ST JOSEPH'S UNIVERSITY
BENGALURU – 560 027

DEPARTMENT OF ENVIRONMENTAL SCIENCE

SYLLABUS FOR POST-GRADUATE COURSE
M. Sc. ENVIRONMENTAL SCIENCE AND SUSTAINABILITY

Syllabus to be followed from 2026-2027 onwards

ST JOSEPH'S UNIVERSITY
BENGALURU - 560 027

DEPARTMENT OF ENVIRONMENTAL SCIENCE

M. Sc. ENVIRONMENTAL SCIENCE AND SUSTAINABILITY

Vision

Empowering and emancipating students through an understanding of the environment, sustainability and related ethical issues.

Mission

Our mission is to develop environmentally conscious citizens who are able to appreciate the environment in its totality. We strive to equip our students with motivation, attitude, sound knowledge, commitment and skills to actively participate, at various levels, in sustainably managing environmental issues.

Curricular Structure for the Postgraduate Programme in M. Sc. ENVIRONMENTAL SCIENCE AND SUSTAINABILITY (I to IV Semester)

Sem	No. of Theory papers (4 credits)	No. of teaching hours per week	No. of practical papers (2 credits)	Total credits (Theory + Practical)
I	5	4	4	20 + 8 = 28
II	5	4	4	20 + 8 = 28
III	5	4	1 (Practical) + 3 (Dissertation) = 4	20 + 8 = 28
IV	Internship			14
Total credits				98

DEPARTMENT OF ENVIRONMENTAL SCIENCE
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Curricular structure for the postgraduate programme in M. Sc. ENVIRONMENTAL SCIENCE AND SUSTAINABILITY

Sem	Paper code	Paper title
I	**ES 7126**	Atmospheric Sciences
	ES 7P126	Meteorology and Air Quality Analysis
	ES 7226	Hydrological Sciences
	ES 7P226	Water and Wastewater Analysis
	ES 7326	Earth Sciences and Solid Waste Management
	ES 7P326	Earth Resources, Soil Analysis and Solid Waste Analysis
	ES 7426	Ecosystem Dynamics, Biodiversity and Wildlife Conservation
	ES 7P426	Ecosystem Assessment, Biodiversity and Wildlife Studies
	ES 7526	Environmental Chemistry and Analytical Methods
II	**ES 8126**	Natural Resources Management
	ES 8P126	Mapping and Natural Resources Studies
	ES 8226	Environmental Forensics
	ES 8P226	Environmental Forensics
	ES 8326	Environmental Impact Assessment and Environmental Audit
	ES 8P326	Environmental Impact Identification and Audit Methods
	ES 8426	Geospatial and Web-GIS applications
	ES 8P426	Geospatial and Web-GIS Applications
	ES 8526	Research Methodology and Environmental Statistics
III	**ES 9126**	Climate Change and Disaster Management
	ES 9P126	Climate Change Assessment and Sustainability Tools
	ES 9226	Sustainable Development
	ES 9326	Corporate Sustainability and Environment, Social & Governance
	ES 9426	Safety, Health & Environment
	ES 9526	Environmental Economics
	ES 9D26	Dissertation
IV	**ES 0I26**	Internship

M.Sc. Environmental Science and Sustainability

SYLLABUS – Theory and Practicals

Semester I

ES 7126 – ATMOSPHERIC SCIENCES

Number of Theory Credits	Number of Lecture Hours / Semester
4	52

Course Specific Objectives	
CSO 1	To provide an integrated understanding of the physical and chemical processes governing the atmosphere.
CSO 2	To develop a scientific understanding and interpretation of global climatic phenomenon.
CSO 3	To provide comprehensive knowledge on approaches to monitor and manage atmospheric pollution.
CSO 4	To provide insights on legal and regulatory aspects of monitoring and controlling atmospheric pollution.

Course Outcomes	
CO 1	The students will be familiar with the concepts of thermal structure of atmosphere, solar radiation, greenhouse effect and the dynamics of the atmosphere.
CO 2	Students will gain an understanding of chemical constituents and will be able to assess air pollution parameters and interaction of pollutant in the atmosphere.
CO 3	Students will comprehend the processes involved in the natural phenomena like weather extremes like cyclones, heat waves, thunderstorms and the like; an understanding of the climatology and climate classification is also made available.
CO 4	Students will get an understanding of various air related laws such as the National Clean Air Programme (NCAP), the Air (Prevention and Control of Pollution) Act, and the Graded Response Action Plan (GRAP).

CONTENTS OF ES 7126: ATMOSPHERIC SCIENCES	52 Hours
Unit – 1: Physical Atmosphere	**13**
Atmosphere: Definition - Evolution of atmosphere - Composition of current atmosphere (Permanent and variable gases) - Thermal structure of atmosphere (adiabatic changes). Standard atmosphere. Atmospheric radiation: Concept - laws of radiation, solar radiation, solar spectrum and solar constant. Distribution of solar insolation above the Earth's surface – scattering, absorption and diffusion. Effect of atmospheric gases, aerosols, clouds (surface and planetary albedo) on solar radiation. Solar radiation at the Earth's surface – Atmospheric window, absorbing elements and their spectrum distribution, optical depth - thick and thin objects, aerosol scattering, estimation of radiative heating and cooling. Terrestrial radiation and its passage through the atmosphere, emission and absorption of terrestrial radiation, Raleigh and Mie scattering, radiative transfer, greenhouse effect and net radiation budget. Atmospheric thermodynamics: Distribution of temperature (Atmospheric stability and inversion), density, pressure and water vapour.	
Unit – 2: Chemical Atmosphere	**13**
Chemical constituents: Nitrogen, hydrogen, halogen, sulphur and carbon-containing compounds in the atmosphere. Oxidising, reducing and Neutral atmospheres. Atmospheric aerosols: Concentration and size, sources, and transformation, Chemical composition, transport and sinks, residence times of aerosols, geographical distribution and atmospheric effects. Chemical and photochemical processes - Chemical and dynamical life time of atmospheric constituents. Eddy diffusion and Turbulence. Ozone Chemistry: Evolution of the Ozone layer, sources and sinks of tropospheric and stratospheric Ozone. Ozone depletion and recovery - Influence of Chlorofluorocarbons, free Ozone, UV-radiations and supersonic transport on Ozone layer. Air Pollution: Sources of pollution, pollutants and their classification. Atmospheric effects - Smog, visibility (Global dimming). Peroxyacetyl Nitrate (PAN) and Acid rain: Formation, impacts and control. Atmospheric Boundary Layer and Planetary Boundary Layer. Mixing layer: Prandtl's theory, Turbulence, Convection and Richardson number. Dispersion of air pollutants: Types of Plume behaviour; Gaussian plume model and K models.	

Unit – 3: Meteorology and Climatology	**13**
Meteorology: Physical, Dynamic and Synoptic meteorology. Concept and measurement of weather components: Temperature; Humidity (Absolute, Specific and Relative); Pressure; Wind speed and direction - Beaufort wind scale; Precipitation - Types, Wegener-Bergeron-Findeisen process and Collision-Coalescence process. Illumination and Cloud cover. Clouds: Formation and classification. Artificial rainfall - Cloud seeding, Cloudbuster and Bioprecipitation. Micro & Meso-scale meteorology. Agro and Hydro meteorology. Climatology: Koppen and Geiger Climate Classification. Tropical monsoon climate. Weather extremes and atmospheric disturbances: Heat waves, Cold waves, Dust storms, Depressions, Cyclones (Formation, Vertical and Horizontal structure and landfall), Thunderstorms, Cloudbursts, Floods, Lightening and Droughts.	
Unit – 4: Approaches to monitor and manage atmospheric pollution	**13**
Measures to reduce process emissions at source and fugitive emissions. Identifying and assessing the quantum of emissions. Control of particulates: Settling chambers, Cyclones, Scrubbers, Electrostatic precipitators (ESP) and Fabric filters (FF). Control of gases: Absorption, Wet scrubbers and packed scrubbers, Flue gas desulfurization (FGD), Catalytic Converters, Selective Catalytic Reduction (SCR), Adsorption, Mist collectors, biofilters. Bharat Stage Standards. Hybrid vehicles. Alternative fuels in India. Electric vehicles. Emission inventories - Particulate matter ($PM_{<1\mu m}$, $PM_{<2.5\mu m}$ and $PM_{<10\mu m}$), Sulphur dioxide, Oxides of Nitrogen, Carbon monoxide, Hydrocarbons and other parameters as per National Ambient Air Quality Standards - NAMP programme. Air Pollution information - IQAir. Air Quality Index (AQI) and Air Quality Life Index (AQLI). Stack monitoring - Particulate matter, Sulphur dioxide, Oxides of Nitrogen and other parameters. Central and State Pollution Control Boards. Air (Prevention and Control of Pollution) Act, 1981. National Clean Air Programme (NCAP). The Graded Response Action Plan (GRAP).	

References

Act, A. (1981). Air (Prevention and Control of Pollution) Act 1981.

Akimoto, H. (2016). *Atmospheric reaction chemistry*. Tokyo: Springer Japan.

Barry, R. G., & Chorley, R. J. (2009). *Atmosphere, weather and climate*. Routledge.

Bhandari, M. P. (2020). *Getting the Climate Science Facts Right: The Role of the IPCC* (pp. i-lii). River Publishers.

Bower, F. A. (2018). *Stratospheric Ozone and Man: Volume II*. CRC Press.

Bridgman, H. A., & Oliver, J. E. (2014). *The global climate system: patterns, processes, and teleconnections*. Cambridge University Press.

Change, I. C. (2013). The physical science basis. *Contribution of working group I to the fifth assessment report of the intergovernmental panel on climate change*, *1535*, 2013.

Change, I. P. O. (2006). 2006 IPCC guidelines for national greenhouse gas inventories. *Institute for Global Environmental Strategies, Hayama, Kanagawa, Japan*.

Critchfield, H. J. (1966). *General climatology* (No. QC981 C73 1966).

Downie, D. L., Brash, K., & Vaughan, C. (2009). *Climate change: A reference handbook*. Abc-Clio.

Edward J. Tarbuck and Frederick K. Lutgens. (1998). *The Atmosphere: An Introduction to Meteorology*. Prentice Hall, 1-434.

Eggleston, H. S., Buendia, L., Miwa, K., Ngara, T., & Tanabe, K. (2006). 2006 IPCC guidelines for national greenhouse gas inventories.

Gordon, A., Grace, W., Byron-Scott, R., & Schwerdtfeger, P. (2016). *Dynamic meteorology*. Routledge.

Hanif, M. A., Nadeem, F., Bhatti, I. A., & Tauqeer, H. M. (2020). *Environmental Chemistry: A Comprehensive Approach*. John Wiley & Sons.

Harrison, G. (2015). *Meteorological measurements and instrumentation*. John Wiley & Sons.

Hocking, M. B. (2016). *Handbook of chemical technology and pollution control*. Elsevier.

Kamyotra, J., Saha, D., Tyagi, S. K., Sen, A. K., Srivastava, R. C., & Pathak, A. (2011). Guidelines for the Measurement of Ambient Air Pollutants. *Central Pollution Control Board-Ministry of Environment & Forests, Govt. of India*.

Knight, D. C. (1961). *The First Book of Air: A Basic Guide to the Earth's Atmosphere*. F. Watts.

Krishnan, R., Sanjay, J., Gnanaseelan, C., Mujumdar, M., Kulkarni, A., & Chakraborty, S. (2020). *Assessment of climate change over the Indian region: a report of the ministry of earth sciences (MOES), government of India* (p. 226). Springer Nature.

Leal Filho, W., Barbir, J., & Preziosi, R. (Eds.). (2019). *Handbook of climate change and biodiversity*. New York: Springer.

Robinson, P. J., & Henderson-Sellers, A. (2014). *Contemporary climatology*. Routledge.

Saha, K. (2008). *The Earth's atmosphere: Its physics and dynamics* (pp. 367-1). Berlin: Springer.

Schifftner, K. C. (2021). *Air pollution control equipment selection guide*. CRC Press.

Schmittner, A. (2018). *Introduction to Climate Science*. Oregon State University.

Schnelle Jr, K. B., Dunn, R. F., & Ternes, M. E. (2015). *Air pollution control technology handbook*. CRC press.

Shonk, J. (2020). *Introducing meteorology: A guide to the weather*. Dunedin Academic Press Ltd.

Singh, J. (Ed.). (2015). *Disaster Management: Future Challenges & Opportunities*. IK International Publishing House.

Spiridonov, V., & Ćurić, M. (2021). *Fundamentals of Meteorology*. Springer.

Suwa, A., & Iguchi, M. (Eds.). (2020). *Sustainability and the Automobile Industry in Asia: Policy and Governance*. Routledge.

Tölgyessy, J. (Ed.). (1993). *Chemistry and biology of water, air and soil: Environmental aspects*. Elsevier.

Visconti, G. (2016). *Fundamentals of Physics and Chemistry of the Atmosphere*. Springer.

Zhongming, Z., Linong, L., Xiaona, Y., Wangqiang, Z., & Wei, L. (2019). 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

Websites:

https://www.qcin.org

https://nabet.qci.org.in

https://cpcb.nic.in

https://kspcb.karnataka.gov.in

https://ksdma.karnataka.gov.in

https://mausam.imd.gov.in

https://public.wmo.int/en

https://waqi.info/

https://app.cpcbccr.com/AQI_India/

https://www.ipcc.ch/

ES 7P126: METEOROLOGY AND AIR QUALITY ANALYSIS

Number of Practical Credits	Number of Practical Hours / Semester
2	52

1. Measurement of Minimum & Maximum Temperature, Relative Humidity and Solar Illuminance
2. Measurement of Atmospheric Pressure, Wind Speed and Direction
3. Construction of Wind rose (Primary and secondary data).
4. Measurement of Rain and Rainfall analysis (Secondary data)
5. Sampling techniques of air
6. Measurement of Particulate matter using Respirable Dust Sampler
7. Measurement of Sulphur dioxide and Oxides of Nitrogen using Respirable Dust Sampler
8. Measurement of Ground Level Ozone using Respirable Dust Sampler
9. Construction of Pollution rose – Particulate matter, Sulphur dioxide and Oxides of Nitrogen (Secondary data)
10. Measurement of Carbon monoxide and Carbon dioxide concentration using NDIR technology
11. Study of Automobile emissions using Flue Gas analyser
12. Study of Air Quality Indices using CPCB AQI Calculator
13. Construction of Gaussian Plume Dispersion models

Activity – Depiction of air quality of different locations of Bengaluru on a map

Visit to Indian Meteorological Department (IMD), Regional CPCB and KSPCB laboratories

References

Kamyotra, J., Saha, D., Tyagi, S. K., Sen, A. K., Srivastava, R. C., & Pathak, A. (2011). Guidelines for the Measurement of Ambient Air Pollutants. *Central Pollution Control Board-Ministry of Environment & Forests, Govt. of India*.

Roy, R. F. (2022). *The Weather Book: A Manual of Practical Meteorology*. BoD–Books on Demand.

Shaw, N. (2015). *Manual of meteorology* (Vol. 3). Cambridge University Press.

Stone, R. G. (1937). Manual of Meteorology, Vol. II, Comparative Meteorology.

M. Sc. Environmental Science and Sustainability

Semester I

ES 7226 – HYDROLOGICAL SCIENCES

Number of Theory Credits	Number of Lecture Hours / Semester
4	52

Course Specific Objectives	
CSO 1	To address the importance of water as a resource along with its consumptive and non-consumptive uses.
CSO 2	To provide knowledge on the concept of virtual waters and integrated water resource management.
CSO 3	To understand the wastewater management strategies.
CSO 4	To create awareness about water quality indices and water governance.

Course Outcomes	
CO 1	Students will have a comprehensive understanding of water as a resource, its properties, types and uses. Further, students will be enabled towards critical thinking in water resource management, addressing environmental concerns, sustainability, and climate change impacts.
CO 2	Students will develop the skills required handle water resource management practices towards enabling sustainable management of water resources.
CO 3	By the end of the course, students will have an understanding of wastewater treatment systems, enabling them to understand the design, components and develop skills required to water and wastewater treatment.
CO 4	Students will have gained an understanding of the socioeconomic, ecological and cultural aspects of water as well as the management of water resources. This will be enabled through an exposure to concepts like Integrated Water Resources Management (IWRM), and the methods for managing and measuring water quality using the Water Quality Index (WQI).

CONTENTS OF ES 7226 – HYDROLOGICAL SCIENCES	52 Hours
Unit – 1: Water resources	**13**
Water as a resource: Classification of water resources – Surface water, Groundwater, Ocean water, Brackish water, Glaciers and Ice caps. Resources properties of water: Universal solvent, Cohesion, Adhesion, High surface tension, High specific heat, Boiling and freezing points, High Heat of vaporization, Amphoteric properties, Capillary action and Occurs as Solid (ice), Liquid and Gas (vapour). Sources and Uses of water (primary, secondary and tertiary sector uses); Concept of virtual water; Health and environmental concerns of availability and quality of water resources. Hydrological cycle: Fluxes, reservoirs, and residence times. Process of heat energy transfer - Radiation, Conduction and Convection; Global Water Balance; Water budget of India. Limnology: Physical, Chemical and Biological limnology. Lotic systems: Springs, Stream profile: Potomon and Rhithron. Lentic systems: Ponds, lakes and estuaries – their types. Photic and thermal stratification of Lentic systems. Marine environment: Zonation, Salinity status of marine environment. Ground water: Zonation; Aquifers; Groundwater flow; Hydraulic head, Conductivity, Permeability, Storativity, and Porosity. Darcy's law. Groundwater flow: Ground water potential; Flow nets; Heterogeneity and Anisotropy. Tracer techniques. Salt water intrusion.	
Unit – 2: Humans influences on Water Resources and Pollution	**13**
Available water resources and their present Utilization. Water use categories: In-stream and off-stream water use; Freshwater, brackish water and saltwater use; Consumptive Use of Water: Agriculture, Industry and Municipal water supply. *Methods of Estimation* - Inflow and outflow studies; Tank and Lysimeter method; Soil moisture studies; Field experimental plots and Integration method. Non-Consumptive Use of Water: Power generation, Navigation, Wildlife habitat and Recreation. The AQUASTAT system.	

Water quality characteristics: Physical (Temperature, Colour, Taste and Odour, Turbidity, Solids); Chemical (Amphoteric nature, Redox reactions, Hydrolysis reaction, pH, EC, Salinity, Alkalinity, Hardness, Ions, Corrosiveness, DO, BOD, COD); and Biological (Microbial Contamination, Total Coliforms and Faecal Coliforms). Transport of contaminants in water environment: Natural and man-made. Surface water pollution: Thermal pollution; Oil pollution; Pesticide pollution; fertiliser pollution and Eutrophication. Ground water pollution: Fluorides, Nitrates and Arsenic. Radioactive substances – Alpha and Beta emitters. Contamination of Oceans: Nutrient pollution, Plastic pollution, Ocean acidification and oil spills. Water pollutants: Phosphates, Heavy metals, Endocrine disrupting chemicals, Persistent Organic Pollutants (POPs), Perfluorooctane Sulfonate (PFOS), Perfluorooctanoate (PFOA) and Phthalate esters.	
Unit – 3: Water and wastewater treatment	**13**
Water Supply Systems: Water demand, Population demand forecasting methods and Water distribution systems. Water and wastewater standards for specific applications. Water treatment: Preliminary, Primary, Secondary and Tertiary treatments. Aeration, Coagulation, Flocculation, Sedimentation, Filtration (Rapid sand filtration and Slow Sand Filtration) and Disinfection (Chlorination and Ozonation). Water softening; Hardness treatment - Desalination, Membrane Techniques, Removal of Taste and Odour, Miscellaneous Treatment Methods, (Lime, Soda Process, Zeolite Process, Demineralization Process). Wastewater treatment: Primary - Screening, Grit removal and Sedimentation. Secondary - Aeration/Activated Sludge Processes and Filtration/Trickling Filters). Disinfection of treated wastewater and disposal methods. Sludge management - Drying, Dewatering and Sludge digestion. Tertiary - Air Stripping, Chemical Coagulation, Flocculation, Biofiltration, Reverse Osmosis and Ion Exchange. Removal of suspended solids: Microscreening, Chemical coagulation and Clarification.	

