CBCS SYLLABUS

FOR

THREE YEARS UNDER-GRADUATE COURSE

IN

ENVIRONMENTAL SCIENCE (HONOURS)

(*w.e.f. 2017*)

BANKURA UNIVERSITY

BANKURA

WEST BENGAL

PIN 722155

STRUCTURE IN ENVIRONMENTAL SCIENCE (HONOURS)

SEMESTER –I

Course Code	Course Title	Credit	Marks			No. of Hours/Week		
			I.A.	ESE	Total	Lec.	Tu.	Pr.
SH/ENV/ 101/C-1	Earth and Earth Surface Processes (T+P)	6 (4+2)	10	40 (25+15)	50	4	-	4
SH/ENV / 102/C-2	Physics & Chemistry of Environment (T+P)	6 (4+2)	10	40 (25+15)	50	4	-	4
SH/ENV / 103/GE-1	Environment & Society (T+P)	6 (4+2)	10	40 (25+15)	50	4	-	4
ACSHP/104/ AECC-1	Environmental Studies	4	10	40	50	4	-	-
Total in Semester - I		**22**	**40**	**160**	**200**	**16**		**12**

SEMESTER –II

Course Code	Course Title	Credit	Marks			No. of Hours/Week		
			I.A.	ESE	Total	Lec.	Tu.	Pr.
SH/ENV / 201/C-3	Water and Water Resources (T+P)	6 (4+2)	10	40 (25+15)	50	4	-	4
SH/ENV / 202/C-4	Land and Soil Conservation and Management (T+P)	6 (4+2)	10	40 (25+15)	50	4	-	4
SH/ENV / 203/GE-2	Human- Wildlife Conflict &Management (T+P)	6 (4+2)	10	40 (25+15)	50	4	-	4
ACSHP/204/ AECC-2	English/Hind/MIL	2	10	40	50	2	-	-
Total in Semester - II		**20**	**40**	**160**	**200**	**14**		**12**

SEMESTER –III

Course Code	Course Title	Credit	Marks			No. of Hours/Week		
			I.A.	ESE	Total	Lec.	Tu.	Pr.
SH/ENV / 301/C-5	Ecology and Ecosystems (T+P)	6 (4+2)	10	40 (25+15)	50	4	-	4
SH/ENV / 302/ C-6	Environmental Biotechnology (T+P)	6 (4+2)	10	40 (25+15)	50	4	-	4
SH/ENV /303/C-7	Atmosphere & Global Climate Change (T+P)	6 (4+2)	10	40 (25+15)	50	4	-	4
SH/ENV / 304/GE-3	Gender &environment (T+P)	6 (4+2)	10	40 (25+15)	50	4	-	4
SH/ENV / 305/SEC-1	Remote Sensing, Geographic Information System &Modeling	2	10	40	50	2	-	-
Total in Semester - III		**26**	**50**	**200**	**250**	**18**		**16**

SEMESTER –IV

Course Code	Course Title	Credit	Marks			No. of Hours/Week		
			I.A.	ESE	Total	Lec.	Tu.	Pr.
SH/ENV /401/C-8	Systematics & Biogeography (T+P)	6 (4+2)	10	40 (25+15)	50	4	-	4
SH/ENV /402/C-9	Urban Ecosystems (T+P)	6 (4+2)	10	40 (25+15)	50	4	-	4
SH/ENV /403/C-10	Environmental Legislation & Policy (T+P)	6 (4+2)	10	40 (25+15)	50	4	-	4
SH/ENV /404/GE-4	Green Technologies (T+P)	6 (4+2)	10	40 (25+15)	50	4	-	4
SH/ENV / 405/SEC-2	Environment Impact &Risk Assessment	2	10	40	50	2	-	-
Total in Semester - IV		**26**	**50**	**200**	**250**	**18**	**-**	**16**

SEMESTER – V

Course Code	Course Title	Credit	Marks			No. of Hours/Week		
			I.A.	ESE	Total	Lec.	Tu.	Pr.
SH/ENV / 501/C-11	Biodiversity & Conservation (T+P)	6 (4+2)	10	40 (25+15)	50	4	-	4
SH/ENV / 502/C-12	Organismal & Evolutionary Biology (T+P)	6 (4+2)	10	40 (25+15)	50	4	-	4
SH/ENV / 503/DSE-1	Energy &Environment (T+P)	6 (4+2)	10	40 (25+15)	50	4	-	4
SH/ENV / 504/DSE-2	Environmental Economics (T+P)	6 (4+2)	10	40 (25+15)	50	4	-	4
Total in Semester – V		**24**	**40**	**160**	**200**	**16**		**16**

SEMESTER – VI

Course Code	Course Title	Credit	Marks			No. of Hours/Week		
			I.A.	ESE	Total	Lec.	Tu.	Pr.
SH/ENV / 601/C-13	Environmental Pollution and Human Health (T+P)	6 (4+2)	10	40 (25+15)	50	4	-	4
SH/ENV / 602/C-14	Natural Resources Management& Sustainability (T+P)	6 (4+2)	10	40 (25+15)	50	4	-	4
SH/ENV / 603/DSE-3	Natural Hazards & Disaster Management (T+P)	6 (4+2)	10	40 (25+15)	50	4	-	4
SH/ENV / 604/DSE-4	Solid Waste Management (T+P)	6 (4+2)	10	40 (25+15)	50	4	-	4
Total in Semester – VI		**24**	**40**	**160**	**200**	**16**		**16**

SH=Science Honours, Env: Environmental Science, ACSHP= Arts Commerce Science Honours pass C= Core Course, AECC= Ability Enhancement Compulsory Course, SEC= Skill Enhancement Course, GE= Generic Elective, DSE= Discipline Specific Elective IA= Internal Assessment, ESE= End-Semester Examination, Lec.=Lecture, Tu.= Tutorial, and Prc.=Practical

Details of course under B.Sc. in Environmental Science (Honours.)

Course	**Credits***	
	Theory +	**Theory +**
I. Core Courses - Theory (14 Papers)	14×4=56	14×5=70
Core Course - Practical/Tutorial*	14×2=28	14×1=14
II. Elective Courses (8 Papers)		
A1. Discipline Specific Electives - Theory (4 Papers)	4×4=16	4×4=16
A2. Discipline Specific Electives Practical/Tutorial* - (4 Papers)	4×2=8	4×2=8
B1. Generic Electives/Interdisciplinary - Theory (4 Papers)	4×4=16	4×4=16
B2. Generic Electives/Interdisciplinary - Practical/Tutorial* (4 Papers)	4×2=8	4×2=8
III. Ability Enhancement Courses		
1. Ability Enhancement Compulsory Courses (AECC) - (2 Papers of 2 Credits each) Environment Science & English/MIL Communication)	2×2=4	2×2=4
2. Skill Enhancement Courses (SEC) (2 Papers of 4 Credits each)	2×4=8	2×4=8
Total Credits	**144**	**144**

***wherever practical is mentioned there will be no tutorial and vice-versa**

Bachelor in Environment Science (Hons.) Courses/Papers Sequence					
Year 1 Semester 1	**Year 1 Semester 2**	**Year 2 Semester 1**	**Year 2 Semester 2**	**Year 3 Semester 1**	**Year 3 Semester 2**
C1: Earth and Earth Surface Processes	C3: Water and Water Resources	C5: Ecology and Ecosystems	C8: Systematics & Biogeography	C11: Biodiversity & Conservation	C13: Environmental Pollution and Human Health
C2: Physics &ChemistryofEnvironment	C4: Land and Soil Conservation and Management	C6: Environmental Biotechnology	C9: Urban Ecosystems	C12: Organismal & Evolutionary Biology	C14: Natural Resources Management & Sustainability
AECC1: Environmental Studies	AECC 2 English Communication /MIL	C7: Atmosphere& Global Climate Change	C10: Environmental Legislation & Policy	DSE1: Energy &Environment	DSE3: Natural Hazards & Disaster Management
GE 1 Environment & Society	GE 2 Human-Wildlife Conflict &Management	SEC1: Remote Sensing, Geographic Information System &Modelling	SEC2: Environment Impact &Risk Assessment	DSE2: Environmental Economics	DSE4: Solid Waste Management
		GE 3 Gender & environment	GE 4 Green Technologies		

SEMESTER –I

CORE COURSE 1:
EARTH AND EARTH SURFACE PROCESSES
(SHENV / 101/C-1)

Total credit 06 (Theory 04 and Practical 02)

Theory (60 Lectures) Marks: 25; Credit: 04

Unit 1: History of Earth (10 lectures)

Solar system formation and planetary differentiation; formation of the Earth: formation and composition of core, mantle, crust, atmosphere and hydrosphere; Chemical differentiation; geological time scale and evolution of Earth's surface features

Unit 2: Earth system processes (10 lectures)

Movement of lithospheric plates; mantle convection and plate tectonics, major plates and hot spots, plate boundaries; Sea Floor Spreading; Earthquakes, volcanism and orogenesis in the light of Plate Tectonic Theory; Models of Isostasy; Pratt and Airy; Continental Drift: Mechanisms and Evidences

Unit 3: Minerals and rocks (15 lectures)

Minerals and important rock forming minerals; Rock Cycle: Lithification and metamorphism; rock structure, igneous, sedimentary and metamorphic rocks; weathering: physical and biochemical processes; erosion: physical processes of erosion, factors affecting erosion

Unit 4: Earth surface processes (15 lectures)

Atmosphere: evolution of earth's atmosphere, composition of atmosphere, physical and optical properties, circulation; interfaces: atmosphere–ocean interface, atmosphere–land interface, ocean–land interface; Evolution of landforms in fluvial, glacial, Aeolian and coastal processes

Unit 5: Mountain: Origin and Evolution (10 lectures)

Formation of Peninsular Indian mountain systems - Western and Eastern Ghats, Vindhyas, Aravallis, and Satpura. Formation of the Himalaya; Evolution of Himalayan and peninsular river systems; formation of Indo-Gangetic Plains,

Practical: Marks 15; Credit: 2

A) Identification of rocks and mineral specimens and their characteristics.
B) Identification of Denudation Processes: Weathering, Erosion and Deposition.
C) Identification of major landforms in the area.

