Institute of Environment and Sustainable Development

M. Sc. in Environmental Sciences (Environmental Technology)

Department of Environment and Sustainable Development, BHU

Code	Subject	Offered by	Credits		
			Theory	Practical	Total
I SEMESTER					
MEST 101	Basics of Earth System Sciences		2	1	3
MEST 102	Basics of Ecological Sciences		2	1	3
MEST 103	Basics of Environmental Biotechnology		2	1	3
MEST 104	Basics of Environmental Chemistry		2	1	3
	Choice Based Credit System (CBCS)	*CBCS (Other Faculty)*	2	1	3
MEST 105M	Concepts and Practices of Sustainability (Minor)		2	-	2
MEST 106M	Environmental Law and Policies (Minor)		2	-	2
MEST 107	Study Tour		-	1	1
Total Credits			16	7	**20**
II SEMESTER					
MEST 201	EIA and Environmental Management System		2	1	3
MEST 202	Environmental Pollution and its Management		2	1	3
MEST 203	Environmental Monitoring Technologies		2	1	3
MEST 204	Remote Sensing and GIS		2	1	3
	Choice Based Credit System (CBCS)	*CBCS (Other Faculty)*	2	1	3
MEST 205M	Natural Hazards and Disaster Risk Management (Minor)		2	-	2
MEST 206M	Environmental Health and Safety (Minor)		2	-	2
MEST 207	Thematic Review and Presentation		-	1	1
Total Credits			**16**	**7**	**20**
III SEMESTER					
	Compulsory for all				
MEST 301	Climate Risk Management		2	1	3
MEST 304	*Industrial Training				2
MEST 302	Statistical Methods		2	1	3
MEST 303M	Industrial Ecology (Minor)		2		2
	Minimum five of the following (MEST 304 to MEST 315):				
MEST 305	Air Monitoring and Management		2	1	3
MEST 306	Water Monitoring and Management		2	1	3
MEST 307	Biodiversity Monitoring and Management		2	1	3
MEST 308	Global Energy Scenario and its Management		2	1	3
MEST 309	Mining Environment and Management		2	1	3
MEST 310	Waste Management Technology		2	1	3
MEST 311	Chemical Hazards and its Management		2	1	3
MEST 312	Environmental Economics		2	1	3
MEST 313	Environmental Modelling		2	1	3
MEST 314	Ecological Engineering		2	1	3
Total Credits			16	7	**25**
IV SEMESTER					
MEST 401	Dissertation/Thesis work		-	-	**8**
MEST 402	Presentation		-	-	**2**
Total Credits					**10**
Overall credits			**20+ 20+ 25 +10 = 75**		

*Industrial training of 6 weeks during summer vacation following semester II

Semester I

MEST 101- Basics of Earth System Sciences Credits: 2

1. **The Earth and climate:** Water in the atmosphere and earth's crust, Glaciers, Surface water, Ground Water, Basic Climatology, Paleoclimates, Tropical Climates.
2. **Chemical Evaluation of the Atmosphere:** Life and earth's atmosphere, Carbon dioxide and oxygen in earth's atmosphere.
3. **Atmospheric Energy and Structure of the Atmosphere:** Radiation transfer mechanism, Concepts of radiation forcing, Solar radiation and the biosphere, structure of earth, atmosphere.
4. **Biogeochemical Cycles:** Sources and sinks of Carbon Cycle, Nitrogen Cycle, Sulpher Cycle, Halogen cycle.
5. **Atmospheric Chemistry:** Sources of trace gases in the atmosphere, key processes in troposphere chemistry, Oxidation chemistry, Halogen chemistry; Particulate matter in atmosphere, Aerosols properties, sources, role and measurements; Stratosphere, Ozone depletion.
6. **Cloud Formation and Chemistry:** Clouds formation, Size and water contents, Dissolved solids in cloud water and rainfall, Dissolution of gases, Reactions and photochemistry.
7. **Boundary Layer Meteorology:** Atmospheric Boundary Layer, Flow over vegetation, Urban boundary layers, Dispersion of pollutants.
8. **Climate Change Science:** Historical evidence of the impacts of human activities on climate, Climate modelling, Evaluation and use of modelling tools, Future Climate, Impact of Climate change, Design of urban infrastructure, Pathways to policy consideration.

Suggested Readings:

[1] Hewitt C N and Jackson A V (2009) Atmospheric Science for Environmental Scientists, Willy- Blackwell.
[2] Thomas Stocker (2011) Introduction to Climate Modelling by, Springer-Verlag Berlin Heidelberg.
[3] Egbert Boeker, Rienk van Grondelle (2011) Environmental Physics: Sustainable Energy and Climate Change. Wiley Publishers.
[4] John Marshall, R. Alan Plumb (2008) Atmosphere, Ocean and Climate Dynamics: An introductory Text. Elsevier
[5] Skinner, B.J., Porter, S.C., and Botkin, D.B. (2011) The Blue Planet: An Introduction to Earth System Science. Willey.

MEST 102- Basics of Ecological Sciences Credits: 2

1. **Scope of Ecology:** The science of ecology; historical development of ecological thoughts in world and India; linking ecology and environmental issues.
2. **Ecological components and their interactions:** Biotic and abiotic environment and its interactions; concept of limiting factors; positive and negative interactions.

3. **Habitat and niche:** Fundamental and realized niche, niche overlap, competitive exclusion, resource partitioning; keystone species; ecological adaptations.

4. **Population Ecology:** Population characteristics; metapopulations; population growth models; biotic potential; carrying capacity; life history models; factors regulating population growth.

5. **Community Ecology:** Nature of communities; community interactions; community structure and attributes; species diversity and dominance.

6. **Ecosystem Ecology:** Ecosystem structure; energy flow, trophic levels, ecological pyramids, ecological efficiencies; ecosystem production; biogeochemical cycling.

7. **Ecological Succession:** Types; mechanisms and models; concept of climax; steady state and stability in ecological systems; ecosystem trends during succession.

8. **Biogeography:** Biogeographical zones of India; general features of major terrestrial and aquatic biomes; theory of island biogeography.

Suggested Readings

[1] Begon, M., C. R. Townsend, and J. L. Harper. (2006) Ecology: from individuals to ecosystems. Blackwell Pub.
[2] Molles, M. (2009) Ecology: concepts and applications (5th ed.). Dubuque IA: McGraw-Hill.
[3] Odum, E. P. and G. W. Barrett. (2005) Fundamentals of ecology. Thomson Brooks/Cole.
[4] Ricklefs, R. E. (2010) The Economy of Nature. W H Freeman and Co.
[5] Smith, T. (2011) Elements of ecology (8th ed.).Pearson Benjamin Cummings, San Francisco.

