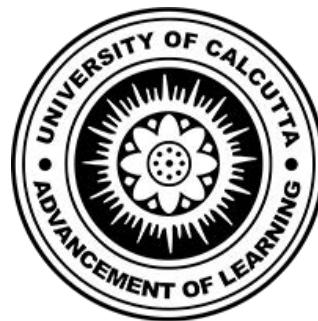


**MODEL COURSE CURRICULUM FOR UNDERGRADUATE  
COURSES UNDER CHOICE BASED CREDIT SYSTEM**

**PROPOSED DRAFT SYLLABUS**

**FOR**

**BACHELOR IN  
ENVIRONMENTAL SCIENCE (HONOURS)**



**UNIVERSITY OF CALCUTTA**

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

<b>Course</b>	<b>Credits*</b>
<b>Theory + Practical</b>	
<b>I Core Courses (14 Papers)</b>	
Core Courses - Theory (14 Papers) (4 Credits each)	14x4=56
Core Course – Practical (2 Credits Each)	14x2=28
<b>II. Discipline Specific Electives (4 Papers)</b>	
Discipline Specific Electives - Theory (4 Papers) (4 Credits)	4x4=16
Discipline Specific Electives - Practical (4 Papers) (2 Credits Each)	4x2=8
<b>III Generic Electives (4 Papers)</b>	
Generic Electives– Theory (4 Papers) (4 Credits)	4x4=16
Generic Electives – Practical (4 Papers) (2 Credits Each)	4x2=8
<b>III. Ability Enhancement Courses (2 Papers)</b>	
1. Ability Enhancement Compulsory Courses (AEC 1) English Communications. (2 credits)	
2. Ability Enhancement Compulsory Courses (AEC 2) Environmental Studies (2 credits)	2x2=4
<b>IV. Skill Enhancement Courses (SEC)</b>	
Skill Enhancement Courses (SEC) (Theory) (2 Papers of 2 Credits each)	2x2=4
<b>Total Credits</b>	<b>140</b>

**Bachelor in Environment Science (Hons.)**  
**Courses/Papers Sequence**

<b>Year 1 Semester 1</b>	<b>Year 1 Semester 2</b>	<b>Year 2 Semester 1</b>	<b>Year 2 Semester 2</b>	<b>Year 3 Semester 1</b>	<b>Year 3 Semester 2</b>
C1: Earth and Earth Surface Processes	C3: Water and Water Resources Management	C5: Ecology and Ecosystems	C8: Systematics & Biogeography	C11: Biodiversity & Conservation Biology	C13: Environmental Pollution and Human Health
C2: Physics & Chemistry of Environment	C4: Land management and soil conservation	C6: Environmental Biotechnology	C9: Urban Ecosystems	C12: Organismal & Evolutionary Biology	C14: Natural Resources Management & Sustainability
AECC1: English Communication /MIL	AECC2: Environmental Studies	C7: Atmosphere & Global Climate Change	C10: Environmental Legislation & Policy	DSE1: Energy & Environment	DSE3: Natural Hazards & Disaster Management
GE1: Environment & Society	GE2: Human-Wildlife Conflict & Management	SEC1: Remote Sensing, Geographic Information System & Modelling	SEC2: Environment Impact & Risk Assessment	DSE2: Environmental Economics and Statistics	DSE4: Solid Waste Management
		GE3: Gender and Environment	GE4: Green Technologies		

## **CORE COURSE 1: EARTH AND EARTH SURFACE PROCESSES**

**Theory (50 Lectures)**

**Unit 1: History of Earth (5 lectures)**

Formation of the Earth: formation and composition of core, mantle, crust, atmosphere and hydrosphere; chemical composition of Earth; geological time scale and major changes on the Earth's surface.

**Unit 2: Earth system processes (15 lectures)**

Movement of lithosphere plates; mantle convection and plate tectonics, major plates and hotspots, plate boundaries; sea floor spread; earthquakes; volcanic activities; orogeny; isostasy; gravitational and magnetic fields of the earth; origin of the main geomagnetic field; continental drift, Pangaea and present-day continents, paleontological evidences of plate tectonics.

Land surface processes: fluvial and glacial processes, rivers and geomorphology; types of glaciers, glacier dynamics, erosional and depositional processes and glaciated landscapes; coastal processes.

**Unit 3: Rocks, weathering and minerals (15 lectures)**

Minerals and important rock forming minerals; rock cycle: lithification and metamorphism; Three rock laws; rock structure, igneous, sedimentary and metamorphic rocks; weathering: physical, biogeochemical processes; erosion: physical processes of erosion, factors affecting erosion; agents of erosion: rivers and streams, glacial and aeolian transportation and deposition of sediments by running water, wind and glaciers.