Suggested Readings

1. Bridge, J., &Demicco, R. 2008. *Earth Surface Processes, Landforms and Sediment deposits*. Cambridge University Press.
2. Duff, P. M. D., & Duff, D. (Eds.). 1993. *Holmes' Principles of Physical Geology*. Taylor & Francis.
3. Gupta, A. K., Anderson, D. M., & Overpeck, J. T. 2003. Abrupt changes in the Asian southwest monsoon during the Holocene and their links to the North Atlantic Ocean. *Nature* **421:** 354-357.
4. Gupta, A. K., Anderson, D. M., Pandey, D. N., &Singhvi, A. K. 2006. Adaptation and human migration, and evidence of agriculture coincident with changes in the Indian summer monsoon during the Holocene. *Current Science* **90:** 1082-1090.
5. Keller, E.A. 2011. *Introduction to Environmental Geology* (5^{th}edition). Pearson PrenticeHall.
6. Krishnan, M. S. 1982. *Geology of India and Burma*. CBS Publishers & Distributors.
7. Leeder, M., Arlucea, M.P. 2005. *Physical Processes in Earth and Environmental Sciences.* Blackwell Publishing.
8. Pelletier, J. D. 2008. *Quantitative Modeling of Earth Surface Processes* (Vol. 304). Cambridge: Cambridge University Press. Chicago.
9. ErachBharucha:Text book of Environmental Studies for Undergraduate Course. Orient BlackswanPvt Ltd.

CORE COURSE 2:

PHYSICS AND CHEMISTRY OF ENVIRONMENT
(SHENV / 102/C-2)
Total credit 06 (Theory 04 and Practical 02)

Theory (60 Lectures) Marks: 25; Credit: 04

Unit 1: Fundamentals of environmental physics (15 lectures)

Part A: Basic concepts of light and matter; quantum mechanics (relation between energy, wavelength and frequency), Electromagnetic spectrum; black body radiation, Kirchhoff's law, Boltzmann equation, photovoltaic and solar cells; scattering of light, Rayleigh and Mie scattering.
Part B: CoriolisForce, gravitational, centripetal, and centrifugal force; concept of heat transfer, conduction, convection; concept of adiabatic lapse rate (dry and moist adiabatic); laws of thermodynamics; concept of heat and work

Unit 2: Movement of pollutants in environment (6 lectures)

Diffusion and dispersion, point and area source pollutants, pollutant dispersal; Gaussian plume model, mixing heights, hydraulic potential, Darcy's equation, types of flow, turbulence.

Unit 3: Fundamentals of environmental chemistry (15 lectures)

Part A: Atomic structure, electronic configuration, periodic properties of elements (ionization potential, electron affinity and electronegativity), types of chemical bonds (ionic, covalent, coordinate and hydrogen bonds); mole concept, molarity and normality,

Part B: Thermodynamic system; types of chemical reactions; acids, bases and salts, solubility products; solutes and solvents; redox reactions, concepts of pH

Part C: Basic concepts of organic chemistry, hydrocarbons, aliphatic and aromatic compounds, organic functional groups, polarity of the functional groups, synthesis of xenobiotic compounds like pesticides and dyes, synthetic polymers.

Unit 4: Atmospheric chemistry (8 lectures)

Composition of atmosphere; photochemical reactions in atmosphere; smog formation, types of smog (sulphur smog and photochemical smog), aerosols; chemistry of acid rain, ozone layer depletion, role of CFCs in ozone depletion.

Unit 5: Water chemistry (8 lectures)

Chemical and physical properties of water; alkalinity and acidity of water, hardness of water, calculation of total hardness; solubility of metals, complex formation and chelation; colloidal particles; heavy metals in water.

Unit 6: Soil chemistry (8 lectures)

Soil composition; relation between organic carbon and organic matter, inorganic and organic components in soil; soil humus; cation and anion exchange reactions in soil; nitrogen, phosphorus and potassium in soil; phenolic compounds in soil.

Practical: Marks 15; Credit:02

A) Measurement of dust particle and soil horizon.
B) To study a soil profile; Measurement of soil temperature and moisture, organic carbon and NPK.
C) To determine pH, chloride, sulphate and nitrate composition of soil.

Suggested Readings

1. Beard, J.M. 2013. *Environmental Chemistry in Society* (2nd edition). CRCPress.
2. Boeker, E. &Grondelle, R. 2011. *Environmental Physics: Sustainable Energy and Climate Change*. Wiley.
3. Connell, D.W. 2005. *Basic Concepts of Environmental Chemistry* (2nd edition). CRCPress.
4. Forinash, K. 2010. *Foundation of Environmental Physics*. Island Press.
5. Girard, J. 2013. *Principles of Environmental Chemistry* (3rd edition). Jones &Bartlett.
6. Harnung, S.E. & Johnson, M.S. 2012. *Chemistry and the Environment*. Cambridge University Press.
7. Hites, R.A. 2012. *Elements of Environmental Chemistry* (2nd edition). Wiley &Sons.
8. Manhan, S. E. 2000. *Fundamentals of Environmental Chemistry*. CRC Press.
9. Pani, B. 2007. *Textbook of Environmental Chemistry*. IK international Publishing House.

GENERAL ELECTIVE 1:

ENVIRONMENT AND SOCIAL ISSUES
(SHENV / 103/GE-1)

Total credit 06 (Theory 04 and Practical 02)

Theory (60 Lectures) Marks: 25 ;Credit: 04

Unit 1: Introduction(6 lectures)

Social and cultural construction of 'environment'; environmental thought from historical and contemporary perspective; Environmental education and Ethics; Deep and shallow ecology.

Unit 2: Issues in environmentalism(10 lectures)

Significant global environmental issues such as climate change, and resource depletion; historical developments in cultural, social and economic issues related to land, forest, and water management in a global context; interface between environment and society.

Unit 3: Development-environment conflict(10 lectures)

Developmental issues and related impacts such as ecological degradation; ecorestoration; environmental pollution; development-induced displacement, resettlement, and rehabilitation: discussion on Project Affected People (PAPs).

Unit 4: Urbanization and environment(10 lectures)

Production and consumption oriented approaches to environmental issues in Indian as well as global context; impact of industry and technology on environment; urban sprawl, traffic congestion and social-economic problems.

Unit 5: Environment and social inequalities (10 lectures)

Inequalities of race, class, gender, region, and nation-state in access to healthy and safe environments; history and politics surrounding environmental, ecological and social justice.

Unit 6: Regulatory framework(4 lectures)

Brief account of Forest Conservation Act 1980, 1988; Land Acquisition Act, 1894, 2007, 2011, 2012; Land Acquisition Rehabilitation and Resettlement Act, 2013.

Unit 7: Community participation(10 lectures)

State, corporate, civil society, community, and individual-level initiatives to ensure sustainable development; case studies of environmental movements (Appiko Movement, Chipko Movement, Narmada BachaoAndolan); corporate responsibility movement; appropriate technology movement; environmental groups and movements, citizen groups; role played by NGOs.

Practical: Tutorials, analysis and exercise based on: Marks:15; Credit 02

A) Preparation of Environmental Impact Assessment of any developmental project.

B) Urban Traffic Survey to assess the vehicular pollution.

C) Environmental Perception survey in rural or urban area.

Suggested Readings

1. Chokkan, K.B., Pandya, H. &Raghunathan, H. (eds). 2004. *Understanding Environment*. Sagar Publication India Pvt. Ltd., New Delhi.
2. Elliot, D. 2003. *Energy, Society and Environment, Technology for a Sustainable Future*. Routledge Press.
3. Guha, R. 1989. *Ecological change and peasant resistance in the Himalaya*. Unquiet Woods, Oxford University Press, Delhi.
4. Leopold, A. 1949. *The Land Ethic*. pp. 201-214. Chicago, USA.
5. National Research Council (NRC). 1996. *Linking Science and Technology to Society's Environmental Goals*. National Academy Press.
6. Pandit, M.K. 2013. Chipko: Failure of a Successful Conservation Movement. In: Sodhi, N.S., Gibson, L. & Raven, P.H. *Conservation Biology: Voices from the Tropics.* pp. 126-127. Wiley- Blackwell, Oxford, UK.

SEMESTER –II

CORE COURSE 3:
WATER AND WATER RESOURCES
(SHENV / 201/C-3)
Total credit 06 (Theory 04 and Practical 02)

Theory (60 Lectures) Marks: 25; Credit: 04

Unit 1: Introduction (4 lectures)

Sources and types of water; hydrological cycle; precipitation, runoff, infiltration, evaporation, evapo-transpiration; classification of water resources (oceans, rivers, lakes and wetlands).

Unit 2: Properties of water (8 lectures)

Physical: temperature, colour, odour, total dissolved solids and total suspended solids; Chemical: major inorganic and organic constituents, dissolved gases, DO, COD, BOD, acidity and alkalinity, electrical conductivity, sodium adsorption ratio; Biological: phytoplankton, benthos, zooplankton, micro and macro-invertebrates.

Unit 3: Surface and subsurface water (12 lectures)

Introduction to surface and ground water; surface and ground water pollution; water table; vertical distribution of water; formation and properties of aquifers; techniques for ground water recharge; river structure and patterns; watershed and drainage basins; importance of watershed and watershed management; rain water harvesting in urban settings.

Unit 4: Wetlands and their management (8 lectures)

Definition of a wetland; types of wetlands (fresh water and marine); ecological significance of wetlands; threats to wetlands; wetland conservation and management; Ramsar Convention, 1971; major wetlands of India.

Unit 5: Marine resource management (6 lectures)

Marine resources; commercial use of marine resources; threats to marine ecosystems and resources; resource management ofmarine ecosystem (planning approach, construction techniques and monitoring of coastal zones).

Unit 6: Water resource in India (8 lectures)

Demand for water (agriculture, industrial, domestic); overuse and depletion of surface and ground water resources; water quality standards in India; hot spots of surface water; role of state in water resources management**.**

Unit 7: Water resources conflicts (8 lectures)

Water resources and sharing problems, case studies on Kaveri and Krishna river water disputes; Multi- purpose

river valley projects in India and their environmental and social impacts; case studies of dams- Narmada and Tehri dam – social and ecological losses versus economic benefits; International conflicts on water sharing between India and her neighbours; agreements to resolve these conflicts.

Unit 8: Major laws and treaties (6 lectures)

National water policy; water pollution (control and prevention) Act 1972; Indus water treaty; Ganges water treaty; Teesta water treaty; National River linking plan: ecological and economic impacts.

Practical: Marks: 15; Credit: 02

A) Estimation of water parameters— Sacchi disc transperancy, DO, combined CO_2, salinity, hardness, alkalinity, acidity, chloride, BOD
B) Determination of Electrical Conductivity by Conductivity Meter

Suggested Readings

1. Bansil, P.C. 2004. *Water Management in India*. Concept Publishing Company, India.
2. Brebbia, C.A. 2013. *Water Resources Management VII*. WIT Press.
3. CEA. 2011. *Water Resources and Power Maps of India*. Central Board of Irrigation & Power.
4. Grumbine, R.E. &Pandit, M.K. 2013. Threats from India's Himalaya dams. *Science* **339**: 36- 37.
5. Loucks, D.P., Stedinger, J.R. &Haith, D. A. 1981. *Water Resource Systems Planning and Analysis*. Englewood Cliffs, NJ, Prentice Hall.
6. Mays, L.W. 2006. *Water Resources Sustainability*. The McGraw-Hill Publications.
7. Schward& Zhang, 2003. *Fundamentals of Groundwater*. John Willey and Sons.
8. Souvorov, A.V. 1999. *Marine Ecologonomics: The Ecology and Economics of Marine Natural Resource Management*. Elsevier Publications.
9. Vickers, A. 2001. *Handbook of Water Use and Conservation*. WaterPlow Press.