MEST 103- Basics of Environmental Biotechnology **Credits: 2**

1. **Organization of genetic material:** Prokaryotes and eukaryotes; replication of genetic material; gene and genetic code, transcription and translation, protein synthesis

2. **Biotechnology tools and techniques:** Isolation and purification DNA, RNA and protein; Polymerase chain reaction (PCR); Electrophoresis; Recombinant DNA techniques; Construction of gene libraries, Gene sequencing; Tissue culture; Bioreactors

3. **Environmental Monitoring:** Bioindicators, Biosensors for environment and human health

4. **Biotechnology in Waste Treatment:** Role of biotechnology in waste treatment, aerobic and anaerobic treatment of solid, liquid and gaseous waste; Treatment of heavy metals-containing wastes

5. **Bioremediation:** Introduction to Bioremediation, Engineering strategies for bioremediation; monitoring the efficacy of bioremediation

6. **Biofuels:** Biotechnological approaches to biofuel production; Microbial fuel cells

7. **Biotechnological applications in :** Micropropagation; Genetic engineering; Marker-Assisted Selection; Biocontrol; Transgenics, Weed Control; Biofertilization, Phytostimulation, health and disease.

8. **Biotechnology and Environment:** Ethics, Public acceptance of biotechnology and Biosafety concerns; genetically modified organisms (GMO) and environment

Suggested Readings:

[1] Altman, Arie (1998) Agricultural Biotechnology, Marcel Dekker, Inc.

[2] Evans, G., and Furlong, J. C. (2010) Environmental biotechnology: Theory and application. Oxford: Wiley-Blackwell.

[3] Fulekar, M. H. (2010) Environmental biotechnology. Enfield, NH: Science Publishers.

[4] Jördening, H.-J., and Winter, J. (2005) Environmental biotechnology: Concepts and applications. Weinheim: Wiley-VCH.

[5] Rittmann, B. E., and McCarty, P. L. (2001) Environmental biotechnology: Principles and applications. Boston: McGraw-Hill.

MEST 104- Basics of Environmental Chemistry Credits: 2

1. **Tropospheric Trace gas Chemistry:** NOx, SO_2, CO, PAN pollution, fog-smog formation, acid rain and precipitation chemistry.

2. **Stratospheric chemistry:** Ozone production, Chapman cycle, Role of CFCs, Polar ozone loss and recovery of stratospheric ozone, Stratospheric-Tropospheric Exchange.

3. **Atmospheric aerosols:** Source, sinks, removal mechanism, Radiative Impact of aerosols: Scattering and visibility reduction, Urban heat island effect and Urban Climate change.

4. **Water Chemistry:** Water resources, hydrological cycle, physical and chemical properties of water, complexation in natural and waste water, role of microorganisms, - Water pollutants- Types – Sources- Heavy metals – Metalloids – Organic – Inorganic – Biological and Radioactive – Types of reactions in various water bodies including marine environment – Eutrophication – Groundwater – Potable water.

5. **Soil Chemistry and Soil Composition:** Organic and Inorganic – Soil, Physical and Chemical Properties – Cation exchange capacity – soil pH – Environmental Properties of soils: Leaching and erosion – reactions with acids and bases – Geochemical reactions that neutralize acidity – Biological Process that neutralize acidity – salt affected soils – Trace metals in soils.

6. **Green Environmental Issues:** Introduction – Ecological and Carbon foot print – Carbon Credits – Carbon Sequestration – Clean Development mechanism (CDM) – Polluters Pay principle – Consumerism.

7. **Green Chemistry:** Principles of Green chemistry- matrices-green computing.

8. **Environmental Applications:** Sustainable mining – Urban forestry – Green buildings – Green building practices – Approaches to green computing – Nanotechnology and Environment.

Suggested Readings:

[1] Daniel J. Jacob (1999) Introduction to Atmospheric Chemistry, Princeton University Press.

[2] John M. Wallace and Hobbs (2006) Atmospheric Science: An Introductory Survey**,** P.V. ISBN-13: 978-0127329512 ISBN-10: 012732951X Edition: 2nd Edition

[3] J. H. Seinfeld and S. N. Pandis, Wiley-Inter science (1998) Atmospheric Chemistry and Physics (ISBN 0-471-17816-0)

[4] Finlayson-Pitts and JN Pitts, Jr., Wiley-Inter Science (2010) Atmospheric Chemistry: Fundamentals and Experimental Techniques (ISBN 0-471-88227-5)

[5] Finlayson-Pitts, B. J. and J. N. Pitts (1999) Jr. Chemistry of the Upper and Lower Atmosphere. Academic Press Inc.

MEST 105M- Concepts and Practices of Sustainability (Minor) Credits: 2

1. **Foundations and history:** The emergence of sustainable development; its formative ideas and roots in development and environment debates; key concepts and principles.

2. **Ecological limits:** The system dynamics of a finite planet; basic thermodynamic and material laws and principles; resource scarcity and carrying capacities.

3. **Environmental Justice:** The problem of allocation in the context of limits; the concept of environmental space and environmental inequality; environmental justice; human rights and the environment.

4. **Sustainable Materials, Technology and Design:** The transformation of production process; infrastructures and systems; concepts of resource efficiency, clean or sustainable technologies, life cycle analysis.

5. **Consumption, Lifestyle and Communication:** Complexity of consumption and lifestyle; the dynamics of transition and social change; the importance of gender issues in sustainable development.

6. **Governance for Sustainability:** History of governance; problem of governing common pool resources; the social contract; policy responses to sustainability; Agenda 21.

7. **Development and Wellbeing:** Quality of life and sustainability; sustainability as capabilities for flourishing within ecological limits; philosophical and ethical dimensions of sustainable development.

8. **Measuring Sustainability:** Sustainability indicators, research methods and reporting, tools, statistics and accounting

Suggested Readings:

[1] Daly, H.E. (1996) The economics of sustainable development. Beacon Press.
[2] Daly H.E. and J. Farley (2010) Ecological economics: Principles and applications. Island Press.
[3] United Nations (2001) Indicators of sustainable development: guidelines and methodologies. United Nations.
[4] Elliott, J. A. (2006) An introduction to sustainable development. Rout ledge.
[5] Roosa, S.A. (2010) Sustainable development handbook, Second Edition. Fairmont Press.

MEST 106M- Environmental Law and Policies (Minor) Credits: 2

1. **Environmental protection in India:** General introduction regarding the Constitutional, Legislative and Institutional mechanisms for environmental protection in India; rules and regulations of central and state Government for Environmental Protection; common law remedies for environmental safeguard.

