractive Industries," Paper prepared for the NAE International Conference on Industrial Ecology, Irvine, CA, May 9-13, 1994.Commoner, B. (1971), The Closing Circle, Bantam Books, New York.

14. Dillon, P.S. (1994), "Implications of Industrial Ecology for Firms," in Allenby and Richards (eds.) The Greening of Industrial Ecosystems, National Academy of Engineering, pp.201-207.

15. Edington, S.M. (1995). "Industrial Ecology: Biotech's Role in Sustainable Development," BioTechnology, January 13:31-34.

16. Ehrenfeld, J.R. (1994), "Industrial Ecology: A Strategic Framework for Product Policy and Other Sustainable Practices," The Second International Conference and Workshop on Product Oriented Policy, Stockholm

17. Frosch, R.A. (1994), "Industrial Ecology: Minimizing The Impact of Industrial Waste," Physics Today, November, pp. 63-68.

18. Frosch, R.A. (1992), "Industrial Ecology: A philosophical introduction," Proc. Natl. Acad. Sci., 89:800-803.

19. Frosch, R.A. and Gallopoulos, N.E. (1992), "Towards an Industrial Ecology," in Bradshaw, et al. (eds.) The Treatment and Handling of Wastes, Chapman and Hall, London, pp.269-292.

20. Industrial Ecology and Sustainability: A Textbook for Students" by Thomas E. Graedel & Matthew J. Eckelman

21. Industrial Ecology and Industry Symbiosis for Environmental Sustainability" (1977): Li Xiaohong, Atlantic Publishers and Distributors Pvt Ltd.

22. Gertler, N. (1995), Industrial Ecosystems: Developing Sustainable Industrial Structures, Masters Thesis, M.I.T., Cambridge, MA.

23. Graedel, T.E. and Allenby, B.A. (1995), "Industrial Ecology," Prentice Hall, New Jersey.

24. Graedel, T.E., Allenby, B.R. and Linhart, P.B. (1993), "Implementing Industrial Ecology," IEEE Technology and Society Magazine, Spring:18-26

25. Jelinski, L.W., Graedel, T.E., Laudise, R.A., et al. (1992), "Industrial Ecology: Concepts and Approaches," Proceedings of The National Academy of Sciences USA 89:793-797.

26. Linden, H.R. (1994), "Energy and Industrial Ecology," in Allenby and Richards (eds.) The Greening of Industrial Ecosystems, National Academy of Engineering, pp.38-60.

27. Lowe, E. (1993), "Industrial Ecology - An Organizing Framework for Environmental Management," Total Quality Environmental Management, Autumn:73-85.

28. Lowe, E. (1992), "Discovering Industrial Ecology: An overview and strategies for implementation," Draft manuscript, Oakland, CA.

29. Patel C. (1992), "Industrial ecology," Proc. Natl. Acad. Sci. USA, 89:798-799.

30. Paton, B., (1994) "Design for Environment: A Management Perspective," in Industrial Ecology and Global Change, Socolow, R. et al. eds., Cambridge University Press, Cambridge, pp. 349-357.

31. Piasecki, B. (1992), "Industrial Ecology: An emerging management science," Proc. Natl. Acad. Sci.USA, 89:873-875

32. Richards, D. J., and Fullerton, A. B. (1994), Industrial Ecology U.S. Japan Perspectives, National Academy of Engineering

33. Socolow, R.H. and C. Andrews, F. Berkhout, V. Thomas (1994), Industrial Ecology and Global Change, Cambridge University Press, Cambridge.

34. Tibbs, H.B.C. (1992), "Industrial Ecology - An Agenda for Environmental Management," Pollution Prevention Review, Spring 1992, pp.167-180.

35. Tibbs, H.B.C. (1991), "Industrial Ecology: An Environmental Agenda for Industry," Arthur D. Little, Inc. Torrens, I.M., and Yeager, K.E. (1994), "Environmental Excellence and Industrial Ecology: The Electric Power Sector," Draft manuscript.

36. Weinberg, M., Eyring, G., Raguso, J., et al., (1994) "Industrial Ecology: The Role of Government,"The Greening of Industrial Ecosystems, National Academy Press, Washington, D.C., pp.123-133.

B.Sc. Part III Semester V
Major Subject (Elective)
STUG05ENVS007
2. Industrial Safety, Health and Environmental Management

Unit I: Principles of Safety Management

1. Concepts and Techniques: History of safety movement, General concepts of management, Planning for safety for optimization of productivity, Quality and safety-line and staff functions for safety, Human factors in industrial health, Budgeting for safety, Safety policy.

2. Techniques -Incident recall technique (IRT), Disaster control, Damage control, Job safety analysis, Safety survey, Safety inspection, Safety sampling, Motivating techniques, Evaluation of performance of supervisors on safety, Safety posters, Safety displays, Safety pledge, Safety lab.

Unit II: Safety Audit

1. Components of Safety Audit – Review of inspection, Remarks by government agencies, Consultants, Experts, Perusal of accident and safety records, Formats, Implementation of audit indication, liaison with departments to ensure co-ordination, check list, identification of unsafe acts of workers and unsafe conditions in the shop floor.

2. Safety Performance Monitoring: Calculation of accident indices, frequency rate, severity rate, frequency severity incidence, incident rate, accident rate, safety "t" score.

Unit III: Accident Investigation and Reporting

1. Concept of an Accident – Reportable and non-reportable accidents, reporting to statutory authorities, principles of accident prevention, Plant safety inspection - objectives and types, check procedure inspection report. Hazard identification and analysis: fault tree analysis, Event tree analysis, failure modes and effects analysis, records for accidents, departmental accident reports, documentation of accidents, unsafe act and condition, domino sequence, supervisory role, role of safety committee, cost of accident.

2. Fire - Basic chemistry/ mechanism, Reasons, prevention & types of fire, extinction of fire, Loss prevention association-Objective, formation, scope &significance, Safety education and training.

Unit IV: Environmental Management

1. Workplace Safety, and Environmental Management Practices: Principles of workplace wellness and safety, Integrated strategy for workplace wellness & safety, Operation and maintenance of pollution control equipments: Air pollution control-Fabric filter, ESPs, Waste water pollution control-O&M of wastewater treatment units, Techniques-handling of fire-fighting equipments, Data collection -Environmental impact assessment, Environmental audit, Energy audit, and ISO14001.

2. Legal Provisions: Functions of national safety council, Factories Act (Amendment) 1987, Maharashtra Factories Rule-1963, Maharashtra Safety Officers Rule-1982, The Workmen Compensation Act-1923, Public Liabilities Insurance Act-1991, Fatal Accident Act, Environment Protection Act,1986.

B.Sc. Part III Semester V
Major Subject (Elective)
STUG05ENVS008
Practical: Industrial Safety, Health and Environmental Management

Practical

1. Air Quality Monitoring at work place: Workplace air quality measurement and assessment.
2. Quality of potable water at work place: Determination of pH, TDS, turbidity, dissolved oxygen, Total hardness and chloride.
3. Measurement of noise levels in industrial areas using noise level meters.
4. Solid waste management: Segregation, storage, and disposal methods at work place as per environmental regulations.
5. Safety practicals: Fire extinguisher operation and fire drill exercises.
6. First aid training and emergency response simulation.
7. Monitoring of heat stress and humidity in industrial environments.
8. Practical Report: Safety Audit of a Laboratory.
9. Measurement of vibration exposure using vibration meters.
10. Industrial Safety Practical – Preparation of job safety analysis report.
11. Laboratory Practical: Study of Material safety data sheets (MSDS) for hazardous chemicals.
12. Determination of pH, turbidity, conductivity, and hardness of industrial effluents.
13. Measurement of biological oxygen demand (BOD) and Chemical oxygen demand (COD)
14. Determination of dissolved oxygen (DO) in wastewater samples.
15. Study of Effluent treatment plant (ETP) processes.
16. Jar Test Experiment: Determination of optimum coagulant dose in effluent treatment.
17. Study of composting, recycling, and waste minimization techniques in industrial establishment.

Books for Reference

1. Gupta, R.S, "Hand Book of Fire Technology" Orient Longman, Bombay 1977
2. Derek, James, "Fire Prevention Hand Book", Butter Worth's and Company, London, 1986.
3. Government of India. *The Fatal Accidents Act, 1855.* Act No. 13 of 1855. New Delhi: Government of India, 1855.
4. Government of India. *The Environment (Protection) Act, 1986.* Act No. 29 of 1986. New Delhi: Ministry of Environment, Forest and Climate Change, 1986.
5. Factories Act 1948, National Building Code and The Gujarat Fire Prevention and Life Safety Measures, Act, 2013.
6. M C Gupta , Manual on natural disaster management in India, M C Gupta, NIDM, New Delhi
7. Hansen, Earl E. *Accident Prevention Manual: Study Guide, 10th Edition.* National Safety Council, 1992.
8. Government of India. *The Factories Act, 1948.* Act No. 63 of 1948. Ministry of Labour & Employment, New Delhi.
9. Bureau of Indian Standards. (2018). *IS 14489:2018 – Occupational safety and health audit – Code of practice.* New Delhi: BIS.
10. Central Pollution Control Board. (Year). *Manual on environmental management in industries.* New Delhi: Government of India.
11. Government of Maharashtra. *The Maharashtra Factories (Safety Officers) Rules, 1982.* Industries, Energy and Labour Department, 1982.
12. Government of India. *The Workmen's Compensation Act, 1923.* Act No. 8 of 1923, Ministry of Labour & Employment, 1923.

13. Government of India. *The Public Liability Insurance Act, 1991.* Act No. 6 of 1991. New Delhi: Ministry of Environment, Forest and Climate Change, 1991.

B.Sc. Part III Semester V
Major Subject (Elective)
STUG05ENVS009
3. Industrial Processes and Pollution Control

Unit I: Cement Industry

1. Introduction: Cement-Definition, Uses, Types of cement (Ordinary portland cement, blended cements, specialty cements), Raw materials required for manufacturing (limestone, clay, shale, gypsum, iron ore, bauxite, fly ash).

2. Manufacturing Steps: Mining and Quarrying, Crushing and grinding, Raw mix preparation, Preheating and precalcination, Clinker production (Pyroprocessing), Clinker cooling, Grinding of clinker and additives, Storage and packaging , Analysis of solid materials for various chemical parameters, Instrumentation.

Unit II: Coal Industry

1. Coal: Formation, Types of coal, mining of coal-surface and underground, Coal beneficiation, Coal bed methane -Method of extraction, Valuable products from fly ash.

2. Coal Testing: Importance, Common test conducted on coal-Calorific value (Gross/Net), Proximate analysis (Moisture, volatile acid, fixed carbon and ash), Ultimate analysis (C,H,O,N,S and ash) ,Ash analysis (Al2O3, SiO2, CaO, MgO, TiO2, Na2O, K2O), Ash fusion temperature, Coke reactivity, Porosity, Density, Reflectivity, Instrumentation.

Unit III: Pulp and Paper Industry

1. Sources of Raw Materials: wood, agricultural residues, recycled paper, Chemical composition of lignocellulosic materials (cellulose, hemicellulose, lignin), Raw material preparation (debarking, chipping, sorting), Pulping processes -Mechanical pulping, Chemical pulping (Kraft process (Sulfate pulping), Sulfite process,Soda pulping, Recovery of chemicals (black liquor recovery), Semi-chemical pulping, recycled fiber processing. Bleaching & chemical treatment- objectives of bleaching (whiteness, brightness, purity), Chlorine-based vs. elemental chlorine-free (ECF) and totally chlorine-free (TCF) bleaching.

2. Paper Manufacturing Steps: Stock preparation, Papermaking machine operations (Headbox and sheet formation,Pressing section (water removal), Drying section (steam-heated cylinders), Calendaring (smoothing and finishing), Finishing & conversion (Cutting, coating, laminating, packaging), Physical tests, Chemical tests, Instrumentation.

Unit IV: Industrial Pollution Control

1. Cement Industry: Air pollutants from raw mill, Clinker stock Piles, Cement mill, Equipments used in pollution control-Fabric filter, ESPs, Environmental management systems for cement industry.

2. Coal Industry: Air water and noise control in coal mining, Overburden dump stabilization and afforestation.

3. Pulp and Paper Industry: List of waste water generating units, Wastewater treatment by physical, chemical and biological methods.

B.Sc. Part III Semester V
Major Subject (Elective)
STUG05ENVS0010
Practical: Industrial Processes and Pollution Control

A. Practicals: Cement

1. Analysis of Physical Parameters:

i. Moisture content determination – oven-drying method for limestone, clay, gypsum, fly ash.
ii. Particle size distribution – sieve analysis or laser diffraction for raw mix uniformity.
iii. Bulk density– measurement by measuring cylinder method of raw materials.