Removal of organic matter: Adsorption using activated carbon and Biological oxidation. Removal of Phosphorous: Chemical precipitation & clarification; and Chemical coagulation & clarification. Lagoons, Septic tanks, Up-flow Anaerobic Sludge Digesters, Aeration ponds, Advanced Oxidation Processes, Rotatory Biological Contactors, Thermal hydrolysis exelys and Phytoremediation.	
Unit – 4: Approaches to monitor and manage water resources	**13**
Ecological, Economic, Social and Cultural values of water. Water crisis and water stress: Water rights and its legal implications; Politics of water sharing. Inter-basin transfer of water and its implications. Catchment hydrology: Watershed – concept, characteristics and management. Sustainable economic viability. Floods – causes, flood routing, estimation of magnitude and frequency of floods and flood management. Hydrographs. Water Harvesting and Conservation: Water Harvesting Techniques; Micro-catchments; Design of Small Water Harvesting Structures; Farm Ponds and Percolation Tanks. Rain water harvesting methods related to rural and urban areas. Urban water management: Urban water supply – Demand forecast and Urban hydrological cycle. Storm water management: Quantification of urban storm water, storage facilities and Master drainage plans. Interaction between urban drainage and solid waste management. Integrated Water Resources Management: Principles, Stages in IWRM planning and implementation – National goals, Water resources issues assessment, Water resources policy/strategy, Implementation plan, Actions of implementation, monitoring and evaluation. Water governance: Water pricing, legislation and law. Private sector involvement in water management: Types and forms. Partnerships for sustainable water governance. Water Quality Indices (WQI): Development of WQI - Selection of parameter, transform the data from a parametric system to a dimensionless system, creation of sub-indices, and computation of the final WQI score using the aggregation of sub-indices.	

References

Ahuja, S. (Ed.). (2014). *Water reclamation and sustainability*. Elsevier.

Anderson, M. G. (2005). *Encyclopedia of hydrological sciences*. J. Wiley.

Brears, R. C. (2016). *Urban water security*. John Wiley & Sons.

Brutsaert, W. (2005). *Hydrology: an introduction*. Cambridge university press.

Chen, D. H. (2016). *Sustainable Water Management*. CRC Press.

Droste, R. L., & Gehr, R. L. (2018). *Theory and practice of water and wastewater treatment*. John Wiley & Sons.

Ferrier, R. C., & Jenkins, A. (2021). Introduction to Catchment Management in 2020. *Handbook of Catchment Management 2e*, 3-24.

Fetter, C. W. & David Kreamer. (2021). *Applied Hydrogeology*. Fifth Edition. Waveland Press.

Frank R. Spellman. (2020). Handbook of Water and Wastewater Treatment Plant Operations. CRC Press.

Goel, P. K. (2006). *Water pollution: causes, effects and control*. New age international.

Goyal, M. K. (2016). *Engineering hydrology*. PHI Learning Pvt. Ltd..

Gray, N. (2017). *Water technology*. CRC Press.

Ho, S. (2019). *Thirsty cities: Social contracts and public goods provision in China and India*. Cambridge University Press.

Hornberger, G. M., & Perrone, D. (2019). *Water resources: Science and society*. Johns Hopkins University Press.

Hornberger, G. M., Wiberg, P. L., Raffensperger, J. P., & D'Odorico, P. (2014). *Elements of physical hydrology*. JHU Press.

Jason Hogan. (2022). *Catchment Hydrology*. SYRAWOOD Publishing House.

Jenkins, A., & Ferrier, R. C. (2021). The Future for Catchment Management. *Handbook of Catchment Management 2e*, 579-587.

Jones, J. A. A. (2014). *Global hydrology: processes, resources and environmental management*. Routledge.

Liu, D. H., & Lipták, B. G. (Eds.). (1999). *Groundwater and surface water pollution*. CRC Press.

Mandri-Perrott, C., Rouse, M. J., Merrett, S., Videira, N., Antunes, P., Santos, R.... & Bratby, J. (2015). IWA Publications. *Water resources*, *15*, 05.

Mays, L. W. (2010). *Water resources engineering*. John Wiley & Sons.

Melesse, A. M., Abtew, W., & Senay, G. (Eds.). (2019). *Extreme Hydrology and Climate Variability: Monitoring, Modelling, Adaptation and Mitigation*. Elsevier.

Metcalf & Eddy, Abu-Orf, M., Bowden, G., Burton, F. L., Pfrang, W., Stensel, H. D.... & AECOM (Firm). (2014). *Wastewater engineering: treatment and resource recovery*. McGraw Hill Education.

Oki, T., Valeo, C., & Heal, K. (Eds.). (2006). *Hydrology 2020: an integrating science to meet world water challenges* (Vol. 300). IAHS Press.

Pahl-Wostl, C. (2015). *Water governance in the face of global change* (p. 25). Switzerland: Springer.

Pennington, K. L., & Cech, T. V. (2021). *Introduction to water resources and environmental issues*. Cambridge University Press.

Price, R. K. (2011). *Urban hydroinformatics: data, models, and decision support for integrated urban water management*. IWA publishing.

Rao, M. N. & Datta, A. K. (2018). *Waste water treatment*. Oxford and IBH Publishing.

Saether,O.M. & de Caritat, P. (2020). *Geochemical Processes, Weathering and Groundwater Recharge in Catchments*. CRC Press.

Sedlak, D. (2014). *Water 4.0: the past, present, and future of the world's most vital resource*. Yale University Press.

Sharp, L. (2017). *Reconnecting people and water: Public engagement and sustainable urban water management*. Routledge.

Shaw, E. M., Beven, K. J., Chappell, N. A., & Lamb, R. (2017). Hydrology, climate and catchment change. In *Hydrology in Practice* (pp. 503-529). CRC Press.

Spulber, N., & Sabbaghi, A. (2012). *Economics of water resources: from regulation to privatization* (Vol. 13). Springer Science & Business Media.

Tchobanoglous, G. (2014). *Wastewater Engineering: Treatment and Resource Recovery-Vol. 2*. McGraw-Hill.

Telmer, K. (2006). Understanding Environmental Pollution, A Primer. *Geoscience Canada*, *33*(1), 34-35.

Theodore, L., & Dupont, R. R. (2019). *Water Resource Management Issues: Basic Principles and Applications*. CRC Press.

Tölgyessy, J. (Ed.). (1993). *Chemistry and biology of water, air and soil: Environmental aspects*. Elsevier.

Website

http://jalshakti-dowr.gov.in/

http://nihroorkee.gov.in/

https://cpcb.nic.in/wqstandards/

https://iahs.info/

https://kspcb.karnataka.gov.in/environmental-monitoring/water

M. Sc. Environmental Science and Sustainability
Semester I
ES 7P226: WATER AND WASTEWATER ANALYSIS

Number of Practical Credits	Number of Practical Hours / Semester
2	52

1. Sampling techniques of water and wastewater
2. Determination of Colour, Turbidity and Transparency
3. Determination of pH, Electrical Conductance and Total Solids
4. Estimation of Oil and grease
5. Estimation of Calcium Hardness and Total Hardness
6. Estimation of Chlorides and Fluoride content
7. Estimation of Sulphates content
8. Estimation of Nitrates content
9. Estimation of Phosphates content
10. Determination of Dissolved Oxygen and Biochemical Oxygen Demand
11. Estimation of Chemical Oxygen Demand
12. Determination of Chromium in effluent samples
13. Determination of Copper in effluent samples
14. Estimation of Optimum dose of coagulants
15. Study of Water Quality Indices

Activity – Depiction of water bodies of Bengaluru on a map
Visit to drinking water treatment plant
Visit to sewage treatment plant

References

Nandini, N. (2009). Handbook on water quality monitoring and Assessment. Sapna Book House, Bengaluru.

Sawyer, C. N. and Mc Carty, P. L. (1978). Chemistry for Environmental Engineering. Mc Graw – Hill International.

Saxena M M. (1990). Environmental Analysis: Water, Soil and Air. Edition, 2. Publisher, Agro Botanical Pub.

Standard Methods for Examination of Water and Wastewater. (2017). APHA – WEF.

Trivedi, P. K. and Goel, P. K. (1984). Chemical and Biological Methods of Water Pollution Studies. Environmental Publication.

Zhang, C. (2007). Fundamentals of environmental sampling and analysis. John Wiley & Sons.

M. Sc. Environmental Science and Sustainability

Semester I

ES 7326 – EARTH SCIENCES AND SOLID WASTE MANAGEMENT

Number of Theory Credits	Number of Lecture Hours / Semester
4	52

Course Specific Objectives	
CSO 1	To provide knowledge on Earth Sciences, pedological processes and soil degradation.
CSO 2	To integrate physical, chemical and biological approaches to manage soil pollution and solid waste.
CSO 3	To disseminate knowledge on various aspects of planning and implementation of waste management strategies.
CSO 4	To provide knowledge on the smart waste management technologies and legal frameworks for sustainable management of solid waste.

Course Outcomes	
CO 1	Students will be equipped with knowledge to analyse, classify and assess soils based on their physical, chemical, and biological properties. Students will be able to identify the minerals and rocks based on their properties and geological importance. An exposure to soil management and sustainable land-use practices is provided.
CO 2	Students would be provided with the knowledge to assess and manage soil health, mitigate soil degradation, and promote sustainable agricultural and environmental practices.
CO 3	Students will have the information and skills they need to solve the critical environmental concerns of soil contamination, erosion, and solid waste pollution; they will be develop skills necessary to promote sustainable soil management and waste disposal practices.
CO 4	Students will be well-versed in the legal and regulatory frameworks with reference to waste management and environmental protection, enabling them to make informed decisions on sustainable waste management and soil restoration.

CONTENTS OF ES 7326 – EARTH SCIENCES AND SOLID WASTE MANAGEMENT	52 Hours
Unit – 1: Geosphere and its resources	**13**
Earth: Origin, age of the Earth, Internal structure of the Earth, Sea floor spreading and Plate tectonics, Rock cycle, Earth's orbital parameters. Principles of stratigraphy – law of superposition, law of original horizontality, law of cross-cutting relationships and law of lateral continuity. Lithostratigraphy, Biostratigraphy and Chronostratigraphy. Geological Time Scale. Mineralogy: Formation and growth. Classification of minerals – *Elements; Oxides and hydroxides; Silicates; Sulphides; Halides; Nitrates, Carbonates and Borates; Sulphates; Phosphates, Arsenates* and *Vanadates;* Rock-forming minerals – *Feldspars, Quartz, Amphiboles, Micas, Olivine, Garnet, Calcite* and *Pyroxenes*. Accessory minerals – *fluorite, zircon and sulfides.* Biomineralogy and Mineral ecology. Mineraloids and Non-minerals. Petrology: Classification – Igneous, Sedimentary and Metamorphic rocks – their formation – types – uses. Endogenic processes: Diastrophism – Concepts of stress and strain, Behaviour of rocks under stress; Folds, joints and faults. Earthquake and Volcanism – Causes, Effects, and Management. Exogenic processes: Types – Weathering, mass wasting, erosion, and deposition. Earth's surface processes – River, Sand dunes, Glaciation, Avalanches and Landslides.	
Unit – 2: Pedology	**13**
Soils – formation, composition and properties, soil forming processes, soil profile. Indian Standard Soil Classification System. Soil types – *Alluvial; Black; Red and Laterite; Arid and Desert; Saline and Alkaline; Peaty and Marshy; Grassland, Forest and Mountain Soils*. Textural classification of soil. Soil structure. Soil mineralogy and soil maps. Physical classification of soil water: Hygroscopic, capillary and gravitational water. Infiltration, permeability, percolation and surface runoff. Biological classification of soil water: Superfluous, available and unavailable water. Soil moisture and soil moisture stress.	

Thermal properties of soils: Soil temperature, heat capacity, thermal expansion and thermal conductivity. Soil ecology: Soil biodiversity, soil food webs, soil trophic dynamics, soil organism interactions (*Rhizobium and Mycorrhizae*), soil organic matter, soil decomposition. Soil atmosphere – Carbon cycling and sequestration, nitrogen cycling and fixation, and phosphorous cycling. Soil fertility and Bio-fertilizers.	
Unit – 3: Soil degradation	**13**
Soil erosion: causes, types and control. Soil pollution: Causes of soil pollution (urban areas, industrial areas, agriculture and livestock, landfills, sewage sludge, municipal solid waste dumps and hazardous waste). Classification of soil pollutants: Organic contaminants and inorganic contaminants. Irrigation as a source of soil contamination – Pesticide pollution, fertiliser pollution, water logging, salinity, alkalinity, Sodium Adsorption Ratio (SAR) and soil sickness. Solid waste pollution: Origin and types of solid wastes, characterisation of solid wastes. Segregation, collection, transportation and disposal of municipal solid waste. Plastic wastes: Sources and categories. Micro plastics. Hazardous wastes: Sources, categories and characteristics. Leachate and its impacts. Biomedical wastes: Sources, categories and characteristics. E-waste: Sources, composition and types. Waste audit.	
Unit – 4: Approaches to manage soil pollution and solid wastes	**13**
Soil remediation: In-situ decontamination; Ex-situ decontamination: on-site and off-site; and confinement/isolation of the affected area. Chemical, physical, solidification/stabilization/immobilization, thermal, and biological (Bioaugmentation, biostimulation, bio-volatilisation, bioremediation and phytoremediation) methods. Waste remediation: Waste management hierarchy.	

Methods of solid, hazardous and biomedical waste treatment: Compositing, vermicomposting bio-methanisation (Bio-methanisation potential), incineration, pyrolysis, secured landfills and Containment technologies, Wet air oxidation, Chemical disinfection, Wet (autoclaving) and dry thermal treatment, Microwave irradiation and Inertization. Leachate management: aerated lagoons and activated sludge, air stripping, pH adjustment, chemical precipitation, oxidation, and reduction. Bioremediation - land farming, biodegradation of recalcitrant and Xenobiotics treatment. E-waste: Recovery for metals and non-metals. Smart waste management: Smart waste bins, waste level sensors, artificial intelligence enabled sorting and recycling robots, garbage truck weighing mechanisms, pneumatic waste pipes, solar-powered trash compactors, E-waste kiosks and recycling apps. Solid Waste Management Rules, 2016 with recent amendments. Construction and Demolition Waste Management Rules, 2016 with recent amendments. The Plastic Waste Management Rules, 2016 with recent amendments. Bio Medical Waste Management Rules, 2016 with recent amendments. E-waste (Management) Rules, 2016 with recent amendments. Hazardous and Other Wastes (Management and Transboundary Movement) Rules, 2016 with recent amendments.	

References

Ajami, H. (2020). Encyclopedia of geology. *Reference module in earth systems and environmental sciences. Elsevier.*

Chandrappa, R., & Das, D. B. (2012). *Solid waste management: Principles and practice*. Springer Science & Business Media.

Das, D. K., & Das, D. K. (2004). *Introductory soil science*. Kalyani publishers.

Gupta, P. K., Yadav, B., & Himanshu, S. K. (Eds.). (2021). *Advances in Remediation Techniques for Polluted Soils and Groundwater*. Elsevier.

Horwath, W. R., & Kuzyakov, Y. (2017). *Climate change impacts on soil processes and ecosystem properties* (Vol. 35). Elsevier.

Hussain, C. M. (Ed.). (2021). *Environmental Management of Waste Electrical and Electronic Equipment*. Elsevier.

Keller, E. A., & Burt, E. M. (1988). *Environmental geology*. Merrill Publishing Company.

Kutílek, M., & Nielsen, D. R. (1994). *Soil hydrology: texbook for students of soil science, agriculture, forestry, geoecology, hydrology, geomorphology and other related disciplines*. Catena Verlag.

Lal, R. (Ed.). (2006). *Encyclopedia of soil science* (No. 11). CRC Press.

Mahapatra G. B. (2017). *A Textbook of Geology*. CBS Publishers & Distributors

Pires, A., Martinho, G., Rodrigues, S., & Gomes, M. I. (2019). *Sustainable solid waste collection and management*. Springer International Publishing Switzerland.

Plaster, E. (2013). *Soil science and management*. Cengage learning.

Rajaram, V., Siddiqui, F. Z., Agrawal, S., & Khan, M. E. (2016). *Solid and liquid waste management waste to wealth: Solid and liquid waste management waste to wealth*. PHI Learning Pvt. Ltd.

Ramachandra, T. V. (2006). *Management of municipal solid waste*. The Energy and Resources Institute (TERI).

Ramakrishnan, M., & Vaidyanadhan, R. (2010). Geology of India (vol. 1 & 2). *GSI Publications*.

Rowell, D. L. (2014). *Soil science: Methods & applications*. Routledge.

Roy, A. B. (2010). *Fundamentals of Geology*. Alpha Science International Limited.

Saleh, H. M. (Ed.). (2021). *Strategies of Sustainable Solid Waste Management*. BoD–Books on Demand.

Sparks, D. L. (Ed.). (1998). *Soil physical chemistry*. CRC press.

Sumner, M. E. (Ed.). (1999). *Handbook of soil science*. CRC press.

Tan, K. H. (2009). *Environmental soil science*. CRC Press.

Twardowska, I., Stefaniak, S., Allen, H. E., & Häggblom, M. M. (Eds.). (2007). *Soil and water pollution monitoring, protection and remediation* (Vol. 69). Springer Science & Business Media.

White, R. E. (1987). *Introduction to the principles and practice of soil science* (No. Second Edition). Blackwell Scientific Publications.

William Harmon Norton. (2022).*The Elements of Geology.* DigiCat.

Website

http://www.geosocindia.org/

https://cpcb.nic.in › waste-management

https://ewasteindia.com

https://hasirudala.in

https://kspcb.karnataka.gov.in/waste-management

https://saahaszerowaste.com

https://site.bbmp.gov.in/departmentwebsites/swm/

https://slusi.dacnet.nic.in

https://wasteventures.com

https://www.india.gov.in/website-soil-and-land-use-survey-india

M. Sc. Environmental Science and Sustainability

Semester I

ES 7P326: EARTH RESOURCES, SOIL ANALYSIS AND SOLID WASTE ANALYSIS

Number of Practical Credits	Number of Practical Hours / Semester
2	52

1. Identification properties of minerals and study of rock forming minerals
2. Identification properties of rocks and study of rocks – Igneous, Sedimentary and Metamorphic
3. Sampling techniques of soils, solid waste and leachate
4. Determination of pH and Electrical conductance of soil/leachate
5. Determination of moisture content (soil/solid waste) and water holding capacity of soil
6. Determination of infiltration potential of soil
7. Determination of calcium and magnesium in soil
8. Determination of organic matter and organic carbon in soil
9. Determination of available nitrogen in soil (Agricultural soil/compost/soils from dump sites)
10. Determination of available phosphorous in soil (Agricultural soil/compost/soils from dump sites)
11. Determination of sodium and available potassium in soil (Agricultural soil/compost/soils from dump sites)
12. Determination of Sodium Adsorption Ratio (SAR) of soil
13. Study of waste generation pattern of a community – Questionnaire method/Waste audit
14. Classification of municipal solid waste – segregation method

Activity – Depiction of soil types of India and Karnataka on a map
Composting methods – aerobic /anaerobic/Vermi-composting
Visit to Biogas plant in the campus
Visit to solid waste dumpsite
Visit to E-waste management units

References

Ahuja, J. S., Virk, M. J. S., 1993. Map Education. Survey of India.