**Unit 4: Earth atmosphere (6 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.

**Unit 5: Mountain and river systems of India (9 lectures)**

Continental collision and mountain formation; Formation of Peninsular Indian mountain systems - Western and Eastern Ghats, Vindhya, Aravallis, etc.; Formation of the Himalaya; perennial river systems and evolution of monsoon in Indian subcontinent; formation of Indo-Gangetic Plains, progression of agriculture in the Indian subcontinent in Holocene; withdrawing monsoon and lessons to draw.

**Practicals:**

1. Identification of rocks & minerals (Hand Specimen)
2. Topological sheet interpretation for geomorphology.
3. Viva Voce

**Suggested Readings**

1. Bridge, J., & Demicco, R. 2008. *Earth Surface Processes, Landforms and Sediment deposits*. Cambridge University Press.
2. Keller, E.A. 2011. *Introduction to Environmental Geology* (5<sup>th</sup> edition). Pearson Prentice Hall.
3. Leeder, M., Arlucea, M.P. 2005. *Physical Processes in Earth and Environmental Sciences*. Blackwell Publishing.

## **CORE COURSE 2: PHYSICS AND CHEMISTRY OF ENVIRONMENT**

**Theory (50 Lectures)**

### **Unit 1: Fundamentals of environmental physics**

**(10 lectures)**

**Part A:** Basic concepts of light and matter; spectroscopic concepts: Introduction to the concept of absorption and transmission of light, Beer-Lambert law; scattering of light, Rayleigh and Mie scattering.

**Part B:** Basic concepts of pressure, force, work and energy; types of forces and their relation (pressure gradient, viscous, Coriolis, gravitational, centripetal, and centrifugal force); concept of heat transfer, conduction, convection; concept of temperature, lapse rate (dry and moist adiabatic); laws of thermodynamics; concept of heat and work, Carnot engine.

### **Unit 2: 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, quantitative volumetric analysis.

**Part B:** Types of chemical reactions; acids, bases and salts, concept of chemical equilibrium, solubility products; solutes and solvents; redox reactions, concepts of pH and pE, electrochemistry, Nernst equation, electrochemical cells.

**Part C:** Basic concepts of organic chemistry, hydrocarbons, aliphatic and aromatic compounds, organic functional groups, polarity of the functional groups, colloid chemistry. Xenobiotic compounds, chemistry of pesticides and dyes, synthetic polymers.

### **Unit 3: Atmospheric chemistry**

**(9 lectures)**

Composition of atmosphere; photochemical reactions in atmosphere; smog formation, types of smog (sulphur smog and photochemical smog), aerosols; chemistry of acid rain, reactions of NO<sub>x</sub> and SO<sub>x</sub>; free radicals and ozone layer depletion, role of CFCs in ozone depletion.

### **Unit 4: Water chemistry**

**(9 lectures)**

Chemical and physical properties of water; Gases in water, Henry's Law, alkalinity and acidity of water, hardness of water, calculation of total hardness; solubility of metals, complex formation and chelation; heavy metals in water.

## **Unit 5: Soil chemistry**

**(7 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.

### **Practicals:**

1. Acidity, Alkalinity, Total Hardness of water, Calcium Hardness of Water
2. Soil Organic Carbon, Cation exchange capacity of soil
3. Viva Voce

### **Suggested Readings**

1. Boeker, E. & Grondelle, R. 2011. *Environmental Physics: Sustainable Energy and Climate Change*. Wiley.
2. Forinash, K. 2010. *Foundation of Environmental Physics*. Island Press.
3. Hites, R.A. 2012. *Elements of Environmental Chemistry* (2<sup>nd</sup> edition). Wiley & Sons.
4. Manhan, S. E. 2000. *Fundamentals of Environmental Chemistry*. CRC Press.

## **GENERAL ELECTIVE 1: ENVIRONMENT AND SOCIETY**

**Theory (50 Lectures)**

### **Unit 1: Introduction**

**(4 lectures)**

Social and cultural construction of 'environment'; environmental thought from historical and contemporary perspective in light of the concepts of Gross Net Happiness and Aldo Leopold's Land Ethic.

### **Unit 2: Issues in environmentalism**

**(7 lectures)**

Significant global environmental issues such as acid rain, 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**

**(7 lectures)**

Developmental issues and related impacts such as ecological degradation; environmental pollution; Climate Change, development-induced displacement, resettlement, and rehabilitation: problems, concerns, and compensative mechanisms; discussion on Project Affected People (PAPs), Climate refugee.

### **Unit 4: Urbanization and environment**

**(7 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; conflict between economic and environmental interests.

### **Unit 5: Gender, 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; environmental ethics, issues and possible solutions. Women's participation in environmental movements and conservation, historical and contemporary case studies, role of women in environmental education, awareness and sustainable development.

### **Unit 6: Regulatory framework**

**(5 lectures)**

Brief account of Forest Conservation Act 1980, 1988; EPA, 1986; Forest Dwellers Act 2008; 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, Silent Valley movement); corporate responsibility movement; appropriate technology movement; environmental groups and movements, citizen groups; role played by NGOs; environmental education and awareness.

### **Practicals:**

Review Paper/ Status Report preparation/presentation.