2. **National Policy on Environment:** National Committee on Environment and Planning (NCEP); Tiwari committee; establishment of MoEF; National Forest Policy; National Water Policy and National Energy Policy; CPCB and SPCBs.
3. **Constitutional provisions for Environmental Protection:** Historical Background of constitutional provisions; Articles related to environmental protections; fundamental duties of citizen and directive principles of state policy, writ provisions for the protection of environment.
4. **National Environmental Legislations**: The Water (Prevention and Control of Pollution) Act, 1974; The Air (Prevention and Control of Pollution) Act, 1981; The Environment (Protection) Act, 1986; Mining Act, 1952; Factories Act; Motor Vehicle Act; Hazardous Waste legislation for pollution abatement; Hospital Waste Management.
5. **National Legislation on Forest and Wildlife:** The Forest (conservation) Act, 1980; The Wildlife (Protection) Act, 1972; The Biodiversity (Protection) Act, 2002; Aims, objectives and major contents with amendments.
6. **Environmental Legislations related to Coastal Regulation Zone (CRZ):** Need of CRZ rules for regulation the activities in coastal zone; Public Interest Litigation; Public Liability Insurance Act.
7. **Legal Institutions:** Jurisdiction of High Courts, Supreme Court and Green Tribunal; concept and need of public interest litigation (PIL)
8. **International Environmental Laws and Treaties:** International agreements/ conventions/ treaties related to environment and sustainable development; Environmental Quality and Transboundary Issues; Role of International agencies on Environmental Protection.

Suggested Readings:

[1] Declaration of: The Stockholm Conference, Rio, Rio+5 and Rio+10.

[2] Anti – Pollution Acts and Commentaries published theorem. UoP, revised M.Sc. (Env.Sci.) Syllabus - 2008-09 14/14 3. Constitution of India [Referred articles from Part-III, Part-IV and Part-IV-A].

[3] P. Leelakrishnan, Environmental and the last (Bullorthworths, Latold, edn.).

[4] Gwendolyn Holmes, Ben Ramnarine Singh, and Louis Theodore (2005), Handbook of environmental management and technology

[5] ISO 14004 – Environmental management systems: General guidelines on principles, systems and supporting techniques (ISO 14004: 1996 (E)). 10. ISO 14001: Environmental management systems: Specification with guidance for use (ISO 14001: 1996b (E)). (International organization for standardization – Switzerland).

MEST 107- Study Tour **Credits: 1**

Semester II

MEST 201- EIA and Environmental Management System Credits: 2

1. **Concept of EIA:** Concept of environment and environmental impact, nexus between development and environment, measurement of impact –physical, social, economic, natural; short term versus long term effect; direct and indirect impact; cumulative and induced impacts; environmental impact factors and area consideration.
2. **Basic principles of EIA:** Scope of EIA, objectives in EIA; basic EIA Principles; classification of EIA: strategic EIA (SEIA), regional EIA, sectoral EIA, project Level EIA; Life Cycle Assessment.
3. **Steps in EIA:** Making inventories; sampling and data processing; cost benefit analysis; impact predictions and modelling: positive and negative impacts, primary and secondary impacts, impact on physical, social and biotic environments.
4. **Methods of EIA:** Adhoc method; Checklist Method; Werner Prestroit study; Smith study; Interaction Matrices- Network and overlays approach.
5. **Socioeconomic Impact Analysis (SIA):** Basic steps in SIA, analysis of public services and facilities; fiscal impact analysis; social impact analysis; impact of economic profile of the community.
6. **Reporting:** Preparing Environmental Impact Statement (EIS); reporting the detailed environmental settings; reporting the impacts of the proposed activities; preparing the interim report; finding alternatives; proposing remedial measures; preparing final environmental impact statement (EIS).
7. **Environment Management Systems:** EMS background, ISO 14000 environment management series; ISO 14001-EMS specification; EMS certification and accreditation; Bureau of Indian Standards (BIS); environmental auditing.
8. **Applications of EIA:** Industries; Urban Development; Land use; Energy Projects.

Suggested Readings:

[1] W. Kurge (1995) Environmental Management System, Prentice Hall, ISO 14001 Certification.

[2] J. Lampercht: ISO 9000 – Preparing for Registration, Dekker Pub. Co. 1992.

[3] Badrinath S. D. and raman N. S.- Certification Scheme for Environmental Audit Chemical Business Vol. 7 (4) 1993. 4. Badrinath S. D. and Rama N. S. – "Environmental Audit: A Step towards an Ecological Economy" Chemical Business Vol. 12, 1994.

[4] Kulkarni, V. S. Khanna P. – "Environmental Aspects of Power Generation" productivity, Vol. 32 (4) 1992.

[5] Chalapati Rao, C. V. et. al. "Environmental Imapct Assessment of Petrochemical Industry: A Case study" Indo-British Workshop on EIRA of petrochemical Industry and EA, Nagpur Jan8 –10, 1994.

MEST 202- Environmental Pollution and its Management Credits: 2

1. **Introduction:** Classification of Pollution and Pollutants, Causes, Effects and Sources of Pollution.
2. **Air Pollution:** Atmosphere and its functions; Primary and Secondary Pollutants, Air Quality Standards.
3. **Water Pollution:** Types, sources and consequences, of water pollution; Point and Non-point Source of Pollution, Major Pollutants of Water, Water pollution control, case studies.
4. **Marine and Nuclear Pollution:** Type and sources of marine pollution, Ocean plastics, Oil spills, Coastal Pollution, Nuclear Power Plants, Nuclear Radiation.
5. **Soil Pollution:** Sources and nature of soil pollution and its harmful effects; Extent of soil degradation and desertification; Soil quality indicators; Soil fertility management.
6. **Noise and Thermal Pollution:** Sources and effects of Noise, sound pressure and intensity levels; Industrial Noise - Occupational Health Hazards, Thermal Comforts, Heat Island Effect.
7. **Solid Waste Pollution:** Sources and generation of solid waste, characterization and classification. Different methods of dispersal and management of solid wastes.
8. **E-WASTE:** Generation, transportation and storage of E-waste; Effects and Control measures.

Suggested Readings:

[1] Tchobanoglous G, Theisen H, Vigil SA (1993) Integrated solid waste management: Engineering principles and management issues, McGraw Hill International editions, Civil Engineering series. Singapore: McGraw Hill Inc.

[2] G. R. Chhatwal et al. (2005) Environmental radiation and thermal pollution and their control, Anmol Publications (Pvt.) Ltd., New Delhi.

[3] Marquita K. Hill (1997) Understanding environmental pollution, Cambridge University Press.

[4] Masters, G.M. (2004) Introduction to environmental engineering and science. Prentice-Hall of India Pvt. Ltd., New Delhi.

