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DEPARTMENT OF ENVIRONMENTAL STUDIES

SEMESTER - III

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COURSES OFFERED BY DEPARTMENT OF ENVIRONMENTAL SCIENCE

Category-I

Environmental Science Courses for Undergraduate Programme of study with Environmental Science as a Single Core Discipline

BSC (H) ENVIRONMENTAL SCIENCE

DISCIPLINE SPECIFIC CORE COURSE – 7 (DSC-EVS-7): ENVIRONMENTAL BIOTECHNOLOGY

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
DSC-EVS-7: ENVIRONMENTAL BIOTECHNOLOGY	4	2	0	2	Class XII pass	NA

Learning objectives

The Learning Objectives of this course are as follows:

- Provide theoretical and practical biotechnological skills for environmental goals
- Evolve ecological foundations of using microorganisms in biodiversity assessment, ecosystems restoration, and environmental remediation
- Relate the microbial ecophysiology with biogeochemical cycles that govern the terrestrial ecosphere
- Emphasize the relevance of biotechnological processes in environmental applications and sustainable development

Learning outcomes

After this course, students will be able to learn the following skills.

- Apply the biotechnological methods to improve environmental management
- Perform comparative protein and DNA sequence analyses to elucidate the phylogenetic relationship
- Analyze non-culturable microbial diversity in the environment and classify microbes based on energy and carbon metabolism

- Plan methods for combined biological nutrient removal (BNR), treat wastewater, and remedify soils and water contaminated with organic and inorganic pollutants

SYLLABUS OF DSC-EVS-7

Theory (02 Credits: 30 lectures)

UNIT – I The Structure and Function of DNA, RNA and Protein (3½ Week) (7 lectures)
DNA: structural forms and their characteristics (B, A, C, D, T, Z); physical properties: UV absorption spectra, denaturation, and renaturation kinetics; biological significance of different forms; Synthesis.

RNA: structural forms and their characteristics (rRNA, mRNA, tRNA; SnRNA, Si RNA, miRNA, hnRNA); biological significance of different types of RNA; synthesis.

Protein: hierarchical structure (primary, secondary, tertiary, quaternary), types of amino acids; post-translational modifications and their significance; synthesis; types and their role: structural, functional (enzymes).

Central dogma of biology; genetic material prokaryotes, viruses, eukaryotes and organelles; mobile DNA; chromosomal organization (euchromatin, heterochromatin - constitutive and facultative heterochromatin).

UNIT – II Recombinant DNA Technology (3½ Week) (7 lectures)
Recombinant DNA: origin and current status; steps of preparation; toolkit of enzymes for manipulation of DNA: restriction enzymes, polymerases (DNA/RNA polymerases, transferase, reverse transcriptase), other DNA modifying enzymes (nucleases, ligase, phosphatases, polynucleotide kinase); genomic and cDNA libraries: construction, screening and uses; cloning and expression vectors (plasmids, bacteriophage, phagmids, cosmids, artificial chromosomes; nucleic acid microarrays

UNIT – III Ecological restoration and bioremediation (5 Week) (10 lectures)
Wastewater treatment: anaerobic, aerobic process, methanogenesis, bioreactors, cell and protein (enzyme) immobilization techniques; treatment schemes for wastewater: dairy, distillery, tannery, sugar, antibiotic industries; solid waste treatment: sources and management (composting, vermiculture and methane production, landfill. hazardous waste treatment); specific bioremediation technologies: land farming, prepared beds, biopiles, composting, bioventing, biosparging, pump and treat method, constructed wetlands, use of bioreactors for bioremediation; phytoremediation; remediation of degraded ecosystems; advantages and disadvantages; degradation of xenobiotics in the environment, decay behavior and degradative plasmids, hydrocarbons, substituted hydrocarbons, oil pollution, surfactants, pesticides, heavy metals degradative pathways.

UNIT – IV Ecologically safe products and processes (3 Week) (6 lectures)
PGPR bacteria: biofertilizers, microbial insecticides, and pesticides; bio-control of the plant

pathogen, Integrated pest management; development of stress-tolerant plants, biofuel; mining and metal biotechnology: microbial transformation, accumulation, and concentration of metals, metal leaching, extraction; exploitation of microbes in copper and uranium extraction.

Practicals/Hands-on Exercises – based on theory (02 Credits: 60 hours)

1. Undertake comparative analyses of the ultrastructure of cells and cellular organelles of prokaryotes and eukaryotes.
2. Analyze UV absorption spectra of DNA, RNA and protein
3. Determine denaturation and renaturation of dsDNA

4-5. Estimate contents of DNA and protein in the given samples

6. Visit contaminated or degraded habitats and analyze their vegetation characteristics and compare them with pristine habitat
7. Characterize and analyze plants documented in practical 6 to identify species having the potential for phytoremediation

8-10. Isolate phosphate-solubilizing bacteria from different soils and assess morphological and functional variations in phosphate-solubilizing bacteria

11. Determine bacterial density in soils sampled from contaminated and pristine habitat
12. Visit and analyze various steps of Sewage/Wastewater treatment processes (STP/WTP).

13-15. Explore and use different molecular databases for application in environmental science

Teaching and learning interface for theoretical concepts

To achieve the course objectives and match with the contents, a wide range of teaching and learning tools will be employed, including (a) Formal lectures; (b) Interactive sessions using visual aid; (c) Case study analyses; (d) Hypothetical scenario building; (e) Group discussion on key topics; and (f) documentary screening and critical analyses.