CORE COURSE 4:
LAND AND SOIL CONSERVATION AND MANAGEMENT
(SHENV / 202/C-4)

Total credit 06 (Theory 04 and Practical 02)

Theory (60 Lectures) Marks: 25; Credit: 04

Unit 1: Introduction (5 lectures)

Land as a resource, soil health; ecological and economic importance of soil; types and causes of soil degradation; impact of soil loss and soil degradation on agriculture and food security; need for soil conservation and restoration of soil fertility.

Unit 2: Fundamentals of soil science (10 lectures)

Soil formation; classification of soil; soil architecture; physical properties of soil; soil texture; soil water holding capacity; soil temperature; soil colloids; soil acidity and alkalinity; soil organic matter. Development of soil profile: Laterite and Pedzol

Unit 3: Soil degradation – causes (10 lectures)

Soil resistance and resilience; nature and types of soil erosion; non-erosive and erosive soil degradation; losses of soil moisture and its regulation; nutrient depletion; soil pollution due to mining and mineral extraction, industrial and urban development, toxic organic chemicals, and organic contaminants in soils; recycling of soil nutrients.

Unit 4: Landuse changes and land degradation (15 lectures)

Land resources: types and evaluation; biological and physical phenomena in land degradation; visual indicators of land degradation; drivers of land degradation - deforestation, desertification; habitat loss, loss of biodiversity; land salinization; human impact.

Unit 5: Costs of land degradation (15 lectures)

Economic valuation of land degradation; onsite and offsite costs of land degradation; loss of ecosystem services; effects on farming communities; effects on food security; effects on nutrient cycles; future effects of soil degradation; emerging threats of land degradation to developing countries.

Unit 6: Controlling land degradation (5 lectures)

Sustainable landuse planning; role of databases and data analysis in landuse planning control and management; land tenure and land policy; legal, institutional and sociological factors; participatory land degradation assessment; integrating land degradation assessment into conservation.

Practical: Marks: 15; Credit: 02

A) Characterization of soil Laterite, Pedzol— Texture, Bulk density, Porosity

B) Determination of Soil parameters—pH, Colour, and conductivity.

Suggested Readings

1. Brady, N.C. & Well, R.R. 2007.*The Nature and Properties of Soils* (13th edition), Pearson Education Inc.
2. Gadgil, M. 1993. Biodiversity and India's degraded lands. *Ambio***22:** 167-172.
3. Johnson, D.L. 2006. *Land Degradation* (2nd edition). Rowman&LittlefieldPublishers.
4. Marsh, W. M. &Dozier,J. 1983. *Landscape Planning: Environmental Applications*. John Wiley and Sons.
5. Oldeman, L. R. 1994. The global extent of soil degradation. *Soil resilience and sustainable land use, 9*. (http://library.wur.nl/isric/fulltext/isricu_i26803_001.pdf).
6. Pandit, M.K. *et al.,* 2007. Unreported yet massive deforestation driving loss of endemic biodiversity in Indian Himalaya. *Biodiversity Conservation* **16**: 153-163.
7. Pandit, M.K. &Kumar, V. 2013. Land use and conservation challenges in Himalaya: Past, present and future. In: Sodhi, N.S., Gibson, L. & Raven, P.H. *Conservation Biology: Voices from the Tropics.* pp. 123-133. Wiley-Blackwell, Oxford, UK
8. Peterson, G. D., Cumming, G. S. & Carpenter, S. R. 2003. Scenario planning: a tool for conservation in an uncertain world. *Conservation Biology* 17: 358-366.
9. Scherr, S. J. 1999. *Soil degradation: A threat to developing-country food security by 2020* (Vol. 27). International Food Policy Research Institute.
10. MahuaBasu&S.Xavier: Fundamentals of Environmental Studies.Cambridge University press.
11. Chapman: Ecology.Cambridge University press.

GENERAL ELECTIVE 2:
HUMAN-WILDLIFE CONFLICT AND MANAGEMENT
(SHENV / 203/GE-2)

Total credit 06 (Theory 04 and Practical 02)

Theory (60 Lectures) Marks: 25; Credit: 04

Unit 1: Introduction to wildlife management (10 lectures)

Need and policy frame of wildlife conservation: philosophy of wildlife management; Role of government, wildlife biologists and social scientists.

Unit 2: Evolution of the concept of wildlife management (10 lectures)

Journey of mankind from predator to conservator; prehistoric association between wildlife and humans: records from Bhimbetkawall paintings; excerpts from rock edicts; Bishnoi community.

Unit 3: Wildlife conservation laws in India (10 lectures)

Types of protected areas (Wildlife Sanctuaries, National Parks, Biosphere Reserves); IUCN categories of protected areas, Natural World Heritage sites; concept of core and buffer area in a protected range, brief introduction to Wildlife Protection Act, 1972; Forest Act, 1927; Environmental Protection Act, 1986; and Forest conservation Act, 1920;
Introduction of Tiger task force, Status of current protected areas in India.

Unit 4: Socio-economic and legal basis of conflicts (10 lectures)

Concepts of development and encroachment, Impact of conflict on humans and wildlife, impact of habitat fragmentation, social inequality in terms of forest conservation: luxury hotels within protected areas *vs*. displacement of native tribes, forest produce as a need *vs.* forest exploitation, introduction to tribal rights in India, demographic profile of tribes in India, importance of forest product, Scheduled tribes and other traditional Forestdwellers (Recognition of forest right) Act, 2006.

Unit 5: Wildlife conflicts (6 lectures)

Insight into the important conflicts:, Human and elephant conflicts of Junglemahal, Fisherman and tiger conflict of Sundarbans, Farmer and Bison conflict in North Bihar Plain.

Unit 6: Human wild life coexistence (14 lectures)

Symbiotic relationship between tribals and forest, forest and development, focus on the inclusive growth of tribes: community participation in forest management, case study of Chipko movement, sacred groves forests, India's Bishnoi community and their conservation practices; ecological- economic welfare and development: conservation of indigenous culture and traditions, role of international organizations: Man and biosphere programmes; concept of conservation reserves and community reserves, importance of wildlife corridors in minimizing the conflicts and conservation.

Practical: Marks: 15; Credit: 02

Preparation of field report based on the visit to a Wild Life Sanctuary/National Park/Zoo/Biosphere Reserve.
Or
Project Report to be submitted on Human Elephant conflict in Junglemahal

Suggested Readings

1. Conover, M. 2001. *Resolving Human Wildlife Conflicts*, CRC Press.
2. Dickman, A. J. 2010. Complexities of conflict: the importance of considering social factors for effectively resolving human–wildlife conflict. *Animal Conservation* **13:** 458-466.
3. Messmer, T. A. 2000. The emergence of human–wildlife conflict management: Turning challenges into opportunities. *International Biodeterioration& Biodegradation* **45**: 97-102.
4. Paty, C. 2007. *Forest Government and Tribe*. Concept Publishing Company.
5. Treves, A. &Karanth, K. U. 2003. Human-carnivore conflictand perspectives on carnivore management worldwide. *Conservation Biology* **17**: 1491-1499.
6. Woodroffe, R., Thirgood, S., &Rabinowitz, A. 2005. *People and Wildlife, Conflict or Co- existence?* (No. 9). Cambridge University Press.

SEMESTER –III

CORE COURSE 5: ECOLOGY AND ECOSYSTEMS
(SHENV / 301/C-5)
Total credit 06 (Theory 04 and Practical 02)

Theory (60 Lectures) Marks:25; Credit: 04

Unit 1: Introduction (5 lectures)

Basic concepts and definitions: ecology, landscape, habitat, biosphere, ecosystems, autecology; synecology; major terrestrial biomes.

Unit 2: Ecology of individuals (10 lectures)

Liebig's Law of the Minimum; Shelford's Law of Tolerance; ecotypes; ecoclines; acclimation; ecological niche; types of niche.

Unit 3: Ecology of populations (10 lectures)

Concept of population; r- and K-selection; characteristics of population: density, dispersion, natality, mortality, life tables, survivorship curves, age structure; population growth: geometric, exponential, logistic, density-dependent; limits to population growth.

Unit 4: Ecology of communities (10 lectures)

Community structure and organization: physiognomy, sociability, species associations, periodicity, biomass, stability, keystone species, ecotone and edge effect; species interactions: mutualism, symbiotic relationships, commensalism, amensalism, protocooperation, predation, competition, parasitism, mimicry, herbivory; ecological succession: primary and secondary successions types of successions, climax community concepts.

Unit 5: Ecosystem ecology (10 lectures)

Types of ecosystem: forest, grassland, lotic, marine, ecosystem structure and function; abiotic and biotic components of ecosystem; primary and secondary production; ecosystem connections: food chain, food web; models of energy flow; ecological efficiencies; ecological pyramids: pyramids of number, biomass, and energy.

Unit 6: Biogeochemical cycles and nutrient cycling (8 lectures)

Carbon cycle; nitrogen cycle; hydrological cycle; nutrient cycle models; ecosystem input of nutrients; biotic accumulation; nutrient supply and uptake; role of mycorrhizae; decomposition and nutrient release; nutrient use efficiency; nutrient budget; nutrient conservation strategies.

Unit 7: Biological invasions (7 lectures)

Concept of exotics and invasives; natural spread versus man-induced invasions; characteristics of invaders; stages of invasion; mechanisms of invasions; invasive pathways; impacts of invasion on ecosystem and communities.

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Practical: Marks:15; Credit: 02

Identification with reasons of the following

A) Study of microfauna of water viz., plankton, (e.g., *Brachionus, Keratella, Cyclops, Cypris, Diaptomus, Nauplius larva, Bosmina, Moina, Eubranchipus*).

B) Study of aquatic flora, e.g., *Spirogyra, Zygnema, Pistia, Eichhornia, Hydrilla, Ceratophyllum, Ipomoea, Azolla, Lemna (minor and major), Limnophilia, Marselea, Nymphae, Nelumbo*.

C) Study of life tables and plotting of survivorship curves of different types from the hypothetical/real data provided.