[5] Kiely, G., (2007) Environmental Engineering. Tata McGraw-Hill.

MEST 203- Environmental Monitoring Technologies Credits: 2

1. **Principles of Environmental Monitoring:** Principles of environmental monitoring; Scales of observation; Sampling types, locations, plans and representative sampling; Types of errors; Quality control checks.
2. **Data Acquisition and Processing:** Units of measurement; automated measurement; Data acquisition system; Data management and quality control; Data processing and documentation.
3. **Weather Monitoring:** Instrumental techniques in weather monitoring; Presentation of weather data, Biodiversity Monitoring: Species surveying and monitoring; Measuring vegetation; Specialized sampling methods and field techniques for animals; Molecular

methods for assessing microbial diversity; Indices for monitoring communities and species.

5. **Soil Monitoring:** Sampling strategies; Instrumental methods for monitoring and analysis of physico-chemical properties of soil.
6. **Air and Noise Monitoring:** Sampling strategies for ambient air quality and stack monitoring; Instrumental methods for analysis of gaseous and particulate pollutants; Noise monitoring.
7. **Surface and Ground Water Monitoring:** Sampling strategies; Instrumental methods for monitoring and physicochemical analysis of ground and surface waters.
8. **Monitoring of Microbial Contaminants:** Sampling strategies and sample preservation techniques; Monitoring techniques for microbial contaminants in air, water, soil and food samples.

Suggested Readings:

[1] Burden, F. R. (2002) Environmental monitoring handbook. New York:McGraw-Hill.
[2] Hill, D.A. (2007) Handbook of biodiversity methods: Survey, evaluation and monitoring. Cambridge: Cambridge University Press.
[3] Sutherland, W.J. (2011) Ecological census techniques: A handbook. Cambridge: Cambridge University Press.
[4] Pansu, M., and Gautheyrou, J. (2006) Handbook of soil analysis: Mineralogical, organic and inorganic methods. Springer.
[5] Nielsen, D., and Nielsen, G.L. (2007) The essential handbook of ground-water sampling. CRC Press/Taylor and Francis.

MEST 204- Remote Sensing and GIS Credits: 2

1. **Background of remote sensing:** History of remote sensing, Indian Remote Sensing satellite, basics of electromagnetic radiation and electromagnetic spectrum, remote sensing process, advantages and limitations of remote sensing.

2. **Remote sensing platforms and sensors:** Ideal remote sensing system, types and characteristics of remote sensing platforms and sensors.

3. **Digital Image Processing:** Photographic and digital imaging, visual image interpretation and digital image.

4. **Concepts of geographical information system (GIS):** Definition of GIS, functions and advantages of GIS, concept of map, coordinate systems and types of projection, attribute data management, modern trends of GIS.

5. **Data Processing in GIS:** Types of datasets, vector and raster datasets meaning and uses, Spatial data models, Geospatial analysis in GIS.

6. **Global navigational satellite system (GNSS):** Basics of GNSS, concepts of global positioning system (GPS), measurement and errors, functional segments of GPS.

7. **Types and Applications of Global Positioning System:** Types of GPS, Differential GPS, future GPS and applications of GPS.

8. **Applications** of Remote Sensing and GIS in different fields.

Suggested Readings:

[1] B. S. Sokhi, S. M. Rashid (1999) Remote sensing of urban environment, Manak Publication (Pvt.) Ltd. New Delhi.
[2] Lillesand and Kiefer (2007) Remote sensing and image interpretation, 3rd Edition, John Wiley & Son Inc., NY.
[3] M. Anji Reddy (2015) Text book of Remote Sensing and Geographical Information System, 3rd Edition, BS publications, Hyderabad, India.
[4] Dr. B. C. Panda. (2008) Remote Sensing Principles and Applications, Viva Books Pvt. Ltd.
[5] Srivastava, P. K., Mukherjee, S., Gupta, M., & Islam, T. (2014) Remote Sensing Applications in Environmental Research, Springer Verlag.

MEST 205M-Natural Hazards and Disaster Risk Management (Minor)Credits:2

1. **Introduction and Overview:** Understanding the Concepts and definitions of Hazard, Disaster, Vulnerability, Risk; Types, Trends, Causes and Consequences of Disasters; Disaster Profile of India.
2. **Institutional Framework, policy and guidelines:** Evolution of Disaster Management in India, Organisation and Structure of Disaster Management in India, National Policy on Disaster Management, National Plan on Disaster Management.
3. **Prevention and Mitigation:** Prevention and Mitigation, Mainstreaming of Disaster Risk Reduction in Developmental Strategy, National Disaster Mitigation Fund.
4. **Preparedness and Response:** Disaster Management Cycle, Institutional Arrangements, Crisis Management Plan and Standard Operating Procedures, Role of Central and State Governments, National Emergency Operation Centre, National and State Disaster Response Force.
5. **Recovery, Reconstruction and Rehabilitation:** Nature of Recovery, Guiding Principles for Post- Recovery, Assessment, Sustainability in Recovery Process, Guidance notes on Recovery.
6. **Capacity Development, Financial Arrangements and International Cooperation:** National Institutions and Disaster Management Centres in the States, Financing the Relief Expenditure, Monitoring of Expenditure from Relief Funds, Hyogo Framework of Action, Agencies of United Nations involved in Disaster Management.
7. **Application of Science and Technology:** Use of Remote Sensing, GIS and GPS, Early warning and disaster Communication, Land use Planning.
8. **Case Studies:** Mega Disasters of India and other parts of world.

Suggested readings:

[1] Disaster Management in India, Ministry of Home Affairs (2011) Govt. of India, New Delhi, pp 233. (www.mha.gov.in).
[2] Disaster Management Act (2005) Published by Govt. of India.
[3] Coppola DP (2007) Introduction to International Disaster Management.
[4] Elsevier Science (B/H), London. Srivastava, HN and Gupta, GD (2006) Management of Natural Disasters in developing countries, Daya Publishers, Delhi.
[5] Phillips, B (2009) Disaster Recovery. CRC Press.