Essential/recommended readings

- Furlong, J. and Evans, G.G., 2011. Environmental Biotechnology: Theory and Application. John Wiley & Sons.
- Jordening, H.J. & Winter J. 2005. Environmental Biotechnology: Concepts and Applications. John Wiley& Sons.
- Nelson, D.L. & Cox, M.M. 2013. Lehninger's Principles of Biochemistry. W.H. Freeman.
- Rittman, B.E. & McCarty, P.L. 2020. Environmental Biotechnology. Principles and Applications. McGraw-Hill, New York.
- Snustad, D.P. & Simmons, M.J. 2011. Principles of Genetics (6th edition). John Wiley& Sons.
- Vallero, D., 2015. Environmental Biotechnology: A Biosystems Approach. Academic Press.
- Wainwright, M., 2012. An introduction to Environmental Biotechnology. Springer Science & Business Media.

Suggestive readings

- Lodish, H., Berk, A., Kaiser, C.A., Kaiser, C., Krieger, M., Scott, M.P., Bretscher, A., Ploegh, H. and Matsudaira, P., 2008. Molecular Cell Biology. Macmillan.
- Moo-Young, M., Anderson, W.A. and Chakrabarty, A.M. eds., 2013. Environmental Biotechnology: Principles and Applications. Springer Science & Business Media.
- Petre, M. ed., 2013. Environmental Biotechnology: New Approaches and Prospective Applications. InTech, Crotia.
- Scagg, A.H. 2005. Environmental Biotechnology. Oxford University Press.
- Souvorov, A.V. 1999. *Marine Ecologonomics: The Ecology and Economics of Marine Natural Resource Management*. Elsevier Publications.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC CORE COURSE – 8 (DSC-EVS-8): ATMOSPHERE & GLOBAL CLIMATE CHANGE

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
ATMOSPHERE & GLOBAL CLIMATE CHANGE	4	2	0	2	Class XII pass	NA

Learning objectives

The Learning Objectives of this course are as follows:

- Analyze dynamics of atmospheric processes, which include their composition, meteorological phenomena, and atmospheric chemistry.
- Gain knowledge on the development of the Earth's atmosphere, its dynamic nature, and variability in turns of the global energy balance.
- Describe air masses and formation and impacts fronts and how they affect local weather patterns,
- Develop a better understanding of the elements of the climate and climate change and human impacts on climate initiative policies.
- Train on different methods to understand the functioning of atmospheric processes and their importance in supporting life on Earth

Learning outcomes

After this course, students will be able to

- understand the underlying physical and chemical basis of the natural and anthropogenic greenhouse effect
- develop pathway analysis to develop linkages between various human-induced emissions of natural greenhouse gases and the formation of aerosols
- appreciate the variability in the Earth's climate and correlate the changing climate with different human activity
- critically evaluate the complexities and uncertainties about scientific evidence for climate change
- analyze Earth's past and Anthropocene and global climate
- correlate effects of global climate changes on human communities and impacts of policy and technology initiatives taken at global and regional levels to combat the climate change

SYLLABUS OF DSC-EVS-8

Theory (02 Credits: 30 lectures)

UNIT – I Introduction and Global Energy Balance (2 Weeks) (4 lectures)

Evolution and development of Earth's atmosphere; atmospheric structure and composition; significance of atmosphere in making the Earth, the only biosphere; Milankovitch cycles. Earth's energy balance; energy transfers in the atmosphere; Earth's radiation budget; greenhouse gases (GHGs); greenhouse effect; global conveyor belt.

UNIT –II Atmospheric circulation (2½ Weeks) (5 lectures)

Movement of air masses; atmosphere and climate; air and sea interaction; southern oscillation; western disturbances; *El Nino* and *La Nina*; tropical cyclone; Indian monsoon and its development, changing monsoon in Holocene in the Indian subcontinent, its impact on agriculture and Indus valley civilization; effect of urbanization on microclimate; Asian brown clouds.

UNIT –III Meteorology and atmospheric stability (2 Weeks) (4 lectures)

Meteorological parameters (temperature, relative humidity, wind speed and direction, precipitation); atmospheric stability and mixing heights; temperature inversion; plume behavior; Gaussian plume model.

UNIT –IV Atmospheric chemistry (2 Weeks) (4 lectures)

Chemistry of atmospheric particles and gases; smog – types and processes; photochemical processes; ions and radicals in atmosphere; acid-base reactions in atmosphere; atmospheric water; roles of hydroxyl and hydroperoxyl radicals in atmosphere.

UNIT –V Global warming and climate change (2½ Weeks) (5 lectures)

Earth's climate through ages; trends of global warming and climate change; drivers of global warming and the potential of different greenhouse gases (GHGs) causing the climate change; atmospheric windows; impacts of climate change on atmosphere, weather patterns, sea level rise, agricultural productivity and biological responses - range shift of species, CO_2 fertilization and agriculture; impact on the economy and spread of human diseases.

UNIT –VI Ozone layer depletion (2½ Weeks) (5 lectures)

Ozone layer or ozone shield; Importance of ozone layer; Ozone layer depletion and causes; Chapman cycle; Orocess of springtime ozone depletion over Antarctica; Ozone-depleting substances (ODS); effects of ozone depletion; mitigation measures and international protocols.

UNIT –VII Climate change and policy (1½ Weeks) (3 lectures)
Environmental policy debate; International agreements; Montreal protocol 1987; Kyoto protocol 1997; Convention on Climate Change; carbon credit and carbon trading; Clean development mechanism.

Teaching and learning interface for theoretical concepts

To achieve the course objectives and match with the contents, a wide range of teaching and learning tools will be employed, including (a) Formal lectures; (b) Interactive sessions using visual aid; (c) Case study analyses; (d) Hypothetical scenario building; (e) Group discussion on key topics; and (f) documentary screening and critical analyses.

