CURRICULUM AND CREDIT FRAMEWORK FOR UNDERGRADUATE PROGRAMMES

Syllabus for

DEPARTMENT OF ENVIRONMENTAL SCIENCE
NAGALAND UNIVERSITY

2023

Approved by 36th Academic Council
(on 17th May, 2023)

Major Courses (Core papers):

Course Code	Title of the Course	Total Credit
FIRST SEMESTER		
C-1T	Earth and Earth Surface Processes	3
C-1P	Practical 1	1
C-2T	Physics and Chemistry of Environment	3
C-2P	Practical 2	1
SECOND SEMESTER		
C-3T	Water and Water Resources	3
C-3P	Practical 3	1
C-4T	Land and Soil Conservation and Management	3
C-4P	Practical 4	1
THIRD SEMESTER		
C-5T	Ecology and Ecosystem	3
C-5P	Practical 5	1
C-6T	Atmosphere and Global Climate Change	3
C-6P	Practical 6	1
FOURTH SEMESTER		
C-7T	Systematics and Biogeography	3
C-7P	Practical 7	1
C-8T	Urban Ecosystem	3
C-8P	Practical 8	1
FIFTH SEMESTER		
C-9T	Biodiversity and Conservation	3
C-9P	Practical 9	1
C-10T	Environmental Pollution and Human Health	3
C-10P	Practical 10	1
C-11T	Environmental Biotechnology	3
C-11P	Practical 11	1
SIXTH SEMESTER		
C-12T	Organism and Evolutionary Biology	3
C-12P	Practical 12	1
C-13T	Natural Resources Management and Sustainability	3
C-13P	Practical 13	1
C-14T	Environmental Legislation and Policy	3
C-14P	Practical 14	1
C-15T	Energy and Environment	3

C-15P	Practical 15	1
SEVEN SEMESTER		
C-16T	Environmental Economics	3
C-16P	Practical 16	1
C-17T	Natural Hazards and Disaster Management	3
C-17P	Practical 17	1
C-18T	Solid Waste Management	3
C-18P	Practical 18	1
C-19T	Research Methodology	4
EIGHT SEMESTER		
C-20T	Research Project/ Dissertation	12
C-21T		4
C-22T		4
C-23T		4

C-1T**: EARTH AND EARTH SURFACE PROCESSES**

Unit 1: History of Earth

Solar system formation and planetary differentiation; 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; Holocene and the emergence of humans, role of humans in shaping landscapes; development of cultural landscapes.

Unit 2: Earth system processes

Movement of lithosphere plates; mantle convection and plate tectonics, major plates and hot spots, 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; continental collision and mountain formation with specific example of the Himalaya.

Unit 3: Minerals and rocks

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 surface processes

Atmosphere: evolution of earth's atmosphere, composition of atmosphere, physical and optical properties, circulation; interfaces: atmosphere–ocean interface, atmosphere–land interface, ocean–land interface; 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 5: Importance of being a mountain

Formation of Peninsular Indian mountain systems - Western and Eastern Ghats, Vindhyas, Aravallis, etc. Formation of the Himalaya; development of glaciers, perennial river systems and evolution of monsoon in Indian subcontinent; formation of Indo-Gangetic Plains, arrival of humans; evolution of Indus Valley civilization; progression of agriculture in the Indian subcontinent in Holocene; withdrawing monsoon and lessons to draw.

Suggested Readings

1. Bridge, J., andDemicco, R. 2008. Earth Surface Processes, Landforms and Sediment deposits. Cambridge University Press.
2. Duff, P. M. D., and Duff, D. (Eds.). 1993. Holmes' Principles of Physical Geology. Taylor and Francis.
3. Gupta, A. K., Anderson, D. M., andOverpeck, 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., andSinghvi, 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 (5th edition). Pearson Prentice Hall.
6. Krishnan, M. S. 1982. Geology of India and Burma. CBS Publishers and 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

C-1P**: Practical 1**

1. Study of terrain characteristics using topo sheets.
2. Study of geomorphophological models – a) Coastal plain, b) Volcanoes, c) Fault block mountains, d) Folded mountains, e) Glaciers, f) Canyon, and g) Coastline
3. Mineralogy–Identification of common rock forming minerals.
4. Petrology – Identification of major rock types – Igneous, Metamorphic, and Sedimentary.
5. Identification of minerals on the basis of physical properties
6. Study of micrometeorological equipments.
7. Determination of relative humidity of air .
8. Determination of atmospheric pressure by using Barometer.
9. Determination of wind speed by using Anemometer.
10. Determination of wind direction by using wind vane.
11. Interpretation of wind rose diagram.