2. Analysis of Chemical Parameters:

i. Loss on Ignition (LOI) – heating raw material to determine volatile content (CO_2, moisture).
ii. Silica (SiO_2) estimation – gravimetric or spectrophotometric methods.
iii. Alumina (Al_2O_3) determination – EDTA titration or spectrophotometry.
iv. Iron oxide (Fe_2O_3) analysis – colorimetric or AAS method.
v. Calcium oxide (CaO) estimation – titration with permanganate or complexometric methods.
vi. Magnesium oxide (MgO) determination – EDTA titration.

3. Analysis of Trace Elements & Impurities

i. Sulphate content – Gravimetric method or spectrophotometry using barium chloride.
ii. Chloride content – Argentometric titration (Mohr's method).
iii. Alkali oxides (Na_2O, K_2O) – Flame photometry.
iv. Heavy metals (Pb, Cd, Cr, Hg) – Atomic absorption spectroscopy (AAS) or ICP-MS.

4. Analysis of Fuel & Additives Analysis

i. Calorific value determination –Bomb calorimeter for coal used in kilns.
ii. Gypsum purity test – $CaSO_4 \cdot 2H_2O$ content analysis.
iii. Pozzolanic activity test – for fly ash or slag additives.

5. Studies on Advanced Characterization of the Raw Materials

i. X-Ray Diffraction (XRD) –Crystalline phase identification of limestone, clay, and additives.
ii. X-Ray Fluorescence (XRF) – Rapid multi-elemental analysis of cement raw mix.
iii. Thermogravimetric Analysis (TGA) – Decomposition behavior of raw materials.
iv. Fourier Transform Infrared Spectroscopy (FTIR) – Functional group analysis in clay minerals.

B. Practical: Coal

1. Laboratory Practicals –Analysis of Raw Material

i. Proximate analysis (basic composition)
ii. Moisture content determination – oven-drying method.
iii. Volatile matter estimation – heating coal in absence of air.
iv. Ash content determination – furnace analysis at 750–800 °C.
v. Fixed carbon calculation – by difference (100 – [moisture + volatile matter + ash]).

2. Ultimate Analysis (Elemental Composition)

i. Carbon, hydrogen, nitrogen, sulphur determination – CHNS analyzer or wet chemical methods.
ii. Oxygen estimation – by difference.
iii. Sulphur forms analysis – Pyritic, sulphate, and organic sulphur determination.

3. Calorific Value & Energy Parameters

i. Gross calorific value (GCV) –Bomb calorimeter.

ii. Net calorific value (NCV) – corrected for moisture and hydrogen content.

4. Mineral & Impurity Analysis

i. Silica (SiO_2), Alumina (Al_2O_3), Iron oxide (Fe_2O_3) –Gravimetric/spectrophotometric methods.
ii. Calcium oxide (CaO), Magnesium oxide (MgO) – EDTA titration.
iii. Trace elements (Pb, Cd, Cr, Hg, As) – Atomic absorption spectroscopy (AAS) or ICP-MS.

5. Pollution & Environmental Parameters

i. Sulphur dioxide potential – estimation of SO_2 emissions from coal combustion.
ii. Nitrogen oxides potential – analysis of fuel-bound nitrogen.
iii. Fly ash characterization – particle size, chemical composition, and pozzolanic activity.

C. Practicals: Pulp and Paper making

i. Black liquor characterization – COD, BOD, solids content from pulping process.
ii. Effluent analysis – pH, turbidity, color, residual lignin.
iii. AOX (Adsorbable Organic Halides) – for chlorine-based bleaching effluents.

Books for Reference

1. Industrial Chemistry- B.K. Sharma, Goel Publication, Meerut, 2000
2. Principles and Practices of Modern Coal Mining- R.D. Singh, New Age International Publishers, New Delhi, 1997
3. Air Pollution –M.N. Rao, Tata McGraw Hill Publishing Company Limited, New Delhi, 2003
4. Environmental Science-S.C. Santra, New Central Book Agency private Limited, 2006
5. Environmental Chemistry-A.K.DE, New Age International Publishers, 2001.
6. Environmental Chemistry – S.S. Dara, S. Chand and Company, New Delhi 2002.
7. Environmental Problems and solution- Asthana, S. Chand and company, New Delhi,2000.
8. Water Supply & Sanitary Engineering: R. C. Rangwala and S. C. Rangwala, Charotal Publishing House, Anand.
9. Wastewater Treatment: M. N. Rao, A. K. Datta, IBH Publishing Company, New Delhi.
10. Water Supply & Sanitary Engineering: G.S. Birdie.
11. Experiments in engineering chemistry,S.S.Dara,S.Chand and company, New Delhi.
12. Chemical Methods for Environmental Analysis (1996), R. Ramesh & M. Anbu, MacMillan India Ltd., Mumbai
13. Environmental Analysis (1994), M.M. Saxena, Agro Botanical Publishers (India)
14. Chemical Methods for Environmental Analysis (1996), R. Ramesh & M. Anbu, MacMillan India Ltd., Mumbai.
15. Handbook of Water and Wastewater Analysis" by Kanwaljit Kaur. Atlantic; Edition (2007); Atlantic Publishers and Distributors (P) Ltd.
16. Chemistry for Environmental Engineering and Science" by Clair N. Sawyer, Perry L. McCarty, and Gene F. Parkin.

B.Sc. Part III Semester V
Minor Subject (Core Subject)
STUG05ENVS0011
Paper III Natural Resource Management

Unit I: Introduction to Natural Resources

1. Foundation of Resource Management: Definition, classification, Renewable and non-renewable resources and importance of natural resources, Evolution of management approaches from traditional to modern, Approaches to resource Management (ecological, economic, and ethnological), Principles of resource management: Sustainable development concepts, Resource conservation strategies, Policy.

2. Biodiversity and Conservation of Natural Resources: Definition & Levels of Biodiversity, Genetic diversity, Species diversity, Ecosystem diversity, Biogeographical classification of India: Major biogeographic zones, India as a mega-diversity nation. Biodiversity hotspots: Locations and significance, Endemic species. Values of biodiversity: Consumptive use, productive use, social, ethical, aesthetic, and option values. Threats to biodiversity, Concepts of conservation:(In-situ conservation (protected areas, national parks, sanctuaries, biosphere reserves), Ex-situ conservation (botanical gardens, zoos, seed banks, gene banks).

Unit II: Forest, Wild life Resources and Management

1. Forest Resources and Community Management: Forest classification by champion and seth, functions of forest – production and protection; Status, types, use, deforestation, and management strategies, Role of indigenous knowledge of the people, community forestry and joint forest management.

2. Wildlife Resources: Classification of wildlife, Role of forests in wildlife conservation, Climate change impacts on wildlife resources, Wildlife census and population estimation methods (Radio telemetry and GPS tracking, Camera trapping and remote sensing, Instrumentation and techniques in wildlife studies), Wildlife corridors and landscape connectivity, Human–wildlife conflict mitigation, Endangered species recovery programs. GIS and remote sensing applications in wildlife management.

Unit III: Land Resources Management

1. Land Resources: Definition, importance, Classification of land resources, Land use systems, land degradation, soil erosion, desertification, Climate change impacts on land resources, Land Use Planning: Principles of land use planning, Agricultural, industrial, and urban land use, Forest land management, Agroforestry systems management, Land degradation neutrality goals (UNCCD framework), Smart land management using AI and data.

2. Water Resources: Sources of Surface water and groundwater resources, Rainwater harvesting and groundwater recharge, Sustainable water use in agriculture, industry, and urban areas, Watershed management practices, Soil–water conservation techniques.

Unit IV: Natural Resource Management-Tools and strategies

1. Participatory and Rapid Rural Appraisal (PRA/RRA): Methods for resource assessment and community involvement, Community-based natural resources management (CBNRM): Strategies for local management and common property rights. Integrated natural resources management (INRM): Watershed management.

2. Environmental Management Systems (EMS): Frameworks for managing environmental impacts. Technology in NRM: Farm field-based technologies, tools, Information and communication technology (ICT): The role of modern tools like GIS, modeling, and ICT in

managing resources, Remote sensing, Environmental impact assessment (EIA) and Environmental Management Systems (EMS), Drone-based Surveys: High- resolution monitoring of ecosystems and wildlife, Digital cartography & GPS.

B.Sc. Part III Semester V
Minor Subject (Core Subject)
STUG05ENVS0012
Practical: Natural Resource Management

A. Practical: Ecological Resource Management

1. Soil Analysis: Testing pH, texture, organic matter, and nutrient content.
2. Water Quality Assessment: Measuring dissolved oxygen, turbidity, BOD, COD, and heavy metals.
3. Biodiversity Studies: Quadrat and transect sampling for species richness and diversity indices.
4. Population Ecology: Mark–recapture method for estimating animal populations.
5. Energy Flow Experiments: Measuring primary productivity using light/dark bottle method.
6. Pollution Monitoring: Air quality measurement (particulate matter, SO_2, NOx).
7. Ecological Footprint Calculation: Estimating human impact on ecosystems.

B. Practical: Economic Resource Management

1. Cost–Benefit Analysis of Resource Use: Case studies on forestry, fisheries, or agriculture.
2. Valuation of Ecosystem Services: Using contingent valuation or travel cost methods.
3. Sustainable Yield Calculations: Fisheries or forest harvest models.
4. Resource Allocation Simulation: Modeling scarcity and distribution using economic tools.
5. Life Cycle Assessment (LCA): Evaluating environmental costs of products.
6. Carbon Accounting: Measuring carbon credits and offsets in resource projects.

C. Practical: Ethnological Resource Management

1. Ethnobotanical Surveys: Documenting traditional plant uses in local communities.
2. Participatory Rural Appraisal (PRA): Mapping community resource use and management practices.
3. Cultural Resource Documentation: Recording indigenous knowledge of water, soil, and forest management.
4. Socio-economic Surveys: Household-level resource consumption studies.
5. Conflict Resolution Case Studies: Role-play exercises on resource-sharing disputes.
6. Traditional Agricultural Practices: Comparative study of indigenous vs. modern farming methods.
7. Community-based Conservation Models: Evaluating success stories of joint forest management or sacred groves.

D. Practical: Land Resource Management

1. Soil Texture Analysis: Determining sand, silt, and clay proportions using sieve and hydrometer methods.
2. Soil pH and Salinity Testing: Measuring acidity/alkalinity and electrical conductivity.
3. Soil Moisture Content: Gravimetric and sensor-based methods to assess water-holding capacity.
4. Soil Nutrient Analysis: Estimation of nitrogen, phosphorus, potassium, and organic carbon.
5. Soil Erosion Studies: Simulating erosion under rainfall and slope conditions.
6. Bulk Density and Porosity Measurement: Evaluating soil compaction and aeration.

E. Practical: Experiments on Watershed

Hydrological Measurements

1. Rainfall measurement with standard rain gauges.
2. Runoff estimation using field plots and empirical formulas.

F. Practical: Soil & Land Capability Studies on Watershed:

1. Determination of bulk density of the soil
2. Case studies on: Participatory rural appraisal (PRA) exercises.

Books for Reference

1. Ecology and Environment- P.D. Sharma, Rastogi Publication, 2001.
2. Environmental Biology and Toxicology- P.D. Sharma, Rastogi Publication, 2004.
3. Animal Ecology and Environmental Biology- H.R. Singh, Vishal Publication.
4. Animal Physiology and Ecology- P.S. Varma, V.K. Agrawal, B.S. Tyagi, S. Chand, 2002.
5. Environmental Biology- P.S. Varma and V.K. Agrawal, S. Chand, 2001.
6. Ecology- E.P. Odum, Oxford and IBH Publishing.
7. Environmental Ecology- P.R. Yadav, Shubhrata R. Mishra, Discovery Publishing House, 2004.
8. Fundamentals of Environmental Biology- S. Arora, Kalyani Publishers, 1985
9. Plant Ecology and Soil Science- R.S. Shukla and P.S. Chandel, S. Chand Publication, 2001.
10. Environmental Management- Dr. Anand S. Bal, Himalaya Publication, 2009.
11. Maintaining Biodiversity in Forest Ecosystem- Malcolm L. Hunter Jr., Cambridge University Press, 1999.
12. Cell Biology, Genetics, Molecular Biology, Evolution and Ecology- P.S. Verma, V.K. Agarwal. S. Chand Publication, 2005.
13. Non-Conventional Energy Sources- G. D. Rai, Khanna Publishers, Delhi
14. Environmental Science- W. Cunningham and Saigo, McGraw Hill, New York.
15. A Textbook of Environment- Agrawal, Mcmillion publication, Mumbai
16. Environmental Chemistry- S. S. Dara, S. Chand and Company, NewDelhi2002.
17. Environmental Chemistry- B.K. Sharma, Goel Publication, Meerut.
18. Air Pollution- M.N. Rao, Tata McGraw Hill Publishing Company Limited, New Delhi, 2003
19. Air Pollution- A. C. Stern
20. Environmental Problems and solution- Asthana, S. Chand and Company, New Delhi.
21. Environmental Science- S. C. Santra, New Central Book Agency private Limited, 2006.
22. Fundamental Concepts of Environmental Chemistry- G. S. Sodhi, Narosa Publishing House, New Delhi, 2002
23. A Textbook of Environmental Science- R.N. Trivedi, Anmol Publications Private Limited, 1997
24. Man and Environment- P. R. Trivedi, Gurdeep Raj, Akshadeep Publishing House, New Delhi, 1997.
25. Fundamental Concepts in Environmental Studies- Dr. D. D. Mishra, S. Chand Publication, 2009.