Practicals/Hands-on Exercises – based on theory (02 Credits: 60 hours)

1. Analyze the atmospheric chemistry of a given area with respect to target greenhouse gas(es) and its changes over time
2. Identify weather patterns and climate of the given region
3. Calculate the carbon footprint of the given institution (homes and/or college)
4. Evaluate the perception of climate change in developed and developing countries
5. Identify the critical factors governing global climate change and relate with the goals of different international governmental and non-governmental organizations

6-7. Compare the targets and achievements in global efforts to combat global climate change during the past three decades

8-9. Estimate the difference in carbon stock between soil and trees of a given area

10. Understand and correlate annual tree ring data with a historical account of climate
11. Identify the critical factors governing global climate change and relate them with the goals of different international governmental and non-governmental organizations
12. Compare climate change policies of selected developed and developing countries

Teaching and learning interface for practical skills

To impart training on technical and analytical skills related to the course objectives, a wide range of learning methods will be used, including (a) laboratory practicals; (b) field-work exercises; (c) customized exercises based on available data; (d) survey analyses; and (e) developing case studies; (f) demonstration and critical analyses; and (h) experiential learning individually and collectively.

Essential/recommended readings

- Barry, R. G. 2003. Atmosphere, Weather and Climate. Routledge Press, UK.
- Hardy, J.T. 2003. Climate Change: Causes, Effects and Solutions. John Wiley & Sons.
- Hoffman, S., Eriksen, T.H. and Mendes, P. eds., 2022. Cooling Down: Local

Responses to Global Climate Change. Berghahn Books.

- Manahan, S.E. 2010. Environmental Chemistry. CRC Press, Taylor and Francis Group.
- Maslin, M. 2014. Climate Change: A Very Short Introduction. Oxford Publications.
- Mathez, E.A. 2009. Climate Change: The Science of Global Warming and our Energy Future. Columbia University Press.
- Salby, M.L., 2012. Physics of the Atmosphere and Climate. Cambridge University Press.
- Speight, J.G., 2019. Global Climate Change Demystified. John Wiley & Sons.
- Wang, Y (2020). Atmosphere and Climate, 2nd Edition, Handbook of Natural Resources Vol VI, CRC Press.

Suggestive readings

- Crate, S.A. and Nuttall, M., 2016. Anthropology and Climate Change: From Actions to Transformations. Routledge.
- Gillespie, A. 2006. Climate Change, Ozone Depletion and Air Pollution: Legal Commentaries with Policy and Science Considerations. Martinus Nijhoff Publishers.
- Harvey, D. 2000. Climate and Global Climate Change. Prentice Hall.
- Hering, E., 2010. Atmosphere and Climate: Studies by Occultation Methods. Springer.
- Philander, S.G. 2012. Encyclopedia of Global Warming and Climate Change (2nd edition). Sage Publications.
- Sauer, T.J. and Norman, J.M. eds., 2011. Sustaining Soil Productivity in Response to Global Climate Change. Wiley-Blackwell.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC CORE COURSE – 9 (DSC-EVS-9): MARINE ECOLOGY

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
MARINE ECOLOGY	4	2	0	2	Class XII pass	NA

Learning objectives

The Learning Objectives of this course are as follows:

- Gain insights into the dynamic processes that affect oceans, i.e., water, seafloor, and abundant life forms
- Identify the role being played by ocean-atmosphere interaction in the climate processes.
- Investigate the role of ocean processes in coastal and marine landform creation.

Learning outcomes

After this course, students will be able to

- Analyze the role of physical processes in the dynamic process of ocean circulation.
- Formulate solutions ailing the current state of the coastal and marine environment in terms of chemical and biological interactions.
- Implement the knowledge base to promote ocean awareness in light of human exploitation of its resources.
- Assess the impacts of environmental and anthropogenic variables on marine ecosystems and biodiversity with time and space
- Use ecological data to predict the impact of a given factor on marine biodiversity and ecology

SYLLABUS OF DSC-9

Theory (02 Credits: 30 lectures)

UNIT – I Introduction (2 Weeks) (4 lectures)

A short history of the oceans and continents, History of marine ecology, Morphologic and tectonic domains of the ocean floor; Ocean basins, Ocean sediments; Composition of seawater, carbon dioxide-carbonate system; Atmospheric circulation, Ocean circulation, Life in the ocean, Pelagic communities, Benthic communities, Uses and abuses of the ocean.

UNIT – II Geography and physical forcing of Marine Ecosystems: (2 Weeks) (4 lectures)

Climate and Circulation of the World Ocean, Geostrophic flow and the central ocean gyres, Convergence zones and fronts, Thermohaline circulation and the origins of deep-water coasts, shallows, and their consequences; Global distribution of ocean productivity, Vertical structure of the pelagic water column, The spring bloom, High-nitrogen low-chlorophyll (HNLC) regions

UNIT – III Biodiversity and biogeography of Ocean (3 Weeks) (6 lectures)
Magnitude of Biodiversity; Biodiversity on Land and Sea, Phylogenetic Classification of Marine Biodiversity, Functional Organization of Pelagic and Benthic Life, Major Patterns in the Distribution of Marine Life (Spatial, latitudinal, longitudinal, depth, bottom type); Biogeography of Functional Traits, Evidence for Island Biogeography, Integrative Models of Marine Diversification, Biogeographic Classifications of the Ocean, Biogeography of the Anthropocene Ocean.

UNIT – IV Macro- and trait-based ecology of marine organisms (3 Weeks) (6 lectures)
Species Interactions, Functional groups of phytoplankton, benthic macrophytes, and grazers; Pelagic food webs, microbial loop, Metabolic scaling and life history, Abundance and the energetic equivalence rule, Macroecology of range size Specialization and resource partitioning, Nonequilibrium dynamics; Biological pump and the global carbon cycle, Trophic control in pelagic ecosystems.