Suggested Readings

1. Groom. B. & Jenkins. M. 2000.*Global Biodiversity: Earth's Living Resources in the 21stCentury.* World Conservation Press, Cambridge, UK.
2. Gurevitch, J., Scheiner, S. M., & Fox, G. A. 2002. *The Ecology of Plants*. Sinauer associates incorporated.
3. Loreau, M. &Inchausti, P. 2002. *Biodiversity and Ecosystem functioning: Synthesis and Perspectives.* Oxford University Press, Oxford, UK.
4. Odum, E.P. 1971. *Fundamentals of Ecology*. W.B. Sounders.
5. Pandit, M.K., White, S.M.&Pocock, M.J.O. 2014. The contrasting effects of genome size, chromosome number and ploidy level on plant invasiveness: a global analysis. *New Phytologist***203:** 697-703.
6. Pimentel, D. (Ed.). 2011. *Biological invasions: Economic and environmental costs of alien plant, animal, and microbe species*. CRC Press.
7. Singh, J.S., Singh, S.P. & Gupta, S.R. 2006. *Ecology, Environment and Resource Conservation.* Anamaya Publications.
8. Wilson, E. O. 1985. The Biological Diversity Crisis. *BioScience***35**: 700-706.

CORE COURSE 6:

ENVIRONMENTAL BIOTECHNOLOGY

(SHENV / 302/ C-6)
Total credit 06 (Theory 04 and Practical 02)

Theory (60 Lectures) Marks: 25; Credit: 04

Unit 1: Cell and Cellular Organelles (15 lectures)

Genetic material of prokaryotes, eukaryotes and organelles; Chromosomal organization (euchromatin, heterochromatin-constitutive and facultative heterochromatin)

Unit 2: The Structure and Function of DNA, RNA and Protein (15 lectures)

DNA: structural forms and their characteristics (B, A, Z); RNA: structural forms and their characteristics (rRNA, mRNA, tRNA), types of amino acids; post- translational modifications and their significance; synthesis; types and their role: structural, functional (enzymes).Central dogma of biology, Fundamentals ofRecombinant DNA Technology

Unit 3: Ecological restoration and bioremediation (20 lectures)

Wastewater treatment: Primary, Secondary and Tertiary; solid waste treatment: sources and management (vermiculture and methane production, landfill. hazardous waste treatment); specific bioremediation technologies: land farming, biopiles, composting, bioventing.

Unit 4: Ecologically safe products and processes (10 lectures)

PGPR bacteria: biofertilizers, microbial insecticides and pesticides, bio-control of plant pathogen, Integrated pest management; development of stress tolerant plants, biofuel.

Practical: Marks:15; Credit: 02

A) Cytological preparation of salivary gland chromosome of *Chironomus* sp.
B) Cytological preparation and Identification of Mitosis of *Alium*spand Meiotic stages from grasshopper testis.
C) To study Southern Blotting, PCR, DNA sequencing and DNA Fingerprinting through Photograph.

Suggested Readings

1. Evans, G.G. & Furlong, J. 2010. *Environmental Biotechnology: Theory and Application* (2nd edition). Wiley-Blackwell Publications.
2. Jordening, H.J. & Winter J. 2005. *Environmental Biotechnology: Concepts and Applications*. John Wiley& Sons.
3. Lodish, H.F., Baltimore, D., Berk, A. Zipursky, S.L. Matsudiara, P. & Darnell, J. 1995. *Molecular Cell Biology*. W.H. Freeman.
4. Nelson, D.L. & Cox, M.M. 2013. *Lehninger's Principles of Biochemistry*. W.H. Freeman.
5. Rittman, B.E. & McCarty, P.L. 2001. *Environmental Biotechnology. Principles and Applications.*

McGraw-Hill, New York.

6. Scagg, A.H. 2005. *Environmental Biotechnology*. Oxford University Press.
7. Snustad, D.P. & Simmons, M.J. 2011. *Principles of Genetics* (6th edition). John Wiley&Sons.
8. Wainwright, M. 1999. *An Introduction to Environmental Biotechnology*. Springer.
9. B.C.Bhattacharyya&Rintu Banerjee: Environmental Biotechnology. Oxford University Press.

CORE COURSE 7:
ATMOSPHERE AND GLOBAL CLIMATE CHANGE
(SHENV /303/C-7)
Total credit 06 (Theory 04 and Practical 02)

Theory (60 Lectures) Marks: 25; Credit: 04

Unit 1: Introduction (4 lectures)

Evolution and development of Earth's atmosphere; atmospheric structure and composition; significance of atmosphere in making the Earth, Milankovitch cycles.

Unit 2: Global energy balance (4 lectures)

Earth's energy balance; energy transfers in atmosphere; Earth's radiation budget; green house gases (GHGs); greenhouse effect; global conveyor belt.

Unit 3: Atmospheric circulation (10 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, effect of urbanization on microclimate

Unit 4: Meteorology and atmospheric stability (8 lectures)

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

Unit 5: Atmospheric chemistry (8 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; role of hydroxyl and hydroperoxyl radicals in atmosphere**.**

Unit 6: Global warming and climate change (10 lectures)

Earth's climate through ages; trends of global warming and climate change; drivers of global warming and the potential of different green house gases (GHGs) causing the climate change; atmospheric windows; impact of climate change on atmosphere, weather patterns, sea level rise.

Unit 7: Ozone layer depletion (10 lectures)

Ozone layer or ozone shield; importance of ozone layer; ozone layer depletion and causes; Chapman cycle; process of spring time ozone depletion over Antarctica; ozone depleting substances (ODS); effects of ozone depletion; mitigation measures and international protocols.

Unit 8: Climate change and policy (6 lectures)

Environmental policy statement; International agreements; Montreal protocol 1987; Kyoto protocol 1997; Convention on Climate Change; carbon credit and carbon trading;

Practical: Marks: 15; Credit: 02

A Project/ Review work/Term-paper on Global warming/ Ozone layer depletion/Any Global crisis/Catastrophic changes.

Suggested Readings:

1. Barry, R. G. 2003. *Atmosphere, Weather and Climate*. Routledge Press, UK.
2. Lal D.S. 2006, *Climatology*,ShardaPustakBhawan, Allahabad
3. Singh S. 2009, *Climatology*,PrayagPustakBhawan, Allahabad
4. Siddhartha K. 2005, *Atmosphere, Weather and Climate*, Kisalaya Publications Pvt. Ltd, New Delhi
5. Gillespie, A. 2006. *Climate Change, Ozone Depletion and Air Pollution: Legal Commentaries with Policy and Science Considerations*. MartinusNijhoff Publishers.
6. Hardy, J.T. 2003. *Climate Change: Causes, Effects and Solutions*. John Wiley & Sons.
7. Harvey, D. 2000. *Climate and Global Climate Change*. Prentice Hall.
8. Manahan, S.E. 2010. *Environmental Chemistry*. CRC Press, Taylor and Francis Group.
9. Maslin, M. 2014. *Climate Change: A Very Short Introduction*. Oxford Publications.
10. Mathez, E.A. 2009. *Climate Change: The Science of Global Warming and our Energy Future*. Columbia University Press.
11. Mitra, A.P., Sharma, S., Bhattacharya, S., Garg, A., Devotta, S. &Sen, K. 2004. *Climate Change and India*. Universities Press, India.
12. Philander, S.G. 2012. *Encyclopedia of Global Warming and Climate Cha*nge (2nd edition)Sage Publications.

GENERAL ELECTIVE 3:
GENDER AND ENVIRONMENT
(SHENV / 304/GE-3)
Total credit 06 (Theory 04 and Practical 02)

Theory (60 Lectures) Marks: 25; Credit: 04

Unit 1: Introduction (2 lectures)

The socially constructed 'gender' concept.

Unit 2: Gender and society (10 lectures)

Gender existence in society; gender: matriarchy and patriarchy (case studies in an Indian context); gender equity issues in rural and urban settings.

Unit 3: Gender and the environment (14 lectures)

Relevance of the concept in an environmental context; evolution of gender hierarchies in historical and contemporary perspective; gendered division of roles in cultural, social and economic perspective; gender inequalities.

Unit 4: Gender, resources and the environment (12 lectures)

Human –Environment relationship; differential dependencies on environmental resources; implications of gendered responses to environmental degradation.

Unit 6: Gender and environmental management (12 lectures)

Women's participation in environmental movements and conservation; historical and contemporary case studies; role of women in environmental education, awareness and sustainable development.

Unit 7: Strategies for change (10 lectures)

Need for gender equity; Instruments for change: education, media, action groups, policy and management; role of ICT in resource availability and consumption.

Practical: Marks: 15; Credit: 02

Tutorial based course.

Suggested Readings

1. Agarwal, B. 1992. *The Gender and Environment Debate: Lessons from India*. Feminist Studies (Minnesota).
2. Agarwal, B. 1997. Gender, Environment and Poverty Interlinks: Regional Variations and Temporal Shifts in Rural India: 1971-1991. *World Development* **25:** 1-42.
3. Agarwal, B. 2001. Participatory exclusions, community forestry, and gender: An analysis for South Asia and a conceptual framework. *World Development* **29:** 1623-1648.

4. Jackson,C.1993.Doingwhatcomesnaturally?Womenandenvironmentindevelopment *World Development* **21:** 1947-63.
5. Krishna, S. 2004. *Livelihood and Gender*. New Delhi, Sage.
6. Leach, M. 2007. Earth Mother myths and other ecofeminist fables: How a strategic notion rose and fell. *Development and Change* **38:** 67-85.
7. Miller, B. 1993. *Sex and Gender Hierarchies*. Cambridge University Press
8. Stein, R. (ed.). 2004. *New Perspectives on Environmental Justice: Gender, Sexuality, and Activism*. Rutgers University Press.
9. Steingraber, S. 1998. *Living Downstream: A Scientist's Personal Investigation of Cancer and the Environment.* New York: Vintage Books.
10. Zwarteveen, M.Z. 1995. *Linking women to the main canal: Gender and irrigation management*. Gatekeeper Series 54, IIED.

SKILL ENHANCEMENT COURSE 1:
REMOTE SENSING, GEOGRAPHIC INFORMATION SYSTEM & MODELLING
(SHENV / 305/SEC-1)
Credit: 02

Theory (Lectures: 30)

Unit 1: Remote Sensing: definitions and principles; electromagnetic spectrum; interaction of EMR with Earth's surface; spectral signature; satellites and sensors; aerial photography and image interpretation.

Unit 2: Geographical Information Systems: definitions and components; spatial and non-spatial data; database generation; database management system; land use/ land cover mapping; data import, processing, and mapping.

Unit 3: Applications and case studies of remote sensing and GIS in geosciences, water resource management, land use planning, forest resources, agriculture, marine and atmospheric studies.