Bottomley, P. J., Angle, J. S., & Weaver, R. W. (Eds.). (2020). *Methods of soil analysis, Part 2: Microbiological and biochemical properties* (Vol. 12). John Wiley & Sons.

Carter, M. R., & Gregorich, E. G. (2007). *Soil sampling and methods of analysis*. CRC press.

Ramakrishna, T. L. 1998. Manual of Rocks, Minerals and Ores of Karnataka. Bharat Geo Guides Publ. Bangalore.

Ramakrishna, T. L. 1998. Mineral Rock Guide of Karnataka. Bharat Geo Guides Publ. Bangalore.

Sathyanarayanswami, B. S. 1985. Engineering Geology – Laboratory Manual. Eurasia Publishing House Pvt. Ltd.

Sparks, D. L., Page, A. L., Helmke, P. A., & Loeppert, R. H. (Eds.). (2020). *Methods of soil analysis, part 3: Chemical methods* (Vol. 14). John Wiley & Sons.

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Semester I

ES 7426 – ECOSYSTEM DYNAMICS, BIODIVERSITY AND WILDLIFE CONSERVATION

Number of Theory Credits	Number of Lecture Hours / Semester
4	52

Course Specific Objectives	
CSO 1	To gain insights on the key concepts and fundamentals of ecology and ecosystem dynamics.
CSO 2	To develop understanding on ecosystem services and the anthropocentric approach influencing ecosystem stability and resilience.
CSO 3	To perceive the values of biodiversity and the major threats leading over-exploitation of biodiversity.
CSO 4	To comprehend on various strategies and policies related to ecosystem, biodiversity and wildlife conservation.

Course Outcomes	
CO 1	Students will demonstrate a comprehensive understanding of the various levels of ecological organization, including individuals, populations, communities, ecosystems, landscapes, and the biosphere.
CO 2	Students will be able to demonstrate a comprehensive understanding of the various levels of ecological organization, including individuals, populations, communities, ecosystems, landscapes and the biosphere. They will be able to explain the interrelationships and interactions at different levels and how they contribute to ecological dynamics.
CO 3	Students will understand biodiversity at genetic, species and ecosystem levels, and evaluate their ecological significance. They will examine wildlife threats like habitat loss, poaching, disease, and climate change, and analyse factors contributing to species decline. Students will also design management protocols for endangered species.
CO 4	Students will analyse conservation goals like habitat protection, species conservation and climate change mitigation. They will assess the role of key species in ecological balance and apply conservation principles to develop sustainable solutions for biodiversity and wildlife challenges. Also, they will be able to apply knowledge of conservation principles to develop sustainable solutions for biodiversity and wildlife conservation challenges.

CONTENTS OF ES 7426: ECOSYSTEM DYNAMICS, BIODIVERSITY AND WILDLIFE CONSERVATION	52 Hours
Unit – 1: Ecology and system dynamics	**13**
Ecology: Levels of organization, Ecology: Divisions of Ecology - approaches in studying Ecology. Significance of space and time (scaling), ecology and natural resources. Ecosystems: Classification of ecosystem. Structure and function of ecosystem. Biogeochemical cycles: Hydrological cycle, sedimentary cycle and gaseous cycles. Energy flow in an ecosystem – productivity - trophic levels; Study of pond and crop land ecosystems. Concept of Standing crop, Standing stock, Mass balance, Material flux rate, Residence time and homeostasis and feedback mechanisms. Community Ecology: Characteristics of a Community – *Species diversity, growth form and structure, dominance, relative abundance, trophic structure*. Population Ecology: Characteristics of Population: *Density, Natality, Mortality, Age distribution, Growth form-Population Equilibrium, Biotic potential, Carrying capacity, Dispersal, Dispersion, Population fluctuations and Population regulation*. Ecological Niche: Concept and Types of niches: Spatial, Trophic and Multidimensional. Niche parameters: Form, Position and Width. Niche Partitioning - Realized and Fundamental Niche. Hutchinson's duality: the relationship between geographic and ecological spaces. Niche conservatism. Niche models. Ecological succession: Types – Hydrarch and Xerarch - Climax vegetation and their theories. Biomes: Concept and classification of biomes. Concept of Ecotone and Edge effect; Ecological equivalents; Ecotypes and Ecophenes; Ecological indicators. Systems ecology: Systems thinking, synthesis, and modelling.	
Unit – 2: Ecosystem services	**13**
Ecosystem Services: Concept and Definition. Regulating services: *Purification of water and air; Carbon sequestration and climate regulation; Waste decomposition and detoxification; Regulation of prey populations; Pollination; Biological pest and disease control; Disturbance regulation (Flood protection).*	

Provisioning services: Food *(crops, wild foods and spices);* Raw materials *(Timber, fuel wood, organic matter, fodder, and fertiliser);* Genetic resources *(crop improvement genes, and health care);* Biogenic minerals; Medicinal resources *(Pharmaceuticals, chemical models, and bioassay organisms)*; Energy *(Hydropower, biomass fuels)*; Ornamental resources *(Fashion, handicrafts, jewellery, pets, worship, decoration, and souvenirs)*. Cultural services: Cultural *(Nature motifs in books, film, painting, folklore, national symbols, advertising); Aesthetics,* spiritual and historical *(Art, religious and heritage value);* Recreational experiences *(Ecotourism, outdoor sports and recreation);* Science and education *(Academic excursions and scientific discovery);* Therapeutic *(Eco-therapy, social forestry and animal assisted therapy).* Supporting services: Nutrient cycling, Soil formation, Primary production and Habitat provision. Valuing ecosystem services: Real market methods of valuation; Surrogate market methods of valuation; Hypothetical market methods of valuation; Non-monetary valuation; Optimization of trade-offs; Types of Decision-Making Analysis (DMA); and Markets & payments for ecosystem services. Millennium Ecosystem Assessment. The future of ecosystem services (Anthropocentric approach).	
Unit – 3: Biodiversity and Wildlife	**13**
Biodiversity: Levels of Biodiversity – (G*enetic diversity, species diversity and ecosystem diversity*). Values of Biodiversity – (*Direct uses - consumptive use value, productive use value; Non-consumptive values - social value, ethical value, aesthetic value, option values and ecosystem service value*). Biodiversity Hotspots: Global and Indian centres. Biogeography of India. Biodiversity profile of India: Forests and Grasslands; Wetlands and Riverine ecosystems; Marine and coastal diversity; Agro-biodiversity; Urban Biodiversity; Invasive Alien species. Threats to biodiversity: Over exploitation, Habitat destruction, fragmentation, urbanisation, agriculture extension, river valley projects, industrialisation, deforestation, invasive species, pollution, acidification of soil and water, mining activities, desertification and climate change. Biodiversity indices: Dominance, Evenness, Simpson, Shannon, Menhinick's richness, Berger-Parker, Margalef's richness, Equitability and Fisher's alpha. Traditional Knowledge and ethics in conservation of biodiversity. Bio-piracy. The Biological Diversity Bill, 2000 and The Biological Diversity (Amendment) Bill, 2021. Convention on Biological Diversity and Agenda 21. National Biodiversity Action Plan (NBAP). **Wildlife**: Wildlife of India. Values of wildlife.	

Values of wildlife: *- Physical utility, economic/monetary value, recreational value, scientific value, ecological value, existence value.* *- Wildlife damage, human animal conflict, loss of economic productivity, wildlife diseases to man and competition effect*. Importance of wildlife: Ecological, economic, socio-cultural, investigatory, medicinal, conservation of biological diversities, importance in agriculture. Threats to wildlife: Over exploitation, habitat loss, encroachment and fragmentation, disease, pollution, invasive and exotic species, Illegal trapping and poaching, agricultural/unrestricted/ over grazing, urbanisation and climate change. Endangered species – Definition, characteristics and reasons for engendering. *Species with a narrow (or single) geographic range, Species with only one or few populations, Species with a small population size, Species with a declining population size, Species hunted or harvested by people, Species with low reproductive ability and/or germplasm-dispersal-ability, Species that require specialised habitat and niche conditions*. Endangered species of India. Endemic species – Concept, types, characteristics, theories of endemism. Endemic Wildlife Species of India. Wildlife (Protection) Act, 1972. The Wildlife Protection Amendment Bill, 2022.	
Unit – 4: Ecosystem conservation	**13**
Conservation (Biodiversity and Wildlife): Definition, need and significance. Conservation vs. Preservation. Conservation goals - Habitat conservation, Prevention of deforestation, Preventing species from extinction, Sustainable harvest of biological resources and climate change mitigation. Terminologies of conservation significance: Keystone species, Foundation species, Umbrella Species and Flagship species, Edge species, Critical link species, Indicator species, Priority species and Rare species. IUCN Red Listed species - Data Deficient, Least Concern, Near Threatened, Vulnerable, Endangered, Critically Endangered, Extinct in the Wild and Extinct. In-situ conservation: Protected areas – Sanctuaries - National Parks – Biosphere Reserves - Project Tiger and Project Elephant; Ramadevarabetta Vulture Sanctuary. Community Conserved Areas – case studies on Black Buck, Snow leopard, Amur falcon and Sarus crane. Ex-situ conservation: Captive breeding (Botanical gardens, zoological parks, seed banks). Case study of *Ailuropoda melanoleuca* (Giant panda), *Ramosmania heterophylla* and *Madhuca insignis.* Cryopreservation, pollen	

storage, tissue culture, genetic engineering, field gene banks. Case study of Indian rhinoceros and black rhinoceros. International conservation efforts: Ramsar Convention, Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), Convention on the Conservation of Migratory Species of Wild Animals (CMS), Trade Records Analysis of Flora and Fauna in Commerce (TRAFFIC). Reducing Emissions from Deforestation and Forest Degradation (REDD) and REDD+. UN Environment Programme World Conservation Monitoring Centre (UNEP-WCMC).	

References

Bharucha, E. (2002). *The Biodiversity of India* (Vol. 1). Mapin Publishing Pvt Ltd.

Boenigk, J., Wodniok, S., & Glücksman, E. (2015). *Biodiversity and earth history*. Springer.

Chapman, J. L. and Reiss, M. J. (1995). Ecology – Principles and Applications. Cambridge University Press.

Dash, M. C. (2001). Fundamentals of Ecology. Tata McGraw-Hill Publishing Co.

Everard, M. (2017). *Ecosystem services: key issues*. Routledge.

Goutam Kumar Saha, Subhendu Mazumdar. 2017.*Wildlife Biology - An Indian Perspective*. Prentice Hall India Pvt., Limited

Grunewald, K., & Bastian, O. (Eds.). (2015). *Ecosystem services–concept, methods and case studies*. Springer.

Grunewald, K., & Bastian, O. (Eds.). (2015). *Ecosystem services–concept, methods and case studies*. Springer.

Jacobs, S., Dendoncker, N., & Keune, H. (Eds.). (2013). *Ecosystem services: global issues, local practices*. Elsevier.

Jacobs, S., Dendoncker, N., & Keune, H. (Eds.). (2013). *Ecosystem services: global issues, local practices*. Elsevier.

Kormondy, E. J. (1996). Concepts of Ecology. Prentice Hall of India.

Krishnamurthy, K. V. (2003). *Textbook of biodiversity*. Science Publishers.

Krishnamurthy, K. V. (2018). *Advanced textbook on Biodiversity: Principles and Practice*. CBS Publ & Dist PVT Limited I.

Maclaurin, J., & Sterelny, K. (2008). What is biodiversity? In *What Is Biodiversity?* University of Chicago Press.

Mamta Rawat, Sumit Dookia and Chandrakasan Sivaperuman. (2015). Aquatic Ecosystem: Biodiversity, Ecology and Conservation. Springer publication.

McCleery, Robert A., Moorman, Christopher, Peterson, M. Nils (Eds.). (2014). Urban Wildlife Conservation - Theory and Practice. Springer publication.

Negi, S. S. (1993). *Biodiversity and its Conservation in India*. Indus Publishing.

Odum, E. P. (1971). Fundamentals of Ecology. W.B. Saunders Co.

Reddy, G. V., Karanth, K. U., Kumar, N. S., Krishnaswamy, J., & Karanth, K. K. (2016). *Recovering biodiversity in Indian forests*. Singapore: Springer.

Ricklefs, R. E. and Miller, (1999). Ecology. W.H. Freeman and Co.

Singh, S.K. 2005. *Textbook of Wildlife Management Text Book Library Edition*. International Book Distributing Company.

Smith, T. M. and Smith, R. L. (2007). Elements of Ecology. Pearson Education.

Tandon, U., Parasaran, M., & Luthra, S. (Eds.). (2017). *Biodiversity: Law, Policy and Governance*. Taylor & Francis.

Weathers, K. C., Strayer, D. L., & Likens, G. E. (Eds.). (2021). *Fundamentals of ecosystem science*. Academic Press.

Website

http://nbaindia.org/

https://kbb.karnataka.gov.in/english

https://teebweb.org/

https://www.basf.com/

https://www.bioatlasindia.org/bai-websites

https://www.biodiversityofindia.org/index.php?title=Other_NGOs_and_environmental_websites

https://www.biologicaldiversity.org/

https://www.cbd.int/convention/

https://www.gbif.org/

https://www.iso.org/committee/8030847.html

https://www.iucn.org/

https://www.nwf.org/Educational-Resources/Wildlife-Guide/Understanding-Conservation/Biodiversity

https://www.unep.org/news-and-stories/story/biodiversity-our-solutions-are-nature

https://www.un-redd.org/

https://www.worldwildlife.org/threats/deforestation-and-forest-degradation

M. Sc. Environmental Science and Sustainability

Semester I

ES 7P426: ECOSYSTEM ASSESSMENT, BIODIVERSITY AND WILDLIFE STUDIES

Number of Practical Credits	Number of Practical Hours / Semester
2	52

1. Sampling technique of plankton
2. Quantitative estimation of phytoplankton – Sedgwick-Rafter method
3. Quantitative estimation of zooplankton – Sedgwick-Rafter method
4. Determination of organic pollution – Palmer's Algal Pollution index
5. Estimation of primary productivity of a pond – Light and Dark bottle method
6. Estimation of primary productivity of terrestrial vegetation – Chlorophyll method
7. Study of plant community – Individual count method/Quadrat method
8. Study of animal community – Line transect method
9. Estimation of carbon capture and storage in trees
10. Identification of ecological indicators
11. Assessment of provisional services of wetland ecosystems – Questionnaire survey method
12. Estimation of animal population size – Mark, Release and Recapture method
13. Hands-on experience with biodiversity assessment software - Paleontological Statistics Software Package for Education and Data Analysis (PAST)

Activity

- Mapping of International, National and State-wise biodiversity and wildlife conservation sites – Hotspots, Ramsar convention sites, Biosphere reserves, National parks, Sanctuaries, Protected areas and Ecologically significant zones.
- Bird watching
- Introduction to global biodiversity databases – Global Biodiversity Information Facility (GBIF), Integrated Biodiversity Assessment Tool (IBAT-alliance)
- A locally relevant case study on biodiversity related aspects.
- People's Biodiversity Register.

References

Henderson, P. A., & Southwood, T. R. E. (2016). *Ecological methods*. John Wiley & Sons.

Michael, P. (1986). Ecological Methods for Field and Laboratory Investigations. Tata Mc Graw-Hill Publishing Co. Ltd.

Ravindranath N. H. and Madelene Ostwald. 2008. Carbon Inventory Methods: Handbook for Greenhouse Gas Inventory, Carbon Mitigation and Roundwood Production Projects. Springer Science + Business Media B.V.1-304.

Ravindranath, S., & Premnath, S. (1997). *Biomass studies: field methods for monitoring biomass*. Mohan Primlani.

Rolan, R. G. (1973). Laboratory and Field Investigations in General Ecology. Macmillan Co.

Standard Method for Examination of Water and Wastewater. (2017). APHA – WEF.

Subrahmanyam, N. S. and Sambamurty, A. V. S. S. (2000). Ecology. Narosa Publishing House.

Sutherland, W. J. (Ed.). (2006). *Ecological census techniques: a handbook*. Cambridge university press.

Trivedi, P. K. and Goel, P. K. (1984). Chemical and Biological Methods of Water Pollution Studies. Environmental Publications.

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Semester I

ES 7526 – ENVIRONMENTAL CHEMISTRY AND ANALYTICAL METHODS

Number of Theory Credits	Number of Lecture Hours / Semester
4	52

Course Specific Objectives	
CSO 1	To provide knowledge about the primary and secondary investigation of the pollutants along with insights on the conventional methods.
CSO 2	To equip students with advanced knowledge on analytical techniques to quantify the concentrations of pollutants in the environment.
CSO 3	To inculcate proficiency in theory and working principles of qualitative and quantitative methods for environmental analysis.
CSO 4	To be able to make informed decision in selecting appropriate tools and techniques towards solving environmental problems.

Course Outcomes	
CO 1	Students will be able to the chemistry of environmental analysis and their roles, apply qualitative methods like elemental analysis, salt analysis, and spot tests for chemical identification. They will be able to perform volumetric calculations, including normality and molarity and develop a sample collection protocol for field investigations.
CO 2	They will be able to define the criteria for selecting an appropriate methods for the analysis for various chemical analysis and to perform them.
CO 3	Students will be able to explain the regions of the electromagnetic spectrum, describe molecular responses such as rotation, vibration, and electronic transitions. They will be able to apply spectroscopic methods like microwave, infrared (IR), and UV-Visible spectroscopy for species identification and estimation. They understand advanced spectral techniques, including NMR and ESR, for structural and analytical applications.
CO 4	Students will be able to explain the principles and applications of various analytical tools. They will be able to interpret instrumentation flowcharts and block diagrams for analytical techniques.

CONTENTS OF ES 7526: ENVIRONMENTAL CHEMISTRY AND ANALYTICAL METHODS	52 Hours
Unit – 1: Basic aspects of physico-chemical analysis	**13**
Primary investigation: Chemical species responsible for specific colour, odour and texture of common samples encountered in environmental analysis – their role and hazards. Secondary investigation: Confirming the nature of chemical species and separating them and identifying them qualitatively – Elemental analysis, Salt analysis, Spot tests in field investigations. Estimations of selected species encountered in field investigations. Conventional methods: Gravimetry and thermal methods.	
Unit – 2: Volumetric analysis – Aqueous and non-aqueous	**13**
Titrations: Criteria involved in selection of a reaction for a titration. Nature of analyte – Steps involved in extracting the analyte completely in to a solution. Titrants – Selection of titrants – Standard solutions (primary and secondary). Criteria for an effective titrant. Methods of determining completion of reactions (end point) – visual indicators and instrumental signals. Role of sensors in field investigations. Precautions to be taken for retaining the activity of the analyte. Calculations involved: Normality (equivalents), Molarity (moles) and Formality. Principles of volumetric calculations with specific examples to the following titrations. - Acid-base titrations; Precipitation titrations; Complexometric titrations; Redox titrations	
Unit – 3: Spectral investigations	**13**
Regions of electromagnetic spectrum. Interaction of a species with light. Various types of responses – rotation, vibration and electronic transition. Different methods to identify and estimate the species in the samples – Microwave spectra, IR spectra, Electronic spectra (UV-Visible spectra). Additional spectral methods – NMR, ESR.	
Unit – 4: Instrumental methods of analysis	**13**
Electroanalytical methods: Potentiometry, Conductometry, Voltametric methods. Optical methods: Colourimetry, Spectrometry (visible and UV), Fourier Transform Infrared (FTIR), Raman spectroscopy, Flame photometry, Turbidimetry and Nephelometry. Spectral methods: Atomic Absorption Spectroscopy, Inductive Coupled Plasma - Optical Emission Spectroscopy (ICP-OES). Diffraction methods: X-ray diffraction – XRF. Radio-chemical methods: Counters and Dosimetry (gas detection, scintillation detections and photo detectors).	