UNIT – V Anthropocene Ocean (2½ Weeks) (5 lectures)
Marine populations in the Anthropocene, Marine defaunation and trophic skew, Empirical evidence for regime shifts in marine ecosystems, Mechanisms of marine regime shifts, Ocean Warming and its effects on community and sea level rise, Ocean Acidification and its effects on organisms and communities, Ecological stoichiometry, Climate change and redistribution of global marine fauna, Tropicalization, The Arctic opening

UNIT – VI Ocean Conservation and Management (2½Weeks) (5 lectures)
Maximum sustainable yield in fisheries, Strategic conservation of vulnerable life stages, Life history and the effectiveness of marine reserves, Organismal Fitness and Adaptation to the Environment, Dispersal, Recruitment, and Metapopulations, Tagging and tracking, Geochemical tags.

Teaching and learning interface for theoretical concepts

To achieve the course objectives and match with the contents, a wide range of teaching and learning tools will be employed, including (a) Formal lectures; (b) Interactive sessions using visual aid; (c) Case study analyses; (d) Hypothetical scenario building; (e) Group discussion on key topics; and (f) documentary screening and critical analyses.

Practicals/Hands-on Exercises – based on theory (02 Credits: 60 hours)

1. Construct microcosm for marine ecology studies
2-3. Determine environmental partitioning of target chemicals in the constructed microcosm
4-5. Determine physico-chemical properties of given sediment sample
6-7. Examine methods to analyze phytoplankton and zooplanktons in the given water samples and its application in analyzing marine ecology
8. Analyze relationships between soil particle characteristics and biological

properties of sediment

9. Analyze oceanographic data by GIS and identify ecologically-relevant oceanographic data using remote sensing
10. Isolate bacteria from the freshwater river and estimate their growth in seawater
11. Determine microbial density in a given marine water sample
12. Compare the biodiversity of freshwater bodies and marine ecosystems by examining a review/research paper
13. Analyze plate tectonic theory and understand the variations in global marine ecosystems
14. Evaluate merit and demerits of ocean acidification manipulation experiments conducted globally
15. Compare and contrast the benefits of using a storage tank, mixing tank, header tank and experimental tank to understand marine ecology

Teaching and learning interface for practical skills

To impart training on technical and analytical skills related to the course objectives, a wide range of learning methods will be used, including (a) laboratory practicals; (b) field-work exercises; (c) customized exercises based on available data; (d) survey analyses; and (e) developing case studies; (f) demonstration and critical analyses; and (h) experiential learning individually and collectively.

Essential/recommended readings

- Arias, A.H. and Menendez, M.C. eds., 2013. Marine Ecology in a Changing World. CRC Press.
- Garrison, T.S., 2014. Essentials of Oceanography. Cengage Learning.
- Kennish, M.J., 2019. Practical Handbook of Marine Science. CRC Press.
- Kaiser, M.J., Jennings, S., Thomas, D.N. and Barnes, D.K., 2011. Marine Ecology: Processes, Systems, and Impacts. Oxford University Press.
- Mann, K.H. and Lazier, J.R., 2013. Dynamics of Marine Ecosystems: Biological-Physical Interactions in the Oceans. John Wiley & Sons.
- Speight, M.R. and Henderson, P.A., 2013. Marine Ecology: Concepts and Applications.
- Thrush, S., Hewitt, J., Pilditch, C. and Norkko, A., 2021. Ecology of Coastal Marine Sediments: Form, Function, and Change in the Anthropocene. Oxford University Press.

Suggestive readings

- Gray, J.S. and Elliott, M., 2009. Ecology of Marine Sediments: from Science to Management. Oxford University Press.
- Miller, C.B., 2009. Biological Oceanography. John Wiley & Sons.
- Pittman, S.J. ed., 2017. Seascape Ecology. John Wiley & Sons.
- Riley, J.P. and Chester, R. eds., 2016. Chemical Oceanography. Elsevier.
- Talley, L.D., 2011. Descriptive Physical Oceanography: An Introduction. Academic press.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVE (DSE-EVS-01): ENVIRONMENTAL ECONOMICS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical/ Practice		
DSE-EVS-01: ENVIRONMENTAL ECONOMICS	4	2	0	2	Class XII pass	NA

Learning objectives

The Learning Objectives of this course are as follows:

- Appreciate critical linkages between fundamentals of environmental economics and environmental conservation
- Evaluate five megatrends involving climate, development, ecology, economy, and technology
- Inculcate market-based instruments in designing sustainable development approaches
- Gain insights into intricacies of economic valuation of biodiversity and ecosystems for making evidence-based conservation and development priorities
- Empower with the integrated use of economics & ecology in decision-making and law-making processes.

Learning outcomes

After the course, the students will be able to

- Use cost-benefit analysis and valuation techniques for environmental economics and natural resource management
- Implement economic and ecological concepts to influence society and policymakers for environmental and biodiversity conservation
- Act as a consultant to industries and government ministries aiming for sustainability
- Serve as a catalyst for developing ecoliterate industry and evolving sustainable policies
- Evolve ideas and economics-based techniques to design policy instruments for pollution control and management

SYLLABUS OF DSE-EVS-01

Theory (02 Credits: 30 lectures)

UNIT – I Introduction to microeconomics (3½ Weeks) (07 lectures)
Definition and scope of environmental economics; environmental economics versus traditional economics; brief introduction to major components of economy: consumer, firm and their interaction in the market, producer and consumer surplus, market failure, law of demand and supply, tangible and non-tangible goods; utilitariasm; Pareto optimality; compensation principle.