C-2T**: PHYSICS AND CHEMISTRY OF ENVIRONMENT**

Unit 1: Fundamentals of environmental physics

Part A: Basic concepts of light and matter; quantum mechanics (relation between energy, wavelength and frequency), black body radiation, Kirchhoff's law, Boltzmann equation, spectroscopic concepts: Introduction to the concept of absorption and transmission of light, Beer–Lambert law, photovoltaic and solar cells; scattering of light, Rayleigh and Mia 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, transmission of electrical power, efficiency of turbines, wind mills and hydroelectric power plants.

Unit 2: Movement of pollutants in environment

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

Part B: Atmospheric chemistry

Composition of atmosphere; photochemical reactions in atmosphere; smog formation, types of smog (sulphur smog and photochemical smog), aerosols; chemistry of acid rain, case studies; reactions of NO_2 and SO_2; free radicals and ozone layer depletion, role of CFCs in ozone depletion.

Unit 3: Fundamentals of environmental chemistry

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: Thermodynamic system; types of chemical reactions; acids, bases and salts, 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, synthesis of xenobiotic compounds like pesticides and dyes, synthetic polymers.

Unit 4: Water chemistry

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 5: Soil chemistry

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.

Suggested Readings

1. Beard, J.M. 2013. Environmental Chemistry in Society (2nd edition). CRC Press.
2. Boeker, E. andGrondelle, R. 2011. Environmental Physics: Sustainable Energy and Climate Change. Wiley.
3. Connell, D.W. 2005. Basic Concepts of Environmental Chemistry (2nd edition). CRC Press.
4. Forinash, K. 2010. Foundation of Environmental Physics. Island Press.
5. Girard, J. 2013. Principles of Environmental Chemistry (3rd edition). Jones and Bartlett.
6. Harnung, S.E. and Johnson, M.S. 2012. Chemistry and the Environment. Cambridge University Press.
7. Hites, R.A. 2012. Elements of Environmental Chemistry (2nd edition). Wiley and Sons.
8. Manahan, S. E. 2000. Fundamentals of Environmental Chemistry. CRC Press.
9. Pani, B. 2007. Textbook of Environmental Chemistry. IK international Publishing House.
10. Sawyer and McCarty 2017. Chemistry for Environmental Engineering and Science. McGraw Hill Publications.

C-2P**: Practical 2**

1. Studies on the concept of molarities, normality and buffer solutions.
2. Determination of organic matter by Walkley's and Black method from soil.
3. Determination of bicarbonate and carbonate alkalinity of water.
4. Determination of pH and Electrical conductivity of soil sample.
5. Determination of water holding capacity, Bulk density and moisture content of soil.
6. Estimation of calcium and magnesium content of soil.
7. Estimation of organic matter in soil.
8. Estimation of available phosphates and total nitrogen in soil.
9. Determination of Total hardness, calcium hardness and magnesium hardness by EDTA complexmetric method.
10. Separation of chlorophyll pigments of green leaf by using thin layer chromatographic technique.
11. Separation of a mixture of amino acid by using paper chromatography.

C-3T**: WATER AND WATER RESOURCES**

Unit 1: Introduction

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

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, phytobenthos, zooplankton, macro-invertebrates and microbes.

Unit 2: Surface and subsurface water

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 3: Wetlands and their management

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.

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

Unit 4: Water resource in India and Major laws and treaties

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.

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.

Unit 5: Water resources conflicts

Water resources and sharing problems, case studies on Kaveri and Krishna river water disputes; Multipurpose 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.

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 and Power.

4. Grumbine, R.E. and Pandit, M.K. 2013. Threats from India's Himalaya dams. Science 339: 36- 37.
5. Loucks, D.P., Stedinger, J.R. and 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. Schwardand 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

C-3P**: Practical 3**

1. To study confined aquifer and unconfined aquifer.
2. To study the Hydrological properties of Rock.
3. Delineation and Morphometric analysis of watershed.
4. Determination of pH, Electrical Conductivity and Turbidity of water sample.
5. Determination of Total Dissolved Solids in water samples.
6. Determination of Chloride in water sample by $AgNO_3$ method.
7. Estimation of Phosphates in water by Ammonium Molybdate method.
8. Estimation of Sulphates in water sample.
9. Estimation of nitrates in water sample.
10. Estimation of fluorides in water sample.
11. Estimation of Dissolved Oxygen, Biochemical Oxygen Demand and Chemical Oxygen Demand in water sample.

C-4T: LAND AND SOIL CONSERVATION AND MANAGEMENT

Unit 1: Introduction and Fundamentals of soil science

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 salinity and sodicity; soil organic matter; micronutrients of soil; nitrogen, sulphur, potassium and phosphorus economy of soil; soil biodiversity; soil taxonomy maps.