26. Environmental Chemistry- A. K. De, New Age International Publishers, 2001.

27. Industrial Safety and Environment- Anupama Prasar. S. K. Kataria & Sons, Delhi

28. Environmental Chemistry- P. S. Sandhu, New Age International Publishers, Mumbai

29. "Managing Natural Resources(2014): Focus on Land and Water" by H.N. Misra and Harikesh N. Misra, Prentice Hall India Learning Private Limited.

30. Integrated Natural Resource Management: The Way Forward" by Vinod Kumar Tripathi, Amitava Rakshit, V.K. Chandola, R.M. Singh, A.K. Nema, and Saswat Kumar Kar, Indian Books and Periodicals. ISBN 13.9789386453082

B.Sc. Part III Semester V
Vocational Skill Course (VSC)
STUG05ENVS0013
Practical: Components of Environmental Science

Section A: Preamble: The Importance of Experiments

i. Water Quality Tests → Ensure safe drinking water and compliance with standards.
ii. Wastewater Tests → Assess pollution load and treatment efficiency.
iii. Air & Noise Monitoring → Evaluate environmental impacts of industries and urbanization.
iv. Solid Waste Studies → Support sustainable waste management practices.

A. Water Quality Analysis

i. Determination of pH of water samples
ii. Determination of turbidity
iii. Determination of total, suspended, and dissolved solids (TDS, SS, DS)
iv. Determination of alkalinity and acidity
v. Determination of hardness (Ca^{2+}, Mg^{2+})
vi. Determination of chloride concentration
vii. Determination of sulfate concentration (turbidimetric/spectrophotometric method)
viii. Determination of fluoride concentration
ix. Determination of residual chlorine
x. Determination of odour and taste in water samples
xi. Determination of sodium, calcium, potassium ions in water

B. Wastewater Analysis

i. Determination of biochemical oxygen demand (BOD)
ii. Determination of chemical oxygen demand (COD)
iii. Determination of Kjeldahl nitrogen (organic nitrogen + ammonia)
iv. Determination of optimum coagulant dose using Jar test apparatus
v. Determination of most probable number (MPN) of coliforms (microbiological test)

C. Air quality & Noise Monitoring/Analysis

i. Measurement of Suspended particulate matter (SPM) and PM10 using high-volume sampler
ii. Measurement of noise levels using sound level meter

D. Solid Waste & Field Work

i. Characterization of solid waste samples (moisture, density, composition)

ii. Field visit to a water treatment plant (WTP) or sewage treatment plant (STP) for practical exposure

Section B: The Importance of Experiments

Experiments in environmental engineering extend beyond traditional approaches by emphasizing innovation and sustainability. They equip students to tackle real-world challenges such as climate change, pollution, and resource scarcity. Moreover, these experiments are closely aligned with the principles of ISO 14001:2015, fostering continual improvement, regulatory compliance, and eco-friendly practices.

A. Renewable Energy & Efficiency

i. Solar energy experiments: Testing efficiency of solar water heaters and solar cookers.
ii. Biodigester efficiency: Analysis of bidigester control parameters viz.,Volatile acids,Total alkalinity,COD and BOD.
iii. Microbial fuel cells: Studies on electricity generation using bacteria.

B. Water Innovation

i. Advanced water purification: Testing efficiency of R.O.plant.
ii. Rainwater harvesting system - Examination of water for various physical and chemical characteristics, followed by comparison with local borewell water.
iii. Greywater experiments- Determination of oil and grease content.
iv. Experiment on heavy metal removal using eco-friendly adsorbents (e.g., biochar).

C. Waste Management & Circular Economy

i. Composting experiments: aerobic vs. anaerobic composting: Determination of organic matter/organic carbon by Walkley–Black Method.
ii. Estimation of acidity and alkalinity in vermiwash for quality assessment.
iii. Studies on E waste dismantling and recovery of metals.
iv. Oven-dry method to determine moisture content percentage in solid waste.

D. Air & Climate Innovation

i. Carbon capture experiments using adsorbents or algae.
ii. Studies on air quality monitoring with IoT sensors.
iii. Studies on noise quality monitoring with IoT sensors.
iv. Studies on greenhouse gas measurement in small-scale setups.

E. Soil & Bioremediation

i. Phytoremediation experiments: Quantitative determination of heavy metal uptake by plants exposed to polluted water.

F. Studies on Modern Methods of Monitoring of Environmental Components.

i. IoT based water quality sensors.
ii. Drone based environmental monitoring (air, soil, vegetation).
iii. GIS mapping of pollution hotspots.
iv. Smart bins with sensors for waste segregation.

Books for reference

1. Laboratory Manual of Water and Wastewater Analysis" (2008): by D.R. Khanna and R. Bhutiani, Daya Publishing House.
2. Standard Analytical Procedures for Water Analysis" (1999): Government of India & Government of The Netherlands.
3. Water Quality Analysis and Treatment" by Dr. Saimah Khan and Dr. Abdul Rahman Khan,

BFC Publications,ISBN: 9789357644600.
4. Practical Environmental Chemistry" by B.K. Sharma
5. R. Gopalan, R. Wilgred Sugumar, (2013): A Laboratory Manual for Environmental chemistry, I. K. International Pvt Ltd, 2013.
6. Manual on Water and Wastewater Analysis" by NEERI (National Environmental Engineering Research Institute,Nagpur.
7. Standard Analytical Procedures align with BIS (Bureau of Indian Standards) and CPCB.
8. Handbook of Water and Wastewater Analysis" by Kanwaljit Kaur. Atlantic; Edition (2007); Atlantic Publishers and Distributors (P) Ltd.

B.Sc. Part III Semester V
STUG05ENVS0014
Field Project (FP)

Preamble: Field projects for degree students should be aligned with their academic discipline, course objectives, and real-world applications. A well-designed field project usually comprises the following components:

1. **Introduction**:
   - Study background and significance.
   - Identify research objectives and address specific problems or questions.
2. **Literature Review**:
   - Review existing research and studies about the topic.
   - Identify knowledge gaps for the project.
3. **Methodology**:
   - Describe fieldwork methods (e.g., surveys, sampling, data collection techniques).
   - Include any applicable tools and equipment.
   - Justification for chosen method.
4. **Study Area**:
   - Location details for fieldwork (e.g., geographic, climatic, ecological aspects).
   - Make use of maps, photographs, or sketches to illustrate the research area.
5. **Data Collection and Analysis**:
   - Data collection methods: quantitative or qualitative.
   - Techniques for analyzing data(software and statistical tools).
6. **Results and Observations**:
   - Analysis of data employing statistical methodologies. Point out and identify important trends, reoccurring patterns, or key insights.
7. **Discussion**:
   - Interpret research results based on objectives and literature
   - Take into account the consequences of findings, limits, and errors.
8. **Conclusions and Recommendations**:
   - Summary of the key findings.
   - Suggestions for future research.
9. **References**: Use properly mentioned scholarly references and sources throughout the report.
10. **Appendices (if necessary)**:
    - Includes raw data, detailed maps, and supplemental figures

B.Sc. Part III Semester V
STUG05ENVS0014
Community Engagement Programme

Preamble: A study-oriented Community Engagement Assignment for degree students should emphasize fostering an understanding of societal challenges, developing teamwork and problem-solving abilities, and using research approaches in real-world settings.

1. Introduction

- Define community engagement and its significance in addressing societal challenges.
- Clearly outline the purpose of the assignment and its objectives (e.g., exploring issues, building empathy, or proposing solutions).

2. Research Topic and Objectives

- Identify a specific community issue or challenge (e.g., health, education, environment, or social equity).
- State the research objectives, such as understanding the problem's root causes, its impact on the community, or proposing actionable interventions.

3. Background and Literature Review

- Provide an overview of relevant research or case studies on similar community engagement efforts.
- Highlight gaps in knowledge or areas that need attention.

4. Methodology

- Describe the research approach (e.g., fieldwork, interviews, surveys, focus groups, or participatory observation).
- Include information on sampling methods, data collection tools, and ethical considerations (e.g., obtaining informed consent from participants).

5. Field Engagement

- Detail the specific activities carried out, such as community workshops, awareness campaigns, or collaborative meetings with stakeholders.

6. Data Collection and Analysis

- Summarize the data collected through field activities, observations, or stakeholder interactions.
- Explain the tools or methods used for analyzing data (e.g., statistical analysis, thematic coding).

7. Findings

- Present key findings from the research and engagement activities.
- Discuss how these findings align with or differ from expectations or literature review insights.

8. Impact Assessment

- Assessment of the impact of the engagement activities on both the community and the researcher (e.g., improved awareness, enhanced skills, or strengthened relationships).
- Evaluate whether the project met its objectives.

9. Recommendations

- Suggest practical solutions or interventions based on research findings.
- Propose strategies for sustainable community development.

10. Challenges

- Highlight the challenges faced during the project, and how the experience influenced their understanding of community dynamics, personal growth.

11. Conclusion

- Summarize the significance of the research and engagement efforts.
- Highlight the long-term value of community collaboration.

12. References and Appendices

- Include citations for all sources used and supplementary materials, such as photographs, raw data, or interview transcripts.

B.Sc. Part III Semester V
STUG05ENVS0015
IKS in Environmental Science-I

Unit I: Attributes of Prithvi (Earth)

1. **Concept of Panchamahabhuta in Ancient India:** Role of Prithvi in cosmology and human physiology, Symbolism of Earth element: stability, structure, and grounding, The Pancha Mahabhuta Framework: Introduction to the five-element theory in ancient philosophies; the manifestation of subtle matter into gross elements. Analytical study of the primary qualities of Earth—Gurutva (heaviness), Kharatva (roughness), Kathina (hardness), Manda (slowness), and Sthiratva (stability) as defined in Nyaya-Vaisheshika traditions.

2. **The Evolution of Hard Matter:** The transition from the subtle cosmic ego (Ahamkara) to the densest element (Prithvi) via the Gandha Tanmatra (subtle attribute of smell) in ancient philosophy.

3. **The Principle of Dhriti (Sustenance):** Earth as the cosmic substrate that yields physical form, boundaries, and mass to all manifest entities.

Unit II: Foundation of Jala Mahabhuta

1. **The Origin of Liquid Matter:** Manifestation of Jala (Water) from Rasa Tanmatra (the subtle element of taste) in ancient philosophy, Symbolism of Jala (water) in cosmology and spirituality, Role of fluidity and cohesion in sustaining life.

2. **Attributes (Gunas) of Jala:** Analytical study of its inherent properties—Drava (fluidity), Snigdha (unctuousness/oiliness), Sheeta (coldness), Manda (slowness), and Guru (heaviness), Jala Mahabhuta in Sharir Rachana (body structure), Association with Rasa dhatu (plasma), Rakta dhatu (blood), lymph, and secretions.

3. **The Principle of Cohesion (Bandhanatva):** Water element as the universal binding agent holding solid particles (Prithvi) together in macrocosmic nature and microcosmic anatomy.

Unit III: The Evolution of Agni (Fire)

1. **The Manifestation of Radiant Matter:** The evolution of Agni (Fire) from the Rupa Tanmatra (subtle element of form and color) in ancient philosophy.

2. Attributes (Gunas) of Tejas/Agni: A deep dive into its inherent qualities—Ushna (heat), Teekshna (sharpness/penetration), Laghu (lightness), Rooksha (dryness), and Vishada (clarity), The use of controlled high-temperature furnaces (Putas) to purify toxic metals and minerals, The transformation of mercury (Parada) and base metals into potent, biocompatible therapeutic formulations (Bhasmas).

3. The Cosmic Transmuter: Agni as the central medium of transformation in ancient rituals, the philosophical concept of transferring material offerings into subtle energy forms. The role of fire in iron-smithing and bronze-casting (e.g., the seamless iron pillars and lost-wax icons of ancient India).

Unit IV: The Genesis of Vayu (Air)

1. The Origin of Motion: The genesis of Akasha (Space) as the first manifest element from Ahamkara (cosmic ego) via the Shabda Tanmatra (subtle attribute of sound) in ancient philosophy, The Principle of Non-Resistance (Anavastatva): Space as the fundamental, unobstructed substrate room for all other elements to exist, expand, and move.

