Proposed 3rd year Syllabus (Academic year 2021 - 2022) (Revision)

T Y B. Sc. (Blended) – Environmental Science Stream

SEM V		
Subject Code	**Title of the Subject**	**Credits**
EVSB 501	Environmental Chemistry	3
EVSB 502	Environmental Law and Policy	3
EVSB 503	Environmental Geosciences	3
EVSB 504	Water & Waste Water Management	3
EVSB 505	Elective Course - 1	2
EVSB 506	Elective Course - 2	2
EVSB 507	Environmental Chemistry - LAB	2
EVSB 508	Environmental Geoscience - LAB	2
EVSB 509	Project/ Dissertation	2
Total Credits		**22**

Elective Courses SEM V		
Subject Code	**Title of the Subject**	**Credits**
Elective Course - 1	Energy & Environment	2
Elective Course - 2	Climate System Science	2

The student cannot choose elective course against the core subject of the specialisation in the 3rd year. Students can choose electives from other streams viz. Physics, Chemistry or Earth Science. They also can choose electives from B. A. Liberal Arts.

SEM VI		
Subject Code	**Title of the Subject**	**Credits**
EVSB 601	Environmental Impact Assessment (Theory & Practical)	3
EVSB 602	Environmental Biotechnology	3
EVSB 603	Remote Sensing and GIS	3
EVSB 604	Solid Waste Management	3
EVSB 605	Elective Course - 3	2
EVSB 606	Elective Course - 4	2
EVSB 607	Environmental Biotechnology - LAB	2
EVSB 608	Remote Sensing and GIS - LAB	2
EVSB 609	Project/ Dissertation	2
Total Credits		**22**

Elective Courses SEM VI		
Subject Code	**Title of the Subject**	**Credits**
Elective Course - 3	Environmental Economics	2
Elective Course - 4	Disaster Management & Mitigation	2

The student cannot choose elective course against the core subject of the specialisation in the 3rd year. Students can choose electives from other streams viz. Physics, Chemistry or Earth Science. They also can choose electives from B. A. Liberal Arts.

Syllabus Details

SEMESTER V

EVSB 501 - Environmental Chemistry	
Topic Details	**No. of Lectures**
Introduction to Green Chemistry What is Green Chemistry? Need for Green Chemistry. Goals of Green Chemistry. Limitations/ Obstacles in the pursuit of the goals of Green Chemistry.	4
• Principles of Green Chemistry and Designing a Chemical synthesis • Twelve principles of Green Chemistry with their explanations and examples; • Designing a Green Synthesis using these principles; • Prevention of Waste/ byproducts; • Maximum incorporation of the materials used in the process into the final products (Atom Economy); • Prevention/ minimization of hazardous/ toxic products; • Designing safer chemicals – different basic approaches to do so; • selection of appropriate auxiliary substances (solvents, separation agents), green solvents, solvent-less processes, immobilized solvents and ionic liquids; • energy requirements for reactions - use of microwaves, ultrasonic energy; • selection of starting materials; avoidance of unnecessary derivatization – careful use of blocking/protecting groups; • use of catalytic reagents (wherever possible) in preference to stoichiometric reagents; • designing of biodegradable products; prevention of chemical accidents; • strengthening/development of analytical techniques to prevent and minimize the generation of hazardous substances in chemical processes	12

Water Chemistry - Reversible and irreversible reactions of water, Cations and anions in water and their sources, Mass Balancing, concepts of DO, BOD, COD, sedimentation, coagulation, filtration, redox potential.	4
Soil Chemistry - Chemistry of salt-affected soils and amendments; soil pH, EC, ESP, SAR; Soil Pollution Management;	4
Future Trends in Green Chemistry Oxidation reagents and catalysts; Biomimetic, multifunctional reagents; Combinatorial green chemistry; Proliferation of solvent-less reactions; non-covalent derivatization; Green chemistry, in sustainable development.	6
Student work - Assignments, Tutorials - Reviews of various research papers, reports, books - Presentations	15