Block diagrams/Flow charts for instrumentation and operations to be arrived at appropriately. Gas Chromatography-Mass Spectrometry (GC/MS, MALDI and TOF), Ion chromatography, CHNS Analyser (Instantaneous Oxidation/Flash Combustion-Dumas Method), Gamma radiation. Bomb colorimeter, Scanning Electron Microscopy (SEM), Nuclear Magnetic Resonance (NMR).	

References

Fundamentals of Analytical Chemistry; Skoog, West. Holler and Crouch 9th Edition; Mary Finch. (2014).

Principles of Instrumental Methods of Analysis; Skoog, Holler and Nieman, 5th edition, Saunders College Publishing, International Limited (1999).

Analytical Chemistry; Gary D Christian; 6th edition; John Wiley and Sons (2010).

Modern Analytical Chemistry; David Harvey; McGraw Hill Higher education publishers, (2000).

Analytical Chemistry Principles; John H Kennnedy, 2nd Edition, Published by Cengage Delmar Learning India Pvt (2011).

Vogel's Text book of quantitative chemical analysis; 6th edition, Pearson Education Limited, (2007).

Organic Spectroscopy, W. Kemp, ELBS London, (1975).

Spectrometric Identification of Organic Compounds, R.M. Silverstein and W.P. Webster, Wiley & Sons, (1999).

Introduction to Spectroscopy, 5th Edition, Donald L. Pavia, Gary M. Lampman and George S. Kriz and James R. Vyvyan. Cengage Learning (2015).

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Semester II

ES 8126 – NATURAL RESOURCES MANAGEMENT

Number of Theory Credits	Number of Lecture Hours / Semester
4	52

Course Specific Objectives	
CSO 1	To develop comprehensive understanding of the dynamics of natural resources and their sustainable utilisation.
CSO 2	To analyse the environmental issues, pressures and conflicts related to Natural resources.
CSO 3	To explore the economy-natural resource interface leading to enhanced and sustainable productivity.
CSO 4	To gain insights into policy and governance framework at national and international levels that shape the management of natural resources.

Course Outcomes	
CO 1	Students will acquire an understanding of the classification of resources, they will explore resource scarcity and management, learn effective methods of resource conservation, focusing on reducing waste and maximizing resource efficiency
CO 2	The course will equip students with knowledge of land and water resources, including their use, effects on the environment, and management techniques. This will be with an emphasis on ecological implications and sustainable practices.
CO 3	Students will be able to comprehend the key issues, which includes forest-based industries, forest genetics conservation, and the economic importance of forests. It emphasizes the role of agroforestry, farm forestry, and urban forestry in sustainable resource management.
CO 4	Students will be prepared to confront global issues and find sustainable solutions towards mitigating, environmental deterioration and resource depletion.

CONTENTS OF ES 8126: NATURAL RESOURCES MANAGEMENT	52 Hours
Unit – 1: Concept of resources and classification	**13**
Resource: Definition; Resource and wealth. Functional theory of resource and dynamic theory of resource. Classification of resources - Organic and inorganic resources; exhaustible and inexhaustible resources; International, National and Individual resources; Ubiquitous and localised resources. Resources scarcity: Definition; types of resources scarcity - Demand-induced, supply-induced and structural. Resource conflicts: Resource extraction, access and control system. Approaches in resource management: Ecological, economic and ethnological. Integrated resource management strategies. Conservation of resources: Methods of conservation - Refuse, reduce, reuse, recycle and recovery - Methods of waste reduction (Increasing the durability of products, utilising material substitution, recycling and marketability of industrial waste). Natural Resources: Definition, Classification of natural resources based on utility potential. Introduction to Natural Resource Bases: Concept of resource base. Factors influencing resource availability, distribution and utilisation patterns - Nature, Culture and Man. Phantom pile concept. Management of common International resources: Ocean, Climate and Antarctica.	
Unit – 2: Land and Water resources	**13**
Land resources: Land as a resource. Land utilization and land-use pattern of India. Agro-climatic zones of India and Karnataka. Types of agriculture and cropping patterns. Environmental implications of conventional agriculture – Soil degradation, Loss of fertility, Pollution due to fertilisers and pesticides, loss of natural biodiversity, water logging, saline and alkaline soils. Soil sickness (Negative Plant-Soil Feedback). Grassland (Rangeland)/Wasteland: Concept, goals, issues and strategies of management. Desertification: Causes, impacts and control measures. Mineral resources: Formation of mineral reserves and deposits. Classification of minerals. Categories of underground, open surface (pit), placer and in-situ mining. Impacts of mining and quarrying; Mineral exploration in Oceans; Deep Sea mining and off shore oil exploration. Ecological conflicts of mineral extraction.	

Distribution of mineral resources in India and at global level. Case studies on mining and stone quarries. Water Resources: Fresh water - Water budget of India - Dams: Impact on environment – alternatives; Droughts and Floods: Causes and Control Strategies. Rain Water Harvesting and ground water recharge; River linking – pros and cons. Marine water – Ocean as a resource - Fisheries, aquaculture – prawns and oysters - Transportation – Shipping (people, goods and oil) and its impacts - Desalinisation – Importance and impacts Groundwater: Impacts of extraction: uplifting and seismic activities, land subsidence, vegetation degradation and food security implications. Water and agriculture: Irrigated and rain-fed cultivation; Types of irrigation. Irrigation and drainage. Nutrient delivery through irrigation. Hydroponics. National Lake and River Conservation Plan. Wetland management - Ramsar Convention Sites. Seawater intrusion, Coastal erosion and reclamation. Coastal zone management - concept, scope, issues and strategies. Watershed Management as participatory soil-water conservation practice.	
Unit – 3: Forest resources	**13**
Forest resources: Concept and its significance. Contribution as resource: Major and minor (NTFPs) forest products. Forest ecosystem concept, stand dynamics-forest succession, competition and tolerance, classification of World's Forest vegetation. Status and distribution of forests in India. Forest genetics resources of India. Documentation and evaluation of Forests Genetic Resources (FGR), in-situ and ex-situ conservation of gene resources. Forest based industries and Indian economy - paper and pulp, furniture, bamboo, sports goods, pencil making, match box, medicinal and pharmaceutical industries. Forest capital theory. Forest Resource Accounting (FRA) - methods and implications. Significance of Farm forestry, Agroforestry, Plantations, Industrial plantation, urban forestry, Avenue trees and Social forestry in reducing resource demands on forests. Forests and people: Forest societies, tribal economic security and forests, interactions between forests and people, importance of forests in traditional farming systems, forests and food security, livestock economy and forests, social and cultural significance of forests - eco-philosophy. Eco-tourism – Pros and cons.	

Forest conflicts: Land use change and forests - wildlife and human conflicts, forest fires and weeds, developmental projects, global warming and forests. Inter-regional and international trade in forest products. Forest policy – National Forest Policy, 1988; Indian Forest Act, Forest Conservation Act, 1980; Forest Conservation Rules *(Vanasamrakshana Adhiniyan – 2023),* Forest Survey Report. Forest rights, customary rights of people - *Scheduled Tribes and other Traditional Forest Dwellers (Recognition of Forest Right) Act, 2006*; Community participation, Ethnobotany, Joint Forest Management (JFM), Common Property Resources (CPRs) and open access resources. Role of Non-Governmental and community-based organisations in forest management.	
Unit – 4: Energy resources	**13**
Energy resources: Concept and its significance. Forms of energy, primary energy sources, Energy and power. Classification of energy resources – Conventional and non-conventional. Renewable and non-renewable. Commercial and non-commercial. Fossil fuel reserves in India: Coal, petroleum, natural gas and lignite. Renewable energy resources: Solar energy - Flat plate collectors, evacuated tube collectors and photovoltaic cells; Wind energy and wind farms; Hydropower – Magnetohydrodynamic power (MHD) and micro-hydel Power; Geo-thermal energy; Tidal energy; Ocean Thermal Energy Conversion (OTEC) Technology; Hydrogen as an alternate fuel. Nuclear energy: Fission energy, fusion energy, nuclear power generation and nuclear reactors. Bioenergy: Biomass energy, Bioconversion technologies, bioethanol and biohydrogen. Biomass (wood) gasification - Fuel wood production and consumption, agro residues as source of energy, pollution free improved biomass cooking stoves. Biogas digesters. Bio-energy plantations: Power generation from energy plantations - producer gas, High Density Energy Plantations (HDEP) and Petro-crops. Recent advances in bio-fuels. Environmental impacts of bio-energy production and usage. Energy from waste: Concept, types and significance. Indian scenario. Energy production and consumption trends in India. Factors affecting India's energy development - Economy and demographics policy and institutional framework. Energy prices and affordability. Social and environmental aspects. Investments in energy production and trade.	

Energy storage systems: Energy storage methods - mechanical, chemical, biological, magnetic and thermal. Energy management: Principles, energy demand estimation and energy pricing. Conservation of energy: Importance, methods of conservation, barriers to energy conservation, measures for promoting energy conservation and eco-friendly energy sources. Energy policies in India. Bureau of Energy Efficiency - Energy Efficiency Standards. The Energy Conservation Building Code. ISO 50001 – Energy Management Systems.	

References

Banks, F. E. (1983). Resources and energy: an economic analysis.

Bebarta, K. C. (2002). *Planning for Forest Resources and Biodiversity Management: Principles, Organization and Methodology*. Concept Publishing Company.

Binkley, D., & Fisher, R. F. (2019). *Ecology and management of forest soils*. John Wiley & Sons.

Cleaver, F. (2017). *Development through bricolage: rethinking institutions for natural resource management*. Routledge.

Jhariya, M. K., Meena, R. S., & Banerjee, A. (Eds.). (2021). *Ecological intensification of natural resources for sustainable agriculture*. Singapore: Springer.

Jorgensen, S. E., & Fath, B. D. (Eds.). (2022). *Environmental Management Handbook, – Six Volume Set*. CRC Press.

Kant, S., & Alavalapati, J. R. (Eds.). (2014). *Handbook of forest resource economics* (pp. 419-420). Earthscan from Routledge.

Krishna, S. (Ed.). (2004). *Livelihood and gender: Equity in community resource management*. SAGE Publications India.

Menon, A., Singh, P., Shah, E., Lele, S., Paranjape, S., & Joy, K. J. (2007). *Community-based natural resource management: issues and cases in South Asia*. SAGE Publications India.

Murty V.V.N.,& Madan Kumar Jha. (2018). *Land and Water Management Engineering,*

Pangannavar, A. Y. (2011). *Forest Resources of India: Problems, Policies, and Initiatives*. New Century Publications.

Panigrahi, B., & Goyal, M. R. (Eds.). (2017). *Soil and Water Engineering: Principles and Applications of Modeling*. CRC Press.

Suresh, R. (2020). Soil And Water Conservation Engineering, Standard Publishers Distributors.

Team, G. E. A. W. (2012). Global energy assessment. *Cambridge Books*.

Tietenberg, T., & Lewis, L. (2018). *Environmental and natural resource economics*. Routledge.

Walther, J. V. (2014). *Earth's natural resources*. Jones & Bartlett Publishers.

Website

http://forestsclearance.nic.in/DivSearch.aspx

http://ifs.nic.in/

http://moef.gov.in/

https://dmg.karnataka.gov.in/25/introduction/en

https://ibm.gov.in/

https://indiawris.gov.in/wris/

https://mnre.gov.in/

https://www.india.gov.in/topics/environment-forest/natural-resources

https://www.india.gov.in/website-soil-and-land-use-survey-india

M. Sc. Environmental Science and Sustainability
Content of Practical Course

ES 8P126: MAPPING AND NATURAL RESOURCES STUDIES

Number of Practical Credits	Number of Practical Hours / Semester
2	52

1. Introduction to survey and use of surveying instruments (Total station, Handheld GPS) for mapping. Type of maps and their utilities
2. Cartographic concept; Essential of cartographic process (scale, projection, direction, elevation)
3. Conventional signs, plan and profile and representation of relief and map numbering system
4. Thematic map and map reading (latitude, longitude and MSL of any point), area measurements, slope measurements
5. Aerial photographs and satellite imageries- its usage in 2D/3D data capturing
6. Delineation of entity like forest, settlements, water bodies, etc using topographical maps
7. Watershed characteristics and delineation using a topographical map.
8. Geotagging of Environmental assets (field activities)
9. Mapping of Forest fire risk zone, Biosphere reserves, National Park, etc
10. Characteristics of agro-climatic zones of Karnataka state and mapping of local agricultural Diversity
11. Identification and documentation of medicinal plants and NTFPs
12. Bhuvan- Indian Geo-platform of ISRO – geographic services (display, editing, interpretation, etc.)

Activity – Visit to nearby forest and document the floral and faunal species

Visit to Institute of Wood Science and Technology

Visit to medicinal garden at Foundation for Revitalisation of Local Health Traditions (FRLHT)

Visit to nearby agricultural area – cropping pattern

Visit to power generation plant

Visit to Biofuel facility

References

Anji Reddy, M. (2001). Textbook of remote sensing and geographical information systems. *S. Publications, Hyderabad*.

Caporuscio, F. (2003). The 22nd Edition of the Manual of Mineral Science. By Cornelis Klein. John Wiley & Sons, Inc., New York, 2002, 641 p.

Kulkarni, V., & Ramachandra, T. V. (2006). *Environmental management*. The Energy and Resources Institute (TERI).

Reddy, M. A., & Reddy, A. (2008). *Textbook of remote sensing and geographical information systems* (pp. 4-4). Hyderabad: BS publications.

Website:

https://bhuvan.nrsc.gov.in/home/index.php

https://ksrsac.karnataka.gov.in/

https://www.arcgis.com/index.html

https://www.qgis.org/en/site/

https://www.surveyofindia.gov.in/

M.Sc. Environmental Science and Sustainability

Semester II

ES 8226 – ENVIRONMENTAL FORENSICS

Number of Theory Credits	Number of Lecture Hours / Semester
4	52

Course Specific Objectives	
CSO 1	To provide students with an understanding of environmental toxicology and forensics, focusing on toxicity mechanisms, toxicokinetics, ecotoxicology, risk assessment, and forensic techniques for pollution identification.
CSO 2	To equip students with the fundamental principles and methodologies of environmental forensics, covering evidence collection, pollution source identification, forensic geochemistry, and analytical techniques, with emphasis on data interpretation, legal compliance and collaboration for investigation and remediation.
CSO 3	To provide students with a comprehensive understanding of bioremediation principles, techniques, and applications, including microbial and plant-based remediation strategies, genetic engineering approaches, pollution monitoring methods and biosafety considerations for sustainable environmental management.
CSO 4	To familiarise students with national and international environmental regulations, focusing on chemical safety and waste management, while analysing case studies on policy implementation and effectiveness in mitigating pollution and ecological risks.

Course Outcomes	
CO 1	Students will analyse environmental toxicology principles, assess toxicant impacts, evaluate toxicokinetic and toxicodynamic processes, and apply forensic techniques for pollution identification and risk assessment.
CO 2	Students will apply forensic techniques to investigate pollution, conduct sampling, use tracers for source identification, assess data, ecological, and legal implications for remediation.
CO 3	Students will evaluate bioremediation techniques, analyse microbial and plant processes, assess genetic engineering in pollution management, and apply biosafety principles for safe interventions.
CO 4	Students will analyse national and international environmental regulations, assess their role in pollution control and safety, and apply legal frameworks to case studies to evaluate challenges, policy effectiveness and remediation strategies.

CONTENTS OF ES 8226: ENVIRONMENTAL FORENSICS	52 Hours
Unit – 1: Fundamentals of Environmental toxicology and Environmental forensics	**13**
Environmental toxicology and Environmental forensics: Definitions – Scope – Brief history and development. **Key concepts:** Pollutants – Contaminants – Toxin – Toxicant – Xenobiotics – Dose – Dosage – Lethal Dose – Effective Dose – Threshold Limit Value – Therapeutic Index – Risk – Safety – Acceptable daily intake – Exposure pathways – Bioaccumulation – Biomagnification – Carcinogens – Mutagens – Teratogens – Endocrine disruptors – Hyposensitivity – Hypersensitivity – Pollution fingerprinting – Site characterization – Trace evidence – Waste profiling. **Toxicity:** Definition, Physical toxicants, Chemical toxicants, Biological toxicants and Radiation. Factors affecting toxicity: Biological factors – absorption and translocation of xenobiotics, functional capacity of the target organs, deposition of xenobiotics in target tissue, tolerance to xenobiotics; Chemical factors – nonspecific and specific reactions of xenobiotics; Genetic factors governing xenobiotic toxicity – basic genetic mutation, xenobiotic accumulation, prolongation of xenobiotic action, hypersensitivity to xenobiotics, sensitivity of haemoglobins, resistance to xenobiotics. **Toxicokinetics:** Absorption, Distribution, Metabolism and Excretion. **Toxicodynamics:** Toxicant interactions with macromolecular targets, Blocking neurotransmitter uptake, Community and trophic levels. Case study – Methyl mercury. **Dose-response relationships:** Principles – Factors affecting toxicological studies – Bioassay methods – Experimental design of toxicity studies (acute, sub-acute and chronic) – Exposure pathways. **Ecotoxicology:** Concepts and principles. **Risk assessment of toxicants:** Applications on human health and ecosystems.	
Unit 2: Environmental forensic investigations	**13**
Principles of environmental forensic: Chain of custody – Sampling and evidence collection – Scientific methodology – Chemical and physical analysis – Pollution source identification and attribution – Environmental pathways and transport – Data interpretation and statistical analysis – Expert testimony – Ecological impact assessment – Legal and regulatory compliance – Interdisciplinary collaboration – Documentation and reporting – Environmental remediation and restoration – Timeline reconstruction.	

Micro and macro environmental forensics: Definition, concept and scope. **Types of environmental contaminants:** Organic contaminants (petroleum products, pesticides); Inorganic contaminants (heavy metals, radionuclides); Emerging contaminants (pharmaceuticals, microplastics). **Environmental forensic investigations** - Forensic sampling techniques: Site investigation, source identification and sample collection – Soil, water, air, biological, process waste - Tank corrosion model for leakages **Pollution source identification and tracing** - Use of stable isotopes to trace contaminant sources - Environmental DNA (eDNA) - Microbial DNA fingerprinting methods for source identification – PCR, 16S rRNA sequencing, metabarcoding and metagenomics - Chemical fingerprinting methods for source identification - Molecular markers and biomarkers in pollution tracing - Use of microbial communities as forensic evidence **Forensic geochemistry** - Geochemical analysis for identifying pollution sources - Soil and water chemical profiling **Environmental tracers in water and air** - Tracing chemical pollutants in aquatic systems - Atmospheric pollutants and their origin determination - Biotechnology and evidence preservation **Toxicological effects and forensic evidence** - Linking toxicity to a specific source in environmental forensics - Investigating the health effects of contaminated sites **Analytical tools – Applications in Environmental Toxicology and Environmental Forensics** - Gas Chromatography-Mass Spectrometry (GC-MS) - High Performance Liquid Chromatography (HPLC) - Inductively Coupled Plasma Mass Spectrometry (ICP-MS) **Data analysis:** Data interpretation, statistical analysis and reporting	
Unit 3: Interdisciplinary relationships between Environmental Forensics, Biotechnology and Microbiology	**13**
Bioremediation: Definitions, concept, types and techniques. **Phytoremediation:** Definitions, factors influencing and mechanisms of phytoextraction, phytostabilsation, phytovolatisation, phytodegradation, rhizofiltration and rhizostabilsation.	