### **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 Scienceand 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.

## **CORE COURSE 3: WATER AND WATER RESOURCES MANAGEMENT**

**Theory (50 Lectures)**

**Unit 1: Water resource** **(5 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** **(10 lectures)**

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

**Unit 3: Surface and Groundwater** **(14 lectures)**

Introduction to surface and ground water; water table; vertical distribution of water; formation and properties of aquifers; hydraulic potential, Darcy's equation, types of flow, turbulence, techniques for ground water recharge; watershed and drainage basins; importance of watershed and watershed management.

**Unit 4: Wetlands and their management** **(6 lectures)**

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

**Unit 5: Water resource in India and Water sharing conflicts** **(15 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. 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.

**Practicals:**

pH, Electrical conductivity, Chloride, Salinity, Dissolved oxygen, TSS, TDS, Iron.

Viva Voce

### **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. Loucks, D.P., Stedinger, J.R. & Haith, D.A. 1981. *Water Resource Systems Planning and Analysis*. Englewood Cliffs, NJ, Prentice Hall.
4. Mays, L.W. 2006. *Water Resources Sustainability*. The McGraw-Hill Publications.
5. Schward & Zhang, 2003. *Fundamentals of Groundwater*. John Willey and Sons.
6. Vickers, A. 2001. *Handbook of Water Use and Conservation*. WaterPlow Press.

## **CORE COURSE 4: LAND MANAGEMENT AND SOIL CONSERVATION**

**Theory (50 Lectures)**

### **Unit 1: Introduction to Land Resource**

**(5 lectures)**

Land as a resource, types and evaluation, 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 profile; soil water holding capacity; soil temperature; soil colloids; soil acidity and alkalinity; soil salinity and sodicity; soil organic matter; micronutrients of soil; nitrogen, sulphur, potassium and phosphorus economy of soil; soil biodiversity; soil taxonomy maps.

### **Unit 3: Soil degradation and conservation**

**(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; fertilizers and fertilizer management; recycling of soil nutrients.

Different techniques of soil conservation (mechanical and biological)

### **Unit 4: Land use changes**

**(5 lectures)**

Land use pattern, drivers of land use and land cover change in major geographic zones and biodiverse regions with particular reference to the Himalaya and the Western Ghats.

### **Unit 5: Land degradation and management**

**(20 lectures)**

Land degradation: biological and physical phenomena; visual indicators of land degradation; drivers of land degradation - deforestation, desertification; habitat loss, loss of biodiversity; range land degradation; land salinization; human population pressure, poverty, socio-economic and institutional factors, 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.

Sustainable land use 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.

**Practicals:**

Soil pH, ECe, Soil moisture, Water Holding Capacity, NPK of Soil (Demonstration only).

Viva voce

**Suggested Readings**

1. Brady, N.C. & Well, R.R. 2007. *The Nature and Properties of Soils* (13<sup>th</sup> edition), Pearson Education Inc.
2. Johnson, D.L. 2006. *Land Degradation* (2<sup>nd</sup> edition). Rowman & Littlefield Publishers.
3. Marsh, W.M. & Dozier, J. 1983. *Landscape Planning: Environmental Applications*. John Wiley and Sons.
4. Scherr, S.J. 1999. *Soil degradation: A threat to developing-country food security by 2020?* (Vol. 27). International Food Policy Research Institute.

## **GENERAL ELECTIVE 2: HUMAN-WILDLIFE CONFLICT AND MANAGEMENT**

**Theory (50 Lectures)**

### **Unit 1: Introduction to wildlife management**

**(6 lectures)**

Need of environmental management; wildlife conservation: moral obligation? Philosophy of wildlife management; why is it necessary to worry about human wildlife conflicts? What is the role of government, wildlife biologists and social scientists.

### **Unit 2: Evolution of the concept of wildlife management**

**(8 lectures)**

Journey of mankind from predator to conservator; prehistoric association between wildlife and humans: records from Bhimbetka wall paintings; conservation of wildlife in the reign of king Ashoka: excerpts from rock edicts; understanding wildlife management, conservation and policies regarding protected areas in 21<sup>st</sup> century; positive values provided by wildlife conservation (monetary, recreational, scientific and ecological benefits).

### **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 of 1972, Forest Act 1927, and Forest conservation Act 1920; introduction of Tiger task force, Status of current protected areas in India. Concept of MAB programme.

### **Unit 4: Socio-economic and legal basis of conflicts**

**(8 lectures)**

Concepts of development and encroachment, who is the intruders: human or animal? 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 produce to tribal populations, Scheduled tribes and other traditional Forest dwellers (Recognition of forest right) Act, 2006.

### **Unit 5: Wildlife conflicts**

**(6 lectures)**

Insight into the important conflicts: conflict of Bharatpur, Human and elephant conflicts of Kerala, Fisherman and tiger conflict of Sundarbans forest, shifting cultivation in North east India. Railway transport and elephant conflicts in north Bengal.