MEST 206M- Environmental Health and Safety (Minor) Credits: 2

1. **Concept of Environmental Health and Safety:** Environmental health criteria; Basic requirements for healthy environment; Safety organization and responsibilities.
2. **Pollution and Human Health:** Health hazards of air and noise pollution; Quality of indoor air and its effect on health; Ventilation standards; Health hazards of radiation pollution; Control measures and management strategies.
3. **Hygiene and Environmental Health:** Housing standard and effect on health; Population explosion and environmental health; Health hazard related to waste disposal, soil pollution; water pollution; Control measures and management strategies.
4. **Environmental Epidemiology:** Epidemiology of communicable, and vector borne diseases; Zoonotic disease; Nosocomial infections; Epidemiological diseases due to pollution India and their Management and control.
5. **Occupational Safety and Health:** Principles of occupational health and safety, occupational diseases of health problem, Heat, Chemicals, Noise, Toxic gases, metals; Health hazards in agriculture, Transportation etc; International Program on Chemical Safety; Control and protection measures for occupational exposure.
6. **Environmental Health Hazard and Risk Assessment:** Hazard and risk; Biological, chemical, physical and psychological health hazard; Health risk assessment and management.
7. **Sanitary Engineering:** Removal and disposal of human waste; Sewage treatment and disposal; Potable water treatment; Solid waste management.
8. **Case Studies:** Cholera, plague and flu related case studies of national and international importance.

Suggested Reading

[1] Morgan, M.T., Barnett, D.B., Beck, J.E (2002) Environmental Health, 3rd Edition, Wadsworth Publishing Company.

[2] Koren,H (2005) Illustrated dictionary and resource directory of environmental and occupational health, CRC Press.

[3] Hilgenkamp, K. (2006) Environmental health: ecological perspectives, Jones and Bartlett Publishers International.

[4] Smedley and Sadhra (2007) Oxford Handbook of Occupational Health, Oxford University Press.

[5] Martel, B., Chemical Risk Analysis (2000) A Practical Handbook, Elsevier Science & Technology, Verlag.

MEST 207- Thematic Review and Presentation Credits: 1

Semester III

MEST 301- Climate Risk Management Credits: 2

1. **Introduction:** Atmosphere and climate, Monsoon, Western disturbances, Atmospheric and Oceanic dynamics, Atmosphere –Ocean processes and Paleoclimate
2. **Climate risk:** Air and water pollution, Acid rain and abatement technologies, Climate change, Climate variability, Climate change science with emphasis on cryosphere, hydrosphere, atmosphere, Climate risk, Climate extremes
3. **Early warning system and Communication:** Monitoring network and prediction methodology, Early warning to risk management agencies, Different types of early warning, Communication links for early warning, Role and use of science and technology -Remote sensing and GIS, weather radars etc, Agencies involved in early warning and their latest achievements
4. **Climate Mitigation:** Greenhouse gases and global warming, Policies and programmes, different mitigation strategies at local, national and international level
5. **Climate adaptation:** What is adaptation, how to adopt, when to adapt, Ecosystem based approach, Policies and programmes, Adaptation strategies in different sectors- water, Agriculture, health etc.
6. **Management and Planning:** Climate and Cities, Infrastructure, Mobility and Transportation, tourism, land uses planning, living, environment planning and public participations, governance and economic development by intelligent use of science and technology.
7. **Tools and Techniques for climate risk management:** Knowledge management and capacity building, Institutional mechanism and issues, Different tools and techniques – statistical methods, mathematical models, satellite information etc., Mathematical models for climate, crop, water, ecological and pollution management and planning
8. **Case studies:** Water management, sustainable agriculture, health care, smart city, environment planning etc.

Suggested Reading

[1] Assessment Report by TERI

[2] Alexander, D.E.; Fairbridge, R.W. (Eds.) (2014) Encyclopedia of Environmental Science, UCL, Institute for risk and disaster reduction, London, UK.

[3] Nerija Banaitiene Business (2012) Management and Economics » "Risk Management - Current Issues and Challenges" ISBN 978-953-51-0747-7, Published: September 12, 2012 under CC BY 3.0 license.

[4] Robert S. Dischel (Author) (2002) Climate Risk and the Weather Market: Financial Risk Management with Weather Hedges, Risk Books Publishers, USA (ISBN-13: 978-1899332526; ISBN-10: 1899332529).

[5] Jochen Zschau, Andreas N. Küppers, Springer Science & Business Media (2003) Early Warning Systems for Natural Disaster Reduction - Computers - 834 pages.

MEST 304- *Industrial Training Credits: 2

MEST 302- Statistical Methods Credit: 2

1. **Data and its Properties**: Types of data; Scales of measurement; Data distribution; Graphical presentation of experimental data
2. **Descriptive Statistics:** Populations and Samples; The Frequency distribution; Measures of central tendency, dispersion and shape; The normal distribution and Central Limit Theorem; Confidence intervals for population mean; The standard score
3. **Student's t Test:** The nature of t distributions; One-sample t-test; Two-sample t-test; Repeated measures t-test; Unequal variance t-test
4. **Analysis of Variance:** Assumptions for use of the ANOVA; The nature of F distribution; The completely randomized design; The randomized complete block design; The repeated measures design; Factorial experiments; Multiple comparisons of means
5. **Chi-Square Tests:** The nature of chi-square distributions; Goodness-of-fit tests; Contingency table analysis; Relative risks and odds ratios
6. **Correlation and Regression:** Scatterplot; The Pearson product-moment correlation coefficient (r); The regression line; The accuracy of prediction; Assumptions underlying regression and correlation; The Coefficient of Determination
7. **Introductory Multivariate Statistics:** General introduction to MANOVA, Principal Components Analysis, Correspondence analysis, Detrended correspondence analysis, Canonical correspondence analysis
8. **Statistical Tools:** Use of statistical software such as SPSS and R for analysis of environmental data

Suggested Readings

[1] Sokal, R.R. and Rohlf, F.J. (2009) Introduction to biostatistics, Second Edition, Dover Publications, Inc., Mineola, New York.

[2] Ott, W. R. (1995) Environmental Statistics and Data Analysis, Lewis Publishers, New Jersey.

[3] J. H. Zar (2010) Biostatistical Analysis, Fifth Edition, Prentice Hall Publications, USA.

[4] G. W. Snedecor and W. G. Cochran. (1989) Statistical Methods, Iowa State University Press, USA.

[5] W. W. Piegorsh and A. J. Bailer Statistical Methods –S.P.Gupta, (2000) Statistics for environmental Biology and Toxicology, Sultan Chand and Sons, New Delhi.

MEST 303M- Industrial Ecology (Minor) Credits: 2

1. **Frameworks of Industrial Ecology:** Definition, goals, state of the industrial environment; population and carrying capacity; industrial production and consumption patterns; ecological foot prints of industries.
2. **Material Flow in Industrial System:** Industrial metabolism; material flow analysis (materials production phase, processing phase, use phase and disposal phase); anthropogenic vs natural fluxes of toxic heavy metals
3. **Energy flow in Industrial System:** Energy flow analysis; primary energy feedstock, energy conversion process; combustion and precombustion; emission factors
4. **Life Cycle Assessment:** Life cycle interpretation; inventory analysis and input/output techniques, process level LCA vs Economic Input-Output (EIO) LCA; Life Cycle Impact Assessment (LCIA); human health and ecosystem health.
5. **Sustainable Production Strategies:** Cleaner production technologies; product life extension; material oriented strategies; process oriented strategies; distribution oriented strategies.