Suggested Reading:

1. Manahan S. E, Environmental Chemistry, CRC Press 2010
2. Girard J., Principles of Environmental Chemistry, Jones Bartlett Learning, 2014
3. A. K. Dey. Environmental Chemistry- New Age International publishers.
4. Bela Torok and Timothy Dransfield (ed.). Green Chemistry. 2017. Elsevier
5. V. K. Ahluwalia. 2013. Green Chemistry: A Textbook. Alpha Science International.
6. Harrison R., Principles of Environmental Chemistry, RSC 2007
7. Hanrahan G., Key concepts of Environmental Chemistry, Elsevier Inc. 2012

EVSB 502 - Environmental Law & Policy	
Topic Details	**Lectures**
Introduction to law and Policy • Sources of law, Concepts, Definitions • Difference between policy and law • Historical background	4
International & Indian environmental movements • Principles of international environmental law • Difference between Indian and Western environmentalism • Modern Environmental movements (Chipko, Apiko, Narmada bachao etc.) • Role of civil society in environmental movements • Indian Government's response to International Conventions / Regulations	3

International Environmental Organizations • Various organisations and institutions (e.g. UNEP, UNFCC, IPCC, etc.) • Changing role of NGOs/ Institutions in conservation and protection of environment • Nexus between natural resources and tribal/ethnic communities • Natural resources and competing human rights.	4
Role of constitution in environment protection • Fundamental rights and duties, Article 48A, 51A (g), 58A, Any relevant Amendments, etc. **Environmental Legislation Indian Context**: • Water Act, 1974 • Air Act, 1981 • Indian Forest Act, 1927/1982 • Environment Protection Act, 1986 • The National Green Tribunal Act 2010 • National Environment Policy • Forest Policy	6
Introduction to major international conferences/ conventions: • The Stockholm Declaration of 1972; • United Nations Conference on Environment and Development 1992; • Rio de Janeiro (Rio Declaration, Agenda 21); • Montreal Protocol 1987; • Kyoto Protocol 1997; • Ramsar convention: • Cartagena Protocol • Convention on Biological Diversity	5
Overview of institutional framework in India • Agencies of Governance and their role in green governance • Government ministries, departments defining policies and laws (MoEFCC, Pollution Control Boards, Forest Department, National Biodiversity Authority, etc.) • Important autonomous boards, commissions and institutions working for protection/ conservation of natural resources (ZSI, BSI, BIS, Niti Ayog, etc.) • Green Justice network (Courts and specialised tribunals) • NGT Act 2010	3

Student Work - Review - Books, Scientific Journals, - Case studies - Group Discussions, etc	20

Suggested Readings:

1. Divan S. & Rosencranz A., Environmental Law and Policy in India. OUP, 2001.
2. Naseem M., Environmental Law in India Mohammad. Kluwer Law, 2011 International.
3. Venkat A. Environmental Law and Policy. PHI, 2011
4. Sands P., Peel J., Principles of International Environmental Law, CUP 2018
5. Abraham C.M. Environmental Jurisprudence in India. Kluwer Law International. 1999.
6. T S Doabia. 2017. Environmental and Pollution Laws in India. 3rd Edition. Publisher: Lexis Nexis
7. P. Leelakrishnan. 2016. Environmental Law in India. 4th edition. Publisher: Lexis Nexis.
8. S. K. Mohanty. 2014. Environment & Pollution Laws – Universal Law Publication.