UNIT – II Environmental economics (4 Weeks) (08 lectures)
Main characteristics of environmental goods; marginal analysis; markets and market failure; social benefit, costs and welfare functions; meaning and types of environmental values; measures of economic values; tangible and intangible benefits; Pareto principle or criterion; Hardin's Thesis of 'The Tragedy of Commons'; Prisoner's dilemma game; methods of abatement of externalities; social cost-benefit analysis; cost-effectiveness analysis.

UNIT – III Economic solutions to environmental problems (3½ Weeks) (07 lectures)
Social costs and benefits of environmental programmes: marginal social benefit of abatement, marginal social cost of abatement; pollution control: policies for controlling air and water pollution, disposal of toxic and hazardous waste- standards vs. emissions charges, environmental subsidies, modelling and emission charges; polluter pay principles; pollution permit trading system.

UNIT – IV Natural resource economics (1½ Weeks) (03 lectures)
Economics of non-renewable resources; economics of fuels and minerals; Hotelling's rule and extensions; taxation; economics of renewable resources; economics of water use, management of fisheries and forests; introduction to natural resource accounting.

UNIT –V Tools for environmental-economic policy (2½ Weeks) (05 lectures)
Growth and environment; environmental audit and accounting, Kuznets curve, environmental risk analysis, assessing benefits and cost for environmental decision making; cost-benefit analysis and valuation: discounting, principles of Cost-Benefit Analysis, estimation of costs and benefits, techniques of valuation, adjusting and comparing environmental benefits and costs.

Teaching and learning interface for theoretical concepts

To achieve the course objectives and match with the contents, a wide range of teaching and learning tools will be employed, including (a) Formal lectures; (b) Interactive sessions using visual aid; (c) Case study analyses; (d) Hypothetical scenario building; (e) Group discussion on key topics; and (f) documentary screening and critical analyses.

Practicals/Hands-on Exercises – based on theory (02 Credits: 60 hours)

1. Conduct cost-benefit analysis of any developmental project
2. Investigate underlying pattern of behavioural economics of selected environmental problem and suggest appropriate solution
3. Calculate energy requirements for decent living in a given country in the background of climate change
4. Determine the potential economic challenges of decarbonization policies and practices being adopted by a country of your choice
5. Apply LCA tools to calculate the energy of construction and manufacturing for appliances, buildings and infrastructure and assess sustainability of the given country
6. Analyze demand and supply curve using
7. Use demand or supply concept and provide empirical evidence on the effects of climate change on the macroeconomy
8. Compare and contrast the demand for and supply of EQ in developed and developing countries
9. Use Marginal Curve Analysis for a given pollution and determine the efficient level of pollution to maximize the net benefits of pollution
10. Determine the social cost of carbon (SCC) to minimize the climate change damages in the cost-benefit analysis of a given project that increase or reduce carbon emission
11. Calculate the value of damages incurred due to release of an additional tonne of carbon into the atmosphere
12. Use Demand for and supply of environmental quality (EQ) in the Environmental Kuznets Curve (EKC) hypothesis
13. Show the usefulness of (a) utility curve analysis, (b) indifference curve analysis, (c) production possibility frontier, (d) market failure or market equilibrium, and (e) Prisoners' dilemma game
14. Conduct an environmental audit of your institution and suggest strategies to improve its sustainability status

Teaching and learning interface for practical skills

To impart training on technical and analytical skills related to the course objectives, a wide range of learning methods will be used, including (a) laboratory practicals; (b) field-work exercises; (c) customized exercises based on available data; (d) survey analyses; and (e) developing case studies; (f) demonstration and critical analyses; and (h) experiential learning individually and collectively.

Essential/recommended readings

- Callan, S.J. and Thomas, J.M., 2013. Environmental economics and management: Theory, policy, and applications. Cengage learning.
- Hanley, N., Shogren, J.F. and White, B., 2016. Environmental economics: in theory and practice. Macmillan International.
- Hawken, P., Lovins, A.B. and Lovins, L.H., 2013. *Natural Capitalism: The Next Industrial Revolution*. Routledge.
- Kolstad, C.D. 2010. Environmental Economics. Oxford University Press.
- Thomas, J.M. & Callan, S.J. 2007.Environmental Economics. Thomson Learning Inc.
- Thampapillai, D.J. and Ruth, M., 2019. Environmental Economics: Concepts, Methods and Policies. Routledge.
- Tietenberg, T. and Lewis, L., 2018. Environmental and Natural Resource Economics. Routledge.

Suggestive readings

- Stahel, W.R. and MacArthur, E., 2019. The Circular Economy: A User's Guide. Routledge, NY, USA.
- Frodermann, L., 2018. *Exploratory Study on Circular Economy Approaches*. Springer, Fachmedien Wiesbaden.
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Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVES (DSE-EVS-2): SOLID WASTE MANAGEMENT

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical/ Practice		
DSE-EVS-2: SOLID WASTE MANAGEMENT	4	2	0	2	Class XII pass	NA

Learning objectives

The Learning Objectives of this course are as follows:

- Understand physical and chemical processes for classifying, segregating, and managing solid wastes
- Characterize the different solid waste types and apply interdisciplinary knowledge for effective solid waste collection and processing of solid waste
- Compare methods of collection, transfer, storage, treatment, disposal, and use of solid waste in developed and developing nations
- Management, construction, and operations of landfill and other solid waste management facilities

Learning outcomes

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

- Conduct the life cycle assessment of solid waste and its impact on the urban metabolisms
- Identify and select landfill sites using GIS and other analytical techniques
- Examine and apply technical and legal solutions for sustainable management of solid waste
- Plan and design waste recycling programmes, compost and incineration facilities, and landfills
- Mine and analyze the relevant data and apply multiple criteria decision-making systems for a sustainable integrated solid waste management plan

SYLLABUS OF DSE-EVS-02

Theory (02 Credits: 30 lectures)

UNIT – I Effect of solid waste disposal on the environment (3 Weeks) (6 lectures)
Sources and generation of solid waste, their classification and chemical composition; characterization of municipal solid waste; hazardous waste and biomedical waste. Impact of solid waste on environment, human and plant health; effect of solid waste and industrial effluent discharge on water quality and aquatic life; mining waste and land degradation; effects of landfill leachate on soil characteristics and groundwater pollution.