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: Soil degradation - causes

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, Shifting cultivation, Forest fire,industrial and urban development, toxic organic chemicals, and organic contaminants in soils; fertilizers and fertilizer management; recycling of soil nutrients.

Unit 3: Land use changes and land degradation

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; range land degradation; land salinization; human population pressure, poverty, socio-economic and institutional factors; drivers of land use and land cover change in major geographic zones and biodiversity regions with particular reference to the Himalaya and the Western Ghats.

Unit 4: Costs of land degradation

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 5: Controlling land degradation

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

Suggested Readings

1. Brady, N.C. and 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). Rowmanand Littlefield Publishers.

4. Marsh, W. M. andDozier,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. andKumar, V. 2013. Land use and conservation challenges in Himalaya: Past, present and future. In: Sodhi, N.S., Gibson, L. and Raven, P.H. Conservation Biology: Voices from the Tropics. pp. 123-133. Wiley-Blackwell, Oxford, UK (file:///Users/mkpandit/Downloads/Raven%20et%20al.%202013.%20CB%20Voices%20from %20Tropics%20(2).pdf) .
8. Peterson, G. D., Cumming, G. S. and 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

C-4P**: Practical 4**

1. Determination of water holding capacity, Bulk density and moisture content of soil.
2. Estimation of calcium and magnesium content of soil.
3. Estimation of organic matter in soil.
4. Estimation of available phosphates and total nitrogen in soil.
5. Determination of organic matter by Walkley's and Black method from soil
6. Quantification of NPK from field soil samples.
7. Estimation of residual chlorine by chlorotex method.
8. Estimation of micronutrients of soil

C-5T**: ECOLOGY AND ECOSYSTEMS**

Unit 1: Introductionand**Ecology of individuals**

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; thermoregulation; strategies of adaptation in plants and animals.

Unit 2: Ecology of populations

Concept of population and meta-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; deterministic and stochastic models of population dynamics; rudreal, competitive and stress-tolerance strategies.

Unit 3: Ecology of communities

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, climax community concepts, examples of succession.

Unit 4: Ecosystem ecology

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.

Unit 5: Biogeochemical cycles, nutrient cycling,and Biological invasions

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.

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.

Suggested Readings

1. Groom. B. and Jenkins. M. 2000.Global Biodiversity: Earth's Living Resources in the 21st Century. World Conservation Press, Cambridge, UK.
2. Gurevitch, J., Scheiner, S. M., and Fox, G. A. 2002. The Ecology of Plants. Sinauer associates incorporated.
3. Loreau, M. and 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.and 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. and Gupta, S.R. 2006. Ecology, Environment and Resource Conservation. Anamaya Publications.
8. Wilson, E. O. 1985. The Biological Diversity Crisis. BioScience 35: 700-706

C-5P: Practical 5

1. Identification and enumeration of phytoplankton/zooplanktons in water body.
2. Estimation of primary productivity of a pond/lake.
3. Estimation of standing crop (biomass) of phytoplankton in aquatic system.
4. Estimation of standing crop and productivity in grassland habitat.
5. Estimation of growth, productivity and characteristics of terrestrial plants.
6. Productivity and biomass estimation of litter fauna.
7. Estimation of chlorophyll in terrestrial plants and phytoplankton.
8. Study of Ecological adaptations–
    a) Hydrophytes and xerophytes and b)Rocky shore and sandy shore fauna
9. Determination of primary production as GPP and NPP by light and dark bottle technique.
10. Profile study of natural pond/lake and manmade reservoir.
11. To study the cover and based area study of tree species
12. To study the light intensity by sunshine record
13. Determination of relative density relative frequency and relative abundance of species by using simulation.

C-6T**: ATMOSPHERE AND GLOBAL CLIMATE CHANGE**

Unit 1: Introductionand**Global energy balance**

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

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

Unit 2: Atmospheric circulation

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

Unit 3: Meteorology and atmospheric stability

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

Unit 4: Atmospheric chemistry

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.

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 5: Global warming and climate change

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_2 fertilization and agriculture; impact on economy and spread of human diseases.

Environmental policy debate; International agreements; Montreal protocol 1987; Kyoto protocol 1997; Convention on Climate Change; carbon credit and carbon trading; clean development mechanism.

Suggested Readings:

1. Barry, R. G. 2003. Atmosphere, Weather and Climate. Routledge Press, UK.
2. Gillespie, A. 2006. Climate Change, Ozone Depletion and Air Pollution: Legal Commentaries with Policy and Science Considerations. MartinusNijhoff Publishers.
3. Hardy, J.T. 2003. Climate Change: Causes, Effects and Solutions. John Wiley and Sons.
4. Harvey, D. 2000. Climate and Global Climate Change. Prentice Hall.
5. Manahan, S.E. 2010. Environmental Chemistry. CRC Press, Taylor and Francis Group.