EVSB 503 - Environmental Geosciences	
Topics	**Lectures**
Geosciences: Definition, branches, applications	2
Fundamentals of Earth System: Origin of Universe (Big Bang Theory), Solar system, Earth and Moon. Meteorites-types and origin. Cosmic abundance of elements, Distribution of elements in solar system and in Earth. Formation and characteristics of Earth Systems (Atmosphere, Lithosphere, biosphere and hydrosphere).	5
Earth structure: Structure of the Earth (Mechanical layers of earth), Geothermal gradients. Earth's magnetic and gravitational fields (origin and effects). Dynamic nature of earth (Plate Tectonics, Mountain building, earthquakes, volcanoes.	5
Earth's Composition: Minerals (Definition, characteristics, classification, basic rock forming minerals); Rocks (Definition, classification, rock cycle)	6
Surface Processes & Landforms: Processes (Physical, chemical, biological) and agents of weathering, erosion, transportation and deposition, products of weathering; Erosional and depositional landforms: Glacial, Aeolian, Fluvial, Coastal, shallow marine and deep marine.	4

Soil: Genesis of Soil; Lateritisation; Soil Profile; Soil texture, structure; Bio-, Physico-, Chemical properties of soil; Soil Classification; Fertility; Land use and Land capability classification; Water-logging, salinization, desertification and degradation of soil.	6
Earth's natural resources: Occurrence and paragenesis of metallic, non-metallic minerals (metallic: Iron, manganese, copper, zinc, noble metals etc.; non-metallic: silica, asbestos, mica, carbonates, evaporites etc., coal, oil and natural gas). Surface and groundwater resources, Hydrological cycle.	6
Geomorphology: Landforms related to various agents (wind, ice, Water- fluvial, coastal and oceanic). Drainage types and density, Stream ordering, Hypsometric analyses.	6
Elements of Geological mapping: Geological mapping, Introduction to Toposheets, concept of scale, types of geographic projections, Representing lithological and structural elements on maps	4
Introduction to Applied Environmental Geology Land-use planning, Land reclamation, watershed management, etc.	3

Suggested Reading:

1. The Earth System (3rd Edition) 3rd Edition- Lee R. Kump, James F. Kasting, Robert G. Crane.
2. Environmental Geology – K.S. Valdiya
3. Plate Tectonics & Crustal Evolution- Kent. C. Condie, 1997
4. A.D. Howard and I Remson : Geology in Environmental Planning
5. Todd, D.K.: Groundwater Hydrology.
6. Davis S.N. and Dewiest R.J.M.: Hydrogeology.
7. Textbook of Soil Science- T.D. Biswas and S.K. Mukherjee
8. The Nature and Properties of Soils, 14th Edition Nyle C., Brady and Ray R. Weil
9. Cesare Emiliani. Planet Earth: Cosmology, Geology, and the Evolution of Life and Environment.
10. G.R. Thompson, & J. Turk. 1998.Introduction to Physical Geology.
11. A.D. Howward and I Remson : Geology in Environmental Planning.
12. T.D. Biswas and S.K. Mukherjee. Textbook of Soil Science.
13. Nyle C., Brady and Ray R. Weil.The Nature and Properties of Soils, 14th Edition
14. Holmes' Principles of Physical Geology 4th ed. 1993 Edition- Arthur Holmes (Ed) P. Mc L. D. Duff
15. D. Burrbank & R. S. Anderson. 2012.Tectonic Geomorphology

16. Umeshwar Prasad. Economic Geology: Economic Mineral Deposits 2nd Ed.

EVSB 504 - Water & Waste Water Management	
Topic Details	**Lectures**
Quantity & Quality of water - Water Requirements for various purposes [e.g. Domestic, Commercial and Industrial. Variation in quantity of water and waste water, Factors affecting rate of demand.	4
Water Sources – Availability & quality of surface water & ground water. quality of raw water. (River zonation with reference to developmental activity)	2
Impact of future growth and development and change in quality of life on water requirements. Need of water quality standards for domestic & industrial purpose. Specifications for drinking water (physical, chemical & bacteriological) by Bureau of Indian Standards & World Health Organization.	2
Fresh Water Treatment - Primary, secondary and Tertiary treatment process. - Advanced treatment methods e.g. Demineralization; Ultra filtration; Reverse osmosis; other membrane filtration systems, etc. - Supercritical water oxidation. - Recent Advancements in Water & Waste water treatment	10
Waste Water Treatment - Primary, secondary and Tertiary treatment process including Biological Treatments - Advanced treatment methods e.g. Demineralization; Ultra filtration; Reverse osmosis; other membrane filtration systems, etc. - Sludge Treatment and Disposal - Supercritical water oxidation. - Recent Advancements in Water & Waste water treatment	10
Introduction to Parameters of Water & Waste Water Engineering & Design Criteria	5
Overview of National River Action Plan	2
Student Work - Review - Books, Scientific Journals - Visit to water & Waste Water treatment Plants, Industries, etc.	10