Unit 4: Basic elements of statistical analyses: Frequency Distribution; sampling; types, errors and fluctuation; measures of central tendency and dispersion; skewness; correlation and regression; curve fitting; Standard Error of Estimate; Absolute Regression Residual Mapping

Practical:

A Project File, comprising one exercise each is to be submitted

B. Georeferencing of maps and images

C. Image classification, post-classification analysis and class editing

D. Overlay and preparation of thematic map

E. Plotting of GPS data in Microsoft Excel

F. GPS data downloading in software and mapping.

Suggested Readings

1. Das N.G. 2010, Statistical Methods Combined Edition (Vol-I & II), Tata McGraw Hill Education Private Ltd., New Delhi
2. Mahmood A. 2012, Statistical Methods in Geographical Studies, Rajesh Publications, New Delhi
3. Sarkar A. 2013, Quantitative Geography: Techniques and Presentations, Orient Black Swan, Kolkata
4. Zar, J.H. 2010. *Biostatistical Analysis* (5^{th}edition). Prentice HallPublications.
5. Edmondson, A. &Druce, D.1996.*Advanced Biology Statistics*. Oxford University Press.
6. Demers, M.N. 2005. *Fundamentals of Geographic Information System*. Wiley & Sons.
7. Fazal S. 2008, GIS Basics, New Age International Publishers, New Delhi
8. Richards, J. A. &Jia, X. 1999. *Remote Sensing and Digital Image Processing*. Springer.
9. Sabins, F. F. 1996. *Remote Sensing: Principles an Interpretation*. W. H. Freeman.

SEMESTER –IV

CORE COURSE 8:
SYSTEMATICS AND BIOGEOGRAPHY
(SHENV / SC/401/C-8)

Total credit 06 (Theory 04 and Practical 02)

Theory (60 Lectures) Marks: 25; Credit: 04

Unit 1: Concept and systematics approaches (6 lectures)

Definition of systematics; taxonomic identification; keys; field inventory; herbarium; museum; botanical gardens; taxonomic literature; nomenclature; evidence from anatomy, palynology, ultrastructure, cytology, phyto-chemistry, numerical and molecular methods; taxonomy databases.

Unit 2: Taxonomichierarchy (6 lectures)

Concept of taxa (species, genus, family, order, class, phylum, kingdom); concept of species (taxonomic, typological, biological, evolutionary, phylogenetic); categories and taxonomic hierarchy**.**

Unit 3: Nomenclature and systems of classification (8 lectures)

Principles and rules (International Code of Botanical and Zoological Nomenclature); ranks and names; types and typification; author citation; principle of priority and its limitations; names of hybrids; classification systems of Bentham and Hooker; Angiosperm Phylogeny Group (APG III) classification.

Unit 4: Numerical and molecular systematic (6 lectures)

Characters; variations; Operational Taxonomic Units; character weighting and coding; phenograms; cladograms; DNA barcoding; phylogenetic tree; clades: monophyly, paraphyly, polyphyly; homology and analogy; parallelism and convergence.

Unit 5: Introduction to Biogeography (8 lectures)

Genes as unit of evolutionary change; mutation; genetic drift; gene flow; natural selection; geographic and ecological variation; biogeographical rules – Gloger's rule, Bergmann's rule, Allen's rule, Geist rule; biogeographical realms and their fauna; endemic, rare, exotic, and cosmopolitan species.

Unit 6: Speciationandextinction (8 lectures)

Types and processes of speciation – allopatric, parapatric, sympatric; ecological diversification; adaptive radiation, convergent and parallel evolution; dispersal and immigration; extinction.

Unit 7: Historical Biogeography (6 lectures)

Earth's history; paleo-records of diversity and diversification; continental drift and plate tectonics and their role in biogeographic patterns – past and present.

Unit 8: Ecological Biogeography (10 lectures)

Species' habitats; environment and niche concepts; biotic and abiotic determinants of communities; species-area relationships; concept of rarity and commonness; Island Biogeography theory; Equilibrium Theory of Insular Biogeography; geography of diversification and invasion; phylogeography.

Unit 9: Conservation Biogeography (2 lectures)

Application of biogeographical rules in design of protected area and biosphere reserves; use of remote sensing in conservational planning.

Practical: Marks: 15; Credit: 02

A) Analysis of OTU.

B) Preparation of Phylogenetic tree from hypothetical data.

Suggested Readings

1. Lomolino, M.V., Riddle, B.R., Whittaker, R.J. & Brown, J.H. 2010. *Biogeography* (4th edition). Sinauer Associates, Sunderland.
2. Mani, M.S. 1974. *Ecology and Biogeography in India*. Dr. W Junk Publishers. The Hague.
3. Singh, G. 2012. *Plant Systematics: Theory and Practice* (3rd edition). Oxford & IBH Pvt. Ltd., New Delhi.
4. Wheeler, Q.D. & Meier R. 2000. *Species Concepts and Phylogenetic Theory: A Debate*. Columbia University Press, New York.
5. Williams, D. M., Ebach, M.C. 2008. *Foundations of Systematics and Biogeography*.Springer.
6. Wilkins, J. S. 2009. *Species: A History of the Idea* (Vol. 1). University of California Press.

CORE COURSE 9:
URBAN ECOSYSTEMS
(SHENV / SC/402/C-9)
Total credit 06 (Theory 04 and Practical 02)

Theory (60 Lectures) Marks: 25; Credit: 04

Unit 1: Environment in an urban setting (12 lectures)

Man as the driver of urban ecosystem; commodification of nature; metros, cities and towns as sources and sinks of resources; resource consumption and its social, cultural, economic and ecological perspectives; urban transformation; High rise buildings, increasing challenges posed by modernity for the environment; urban pollution (air, water, soil).

Unit 2: Urban dwelling (14 lectures)

Housing scenario across a range of large-medium-small cities; poverty and slums in an urban context; Town planning Acts and their environmental aspects; energy consumption and waste disposal as well as accumulation; environmental costs of urban infrastructure.

Unit 3: Urban interface with the environment (12 lectures)

Management of urban environment; alternative resources; policy and management decisions; urban settings as loci of sustainability; challenges associated with sustainability and urban future**.**

Unit 4: Natural spaces in a city (10 lectures)

Concept of 'controlled nature'; scope, importance and threats to nature in the city; organization and planning of green spaces such as parks, gardens and public spaces; concept of green belts; urban natural forest ecosystem as green lungs.

Unit 5: Planning and environmental management (12 lectures)

Urban planning and its environmental aspects from historical and contemporary perspectives; benefits of environmental management; introduction to green buildings; urban governance; political complexity of applying ecological science to urban policy and planning, smart cities.

Practical: Marks: 15; Credit: 02

Project File, containing the following reports is to be submitted

a) Urban Dwelling types- pucca or katcha house, room density
b) Urban Water Supply
c) Solid Waste Disposal system
d) Urban Sanitation and hygiene

Suggested Readings

1. D'Monte, Darryl. 1985. *Industry versus Environment Temples or Tombs*. Three Controversies, Delhi, CSE.
2. Ernstson, H. 2011. *Re-translating nature in post-apartheid Cape Town: The material semiotics of people and plants at Bottom Road*. In: Heeks, R., (Ed.) Conference on "Understanding Development through Actor-Network Theory", London School of Economics, 30 June, London.
3. Gaston, K.J. 2010. *Urban Ecology*. Cambridge University Press, New York.
4. Grimm, N. B., Faeth, S. H., et al. 2008. Global Change and the Ecology of Cities. *Science* **319**: 756-760.
5. Hinchliffe, S. &Whatmore, S. 2006. Living cities: Towards a politics of conviviality. *Science as Culture* **15**: 123–138.
6. McIntyre, N.E. 2000. Urban ecology as an interdisciplinary field: differences in the use of 'urban' between the social and natural sciences. *Urban Ecosystems* **4**: 5-24.
7. Montgomery, M.R. 2009. Urban Transformation of the developing world. *Science* **319:** 761-764.
8. Richter, M. &Weiland, U. (ed.). 2012. *Applied Urban Ecology*. Wiley-Blackwell, UK.

CORE COURSE 10:
ENVIRONMENTAL LEGISLATION AND POLICY
(SHENV / SC/403/C-10)
Total credit 06 (Theory 04 and Practical 02)

Theory (60 Lectures) Marks: 25; Credit: 04

Unit 1: Introduction(5 lectures)

Constitution of India; fundamental rights; fundamental duties; National Green Tribunal.

Unit 2: History of environmental legislation and policy (10 lectures)

Ancient period: Kautilya'sArthashastra, Yajnavalkyasmriti and Charaksamhita; Medieval period: forests as woodland and hunting resourcesduring Mughal reign; British India: Indian Penal Code 1860,Forest Act, 1865; Fisheries Act, 1897; Independent India: Van Mahotsava(1950), National Forest Policy, 1952;Ganga Action Plan.

Unit 3: Environmental legislation (5 lectures)

Legal definitions (environmental pollution, natural resource, biodiversity, forest, sustainable development); Article 48A; Article 51 A

Unit 4: Legislative Instruments (20 lectures)

Basic Principle of-The Indian Forest Act, 1927; The Wildlife (Protection) Act, 1972; The Water (Prevention and Control of Pollution) Act, 1974; The Forests (Conservation) Act, 1980; The Air (Prevention and Control of Pollution) Act, 1981; The Environment (Protection) Act, 1986; Motor Vehicle Act, 1988; The Public Liability Insurance Act, 1991; Noise Pollution (Regulation and Control) Rules, 2000; The Biological Diversity Act, 2002; The National Green Tribunal Act, 2010.

Unit 5: Government institutions (5 lectures)

Role of Ministry of Environment, Forests & Climate Changein environmental law and policy making; role of central and state pollution control boards in environmental law and policy making.

Unit 6: Case studies (5 lectures)

National Green Tribunal: Aditya N Prasad *vs.* Union of India & Others; Ganga Tanneries Case: M.C. Mehta *vs.* Union of India 1988; environmental education case: M.C. Mehta *vs.* Union of India, WP 860/1991.

Unit 7: International laws and policy (10 lectures)

Stockholm Conference (1972); United Nations Conference on Environment and Development (1992); Rio de Janeiro (Rio Declaration, Agenda 21); Copenhagen and Paris summits; Ramsar convention.

Practical: Marks: 15; Credit: 02
Tutorial and case study based.

Suggested Readings

1. Abraham, C.M. 1999. *Environmental Jurisprudence in India*. Kluwer Law International.
2. Agarwal, V.K. 2005. Environmental Laws in India: Challenges for Enforcement. *Bulletin of the National Institute of Ecology* **15**: 227-238.
3. Divan, S. &Rosencranz, A. 2001. *Environmental Law and Policy in India*. Oxford University Press.
4. Divan, S. &Rosencranz, A. 2002. *Environmental Law and Policy in India: Cases, Materials and Statues* (2^{nd}edition). Oxford UniversityPress.
5. Gupta, K.R. 2006. *Environmental Legislation in India*. Atlantic Publishers and Distributors.
6. Leelakrishnan, P. 2008. *Environmental Law in India* (3^{rd}edition). LexisNexisIndia.
7. Naseem, M. 2011. *Environmental Law in India Mohammad*. Kluwer Law International.
8. Venkat, A. 2011. *Environmental Law and Policy*. PHI Learning Private Ltd.
9. P.D.Sharma.2016.Ecology and Environment. 13th Revised &Updated Edition, Rastogi Publication.