6. Maslin, M. 2014. Climate Change: A Very Short Introduction. Oxford Publications.
7. Mathez, E.A. 2009. Climate Change: The Science of Global Warming and our Energy Future. Columbia University Press.
8. Mitra, A.P., Sharma, S., Bhattacharya, S., Garg, A., Devotta, S. andSen, K. 2004. Climate Change and India. Universities Press, India.
9. Philander, S.G. 2012. Encyclopedia of Global Warming and Climate Change (2nd edition). Sage Publications

C-6P**: Practical 6**

1. Study of meteorological instruments.
2. Determination of Maximum and Minimum temperature using psychomotor.
3. Determination of relative humidity in ambient atmosphere.
4. Determination of solar radiation and illuminations.
5. Study of precipitation, rainfall analysis and Indian monsoon patterns.
6. Determination of wind speed and direction by anemometers
7. Estimation of ambient carbon dioxide.
8. Study of clouds and their types.
9. Study of Wind roses and pollution roses.
10. Community perception on climate change–Questionnaire method.
11. Quantification of green house gas emissions from a) Energy sector, b) Industrial sector, c) Agriculture and forestry sector, and d) Waste sector.

C-7T**: SYSTEMATICS AND BIOGEOGRAPHY**

Unit 1: Concept and systematics approaches

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: Taxonomic hierarchy

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

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; classification systems of Bentham and Hooker; Angiosperm Phylogeny Group (APG III) classification.

Unit 3: Numerical and molecular systematics

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

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 4: Speciation and extinction Historical Biogeography

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.

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.

Unit 5: Ecological Biogeography and Conservation Biogeography

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.

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

Suggested Readings

1. Lomolino, M.V., Riddle, B.R., Whittaker, R.J. and 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 and IBH Pvt. Ltd., New Delhi.
4. Wheeler, Q.D. and 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

C-7P**: Practical 7**

1. Field and Herbarium techniques: Description and identification of plants; identification test of plant specimens; study of Nagaland flora; Vegetation quantification; field sampling.
2. Estimation of quantitative and qualitative characteristics of community: frequency, density, abundance, basal area, physiognomy, phenology and productivity

C-8T**: URBAN ECOSYSTEMS**

Unit 1: Introduction

Introduction to urbanization; urban sprawl and associated environmental issues.

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; urban pollution (air, water, soil).

Unit 2: Urban dwelling

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

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

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, Green infrastructure, Sponge cities; urban natural forest ecosystem as green lungs.

Unit 5: Planning and environmental management

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.

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. andWhatmore, 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. and Weiland, U. (ed.). 2012. Applied Urban Ecology. Wiley-Blackwell, UK

C-8P**: Practical 8**

1. Estimation of particulate matter, sulphur dioxide and oxides of nitrogen in ambient air.
2. Determination of relative density of sewage sample.
3. Estimation of volatile solids from sewage sample by gravimetric analysis.
4. Determination of Sludge Volume Index (SVI) in the sewage sample.
5. Determination of Total, settleable, suspended and dissolved solids in wastewater sample.
6. Determination of Hardness, Fluoride, Chlorides, DO, BOD COD in wastewater sample.
7. Determination of dose of chorine for disinfection of sewage.
8. Determination of Urban Infrastructure Index (UFI).
9. Determination of Water Quality Index (WQI).
10. Determination of Environmental Pollution Index (EPI).
11. Determination of life quality index.
12. Determination of Comprehensive environmental pollution index (CEPI).

C-9T**: BIODIVERSITY AND CONSERVATION**

Unit 1: Levels of organization in living world Importance of biodiversity

From genes to ecosystems; tree of life; history of character transformation; organic evolution through geographic time scale;

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 2: Biodiversity patterns and biodiversity estimation

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

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; molecular techniques: RAPD, RFLP, AFLP; NCBI database, BLAST analyses.

Unit 3: Threats to biodiversity

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

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

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.

Suggested Readings

1. Gaston, K J. and 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. andGrumbine 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). Sinauer Associates, Sunderland, USA.
5. Singh, J. S. and Singh, S. P. 1987. Forest vegetation of the Himalaya. The Botanical Review 53: 80-192.
6. Singh, J. S., Singh, S.P. and Gupta, S. 2006. Ecology, Environment and Resource Conservation. Anamaya Publications, New Delhi.
7. Sodhi, N.S. and Ehrlich, P.R. (Eds). 2010. Conservation Biology for All. Oxford University Press.
8. Sodhi, N.S., Gibson, L. and Raven, P.H. 2013. Conservation Biology: Voices from the Tropics. Wiley-Blackwell, Oxford, UK

C-9P**: Practical 9**

1. Identification of wild animals by using pug marks.
2. Identification of wild species by using feeding signs and artifacts.
3. Determination of relative abundance of light attracting insects by using light trap.
4. Determination of birds population by using Lincoln index (Simulation)
5. Determination of total population /density of birds from nesting ground during breeding season / or determination of total population of birds by using nests.
6. Identification of mammals from the hair morphology and histology.
7. To study the bird species by using vocal display.
8. Determination of burrowing animal's population by using their artifacts.
9. Field visit for the study of wild species and collection of samples from various domestic and wild animals.
10. Visit to Zoo/ National park /Sanctuary / Aquarium for the study of wildlife.
11. Field visit to study the habitat components of wild species.