## **Unit 6: Human wildlife coexistence**

**(12 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; conservation of indigenous culture and traditions, concept of conservation reserves and community reserves.

### **Practicals:**

Documentation of wildlife resources in India (visit to museum/zoo/bird watching/sanctuary/Ramsar site)

### **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 Biodegradation & Biodegradation* 45: 97-102.
4. Paty, C. 2007. *Forest Government and Tribe*. Concept Publishing Company.
5. Treves, A. & Karanth, K.U. 2003. Human-carnivore conflict and perspectives on carnivore management worldwide. *Conservation Biology* 17: 1491-1499
6. Woodroffe, R. 2005. *People and Wildlife: Conflict and Coexistence*. Cambridge.
7. Woodroffe, R., Thirgood, S., & Rabinowitz, A. 2005. *People and Wildlife, Conflict or Co-existence?* (No. 9). Cambridge University Press.

## **CORE COURSE 5: ECOLOGY AND ECOSYSTEMS**

### **Theory (50 Lectures)**

#### **Unit1: Introduction to Ecology**

**(12 lectures)**

Basic concepts and definitions: ecology, landscape, habitat, ecozones, biosphere, ecosystems, ecosystem stability, resistance and resilience; autecology; synecology; major terrestrial biomes. Ecological amplitude; Liebig's Law of the Minimum; Shelford's Law of Tolerance; phenotypic plasticity; ecotypes; ecoclines; acclimation; ecological niche; types of niche: Eltonian niche, Hutchinsonian niche, fundamental niche, realized niche; niche breadth; niche partitioning; niche differentiation.

#### **Unit 2: Population Ecology**

**(8 lectures)**

Concept of population; 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 3: Community Ecology**

**(8 lectures)**

Discrete versus continuum community view; 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, models and types of successions, and meta-population; r- and K-selection, climax community concepts, examples of succession, ruderal, competitive and stress-tolerance strategies

#### **Unit 4: Ecosystem ecology**

**(15 lectures)**

Types of ecosystem: forest, grassland, lentic, lotic, estuarine, marine, desert, wetlands; ecosystem structure and function; abiotic and biotic components of ecosystem; ecosystem boundary; ecosystem function; ecosystem metabolism; primary production and models of energy flow; secondary production and trophic efficiency; ecosystem connections: food chain, food web; detritus pathway of energy flow and decomposition processes; ecological efficiencies; ecological pyramids: pyramids of number, biomass, and energy. 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; invasive ecogenomics - role of polyploidy and genome size in determining invasiveness; economic costs of biological invasions.

## **Unit 5: Biogeochemical cycles and nutrient cycling**

**(7 lectures)**

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

### **Practical:**

Field study in ecology from any one of the following bio-geographical area (coastal/forest/wetlands) with report submission and field viva voce.

### **Suggested Readings**

1. Groom, B. & Jenkins, M. 2000. *Global Biodiversity: Earth's Living Resources in the 21<sup>st</sup> Century*. 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**

### **Theory (50 Lectures)**

#### **Unit 1: The Structure and Function of DNA, RNA and Protein (12 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 2: Recombinant DNA Technology (12 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, phage, cosmid, artificial chromosomes)

#### **Unit 3: Biotechnology of Solid waste and solid waste treatment (16 lectures)**

Wastewater treatment: anaerobic, aerobic process, methanogenesis, bioreactors, cell and protein (enzyme) immobilization techniques; 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, use of bioreactors for bioremediation; phytoremediation; remediation of degraded ecosystems; degradation of xenobiotics in environment

**Unit 4: Ecologically safe products and processes****(7 lectures)**

PGPR bacteria: biofertilizers, microbial insecticides and pesticides, bio-control of plant pathogen, Integrated pest management; development of stress tolerant plants, biofuel; mining and metal biotechnology: microbial transformation, accumulation and concentration of metals, metal leaching.

**Unit 5: GMs and GMOs****(3 lectures)**

Concept of GM and GMOs, case studies, biosafety protocol

**Practicals:**

Review paper preparation/presentation on topics related to Environmental Biotechnology.

**Suggested Readings**

1. Evans, G.G. & Furlong, J. 2010. *Environmental Biotechnology: Theory and Application* (2<sup>nd</sup> 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* (6<sup>th</sup> edition). John Wiley& Sons.
8. Wainwright, M. 1999. *An Introduction to Environmental Biotechnology*. Springer.

## **CORE COURSE 7: ATMOSPHERE AND GLOBAL CLIMATE CHANGE**

**Theory (50 Lectures)**

**Unit 1: 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 2: Atmospheric circulation** **(12 lectures)**

Movement of air masses; atmosphere and climate; air and sea interaction; southern oscillation; western disturbances; *EI Nino* and *La Nina*; tropical cyclone; Indian monsoon and its development, effect of urbanization on micro climate; Asian brown clouds.