2. Attributes (Gunas) of Vayu: A comprehensive study of its intrinsic qualities—Chala (mobility/constant motion), Laghu (lightness), Sheeta (coldness), Rooksha (dryness), and Sookshma (subtlety), Vishada (clarity), and Vibhu (omnipresence/all-pervasiveness). The Universal Kinetic Force: Vayu as the primary instigator of all cosmic and mechanical movements (Prana/Chesta) in the universe, acting as the bridge between potential and kinetic energy.

3. Philosophical Concept of Akasha ((Ether/ Space): Meaning, symbolism, and role in cosmology, Akasha- Representation as expansiveness, subtlety, and the medium for sound, Relationship between ether and auditory perception, Akasha versus Western concepts of space and ether, Parallels with physics (space-time, vacuum, quantum field), Space element in spiritual practice and consciousness.

References

1. Taittiriya Upanishad (II.1.1)
2. Rigveda (Prithvi Sukta - 10.18):
3. Atharvaveda (Bhumi Sukta - 12.1):
4. Charaka Samhita (Sharira Sthana, Chapter 1 & 5):
5. Sushruta Samhita (Sutra Sthana, Chapter 15 & 42):
6. Vaisheshika Sutras of Kanada (Chapter 2, Ahnika 1):
7. Padartha-Dharma-Samgraha of Prashastapada (Prithvi Nirupanam):
8. Tarka-Samgraha of Annambhatta:
9. Samkhya Karika of Ishvarakrishna (Karikas 22, 24, 25, and 38):
10. Bhagavata Purana (Canto 2, Chapter 5 & Canto 3, Chapter 26):
11. Yoga Sutras of Patanjali (Sadhana Pada & Vibhuti Pada):
12. Bhagavad Gita (Chapter 7, Verse 4 & Chapter 18, Verses 33-35):

B.Sc. Part

III Semester V Question Paper Pattern Major and Minor Subject

Time: 3:00 Hours **Max. Marks: 40**

Que. 1. Long Question from unit I **(8 Marks)**

OR

a) Short Question from unit I **(04 Marks)**

b) Short Question from unit I **(04 Marks)**

Que. 2. Long Question from unit II **(08 Marks)**

OR

a) Short Question from unit II **(04 Marks)**

b) Short Question from unit II **(04 Marks)**

Que. 3. Long Question from unit III **(08 Marks)**

OR

a) Short Question from unit III **(04 Marks)**

b) Short Question from unit III **(04 Marks)**

Que. 4. Long Question from unit IV **(08 Marks)**

OR

a) Short Question from unit IV **(04 Marks)**

b) Short Question from unit IV **(04 Marks)**

Que. 5. Answer in brief: **(08 Marks)**

Solve any 8 out of 12 questions (3 questions from each unit) **(1 Mark each)**

National Education Policy 2020

FACULTY OF SCIENCE AND TECHNOLOGY

Syllabus B.Sc. Semester VI

Program: TYUGP

Major Course: Environmental Science

With effect from Session: 2026-2027

THE DISTRIBUTION OF MARKS FOR ON THE JOB TRAINING (Semester VI)

STUG06ENVS0013

Total marks: 40

1. Attendance & Discipline	**-**	**05 Marks**
2. Technical Skills & Task Performance	**-**	**20 Marks**
3. Completion of Project / Assignment/training Work	**-**	**10 Marks**
4. Final Report / Documentation	**-**	**05 Marks**

THE DISTRIBUTION OF MARKS FOR THE WORK ON RESEARCH PROJECT (Semester VI)

STUG06ENVS0013

Total marks: 40

1. Topic Selection & Proposal	**-**	**05 Marks**
2. Data Collection & Analysis	**-**	**20 Marks**
3. Report Writing / Documentation	**-**	**10 Marks**
4. Presentation / Viva-Voce	**-**	**05 Marks**

Gondwana University, Gadchiroli
NEP 2020 U.G. PROGRAMME SESSION 2026-27
Faculty of Science and Technology
Programme Name - B.Sc. Sem VI (Environmental Science) (Level-5.5) **Revised Scheme**

Sr. No.	Course Category	Subject name	Total Credit	Teaching Scheme (Hrs)			Examination Scheme									Total Marks
							Theory					Practical				
				Theory	Practical	Total Hrs.	UA	CA	Total Mark	Min. Passing	Duration of Exam (Hrs)	UA	CA	Total Mark	Min. Passing	
1	Major Subject (Core Subject) Annexure-VII	Paper VII: Environmental management	2+2=4	02	04	06	40	10	50	20	03	30	20	50	25	100
		Paper VIII: Environmental restoration	2+2=4	02	04	06	40	10	50	20	03	30	20	50	25	100
2	Major Subject (Elective) Annexure-VIII	Paper DSE-II: 1. SOP in Environmental Science 2. Renewable Technologies 3. ISO and EMS	2+2=4	02	04	06	40	10	50	20	03	30	20	50	25	100
3	Minor Subject (Core Subject) Annexure-IX	Paper-IV Urban Environment	2+2=4	02	04	06	40	10	50	20	03	30	20	50	25	100
4	OJT/RP Annexure-X	Based on Major subject-	04	--	08	08	--	--	--	--	--	60	40	100	50	100
5	IKS(SS) Annexure-XI	IKS-Subject Specific IKS in Environmental Science-II	02	02	-	02	40	10	50	20	02	--	--	--	--	50
Total			22	10	24	34	200	50	250	100	14	180	120	300	150	550

B.Sc. Semester VI(Environmental Science)					
Sr. No		**Course Code**	**Course Title**	**Paper Title**	**Credits**
1.	Major	**STUG06ENVS001**	Major subject–P VII (Theory)	Environmental management	**2**
		STUG06ENVS002	Major subject–P VII(Practical)	Practical based on - Environmental management	**2**
		STUG06ENVS003	Major subject–P VIII(Theory)	Environmental restoration	**2**
		STUG06ENVS004	Major subject–P VIII (Practical)	Practical based on- Environmental restoration	**2**
2.	Any one from major elective subject	**STUG06ENVS005**	Major (Elective) (T)	1. SOP in Environmental Science	**2**
		STUG06ENVS006	Major (Elective) (P)	Practical based on: SOP in Environmental Science	**2**
		STUG06ENVS007	Major (Elective) (T)	2. Renewable Technologies	**2**
		STUG06ENVS008	Major (Elective) (P)	Practical based on: Renewable Technologies	**2**
		STUG06ENVS009	Major (Elective) (T)	3. ISO and EMS	**2**
		STUG06ENVS0010	Major (Elective) (P)	Practical based on: ISO and EMS	**2**
3.	Minor	**STUG06ENVS0011**	Minor Course (T)	Urban Environment	**2**
		STUG06ENVS0012	Minor Course (P)	Practical based on: Urban Environment	**2**
4	OJT	**STUG06ENVS0013**	OJT/RP	Based on Major Subject	**4**
5	IKS	**STUG06ENVS0014**	IKS(SS) Subject Specific	IKS in Environmental Science -II	**2**

B.Sc. Part III Semester VI
Major Subject (Core Subject)
STUG06ENVS001
Paper VII Environmental Management

Unit I: Solid Waste and Hazardous Waste Management

1. **Solid Waste:** Definition. Sources of solid waste. Classification. Characteristic of solid waste: physical, chemical and biological. Factors affecting solid waste generation. Separation of solid waste at source. Method of collection.Location of transfer station.
2. **Methods of Treatment and Disposal:** Composting. Sanitary land filling. Thermal process: incineration, pyrolysis and gasification. Recycling of paper and paper board, plastics and glass.
3. **Hazardous Waste and its Management:** Definition, Classification, Management of Chemical waste, nuclear waste, biomedical waste and electronic waste (E-waste).Hazardous waste treatment technology: On site disposal and Off-site disposal.

Unit II: Industrial Wastewater Treatment

1. **Wastewater Treatment:** Sources of wastewater. Objectives of treatment. Preliminary treatment: screening, comminuting, grit removal, Primary sedimentation.
2. **Secondary Treatment:** Activated sludge. Trickling filters. Stabilisation pond. Up-flow anaerobic sludge blanket reactor.
3. **Tertiary Treatment:** Wastewater disposal and reuse. Nutrient removal. Solid removal. Ozone treatment. Reverse osmosis. Ultraviolet filtration. Ion exchange. Concept of common effluent treatment plant (CETP).

Unit III: Cleaner Technologies and EMS

1. **Cleaner Technologies:** Pollution reduction at source. Material modification and end of pipe technology. Eco labelling and Green building.
2. **Tools for Pollution Prevention:** Tool for pollution prevention. Public disclosure and pollution control. Polluter pay principle. Industrial rating. Carbon trading: Role of UNFCC, Kyoto protocol. Joint implementation. Clean development mechanism (CDM). Carbon trading. Carbon credit. Ecological foot print.
3. **Environmental Management System:** ISO 9001:2015 and its updated version, Origin of EMS. Key components of EMS,Benefits of EMS, Role of EMS, purpose, core element of EMS, by ISO 14001:2015, ISO 14004:2016, ISO 14040:2006.

Unit IV: Environmental Impact Assessments

1. **EIA:** Origin of EIA. Objectives of EIA. EIA procedure(Screening, Scoping, Baseline studies, Impact identification, Impact prediction and assessment, Mitigation, Environmental management plan (EMP), Public participation, Environmental impact statement (EIS), Review and decision-making), Applications of Environmental Impact Assessment
2. **Environmental Audit:** Definition. Scope and objectives. Guidelines for EA. Procedure for carrying EA. Benefits of EA.
3. **Environmental Management Plan:**. Project operation phase, Construction phase. Post project environmental monitoring. Socio economic environment. Development of green belt around industry.

B.Sc. Part III Semester VI
Major Subject (Core Subject)
STUG06ENVS002
Practical: Environmental Management

Practical: Environmental Management

1. Determination of physical parameters of (I) well water and (II) river water.
2. Determination of residual chlorine/free chlorine from municipal water sample.
3. Estimation of Ni2+ by spectrophotometry.
4. Estimation of sulphates by colorimetry/ spectrophotometry.
5. Estimation of phosphates by spectrophotometry.
6. Measurement of noise by dB meter in silent, industrial, residential and commercial zones.
7. Determination of reverse osmosis plants clean water and waste water for TDS and other physical and chemical parameters.
8. Estimation of copper from water sample/waste water sample.
9. Determination of nitrate from ground water sample.

Books for Reference

1. Natural Hazards-Local, National, Global: G. F. White, Oxford University Press.
2. Laboratory Manual for the Examination of Water, Waste water and soil: H. H. Rupa and H. Krist; V C H Publication
3. Environmental Impact Analysis Handbook: J. G. Rau and D. C. Wooten; McGraw-Hill Book Co.
4. Environmental Impact Assessment, L. W. Canter, McGraw Hill Publication,
5. Methods of Environmental Impact Assessment: P. Morris & R. Therivel ; UCL Press
6. Environmental Impact Assessment (2003): A. K. Srivastav; APH Publishing Corporation
7. Introduction to Environmental Impact Assessment: Glasson; Research Press
8. Sustainable development (Vol. I & II): N. L. Gupta and K. K. Gurjar (ed); Rawat Publications
9. Environmental management: G. N. Pandey; Vikash Publishing House
10. Environnemental management: H. M. Saxena; Rawat Publications
11. Environmental Law and Policy in India: S. Divan and A. Rosencranz; Oxford University Press
12. Environmental Management –Physio-ecological facets (Vol. I & II): Rai, Mohapatra & Goel (ed); Rawat Publications.
13. Environmental Management in India (Vol. I & II): R. K. Sapru; Ashish Publishing House
14. Soli J. Arcivala: Waste Water Treatment for Pollution Control. TMH 1986.
15. Vijay Kulkarni & T. V. Ramchandra: Environnemental Management. Environmental Engineering Series; Publ. Commonwealth of Learning, Indian Institute of Science (IISC), Bangalore.
16. Environmental Management B. Khitolia, S Chand Publication, New Delhi
17. Solomon Raju: Ecotourism, Ecorestoration & Development, New central book agency, Bangalore.
18. Standard methods for examination of water and waste water, APHA.

B.Sc. Part III Semester VI
Major Subject (Core Subject)
STUG06ENVS003
Paper VIII Environmental Restoration

Unit I: Restoration Ecology

1. Basics of Restoration Ecology: Definition, Objectives of restoration (ecological, social, economic), Difference between conservation, rehabilitation, and restoration, Necessity of eco-restoration, Concept, Types of restoration, Natural recovery vs. active restoration vs. rehabilitation, Holistic approach in restoration, scope of ecological/environmental restoration.