Microbial communities in contaminated sites – Microbial bioremediation – Bioaugmentation and Biostimulation: Concepts and types. **Microbial degradation pathways** – Monitoring techniques involved in pollution level monitoring and to track bioremediation efforts. Microbial indicators of ecosystem health. Degradation of DDT, PCBs and plastics. **Genetic modification for environmental solutions** – Concept, applications and examples. **Genetic engineering:** Concepts of recombinant DNA technology, Enzymes in genetic engineering (restriction enzymes, ligases, DNA/RNA polymerases), vectors for cloning (plasmid and bacteriophage). Concepts of crop improvement using genetic engineering. Biocontrol: Biological insecticides (*B. thuringiensis*, *B. sphaericus* and *Baculovirus*), Biofertilisers. **Biosafety:** Biosafety levels (BSL), Organisms in various BSL.	
Unit 4: Regulatory frameworks and Case studies	**13**
National frameworks The National Green Tribunal (NGT) Act, 2010 The Manufacture, Storage, and Import of Hazardous Chemicals Rules, 1989 The Chemical Weapons Convention (CWC) Act, 2000 The Food Safety and Standards Act, 2006 The Bio-Medical Waste Management Rules, 2016 **International frameworks** International Programme on Chemical Safety (IPCS) Stockholm Convention on Persistent Organic Pollutants (POPs) Hazard Communication Standard (HCS) Classification, Labelling and Packaging (CLP) Regulation Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) **Indicative case studies on –** - Air pollution in Delhi - Mining and water contamination - Heavy metal pollution in The Ganga River Basin - Solid waste disposal (Any Indian city) - Gas leaks - Oil spills - Plastic pollution in the oceans - Dumping of hazardous / toxic waste	

References

Anwer, M. A. (Ed.). (2017). Biopesticides and bioagents: novel tools for pest management. CRC Press.

Bell, S., McGillivray, D., Pedersen, O. W., Lees, E., & Stokes, E. (2017). Environmental law. Oxford University Press.

Chopra, K. (2017). Development and environmental policy in India: the last few decades. Singapore: Springer Singapore.

Cockerham, L. G., & Shane, B. S. (2019). Basic environmental toxicology. Routledge.

Das, S. (Ed.). (2014). Microbial biodegradation and bioremediation. Elsevier.

Divan, S., & Rosencranz, A. (2022). Environmental law and policy in India: cases and materials. Oxford University Press.

Forbes, T. L. (1993). Ecotoxicology in theory and practice. Springer Science & Business Media.

Kobilinsky, L. (Ed.). (2011). Forensic chemistry handbook. John Wiley & Sons.

Kohli, K., & Menon, M. (2022). Development of Environment Laws in India. Cambridge University Press.

Malik, J. A., & Goyal, M. R. (Eds.). (2022). Bioremediation and Phytoremediation Technologies in Sustainable Soil Management. CRC Press.

Morrison, R. D., & Murphy, B. L. (2010). Environmental forensics: contaminant specific guide. Elsevier.

Morrison, R. D., & Murphy, B. L. (2010). *Environmental forensics: contaminant specific guide*. Elsevier.

Murphy, B. L., & Morrison, R. D. (Eds.). (2014). Introduction to environmental forensics.

Nicholl, D. S. (2023). An introduction to genetic engineering. Cambridge University Press.

Prasad, R., & Aranda, E. (2018). Approaches in bioremediation. Springer International Publishing.

Rose, J. (Ed.). (2003). *Environmental toxicology* (Vol. 7). CRC Press.

Shelton, D. (2021). International Environmental Law (Vol. 4). Brill.

Singh, A., & Ward, O. P. (Eds.). (2004). Applied bioremediation and phytoremediation (Vol. 1). Berlin: Springer.

Sparling, D. W. (2016). Ecotoxicology essentials: environmental contaminants and their biological effects on animals and plants. Academic Press.

Vallero, D. A. (2015). Environmental biotechnology: a biosystems approach. Academic press.

Venkat, A. (2011). Environmental law and policy. PHI Learning Pvt. Ltd..

ES 8P226: ENVIRONMENTAL FORENSICS

Number of Practical Credits	Number of Practical Hours / Semester
2	52

1. Good Lab Practises (GLP) and introduction to various instruments and their function: pH meter, Incubator, Laminar air flow unit, autoclave, hot air oven, light microscope
2. Bioassay for toxicity testing – Part A
3. Bioassay for toxicity testing – Part B
4. Soil toxicity testing - Susceptibility testing of bacteria – heavy metals and pesticide analysis
5. Heavy metal detection in water and wastewater
6. Isolation of bacteria and fungus in air
7. Gram's staining of bacterial culture and fungal staining and observation
8. Colony characterization and cell counting using Haemocytometer
9. Chemical fingerprinting and tracing the sources of sediments
10. Isolation of DNA by from environmental samples
11. Separation of DNA by Gel electrophorosis
12. Biochemical tests – Starch hydrolysis, Gelatin liquefaction
13. Biochemical tests – MPN, Catalase and IMViC tests
14. Biodegradation of dye from contaminated sites

References

Bhaisora, C. P., & Chaudhary, S. R. (2020). Practical Manual of Forensic Medicine and Toxicology. New Central Book Agency.

Carson, S., Miller, H. B., Srougi, M. C., & Witherow, D. S. (2019). Molecular biology techniques: a classroom laboratory manual. Academic Press.

Das, S., & Dash, H. R. (2014). Microbial biotechnology – A laboratory manual for bacterial systems. Springer.

Duarte, A. C., Cachada, A., & Rocha-Santos, T. A. (Eds.). (2017). Soil pollution: from monitoring to remediation. Academic Press.

Erkmen, O. (2021). Laboratory practices in microbiology. Academic Press.

Green, L. H., & Goldman, E. (Eds.). (2021). Practical handbook of microbiology. CRC press.

Harrigan, W. F., & McCance, M. E. (2014). Laboratory methods in microbiology. Academic press.

Hurst, C. J., Crawford, R. L., Garland, J. L., & Lipson, D. A. (Eds.). (2007). Manual of environmental microbiology. American Society for Microbiology Press.

Petrisor, I. G. (2014). Environmental forensics fundamentals: A practical guide. CRC Press.

Seidman, L. A., Kraus, M. E., Brandner, D. L., & Mowery, J. (2022). Laboratory Manual for Biotechnology and Laboratory Science: The Basics. CRC Press.

Shanmugam, S., Kumar, T. S., & Panneer Selvam, K. (2019). Laboratory handbook on biochemistry. PHI Learning Pvt. Ltd.

M.Sc. Environmental Science and Sustainability

Semester II

ES 8326 – ENVIRONMENTAL IMPACT ASSESSMENT AND ENVIRONMENTAL AUDIT

Number of Theory Credits	Number of Lecture Hours / Semester
4	52

Course Specific Objectives	
CSO 1	To provide insights on the basic principles, objectives, core values and pillars of Environmental Impact Assessment.
CSO 2	To provide knowledge on the EIA methodologies, impact identification, impact prediction and impact mitigation strategies.
CSO 3	To comprehend the environmental impacts and mitigation measures of various developmental projects with case studies.
CSO 4	To gain insights on the environmental audit procedures and accreditation bodies of India.

Course Outcomes	
CO 1	The students will develop the knowledge, skills and competencies required to assess environmental impacts, participate in the decision-making process, and promote sustainable development through effective EIA practices.
CO 2	Students will have a thorough understanding of methodologies, tools and strategies used in EIA. They will also be able to make an informed choice of the impact identification methods most appropriate to the development activity chosen.
CO 3	The students will be able to evaluate how decisions and projects will affect the environment and effectively convey those effects to stakeholders, encouraging thoughtful, responsible decision-making.
CO 4	Students will be proficient in integrating environmental management practices into organisational strategies and will be prepared to carry out environmental audits.

CONTENTS OF ES 8326: ENVIRONMENTAL IMPACT ASSESSMENT AND ENVIRONMENTAL AUDIT	**52 Hours**
Unit – 1: Concept of an EIA	**13**
Environmental Impact Assessment: Definition, history and evolution. Initial Environmental Examination and Full-scale Environmental Impact Assessment. Basic principles of an EIA: *Prevention is better than repair*, *System dynamics and Black-box approach*. Objectives, Salient features and Core values of an EIA. Stakeholders of an EIA: *Proponent, Decision maker, Review commission, Legal advisors, Public interest groups and Consultancy companies*. Analytical functions associated with EIA: *Defining scope of an EIA, Identification and description of the existing environmental system, prediction and impact evaluation and analysis*. Steps in an EIA: *Screening, Scoping & consideration of alternatives, Baseline data collection, Impact prediction, Assessment of alternatives, Delineation of mitigation measures, preparation of environmental impact statement, Public hearing, Environment Management Plan, Decision making and Monitoring the clearance conditions*. Components to be considered in an EIA: *Air, Water, Nosie, Land, Biological environment, Socio-economic and Health Environment, Risk Assessment*. Pillars of an EIA: *Transparency, certainty, participation and inclusion, practicability, flexibility, cost-effectiveness, credibility and accountability*.	
Unit – 2: Impacts and their methods of identification	**13**
Impact: Definition, Types - *Direct, Indirect and Cumulative; Primary secondary, Tertiary and chain impacts; Positive and negative; local and widespread impacts; random and predictable impacts; and short and long term impacts*. Methods of impact evaluation: Characteristics, Criteria for the selection of EIA methodology: *General, impact identification, impact measurement, impact interpretation and evaluation and impact communication*. Types of EIA: *Strategic EIA, regional EIA, sectoral EIA, project level EIA and life cycle assessment*. EIA Methodologies: Rapid and Comprehensive EIA. Characteristics of methods of Impact Identification.	

Methods of Impact Identification: *Ad-hoc methods, Checklist methods, Matrices methods, Networks methods, Overlay methods, Environmental index using factor analysis, Cost-benefit analysis, Predictive or Simulation methods*. Methods of Impact Prediction: *Explorative and Normative; Field and laboratory methods; Physical models; statistical models; mathematical models; Geographic Information System and Expert judgements*. Impact Mitigation: Concept, Hierarchy in impact mitigation: *Avoid, Reduce, Remedy, Compensate and Enhance*.	
Unit – 3: Prediction & Assessment of Impacts and Case Studies	**13**
Prediction & Assessment of Impacts on 1. *Soil and ground water environment* 2. *Surface Water Environment* 3. *Biological Environment* 4. *Air Environment* 5. *Noise Environment* 6. *Socio-economic and human health impacts* 7. *Environmental Risk Assessment and Risk Management* List of projects requiring Prior Environment Clearance or Prior Environment Permission - Category A, B1 & B2 projects. Case Studies (*Assignments are to be assigned after an Overview and discussing the structure*): 1. *Industrial projects* 2. *Sugar, Distilleries and molasses-based manufacturing units* 3. *Pulp & Paper Industry* 4. *Power projects – Hydel, Thermal and Nuclear Power* 5. *River Valley projects* 6. *Mining projects* 7. *Infrastructural projects/Industrial Estates - Building Construction and Area Development projects, Special Economic Zones (SEZs)* 8. *Common Effluent Treatment Plants (CETP)/Treatment, Storage and Disposal Facilities (TSDFs)* 9. *Common Municipal Solid Waste Management Facility (CMSWMF) involving land filling and / or incineration* 10. *Highways or Expressways or Multi-modal corridors or Ring Roads*	

11. Textile industries with reference to MSME 12. IT industries with reference to National Building Code related to Energy/Urban Heat Islands.	
Unit – 4: Environmental audit and Accreditation bodies	**13**
Environmental Management System – Concept, principles and objectives. Overview of ISO 14001. **Environmental Audit** Concept, Objectives and advantages. Internal and External audit. Types of Environmental Audit: Environmental Compliance Audits, Environmental Management Audits, Performance Environmental Audits and Due-diligence audits Raw material audit; Water audit, Energy audit, Health & Safety audit and Waste & Waste Minimisation audit. Audit procedure: Pre-audit activities, On-site activities and Post-audit activites. Evaluation of Audit data and Preparation of audit report. Auditor profile. Salient features of Environment (Protection) Act, 1986. **Accreditation bodies** National Productivity Council (NPC) Quality Control of India (QCI) National Accreditation Board for Certification Bodies (NABCB) National Accreditation Board for Education and Training (NABET) National Accreditation Board for Testing and Calibration Laboratories (NABL) International Accreditation Forum (IAF) International Laboratory Accreditation Cooperation (ILAC)	

References

Anjaneyulu, Y., & Manickam, V. (2011). *Environmental impact assessment methodologies*. CRC Press/Balkema, Taylor & Francis Group.

Barrow, C. J. (1997). *Environmental and social impact assessment: an introduction*. Arnold, Hodder Headline, PLC.

Buckley, R. (1991). Guidelines for environmental audit. In *Perspectives in Environmental Management* (pp. 121-164). Springer, Berlin, Heidelberg.

Canter, L. W., & Hill, L. G. (1979). Handbook of variables for environmental impact assessment.

Eccleston, C., & Doub, J. P. (2012). *Preparing NEPA environmental assessments: a user's guide to best professional practices*. CRC Press.

Erickson, P. A. (1994). *A practical guide to environmental impact assessment*. Academic Press Inc.

Gilpin, A. (1995). *Environmental impact assessment: cutting edge for the 21st century*. Cambridge University Press.

Kaur, S., & Gupta, N. (2011). Environmental auditing for protecting environmental rights in India. *Learning Community-An International Journal of Educational and Social Development*, *2*(1), 139-146.

Kulkarni, V., & Ramachandra, T. V. (2006). *Environmental management*. The Energy and Resources Institute (TERI).

Maughan, J. T. (2013). *Environmental impact analysis: Process and Methods*. CRC Press.

Morgan, R. K. (1999). *Environmental impact assessment: a methodological approach*. Springer Science & Business Media.

Petts, J. (Ed.). (2009). *Handbook of Environmental Impact Assessment, Volume 2: Impact and Limitations* (Vol. 2). John Wiley & Sons.

Website

http://environmentclearance.nic.in/

http://moef.gov.in/

https://iaf.nu/en/home/

https://ilac.org/

https://nabcb.qci.org.in/

https://nabet.qci.org.in/

https://nabl-india.org/

https://parivesh.nic.in/Notifications.aspx?id=EC

https://www.iso.org/standard/23157.html

https://www.qcin.org/

ES 8P326: ENVIRONMENTAL IMPACT IDENTIFICATION AND AUDIT METHODS

Number of Practical Credits	Number of Practical Hours / Semester
2	52

1. Study of recent EIA notification and guidelines
2. A review of various EIA reports
3. Development of data sheet and analysis - Ad-hoc methods for EIA
4. Development of data sheet and analysis - Checklist methods for EIA
5. Development of data sheet and analysis - Matrices methods for EIA
6. Development of data sheet and analysis - Networks methods for EIA
7. Development of data sheet and analysis - Overlay methods for EIA
8. Development of questionnaire and data collection - Socio-economic dimensions of a project
9. Development of questionnaire and data collection - Health impacts of a project
10. Development of datasheet to analysis the Environmental Risk Assessment and Risk Management in an industry
11. Cost-benefit analysis of development projects
12. Water audit – Clean water, grey water and black water
13. Energy audit – Electricity and fossil fuel
14. Waste audit – Solid and Liquid

(Any relevant open-source software to be used for Sl. No. 12 – 14).

Activity – Visit to Environmental consultancy companies

Participation in public hearings

Preparation of EIA for some typical developmental activity

References

Arts, J., & Morrison-Saunders, A. (Eds.). (2012). *Assessing impact: handbook of EIA and SEA follow-up*. Routledge.

Barton, H., & Bruder, N. (2014). *A guide to local environmental auditing*. Routledge.

Carroll, B., & Turpin, T. (2002). *Environmental impact assessment handbook: A practical guide for planners, developers and communities*. Thomas Telford.

Erickson, P. A. (1994). *A practical guide to environmental impact assessment*. Academic Press Inc..

Munier, N. (2004). *Multicriteria environmental assessment: a practical guide*. Springer Science & Business Media.

Nelson, D. D. (1998). *International environmental auditing*. Government Institutes.

Rathi, A. K. A. (2021). *Handbook of Environmental Impact Assessment: Concepts and Practice*. Cambridge Scholars Publishing.

Thompson, D., & Wilson, M. J. (1994). Environmental auditing: theory and applications. *Environmental Management*, *18*(4), 605-615.

M.Sc. Environmental Science and Sustainability

Semester II

ES 8426 – GEOSPATIAL AND WEB-GIS APPLICATIONS

Number of Theory Credits	Number of Lecture Hours / Semester
4	52

Course Specific Objectives	
CSO 1	To provide a comprehensive understanding of fundamentals of mapping and various elements of a map.
CSO 2	To equip learners with the processes of remote sensing and utilization of different satellites and sensors for data acquisition.
CSO 3	To articulate the role of GNSS satellites to enable the positioning of objects and explore new ways of GPS data collection using mobile based apps.
CSO 4	To develop skills in spatial analysis techniques including interpolation methods, overlay analysis, buffer analysis and network operations.

Course Outcomes	
CO 1	Students will gain foundational understanding of GIS concepts, will be able to read maps, analyse tasks and interpret spatial data.
CO 2	They will develop an understanding of the processes involved in remote sensing and the technologies used to acquire data from satellites and sensors; will be able to acquire data, analyse and develop target specific presentations.
CO 3	Students will understand the role of GNSS satellites in object positioning and navigation with application of GPS technology for accurate geospatial data collection. They will be able to utilise mobile-based applications for efficient GPS data acquisition and analysis.
CO 4	Students will develop proficiency in spatial analysis techniques, including interpolation methods for data prediction and application of overlay analysis to combine multiple datasets and derive meaningful insights.

CONTENTS OF ES 8426: GEOSPATIAL AND WEB-GIS APPLICATIONS	52 Hours
Unit - 1: Basic MAP and GIS Concepts	**13**
Definition of map, fundamental aspects of a map- point, lines and polygons, map scale and types of scales GIS definitions, Advantages of GIS - Paper maps over digital maps, Type of GIS software – Open sources vs proprietary. Spatial & Non-spatial Data: Data vs information, data type, data sources, characteristics of spatial and non-spatial data. Data models - raster and vector. Map elements. Projections and Coordinate Systems – introduction to geoids, ellipsoids and datums, types of coordinate systems, significance of map projections, types of projections Cylindrical, conical and azimuthal projections.	
Unit - 2: Remote Sensing	**13**
Introduction to remote sensing, process of remote sensing, types of remote sensing. Concept of pixel, satellite and sensors used in remote sensing, multispectral and hyperspectral sensors. Concept of microwave remote sensing. Types of resolutions -spatial, temporal, radiometric and spectral, examples of remote sensed data. Scattering and types of scattering- Rayleigh and Mie scattering. Downloading satellite imagery and DEM from online sources.	
Unit - 3: Data Collection and GNSS basics	**13**
Data Collection: Sources of spatial data, sources of non-spatial data. GNSS**:** Concept, Components-Space segment, Control segment, User segment. GPS Observations, Errors in GPS Observations, mobile-based apps for collecting location data, importing GPS data into GIS software.	
Unit - 4: Manipulation and Analysis of Data	**13**
Measurement of lengths, perimeter and areas, queries, buffer analysis, topology, neighborhood operations, network operations, overlay analysis, and surface analysis. Interpolation and its methods. Role of GIS in developmental projects. Multi-criteria decision-making using GIS.	