Suggested Readings:

1. Garg S.K., Water Supply Engineering (Vol-I & II), Khanna Publishers
2. Peavy H.S., Rowe D.R. & Tchobanoglous G., "Environmental Engineering". McGraw Hill International Edition.
3. Karia G.L., Wastewater Treatment: Concepts and Design Approach, PHI, 2013.

4. Metcalf & Eddy, "Wastewater Engineering- Treatment and Reuse," Tata McGraw Hill, 4th Edn., 2003.
5. Rangwala. Water supply and sanitary engineering.
6. K.N. Duggal. Elements of Environmental Engineering
7. G. S. Birdie and J. S. Birdie. Water Supply and Sanitary Engineering
8. McGhee T. J., "Water Supply and Sewerage", McGraw-Hill, Inc., 1991.
9. Davis M. L. & Cornwell D. A., "Introduction to Environmental Engineering", McGraw-Hill, Inc.,1991.
10. Sawyer C. N., McCarty P. L., Parkin G. F., "Chemistry for Environmental Engineers", McGraw-Hill, 1994.
11. Punmia B.C., Environmental Engineering (Vol-I & II), Laxmi Publishers.

Elective Course 1 - Energy and Environment	
Topic Details	**Lectures**
• Introduction (Sources of energy and their classification; Energy forms and transformation. Energy requirement, Usage patterns)	4
Fossil Fuels • Classification, composition, physiochemical characteristics; • Energy content of coal, petroleum and natural gas; • Formation, reserves, exploration/ mining and uses of Coal, Oil and Natural gas; • Environmental problems associated with exploration / mining, processing, transportation and uses	4
Nuclear energy Fission and fusion, Nuclear fuels, – Mining and processing of Uranium –concentration, refining, enrichment, fuel fabrication and fuel cycle; Nuclear reactors and radioactive waste; Environmental implications.	4
Renewable Energy - Hydal; Solar; Wind; Geothermal; Bioenergy • Sources & Potentials in India, • Methods of Energy Harnessing / extraction, • Methods of usage/storage • Energy conservation measures • Environmental Implications	4

Energy & Climate Change • Current energy infrastructure (Global & Indian context) • Future technologies: carbon sequestration, biofuels, hydrogen fuel cells, etc. • Impacts on the environment;	2
Student Work • Case Studies • Review - Books, Scientific Journals • Group Discussions, etc • Field Visit	12

Suggested Readings

1. Renewable Energy – Environment and Development: M. Dayal; Konark Pub. Pvt. Ltd.
2. Alternative Energy: S. Vandana; APH Publishing Corporation
3. Nuclear Energy – Principles, practice and prospects: S. K. Agarwal; APH Publishing Corporation
4. Bio-Energy Resources: Chaturvedi; Concept Pub.
5. National Energy – policy, crisis and growth: V S. Mahajan; Ashis Publishing House
6. Geography and Energy – Commercial energy systems and national policies: J.D. Chapman

Elective Course 2 - Climate System Science	
Topic Details	**Lectures**
The Science of Climate Change - Introduction - History of Climate Change on Earth - The global carbon cycle - Green House Gases - Anthropogenic contributions	2
Climate modeling and feedback Mechanisms: - linkages between atmosphere, oceans, biosphere, etc.	3
Politics of Climate Change - Global Politics of Climate Change - United Nations Framework Convention on Climate Change (UNFCC) - Intergovernmental Panel on Climate Change (IPCC)	3