**Unit 3: Meteorology and atmospheric stability** **(14 lectures)**

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

**Unit 4: Global warming and climate change** **(12 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, agricultural productivity and biological responses - range shift of species, CO<sub>2</sub> fertilization and agriculture; impact on economy and spread of human diseases.

Environmental policy debate; International agreements; Kyoto protocol 1997; Convention on Climate Change; carbon credit and carbon trading; clean development mechanism.

**Unit 5: Ozone layer depletion** **(8 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 - Montreal protocol 1987.

### **Practicals:**

Atmospheric pressure, relative humidity, rainfall, insolation, wind speed, light intensity .

Viva-voce.

### **Suggested Readings:**

- a. Barry, R. G. 2003. *Atmosphere, Weather and Climate*. Routledge Press, UK.
- b. Gillespie, A. 2006. *Climate Change, Ozone Depletion and Air Pollution: Legal Commentaries with Policy and Science Considerations*. Martinus Nijhoff Publishers.
- c. Hardy, J.T. 2003. *Climate Change: Causes, Effects and Solutions*. John Wiley & Sons.
- d. Harvey, D. 2000. *Climate and Global Climate Change*. Prentice Hall.
- e. Manahan, S.E. 2010. *Environmental Chemistry*. CRC Press, Taylor and Francis Group.
- f. Maslin, M. 2014. *Climate Change: A Very Short Introduction*. Oxford Publications.
- g. Mathez, E.A. 2009. *Climate Change: The Science of Global Warming and our Energy Future*. Columbia University Press.
- h. Mitra, A.P., Sharma, S., Bhattacharya, S., Garg, A., Devotta, S. & Sen, K. 2004. *Climate Change and India*. Universities Press, India.
1. Philander, S.G. 2012. *Encyclopedia of Global Warming and Climate Change* (2<sup>nd</sup> edition). Sage Publications.

## **SKILL ENHANCEMENT COURSE 1: REMOTE SENSING, GEOGRAPHIC INFORMATION SYSTEM & MODELLING**

### **Theory (Lectures: 30)**

**Unit 1:** Remote Sensing: definitions and principles; electromagnetic (EME) 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; raster and vector data; database generation; database management system; land use/ land cover mapping; overview of GIS software packages; GPS survey, 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.

### **Suggested Readings**

1. Demers, M.N. 2005. *Fundamentals of Geographic Information System*. Wiley & Sons.
2. Richards, J.A. & Jia, X. 1999. *Remote Sensing and Digital Image Processing*. Springer.
3. Sabins, F.F. 1996. *Remote Sensing: Principles an Interpretation*. W.H. Freeman.

## **GENERAL ELECTIVE 3: GENDER AND ENVIRONMENT**

**Theory (50 Lectures)**

**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 as means of social exclusion (case studies in an Indian context); gender equity issues in rural and urban settings.

**Unit 3: Gender and the environment** (10 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** (10 lectures)

Knowledge about the environment among men and women; differential dependencies on environmental resources; implications of gendered responses to environmental degradation.

**Unit 6: Gender and environmental management** (10 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** (8 lectures)

Need for gender equity; Instruments for change: education, media, action groups, policy and management; equity in resource availability and consumption for a sustainable future.

### **Practicals:**

Socio-economic survey of Gender and Society vis-a-vis environment and resource management

Report preparation/ presentation and Viva-voce

## 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. Doing what comes naturally? Women and environment in development *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.

## **CORE COURSE 8: SYSTEMATICS AND BIOGEOGRAPHY**

**Theory (Lectures: 50)**

**Unit 1: Concept and systematics approaches (12 lectures)**

Definition of systematics; taxonomic identification; keys; field inventory; herbarium; museum; botanical gardens; taxonomic literature; nomenclature; evidence from anatomy, ultrastructure, cytology, phytochemistry, numerical and molecular methods. Concept of taxa (species, genus, family, order, class, phylum, kingdom); concept of species (taxonomic, typological, biological, evolutionary, phylogenetic); categories and taxonomic hierarchy.

**Unit 2: Nomenclature and systems of classification (6 lectures)**

Principles and rules (International Code of Botanical and Zoological Nomenclature); ranks and names; types and typification; author citation; valid publication; rejection of names; principle of priority and its limitations; names of hybrids.

**Unit 4: Biogeography (6 lectures)**

Biogeographical rules – Gloger's rule, Bergmann's rule, Allen's rule, Geist rule; biogeographical realms and their fauna; endemic, rare, exotic, and cosmopolitan species.

**Part-A: 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; biogeographical dynamics of climate change and Ice Age.

**Part-B: 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.

**Part-C: Conservation Biogeography (2 lectures)**

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

## **Unit 5: Speciation and extinction**

**(8 lectures)**

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

### **Practicals:**

Identification of suitable flora and fauna (Definite list of specimens of ecological and economic significance).

Identification Key Preparation.