References

Anji Reddy, M. (2001). Textbook of remote sensing and geographical information systems. *S. Publications, Hyderabad*.

Anji, R. (2010). Textbook of Geographical Information Systems. *BS Publication, third edition, Hyderabad*.

Collier, P. (2007). Geographical Information Systems: An introduction. *Geography*, *92*(3), 303.

De By, R. (2005). Principles of Geographical Information Systems. ITC Educational Textbook series; 1. *International Institute for Geo-Information Science and Earth Observation (ITC), Hengelosestraat*, *99*.

Haklay, M. (2014). *Geographical information systems* (pp. 203-214). London, UK: Routledge.

Ian, H. (2010). *An introduction to geographical information systems*. Pearson Education India.

Longhay Paul, A. (1999). Geographical Information Systems. *a textbook published by John Witley & Sons, Inc, New York*.

Longley, P. A., Goodchild, M. F., Maguire, D. J., & Rhind, D. W. (2005). *Geographic information systems and science*. John Wiley & Sons.

Reddy, M. A., & Reddy, A. (2008). *Textbook of remote sensing and geographical information systems* (pp. 4-4). Hyderabad: BS publications.

Sahu, K. C. (2007). *Textbook of remote sensing and geographical information systems*. Atlantic Publishers & Dist.

Zorin, D. O. (2016). Geographical information systems of ecological safety: textbook. *Ivano-Frankivsk, Suprun, VP*, *180*.

Website:

https://bhuvan.nrsc.gov.in/home/index.php

https://ksrsac.karnataka.gov.in/

https://www.arcgis.com/index.html

https://www.isro.gov.in/update/01-sep-2008/national-remote-sensing-agency-becomes-isro-centre

https://www.qgis.org/en/site/

https://www.surveyofindia.gov.in/

ES 8P426: GEOSPATIAL AND WEB-GIS APPLICATIONS

Number of Practical Credits	Number of Practical Hours / Semester
2	52

1. Introduction to GIS and its components. Concepts and theory
2. Understanding Google Earth Pro - hands on exercise (spatial data capturing and analysis)
3. QGIS (3 practical classes)
    a. Georeferencing
    b. Digitization
    c. Labelling, styling, print composer and map generation
4. Q GIS - Data views, attribute data visualization spatial join
5. QGIS- Spatial analysis - buffer, union, intersection
6. Land-use land-cover digitisation from aerial photographs, satellite images.
7. Representation of site-specific results of various environmental parameters using GIS
8. Elevation data (DTM and DEM) downloading using Bhuvan portal (2 practical classes)
    a. Slope
    b. Aspect
    c. Viewshed
    d. Hillside analysis
9. Field data collection using GPS for Environmental Monitoring
10. Field data collection using mobile applications for Environmental Monitoring
11. Introduction to drone technology and demonstrations
12. Multi-criteria decision making using GIS – Weightage analysis and Overlays

Activity – Project presentation on Environment and review.

References

Anji Reddy, M. (2001). Textbook of remote sensing and geographical information systems. *S. Publications, Hyderabad*.

Anji, R. (2010). Textbook of Geographical Information Systems. *BS Publication, third edition, Hyderabad*.

Collier, P. (2007). Geographical Information Systems: An introduction. *Geography*, *92*(3), 303.

De By, R. (2005). Principles of Geographical Information Systems. ITC Educational Textbook series; 1. *International Institute for Geo-Information Science and Earth Observation (ITC), Hengelosestraat*, *99*.

Haklay, M. (2014). *Geographical information systems* (pp. 203-214). London, UK: Routledge.

Ian, H. (2010). *An introduction to geographical information systems*. Pearson Education India.

Longhay Paul, A. (1999). Geographical Information Systems. *a textbook published by John Witley & Sons, Inc, New York*.

Longley, P. A., Goodchild, M. F., Maguire, D. J., & Rhind, D. W. (2005). *Geographic information systems and science*. John Wiley & Sons.

Reddy, M. A., & Reddy, A. (2008). *Textbook of remote sensing and geographical information systems* (pp. 4-4). Hyderabad: BS publications.

Sahu, K. C. (2007). *Textbook of remote sensing and geographical information systems*. Atlantic Publishers & Dist.

Zorin, D. O. (2016). Geographical information systems of ecological safety: textbook. *Ivano-Frankivsk, Suprun, VP*, *180*.

Website:

https://bhuvan.nrsc.gov.in/home/index.php

https://ksrsac.karnataka.gov.in/

https://www.arcgis.com/index.html

https://www.isro.gov.in/update/01-sep-2008/national-remote-sensing-agency-becomes-isro-centre

https://www.qgis.org/en/site/

https://www.surveyofindia.gov.in/

M.Sc. Environmental Science and Sustainability

Semester II

Title of the Course: **ES 8526 – RESEARCH METHODS AND ENVIRONMENTAL STATISTICS**

Number of Theory Credits	Number of Lecture Hours / Semester
4	52

Course Specific Objectives	
CSO 1	To develop research orientation by imparting knowledge on research framework, design of experiments, analysis, interpretation and presentation.
CSO 2	To analyse wide range of applications of statistics in environmental management and decision-making.
CSO 3	To impart technical skills by utilizing statistical tools and software in environmental data analysis.
CSO 4	To equip the learners with critical skills needed to conceptualise, write and present their work.

Course Outcomes	
CO 1	Students will be able to define the significance and motivation behind research in environmental science; identify various types of research, research approaches, and the distinction between research methods and methodology. They will understand the criteria for good research and develop research plans.
CO 2	Students will understand the role of statistics in analysing environmental data. They will be able to understand the sampling tools, identify and mitigate sampling and non-sampling errors in environmental studies. They will be capable of effectively organising, representing and interpreting environmental data.
CO 3	Students will be able to define probability and apply rules for calculating probabilities in environmental data analysis. They will be able to analyse and interpret discrete and continuous variables using different distributions.
CO 4	Students will be able to perform ANOVA to compare means across groups; apply various tests for environmental analysis. They will understand the features, variables, constants, and operators in R programming. They will be able to develop professional research reports and theses, focusing on structure, language, clarity and ethics.

Title of the Course: **ES 8526 – RESEARCH METHODS AND ENVIRONMENTAL STATISTICS**	**52 Hours**
Unit – 1: Research Framework - Design, Data collection and analysis	**13**
Aim and Objectives of Research: Significance of Research in Environmental Science; Motivation in Research; Types of research; Research approaches. Research methods *vs.* Methodology. Research process. Criteria of Good Research. Purpose and Formulation of Research: Defining research problem. Selecting the problem. Literature review in defining a problem - Primary and secondary sources – reviews, monographs - patents – web as a source - Identifying gap areas from literature review. Setting up of Hypothesis. Research design: Basic Principles, Need and features of research design, Important concepts relating to research design – Observation and Facts, Prediction and Explanation, Orientation, Reasoning, Development of Models. Research plan - Exploration, Description, Experimentation and Determining experimental and sample designs. Data collection and analysis: Observation, Interviews, Schedules and Questionnaire. Tabulation, Processing and Interpretation of Data. Principles of experimental design, Randomization, Blocking, Replication and Extraneous Variables. Completely Randomized Design and Randomized Block Design.	
Unit 2: Sampling and Descriptive statistics	**13**
Statistics and Biostatistics: Definition, Functions and limitations of Statistics. Significance of Statistics in Environmental Sciences. Sampling and Census: Definitions. Sample and Population. Need for sampling. Probability Sampling methods – Simple Random Sampling, Stratified Random Sampling, Systematic Random Sampling, Cluster sampling and Multi-stage sampling. Non-Probability Sampling methods – Quota Sampling and Judgement Sampling, Snow-ball sampling and Self-selecton / Voluntary Response Sampling. Sampling errors and non-sampling errors. Introduction to Microsoft Excel, SPSS and Power BI. Measures of Central Tendency: Mean, Median and Mode; Measures of Dispersion: Range, Percentile, Standard Deviation, coefficient of variation, Kurtosis and Skewness. Organisation and representation of data: Histograms, Stem-and Leaf Plots and Box Plots.	

Unit – 3: Probability Theory; Correlation & Regression and Inferential Statistics	**13**
Probability: Definition, Rules for Calculating Probabilities. Discrete random variables: Binomial and Poisson Probability distributions. Continuous random variables: Normal and Standard normal distributions. Correlation and Regression Correlation: Definition and Significance. Karl Pearson's Coefficient of Correlation and Spearman's Rank Correlation; Likert scale. Regression: Definition and Significance. Regression analysis - Simple linear regression. Significance testing of correlation and regression coefficients. Single and Double-blind Experiments. Point and Interval estimates. Sampling distributions: t, Chi-square, F-distributions. Hypothesis testing: Null and alternative hypotheses, decision criteria, critical values, type I and type II errors, the meaning of statistical significance, power of a test, Student's t-test – independent and dependent tests, Least Significant Difference, Chi-square test – test of goodness of fit.	
Unit – 4: Hypothesis Testing, R Programming and Report Writing	**13**
Analysis of Variance: One-way ANOVA and Two- way ANOVA. F-test, Signed rank test, Rank sum test, Kruskal-Wallis test and Post ANOVA tests: Tukey's test and Dunnett's Test. R Programming: Features, Variables, Constants and Operators in R, Input and Output Option in R. Report Writing: Preparation of report: Organization and Significance of reports/thesis - Different steps in the preparation – Layout, structure and Language of typical reports – Illustrations and tables - Bibliography, referencing and footnotes. Presentation: Oral presentation, Planning, Preparation, Practice, Making presentations, Use of audio-visual aids. Ethical issues: Ethical committees, Copyright, Royalty, Intellectual Property Rights and Patent Law. Reproduction of published material: Plagiarism, Citation and Acknowledgements. Reproducibility and Accountability. Publications: Significance and types.	

References:

Bernard, H. R., & Bernard, H. R. (2013). *Social research methods: Qualitative and quantitative approaches*. Sage.

Chawla, D., & Sodhi, N. (2011). *Research methodology: Concepts and cases*. Vikas Publishing House.

Chawla, D., & Sodhi, N. (2011). *Research methodology: Concepts and cases*. Vikas Publishing House.

Chih-Pei, H. U., & Chang, Y. Y. (2017). John W. Creswell, research design: Qualitative, quantitative, and mixed methods approaches. *Journal of Social and Administrative Sciences*, *4*(2), 205-207.

Creswell, J. W., & Poth, C. N. (2016). *Qualitative inquiry and research design: Choosing among five approaches*. Sage publications.

Denzin, N. K., & Lincoln, Y. S. (Eds.). (2011). *The Sage handbook of qualitative research*.

Devi, P. S. (2017). *Research methodology: A handbook for beginners*. Notion Press.

Fisher, R. A. (1960). The design of experiments. *The design of experiments.* (7th Ed).

Gilbert, R. O. (1987). *Statistical methods for environmental pollution monitoring*. John Wiley & Sons.

Grafen, A., Hails, R., Hails, R., & Hails, R. (2002). *Modern statistics for the life sciences* (Vol. 123). Oxford: Oxford University Press.

Hesse-Biber, S. N., & Johnson, R. B. (Eds.). (2015). *The Oxford handbook of multimethod and mixed methods research inquiry*. Oxford University Press.

Kirk, R. E. (2012). *Experimental design: Procedures for the behavioral sciences*. Sage Publications.

Kothari, C. (2017). Research methodology methods and techniques by CR Kothari. *Published by New Age International (P) Ltd., Publishers*, *91*.

Kumar, R. (2018). *Research methodology: A step-by-step guide for beginners*. Sage.

Ott, W. R. (1994). *Environmental statistics and data analysis*. CRC Press.

Qian, S. S. (2016). *Environmental and ecological statistics with R*. Chapman and Hall/CRC.

Reis, H. T., & Judd, C. M. (Eds.). (2000). *Handbook of research methods in social and personality psychology*. Cambridge University Press.

Saunders, M., Lewis, P., & Thornhill, A. (2009). *Research methods for business students*. Pearson education.

Williams, J. M., Booth, W. C., & Colomb, G. G. (1995). The craft of research.

Zar, J. H. (1999). *Biostatistical analysis*. Pearson Education India.

Website:

https://data.gov.in/organization/national-bureau-statistics

https://mospi.gov.in/

https://mospi.gov.in/nsso

https://unstats.un.org/unsd/envstats/qindicators.cshtml

https://wesr.unep.org/article/statistics-explorer

https://www.indiaenvironmentportal.org.in/

https://www.isical.ac.in/

https://www.neeri.res.in/

https://www.oecd-ilibrary.org/environment/data/oecd-environment-statistics_env-data-en

https://www.spss.co.in/

M.Sc. Environmental Science and Sustainability
Semester III

Title of the Course: **ES 9126 – CLIMATE CHANGE AND DISASTER MANAGEMENT**

Number of Theory Credits	Number of Lecture Hours / Semester
4	52

Course Specific Objectives	
CSO 1	To provide thorough understanding on climate change science with impacts of climate change on various sectors
CSO 2	To create awareness on the sources of meteorological data and GHG protocols of climate change.
CSO 3	To explore the legal, scientific, biological and market-based mechanisms to mitigate climate change.
CSO 4	To develop deep understanding on relationship of climate change and disasters and profound mitigation measures for disaster management.

Course Outcomes	
CO 1	Students will be able to analyse the scientific basis of climate change, assess its impacts on various sectors, evaluate anthropogenic drivers and interpret observed/projected climate trends to develop strategies for mitigation and adaptation.
CO 2	Students will be able to identify and utilise key scientific data sources for climate research, analyse global and national greenhouse gas protocols. They will be able to evaluate international / national efforts in addressing climate change and promoting climate justice.
CO 3	Students will be able to evaluate and apply climate change mitigation / adaptation strategies; assess vulnerability and climate justice, understand market-based mechanisms for climate management; calculate key environmental metrics such as carbon and water footprints, while analysing the role of climate finance in supporting sustainable development
CO 4	Students will be able to analyse the causes and impacts of natural and man-made disasters; assess disaster trends and vulnerability in India; develop and apply disaster risk reduction frameworks and arrive at strategies for disaster mitigation, preparedness and response.

Title of the Course: **ES 9126 – CLIMATE CHANGE AND DISASTER MANAGEMENT**	**52 Hours**
Unit – 1: Climate Change Science	**13**
Climate Change Science: Concept, significance and causes. History of climate change. Greenhouse gases and greenhouse effect. Increase in atmospheric carbon dioxide concentration, increase in surface mean temperature, variability in precipitation, sea level rise, melting of ice and glaciers. Impacts of Climate Change on Various Sectors: Health, agriculture, forestry, water resources, coastal areas, species & natural areas, industry, settlements and society – climate refugees. Anthropogenic Drivers of Climate Change: Energy sector; Industrial process and product use sector; Agriculture, forestry & other land use sectors; and Waste sector. Trends and Impacts of Climate Change: Observed and projected impacts for different regions. Uncertainties in the projected impacts of climate change and risk of irreversible changes.	
Unit – 2: Scientific Data, Legal and Policy Framework	**13**
Sources of Scientific Data: The World Meteorological Organization (WMO), The National Oceanic and Atmospheric Administration (NOAA), Scripps Institution of Oceanography (SIO), The Intergovernmental Panel on Climate Change (IPCC), World Resources Institute (WRI), The India Meteorological Department (IMD), National Disaster Management Authority (NDMA) and Karnataka State Natural Disaster Monitoring Centres (KSNDMC). GHG Protocols: ISO 14064 - International standard for GHG emissions inventories and verification. IPCC guidelines for national greenhouse gas inventories. GreenCo Rating System. Efforts towards climate change: UN Conference on the Human Environment 1972, Rio Earth Summit 1992, Agenda 21, Kyoto Protocol 1997, Rio+20, Conference of Parties (CoPs) and Paris Agreement - Nationally Determined Contributions (NDCs) towards climate justice. National Action Plan on Climate Change (NAPCC), India's NDCs.	
Unit – 3: Climate Change Mitigation and Adaptation	**13**
Climate change mitigation: Definition, Factors to be considered for climate change mitigation - renewable energy; energy efficiency; sustainable transportation; carbon capture & storage; afforestation & reforestation; low carbon development; waste reduction & management; sustainable agricultural practices; low carbon tech; building codes & standards; education and awareness. Alternative development models. Mission LiFE.	

The United Nations Programme on Reducing Emissions from Deforestation and Forest Degradation (UN-REDD and REDD+ Programmes). Climate change adaptation: Definition, Vulnerability Assessment and climate justice. Factors to be considered for Climate Change Adaptation - Coastal Protection; Water Management; Land-Use planning; Ecosystem Restoration; Infrastructure Upgrades; Heat wave preparedness; Urban Heat Islands; Health Management; Disaster Risk Reduction; Sustainable Agriculture, Education and awareness. Biological capacity and Ecological footprints: Definitions, Carbon footprint, water footprint, Global Footprint Network. Earth Overshoot Day. Market-based mechanisms for managing climate change: Clean Development Mechanism, Carbon emission trading, Carbon pricing, Carbon credits, Carbon offsets and Carbon markets. Climate finance – Green Climate Fund and Adaptation Fund. Calculation of Social Cost of Carbon.	
Unit – 4: Disaster Management **Disasters:** Definition: Natural disasters (earthquakes, floods, cyclones, landslides, droughts); Man-made disasters (industrial accidents, nuclear accidents, chemical spills). **Disaster trends:** Frequency, magnitude and impact. Disaster statistics and trends in India. **Disaster management:** Mitigation, preparedness, response and recovery. Geography and Vulnerability of India: Region-specific hazards (Himalayan earthquakes, coastal cyclones, river floods); Vulnerability mapping in India; Vulnerable communities. **Disaster Risk Reduction (DRR) Framework:** The Sendai Framework for Disaster Risk Reduction (2015-2030). Mitigation Measures for Natural Disasters: Structural measures (flood barriers, earthquake-resistant buildings, etc.); Non-structural measures (early warning systems, land-use planning, education and awareness): Disaster Risk Financing and Insurance. **National Policy on Disaster Management:** Disaster Management Act, 2005 (India). Aims, objectives, and key components of National Policy on Disaster Management. NDMA Guidelines on Mitigation Measures. Coordination between NDMA, NDRF, UNDP, Government, NGOs and communities. **Climate Change and Disasters in India:** Changing rainfall patterns, sea level rise, and the increase in extreme weather events. Role of local adaptation strategies in disaster risk reduction. Indigenous knowledge and community resilience; Community-based disaster risk management (CBDRM) practices; Disaster education in formal sector and communities; disaster response drills.	**13**

Disaster Mitigation and Technology: Early warning systems (Flood, cyclone and earthquake alerts), remote sensing, Use of drones and GIS; Smart disaster management tools. **Disaster preparedness and response:** National, State and Local-level plans; Early warning and emergency response strategies; simulation and mock drills. **Case studies:** Bhopal Gas tragedy, Vizag gas leak, Indian Tsunami, Kerala floods, Kodagu floods, Locust attacks. **Dam safety:** Issues, emergencies preparedness and mitigative measures. National Dam Safety Bill.	