- Kyoto Protocol, Paris Agreement, etc. - Indian contribution towards Climate Change	
Impacts of Climate Change - Freshwater Resources - Terrestrial and Inland Water Ecosystems - Ocean Environments - Food Security and Food Production - Human Health, Livelihoods & Poverty	4
Climate Change Adaptation & Mitigation Strategies	2
Planning for Climate Change	2
Student work - Reviews of various research papers, reports, books - Presentations - Group discussions - Visit to Industry/ Field	14

Suggested readings:

1. Lutgens & Tarbuck. The Atmosphere.
2. Cunningham & Cunningham. Fundamentals of Environmental Science: A Global Concern.
3. Chew S.C., The recurring dark ages: ecological stress, climate changes, and system transformation. Rowman Altamira, 2006.
4. William F. Ruddiman. Earth's Climate: Past and Future.
5. IPCC Reports on Climate Change

EVSB 507 - Environmental Chemistry – LAB

1. Green Synthesis of the following compounds: adipic acid, catechol, disodiumc iminodiacetate (alternative to Strecker synthesis)
2. Microwave assisted reactions in water: Hofmann Elimination, methyl benzoate to benzoic acid, oxidation of toluene and alcohols; microwave assisted reactions in organic solvents: Diels-Alder reaction and Decarboxylation reaction,
3. Ultrasound assisted reactions: sono-chemical Simmons-Smith Reaction (Ultrasonic alternative to Iodine)
4. Green Counterpart of common organic reactions: Aldol, Friedel-Crafts, Michael, Knoevenagel, Cannizzaro, benzoin condensation and Dieckmann condensation,
5. Rearrangement Reaction by Green Approach: Fries rearrangement, Claisen rearrangement, Beckmann rearrangement, Baeyer-Villiger oxidation.

6. Alkalinity Test; Turbidity Test; pH and Conductivity Test;
7. Estimation of Hardness; Estimation of BOD and COD; Estimation of residual chlorine.

Optional

1. Field Visit to a water treatment site, sampling, analysis, and reporting on the same;
2. Visit to a STP or ETP site and reporting
3. Field visits to Chemical Industry.

EVSB 508 - Environmental Geoscience– LAB

1. Rock forming minerals – Hand specimens
2. Ore Minerals – Hand specimens
3. Identification of rocks – Igneous, Sedimentary, metamorphic
4. Geomorphology – Drainage Pattern, types, etc.
5. Soil Classification
6. Sampling and analysis of organic matter, nitrate, sulphate, TDS and COD of waste water/ contaminated soil.

EVSB 509 – Project/ Dissertation

Project-based learning offers an opportunity to the students to work independently under guidance of a supervisor. Students will be assigned to the on campus faculty/ research scientists from various national research institutes such as NCL/ IISER/ IITM etc/ experts from NGOs working in environmental field/others; under whose guidance he or she would work on a problem keeping the focus to enhance their own ability to critical thinking, identification of research problems and research gaps, formulate research objectives, formulation of research plan, and problem solving via execution of specific experiments, and develop specialized skills to handle specific problems. This would train the students to nurture their creativity and innovative ideas, collaboration/teamwork and leadership, communications, learning self-reliance and project management.

Adequate assessment requirements for individual marking are presentations with discussions and seminars on the working process and the results.