Viva voce

### **Suggested Readings**

1. Lomolino, M.V., Riddle, B.R., Whittaker, R.J. & Brown, J.H. 2010. *Biogeography* (4<sup>th</sup> 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* (3<sup>rd</sup> 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

**Theory (50 Lectures)**

### **Unit 1: Environment in an urban setting**

**(8 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; increasing challenges posed by modernity for the environment.

### **Unit 2: Urban dwelling**

**(12 lectures)**

Urban Sprawl; 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.

### **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; introduction to green buildings; rainwater harvesting (Corporation and Municipal areas); urban governance; political complexity of applying ecological science to urban policy and planning, smart cities.

**Practicals:** Urban survey (Corporations and Municipal areas) and field report submission.

### **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**

**Theory (50 lectures)**

**Unit 1: Introduction** **(4 lectures)**

Constitution of India; fundamental rights; fundamental duties; Union of India; union list, state list, concurrent list; legislature; state assemblies; judiciary; panchayats and municipal bodies.

**Unit 2: History of environmental legislation and policy** **(8 lectures)**

Provision of Environmental Conservation - British India: Indian Penal Code 1860, Forest Act 1865, Fisheries Act 1897; Independent India: Van Mahotsava 1950, National Forest Policy 1952, National Forest Policy 1988.

**Unit 3: Environmental legislation** **(25 lectures)**

Legal definitions (environmental pollution, natural resource, biodiversity, forest, sustainable development); Article 48A (The protection and improvement of environment and safeguarding of forests and wildlife); Article 51 A (Fundamental duties).

The Indian Forest Act 1927; The Wildlife (Protection) Act 1972; The Water (Prevention and Control of Pollution) Act 1974; The Water (Prevention and Control of Pollution) Cess Act 1977; 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 Schedule Tribes and other Traditional Dwellers (Recognition of Forests Rights) Act 2006; The National Green Tribunal Act 2010; scheme and labeling of environment friendly products, Ecomarks.

**Unit 4: Role of Government institutions and National Policies** **(5 lectures)**

Role of Ministry of Environment, Forests & Climate Change in environmental law and policy making; role of central and state pollution control boards in environmental law and policy making; National Green Tribunal; National Environment Policy, 2006.

**Unit 5: International laws and policy** **(5 lectures)**

Stockholm Conference 1972; United Nations Conference on Environment and Development 1992; Rio de Janeiro (Rio Declaration, Agenda 21); Montreal Protocol 1987; Kyoto Protocol 1997; Copenhagen and Paris summits; Ramsar convention.

**Practicals:** Review of different Case studies on Environmental Issues.

## **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<sup>nd</sup> edition). Oxford University Press.
5. Gupta, K.R. 2006. *Environmental Legislation in India*. Atlantic Publishers and Distributors.
6. Leelakrishnan, P. 2008. *Environmental Law in India* (3<sup>rd</sup> edition). LexisNexis India.
7. Naseem, M. 2011. *Environmental Law in India Mohammad*. Kluwer Law International.
8. Venkat, A. 2011. *Environmental Law and Policy*. PHI Learning Private Ltd.

## **SKILL ENHANCEMENT COURSE 2: ENVIRONMENTAL IMPACT AND RISK ASSESSMENT**

### **Theory (30 Lectures)**

**Unit 1:** Environmental impact assessment (EIA): definitions, introduction and concepts; rationale and historical development of EIA; scope and methodologies of EIA; role of project proponents, project developers and consultants; Terms of Reference; impact identification and prediction; baseline data collection; Environmental Impact Statement (EIS), Environmental Management Plan (EMP)

**Unit 2:** Rapid EIA; Strategic Environmental Assessment; Social Impact Assessment; Cost-Benefit analysis; Life cycle assessment; environmental appraisal; environmental management - principles, problems and strategies; environmental planning; environmental audit; introduction to ISO and ISO 14000; sustainable development.

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

### **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.

## **GENERAL ELECTIVE 4: GREEN TECHNOLOGIES**

### **Theory (50 lectures)**

**Preamble:** This paper introduces students to the concept of green technology, its goals and advantages. It also highlights potential role of green technologies in realizing the goal of sustainable development and focuses on community participation to tap the economic benefits associated with switching to green technologies.

#### **Unit 1: Green technologies (10 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; Green technologies in historical and contemporary perspectives; successful green technologies: wind turbines, solar panels; 3R's of green technology: recycle, renew and reduce.

#### **Unit 2: Green infrastructure, planning and economy (12 lectures)**

Green buildings; history of green buildings, need and relevance of green buildings over conventional buildings, construction of green buildings; associated costs and benefits; outlined examples of green buildings; LEED certified building; Eco-mark certification, establishment of Eco-mark in India, its importance and implementation; 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.

#### **Unit 3: Applications of green technologies (12 lectures)**

Increase in energy efficiency: cogeneration, motor system optimization, oxy-fuel firing, isothermal melting process, energy efficient fume hoods, 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, promotion and/or subsidy of alternative forms of transportation for employees, such as carpools, fuel efficient vehicles, and mass transit, methane emissions reduction and/or reuse).