2. Approaches of Restoration: Primary approaches to restoration(passive restoration, active restoration, rehabilitation, and reclamation), Nature's healing potential, Assisted natural regeneration, Ecological principles in restoration (Reference ecosystems, Ecosystem processes, Resilience and succession, Biodiversity conservation, Adaptive management, Socio-ecological Integration, Sustainability and climate resilience), Habitat restoration (forests, wetlands, grasslands, rivers, coastal zones).

3. Strategies of Restoration: Strategies (long vs short term), Long-term ecological monitoring methods, Climate-smart restoration strategies, Strategic role of government agencies (Policy & Regulation – Formulating laws, guidelines, and standards for restoration projects, Funding & Resource, Technical expertise), Monitoring & Enforcement – Ensuring compliance with environmental laws and restoration targets, Strategic Role of NGOs(Community mobilization, Awareness & Education, Grassroots implementation, Advocacy & partnerships).

Unit II: Eco-Restoration Methods

1. Steps of Eco-Restoration: Five step wise eco-restoration, Restoration monitoring indicators, Biophysical analysis, Assessment of degraded ecosystems (Identifying the types of degradation, biodiversity loss, and ecological functions affected).

2. Restoration Processes: Defining the problem and engaging stakeholders, Assessing the problem, developing ecological restoration goals, developing ecological restoration objectives, designing ecological restoration approach, managing adaptively: Monitor, Evaluate, Adjust and Communicate, Restoration Tools & Techniques: Physical tools: land contouring, erosion control, hydrological adjustments, Chemical tools: soil amendments, pollution remediation, Biological tools: reforestation, afforestation, biofertilizers, mycorrhizae, microbial inoculation,

3. Eco-Restoration by Plants: Measures to restore environment: Phyto-extraction, phyto-stabilization, phyto-transformation, phyto-volatilisation, rhizo-filtration, rhizosphere bioremediation.

Unit III: Eco-Restoration of Abiotic Environment

1. Restoration of Lands: Restoration of degraded lands. Restoration of soil fertility. Restoration of mine affected lands (coal mine, manganese mine, uranium mine, gold mine). Restoration of damaged dunes. Restoration of wasteland, Restoration of non-mineral extracted plains and hills.

2. Eco-Restoration of Water and Air: Eco-restoration of groundwater, surface water (restoration of lakes, river, streams). Urban ecological restoration (green belts, rooftop gardens, wetlands in cities), Restoration of contaminated air: planting air pollutants absorbing plants, potential of carbon sequestration, design of space for plantation, Role of local biodiversity management committee for restoration.

3. Eco-Restoration of Hazard Hit Areas: Eco-restoration of super cyclonic hit areas. Restoration of snowstorm hit areas. Restoration of earthquake hit areas, volcanoes, landslides and floods affected areas.

Unit IV: Eco-Restoration of Biotic Environment

1. Restoration of Natural Resources: Restoration of forest land, range land, restoration of wild animals, plants, role of forest research institutes. IIFM-Bhopal. Gene pool campaign.

2. Restoration of Biological Diversity: Acceleration of ecological succession. Reintroduction of biota. Restoration of wetland by mangroves. Restoration of mangroves (natural and artificial). Invasive species management and biological control.

3. Socio-Economic Issues of Restoration: Benefits of restoration to local inhabitants. Socioeconomic issues of lake beautification. Socioeconomic issues related with declaration of wildlife sanctuaries. Reasons of man-animal conflict. Wildlife tourisms- benefits to local villagers. Issues regarding rehabilitation of Great Indian Bustard (GIB) in Maharashtra. Issues about conservation of wild buffaloes in Buster, Chhattisgarh and rhinoceros in Assam. Environmental education and its role in conservation and restoration.

B.Sc. Part III Semester VI
Major Subject (Core Subject)
STUG06ENVS004
Practical: Environmental Restoration

Practical: Environmental Restoration

1. Determination of total organic carbon in soil.
2. Determination of pH value of different types of soil.
3. Determination of water holding capacity of soil.
4. Study of the soil profiles w.r.t. electrical conductivity of soil at different depth.
5. Determination of suspended solids and total solids of raw sewage.
6. Collection, processing and analysis of vermicompost for organic matter, pH and acidity.
7. Studies on coal mine affected areas:
   i. Collection of fresh over burden sample
   ii. Analysis of leachates for physicochemical analysis (pH, total solids, sulphate and phosphate)
8. Estimation of Chemical Oxygen Demand of the given wastewater sample by open reflux method.

Books for Reference

1. Managing Cover Crops Profitably, Handbook Series Book, Published by the Sustainable Agriculture Research and Education (SARE) program

2. Building Soils for Better Crops Sustainable Soil Management. Fred Magdoff and Harold van Es Handbook Series Book by the Sustainable Agriculture Research and Education (SARE) program. 2009.

3. Manage insect on your farm, Miguel A. Altieri and Clara I. Nicholls with Marlene A. Fritz, Published by the Sustainable Agriculture Network Beltsville, MD, USA.

4. A Whole-Farm Approach to Managing Pests, Sustainable Agriculture Research and Education (SARE) program.

5. Smart Water Use on Your Farm or Ranch, Sustainable Agriculture Research and Education (SARE) program.

6. Ecological Restoration: A Practical Approach, Steven I. Apfelbaum Applied Ecological Services, Inc. Brodhead, WI 53520

7. Eco-restoration of a high-sulphur coal mine overburden dumping site in northeast India: A case study J Dowarah, H P Deka Boruah, J Gogoi, N Pathak, N Saikia and A K Handique,

Biotechnology Division, North-East Institute of Science & Technology, CSIR, Jorhat 785 006, Assam, India.
8. Dead Planet, Living Planet – Biodiversity and Ecosystem Restoration for Sustainable Development. A Rapid Response Assessment. United Nations Environment Programme, GRID-Arendal.
9. Wetland Restoration: A Handbook for NZ Freshwater Systems, Campbell, D. and Jackson, R. New Zealand Hydrological and Limnological Societies, Christchurch, New Zealand. 2004.
10. Cyclic floodplain rejuvenation, Jos van Alphen, Ministry of Transport, Public Works and Water management Directorate Eastern Netherlands December, 2001.
11. Wetland Restoration: A Handbook for NZ Freshwater Systems, Native Fauna, Corinne Watts, Monica Petersand Alastair Suren.
12. Standard methods for examination of water and waste water, APHA.

B.Sc. Part III Semester VI
Major Subject (Elective)
STUG06ENVS005
1. SOP in Environmental Science

Unit I: Fundamentals of SOPs

1. SOPs in Environmental Science: Definition, importance of SOPs in environmental science, concept, Objectives, scope of SOPs (Hazard Identification and Control, Detailed instructions, Consistency and Standardization, Documentation and training, Regular review and update), Benefits (Quality assurance, regulatory compliance, and training), phases of SOP, The four P's of an SOP, Types of SOPs (technical, administrative, safety-related), Structure and components of a standard SOP document.

2. Quality Assurance (QA) and Quality Control (QC): Concepts of QA/QC in environmental data collection and analysis, Introduction to Quality management systems (QMS) (e.g., ISO 17025, ISO 14000 series). Structure and format of an SOPs (Title, Purpose, Scope, Roles and responsibilities, Equipment/Reagents, Procedure steps, Data analysis/reporting, Health and Safety, and document control). SOP Lifecycle Management (Preparation, Review, Approval, Revision, Archival, and Training protocols).

Unit II: SOPs in Environmental Education

1. Environmental Education SOPs: Objectives (Awareness about environmental issues, promoting sustainable practices through experiential learning, integration of environmental education into academic and extracurricular activities), Scope (Applicable to schools, colleges, and community-based student groups, covers classroom sessions, field visits, workshops, and campaigns), Stakeholder roles in implementing environmental education SOPs,

2. Phases of Environmental Education SOPs : Planning: Identification of target groups, objectives, preparation of schedules, Curriculum development: Climate change, biodiversity, pollution, waste management, renewable energy, Resource Allocation: Arrangement of venues, teaching aids, safety gear, and budget, Implementation: Organisation of sessions, Field visits (nature trails, recycling plants, water treatment facilities), Monitoring & Evaluation: Feedback, assessment of learning outcomes, and effectiveness, Reporting & Follow-up: Document activities, preparation of reports, and planing through eco-clubs or annual events, SOP flow in environmental education(Initiation, Preparation, Execution, Evaluation, Reporting).

Unit III: Field SOPs

1. **SOPs for Environmental and Ecological Field Studies:** Environmental impact assessment (EIA) procedures, Biodiversity surveys and habitat monitoring, SOPs for ecological fieldwork (flora and fauna sampling),GIS and remote sensing applications in environmental studies, Safety protocols in field research.

2. **SOPs in Environmental Management:** Pollution control SOPs (Air pollution monitoring and mitigation, Water pollution treatment and effluent management, Noise pollution measurement and control, Noise pollution measurement and control), Waste management SOPs (Solid waste segregation, recycling, and disposal, Hazardous and biomedical waste handling, E-waste management protocols). Laboratory SOPs.

Unit IV: Resource Management SOPs

1. SOPs for Resource Conservation: Resource management SOPs (Energy conservation and renewable energy integration, Water conservation and rainwater harvesting, Sustainable land use and biodiversity conservation), Safety & Emergency SOPs (Risk and disaster management procedures, Emergency response for chemical spills, leaks, and fires, Occupational health and environmental safety).

2. **SOPs for Reporting and Compliance Management:** Reporting SOPs (Environmental statistics and data analysis, Environmental audits and compliance reporting, Documentation, record keeping, and continual improvement cycles), Implementation and training, Training programs, Competency Testing (Evaluating personnel proficiency), Auditing and Review,Corrective and Preventive Actions (CAPA), Standardized procedures for addressing non-compliance or procedural failures.

B.Sc. Part III Semester VI
Major Subject (Elective)
STUG06ENVS006
Practical: SOP in Environmental Science

Practical: SOP in Environmental Science

A. General Laboratory SOP Practicals

i. Preparation of SOPs: Writing and documenting step-by-step procedures for common lab tasks.

ii. Calibration of Instruments: Standard methods for calibrating pH meters, spectrophotometers, balances, and DO meters.

iii. Sample Collection & Preservation: SOPs for collecting soil, water, and air samples with proper labeling and storage.

iv. Glassware Cleaning & Sterilization: Standardized washing, rinsing, and sterilization techniques.

v. Waste Disposal Protocols: Segregation, neutralization, and safe disposal of chemical and biological waste.

B. Environmental Monitoring SOP Practicals

i. Water Quality Testing SOPs: Procedures for BOD, COD, turbidity, hardness, and heavy metal analysis.

ii. Air Quality Monitoring SOPs: Calibration and operation of air samplers for SO_2, NOx, and particulate matter.

iii. Soil Analysis SOPs: Standard methods for pH, organic carbon, texture, and nutrient estimation.

iv. Noise Pollution Measurement SOPs: Using noise level meters with calibration and reporting formats.

v. Microbial Analysis SOPs: Standard plating and incubation procedures for environmental microbiology.

C. Safety & Quality Control SOP Practicals

i. Risk Assessment & Safety SOPs: Fire safety drills, chemical handling, and PPE usage.

ii. Quality Assurance SOPs: Replication of experiments, maintaining logbooks, and error-checking protocols.

iii. Instrument Maintenance SOPs: Routine checks for centrifuges, incubators, and autoclaves.

iv. Data Recording & Reporting SOPs: Standardized formats for lab notebooks, digital records, and result validation.

D. Applied Environmental SOP Practicals

i. GIS & Remote Sensing SOPs: Standard workflows for land-use mapping and environmental modeling.

ii. EIA (Environmental Impact Assessment) SOPs: Stepwise procedure for baseline data collection and analysis.

iii. Carbon Footprint Assessment SOPs: Standardized calculation methods for emissions and offsets.

iv. Sustainable Resource Use SOPs: Procedures for evaluating renewable energy systems or waste recycling efficiency.

Books for reference

1. Guidance for Preparing Standard Operating Procedures (SOPs)(2007)– U.S. Environmental Protection Agency (EPA).

2. Atul Mathur (2024): Best Practices for Writing Standard Operating Procedures (SOPs), A Comprehensive Guide Independently Published.

3. Rupendra Singh (2024): UGC NET/JRF Fundamentals of Environmental Sciences,catalyst centerofexcellence.

4. Amitava Mitra (2021), Fundamentals of Quality Control and Improvement, John Wiley & Sons Inc.

5. Milton P. Dentch(2016), The ISO 14001:2015 Implementation Handbook, ASQ Quality Press,Milwaukee, Wisconsin.

6. Archana Tomar (2011), Environmental Education, Kalpaz Publications.

7. S. C. Santra (2022), Environmental science, new central book agency (p) ltd.

8. M.C. Dash (2019), Concepts of Environmental Management for Sustainable Development, Dreamtech Press.

9. R.N. Sankar & Ajith (2015), Environmental Management, OUP India.

10. Environmental Management System – ISO 14001 EMS Guide – ISMS.online

11. Ajith Sankar R. N (2015), Concepts of Environmental Management for Sustainable development. Oxford University Press.

12. B. D. Fath (2022): Environmental Management Handbook, Second Edition,Taylor & Francis.

13. Christopher Sheldon and Mark Yoxon, (2002), Installing Environmental Management Systems: A Step-by-step Guide, Earthscan edition.