Syllabus Details – Semester VI

EVSB 601 - Environmental Impact Assessment (EIA) & Risk Analysis (Theory & Practical)	
Topic Details	**Lectures**
Introduction	2
Sustainable Development challenges and need for EIA. Definition, aims and objectives of EIA. Concepts of EIA and Scope of EIA. Evolution of EIA. Benefits and Drawbacks of EIA process.	
Legislation and Procedures	2
EIA notification 2006 and other legislative requirements and administrative procedures India and its implementation, in India. Accreditation of EIA consultants by Quality Control of India – NABET requirements and guidelines.	
Assessing Environmental Impacts: The EIA Approach	8
- EIA as a planning process: developmental plans, policies and strategies for developmental projects - Steps in EIA process, - Impact Assessment methodologies - Identification, Prediction and assessment of impacts - Public Participation (PP) - Preparing an EIA report /Environmental Impact Statement (EIS)	
Case Studies	5
Introduction to Strategic Environmental Assessment (SEA)	1
Risk Assessment	3
- Intro to Risk Assessment & concepts of risk analysis - Logic trees - Intro to international standards	
Eco-toxicology	2
Introduction to toxicology, Principles of toxicology with reference to Environment, scope of toxicology. Concepts of Toxicology: Exposure, Dose Response Relationships, TLM and Lethality Studies. Biochemical basis toxicity – mechanism of toxicity and receptor mediated events, acute and chronic toxicity.	
Toxicants in the Environment	2
Toxic substances in the environment, its types, their sources and entry routes. Transport of toxicants by air, soil and water: transport through food chain - bioaccumulation and biomagnifications of toxic materials in food chain.	
Effects and Evaluation of Toxicity	2

Classification, Methods of assessment, Types of Bioassay, bioassay test models and classification, Threshold Limit Value (TLV), LC_{50}, LD_{50}, toxicity testing: lethal, sub-lethal & chronic tests.	
Student work / Practical	
• Reconnaissance surveys, • Field work for collecting baseline data, assessment of alternatives • Assignments / Tutorials • Reviews of various reports, books • Presentations	18

Suggested Reading:

EIA

1. Judith, P. Handbook of Environmental Impact Assessment. Blackwell Science. 1999.
2. Marriott, B. Environmental Impact Assessment: A Practical Guide. McGraw-Hill, New York, USA. 1997.
3. Larry W. Canter. Environmental Impact Assessment. McGraw Hill, Inc, New York
4. Y. Anjaneyulu and Valli Manickam. Environmental Impact Assessment Methodologies. BSP publications, Hyderabad.
5. Morgan, R. K. (1998). Environmental impact assessment: a methodological perspective. Springer Us.
6. Paliwal, R. (2006). EIA practice in India and its evaluation using SWOT analysis. Environmental Impact Assessment Review, 26(5), 492–510.
7. The environment (Projection) Act 1986
8. The Environmental Impact Assessment Notification, 1994, GoI
9. Environmental Impact Assessment Notification, 2006
10. Environmental Impact Assessment Notification, 2020 (draft)

Risk Assessment / Toxicology:

1. Shaw I.C. and Chadwick J. Principles of Environmental Toxicology, Taylor & Francis, 2008
2. Ming-Ho Yu, Humio Tsunoda, Masashi Tsunoda. (2011). Environmental Toxicology: Biological and Health Effects of Pollutants, 3rd Edition, CRC Press.
3. Stephen M. Roberts, Robert C. James, Phillip L. Williams (2015). Principles of Toxicology: Environmental and Industrial Applications. 3rd Edition, Wiley Publishers.
4. N Plant. (2003) (eds). Molecular Toxicology Taylor & Francis Publishers.
5. SataKe M, Mido Y, Yasuhisa H, Taguchi S, Sethi MS (2013) (eds). Environmental Toxicology Discovery Publishing House, India.