GENERAL ELECTIVE 4:
GREEN TECHNOLOGIES
(SHENV / SC/404/GE-4)
Total credit 06 (Theory 04 and Practical 02)

Theory (60 Lectures) Marks: 25; Credit: 04

Unit 1: Introduction **(5 lectures)**

Definition and concepts: green technology, green energy, green infrastructure, green economy, and, green chemistry; sustainable consumption of resources; individual and community level participation such as small-scale composting pits for biodegradable waste, energy conservation; encouraged use of public transport instead of private transport.

Unit 2: Green technologies **(5 lectures)**

Green technologies in historical and contemporary perspectives; successful green technologies: wind turbines, solar panels; 3 R's of green technology: recycle, renew and reduce; paradigm shift from 'cradle to cradle' to 'cradle to grave'

Unit 3: **Green infrastructure, planning and economy** **(15 lectures)**

Concept and frame of Green buildings; construction of green buildings; associated costs and benefits; outlined examples of green buildings; LEED certified building.

Green planning: role of governmental bodies, land use planning, concept of green cities, waste reduction and recycling in cities, role of informal sector in waste management, public transportation for sustainable development, green belts; Introduction to UNEP's green economy initiative, inclusive economic growth of the society, REDD+ initiative, and cap and trade concept; green banking.

Unit 4: Applications of green technologies **(15 lectures)**

Compact fluorescent lights (CFLs), motion detection lighting, or programmable thermostats. Green House Gas (GHG) emissions reduction: carbon capture and storage (CCS) technologies, purchase and use of carbon offsets. Basics of- Pollution reduction and removal, Flue Gas Desulfurization (FGD) methods, catalytic or thermal destruction of NOX, Fluidized Bed Combustion, Dioxins reduction and removal methods, Thermal Oxidizers or Wet Scrubbers to neutralize chemicals or heavy metals, solvent recovery systems, Low Volatile Organic Compound (VOC) paints and sealers.

Unit 5: **Green chemistry** **(10 lectures)**

Introduction to green chemistry; principles and recognition of green criteria in chemistry; green nanotechnology; reagents, reactions and technologies by green alternativeseg. H_2O_2, TiO_2, Chitin

Unit 6: Green future **(10 lectures)**

Agenda of green development; reduction of ecological footprint; role of green technologies towards a

sustainable future; green practices to conserve natural resources (organic agriculture, agroforestry, reducing paper usage and consumption, etc.); development of environmental friendly technologies.

Practical: Marks: 15; Credit: 02

Tutorials and field based.

Suggested Readings

1. Anastas, P.T. & Warner, J.C. 1998. *Green Chemistry: Theory & Practice*. Oxford University Press.
2. Arceivala, S.L. 2014. *Green Technologies: For a Better Future*. Mc-Graw Hill Publications.
3. Baker, S. 2006. *Sustainable Development*. Routledge Press.
4. Hrubovcak, J., Vasavada, U. &Aldy, J. E. 1999. *Green technologies for a more sustainable agriculture* (No. 33721). United States Department of Agriculture, Economic Research Service.
5. Thangavel, P. &Sridevi, G. 2015. *Environmental Sustainability: Role of Green Technologies*. Springer Publications.
6. Woolley, T. &Kimmins, S. 2002. *Green Building Handbook* (Volume 1 and 2). Spon Press.

SKILL ENHANCEMENT COURSE 2:
ENVIRONMENTAL IMPACT AND RISK ASSESSMENT
(SHENV / 405/SEC-2)
Credit: 02

Theory (30 Lectures) Marks: 25

Unit 1: Environmental impact assessment (EIA): definitions, introduction and concepts; rationale and historical development of EIA; scope and methodologies of EIA; Impact identification and prediction; baseline data collection; Environmental Impact Statement (EIS), Environmental Management Plan (EMP):principles, problems and strategies

Unit 2: Strategic Environmental Assessment; Social Impact Assessment; Cost-Benefit analysis; Life cycle assessment; environmental appraisal; environmental planning; environmental audit; Principles of International Standard Organizations

Unit 3: EIA regulations in India; status of EIA in India; current issues in EIA; case study of hydropower projects/ thermal projects.

Unit 4: Risk assessment: introductionand scope; project planning; toxicity assessment; hazard identification and assessment; risk characterization; risk communication; environmental monitoring; community involvement; legal and regulatory framework; human and ecological risk assessment**.**

Practical: Marks:15

Project File, comprising one exercise each is to be submitted

a) Impact Assessment Methods- Adhoc, Matrix- simple, weighted, Checklist methods
b) Preparation of Environmental Impact Statement (EIS)
c) Risk Zone Mapping

Suggested Readings

1. Barrow, C.J. 2000. *Social Impact Assessment: An Introduction.* Oxford University Press.
2. Glasson, J., Therivel, R., Chadwick, A. 1994. *Introduction to Environmental Impact Assessment*. London, Research Press, UK.
3. Judith, P. 1999. *Handbook of Environmental Impact Assessment*. Blackwell Science.
4. Marriott, B. 1997. *Environmental Impact Assessment: A Practical Guide*. McGraw-Hill, New York, USA.
5. Westman W.E. 1985, *Ecology, Impact Assessment and Environmental Planning*, John Wiley, New York

SEMESTER –V

CORE COURSE 11:
BIODIVERSITY AND CONSERVATION
(SHENV / 501/C-11)
Total credit 06 (Theory 04 and Practical 02)

Theory (60 Lectures) Marks: 25; Credit: 04

Unit 1: Levels of organization in living world (8 lectures)

Organic evolution through geographic time scale; species concept and types of speciation.

Unit 2: Biodiversity patterns (4 lectures)

Spatial patterns: latitudinal and elevational trends in biodiversity; temporal patterns: seasonal fluctuations in biodiversity patterns; importance of biodiversity patterns in conservation.

Unit 3: Biodiversity estimation (10 lectures)

Sampling strategies and surveys: floristic, faunal, and aquatic; qualitative and quantitative methods: scoring, habitat assessment, richness, density, frequency, abundance, evenness, diversity, biomass estimation; community diversity estimation: alpha, beta and gamma diversity.

Unit 4: Importance of biodiversity (8 lectures)

Economic values – medicinal plants, drugs, fisheries and livelihoods; ecological services – primary productivity, role in hydrological cycle, biogeochemical cycling; ecosystem services – purification of water and air, nutrient cycling, climate control, pest control, pollination, and formation and protection of soil; social, aesthetic, consumptive, and ethical values of biodiversity.

Unit 6: Threats to biodiversity (10 lectures)

Natural and anthropogenic disturbances; habitat loss, habitat degradation, and habitat fragmentation; climate change; pollution; hunting; over-exploitation; deforestation; hydropower development; invasive species; land use changes; overgrazing; consequences of biodiversity loss; Intermediate Disturbance Hypothesis.

Unit 7: Conservation of biodiversity (10 lectures)

In-situ conservation (Biosphere Reserves, National Parks, Wildlife Sanctuaries); *Ex-situ* conservation (botanical gardens, zoological gardens, gene banks, seed and seedling banks, pollen culture, tissue culture and DNA banks), role of local communities and traditional knowledge in conservation; biodiversity hotspots; IUCN Red List categorization – guidelines, practice and application; Red Data book; ecological restoration; afforestation; social forestry; agro forestry; joint forest management; role of remote sensing in management of natural resources.

Unit 8: Biodiversity in India (10 lectures)

India as a mega diversity nation; phytogeographic and zoogeographic zones of the country; forest types and forest cover in India; fish and fisheries of India; National Biodiversity Action Plan.

Practical: Marks: 15; Credit: 02

A) Determination of population density in a natural/hypothetical community by quadrate method and calculation of Shanon-Weiner diversity index for community Study.
B) Analysis of frequency distribution of plants in a piece of vegetation by quardrat method.

Suggested Readings

1. Gaston, K J. & Spicer, J.I. 1998. *Biodiversity: An Introduction.* Blackwell Science, London, UK.
2. Krishnamurthy, K.V. 2004. *An Advanced Text Book of Biodiversity - Principles and Practices*. Oxford and IBH Publications Co. Pvt. Ltd. New Delhi.
3. Pandit, M.K. &Grumbine R.E. 2012. Ongoing and proposed hydropower development in the Himalaya and its impact on terrestrial biodiversity. *Conservation Biology* **26**:1061-1071.
4. Primack, R.B. 2002. *Essentials of Conservation Biology* (3rd edition). SinauerAssociates, Sunderland, USA**.**
5. Singh, J. S. & Singh, S. P. 1987. Forest vegetation of the Himalaya. *The Botanical Review* **53**: 80-192.
6. Singh, J. S., Singh, S.P. & Gupta, S. 2006. *Ecology, Environment and Resource Conservation.* Anamaya Publications, New Delhi.
7. Sodhi, N.S. & Ehrlich, P.R. (Eds). 2010. *Conservation Biology for All*. Oxford University Press.
8. Sodhi,N.S.,Gibson,L.&Raven,P.H.2013.*ConservationBiology:VoicesfromtheTropics.* Wiley-Blackwell, Oxford, UK.
9. D.K.Asthana:Text book of Environmental Studies. S. ChandPublication
10. H.R.Singh:Environmental Biology. S. Chand Publication

CORE COURSE 12:
ORGANISMAL AND EVOLUTIONARY BIOLOGY
(SHENV / SC/ 502/C-12)
Total credit 06 (Theory 04 and Practical 02)

Theory (60 Lectures) Marks: 25; Credit: 04

Unit 1: History of life on Earth (10 lectures)

Paleontology and evolutionary History; evolutionary time scale; eras, periods and epoch; major events in the evolutionary time scale; origins of unicellular and multi cellular organisms; major groups of plants and animals; stages in primate evolution including Homo.

Unit 2: Introduction (10 lectures)

Lamarck's concept of evolution; Darwin's Evolutionary Theory: variation, adaptation, struggle, fitness and natural selection; Mendelism; spurious mutations; The Evolutionary Synthesis.

Unit 3: Evolution of unicellular life (10 lectures)

Origin of cells and unicellular evolution and basic biological molecules; abiotic synthesis of organic monomers and polymers; Oparin-Haldane hypothesis; study of Miller; evolution of prokaryotes; origin of eukaryotic cells; evolution of unicellular eukaryotes; anaerobic metabolism, photosynthesis and aerobic metabolism.

Unit 4: Geography of evolution (5 lectures)

Biogeographic evidence of evolution; patterns of distribution; historical factors affecting geographic distribution; evolution of geographic patterns of diversity.