6. **Waste management strategies:** Generation of toxic wastes (solid, liquid and gaseous wastes); waste management techniques: remanufacturing, recycling, waste to energy; landfill disposal.
7. **Management of Industrial Hazards:** Human health protection; occupational health management; hazard management strategies.
8. **Green Belt Designing:** Role of green belt in industrial systems, selection of trees and green belt designing; compensatory forestry

Suggested readings:

[1] Industrial Ecology-By Thomas E. Graedel, Second Edition, (2002) Prentice Hall Publications.

[2] Perspectives on Industrial Ecology- Dominique Bourg, Suren Erkma, (2003) Greenleaf Publishing Limited,

[3] Industrial Ecology: Environmental Chemistry and Hazardous Waste - Stanley E. Manahan, Lewis Publishers, 1999

MEST 305- Air Monitoring and Management Credits: 2

1. **The atmosphere:** Natural constituents of air; Vertical structure; Water in the atmosphere; Concepts and Measurements of atmospheric boundary layer
2. **Air Pollution Meteorology:** Principles of meteorology applied to air quality; Wind roses; Atmospheric stability; Inversion conditions; Mixing heights; Atmospheric turbulence; Plume rise; Effect of meteorology on plume behaviour
3. **Air pollutants and its effect:** Emission sources of primary pollutants, Volatile organic compounds, Persistent organic pollutants; Secondary pollutants and their sources; Emission factors; Natural and anthropogenic particle sources; Effect of air pollutants on biota and materials.
4. **Indoor air pollution:** Pollutants of Indoor air, their sources, fate and health impacts; Sick building syndrome; Volatile organic compounds; Bioaerosols; Monitoring of Indoor air quality; Building ventilation.
5. **Measurement of gases and particulates:** Objectives of Air Pollution Monitoring; Selection of monitoring locations; Sampling requirements; Measurement techniques; Gas sampling and measurement systems; Particle sampling and measurement systems.
6. **Representation of air quality data:** Period averages; Diurnal and seasonal variations; Frequency distributions; Pollutant standards indices; Air pollution indices; Emission inventories its concept and methodologies; Air quality norms and standards.
7. **Air pollution modelling:** Principles of air quality modelling; Deterministic, Stochastic and Simulation models; Dispersion models - Gaussian models, Box models, Eulerian Models, Lagrangian Models; Chemical mass balance models; Model validation and uncertainties.
8. **Control of Air pollution:** Air pollution prevention and control technologies; Gas specific removal technologies; Removal of particulate matter, liquid droplets and mist; Green technology.

Suggested Readings

[1] Schnelle, Jr., K. B. and Charles A. Brown (2002) Air Pollution Control Technology Handbook. CRC Press.
[2] Colls, J. (2002) Air Pollution. Spon Press, an imprint of the Taylor and Francis Group.
[3] Masters, G.M. (2004) Introduction to environmental engineering and science, Prentice-Hall of India Pvt. Ltd., New Delhi.
[4] Kiely, G., (2007) Environmental Engineering, Tata McGraw-Hill.
[5] Bruno Sportisse (2009) Fundamentals in Air Pollution: From Process to Modelling, Springer.

MEST 306 Water Monitoring and Management Credits: 2

1. **Distribution of water and hydrological cycle:** Global distribution of water, hydrological cycle and its components, variables for water balance on earth

2. **Properties of water and water quality standards**: Physico-chemical and biological properties of surface and subsurface water, National and International water quality standards

3. **Sources of water pollution and its effect:** Major sources of water pollution and its effect on surrounding water bodies, flora and fauna, and aquatic ecosystem

4. **Water management:** Water management strategies, surface and ground water resources and its management, problems and solutions, future challenges

5. **Watershed development and analysis:** Definition and concept of watershed, watershed development, watershed morphometric analysis and its applications

6. **Water Conservation and restoration:** Rain water harvesting, artificial recharging of ground water and recycling of domestic and industrial waste waters

7. **Waste water treatment technology:** Treatment technologies for domestic and industrial waste waters, sewage water treatment plants-components and operation.

8. **Hydropower projects and river linking:** Hydropower projects in India, current challenges and solutions, role of river linking in water management, advantages and disadvantages of river linking

Suggested readings:

[1] Pahl-Wostl, Claudia; Kabat, Pavel; Möltgen, Jörn (Eds.) (2008) Adaptive and Integrated Water Management.
[2] Hlavinek, P.; Kukharchyk, T.; Marsalek, J.; Mahrikova, I.(Eds.) (2006) Integrated Urban Water Resources Management.
[3] B.D. Tripathi (2001) Water pollution: An experimental approach CBS, Publishers.
[4] Boyd, C. E. (2012) Water quality: an introduction. Springer Science & Business Media.
[5] Standard methods for the examination of water and wastewater (Vol. 10). American Public Health Association. American Public Health Association, American Water Works Association, Water Pollution Control Federation, & Water Environment Federation. (1955).

MEST 307-Biodiversity Monitoring and Management credits: 2

1. **Understanding Biodiversity:** Defining Biodiversity; Global biodiversity patterns; Current losses of biodiversity; Biodiversity hotspots

2. **Valuing biodiversity:** Economic evaluation of biodiversity and its contribution to ecosystem services
3. **Monitoring Biodiversity:** Types of biodiversity and its measurement; Diversity indices; Biodiversity assessment techniques; Use of remote sensing and GIS for biodiversity assessment
4. **Sustainable Biodiversity Conservation and Management:** *In-situ* and *Ex-situ* conservation approaches; Protected area networks; Integrating sustainable development and conservation through benefit sharing, participatory approach and stakeholder analysis
5. **Methods for integrated conservation development projects:** Use of problem trees and objective trees, options analysis, Logical framework analysis, Risk analysis and stakeholder participation matrix in sustainable biodiversity management
6. **Legislation related to Protection and Management of Biodiversity:** Indian Forest Act (1927); Wildlife (Protection) Act (1972); Forest (Conservation) Act (1980); Biodiversity Act (2002) and National Biodiversity Authority of India
7. **National and international programmes** and conventions for biodiversity conservation; CITES, Ramsar Covention, CBD, National Biodiversity Action Plan of India
8. **Case Studies:** Ramsar sites in India; Project tiger and Project Elephant

Suggested Readings:

[1] Jeffries, M. J. (2006) Biodiversity and Conservation (Second edition). Rutledge.