C-10T **: ENVIRONMENTAL POLLUTION AND HUMAN HEALTH**

Unit 1: Introduction

Definition of pollution; pollutants; classification of pollutants.

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 2: Water pollution

Sources of surface and ground water pollution; Transportation, Transformation and Fate of pollutants; water quality parameters and standards; organic waste and water pollution; eutrophication; 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 3: Soil pollution and Noise pollution

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

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 4: Radioactive, thermal pollution and Marine pollution

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

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 5: Chemistry of environmental pollutants and Pollution control

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.

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.

Suggested Readings

1. Gurjar, B.R., Molina, L.T. and Ojha C.S.P. 2010. Air Pollution: Health and Environmental
2. Impacts. CRC Press, Taylor and Francis.

3. Hester, R.E. and Harrison, R.M. 1998. Air Pollution and Health. The Royal Society of
4. Chemistry, UK.
5. Park, K. 2015. Park's Textbook of Preventive and Social Medicine (23rd edition). Banarsidas
6. Bhanot Publishers.
7. Pepper, I.L., Gerba, C.P. andBrusseau, M.L. 2006. Environmental and Pollution Science.
8. Elsevier Academic Press.
9. Purohit, S.S. and Ranjan, R. 2007. Ecology, Environment and Pollution. Agrobios Publications.
10. Vesilind, P.J., Peirce, J.J., and Weiner R.F. 1990. Environmental Pollution and Control.
11. Butterworth-Heinemann, USA

C-10P**: Practical 10**

1. Collection techniques and sampling devices for gaseous pollutants
2. Determination at carbon dioxide from air by using Lungs Zincondroff apparatus.
3. Determination of NOx in ambient air by high volume sampler (HVS).
4. Measurement of SOxby high volume sampler (HVS).
5. Measurement of SPM by using high volume sampler (HVS).
6. Measurement of RSPM by using Respirable Dust Sampler.
7. Determination of atmospheric lead and other metals by using impinger techniques and AAS.
8. Determination of polynuclear aromatic hydrocarbon from air.
9. Study of the effect of heavy metal concentration on seed germination
10. Cytological study of nano toxins on onion root tips
11. Study of rate of uptake of metal toxins by different species of plants.
12. Study of Chlorosis and Necrosis in plant species

C-11T**: ENVIRONMENTAL BIOTECHNOLOGY**

Unit 1: The Structure and Function of DNA, RNA and Protein

DNA: structural forms and their characteristics (B, A, C, D, T, and 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, SiRNA, miRNA, hnRNA); biological significance of different types of RNA; synthesis. Protein: hierarchical structure (primary, secondary, tertiary, and quaternary), types of amino acids; posttranslational 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

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

Unit 3: Ecological restoration and bioremediation

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

Unit 4: Ecologically safe products and processes

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, extraction; exploitation of microbes in copper and uranium extraction.

Suggested Readings

1. Evans, G.G. and Furlong, J. 2010. Environmental Biotechnology: Theory and Application (2nd edition). Wiley-Blackwell Publications.
2. Jordening, H.J. and Winter J. 2005. Environmental Biotechnology: Concepts and Applications. John Wileyand Sons.

3. Lodish, H.F., Baltimore, D., Berk, A. Zipursky, S.L. Matsudiara, P. and Darnell, J. 1995. Molecular Cell Biology. W.H. Freeman.
4. Nelson, D.L. and Cox, M.M. 2013. Lehninger's Principles of Biochemistry. W.H. Freeman.
5. Rittman, B.E. and 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. and Simmons, M.J. 2011. Principles of Genetics (6th edition). John Wileyand Sons.
8. Wainwright, M. 1999. An Introduction to Environmental Biotechnology. Springer