14. APHA (American Public Health Association, American water works Association and water pollution control federation). (1980), Standard methods for the examination of water and waste water, Publication Health Association, washington, DC, USA.

B.Sc. Part III Semester VI
Major Subject (Elective)
STUG06ENVS007
2. Renewable Technologies

Unit I: Introduction to Energy

1. Energy Basics: Conventional and nonconventional sources of energy, Primary, secondary, commercial, non-commercial sources of energy, First and Second Laws of Thermodynamics, fundamental heat transfer modes (conduction, convection, radiation), Current energy consumption trends, conventional energy resource depletion, the role of renewable energy in achieving Net-Zero and energy security.

2. Energy Efficiency, Impacts and Conservation: Principles and technologies for optimizing energy use, Comparison of renewable vs. non-renewable sources in terms of pollution and Life Cycle Assessment (LCA), Electrical Energy Conservation, Thermal Energy Conservation, Energy conservation in manufacturing processes, Energy Audits: Types of audits, Instruments for energy auditing, Methodology and reporting.

Unit II: Solar Energy Technology

1. Solar Energy Systems: Solar constant, solar spectrum, Measurement of solar radiation using devices like pyranometers, Solar Thermal Systems: Principles of conversion, types of collectors (flat plate and concentrating), Solar energy applications (solar water heating, solar cooking, large-scale Concentrating Solar Power (CSP).

2. Solar Photovoltaic (PV) Systems: PV Cell Theory: Photovoltaic effect, p-n junction, I-V (current-voltage) characteristics, Photovoltaic effect: conversion of light into electricity, PV cell structure and working mechanism, Environmental Impacts of Solar PV(Positive impacts: reduction in greenhouse gas emissions, Contribution to sustainable energy transition, Negative impacts: Land use and habitat disruption (large solar farms), Resource extraction for PV materials (silicon, rare metals), End-of-life disposal and recycling challenges (e-waste, toxic materials).

Unit III: Wind Energy Technology

1. Wind Resource Assessment: Origin of wind, and methods for site selection and wind data analysis, Wind Energy Conversion Systems (WECS): Horizontal Axis Wind Turbines (HAWT) and Vertical Axis Wind Turbines (VAWT), Hydropower: Classification of hydro plants (micro, mini, small, large), principles of operation, turbines (Pelton, Francis, Kaplan), Ocean thermal energy conversion (OTEC), environmental impacts.

2. Geothermal Energy: Sources of geothermal energy, types of power plants (flash, dry steam, binary cycle), and geothermal heat pumps for heating/cooling, Ocean Energy: Principles and technology for Tidal Power (barrages, stream turbines) and Wave Power (point absorbers, oscillating water columns).

Unit IV: Non-Conventional Eenergy Technologies

1. Biomass Resources: Classification of biomass (wood, agricultural residue, waste), and energy content, Thermochemical Conversion: Direct combustion, gasification producers/syngas), and pyrolysis, Biochemical Conversion: Anaerobic digestion (biogas production, biogas to CNG and LNG), and fermentation (ethanol production), Biofuels: Production and characteristics of biodiesel and bioethanol.

2. Kinetic Energy Harvesting: Piezoelectric Floors, Kinetic Tiles, Human-Powered Energy Harvesting: Broader category including hand-crank devices, bicycle dynamos, and wearable energy harvesters.

B.Sc. Part III Semester VI
Major Subject (Elective)
STUG06ENVS008
Practical: Renewable Technologies

Practicals: Renewable Technologies

A. 1. Coal Analysis

i. Proximate analysis: moisture, volatile matter, ash, fixed carbon.
ii. Ultimate analysis: carbon, hydrogen, nitrogen, sulfur, oxygen content.
iii. Calorific value determination using a bomb calorimeter (gross & net CV).
iv. Ash analysis: fusion temperature, composition.

2. Studies on LNG (liquefied natural gas) handling techniques.
3. Study of CNG (compressed natural gas) storage and safety systems.
4. PV Module Characteristics: I–V characteristics of a solar PV module under varying irradiance and temperature.
5. Study of flat plate collector and evacuated tube collector.
6. Study of a box type solar cooker and calculation of its thermal efficiency.

B. Wind Measurement & Characteristics: Measurement of wind speed and direction using anemometer and wind vane.

C. Biomass Characterization:

i. Proximate analysis: moisture, volatile matter, ash, fixed carbon.
ii. Ultimate analysis: carbon, hydrogen, nitrogen, sulfur, oxygen content.
iii. Calorific value measurement using a bomb calorimeter.
iv. Bulk density and particle size distribution of biomass feedstock.

C. Laboratory Practicals on: Determination of Biogas Plant Feed and Digestate/Slurry w.r.t. pH,Total solids (TS) and volatile solids (VS) Nutrient analysis**:** nitrogen (N), phosphorus (P), potassium (K) content. Organic matter reduction efficiency (comparison with raw feed) Calorific value of residual solids. Gas composition analysis (CH_4, CO_2, H_2S) during digestion.Fertilizer value assessment of slurry for agricultural use. Microbial analysis (presence of pathogens, coliform reduction).

Books for reference

1. 1. B. H. Khan, “Non-Conventional Energy Resources”.
2. Godfrey Boyle, “Renewable Energy”.
3. D. P. Kothari, K. C. Singhal, and Rakesh Ranjan, “Renewable Energy Sources and Emerging Technologies”.
4. S. P. Sukhatme and J. K. Nayak, “Solar Energy: Principles of Thermal Collection and Storage”.
5. Chetan Singh Solanki, “Solar Photovoltaic: Fundamentals, Technologies and Application”.
6. A. R. Jha, “Solar Cell Technology and Applications”.
7. John Balfour, Michael Shaw, and Sharlene Jarosek, “Introduction to Photovoltaics”.
8. Antonio Luque and Viacheslav Andreev, “Concentrator Photovoltaic”.
9. Soteris A. Kalogirou, “Solar Energy Engineering: Processes and Systems”.
10. J. A. Duffie and W. A. Beckman, “Solar Engineering of Thermal Process”.
11. D. Yogi Goswami, “Principles of Solar Engineering”.
12. H. P. Garg and J. Prakash, “Solar Energy: Fundamentals and Applications”.
13. J. F. Manwell, J. G. McGowan, and A. L. Rogers, “Wind energy explained: Theory, Design and Application”.

14.. E. Hau, "Wind Turbines: Fundamentals, Technologies, Application, Economics".
15. T. Burton, D. Sharpe, N. Jenkins, & E. Bossanyi, "Wind Energy Handbook".
16. Harsh K. Gupta and Sukanta Roy, "Geothermal Energy: An Alternative Resource for the 21st Century".
17. K. C. Khandelwal and S. S. Mahdi, "Biogas Technology: A Practical Handbook".
18. N. S. Rathore and A. K. Kurchania, "Biomethanation Technology".
19. A. N. Mathur and N. S. Rathore, "Biogas: Production management and utilization".
20. Liangwei Deng, Yi Liu, and Wenguo Wang, "Biogas Technology".
21. Wim Soetaert and Erick J. Vandamme, "Biofuels".
22. Caye M. Drapcho and Terry H. Walker, "Biofuels Engineering Process Technology".
23. Ahindra Nag, "Biofuels Refining and Performance".
24. Solar Energy Laboratory Manual – MNRE (Ministry of New and Renewable Energy, India).
25. Solar Photovoltaic Technology and Systems: A Manual for Laboratory and Field Experiments – Chetan Singh Solanki.
26. Solar Engineering of Thermal Processes – John A. Duffie & William A. Beckman (includes lab-scale experiments and SOPs).
27. Wind Energy Laboratory Manual – Anna University / AICTE Curriculum.
29. Wind Energy Explained: Theory, Design and Application – James F. Manwell, Jon G. McGowan, Anthony L. Rogers.
30. Biomass Energy Laboratory Manual – TERI (The Energy and Resources Institute)
31. Biomass Assessment Handbook – Frank Rosillo-Calle.
32. Hydropower Engineering Handbook – John S. Gulliver & Roger E.A. Arndt.
33. Renewable Energy Laboratory Manual – AICTE / NITTTR Curriculum for Engineering Colleges.
34. Handbook of Renewable Energy Technology – Ahmad Hemami.
35. Renewable Energy Handbook – D. Yogi Goswami & Frank Kreith.
36. Standard Methods for Renewable Energy Experiments – International Energy Agency (IEA) Technical Reports.
37. G.D. Rai (2018), Non-Conventional Energy Sources, Khanna Publishers, New Delhi.

B.Sc. Part III Semester VI
Major Subject (Elective)
STUG06ENVS009
3. ISO and EMS

Unit I: Fundamentals of Management Systems

1. Management Systems: Definition and purpose of a management system, The Seven Quality Management Principles(Customer focus, Leadership, Engagement of people, Process approach, Improvement, Evidence-based decision making, Relationship management),The value of implementing ISO 9001 for businesses (e.g., improved efficiency, customer satisfaction, and market access), Importance of global standards in trade, safety, and environment, PDCA (Plan–Do–Check–Act) cycle, Risk-based thinking and continual improvement, role of the International Organization for Standardization, Structure and functioning of ISO committees, Implementation steps and certification process,

2. **ISO 9001 – Quality Management System (QMS):** Structure of ISO 9001:2015 standard, Context of the organization, Leadership and commitment, Planning (risk-based thinking, objectives, continual improvement), Support (resources, competence, awareness, communication, documented information).

Unit II: Fundamentals of Environmental Management System

1. Principles of EMS: Definition, Scope of Environmental Management Systems, Importance of EMS in sustainable development, Core Principles (Environmental Policy, Planning, Implementation & Operation, Performance Evaluation, Continual Improvement, Evolution of environmental standards (ISO 14000 family), Benefits of ISO 14001.

2. **ISO and EMS Framework:** Structure and requirements of ISO 14001:2015, Plan–Do–Check–Act (PDCA) cycle in EMS, Environmental aspects and impacts identification, Life-cycle perspective in environmental management, Developing an environmental policy statement, Implementation & Operation (Roles and responsibilities in EMS, Training, awareness, and communication, Documentation and record-keeping, Operational control and emergency preparedness. Monitoring & Evaluation (Performance measurement and indicators, Internal audits and management reviews, Corrective and preventive actions, Continual improvement strategies.

Unit III: ISO framework

1. **ISO Series Guidelines:** ISO 14005:2010(Guidelines for phased implementation of EMS), ISO 14031:2013(Environmental performance evaluation-Guidelines), ISO 14046:2014(Water footprint assessment of products, processes, and organizations), ISO 14001:2015(Environmental Management Systems — Requirements with guidance for use), ISO 14004:2016(General guidelines on principles, systems, and support techniques for EMS), ISO 14006:2020 (Guidelines for incorporating eco-design into EMS), ISO 14015:2021(Environmental assessment of sites and organizations),

2. **ISO 14000 Environmental Standards:** ISO 14020–14025 series (Environmental labels and declarations (eco-labeling standards), ISO 14030(Post-production environmental assessment), ISO 14040–14049 series (Life Cycle Assessment (LCA) — Principles, framework, requirements, and examples), ISO 14064–14067 series (Greenhouse gas emissions and carbon footprint standards), ISO 14090–14097 series (Climate change adaptation and mitigation standards).

Unit IV: Performance Evaluation of EMS

1. Monitoring, Measurement, Analysis, and Evaluation: Tracking performance against objectives and operating criteria. Evaluation of Compliance: Regularly assessing conformance with legal and other requirements. Internal Audit: Planning and conducting systematic audits to determine if the EMS conforms to the standard and is effectively implemented. Management Review: Top management formally reviewing the system's suitability, adequacy, and effectiveness.

2. Improvement Initiatives in ISO 14001:2015 EMS: Waste Reduction & Resource Efficiency, Energy Efficiency Programs, Pollution Prevention, Compliance & Risk Management, Employee Engagement & Training, Continual Improvement via PDCA, ISO 14001:2015 EMS Case Studies. Monitoring & Evaluation (Performance measurement and indicators, Internal audits and management reviews, Corrective and preventive actions, Continual improvement strategies.

B.Sc. Part III Semester VI
Major Subject (Elective)
STUG06ENVS0010
Practical: ISO and EMS

Laboratory Practicals on ISO

A. Documentation & Quality Manual

i. Preparation of Standard Operating Procedures (SOPs) as per ISO 9001 requirements.
ii. Drafting a Quality Manual for a laboratory or department.
iii. Maintaining records and logbooks in compliance with ISO standards.