[2] Sutherland, W. (2000) The conservation handbook-research, management and policy. Blackwell Science Ltd.

[3] Milner-Gulland, E.J. and M. Rowcliffe (2007) Conservation and Sustainable Use: A Handbook of Techniques. Oxford University Press.

[4] Weddell, B. J. (2002) Conserving living natural resources: In the context of a changing world. Cambridge, U.K: Cambridge University Press.

[5] Ausden, M. (2010) Habitat management for conservation: A handbook of techniques. Oxford Univ. Press.

MEST 308- Global Energy Scenario and its Management Credits: 2

1. **Sources of energy**: Conventional and non-conventional, Global patterns of energy consumption, rising demand and supply, Energy needs of growing Economy, Long Term Energy Scenario.

2. **Solar energy:** Earth Sun Relationship (Angles and Models, Earth and Sun Relation), Measurement, and technologies based upon solar energy.

3. **Wind energy:** Structure and function of wind turbines and associated technologies their scope and potential in India.

4. **Geothermal and Ocean energy:** Scope and potential in India, OTEC System, ocean wave energy system, ocean tidal energy system.

5. **Electrical and Thermal Energy:** Electricity tariff, Load management and Maximum demand control, Power factor; Thermal energy contents of fuel, Temperature and Pressure, Heat capacity, Sensible and Latent heat, Evaporation, Condensation, Steam, Moist air and Humidity, Heat transfer, Units and conversion.

6. **Energy Pricing, Energy Sector Reforms, Energy, and Environment:** Air Pollution, Climate Change, Energy Security, Energy Conservation, and its Importance,

7. **Energy Strategy for the Future:** Methods of energy conservation in households and industries. Hydrogen, alcogol, biodiesel and fuel cells as future energy sources, Energy Conservation Act-2001 and its Features.

8. **Case studies:** Solar Steam Cooking System at Tirumala, Andhra Pradesh; Village Energy Security Programme; Clean energy for Ladakh.

Suggested Readings:

[1] John W Twidell and Anthony d Weir (2006) Renewable Energy Resources, Published by E and F N Spon Ltd, London. 2006.

[2] W.R.Murphy & G.McKay (2007) Energy Management. Edition: ISBN: 9788131207383.

[3] S. C. Bhatia (2014) Advanced Renewable Energy Systems (in 2 Vols.). Edition: 2014. ISBN: 9789380308432.

[4] Staniskis, Jurgis Jayaraman, C (2010) Cleaner Production and Energy Conservation for Sustainable Development Nam S&T Centre. Edition : 2010. ISBN : 9788170356363.

[5] Pradeep Chaturvedi and Shalini Joshi (Ed.) (1997). Strategy for Energy Conservation in India. Edition: 1997. ISBN: 8170226430.

MEST 309- Mining Environment and Management Credits: 2

1. **Introduction to rock and minerals:** Importance; Classification and properties of rocks and minerals; Rock cycle.

2. **Distribution of Minerals:** Geological and geographical distribution of metallic and non-metallic mineral deposits in India

3. **Mining in India:** Importance of mining; Types of mining; Major mining areas of India; Agencies involved in mining.

4. **Impacts of Mining:** Social impacts; Economic impacts; Impact of mining on soil, water and air quality; Impact of mining on forest and wildlife.

5. **Health Impacts:** Impact of mining activities on human health; Strategies for minimizing the health effects.

6. **Sustainable Mining Techniques:** Minimizing the environmental impacts during mining operations; Phytomining; Bioleaching

7. **Restoration and Management of Mine Spoils:** Mine waste disposal and related problems; Ecological restoration of mined areas; Sustainability indicators for evaluating the performance of restored system

8. **Case Studies:** Restoration of coal mined areas in India; Bauxite mined areas in India

Suggested Readings:

[1] G. Tyler Miller Jr. (2010) Living in the Environment: Principles, Connections, and Solutions.

[2] Karheinz Spitz and John Traudlinger (2008) Mining and the Environment: From ore to Metals CRC Press.

[3] Jerrold J Marcus Mining Environmental Handbook (1997), World Scientific.

[4] MritunjoySengupta (1993) Environmental Impacts of Mining Monitoring, Restoration, and Control Lewis Publishers.
[5] U Ashwathanarayana (2005) Mineral Resources Management and the Environment, AA Balkema Publishers.

MEST 310- Waste Management Technology Credits: 2

1. **Introduction:** Generation, Sources, Types, classification and composition of solid wastes, Problem associated with improper waste management, Waste management system in India.

2. **Composition of solid waste:** Physical and chemical composition of solid waste, waste generation rates, collection, transportation and storage

3. **Solid waste Management:** Plan, waste minimization technologies, 4 R (recycle, reuse, recover and reduce) principle, Incineration, Land filling.

4. **Waste to energy conversion:** Pyrolysis, Composting, Biomethanation, and recycling; Refused Derived Fuels, Land fill gas (LFG).

5. **Hazardous Waste Management:** Sources, Types and Classification of hazardous waste and its management, Guidelines for HWM.

6. **Biomedical Waste:** Sources, Types and Classification of Biomedical Waste and its management.

7. **Laws and Policies for SWM:** Legislation and governance of different solid waste management.

8. Application of phytoextraction and biofiltration techniques for waste management, design of biogas system, disposal of some industrial solid waste like Fly ash and Red mud.

Suggested Readings:

[1] Frank Kerith, McGraw Hill (1994) Handbook of solid management, Inc. USA.
[2] Charles A. Wentz, Mcgraw-Hill (1989) Hazardous waste management, New York.
[3] Jagbir Singh, A. L. Ramanathan (2009) Solid Waste Management Paperback. I K International Publishing House Pvt. Ltd (12 January 2009) ISBN-10: 9380026420 ISBN-13: 978-9380026428
[4] George Tchobanoglous, Hilary Theisen, S. A. Vigil (1993) Integrated solid waste management: engineering principles and management issues McGraw-Hill.
[5] B.B. Hosetti (2006) Prospects and Perspectives of Solid Waste Management. ISBN: 9788122417777, 1st Edition.

MEST 311-Chemical Hazards and its Management Credits: 2

1. **Principles:** Environmental toxicology in Air, water, soil and remedial measures, sources and entry routes of chemicals as toxicants.

2. **Sources of Chemical Toxicants into the Environment**: Transport Processes; Equilibrium Partitioning; Transformation Processes; Environmental Fate Models.

3. **Exposure to chemical hazards:** Types of exposures; Response to exposures; Dose-response relationship, lethal and sub-lethal doses; No observable effect level (NOEL), minimum lethal dose (MLD) and LD50; Detoxification mechanisms in plants, animals and human beings.