C-11P**: Practical 11**

1. Preparation of culture media and study of colony characteristics.
2. Micrometry and Haemocytometer.
3. Isolation and Identification of fungal and bacterial colonies from air and soil.
4. Bacterial examination of water–Total and Faecal coliforms by MPN and MF techniques.
5. Determination of *Escherichia coli* in water – MPN, Plate count, and Membrane filtration techniques
6. Isolation and identification of bacteria and fungi from fruits and vegetables.
7. Isolation and identification of bacteria and fungi from touch surface of working places.
8. Study of phylloplane/ rhizosphere microflora.
9. Biochemical tests a) Indole test, b) Methyl red, c) Vogues Proskaeur test, d)Citrate utilization test, e)Catalase test, f) Oxidase test, g) Urease test, h) Sugar fermentation test, i) Gelatin hydrolysis, j) Casein hydrolysis, and k) Amylase production.
10. Antibiotic sensitivity tests.
11. To study morphology of yeast cell by negative staining technique.
12. Developing stir tank reactor / suspension reactor for *Ex-situ* bioremediation.
13. Estimation of protein, carbohydrates, fats and amino acid content in biological samples.

C-12T **: ORGANISMAL AND EVOLUTIONARY BIOLOGY**

Unit 1: History of life on Earth

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.

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

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; evolution of prokaryotes; origin of eukaryotic cells; evolution of unicellular eukaryotes; anaerobic metabolism, photosynthesis and aerobic metabolism.

Unit 3: Geography of evolution

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

Unit 4: Molecular evolution

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 5: Fundamentals of population genetics

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; coevolution; Hardy-Weinberg Law.

Suggested Readings

1. Futuyma, D.J. 2009. Evolution (2nd edition). Sinauer Associates.
2. Gillespie, J. H. 1991. The Causes of Molecular Evolution. Oxford University Press.
3. Graur, D. and 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. and 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., and Painter, I. S. 1998. Estimating the rate of evolution of the rate of molecular evolution. Molecular Biology and Evolution 15: 1647-1657

C-12P**: Practical 12**

1. Calculation of different biodiversity indices
2. Calculations based on population genetics

C-13T**: NATURAL RESOURCE MANAGEMENT AND SUSTAINABILITY**

Unit 1: Introductionand Resource management

Resource and reserves; classification of natural resources; renewable and non-renewable resources; resource degradation; resource availability and factors influencing its availability; land resources; water resources; fisheries and other marine resources;

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.

Unit 2: Natural resources and conservation

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

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: Non-renewable energy resources

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.

Unit 5: Renewable energy resources

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.

Suggested Readings

1. Craig, J.R., Vaughan. D.J. and Skinner. B.J. 1996. Resources of the Earth: Origin, Use, and
2. Environmental Impacts (2nd edition). Prentice Hall, New Jersey.

3. Freeman, A.M. 2001. Measures of value and Resources: Resources for the Future. Washington
4. DC.
5. Freeman, A.M. 2003. Millennium Ecosystem Assessment: Conceptual Framework. Island
6. Press.
7. Ginley, D.S. andCahen, D. 2011. Fundamentals of Materials for Energy and Environmental
8. Sustainability. Cambridge University Press.
9. Klee, G.A. 1991. Conservation of Natural Resources. Prentice Hall Publication.
10. Miller, T.G. 2012. Environmental Science. Wadsworth Publishing Co.
11. Owen, O.S, Chiras, D.D, andReganold, J.P. 1998. Natural Resource Conservation –
12. Management for Sustainable Future (7th edition). Prentice Hall.
13. Ramade, F. 1984. Ecology of Natural Resources. John Wiley and Sons Ltd.
14. Tiwari, G.N. and Ghosal. M. K. 2005. Renewable Energy Resources: Basic Principles and

C-13P**: Practical 13**

1. To assess the lifecycle of different industrial product from cradle to grave.
2. To study the recycling, reuse and disposal practices of different industrial wastes.
3. To study zero waste technology of any two industrial units.
4. To study in detail on the provisions of ISO 14000, with respect to green product design.
5. To study on ecollabelling from pharmaceuticals, foods, cosmetics, automobiles and electronic industry.
6. To assess the impact of materials on biodiversity, resources and ecosystems.
7. To study bio-fuel production methods and characterization for biodiesel and bio-ethanol.
8. To study the application of green chemistry concept in industries.
9. To study application of green chemistry concept in agricultural related practices and food processing units.
10. To study in detail the concept of green building in urban areas.
11. To study the chemical reactive involve in green nanotechnology, nano-particle production and characterization.

C-14T**: ENVIRONMENTAL LEGISLATION AND POLICY**

Unit 1: Introduction

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

Unit 2: History of environmental legislation and policy

Ancient period: worship of water, air, trees; Mauryan 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, Orissa River pollution and prevention Act 1953.

Unit 3: Environmental legislation and Government institutions

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).

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

Unit 4: Legislative Instruments

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 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 5: Case studies and International laws and policy

National Green Tribunal: Aditya N Prasad vs. Union of India and 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.

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.