Unit 5: Molecular evolution (10 lectures)

Neutral evolution; molecular divergence and molecular clocks; molecular tools in phylogeny, classification and identification; protein and nucleotide sequence analysis; origin of new genes and proteins; gene duplication and divergence.

Unit 6: Fundamentals of population genetics (15 lectures)

Concepts of populations, gene pool, gene frequency; concepts and rate of change in gene frequency through natural selection, migration and genetic drift; adaptive radiation; isolating mechanisms; convergent evolution; sexual selection; co- evolution; Hardy-Weinberg Law.

Practical: Marks: 15; Credit: 02

A) Study of Homology and analogy from suitable specimens.
B) Study of verification of Hardy-Weinberg Law by Chi-Square Analysis.

Suggested Readings

1. Futuyma, D.J. 2009. *Evolution* (2nd edition). SinauerAssociates.

2. Gillespie, J. H. 1991. *The Causes of Molecular Evolution*. Oxford University Press.
3. Graur, D. & Li, W.H. 1999. *Fundamentals of Molecular Evolution* (2nd edition). Sinauer Associates.
4. Kimura, M. 1984. *The Neutral Theory of Molecular Evolution*. Cambridge University Press.
5. Minkoff, E.C. 1983. *Evolutionary Biology*. Addison Wesley. Publishing Company.
6. Nei, M. & Kumar, S. 2000. *Molecular Evolution and Phylogenetics*. Oxford University Press.
7. Nei, M. 1975. *Molecular Population Genetics and Evolution*. North-Holland Publishing Company.
8. Nei, M. 1987. *Molecular Evolutionary Genetics*. Columbia university press.
9. Thorne, J. L., Kishino, H., & Painter, I. S. 1998. Estimating the rate of evolution of the rate of molecular evolution. *Molecular Biology and Evolution* **15**: 1647-1657.

DISCIPLINE SPECIFIC ELECTIVE 1:
ENERGY AND ENVIRONMENT
(SHENV / 503/DSE-1)
Total credit 06 (Theory 04 and Practical 02)

Theory (60 Lectures) Marks: 25; Credit: 04

Unit 1: Introduction **(8 lectures)**

Defining energy; forms and importance; energy use from a historical perspective: sources and sinks of energy; energy over-consumption in urban setting

Unit 2:Energy resources **(8 lectures)**

Global energy resources; renewable and non-renewable resources: distribution and availability; energy-use scenarios in rural and urban setups; energy conservation.

Unit 3: Energy demand **(10 lectures)**

Global energy demand: historical and current perspective; energy demand and use in domestic, industrial, agriculture and transportation sector; generation and utilization in rural and urban environments; changes in demand in major world economies; energy subsidies and environmental costs.

Unit 4: Energy, environment and society **(10 lectures)**

Nature, scope and analysis of local and global impacts of energy use on the environment; fossil fuel burning and related issues of air pollution, greenhouse effect, global warming and, urban heat island effect; nuclear energy and related issues such as radioactive waste, spent fuel; social inequalities related to energy production, distribution, and use.

Unit 5: Energy, ecology and the environment **(6 lectures)**

Energy production, transformation and utilization associated environmental impacts (Chernobyl and Fukushima nuclear accidents, construction of dams, environmental pollution); energy over-consumption and its impact on the environment, economy, and global change.

Unit 6: Politics of energy policy **(8 lectures)**

Political choices in energy policy globally and in the Indian context (historical and contemporary case studies); domestic and international energy policy; energy diplomacy and bilateral ties of India with her neighbors.

Unit 7: Our energy future **(10 lectures)**

Current and future energy use patterns in the world and in India; evolution of energy use over time; alternative sources as green energy (biofuels, wind energy, solar energy, geothermal energy; ocean

energy; nuclear energy); need for energy efficiency; energy conservation and sustainability; Strategies for sustainable energy mix and management.

Practical: Marks:15; Credit: 02
Tutorial-based.

Suggested Readings

1. McKibben, B. 2012. *Global Warming's Terrifying New Math*, Rolling Stone Magazine.
2. Craig. J.R., Vaughan, D.J., Skinner. B.J. 1996. *Resources of the Earth: Origin, use, and environmental impact* (2^{nd}edition). Prentice Hall, NewJersey.
3. Elliott, D. 1997. *Sustainable Technology. Energy, Society and Environment* (Chapter 3). New York, Routledge Press.
4. Rowlands, I.H. 2009. *Renewable Electricity: The Prospects for Innovation and Integration in Provincial Policies* in Debora L. Van Nijnatten and Robert Boardman (eds), Canadian Environmental Policy and Politics: Prospects for Leadership and Innovation, Third Edition. Oxford University Press, pp. 167-82.
5. Oliver, J. 2013. Dispelling the Myths about Canada's Energy Future, Policy: Canadian Politics and Public Policy, June-July.
6. Mallon, K. 2006. *Myths, Pitfalls and Oversights, Renewable Energy Policy and Politics: A Handbook for Decision-Making*. EarthScan.

DISCIPLINE SPECIFIC ELECTIVE 2:
ENVIRONMENTAL ECONOMICS
(SHENV / 504/DSE-2)
Total credit 06 (Theory 04 and Practical 02)

Theory (60 Lectures) Marks: 25; Credit: 04

Unit1: Introduction to microeconomics (15 lectures)

Definition and scope of environmental 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.

Unit 2: Environmental economics (15 lectures)

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; Hardin's Thesis of 'The Tragedy of Commons' Externalities; social cost benefit analysis; cost-effectiveness analysis.

Unit 3: Economic solutions to environmental problems (15 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, environmental subsidies, modelling and emission charges; polluter pay principles; pollution permit trading system.

Unit 4: Natural resource economics (5 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 5: Tools for environmental economic policy (10 lectures)

Growth and environment; environmental audit and accounting, Kuznets curve, environmental risk analysis, comparison of environmental benefits and costs.

Practical: Credit:02
Tutorials, analysis and exercise based.

Suggested Readings

1. Arrow, K., Bolin, B., Costanza, R., Dasgupta, P., Folke, C., Holling, C.S., Jansson, B.O., Levin, S., Maler, K.G., Perrings, C., Pimentel, D. 1995. Economic growth, carrying capacity, and the environment. *Ecological Economics* **15**: 91-95.

2. Hanley, N., Shogren, J. F., & White, B. 2007. *Environmental Economics: In Theory and Practice*. Palgrave Macmillan.
3. Kolstad, C.D. 2010. *Environmental Economic*s. Oxford University Press.
4. Perman, R. 2003. *Natural Resource and Environmental Economics*. Pearson Education.
5. Singh, K. &Shishodia, A. 2007. *Environmental Economics: Theory and Applications*. Sage Publications.
6. Thomas, J.M. &Callan, S.J. 2007.*Environmental Economics*. Thomson Learning Inc.
7. Tietenberg, T. 2004. *Environmental and Natural Resource Economics* (6^{th}Edition). Pearson Education Pvt. Ltd.
8. Tietenberg, T. H. & Lewis, L. 2010. *Environmental Economics and Policy*. Addison-Wesley.
9. Turner, R. K., Pearce, D., & Bateman, I. 1994. *Environmental Economics: An Elementary Introduction*. Harvester Wheatsheaf.

SEMESTER –VI

CORE COURSE 13:
ENVIRONMENTAL POLLUTION AND HUMAN HEALTH
(SHENV /601/C-13)
Total credit 06 (Theory 04 and Practical 02)

Theory (60 Lectures) Marks: 25; Credit: 04

Unit 1: Introduction (2 lectures)

Definition of pollution; pollutants; classification of pollutants.

Unit 2: Air pollution (8 lectures)

Ambient air quality: monitoring and standards (National Ambient Air Quality Standards of India); air quality index; sources and types of pollutants (primary and secondary); smog (case study); effects of different pollutants on human health (NO_X, SO_X, PM, CO, CO_2, hydrocarbons and VOCs) and control measures; indoor air pollution: sources and effects on human health.

Unit 3: Water pollution (10 lectures)

Sources of surface and ground water pollution; water quality parameters and standards; organic waste and water pollution; eutrophication; COD, BOD, DO; effect of water contaminants on human health (nitrate, fluoride, arsenic, chlorine, cadmium, mercury, pesticides); water borne diseases; concept and working of effluent treatment plants (ETPs).

Unit 4: Soil pollution (5 lectures)

Causes of soil pollution and degradation; effect of soil pollution on environment, vegetation and other life forms; control strategies.

Unit 5: Noise pollution (5 lectures)

Noise pollution – sources; frequency, intensity and permissible ambient noise levels; effects on communication, impacts on life forms and humans - working efficiency, physical and mental health; control measures.

Unit 6: Radioactive and thermal pollution (5 lectures)

Radioactive material and sources of radioactive pollution; effect of radiation on human health (somatic and genetic effects); thermal pollution and its effects.

Unit 7: Marine pollution (5 lectures)

Marine resources and their importance; sources of marine pollution; oil spill and its effects; coral reefs and their demise; coastal area management; existing challenges and management techniques (planning, construction, environmental monitoring of coastal zones).

Unit 8: Chemistry of environmental pollutants (10 lectures)

Solubility of pollutants (hydrophilic and lipophilic pollutants), concept of biotransformation and bioaccumulation, concept of radioactivity, radioactive decay and half-life of pollutants; organometallic compounds, acid mine drainage.

Unit 9: Pollution control (10 lectures)

Activated Sludge Process (ASP) – Trickling Filters – oxidation ponds, fluidized bed reactors, membrane bioreactor neutralization, ETP sludge management; digesters, up flow anaerobic sludge blanket reactor, fixed film reactors, sequencing batch reactors, hybrid reactors, bioscrubbers, biotrickling filters; regulatory framework for pollution monitoring and control; case study: implementation of CNG.

Practical: Marks: 15; Credit: 02

A) Identification and listing of different types of water and soil pollutants in the locality.
B) Visit and report to study the functioning of water treatment/sewage treatmentplant.
C)LC_{50} calculation by probit analysis with data provided (theoretical).

Suggested Readings

1. Gurjar, B.R., Molina, L.T. &Ojha C.S.P. 2010. *Air Pollution: Health and Environmental Impacts*. CRC Press, Taylor & Francis.
2. Hester, R.E. & Harrison, R.M. 1998. *Air Pollution and Health*. The Royal Society of Chemistry, UK.
3. Park, K. 2015. *Park's Textbook of Preventive and Social Medicine* (23rd edition).Banarsidas Bhanot Publishers.
4. Pepper, I.L., Gerba, C.P. &Brusseau, M.L. 2006. *Environmental and Pollution Science*. Elsevier Academic Press.
5. Purohit, S.S. &Ranjan, R. 2007. *Ecology, Environment & Pollution*. Agrobios Publications.
6. Vesilind, P.J., Peirce, J.J., & Weiner R.F. 1990. *Environmental Pollution and Control*. Butterworth-Heinemann, USA.
7. Saha T.K. 2010. Ecology and Environmental Biology, Books and Allied (P) Ltd. Kolkata.
8. Santra S.C. 2005. Environmental Science, New Central Book Agency (P) Ltd. Kolkata.
9. Environmental Studies—Prof S.V.S Rana.--Rastogi Publication.
10. Text book of Ecology: The Experimental Analysis of distribution & abundance--(Charles J. Krebs).Pearson Education.