Pollution reduction and removal (Flue Gas Desulfurization (FGD) methods, catalytic or thermal destruction of NO<sub>x</sub>, 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 4: Green chemistry****(8 lectures)**

Introduction to green chemistry; principles and recognition of green criteria in chemistry; bio-degradable and bio-accumulative products in environment; green nanotechnology; reagents, reactions and technologies that should be and realistically could be replaced by green alternatives; photodegradable plastic bags.

**Unit 5: Green future****(8 lectures)**

Agenda of green development; reduction of ecological footprint; role of green technologies towards a sustainable future; major challenges and their resolution for implementation of green technologies; green practices to conserve natural resources (organic agriculture, agroforestry, reducing paper usage and consumption, etc.); emphasis on waste reduction instead of recycling, emphasis on innovation for green future; role of advancement in science in developing environmental friendly technologies.

**Practicals:**

Vermicomposting, Review of project/status report on rainwater harvesting/alternative energy.

**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.

## **CORE COURSE 11: BIODIVERSITY AND CONSERVATION BIOLOGY**

**Theory (50 Lectures)**

### **Unit 1: Biodiversity patterns and estimation**

**(12 lectures)**

Definition; Types; Spatial patterns: latitudinal and elevational trends in biodiversity; temporal patterns: seasonal fluctuations in biodiversity patterns.

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 2: 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 3: 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; man wildlife conflicts; consequences of biodiversity loss; Intermediate Disturbance Hypothesis.

### **Unit 4: Conservation of biodiversity**

**(10 lectures)**

Importance of biodiversity patterns in conservation; 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 5: 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; impact of hydropower development on biological diversity; status of protected areas and biosphere reserves in the country; National Biodiversity Action Plan.

**Practicals:** Biodiversity assessment in local field work: report submission and viva voce

### 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* (3<sup>rd</sup> edition). Sinauer Associates, 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. *Conservation Biology: Voices from the Tropics*. Wiley-Blackwell, Oxford, UK.

## **CORE COURSE 12: ORGANISMAL AND EVOLUTIONARY BIOLOGY**

### **Theory (50 Lectures)**

#### **Unit 1: History of life on Earth**

**(17 lectures)**

Part-A : Paleontology and evolutionary History; evolutionary time scale; eras, periods and epoch; major events in the evolutionary time scale; stages in primate evolution including Homo.

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

#### **Unit 2: Evolution of unicellular life**

**(8 lectures)**

Origin of cells and unicellular evolution and basic biological molecules; abiotic synthesis of organic monomers and polymers; Oparin-Haldane hypothesis; study of Miller; the first cell;

#### **Unit 3: Geography of evolution**

**(5 lectures)**

Biogeographic evidence of evolution; patterns of distribution.

#### **Unit 4: Molecular evolution**

**(7 lectures)**

Neutral evolution; molecular divergence and molecular clocks; molecular tools in phylogeny, classification and identification; protein and nucleotide sequence analysis.

#### **Unit 5: Fundamentals of population genetics**

**(13 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; speciation (allopatric, sympatric, peripatric and parapatric); convergent evolution; sexual selection; co-evolution; Hardy-Weinberg Law.

**Practicals:** Numerical problems on pedigree and population genetics.

#### **Suggested Readings**

1. Futuyma, D.J. 2009. *Evolution* (2<sup>nd</sup> edition). Sinauer Associates.
2. Gillespie, J. H. 1991. *The Causes of Molecular Evolution*. Oxford University Press.
3. Graur, D. & Li, W.H. 1999. *Fundamentals of Molecular Evolution* (2<sup>nd</sup> 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**

### **Theory (50 Lectures)**

#### **Unit 1: Energy resources (12 lectures)**

Defining energy; forms and importance; Global energy resources; renewable and non-renewable resources: distribution and availability; sources and sinks of energy; past, present, and future technologies for capturing and integrating these resources into our energy infrastructure.

#### **Unit 2: Energy demand (7 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; environmental costs.

#### **Unit 3: Energy, environment and society (15 lectures)**

Energy production as driver of environmental change; nature, scope and analysis of local and global impacts of energy use on the environment; fossil fuel burning and related issues of air pollution, nuclear energy and related issues such as radioactive waste, spent fuel; 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; social inequalities related to energy production, distribution, and use; energy conservation.

#### **Unit 4: Our energy future (16 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; tidal energy, ocean energy; nuclear energy); need for energy efficiency; energy conservation and sustainability; action strategies for sustainable energy management from a future perspective.

### **Practicals:**

Poster presentation and documentation

### **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<sup>nd</sup> edition). Prentice Hall, New Jersey.

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 AND STATISTICS**

### **Theory (50 Lectures)**

#### **Unit 1: 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- standards vs. emissions charges, environmental subsidies, modelling and emission charges; polluter pay principles; pollution permit trading system.

#### **Unit 2: 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 3: Tools for environmental economic policy (10 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.