UNIT – II Common methods to manage solid waste (2 Weeks) (4 lectures)
Different techniques used in the collection, storage, transportation and disposal of solid waste (municipal, hazardous and biomedical waste); landfill (traditional and sanitary landfill design); thermal treatment (pyrolysis and incineration) of waste material; drawbacks in waste management techniques.

UNIT – III Industrial waste management and resource recovery (4 Weeks) (8 lectures)
Types of industrial waste: hazardous and non-hazardous; effect of industrial waste on air, water and soil; industrial waste management and its importance; stack emission control and emission monitoring; effluent treatment plant and sewage treatment plant. 4R- reduce, reuse, recycle and recover; biological processing - composting, anaerobic digestion, aerobic treatment; reductive dehalogenation; mechanical biological treatment; green techniques for waste treatment.

UNIT – IV Integrated waste management and waste-to-energy (4 Weeks) (8 lectures)
Concept of Integrated waste management; waste management hierarchy; methods and importance of Integrated waste management. Concept of energy recovery from waste; refuse-derived fuel (RDF); different WTE processes: combustion, pyrolysis, landfill gas (LFG) recovery; anaerobic digestion; gasification. Life-cycle assessment (LCA): Cradle to grave approach; lifecycle inventory of solid waste; role of LCA in waste management; advantage and limitation of LCA; case study on LCA of a product.

UNIT – V Policies for solid waste management (2 Weeks) (4 lectures)
Municipal Solid Wastes (Management and Handling) Rules 2000; Hazardous Wastes Management and Handling Rules 1989; Bio-Medical Waste (Management and Handling) Rules 1998; Ecofriendly or green products.

Teaching and learning interface for theoretical concepts

To achieve the course objectives and match with the contents, a wide range of teaching and learning tools will be employed, including (a) Formal lectures; (b) Interactive sessions using visual aid; (c) Case study analyses; (d) Hypothetical scenario building; (e) Group discussion on key topics; and (f) documentary screening and critical analyses.

Practicals/Hands-on Exercises – based on theory (02 Credits: 60 hours)

1. Conduct life cycle assessment of solid waste generated in your institute/residential area/city
2. Design a composting pit for solid waste management in your institute or its nearby area
3. Conduct geotechnical characterization of the selected solid waste generated in the given area
4. Determine microbial density in the given solid waste collected from your institute
5. Estimate environmental impacts of greenhouse gases released and energy recovery from solid waste being collected in a given landfill
6. Assess cost-benefit analysis of various processing options of the given solid waste being managed in your city
7. Field survey of solid waste dumping site of your city, document the quantum of waste being collected and stored, and identify the hidden environmental issues
8. Analyze the site plan of the waste dumping site visited in 7, and compare and contrast it with the most successful design being used in the given developed country
9. Screen a documentary on solid waste management of national or international relevance. Identify and analyze socio-economic impacts and suggest scientific solutions to address the concerned environmental challenges.
10. Critically evaluate the recent plastic management policy of your country and make specific recommendations for immediate amendment aiming for environmental sustainability
11. Select a type of solid waste and prepare a documentary of its management in your city highlighting the merit/demerit of current practices, associated socio-economic and environmental issues and possible solutions suggested by experts
12. Compare and contrast solid waste management practices being adopted in two areas of your city with photographic and videographic evidence

Teaching and learning interface for practical skills

To impart training on technical and analytical skills related to the course objectives, a wide range of learning methods will be used, including (a) laboratory practicals; (b) field-work exercises; (c) customized exercises based on available data; (d) survey analyses; and (e) developing case studies; (f) demonstration and critical analyses; and (h) experiential learning individually and collectively.

Essential/recommended readings

- Bagchi, A. 2004. Design of Landfills and Integrated Solid Waste Management. John Wiley & Sons.
- Blackman Jr, W.C., 2016. Basic Hazardous Waste Management. CRC press.
- Chang, N.B. and Pires, A., 2015. Sustainable Solid Waste Management: A Systems Engineering Approach. John Wiley & Sons.

- Kaza, S., Yao, L., Bhada-Tata, P. and Van Woerden, F., 2018. What A Waste 2.0: A Global Snapshot of Solid Waste Management to 2050. World Bank Publications.
- McDougall, F. R., White, P. R., Franke, M., & Hindle, P. 2008. Integrated Solid Waste Management: A Life Cycle Inventory. John Wiley & Sons.
- Rada, E.C. ed., 2016. Solid Waste Management: Policy and Planning for a Sustainable Society. CRC Press.

Suggestive readings

- Asnani, P.U. and Zurbrugg, C., 2007. Improving Municipal Solid Waste Management in India: A Sourcebook for Policymakers and Practitioners. World Bank Publications.
- Christensen, T. ed., 2011. Solid Waste Technology and Management. John Wiley & Sons.
- Tchobanoglous, G. and Kreith, F., 2002. Handbook of Solid Waste Management. McGraw-Hill Education.
- Vanatta, B., 2000. Guide for Industrial Waste Management. Diane Publishing.