References:

Anonymous. 2021. Climate Change Book - A Brief History of Climate Change, Climate Science, Climate Hysteria, Climate Denial, Climate Debate, and Reasons for Hope. Amazon Digital Services LLC - KDP Print US. University Press.

Bhandari, M. P. (2022). *Getting the Climate Science Facts Right: The Role of the IPCC*. CRC Press.

Ellis, E. C., & Ellis, E. C. (2018). *Anthropocene: a very short introduction* (Vol. 558). Oxford University Press.

Islam, M. N., & van Amstel, A. (Eds.). (2022). India II: Climate Change Impacts, Mitigation and Adaptation in Developing Countries.

Islam, M. R., & Khan, M. M. (2019). *The Science of Climate Change*. John Wiley & Sons.

Maslin, M. (2008). *Global warming: a very short introduction*. OUP Oxford.

Maslin, M. (2014). *Climate change: a very short introduction*. OUP Oxford.

McGuire, B. (2006). *Global catastrophes: a very short introduction*. OUP Oxford.

Pörtner, H. O., Roberts, D. C., Adams, H., Adler, C., Aldunce, P., Ali, E., ... & Ibrahim, Z. Z. (2022). *Climate change 2022: Impacts, adaptation and vulnerability* (p. 3056). Geneva, Switzerland: IPCC.

Ramesh, M. (2018). *The Climate Solution: India's Climate-Change Crisis and What We Can Do about It*. Hachette UK.

Richard Mahapatra. 2022. Climate India 2022: An assessment of extreme weather events. Centre for Science and Environment Publication, New Delhi.

Shrivastava, A. K. 2020. Textbook of Disaster Management. Scientific Publishers.

State of India's Environment. 2023. Centre for Science and Environment Publication, New Delhi.

Ting, D. K., & Stagner, J. A. (Eds.). (2021). *Climate Change Science: Causes, Effects and Solutions for Global Warming*. Elsevier.

Zhongming, Z., Linong, L., Xiaona, Y., Wangqiang, Z., & Wei, L. (2022). AR6 synthesis report: Climate change 2022.

Website:

https://climateactiontracker.org/

https://ghgprotocol.org/

https://ksdma.karnataka.gov.in/

https://mausam.imd.gov.in/

https://ndma.gov.in/

https://public.wmo.int/en

https://unfccc.int/

https://unfccc.int/process/bodies/supreme-bodies/conference-of-the-parties-cop

https://unfccc.int/process-and-meetings/the-paris-agreement/nationally-determined-contributions-ndcs/indcs

https://www.bsigroup.com/

https://www.ipcc.ch/

https://www.noaa.gov/

https://www.scripps.edu/

https://www.wri.org/indc-definition

Content of Practical Course

ES 9P126: CLIMATE CHANGE ASSESSMENT AND SUSTAINABILITY TOOLS

Number of Practical Credits	Number of Practical Hours / Semester
2	52

1. Study of Guidelines - ISO 14064, IPCC, GRI, WRI and CEA
2. Collection of Scientific Data for Climate Change Studies - Real-time and Published data
3. Study of Emission Factor Databases for Greenhouse Gas Inventory
4. Inventorisation of GHG emissions from the Energy sector – Petrol, Diesel and Electricity sources
5. Inventorisation of GHG emissions from Agricultural sector - Livestock and Fertiliser sources
6. Inventorisation of GHG emissions from Waste sector - Municipal solid waste, Domestic and Industrial wastewater
7. Quantification of Carbon footprint and Water footprint of an Institution/Organisation
8. Calculation of Human Development index / Sustainable Development Index
9. Calculation of Sustainable Value of an Organisation – SV calculator
10. Quantification of Handprint of an Institution/Organisation
11. Introduction to ESG Reporting / Life Cycle Assessment Software
12. Rating of Buildings - GRIHA standards
13. Mapping and analysis of the supply chain of a product

Activity – Visit to consultancy companies offer ESG service

Visit to a green building

References

Eggleston, H. S., Buendia, L., Miwa, K., Ngara, T., & Tanabe, K. (2006). *2006 IPCC guidelines for national greenhouse gas inventories*. United Nations Development Programme.

Franchetti, M. J., & Apul, D. (2012). *Carbon footprint analysis: concepts, methods, implementation, and case studies*. CRC press.

GRIHA A Council Publication. (2022). *GRIHA Version 2019: The Sustainable Habitat Handbook (6 Volume Set)*. Energy and Resources Publisher.

Wintergreen, J., & Delaney, T. (2007, May). ISO 14064, International standard for GHG emissions inventories and verification. In the 16th *annual international emissions inventory conference, Raleigh, NC*.

Zhongming, Z., Linong, L., Xiaona, Y., Wangqiang, Z., & Wei, L. (2019). 2019 *Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. United Nations Development Programme.

Website:

https://www.ipcc.ch/

https://mausam.imd.gov.in/

https://www.wri.org/indc-definition

https://ghgprotocol.org/

https://www.usgbc.org/leed

https://www.grihaindia.org/

https://sustainabilitytimes.com/

M.Sc. Environmental Science and Sustainability

Semester III

Title of the Course: **ES 9226 – SUSTAINABLE DEVELOPMENT**

Number of Theory Credits	Number of Lecture Hours / Semester
4	52

Course Specific Objectives	
CSO 1	To provide in-depth knowledge on concepts and approaches to attain sustainable development.
CSO 2	To give insights on sustainable development goals along with tools to assess sustainable development.
CSO 3	To analyse the life cycle assessment methodology to be able to calculate footprint and handprints.
CSO 4	To develop skillsets on sustainable building and infrastructure rating systems for planning of sustainable cities.

Course Outcomes	
CO 1	Students will critically analyse sustainable development, evaluate sustainability approaches, identify synergies and trade-offs across environmental, social, and economic dimensions, and apply key frameworks and tools to address sustainability challenges at various levels.
CO 2	Students will understand and analyse the Sustainable Development Goals (SDGs), assess their global and Indian relevance, evaluate methods for SDG localization in India, and use sustainable development indices to track progress towards the SDGs.
CO 3	Students will identify and apply sustainable development indicators, assess sustainability using tools like environmental auditing and impact assessments, and evaluate the effectiveness of strategies using SMART indicators and stakeholder engagement.
CO 4	Students will conduct Life Cycle Assessments (LCA) to evaluate the impacts of products and services, apply sustainability frameworks for responsible consumption and production, and use LCA tools and software to analyse footprints and handprints for promoting sustainable practices across industries. Students will be able to evaluate the impacts of urbanization on key sectors such as water, energy and transportation. They will be able to participate in designing sustainable cities and buildings. They will be enabled to use rating systems like IGBC, GRIHA, and LEED; promote resilience and sustainable lifestyles in urban planning, incorporating green spaces, energy efficiency and urban agriculture.

Title of the Course: **ES 9226 – SUSTAINABLE DEVELOPMENT**	**52 Hours**
Unit – 1: Sustainable Development	**14**
Sustainable Development: Definition. Conventional development model and its criticisms. Sustainability vs Sustainable Development. Approaches to sustainable development: Hartwick-Solow or Weak sustainability approach; London school or Strong sustainability approach and safe minimum standards approach – Anthropocene and Planetary boundaries. The concept of finitude, fragility and fairness in sustainable development. Components of sustainable development: Environment, Social, Economic and Cultural. Synergies, trade-offs and conflicts in Sustainable Development. Geographic Perspectives and Sustainable Development: The role of Spatial Scale in Sustainable Development and Interaction between different Spatial Levels. Linking Local and Global Sustainability. Evolution of Sustainable Development perspectives: Brundtland Commission, 1987, Agenda 21, MDGs and SDGs; United Nations summits and their outcomes. Transboundary issues, Multilateral Environmental Agreements, Conventions and Protocols. Key Concepts for Sustainable Development: *Factor 4 and Factor 10. The goals of sustainability (Ehrlich and Holdren's IPAT equation); Systems Thinking; Life Cycle Thinking; The Circular Economy; Industrial Ecology; Green Economy and Low Carbon Economy; The Natural Step; Resource Efficiency and Decoupling; Eco-efficiency and Triple Bottom Line.*	
Unit – 2: Sustainable Development Goals	**8**
Sustainable Development Goals: Introduction, Objectives and Significance. An overview of Sustainable Development Goals and Targets: Global and Indian perspective. Sustainable Development Goals Integration: Indian Model of SDG localisation. Sustainable Development indices. Sustainable Development Goals India index.	
Unit – 3: Indicators of Sustainable Development and Sustainability Assessment	**8**
Indicators of Sustainable Development: *Pressure indicators, State indicators, Response indicators, Impact indicators, Efficiency indicators, Sustainable indicators, Environmental performance indicators*. Uses of Indicators. Characteristics of a good indicator - SMART - *Specific, Measurable, Achievable, Realistic and Time-Bound*. Sustainability Assessment: Introduction and need. Tools of sustainability assessment - *Environmental Management Systems; Environmental Auditing;*	

Cleaner Production Assessment; Environmental Impact Assessment; Strategic Environmental Assessment; Design for Sustainability and Stakeholder Engagement.	
Unit – 4: Life Cycle Assessment	**14**
Life Cycle Assessment: Definition, Goal and Scope. Sustainable consumption and production policy frameworks. Instruments for sustainable extraction, use and management of raw materials - Sustainable Procurement. Instruments for cleaner production. Instruments for better products, services and the marketplace. Instruments for smarter consumption. Instruments for end-of-life management. Life Cycle Assessment Methodology: *Life Cycle Inventory; Life Cycle Impact Assessment*; Interpretation and Presentation of Results; The Iterative Nature of LCA; Methodological Choices; LCI Databases and LCA Software; Strengths and Limitations of LCA. Environmental Life Cycle Costing, Social Life Cycle Assessment, and Life Cycle Sustainability Assessment: LCA Applications; Eco-labelling and Environmental Product Declarations and Product Category Rules. Footprints: Ecological Footprint; Carbon Footprint; Water Footprint; Energy Footprint; Waste Footprint including E-waste; Foodprint; Industrial Footprint, Agricultural Footprint – Case studies. Handprints: Concept and significance.	
Unit - 5: Sustainable Cities and Communities	**8**
Sustainable Cities (Urbanisation and its impact of growth on Water, Energy, Non-motorised and motorised transport, Waste generation). Building Resilience in Cities; Planning for Sustainable Cities. Significance of green spaces. Comprehensive Sustainable Development Plan (CSDP). Case studies. Sustainable Buildings and Infrastructure Rating Systems: Indian Green Building Council (IGBC), Green Rating for Integrated Habitat Assessment (GRIHA), Leadership in Energy and Environmental Design (LEED), Excellence in Design for Greater Efficiencies (EDGE); Sustainable Energy/Energy Sustainability (BEE) and Urban Agriculture. Principles of Sustainable Lifestyle.	

References:

Alexander, D. (2016). Sustainability: A History by Jeremy L. Caradonna, Oxford University Press, New York, 2014, 336 pp., hardcover $29.95 (ISBN 978-0199372409). *The Canadian Geographer/Le Géographe canadien*, *60*(4), e56-e56.

Bass, S., & Dalal-Clayton, B. (2012). *Sustainable development strategies: a resource book*. Routledge.

Brundtland, G. H. (2015). Our Common Future": The World Commission on Environment and Development (WCED)/GH Brundtland–Oxford.

Chakraborty, T., Mukherjee, D., & Saha, S. (2020). *Contemporary Issues in Sustainable Development*. CRC Press.

Cunningham, W. P., Cunningham, M. A., & Saigo, B. W. (2001). *Environmental science: A global concern* (Vol. 412). New York: McGraw-Hill.

De Vries, B. J. (2012). *Sustainability science*. Cambridge University Press.

Enders, J. C., & Remig, M. (2014). Theories of sustainable development: An introduction. In *Theories of sustainable development* (pp. 1-5). Routledge.

Faucheux, S., O'Connor, M., & Van Der Straaten, J. (1998). *Sustainable Development: Concepts, Rationalities and Strategies: Editors' Introduction* (pp. 1-15). Springer Netherlands.

Heinrichs, H. (2019). Strengthening sensory sustainability science—theoretical and methodological considerations. *Sustainability*, *11*(3), 769.

Kish, K., & Quilley, S. (2021). *Ecological Limits of Development: Living with the Sustainable Development Goals*. Routledge.

Kumar, S. (2017). EF Schumacher 1911–1977. In *Key Thinkers on The Environment* (pp. 217-222). Routledge.

Lenton, T. (2016). *Earth system science: a very short introduction* (Vol. 464). Oxford University Press.

Meadows, D., Randers, J., & Meadows, D. (2004). *Limits to growth: The 30-year update*. Chelsea Green Publishing.

Muthukrishnan, S. (2015). *Economics of environment*. PHI Learning Pvt. Ltd.

Ramakrishnan, P. S. (2001). *Ecology and sustainable development*. National Book Trust.

Ramjeawon, T. (2020). *Introduction to Sustainability for Engineers*. CRC Press.

Roorda, N. (2020). *Fundamentals of sustainable development*. Routledge.

Sachs, J. D. (2015). The age of sustainable development. In *The Age of Sustainable Development*. Columbia University Press.

Sachs, J., Woo, W. T., Yoshino, N., & Taghizadeh-Hesary, F. (Eds.). (2019). Handbook of green finance: Energy security and sustainable development.

Steger, M. B. (2017). *Globalization: A very short introduction* (Vol. 86). Oxford University Press.

Website:

https://sustainabilitytimes.com/

https://sustainabledevelopment.un.org/index.html

https://www.globalreporting.org/

https://www.sustainabilityconsortium.org/

https://www.un.org/sustainabledevelopment/

https://www.unsdsn.org/

https://www.weforum.org/

https://www.wri.org/

M.Sc. Environmental Science and Sustainability

Semester III

Title of the Course: **ES 9326 – CORPORATE SUSTAINABILITY AND ENVIRONMENT, SOCIAL & GOVERNANCE**

Number of Theory Credits	Number of Lecture Hours / Semester
4	52

Course Specific Objectives	
CSO 1	To explore the key concepts on corporate sustainability and corporate social responsibility.
CSO 2	To develop standards and attitudes in understanding ESG and complex environmental issues.
CSO 3	To comprehend on the relationship between business activities and environmental issues along with impact of climate risks on financial systems.
CSO 4	To highlight the ESG disclosures, frameworks and collaborative initiatives to attain sustainable development goals.

Course Outcomes	
CO 1	Students will be able to critically analyse corporate sustainability concepts; apply the Triple Bottom Line framework, assess responsible investment strategies; understand the role of Corporate Social Responsibility (CSR) in sustainable development, with a focus on its evolution, regulatory provisions in India and environmental responsibility practices.
CO 2	Students will be able to assess the significance of Environmental, Social, and Governance (ESG) factors in business; apply frameworks for evaluating environmental impacts and social contributions; demonstrate proficiency in governance structures, reporting methods; understand corporate ethical standards, with a focus on sustainability and stakeholder engagement.
CO 3	Students will be able to understand the principles of integrated reporting, identify its key components; apply best practices in preparing and assuring integrated reports, with a focus on sustainability, materiality. They will understand the role of assurance providers in ensuring credibility and transparency in business reporting.
CO 4	Students will be able to identify the key drivers for sustainability disclosures, engage with relevant stakeholders and understand the various international / regional ESG frameworks, including the GRI, SASB, and CSRD. Students will also be equipped to analyse corporate sustainability reporting practices and demonstrate leadership in sustainability through case study insights from different industries.

Title of the Course: **ES 9326 – CORPORATE SUSTAINABILITY AND ENVIRONMENT, SOCIAL & GOVERNANCE**	**52 Hours**
Unit – 1: Corporate Sustainability	**8**
Corporate Sustainability: Overview, Debates surrounding corporate sustainability. Triple Bottom Line – meaning and components. Responsible Investing: Impact Investing, Social Impact Investing, ESG Investing. Corporate Social Responsibility (CSR): Meaning, history and evolution, drivers of CSR, Sustainable development and CSR. Moral and economic arguments for CSR. CSR in India – Overview, Provisions of the Companies Act, 2013. Corporate Environmental Responsibility.	
Unit – 2: Environment, Social and Governance	**20**
Environment, Social and Governance: Meaning, Importance and Components. Environment Factors – Concepts of climate change, climate change mitigation, climate change adaptation and other environmental issues; Relationship between business activities and environmental issues, impact of climate risks on the financial system; climate related physical and transition risks to business; Circular economy; Clean and technological innovation, green and ESG-related products; the Blue Economy. Environmental reporting: Significance, methods for measuring and reporting on environmental impacts - *Ecological footprints*. …….. Social Factors – Stakeholders, key social concepts including human capital, development, employment standards, health and safety; product liability/consumer protection: safety, quality, health and demographic risks, and data privacy and security; stakeholder opposition/controversial sourcing. Social reporting: Significance, methods for measuring and reporting on social impacts. Social impact assessment tools - *Social Return on Investment (SROI)*. …….. Governance Factors - Board structure, diversity, effectiveness, and independence; executive remuneration, performance metrics, and Key Performance Indicators (KPIs); Reporting and Transparency; financial integrity and capital allocation; Business ethics. Role of auditors in corporate governance. Governance reporting: Significance, methods for measuring and reporting on governance performance. Corporate governance frameworks and codes - *The Organisation for Economic Co-operation and Development (OECD) Principles of Corporate Governance.*	

Unit 3: Integrated reporting, Assurance and Verification	**10**
Integrated reporting: Overview of integrated reporting and its benefits. Key components of an integrated report. Examples of integrated reports and best practices for preparing them. Assurance and verification: Overview of assurance and verification in sustainability reporting. Types of assurance and verification (internal audit, external assurance). Best practices for selecting and working with assurance providers. Principles of materiality.	
Unit – 4: ESG Disclosures	**14**
Drivers for sustainability disclosures: Investor interest, consumer interest and regulatory bodies. Engaging with stakeholders - *Customers, suppliers, employees and investors.* Collaborative initiatives - *Industry associations and multi-stakeholder partnerships.* ESG Frameworks: Meaning – International Frameworks: Environmental Performance Index (EPI); Global Reporting Initiative (GRI); Carbon Disclosure Project (CDP); Sustainability Accounting Standards Board (SASB); United Nations Global Compact; The Taskforce on Nature-related Financial Disclosures (TNFD), International Sustainability Standards Board (ISSB) and Science Based Targets (SBT). The Corporate Sustainability Reporting Directive (CSRD). Sustainable Finance Disclosure Regulation (SFDR). Securities Exchange Board of India (SEBI) - Business Responsibility and Sustainability Report (BRSR). Sustainability leadership: Case studies of different industries.	

References:

Aras, G. (2016). *A handbook of corporate governance and social responsibility*. CRC Press.

Baxi, C. V., & Prasad, A. (Eds.). (2005). *Corporate social responsibility: Concepts and cases: The Indian experience*. Excel Books India.

Gupta, D. (2022). *Casebook of Strategic Corporate Social Responsibility*. Springer Singapore.

Mallin, C. A. (Ed.). (2009). *Corporate social responsibility: A case study approach*. Edward Elgar Publishing.

Matos, P. (2020). ESG and responsible institutional investing around the world: A critical review.

Mondal, S., & Das, G. (2021). *Business, sustainable development & other emerging issues*. Sheba Blake Publishing.

Moon, J. (2014). *Corporate social responsibility: A very short introduction* (Vol. 414). Oxford University Press, USA.