B. Calibration & Measurement

i. Calibration of laboratory instruments (balances, thermometers, pH meters) following ISO 9001 guidelines.

C. Internal Audit & Non-Conformity

i. Conducting a mock internal audit of a laboratory process.
iii. Case study on audit findings and management review.

D. Process Control & Quality Assurance

i. Process mapping of laboratory workflows (sample collection → testing → reporting).
ii. Risk assessment of critical processes.
iii. Demonstration of continuous improvement cycle (PDCA – Plan, Do, Check, Act).

E. Customer Focus & Feedback

i. Designing a customer satisfaction survey for laboratory services.
ii. Case study on handling customer complaints under ISO 9001 framework.
iii. Analysis of feedback data to improve quality.

F. Laboratory Practicals in EMS: Waste Management & Segregation

i. Identification, segregation, and safe disposal of hazardous and non-hazardous waste.
ii. Practical exercise on labeling and storage of chemical waste.
iii. Practical exercise on labeling and storage of chemical waste.

G) Environmental Quality Assessment and Reporting in Accordance with ISO 14001:2015 EMS Standards

i. Water Quality Assessment and Reporting in Accordance with ISO 14001:2015 EMS Standards.
ii. Heavy metal detection in water samples and Reporting in Accordance with ISO 14001:2015 EMS Standards.
iii. Air quality monitoring measurement of particulate matter (pm2.5, pm10) and reporting in accordance with ISO 14001:2015 EMS Standards.
iv. Monitoring of gaseous pollutants such as SO_2, NOx, and CO.

H) Soil Testing Reporting in Accordance with ISO 14001:2015 EMS Standards

i. Analysis of soil texture, pH, organic matter, and heavy metal contamination.
ii. Study of soil erosion and conservation methods.

I) Energy and Resource Audits

i. Laboratory audit of electricity, water, and chemical usage.
ii. Practical on energy conservation techniques in lab operations.
iii. Practical on energy conservation techniques in lab operations.

J) Environmental Risk Assessment

i. Hazard identification and risk analysis for laboratory chemicals.

Books for reference

1. Stephen P. Robbins, David A. De Cenzo, Mary Coulter (2016): Fundamentals of Management: Essential Concepts and Applications. Pearson Education India.
2. Peter F. Drucker, Management: Tasks, Responsibilities, Practices.
3. L.M. Prasad (2022) – Principles and Practice of Management, S. Chand & Co. New Delhi.
4. The Indian Managers Handbook (2020): The definitive guide to management excellence Hardcover, DK India; Penguin Random House.
5. Ricky W. Griffin – Fundamentals of Management. South-Western College Publishing
6. Kenneth Blanchard and Spencer Johnson (1982), The One Minute Manager A legendary book. William Morrow & Company.
7. Shrouty Vivek A (2021): ISO 9001:2015 Understanding its Anatomy, Diagnosis and Inside Story, Zorba Books.
8. Dale H. Besterfield, Carol Besterfield, Glen H. Besterfield, Mary Besterfield-Sacre, Hemant Urdhwareshe, and Rashmi Urdhwareshe(2018):Total Quality Management, Pearson Education
9. S. Luthra, D. Garg, A. Agarwal, S.K. Mangla (2020), Total Quality Management (TQM): Principles, Methods, and Applications, CRC Press (an imprint of Taylor & Francis).
10. C. Manoharachary, P. Jayarama Reddy, and M. A. Singara Charya (2019), Principles of Environmental Studies (Ecology, Economics, Management and Law), BS Publications (BSP Books).
11. Pradip Swarnakar, Stephen Zavestoski, and Binay Kumar Pattnaik (2017), 'Bottom-up' Approaches in Governance and Adaptation for Sustainable Development: Case Studies from India and Bangladesh SAGE Publications India.
12. B.W. Marguglio (1991), Environmental Management Systems, CRC Press (or Marcel Dekker Inc.)
13. Vijay Gawaikar(2023), ISO 14001:2015 Implementation handbook an indian context, orange books publication
14. Ramesh C. Grover and Sachin Grover(2017), Winning The Environmental Challenge With ISO 14001:2015, notion press,
15. Ramesh R. Lakhe, Kranti P. Dharkar, and Milind P. Joshi (2023), ISO 14001:2015 Environment Management System Pictorial Pocket Book, Independent publication.
16. Syed Haider (2010), Environmental Management System ISO 14001 - 2004: Handbook of Implementation and Management.
17. Mohamed-Ali Ibrahim (2015), Mastering ISO 14001:2015 – Best Practices, Case Studies, and Compliance Strategies, Independently Published.

B.Sc. Part III Semester VI
Minor Subject
STUG06ENVS0011
Paper IV Urban Environment

Unit I: Fundamentals of Urban Environment

1. Introduction to Urban Environment: Definition, scope, and importance, Principles of Sustainable Urban Development and Resilient Cities. Urbanization in India and global context, Urbanization Process (Growth of cities due to migration, industrialization, and economic development, Transformation of rural landscapes into urban ones). Urban land use patterns (Central Business District, inner city, suburbs, urban-rural fringe), Brownfield and Greenfield sites and their environmental implications.

2. Built Environment: Concept of the Anthropocene, Urban Infrastructure (Housing and slums, Transportation systems, Water supply, sanitation, and drainage), Natural Environment in Cities (Urban ecosystems (parks, rivers, wetlands, biodiversity), Urban Environmental Issues(Air pollution in cities, Urban heat island effect, Noise pollution, Solid waste management and recycling), Social & Economic Dimensions(Population density, lifestyle, and consumption patterns), Urban sprawl and its environmental consequences. Urban poverty, slums, and inequality.

Unit II: Urban Ecology

1. Fundamentals of Urban Ecology: Definitions of urban ecology (Ecology in the city, Ecology of the city, Ecology for the city), principles of urban ecology, concept of urban ecosystems, urban green spaces, ecological footprint of cities, The city as an Anthropogenic Biome. The city as an ecosystem (Biotic components and abiotic components, structure and function, energy flow, food webs).

2. Urban Ecosystem Structure and Function: Urban Metabolism: Components of Urban Metabolism (Inputs: energy, water, food, raw materials, land), Outputs (waste, emissions, wastewater, solid waste), Biogeochemical Cycles in Cities (The role of the built environment in altering the cycling of Carbon (C), Nitrogen (N), and Phosphorus (P),Urban soils: compaction, contamination, and altered nutrient levels), Urban Hydrology(Stormwater runoff and flooding and water pollution), Urban Fauna and Wildlife.

Unit III: Study of Urban Environment

1. Urban Metabolism Analysis: Quantifying the input- -output of key resources: energy (electricity, fuel), water, food, and building materials, Material Flow Analysis (MFA) and Energy Flow Analysis (EFA) to track consumption patterns, Linking urban consumption to its Ecological Footprint and global environmental impact. Ecological footprint and carbon footprint analysis, Life Cycle Assessment (LCA) in urban context.

2. Urban Hydrology and Water Quality: Analysis of stormwater runoff, analysis on contamination sources and the ecological health of urban rivers, lakes. Investigating the distribution, adaptation of plant and animal species in highly modified urban habitats. Studies on invasive species dynamics in urban corridors and disturbed areas. Research on Urban Rewilding and restoration ecology in urban settings. Analysis of soil properties, contamination (heavy metals, microplastics), and the role of soil in nutrient cycling and plant health in built areas.

Unit IV: Management of Urban Environment

1. Sustainable Urban Governance: Community participation in urban governance, Role of NGOs and civil society in urban sustainability, energy, water, and waste management in cities, Green/Blue Infrastructure (GBI) and Nature-Based Solutions (NBS), Green economy and circular economy in

cities, use of GIS and remote sensing in urban planning, Renewable energy technologies in urban areas, solid Waste management technologies (recycling, composting, waste-to-energy), urban ecological restoration (e.g., brownfield remediation, wetland creation, The Miyawaki method of plantation).

2. Urban Ecosystem Services: Provision of ecosystem services by urban green spaces (carbon sequestration, air filtration, cooling). Hyperlocal air quality sensing, mitigating the Urban Heat Island (UHI) effect, Sustainable transport systems (metro, EVs and BRT), Climate-resilient infrastructure and green building technologies. Smart Cities and Data Analytics: The role of Digital Twins, IoT sensors, and Big Data in environmental monitoring and governance.

B.Sc. Part III Semester VI
Minor Subject
STUG06ENVS0012
Practical: Urban Environment

Practical: Monitoring & Measurement

A. Air Quality Assessment:

i. Measure particulate matter PM2.5 and PM10 or specific gaseous pollutants NOx,Sox at different urban locations (e.g., near traffic, in a park).

ii. Compare air quality on different days or times to study the impact of human activity (e.g., rush hour vs. non-rush hour).

B. Urban Heat Island (UHI) Study:

i. Measure and compare surface and ambient air temperatures in different locations of the area (residential, green space, water body).

ii. Analyze satellite or remote sensing data to map UHI intensity.

C. Water Quality Analysis:

i. Collection of water samples from urban sources (e.g., rivers, streams, stormwater runoff) and test for key pollutants like heavy metals, nitrates, phosphates, or E. coli bacteria.

D. Noise Pollution Mapping:

i. Use noise meters to map noise levels across different parts of the city (e.g., residential vs. commercial zones, near airports/train tracks) to quantify anthropogenic noise.

E) Biodiversity & Ecology Practicals

i. Conduct transect or quadrat sampling in urban green spaces (parks, gardens, street trees) to identify and quantify plant and insect species, comparing diversity to non-urban areas.

ii. Use citizen science tools like iNaturalist or eBird to document species distribution and abundance.

F. Urban Evolutionary Biology

i. Analyze the impact of artificial light at night (ALAN) on animal behavior (e.g., observing moth attraction or bird nesting patterns).

G) Soil and Sediment Analysis

i. Collect soil or sediment cores from different urban environments for physical and chemical analysis to look for anthropogenic markers like plastic fragments, microplastics, or elevated levels of heavy metals from industrial history.

H. Resource & Waste Management Practicals

1. Urban Metabolism Study:

i. Track the inflow and outflow of a single resource (e.g., water, electricity, or solid waste) for a specific building, school, or neighborhood over a given time period and calculate the per capita consumption or waste generation rate.

2. Solid Waste Composition Analysis:

i. Sort and analyse different categories of municipal solid waste (e.g., plastics, paper, organics, construction debris) to understand urban consumption patterns and recycling effectiveness.

I. Practicals on Urban Water Supply (Water Quality Analysis)

1. Physical Parameters

i. Turbidity Measurement: Determine the concentration of suspended solids (cloudiness) in water samples collected from the sources, treatment plant outlet, and various points in the distribution network using a turbidimeter.

ii. Total Dissolved Solids (TDS) and Conductivity: Measure the electrical conductivity and subsequently calculate the TDS of water samples.

iii. pH and Temperature: Measure the pH and temperature and of different water samples to ensure the water is within the acceptable range.

2. Chemical Parameters

i. Residual Chlorine Analysis: Measure the concentration of free and total chlorine residual at the treatment plant and the farthest point of the distribution network.

ii. Determination of hardness: Determine the total hardness (calcium and magnesium ions) using an EDTA titrimetric method.

iii. Alkalinity and Acidity: by Titrimetric Method

iv. Heavy Metal and Trace Contaminants: Analyze for contaminants like Lead (Pb), Iron (Fe), or Nitrate (NO) using specialized equipment like an Atomic Absorption Spectrophotometer (AAS) or spectrophotometer.

3. Biological/Microbial Parameters

i. Total Coliform and E coli Enumeration: Use the Membrane Filter (MF) technique or Multiple Tube Fermentation (MTF) technique (Most Probable Number or MPN) to detect and quantify total coliforms and E. coli.

ii. Biochemical Oxygen Demand (BOD) Test: Determination of Biochemical Oxygen Demand (BOD) of raw sewage to quantify the organic pollution load entering the treatment plant.

J. Treatment Process

i. Jar Test for Coagulation-Flocculation: Use a Jar Test Apparatus to determine the optimal dosage of a coagulant (e.g., alum, ferric chloride) required to treat a sample of turbid raw water.

K. Water Audit and Non-Revenue Water (NRW) Estimation: Collect and analyze data on the total volume of water supplied and the total volume billed to estimate water losses (leakages, unauthorized use). This is a crucial urban water management exercise.

L. Vegetation Survey and Diversity Index Calculation (Field & Lab)

i. Field: Conduct quadrat sampling (a fixed area plot) or transect surveys in an urban park, green roof, or street verge to identify and count plant species (flora) and record ground cover.

ii. Lab: Calculate Biodiversity Indices such as the Shannon-Wiener Index or Simpson's Index to compare species diversity between different habitat types (e.g., managed lawn vs. forest patch vs. abandoned lot).