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. andRosencranz, A. 2001. Environmental Law and Policy in India. Oxford University Press.

4. Divan, S. andRosencranz, A. 2002. Environmental Law and Policy in India: Cases, Materials and Statues (2nd 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 (3rd 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

C-14P**: Practical 14**

1. Study on International and National standard of Air, Water and Soil
2. Study in detail on Environmental accounts, auditing, green funding, and taxes trade and environmental management in any two industrial units.
3. To evaluate the adverse effect of lack of environmental planning in industries (any two)
4. To prepare base line data on water, soil, air, natural assets, demography, and heritage of any two project areas.
5. Study of rural and urban environmental planning at regional level.
6. Study on resource planning at regional and national level.
7. Study on Gandhian concept of self relied villages.
8. Preparation of EIA statement for development activities.
9. Preparation ofEnvironmental Audit Report of any one industry.
10. Preparation of TOR (Turn of Reference) for EIA in any two industries
11. To study the Ramsar Convention on wetlands with few case studies.
12. To study the application of Vienna Convention Montreal protocol and kyoto protocol in India.
13. To study trade and commerce practice and fair environmental practice at national and international level.

C-15T**: ENERGY AND ENVIRONMENT**

Unit 1: Introduction

Defining energy; forms and importance; energy use from a historical perspective: discovery of fire, discovery of locomotive engine and fossil fuels, electrification of cities, oil wars in the Middle East, advent of nuclear energy; sources and sinks of energy; energy over-consumption in urban setting

Unit 2: Energy resources and Demand

Global energy resources; renewable and non-renewable resources: distribution and availability; past, present, and future technologies for capturing and integrating these resources into our energy infrastructure; energy-use scenarios in rural and urban setups; energy conservation.

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 3: Energy, environment and society

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 4: Energy, ecology and the environment

Energy production as driver of environmental change; 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 5: Politics of energy policy

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.

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; action strategies for sustainable energy mix and management from a future perspective.

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 (2nd 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
6. and Public Policy, June-July.
7. Mallon, K. 2006. Myths, Pitfalls and Oversights, Renewable Energy Policy and Politics: A Handbook for Decision-Making. EarthScan.

C-15P**: Practical 15**

1. Study of ISO: 14000 and OSHAS 18000
2. Studies on LCA of pulp and paper industry, food industry and crop plants.
3. To study zero waste technology of any two industrial units.
4. To study in detail on the provisions of ISO 14000, with respect to green product design.
5. To study on ecollabelling from pharmaceuticals, foods, cosmetics, automobiles and electronic industry.
6. To assess the impact of materials on biodiversity, resources and ecosystems.
7. To study bio-fuel production methods and characterization for biodiesel and bio-ethanol.
8. To study the application of green chemistry concept in industries.
9. To study application of green chemistry concept in agricultural related practices and food processing units.
10. To study in detail the concept of green building in urban areas.
11. To study the chemical reactive involve in green nanotechnology, nano-particle production and characterization.

C-16T**: ENVIRONMENTAL ECONOMICS**

Unit1: Introduction to microeconomics

Definition and scope of environmental economics; environmental economics versus traditional economics; brief introduction to major components of economy: consumer, firm and their interaction in the market, producer and consumer surplus, market failure, law of demand and supply, tangible and non tangible goods; utilitariasm; Pareto optimality; compensation principle.

Unit 2: Environmental economics

Main characteristics of environmental goods; marginal analysis; markets and market failure; social benefit, costs and welfare functions; meaning and types of environmental values; measures of economic values; tangible and intangible benefits; Pareto principle or criterion; Hardin's Thesis of 'The Tragedy of Commons'; prisoner's dilemma game; methods of abatement of externalities; social cost benefit analysis; cost-effectiveness analysis.

Unit 3: Economic solutions to environmental problems

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 4: Natural resource economics

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

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.

Suggested Readings

1. Arrow, K., Bolin, B., Costanza, R., Dasgupta, P., Folke, C., Holling, C.S., Jansson, B.O.,
2. Levin, S., Maler, K.G., Perrings, C., Pimentel, D. 1995. Economic growth, carrying capacity,
3. and the environment. Ecological Economics 15: 91-95.
4. Hanley, N., Shogren, J. F., and White, B. 2007. Environmental Economics: In Theory and
5. Practice. Palgrave Macmillan.
6. Kolstad, C.D. 2010. Environmental Economics. Oxford University Press.
7. Perman, R. 2003. Natural Resource and Environmental Economics. Pearson Education.
8. Singh, K. andShishodia, A. 2007. Environmental Economics: Theory and Applications. Sage