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DISCIPLINE SPECIFIC ELECTIVE (DSE-EVS-3): ENVIRONMENTAL MODELLING

Credit distribution, Eligibility and Pre-requisites of the Course

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical/ Practice		
DSE-EVS-3: ENVIRONMENTAL MODELLING	4	2	0	2	Class XII pass	NA

Learning objectives

The Learning Objectives of this course are as follows:

- Gain insights into the concepts, methods, tools and application of environmental modelling
- Appreciate modelling approach with a clear understanding of its scope, limitations and complexity
- Improve knowledge of fate and transport of pollutants and important natural processes and events
- Empower with the application of modelling in ecosystem management via better environmental management, decision making and policy development

Learning outcomes

After the course, students will be able to:

- Choose the appropriate model for a given ecological question or environmental concern
- Overcome the common challenges of model building for improved predictability
- Evolve a better plan to implement and validate model outputs
- Apply models while keeping in view the strength and weaknesses of different model types
- Practice sustainability management, implement cleaner technologies, and argue in favour of environmental protection.

SYLLABUS OF DSE-EVS-3

Theory (02 Credits: 30 lectures)

UNIT – I Working with models (4 Weeks) (8 lectures)

Goals, objectives, scope and process of modelling in the environment. Modelling approach: deterministic, stochastic and physical. How to choose, construct and interpret statistical models, Statistical frameworks, Philosophy of statistical modeling, Fitting models to realworld data, Techniques–from simple (distribution fitting) to complex (state-space modeling), Techniques for data manipulation and display. Uncertainties in model development: Design, analysis, documentation, and communication; Data availability and optimal modelling, Reliability of ecological models

UNIT – II Modelling in Science and Environment (5 Weeks) (12 lectures)
Science models: Visual models, Mathematical models, and Computer models. Model types: Conceptual, Mathematical, and Computational Models; Individual- or agent-based models, Unstructured population models, and Stage-structured matrix models, Single-, two-, and three-state variable models. Environmental models: Fate and transport models, Emissions and activities models, Exposure models, and Impact models; Models of common ecosystems (aquatic, terrestrial, and man-managed) for biodiversity conservation and ecosystem management; Model of the socio-ecological system.

UNIT – III Models for "out of balance" or environmental problems (5 Weeks) (10 lectures)
Acidification models in water pollution, Eutrophication models, Models of oxygen depletion, Fire and the spread of fire, Air pollution, Toxic substance pollution, Climate, weather and global warming, Environmental/ecological modeling for regulatory risk assessments and hazard predictions.

Teaching and learning interface for theoretical concepts

To achieve the course objectives and match with the contents, a wide range of teaching and learning tools will be employed, including (a) Formal lectures; (b) Interactive sessions using visual aid; (c) Case study analyses; (d) Hypothetical scenario building; (e) Group discussion on key topics; and (f) documentary screening and critical analyses.

Practicals/Hands-on Exercises – based on theory (02 Credits: 60 hours)

1. Test and practice different steps of model development
2. Validate the functioning of the model developed at 1
3. Apply the model to predict outcomes of different environmental scenarios
4. Formulate mathematical and computational models to visualize solar radiance on Earth
5. Develop model wind speed at a given area for establishing wind energy and power plant
6. Evaluate the given multiple leaf-layer model
7. Formulate, implement and evaluate the discrete model for population dynamics
8. Develop a model to predict predator-prey dynamics
9. Analyze competition between different species using an appropriate model
10. Model hydrological networks of the given area
11. Visualize digital elevation data for hydrological network analysis

12. Compare and contrast commonly used software for environmental and ecological modelling

Teaching and learning interface for practical skills

To impart training on technical and analytical skills related to the course objectives, a wide range of learning methods will be used, including (a) laboratory practicals; (b) field-work exercises; (c) customized exercises based on available data; (d) survey analyses; and (e) developing case studies; (f) demonstration and critical analyses; and (h) experiential learning individually and collectively.

Essential/recommended readings

- Beven, K., 2018. Environmental modelling: an uncertain future? CRC press.
- Essington, T.E., 2021. Introduction to Quantitative Ecology: Mathematical and Statistical Modelling for Beginners. Oxford University Press.
- Holzbecher, E., 2012. Environmental Modelling: Using MATLAB. Springer Science & Business Media.
- Jørgensen, S.E., 2009. Ecological Modelling: An Introduction. WIT press.
- Kelly, R.E., Drake, N.A. and Barr, S.L. eds., 2004. Spatial Modelling of the terrestrial environment. John Wiley & Sons.
- Sang, N. ed., 2020. Modelling Nature-Based Solutions: Integrating Computational and Participatory Scenario Modelling for Environmental Management and Planning. Cambridge University Press.
- Skidmore, A., 2017. Environmental Modelling with GIS and Remote Sensing. CRC Press.
- Wainwright, J. and Mulligan, M. eds., 2013. Environmental Modelling: Finding Simplicity in Complexity. John Wiley & Sons.

Suggestive readings

- Clark, J.S. and Gelfand, A.E. eds., 2006. Hierarchical modelling for the environmental sciences: statistical methods and applications. OUP Oxford.
- Emetere, M.E., 2019. Environmental Modeling Using Satellite Imaging and Dataset Re-processing. Springer International Publishing.
- Fort, H., 2020. Ecological Modelling and Ecophysics: Agricultural and Environmental Applications. IOP Publishing.
- Parnis, J.M. and Mackay, D., 2020. Multimedia Environmental Models: The Fugacity Approach. CRC Press.
- Soetaert, K. and Herman, P.M., 2009. A Practical Guide to Ecological Modelling: Using R as a Simulation Platform (Vol. 7, No. 7). New York: Springer.