#### **Unit 4: Statistical techniques applied to Environmental systems (20 lectures)**

Variables, population and Sampling, sampling methods, sampling error, frequency distribution, bar diagram, pie diagram, arithmetic and geometric mean, mode, median, measures of deviation, null and alternative hypothesis, probability distribution, t-test,  $\chi^2$  Test, correlation and regression.

### **Practicals:**

Numerical problems on biostatistics (Chi-Square test and Student's t test)

### **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 Economics*. 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<sup>th</sup> 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.
10. Zar, J.H. 2010. *Biostatistical Analysis* (5<sup>th</sup> edition). Prentice Hall Publications.
11. Das, N.G. *Statistical Methods*. McGraw Hill Publication.
12. Rastogi, B.B. *Biostatistics*. MEDTEC.

## **CORE COURSE 13: ENVIRONMENTAL POLLUTION AND HUMAN HEALTH**

**Theory (50 Lectures)**

### **Unit 1: Introduction** **(9 lecture)**

Definition of pollution; pollutants; classification of pollutants. Solubility of pollutants (hydrophilic and lipophilic pollutants), transfer of pollutants within different mediums, role of chelating agents in transferring pollutants, concept of biotransformation and bioaccumulation, concept of radioactivity, radioactive decay and half-life of pollutants, organometallic compounds, acid mine drainage.

### **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 ( $\text{NO}_x$ ,  $\text{SO}_x$ , PM, CO,  $\text{CO}_2$ , hydrocarbons and VOCs) and control measures; indoor air pollution: sources and effects on human health.

### **Unit 3: Water pollution** **(8 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** **(4 lectures)**

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

### **Unit 5: Noise pollution** **(3 lectures)**

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

### **Unit 6: Radioactive and thermal pollution** **(4 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****(4 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: 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: Ganga Action Plan; Yamuna Action Plan; implementation of CNG in NCT of Delhi.

**Practicals:**

BOD, COD, Noise (dB(A)), SPM, RSPM, Dust fall rate, Soil respiration.

Viva Voce

**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* (23<sup>rd</sup> 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.

## CORE COURSE 14: NATURAL RESOURCE MANAGEMENT AND SUSTAINABILITY

Theory (50 Lectures)

### Unit 1: Introduction

(7 lectures)

Resource and reserves; classification of natural resources; renewable and non-renewable resources; resource degradation; resource conservation; resource availability and factors influencing its availability; land resources; water resources; fisheries and other marine resources; energy resources; mineral resources; human impact on natural resources; ecological, social and economic dimension of resource management.

### Unit 2: Natural resources and conservation

(7 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 foodproblem, techniques to increase world food production, green revolution.

### Unit 3: Mineral resources

(8 lectures)

Mineral resources and the rock cycle; identified resources; undiscovered resources; reserves; 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; environmental effects of extracting and using mineral resources.

### Unit 4: Energy resources

(20 lectures)

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

**Part B:** Energy efficiency; life cycle cost; cogeneration; solar energy: technology, advantages, passive and active solar heating system, solar thermal systems, solar cells, JNN solar mission; hydropower: technology, potential, operational costs, benefits of hydropower development; nuclear power: nuclear fission, fusion, reactors, pros and cons of nuclear power, storage of radioactive waste, radioactive contamination; tidal energy; wave energy; ocean thermal energy conversion (OTEC); geothermal energy; energy from biomass; bio-diesel.

## **Unit 5: Resource management**

**(8 lectures)**

Approaches in resource management: ecological approach; economic approach; ethnological approach; implications of the approaches; integrated resource management strategies; concept of sustainability science: 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.

### **Practicals:**

Project Work: Submission of report & presentation

### **Suggested Readings**

1. Craig, J.R., Vaughan. D.J. & Skinner. B.J. 1996. *Resources of the Earth: Origin, Use, and Environmental Impacts* (2<sup>nd</sup> edition). Prentice Hall, New Jersey.
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* (7<sup>th</sup> edition). Prentice Hall.
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**

**Theory (50 Lectures)**

### **Unit 1: Introduction**

**(3 lectures)**

Definition of hazard; natural, technological, and 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**

**(16 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 hazards associated with it; 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**

**(4 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**

**(6 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**

**(6 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.

### **Practicals:**

Poster / Model preparation and presentation on topic related to national and international disaster and disaster management.

### **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., Mortheikai, 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**

**Theory (50 Lectures)**

**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** **(5 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** **(12 lectures)**

Different techniques used in 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 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** **(6 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: Policies for solid waste management**

**(10 lectures)**

Municipal Solid Wastes (Management and Handling) Rules 2000; Hazardous Wastes Management and Handling Rules 1989; Bio-Medical Waste (Management and Handling) Rules 1998; Plastic Waste (Management and Handling) Rules, 2011; E-Waste (Management) Rules, 2016

### **Practicals:**

Visit to a Solid Waste Management site and Report submission.

### **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*. Washington D.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.