Nemoto, N., & Morgan, P. J. (2020). *Environmental, social, and governance investment: Opportunities and risks for Asia*. Asian Development Bank Institute.

Prabakaran, S. (2010). *Business ethics and corporate governance*. Excel Books India.

Rezaee, Z., Tsui, J., Cheng, P., & Zhou, G. (2019). *Business sustainability in Asia: Compliance, performance, and integrated reporting and assurance*. John Wiley & Sons.

Schaper, M. (Ed.). (2016). *Making ecopreneurs: Developing sustainable entrepreneurship*. CRC Press.

Solomon, J. (2020). *Corporate governance and accountability*. John Wiley & Sons.

Tricker, R. I. (2015). *Corporate governance: Principles, policies, and practices*. Oxford University Press, USA.

Visser, W., Matten, D., Pohl, M., & Tolhurst, N. (2010). *The A to Z of corporate social responsibility*. John Wiley & Sons.

Website:

https://www.cdp.net/

https://www.corporateknights.com/

https://www.csrwire.com/

https://www.ethicalcorp.com/

https://www.globalreporting.org/

https://www.sasb.org/

https://www.unpri.org/

M.Sc. Environmental Science and Sustainability
Semester III

Title of the Course: **ES 9426 – SAFETY, HEALTH & ENVIRONMENT**

Number of Theory Credits	Number of Lecture Hours / Semester
4	52

Course Specific Objectives	
CSO 1	To understand interrelatedness of environmental science and safety at work place.
CSO 2	To be able to identify hazards at workplace and to carry out risk assessment.
CSO 3	To understand fire accidents, their management and to familiarise with the concepts of Occupational Safety and Health (OSH).
CSO 4	To familiarise with the safety rules, guidelines and protocols at workplace.

Course Outcomes	
CO 1	Students will understand and apply key Safety, Health, and Environment (SHE) principles, including accident prevention, risk assessment, ergonomics and PPE selection. They will be able to implement safety management practices, investigate accidents and address work-related health issues to improve workplace safety and productivity.
CO 2	Students will be able to apply various hazard analysis techniques to identify and assess risks in workplace settings. They will demonstrate proficiency in conducting hazard identification, risk assessment (HIRA) and implementing effective control measures. Students will also gain practical knowledge of the work permit system, risk communication and first aid procedures.
CO 3	Students will be able to identify fire hazards, assess fire risks, and apply fire safety practices. They will gain knowledge in fire classification, extinguisher selection, fire risk control systems, along with understanding the principles of fire safety management and emergency planning.
CO 4	Students will understand key OSH laws, international frameworks (ILO, WHO, ISO), process safety management and emergency management. They will apply risk analysis tools like ALOHA and emergency planning protocols.

Title of the Course: **ES 9426 – SAFETY, HEALTH & ENVIRONMENT**	**52 Hours**
Unit – 1: Safety, Health and Environment (SHE)	**14**
Safety, Health and Environment (SHE): Definitions and significance. History and development. Environment, Health and Safety Policy. Characteristics of work-related illness - hypertension, affective disorders, alcohol dependence, and musculoskeletal disorders associated with fatigue, absenteeism and loss of productivity. Industrial Safety – Objectives and goals, Principles of safety management. National Safety Council (India) – Objectives, roles and NSD pledge. Industrial accident: Introduction, meaning, near miss, industrial accidents - types, Causes - Unsafe Act, Unsafe condition, Difference between Unsafe acts and unsafe conditions, Examples, Consequences. 5W and 1H investigation theory and documentation. Investigation of accidents – methodology, outcomes, Reports, Benefits. Measurement of Safety Performance. Accident Prevention: Introduction, principles, Domino's theory of Accident Causation, Frank bird's Domino theory. Hazop Studies - Introduction, Risk based Decision-making, ALARP – As. Low As Reasonably Practical (LARP), So Far As Is Reasonably Practicable (SFAIRP), Risk and Risk Matrix. Five E's for Accident Prevention at the workplace. Housekeeping: Introduction, Meaning. Advantages, Profits. Introduction to 5S principle, Advantages, Roles of employees. Ergonomics: Introduction, meaning, Application, Objectives, safety program. Musculoskeletal disorders (MSDs) - Signs and symptoms, Engineering controls. Personal Protective Equipment's (PPEs): Introduction, Requirements, points to be considered when selecting, types based on hazards, maintenance. Benefits & Limitations of PPE's. Indian standards of PPE's - Specification of safety PPE's based on Indian standard. Best practice indicators - Plan, Do, Check and Act (PDCA).	
Unit – 2: Hazard Identification and Risk Assessment	**14**
Hazard Analysis Techniques: Introduction, Requirements for Hazard Analysis, Various Hazard Analysis Techniques. Fault Tree Analysis (FTA) - Application of FTA with a Typical Example, Symbols used Construction, Advantages and Disadvantages, Summary. Event Tree Analysis (ETA), Failure Mode and Effects Analysis (FMEA), Health Hazard Analysis (HHA) –Methodology.	

Hazard Identification and Risk Assessment (HIRA): Term and Definitions, Basic Concepts, Planning and Conducting of HIRA, Process of HIRA, Flow chart for HIRA process, Hazard identification - Health hazards, Safety hazards, Environmental hazards, Hazard identification technique, The hazard identification and assessment methodology, Analyse and estimate risk - Likelihood of an occurrence, Severity of hazard, Risk assessment, Control- Selecting a suitable control, Types of Control - Engineering control, Administrative controls, Monitoring controls - Safe work procedures, Documenting HIRA. Work Permit System: Introduction, Definition and Meaning, Purpose, Type of work Requiring work Permit, List of Safety Documents, Type of Work Permits – Hot Work Permits, Cold Work Permits, Confined Spaces / Vessel Entry Work Permits, Chemical Work Permits, Height Work Permit, Electrical Isolation Permit, Excavation Permit, Blasting work Permits and Industrial Radiography Permits. Limited Work Permit, Contributing Factors for Work Permit, Application of Work Permit System, Permit Issue, Review, Validation, Cancellation, and Completion of Work, Administration Process for Work Permit System, Benefits and Limitations of Work Permit System. Risk assessment: Definition of Risk, Exposure assessment, Comparative risk analysis, Risk matrix, Risk rating and Risk communication. Risk analysis: Definition. Process of risk analysis - Identification, Analysis, Evaluation, Treatment and Review. Qualitative Risk Analysis Methods - Bow Tie analysis, The Delphi Technique, The SWIFT Analysis and The Fly Analysis. Quantitative Risk Analysis Methods - Failure Mode & Effect Analysis (FMEA), Fault Tree Analysis (FTA) and Event Tree Analysis (ETA). First aid: Introduction, principles, training in first aid, Cardio Pulmonary Resuscitation-CPR, First aid procedures - electrical shocks, poisons, open wounds, Control of bleeding and Snakebites.	
Unit – 3: Fire Safety and Management	**14**
Fire at work place: Definition and causes of fire. Fire development and its severity, effect of enclosure, need for early detection of fire. Fire safety foundation: Definitions- Occupational health and safety, Safety, Ill health, Accident. Incident, Environmental protection, Hazard, Risk. Scope and nature, the moral, legal and financial reasons for promoting good standards of safety within an organisation, The business case for managing fire safety, The nature and sources of safety information, The basis of a system for managing safety. Anatomy of Fire: Introduction, Elements of Combustion - The fire triangle, the fire tetrahedron, Products of Combustion, Heat of reaction and	

calorific value, Flash point, Fire point, Ignition temperature and spontaneous combustion. Stages of combustion. Principles of fire spread – Convection, Conduction and Radiation. Classification of Fire & Extinguishers: Classification of Fire. Techniques of fire extinction - starvation, smothering, cooling, and Inhibition. Extinguishing agents. Halon and its detrimental effects on environment. Alternatives of Halon. Types of extinguishers, method of operation, maintenance. Selection of fire extinguishers. Fire risk assessment: Introduction, Definitions relating to fire risk assessment - Fire hazard, Fire risk, Fire risk assessment, Fire risk controls Risk control systems (RCS). Risk assessment process - Practical steps, recording the assessment, the emergency plan, Fire Safety Audit, Case study of a fire risk assessment record and action plan.	
Unit – 4: Occupational Safety and Health (OSH)	**10**
Major OSH Laws & Regulations - Salient features of the Factories Act, 1948, the Mines Act, 1952 and Mines Rules, 1955, the Dock Workers (Safety, Health and Welfare) Act, 1986, the Building & Other Construction Workers (Regulations of Employment and Conditions of Service) Act, 1996 (BOCW Act), National Policy on Safety, Health and Environment at Workplace (NPSHEW). International Labour Organization (ILO) – ILO member states, Governing Body, International Labour Conference and Code, Conventions and Recommendations, Fundamental Conventions. World Health Organization (WHO) – Constitution and History, Work, Activities. Process Safety Management (PSM) – Meaning, 14 elements, Performance Measurements to Determine Effectiveness of PSM Programme. International Organization for Standardization (ISO) - Salient Features, ISO- 14001 – Purpose, Features, Application, Overview of Requirements for ISO 14001, Environmental Performance Improvement, Benefits. ISO 45001 – Introduction, Purpose, Requirements and structure, Benefits. Emergency Management: Introduction, Need, Definition - Emergency, Emergency Management, Causes of Emergency, Types of Emergencies, On-Site Emergency - Objectives, Main Elements. Off-Site Emergency Plan – Mock drills. Application of software in risk analysis – ALOHA.	

References:

Alston, F., & Millikin, E. J. (2015). *Guide to Environment Safety and Health Management: Developing, Implementing, and Maintaining a Continuous Improvement Program* (Vol. 35). CRC Press.

Asfahl, C. R., & Rieske, D. W. (2010). *Industrial safety and health management*. Prentice Hall.

Botkin, D. B., & Keller, E. A. (1998). *Environmental science: earth as a living planet* (No. Ed. 2). John Wiley & Sons Ltd.

Brauer, R. L. (2022). *Safety and health for engineers*. John Wiley & Sons.

Ferrett, E. (2020). Introduction to Health and Safety at Work: for the NEBOSH National General Certificate in Occupational Health and Safety.

Friend, M. A., & Kohn, J. P. (2023). *Fundamentals of occupational safety and health*. Rowman & Littlefield.

Hazinski, Mary Fran. *Nursing care of the critically ill child*. Elsevier Health Sciences, 2012.

Holt, A. S. J., & Allen, J. (2015). *Principles of health and safety at work*. Routledge.

Koradecka, D. (Ed.). (2010). *Handbook of occupational safety and health*. CRC Press.

Narayanan, K. T. (2015). *Safety, Health and Environment Handbook*. McGraw - Hill Education

Popendorf, W. (2019). *Industrial hygiene control of airborne chemical hazards*. CRC Press.

Rawat, B., & CHAUBEY, D. (2022). *Workforce Training And Development For HR Capacity Building In Some Selected SMEs Of Uttarakhand*. Book Rivers.

Reese, C. D. (2018). *Occupational health and safety management: a practical approach*. CRC press.

Rom, W. N., & Markowitz, S. B. (Eds.). (2007). *Environmental and occupational medicine*. Lippincott Williams & Wilkins.

Zambelli, S., & Šantek, D. (2019). Occupational health and safety management system-ISO 45001. *Zbornik Radova/20. međunarodni simpozij o kvaliteti. Kvaliteta jučer, danas, sutra. Pula, Croatia,* 343-357.

Websites:

http://www.nioh.org/

https://www.cdc.gov/niosh/

https://www.cii.in/

https://www.epa.gov/

https://www.indianchemicalcouncil.com/

https://www.iogp.org/

https://www.iosh.com/

https://www.nsc.org.in/

https://www.osha-india.com/

https://www.sheaindia.org/

https://www.sra.org/

https://www.who.int/

M.Sc. Environmental Science and Sustainability

Semester III

ES 9526 – ENVIRONMENTAL ECONOMICS

Number of Theory Credits	Number of Lecture Hours / Semester
4	52

Course Specific Objectives	
CSO 1	To provide understanding of economics, the cost-benefit analysis and link between environment and economics.
CSO 2	To examine the market failures and externalities.
CSO 3	To conceptualise the methods of valuing environmental assets.
CSO 4	To address International trade and transboundary environmental issues.

Course Outcomes	
CO 1	Students will grasp foundational economic concepts, including environmental economics, microeconomics and macroeconomics. They will analyse the relationship between the economy and environment, focusing on resource economics, decision-making, and the circular flow of resources.
CO 2	Students will grasp key economic concepts like diminishing marginal utility, demand and supply laws, opportunity cost, cost-benefit analysis, and market equilibrium, including producers' and consumers' surplus.
CO 3	Students will understand the dynamics of competitive markets, price mechanisms, and market failures, including externalities, public goods, and asymmetric information. Students will understand the need for economic valuation, apply decision-making frameworks like cost-benefit and cost-effectiveness analysis and evaluate various techniques for economic valuation, including market-based, revealed preference and stated preference methods.
CO 4	Students will evaluate the impact of inequality, poverty and affluence on environmental degradation; understand the basis of international trade, externalities and differential environmental standards.

CONTENTS OF ES 9426: ENVIRONMENTAL ECONOMICS	52 Hours
Unit - 1: Introduction to economics	**10**
Economics: Definitions – Environmental economics – Need. Economic approaches – Microeconomics, production possibility curve – choice making (concepts). Macroeconomics - National income, aggregate demand and supply. Determination of Output, Employment and Prices. Positive and Normative economics (concepts). Circular flow of resources between environment and economy. Link between economics and the environment, philosophical perspectives to decision making relating to environmental issues. Resource economics.	
Unit - 2: Consumption, Production and Welfare	**10**
Consumption – Laws of diminishing marginal utility, the law of demand. Supply – Laws of production, cost of production (concepts) – marginal cost and marginal revenue (benefits); Concept of opportunity cost, revenue, neo-classical framework. Welfare – Pareto optimality. Equilibrium – producers and consumers surplus (concepts)	
Unit - 3: Market failure and externalities	**12**
Competitive markets, price mechanism and market failure- Incomplete and missing markets. Externalities- divergence between private and social – costs and benefits; negative and positive externalities in production and consumption. Causes of market failure – nature of goods, public goods; property rights – types, Hardin's tragedy of commons, Coase theorem, Elinor Ostrom's logic of collective action, asymmetric information. Rationale for government intervention.	
Unit - 4: Instruments for environmental protection	**8**
Economic instruments – secure property rights, creation of markets – tradable emission permits, fiscal instruments – tax and subsidies. Liability systems, Liability rules – non-compliance fees, performance bonds and deposit refunds. Compliance through regulation – command and control methods – setting environmental quality standards – restrictions and bans. Voluntary agreements – negotiated target setting. Informational instruments – role of Governments in collecting and disseminating information; Education and training.	
Unit - 5: Environmental valuation techniques	**8**
Economic valuation - Need. Decision-making framework – cost-benefit analysis, cost-effective analysis. Total economic value framework components. Techniques of economic valuation- Market-based approach	

in productivity technique, change in income technique, replacement cost technique, preventive expenditure technique and relocation technique. Revealed preference approach- Hedonic pricing method, wage differential technique, proxy good technique, travel cost method. Stated preference method – contingent valuation method. Limitations of economic valuation (concepts).	
Unit - 6: Economic development, international trade and trans-boundary environmental issues	**4**
Inequality, poverty and affluence – effect on environment degradation and depletion - environmental Kuznets curve. Basis of international trade-comparative cost and resource endowment; problem of international externalities, differential environmental standards – NIMBY, international protocols (summary).	

References

Asafu-Adjaye, J. (2005). *Environmental economics for non-economists: techniques and policies for sustainable development*. World Scientific Publishing Company.

Hanley, N., and Shogren, J. F. (2006). *Environmental economics: in theory and practice*. London: Macmillan.

Hanley, N., Shogren, J. F., & White 2nd, B. (2006). Environmental Economics. *Theory and Practice, Maximilian texts in economics, Hampshire, England. Ingemann, Jan Holm (2006) The Evolution of Organic Agriculture in Denmark, Working paper, Department of Economics, Politics and Public Administration, Alborg University*, *4*, 99-121.

Harris, J. M., & Roach, B. (2017). *Environmental and natural resource economics: A contemporary approach*. Routledge.

Karpagam, M. (2006). *Environmental economics: A textbook*. Revised Ed., Sterling Publishers Pvt. Ltd.

Muthukrishnan, S. (2024). *Economics of environment*. 3rd Edition, PHI Learning Pvt. Ltd.

Smith, S. (2011). *Environmental economics: A very short introduction* (Vol. 284). Oxford University Press, USA.

Tietenberg, T. (2000). Environmental and Natural Resource Economics. 5th Edition. Addison Wesley.

Turner, R. K., Turner, R. K., Pearce, D. W., & Bateman, I. (1993). *Environmental economics: an elementary introduction*. Johns Hopkins University Press.

ES 9D26 – DISSERTATION

ES 9P226, ES 9P326 and ES 9P426 are combined to form the dissertation component and paper code is **ES 9D26**.

Dissertation work in Environmental Science and Sustainability holds significant importance as it provides students with an opportunity to conduct in-depth research on critical environmental issues, contributing to the understanding and advancement of sustainable practices.

This project carried out individually by the students allows them to explore a specific area of their interest under the guidance of a mentor. The topics for the dissertation are chosen in consultation with the guide to ensure alignment with both academic goals and real-world relevance. The process of developing a dissertation enhances research skills, critical thinking and problem-solving abilities, equipping students with the knowledge and expertise to address complex environmental challenges. Moreover, it fosters a deeper understanding of the interconnectedness of natural and human systems, preparing graduates to make meaningful contributions to the field of sustainability.

Although the dissertation is prescribed in the third semester of the course, it is advisable to initiate the process at the beginning of the second semester. Starting early allows students to complete crucial groundwork and conduct a thorough literature review before the inter-semester vacations. This preparatory phase is essential for gaining a solid understanding of the existing research and identifying gaps in the field, which can then inform the direction of the dissertation. By completing these initial tasks ahead of time, students can ensure that the subsequent phases, such as fieldwork, data collection, analysis and reporting, are carried out more efficiently. A well-planned and early start not only reduces pressure but also enhances the overall quality of the research, providing ample time for critical reflection and revision.

ES 0I26: INTERNSHIP

IV SEMESTER

The Fourth Semester of M. Sc. Environmental Science and Sustainability is dedicated to internship programme with the industry.

Internship with an institution is an integral part of the M. Sc. Environmental Science and Sustainability course. This is carried out by individual students in association with Environmental Consultancies, Environmental Auditors, Production and Processing Industries, Certified Laboratories, Certification and/or Assurance Bodies, Pollution Control Boards, Research Institutions, Non-Governmental Organisations involved in environmental assessment / acting as public interest representatives related to EIA, Quasi-government bodies and other relevant institutions with the formal approval of the Department of Environmental Science, St Joseph's University, Bengaluru.

To enable the process of selecting the relevant industry specific to a particular student, students are encouraged to initiate the interaction with industries towards the end of second semester.

An option of working with the collaborating industry is enabled in the form of dissertation in the third semester. As there is only one practical to be taught in the laboratories, students will be provided with an option of interacting with their chosen industry and work for the dissertation with the industry.

This will be a win-win situation for the student and industry as the student gains an exposure to the industry by the interaction; and the industry will benefit by offering an internship (in the Fourth Semester) to a student who is aware of the scope of the industry and its work culture.

NOTE:

- If there is no option for a student to work outside the University, such student may take up a dissertation work equivalent to 14 credits.
- A teacher guide is to be allotted for the same.
- Evaluation criteria will remain same as described for the internship.