CORE COURSE 14:
NATURAL RESOURCE MANAGEMENT AND SUSTAINABILITY
(SHENV /602/C-14)
Total credit 06 (Theory 04 and Practical 02)

Theory (60 Lectures) Marks: 25; Credit: 04

Unit 1: Introduction (10 lectures)

Resource and reserves; classification of natural resources; renewable and non-renewable resources; resource degradation; resource conservation; land resources; water resources; fisheries and other marine resources; energy resources; mineral resources; ecological, social and economic dimension of resource management**.**

Unit 2: Natural resources and conservation (10 lectures)

Forest resources: economic and ecological importance of forests, forest management strategies, sustainable forestry; water resources: supply, renewal, and use of water resources, freshwater shortages, strategies of water conservation; soil resources: importance of soil, soil conservation strategies; food resources: world food problem, techniques to increase world food production, green revolution.

Unit 3: Mineral resources (10 lectures)

Mineral resources; phantom pile; types of mining: surface, subsurface, open-pit, dredging, strip; reserve-to-production ratio; global consumption patterns of mineral resources; techniques to increase mineral resource supplies; ocean mining for mineral resources; Economic and Environmental approaches of Resource utilization

Unit 4: Non-renewable energy resources (10 lectures)

Oil: formation, exploration, extraction and processing, natural gas: exploration, liquefied petroleum gas, liquefied natural gas; coal: reserves, classification, formation, extraction, processing, environmental impacts of non-renewable energy consumption; impact of energy consumption on global economy; application of green technology; future energy options and challenges.

Unit 5: Renewable energy resources (10 lectures)

Solar energy: technology, advantages, passive and active solar heating system, solar thermal systems, solar cells; hydropower: technology, potential, operational costs, benefits of hydropower development; nuclear power: technology, potentialcost-benefit analysis of nuclear power; tidal energy; wave energy; ocean thermal energy conversion (OTEC); geothermal energy; energy from biomass; bio-diesel.

Unit 6: Resource management **(10 lectures)**

Approaches in resource management: ecological approach; economic approach; implications of the approaches; integrated resource management strategies; concept of sustainability: different approach towards sustainable development and its different constituents; sustainability of society, resources and framework; sustainable energy strategy; principles of energy conservation; Indian renewable energy programme.

Practical: Marks: 15; Credit: 02

A)To prepare energy budget of a cropping system aquaculture (Theoretical perspective).
B) To determine energy efficiencies from the given data.

Suggested Readings

1. Craig, J.R., Vaughan. D.J. & Skinner. B.J. 1996. *Resources of the Earth: Origin, Use, and Environmental Impacts* (2nd edition). Prentice Hall, NewJersey.
2. Freeman, A.M. 2001. *Measures of value and Resources: Resources for the Future*. Washington DC.
3. Freeman, A.M. 2003. *Millennium Ecosystem Assessment: Conceptual Framework*. Island Press.
4. Ginley, D.S. &Cahen, D. 2011. *Fundamentals of Materials for Energy and Environmental Sustainability*. Cambridge University Press.
5. Klee, G.A. 1991. *Conservation of Natural Resources*. Prentice Hall Publication.
6. Miller, T.G. 2012. *Environmental Science*. Wadsworth Publishing Co.
7. Owen, O.S, Chiras, D.D, &Reganold, J.P. 1998. *Natural Resource Conservation – Management for Sustainable Future* (7th edition). PrenticeHall.
8. Ramade, F. 1984. *Ecology of Natural Resources*. John Wiley & Sons Ltd.
9. Tiwari, G.N. &Ghosal. M. K. 2005. *Renewable Energy Resources: Basic Principles and Application*. Narosa Publishing House.

DISCIPLINE SPECIFIC ELECTIVE 3:
NATURAL HAZARDS AND DISASTER MANAGEMENT

(SHENV / 603/DSE-3)

Total credit 06 (Theory 04 and Practical 02)

Theory (60 Lectures) Marks: 25; Credit: 04

Unit 1: Introduction (5 lectures)

Definition of hazard; context hazards; concept of risk and vulnerability; reasons of vulnerability - rapid population growth, urban expansion, environmental pollution, epidemics, industrial accidents, inadequate government policies**.**

Unit 2: Natural hazards (15 lectures)

Natural hazards: hydrological, atmospheric & geological hazards; earthquake: seismic waves, epicenter; volcanoes: causes of volcanism, geographic distribution; floods: types and nature, frequency of flooding; landslides: causes and types of landslides, landslide analysis; drought: types of drought - meteorological, agricultural, hydrological, and famine; Glacial Lake Outburst Floods (GLOF); tornadoes, cyclone & hurricanes; tsunamis: causes and location of tsunamis; coastal erosion, sea level changes and its impact on coastal areas and coastal zone management.

Unit 3: Anthropogenic hazards (15 lectures)

Impacts of anthropogenic activities such as rapid urbanization, injudicious ground water extraction, sand mining from river bank, deforestation, mangroves destruction; role of construction along river banks in elevating flood hazard; disturbing flood plains. Deforestation and landslide; Large scale developmental projects like dams and nuclear reactors in hazard prone zones; nature and impact of accidents, wildfires and biophysical hazards. Case studies of Bhopal, Minamata and Chernobyl disaster.

Unit 4: Risk and vulnerability assessment (5 lectures)

Two components of risk: likelihood and consequences, qualitative likelihood measurement index; categories of consequences (direct losses, indirect losses, tangible losses, and intangible losses); application of geoinformatics in hazard, risk & vulnerability assessment.

Unit 5: Mitigation and preparedness (10 lectures)

Concept of mitigation; types of mitigation: structural and non-structural mitigation, use of technologies in mitigations such as barrier, deflection and retention systems; concept of preparedness; importance of planning, exercise, and training in preparedness; role of public, education and media in hazard preparedness**.**

Unit 6: Disaster management in India (10 lectures)

Lessons from the past considering the examples of Bhuj earthquake, tsunami disaster, and Bhopal tragedy; National Disaster Management Framework, national response mechanism, role of government bodies such as NDMC and IMD; role of armed forces and media in disaster management; role of space technology in disaster management; case study of efficient disaster management during cyclone '*Phailin*' in 2013**.**

Practical: Marks: 15; Credit: 02

A Project File, comprising one exercise each is to be submitted

a. Construction of Hydrograph, Unit Hydrograph, Rating Curve
b. Risk and Vulnerability Analysis of any hazard
c. Vulnerability Mapping

Suggested Readings

1. Coppola D. P. 2007. *Introduction to International Disaster Management*. Butterworth Heinemann.
2. Cutter, S.L. 2012. *Hazards Vulnerability and Environmental Justice*. EarthScan, Routledge Press.
3. Keller, E. A. 1996. *Introduction to Environmental Geology*. Prentice Hall, Upper Saddle River, New Jersey.
4. Pine, J.C. 2009. *Natural Hazards Analysis: Reducing the Impact of Disasters*. CRC Press, Taylor and Francis Group.
5. Schneid, T.D. & Collins, L. 2001. *Disaster Management and Preparedness*. Lewis Publishers, New York, NY.
6. Smith, K. 2001. *Environmental Hazards: Assessing Risk and Reducing Disaster*. Routledge Press.
7. Wallace, J.M. & Hobbs, P.V. 1977. *Atmospheric Science: An Introductory Survey*. Academic Press, New York.
8. Wasson,R.J.,Sundriyal,Y.P.,Chaudhary,S.,Jaiswal,M.K.,Morthekai,P.,Sati,S.P.&Juyal, N. 2013. A 1000-year history of large floods in the upper Ganga catchment, central Himalaya, India.*Quaternary Science Reviews* **77**: 156–166.

DISCIPLINE SPECIFIC ELECTIVE 4:
SOLID WASTE MANAGEMENT

(SHENV / 604/DSE-4)

Total credit 06 (Theory 04 and Practical 02)

Theory (60 Lectures) Marks: 25; Credit: 04

Unit 1: Introduction (3 lectures)

Sources and generation of solid waste, their classification and chemical composition; characterization of municipal solid waste; hazardous waste and biomedical waste.

Unit 2: Effect of solid waste disposal on environment (8 lectures)

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; effect of land fill leachate on soil characteristics and ground water pollution.

Unit 3: Solid waste Management (14 lectures)

Collection, storage, transportation and disposal of solid wastes (municipal, hazardous and biomedical waste); landfill (traditional and sanitary landfill design); thermal treatment (pyrolysis and incineration) of waste material; disadvantages in waste management techniques.

Unit 4: Industrial waste management (6 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.

Unit 5: Resource Recovery (8 lectures)

4R- reduce, reuse, recycle and recover; biological processing - composting, anaerobic digestion, aerobic treatment; reductive dehalogenation; mechanical biological treatment; green techniques for waste treatment.

Unit 6: Waste- to- energy (WTE) (4 lectures)

Concept of energy recovery from waste; refuse derived fuel (RDF); different WTE processes: combustion, pyrolysis, landfill gas (LFG) recovery; anaerobic digestion; gasification.

Unit 7: Integrated waste management (4 lectures)

Concept of Integrated waste management; waste management hierarchy; methods and importance of Integrated waste management.

Unit 8: Life cycle assessment (LCA) (5 lectures)

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 9: Policies for solid waste management (8 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.

Practical: Marks: 15; Credit: 02

A) A study of local resources and types of industrial waste.
B) Demonstration of compositing technique.

Suggested Readings

1. Asnani, P. U. 2006. Solid waste management. *India Infrastructure Report 570*.
2. Bagchi, A. 2004. *Design of Landfills and Integrated Solid Waste Management*. John Wiley & Sons.
3. Blackman, W.C. 2001. *Basic Hazardous Waste Management*. CRC Press.
4. McDougall, F. R., White, P. R., Franke, M., &Hindle, P. 2008. *Integrated Solid Waste Management: A Life Cycle Inventory*. John Wiley & Sons.
5. US EPA. 1999. *Guide for Industrial Waste Management*. WashingtonD.C.
6. White, P.R., Franke, M. &Hindle P. 1995. *Integrated Solid waste Management: A Lifecycle Inventory*. Blackie Academic & Professionals.
7. Zhu, D., Asnani, P.U., Zurbrugg, C., Anapolsky, S. & Mani, S. 2008. *Improving Municipal Solid waste Management in India.* The World Bank, Washington D.C.