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DISCIPLINE SPECIFIC ELECTIVE (DSE-EVS-4): BIOPROSPECTING

Credit distribution, Eligibility and Pre-requisites of the Course

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical/ Practice		
DSE-EVS-4: BIOPROSPECTING	4	2	0	2	Class XII pass	NA

Learning objectives

The Learning Objectives of this course are as follows:

- Learning the concepts and practices of bioprospecting.
- Empower with traditional and modern knowledge related to bioprospecting
- Gain insights into the discovery of novel chemicals of industrial and ecological significance
- Link between the traditional knowledge and the current state of development
- Approaches being used for bioprospecting and regulations relevant to safeguard biodiversity and traditional knowledge

Learning outcomes:

After the course, students will be able to

- Inventorize and monitor biodiversity in different agro-ecological regions
- Act as a catalyst in the discovery of novel compounds from biodiversity across the ecosystems
- Identify alternative sources of chemicals/genes relevant to industry and society
- Evolve combinatorial approaches for screening and isolation of targeted compounds/genes
- Implement relevant policies and laws for safeguarding biodiversity and ancient knowledge

SYLLABUS OF DSE-EVS-4

Theory (02 Credits: 30 lectures)

UNIT – I Concept and Scope (2 Weeks) (4 lectures)

Definition, Types, and Current practices; Relevance for society, industry, environment, ecosystems, biodiversity and policy; Global status and national efforts

UNIT – II Targets of Bioprospecting (3 Weeks) (6 lectures)
Novel chemicals, genes, genotypes, population, idea, and design. Plants, microbes, animals, bioactive compounds, and chemicals. Relevant case studies focusing on different target; Success and failure of bioprospecting in sustainable development

UNIT – III Approaches and Methods of Bioprospecting (5 Weeks) (10 lectures)
Traditional knowledge, ehnopharmaceutical, ecological, and phylogenetic; Biosynthesis and chemical modification, Genetic engineering, Expression of the target gene, Cultivation and mass propagation of target organism; Choice of approach and its limitations or strength. Tools and techniques to practice bioprospecting; Biochemical, physiological, molecular, and chemical assays; Genomic, proteomic, Computational biology and combinatorial.

UNIT – IV Application of Bioprospecting (3 Weeks) (6 lectures)
Novel drug development, Species and genetic resource conservation, Sustainable use and conservation of biodiversity, Ecosystem management, Industrial sustainability, Agriculture sustainability, Sustainable health, Disease regulation, and culture conservation, Bridge between ancient knowledge to a modern approach to sustainable development.

UNIT – V Laws and Policies Relevant to Bioprospecting (2 Weeks) (4 lectures)
Convention on biodiversity; Benefit-sharing, Biodiversity Act, Intellectual Property Rights, Biopiracy; Case studies on neem, turmeric, and basmati rice;

Teaching and learning interface for theoretical concepts

To achieve the course objectives and match with the contents, a wide range of teaching and learning tools will be employed, including (a) Formal lectures; (b) Interactive sessions using visual aid; (c) Case study analyses; (d) Hypothetical scenario building; (e) Group discussion on key topics; and (f) documentary screening and critical analyses.

Practicals/Hands-on Exercises – based on theory (02 Credits: 60 hours)

1. Field visit to a local nursery and document medicinal plants having importance in pharmaceutical industry nationally and globally and identify the bioactive compounds
2. Isolate alkaloids from target species using differential solvent fractionation techniques
3. Analyze the separated bioactive compound from 2 using wavelength spectra and chromatographic technique
4. Determine the antimicrobial activity of the given compound or compound fractionated in 2
5. Screen microbes and plants for their ability to produce different glycosides of ecological and economic significance
6. Isolate and prospect microbes of ecological significance, especially for promoting plant growth
7. Test the given plant extract or microbial culture for their ability to control phytodiseases causing organism
8. Fractionate pigments from targeted plants and microbes and determine their potential industrial use

9. Apply computational biology and phylogenetic approach to identify the novel source of targeted compound/gene/protein or enzyme
10. Screen plants for their antioxidant potential and reduce the oxidative stress
11. Visit laboratories / Industries / Institutes engaged in bioprospecting and submit the report in a prescribed format
12. Analyze policies related to bioprospecting and identify the areas for amendments to improve their applicability

Teaching and learning interface for practical skills

To impart training on technical and analytical skills related to the course objectives, a wide range of learning methods will be used, including (a) laboratory practicals; (b) field-work exercises; (c) customized exercises based on available data; (d) survey analyses; and (e) developing case studies; (f) demonstration and critical analyses; and (h) experiential learning individually and collectively.

Essential/recommended readings

- Bull, A.T., 2004. Microbial Diversity and Bioprospecting. ASM Press.
- Hayden, C. 2020. When Nature Goes Public: The Making and Unmaking of Bioprospecting in Mexico (Vol. 1). Princeton University Press.
- Paterson, R. and Lima, N. eds., 2016. Bioprospecting: Success, Potential and Constraints (Vol. 16). Springer.
- Sampath, P.G., 2005. Regulating Bioprospecting: Institutions for Drug Research, Access, and Benefit-Sharing. United Nations University Press.
- Harvey, A.L. and Gericke, N., 2011. Bioprospecting: creating a value for biodiversity. Research in Biodiversity–Models and Applications, InTech Open, pp.323-338.

Suggested readings

- Hewlett, J., 2000. Bioprospecting: Purifying Protein by Design. Hofstra University, New York State Education Department
- Hsu, E. and Harris, S. eds., 2010. Plants, Health and Healing: On the Interface of Ethnobotany and Medical Anthropology (Vol. 6). Berghahn Books.
- Pavlinov, I. ed., 2011. Research in Biodiversity: Models and Applications. BoD–Books on Demand. InTech Open.

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