4. **Toxicity testing:** Principles and methods of toxicity testing using *in-vivo* and *in-vitro* methods; Standards for toxicity testing.

5. **Toxic effects of Chemicals:** Cellular, molecular and biochemical effects of metals and metalloids in living organisms; Carcinogens, Mutagens and teratogens.

6. **Pesistent chemical hazards:** Types of Xenobiotics and their effects including persistent organic pollutants (POPs) in living organisms.

7. **Food and toxins:** Food adulteration, contaminations and other biologically related health hazards.

8. **Occupational health**: Occupational health hazards and case studies including Minamata disease in Japan; Bhopal disaster; Endosulfan pollution in Kerala; Arsenic poisoning in Indo-Gangetic plain.

Suggested Readings:

[1] Hodgson, E. (2010) A Textbook of Modern Toxicology. Hoboken: John Wiley and Sons.

[2] Landis, W. G., and Yu, M.-H. (2004) Introduction to environmental toxicology: Impacts of chemicals upon ecological systems. Boca Raton, FL: CRC Press.

[3] Wright, David A., and Pamela Welbourn. (2002) Environmental toxicology. Cambridge, UK: Cambridge University Press.

[4] Zakrzewski, S. F., and Zakrzewski, S. F. (2002) Environmental toxicology. New York: Oxford University Press.

[5] Martel, B. (2000) Chemical Risk Analysis - A Practical Handbook, Elsevier Science & Technology.

MEST 312- Environmental Economics Credits: 2

1. **Principles of environmental economics:** nature and scope; school of thoughts and theories.
2. **Production and environment:** environmental component (land, labour and capital) as a factor of production; environmental impacts of production.
3. **Welfare Economics:** Pegouvian externalities, Coasian property rights, Paroto optimality, compensating variation principles, willingness to pay.
4. **Demand and supply:** environment relationships and interactions, utility and elasticity, indifference curve, market mechanism and environment.
5. **Cost Benefit Analysis (CBA):** rationale and application, private cost and social cost; social CBA and economic CBA, financial analysis of projects.
6. **Resource Economics:** environmentally compatible resource exploitation and consumption, resource pricing techniques.
7. **Property regimes:** common and private property, theories in property management.
8. **Economic instruments for environmental protection:** polluter pay principles, incentives and subsidies, Green Taxes, Carbon Tax, etc.

Suggested Readings:

[1] H. Daly and J. Farley (2010) Ecological Economics: Principles and Applications, 2nd Edition, Island Press.
[2] B.C. Field and M.K. Field. McGraw-Hill/Irwin (2006) Environmental economics.
[3] K.A. Gould, T.L. Lewis (2009) Twenty Lessons in Environmental Sociology, Oxford University Press.
[4] N Hanley., J.Shogren and B.White (2001) Introduction to Environmental Economics 1st edition Oxford University, Press.
[5] B Field and M Field (1997) Environmental Economics: an Introduction, 3rd edition. New York: McGraw Hill.

MEST 313- Environmental Modelling Credits: 2

1. **Introduction:** Theory and practice of modelling, types of models, modelling steps and ingredients; the modeller's toolkit.
2. **Model formulation:** Model formulation; physical models; conceptual models; mathematical models; simulation models.
3. **Sensitivity and uncertainty evaluation:** Sensitivity analysis; Monte Carlo simulation; uncertainty evaluation; uncertainty boundary; structure and parameter; uncertainty in model outputs; input data and equation errors.
4. **Air pollution modelling:** Principles of air quality modelling; plume height estimation; dispersion models; Eulerian Models, Lagrangian Models; receptor models.
5. **Hydrological modelling:** Fundamentals of water quality modelling, ground and surface water modelling, aquifers contamination, salt water intrusions; rainfall runoff modelling.
6. **Mesoscale modelling:** Fundamentals of Mesoscale modelling; types of mesoscale models; boundary and initial conditions; coordinate systems; parameterization schemes.
7. **Climate Modelling:** Basic principles of general circulation modelling; grid-point and spectral GCMs; role of the ocean in climate modelling; concepts of ocean – atmosphere coupled models.
8. **Development and application of environmental model**: Development and application of environmental model; information and decision support systems; model demonstration.

Suggested Readings:

[1] Mike J. Barnsley (2007) Environmental Modelling: A Practical Introduction. CRC Press.
[2] Soetaert, Karline and Peter M.J. Herman (2009) A Practical Guide to Ecological Modelling: Using R as a Simulation Platform. Springer, New York.
[3] William E. Grant and Todd M. Swannack (2011) Ecological Modelling- A common sense approach to theory and practices. Blackwell Publishing.
[4] Thomas Stocker (2011) Introduction to Climate Modelling. Springer-Verlag Berlin Heidelberg.
[5] Michael J Barnsley. (2006) Environmental modeling. CRC Press (Taylor and Francis Group)

MEST 314- Ecological Engineering Credits: 2

1. **Ecosystem degradation:** Causes of degradation: National and international status of ecosystem degradation.

2. **Ecology of Degraded Systems:** Ecological profiling of the degraded system; Impact of disturbances on the structure and functioning of ecosystems.

3. **Ecological Engineering:** Principles of ecological engineering; Ecological engineering as a tool for the restoration of degraded systems.

4. **Tools for Restoration:** Phytorestoration; Microbial based restoration; Assisted restoration of degraded system.

5. **Restoration of forests:** Acceleration of ecological succession; Reintroduction of flora and fauna; Reintroduction of key species; Restoration based on functional diversity.

6. **Restoration of grassland ecosystems:** Introduction of suitable species; Restoration based on key species; Integrated restoration techniques.

7. **Ecological restoration of wetlands:** Physical, chemical and biological methods; Engineering techniques for wetland restoration.

8. **Restoration of wastelands and degraded/contaminated lands:** Physical, chemical and biological methods; Integrated restoration techniques.

Suggested Readings:

[1] William J. Mitsch, Sven Erik Jrgensen, Wiley (2004) Ecological Engineering and Ecosystem Restoration.

[2] Jordan, W.R., et al. (1987) Restoration Ecology, Cambridge University Press.

[3] Clewell, A. F., and J. Aronson. (2007) Ecological Restoration: Principles, Values, and Structure of an Emerging Profession, Island Press, Washington, DC.

[4] Doyle, M., and C. A. Drew (eds). (2008) Large-Scale Ecosystem Restoration, Island Press, Washington, DC.

[5] Michael J G, van Eeten, Emery Roe (2002) Ecology, Engineering and Management: Reconciling ecosystem rehabilitation and service reliability.

Semester IV

MEST 401- Dissertation/Thesis work Credits: 8

MEST 402- Presentation Credits: 2