9. Publications.
10. Thomas, J.M. and Callan, S.J. 2007.Environmental Economics. Thomson Learning Inc.
11. Tietenberg, T. 2004. Environmental and Natural Resource Economics (6th Edition). Pearson
12. Education Pvt. Ltd.
13. Tietenberg, T. H. and Lewis, L. 2010. Environmental Economics and Policy. Addison-Wesley.
14. Turner, R. K., Pearce, D., and Bateman, I. 1994. Environmental Economics: An Elementary
15. Introduction. Harvester Wheatsheaf

C-16P**: Practical 16**

1. Calculation of mean, mode & median of data.
2. Calculation of standard deviation and co-efficient of variation of data.
3. Calculation of Karl Person's Co-efficient of Co-relation.
4. Calculation of Regression from the data.
5. Calculation of variance and standard error (SE) from data.
6. Problems on probability, t-test, Z-test, and f-test.
7. Problems on ANOVA and Chi-square test
8. Application of statistical software for studying environmental statistics

C-17T**: NATURAL HAZARDS AND DISASTER MANAGEMENT**

Unit 1: Introduction

Definition of hazard; definition of Natural hazards: hydrological, atmospheric and 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 and hurricanes; tsunamis: causes and location of tsunamis; coastal erosion, sea level changes and its impact on coastal areas and coastal zone management.

Unit 2: Anthropogenic hazards

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 3: Risk and vulnerability assessment

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 and vulnerability assessment.

Unit 4: Mitigation and preparedness

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 5: Disaster management in India

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.

Suggested Readings

1. Coppola D. P. 2007. Introduction to International Disaster Management. Butterworth
2. Heinemann.
3. Cutter, S.L. 2012. Hazards Vulnerability and Environmental Justice. EarthScan, Routledge
4. Press.
5. Keller, E. A. 1996. Introduction to Environmental Geology. Prentice Hall, Upper Saddle River, New Jersey.

6. Pine, J.C. 2009. Natural Hazards Analysis: Reducing the Impact of Disasters. CRC Press,
7. Taylor and Francis Group.
8. Schneid, T.D. and Collins, L. 2001. Disaster Management and Preparedness. Lewis Publishers, New York, NY.
9. Smith, K. 2001. Environmental Hazards: Assessing Risk and Reducing Disaster. Routledge Press.
10. Wallace, J.M. and Hobbs, P.V. 1977. Atmospheric Science: An Introductory Survey. Academic Press, New York.
11. Wasson, R.J., Sundriyal, Y.P., Chaudhary, S., Jaiswal, M.K., Morthekai, P., Sati, S.P.andJuyal, N. 2013. A 1000-year history of large floods in the upper Ganga catchment, central Himalaya, India. Quaternary Science Reviews 77: 156–166

C-17P**: Practical 17**

1. Preparation of EIA statement for development activities
2. Preparation of Environmental Audit Report of any one industry
3. Preparation of TOR (Turn of Reference) for EIA in any two industries
4. To evaluate the adverse effect of lack of environmental planning in industries (any two)
5. To prepare base line data on water, soil, air, natural assets, demography, and heritage of any two project areas.
6. Preparation of Hazard Zonation map by using Remote Sensing and GIS

a. Seismic micro zonation maps

b. Landslide hazard zonation mapping using Landslide Hazard Evaluation Factor rating scheme.

c. Glacial lake outburst flood hazard zonation mapping based on open source data

ES18T: SOLID WASTE MANAGEMENT

Unit 1: Introduction and Effect of solid waste disposal on environment

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

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 2: Solid waste Management and Industrial waste management

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.

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 3: Resource Recovery and Waste- to- energy (WTE)

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

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

Unit 4: Integrated waste management and Life cycle assessment (LCA)

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

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 5: Policies for solid waste management

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.

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 and Sons.
3. Blackman, W.C. 2001. Basic Hazardous Waste Management. CRC Press.
4. McDougall, F. R., White, P. R., Franke, M., andHindle, P. 2008. Integrated Solid Waste
5. Management: A Life Cycle Inventory. John Wiley and Sons.

6. US EPA. 1999. Guide for Industrial Waste Management. Washington D.C.
7. White, P.R., Franke, M. andHindle P. 1995. Integrated Solid waste Management: A Lifecycle
8. Inventory. Blackie Academic and Professionals.
9. Zhu, D., Asnani, P.U., Zurbrugg, C., Anapolsky, S. and Mani, S. 2008. Improving Municipal Solid waste Management in India. The World Bank, Washington D.C.

C-18P : Practical 18

1. To assess the lifecycle of different industrial product from cradle to grave.
2. To study the recycling, reuse and disposal practices of different industrial wastes.
3. To study zero waste technology of any two industrial units.
4. To study in detail on the provisions of ISO 14000, with respect to green product design.
5. To study bio-fuel production methods and characterization for biodiesel and bio-ethanol.