Books for reference

1. R. Ramachandran (1990), Urbanization and Urban Systems in India, Oxford University Press (OUP India).
2. Kiran Jalem, S. Chaudhary, and Jatin Prasad(2024), Urban Planning and Development, Smart Cities and Ease of Living in India, New Century Publications, New Delhi.
3. Darshini Mahadevia and Rutool Sharma (2025), Urban Planning and Its Discontents: Practice in Contemporary India, Routledge India (an imprint of Taylor & Francis).
4. Springer Nature (2025), Forecasting the urban footprint (2025), LULC change and transition modelling in Haryana's peri-urban tehsils.
5. Pramit Verma, Pardeep Singh, Rishikesh Singh, A. S. Raghubanshi (2020), Urban Ecology: Emerging Patterns and Social-Ecological Systems, Elsevier Science.
6. Kirsten M. Parris (2016), Ecology of Urban Environments, Wiley-Blackwell.
7. John M. Marzluff, Eric Shulenberger, Wilfried Endlicher, Marina Alberti, Gordon Bradley, Clare Ryan, Ute Simon, and Craig ZumBrunnen(2008), Urban Ecology: An International Perspective on the Interaction Between Humans and Nature, Springer.
8. C. Nagaraja Rao (2016), Urban Governance in India, Kalpaz Publications (an imprint of Gyan Books).
9. S.C. Rangwala (2024), Town Planning, Charotar Publishing House Pvt. Ltd.
10. Andressa V. Mansur, Robert I. McDonald, Burak Güneralp, HyeJin Kim, Henrique M. Pereira, et al (2022), Nature futures for the urban century: Integrating multiple values into urban management, Elsevier.
11. N. R. Krishnan (2022), A Green Economy: India's Sustainable Development, Notion Press.
12. Council on Energy, Environment and Water (CEEW) (2025), Building a Green Economy for Viksit Bharat: New Opportunities for Jobs, Growth and Sustainability in India.
13. Standard methods for Examination of Water and Wastewater,18th edition 1992, American Public Health Association (APHA), American Water Works Association (AWWA), New York.
14. Water and wastewater analysis. National Environmental Engineering Research Institute (NEERI), Nagpur.
15. A Textbook of Experiments and Calculations in Engineering Chemistry- S.S. Dara, S.Chand and Company Ltd. New Delhi 2003.
16. Handbook of Methods in Environmental Studies, Vol-I Water and Waste Water AnalysisS.K. Maity, ABD Publishers, Jaipur India.
17. Handbook of Methods in Environmental Studies, Vol-II Air, Noise, Soil Over Burden Solid Waste And Ecology- S.K. Maity, ABD Publishers, Jaipur India.
18. Chemical Methods for Environmental Analysis (1996), R. Ramesh & M. Anbu, MacMillan India Ltd., Mumbai
19. A Manual of Practical Methods in Environmental Science (1998), Environmental Research Academy, Visakhapatnam, India.
20. D.R. Khanna, R. Bhutiani Laboratory Manual of Water and Wastewater Analysis- Practical step-by-step methods for chemical, physical, and biological water quality testing

B.Sc. Part III Semester VI
STUG06ENVS0013
On the Job Training

Preamble: On-the-Job Training (OJT) is one of the most valuable components of professional education because it effectively bridges the gap between theoretical classroom learning and practical, real-world application. Students acquire practical experience utilizing the relevant tools, equipment, and processes. The essential elements of a successful student OJT program usually include the following components. Students are expected to complete the following tasks in order to successfully finish their OJT program.

1. Pre-Training Preparation

i. Orientation session by the institution.
ii. Selection of industry/organization for placement.
iii. Signing of training agreements or MoUs between student, institution, and employer.
iv. Safety briefing and workplace rules introduction.

2. Induction at Workplace

i. Introduction to company policies, culture, and organizational structure
ii. Familiarization with tools, equipment, and facilities
iv. Assignment of initial tasks and responsibilities

3. Skill Development Phase

i. Hands-on practice under supervision
ii. Learning technical skills relevant to the field (e.g., engineering and environmental science)
iii. Participation in routine work activities (production, analysis, reporting, etc.)

4. Knowledge Integration

i. Application of classroom/theoretical knowledge to real-world tasks
ii. Problem-solving exercises and case studies

5. Monitoring and Mentorship

i. Regular feedback sessions with supervisors/mentors
ii. Daily/weekly reporting of tasks completed

6. Professional Development

i. Training in soft skills: communication, teamwork, time management
ii. Development of leadership and decision-making abilities

7. Assessment and Evaluation

i. Continuous assessment based on performance, punctuality, and attitude
ii. Practical tests or demonstrations of acquired skills
iii. Submission of progress reports/logbooks to faculty coordinators
iv. Employer feedback form on student performance

8. Final Reporting

i. Preparation of a detailed training report (objectives, tasks, learning outcomes, challenges, solutions)
ii. Presentation/seminar before faculty and peers.
iii. Submission of certificates or completion letters from the employer
iv. Final evaluation by institution (marks/grades/credits awarded)
iv. Career guidance based on training experience

B.Sc. Part III Semester V
STUG06ENVS0013
Research Project (RP)

Preamble: It is essential for students to choose a research topic within the field of environmental science. In order to reach a final result, the work involves data collection, analysis, and interpretation. The preparation pages (title page, certificate, acknowledgement page, table of contents, list of tables and figures), References, and Appendices should all be included in the thesis. At the end of the session, the report should be submitted in by the students in the format below.

Title Page

Table of Contents

1. Introduction: This part of a research project should explain to readers the significance of the subject. Also, pertinent information on the subject should be included. In simple terms, the introduction should explain to readers why you have selected the subject or problem and what makes it relevant.

2. Literature Review: It is basically a survey about what other professionals have written or demonstrated about the problem that one is addressing.

3. Materials and Methods or Experimental: The research design should be such that it is able to explain a set of questions like, what experiments were used in the study and what the purpose of those experiments was.

4. Results and Discussion: The writing of this thesis chapter should enable it to explain the findings using the relevant figures and tables. The results need to be presented, clarified, and analysed in order to improve understanding and drawing conclusions.

5. Summary and Conclusion: This part should act as a summary of the whole thesis for the readers. The conclusion must contain a very brief synopsis of research and design, a summary of the approach used and a glimpse of the results. One has to make sure that the conclusion part is brief, crystal clear and very concise.

6. References: It includes list of all sources cited in the report, formatted according to the specified citation style and proper citation of all external references, including books, journals, articles, and online resources.

B.Sc. Part III Semester VI
STUG06ENVS0014
IKS in Environmental Science-II

Unit I: The Foundations of Ancient Environmental Science

1.Prithvi (Earth/Lithosphere): Soil health, land conservation, and the Earth as a nurturing mother (Bhumi Sukta from the Atharva Veda).

2.Apas (Water/Hydrosphere): Hydrological cycles, sacredness of rivers, and ancient water preservation techniques (dynamic water-harvesting structures stepwells, johads).

3.Tejas (Energy/Sun/Fire): Solar energy as the driver of life, photosynthesis, and atmospheric balance.

4.Vayu (Air/Atmosphere): Atmospheric composition, the importance of pure air (Prana), and ancient methods to reduce air pollution (like Yajna or ritual smoke chemistry).

5. Akasha (Space): Sound pollution, spatial balance, and cosmic interconnectedness, Varahamihira's Brihat Samhita—ancient methods of predicting rainfall, droughts, and earthquakes using planetary movements and animal behavior.

Unit II: Ecosystems and Biodiversity – Vana (Forests) and Jiva (Life)

1.Classification of Forests: Study of Mahavana (dense natural forests), Tapovana (sacred groves/meditation forests), and Srivana (production forests).

2.Sacred Groves (Deorais/Kavus): Ancient community-led biodiversity hotspots and gene pools.

3.Flora and Fauna Conservation: The ethical treatment of animals (Ahimsā) and plants. Concepts from the Vrikshayurveda (ancient plant science, companion planting, and plant diseases).

4.Wildlife Sanctuaries: Kautilya's Arthashastra guidelines on establishing Abhayaranyas (sanctuaries where hunting was strictly prohibited).

Unit III: Environmental Ethics and Sustainability – Rita and Dharma

1.Rita (The Cosmic Law): Understanding natural equilibrium and why disrupting it leads to environmental disasters.

2.Isavasyopanishad Principle: The philosophy of consumption: "Tena Tyaktena Bhunjitha" (Consume only what you need, do not covet what belongs to others).

3.Eco-Spirituality: The practice of seeing divinity in nature (worship of rivers, mountains, and trees like Pipal and Tulsi) as a psychological tool for conservation.

4.Emperor Ashoka's environmental governance: Foundations of Environmental Ethics, Wildlife and Biodiversity Conservation, Resource Management and Public Infrastructure.

Unit IV: Sustainable Agriculture and Waste Management

1.Ancient Farming: Varahamihira's Brihat Samhita—ancient methods of predicting rainfall, droughts, and earthquakes using planetary movements and animal behavior.

2.Organic farming: Agronomic and agrostological methods, crop rotation, and maintaining soil fertility without chemical fertilizers.

3.Animal Husbandry: The ecological role of cattle in a circular economy (manure, pest control, and soil rejuvenation).

4.Waste Treatment: Natural decomposition, recycling, and the strict ancient municipal laws regarding public sanitation found in the Indus Valley and Maurya empires.

References

1.Devi, C. A. (Trans.). (1977). The Atharva Veda: Bhumi Sukta (Hymn to the Earth). Clarified Edition. Modern Book Depot.

2.Panikkar, R. (1977). The Vedic Experience: Mantramañjarī: An Anthology of the Vedas for Modern Man and Contemporary Celebration. University of California Press.

3.Randhawa, M. S. (1980). A History of Agriculture in India (Vol. 1: Beginning to 12th Century). Indian Council of Agricultural Research (ICAR).

4. Varahamihira (6th Century CE). Brihat Samhita. Translated by M. Ramakrishna Bhat (1981). Motilal Banarsidass (2 Volumes).

5. Dwivedi, O. P., & Tiwari, B. N. (1987). Environmental Crisis and Hindu Religion. Gitanjali Publishing House.

6. Prime, R. (1992). Hinduism and Ecology: Seeds of Truth. Cassell Publishers.

7. Kautilya (c. 4th Century BCE). The Arthashastra. Translated by L.N. Rangarajan (1992). Penguin Classics.

8. Agarwal, A., & Narain, S. (Eds.). (1997). Dying Wisdom: Rise, Fall and Potential of India's Traditional Water Harvesting Systems. Center for Science and Environment (CSE).

9. Kenoyer, J. M. (1998). Ancient Cities of the Indus Valley Civilization. Oxford University Press.

10.Vannucci, M. (1999). Ecological Readings in the Veda: Matter, Life, Mind. D.K. Printworld.

11. Baartmans, F. (2000). The Holy Forest: Reflections on Modern Ecology and Ancient Indian Traditions. B.R. Publishing Corporation.

12.Livingston, M. (2002). Steps to Water: The Ancient Stepwells of India. Princeton Architectural Press.

13.Chapple, C. K. (2002). Nonviolence to Animals, Earth, and Self in Asian Traditions. State University of New York Press.

14.Mishra, A. (2011). Aaj Bhi Khare Hain Talaab (The Ponds Are Still Relevant). Gandhi Peace Foundation.

15.Haberman, D. L. (2012). People Trees: Worship of Trees in Northern India. Oxford University Press.

16.Eck, D. L. (2012). India: A Sacred Geography. Harmony Books.

17.Thapar, R. (2012). Aśoka and the Decline of the Mauryas. Oxford University Press (Revised Edition).

18.Trautmann, T. R. (2015). Elephants and Kings: An Environmental History. University of Chicago Press.

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Question Paper Pattern
Major and Minor Subject

Time: 3:00 Hours **Max. Marks: 40**

Que. 1. Long Question from unit I **(8 Marks)**

OR

a) Short Question from unit I **(04 Marks)**

b) Short Question from unit I **(04 Marks)**

Que. 2. Long Question from unit II **(08 Marks)**

OR

a) Short Question from unit II **(04 Marks)**

b) Short Question from unit II **(04 Marks)**

Que. 3. Long Question from unit III **(08 Marks)**

OR

a) Short Question from unit III **(04 Marks)**

b) Short Question from unit III **(04 Marks)**

Que. 4. Long Question from unit IV **(08 Marks)**

OR

a) Short Question from unit IV **(04 Marks)**

b) Short Question from unit IV **(04 Marks)**

Que. 5. Answer in brief: **(08 Marks)**

Solve any 8 out of 12 questions (3 questions from each unit) **(1 Mark each)**