6. Subramanian MA (2010) (eds). Toxicology: Principles and Methods MJP Publishers, India.

EVSB 602 - Environmental Biotechnology	
Topic Details	**Lectures**
Introduction & Basic concepts Definitions, scope of environmental biotechnology, applications in environmental resource conservation, sustainability, cleanup/bioremediation, biodegradation, transgenics/genetic engineering	5
Environmental Microbiology - Microbes in Environment - Biotransformation and Biodegradation	6
Biotechnological Tools and Techniques **-** Background, scope, various biotechnological tools and their significance for environmental analysis - Basics of microbial, plant and animal tissue culture techniques	5
Basics of recombinant DNA technology DNA/RNA, molecular cloning, Gene cloning Vehicles- vector: plasmids, cosmids, phage vectors- λ and M13, YACs, BACs, expression vectors, Agrobacterium vectors, host – properties of host	5
Enzymes for recombinant DNA technology Restriction enzymes, ligases, polymerases, alkaline phosphatase.	4
Transformation Techniques of introducing DNA in bacteria, animal and plant cells Selection of transformants & characterization	4
Polymerase chain reactions (PCR) and modifications	3
DNA sequencing techniques Maxam-Gilbert's method, Sanger's Dideoxy method, Automated DNA sequencing, Next generation sequencing	3
Biotechnology for Environment	
Concepts and applications Environmental Biotechnology of Bioremediation (including Phytoremediation), Biopesticides, Bio-composting, Biomining, Bio-methanation, Bioleaching, Biosensors, etc.	7

GMOs and environment, International Conventions & Policies, biosafety and regulations, risks associated with production and release of GMOs- risk assessment, ways to reduce risks	3

Suggested Reading:

1. Jördening, H.J. and Winter, J. eds., Environmental biotechnology: concepts and applications. John Wiley & Sons, 2005.
2. Singh, B.D. and Singh, B.D., Biotechnology expanding horizons. Kalyani publishers. 2007.
3. Lehninger, A.L., Nelson, D.L., Cox, M.M., Lehninger principles of biochemistry. Macmillan, 2005.
4. Elliott, W.H., Elliott, D.C. and Jefferson, J.R., Biochemistry and molecular biology (Vol. 2001, p. 586). Oxford: Oxford University Press, 1997.
5. Wang, L.K., Ivanov, V., Tay, J.H. and Hung, Y.T. eds., Environmental biotechnology (Vol. 10). Springer Science & Business Media, 2010.
6. Rittmann, B.E. and McCarty, P.L., Environmental biotechnology: principles and applications. Tata McGraw-Hill Education, 2012.
7. Patel A.H., Industrial microbiology. Macillan India Ltd, 2000.
8. Nalwa, H.S. ed., Nanostructured materials and nanotechnology: concise edition. Elsevier, 2001.
9. Doble, M., Kruthiventi, A.K. and Gaikar, V.G., Biotransformations and bioprocesses. CRC Press, 2004.
10. Hambleton, P., Melling, J. and Salusbury, T.T. eds., Biosafety in industrial biotechnology. Glasgow: Blackie Academic & Professional, 1994.
11. A. H. Scragg, Alan H. Environmental Biotechnology: Oxford University Press
12. Martin Alexander. Biodegradation and Bioremediation: Academic Press.
13. Kirsten Heimann, Obulisamy Parthiba Karthikeyan, Subramanian Senthikannan Muthu, Environmental Footprints and eco-design of Products and Processes: Biodegradation and Bioconversion of Hydrocarbons. Springer.
14. Wang-Yu-Tong, Xue-Cheng Zhang, Shan-Qun Jiang, Xiang Dong. Integrated Biotechnology: Fundamentals and Applications. Stadium Press.
15. Neil Willey, Phytoremediation: Methods and Reviews. Humana Press.
16. John M.s. Barllett, David Stirling, PCR Protocols, Humana Press.

EVSB 603 - REMOTE SENSING AND GIS	
Topic	**Lectures**
UNIT 1: Remote sensing - Introduction, History Of RS, Components - EMR spectrum, Active and passive remote sensing, Atmospheric windows - Types of remote sensing: Optical, Thermal, Microwave, Hyperspectral, RADAR, LIDAR - Resolution of Remote sensing data: Spatial, Spectral, Radiometric and Temporal - Interaction of EMR with the earth's surface and atmosphere: Energy response mechanism: Reflection, Absorption, Transmission, Scattering, Refraction, Reflectance, Emission and scattering - Spectral reflectance curve for vegetation, soil, water - Types of platforms, Geostationary orbit and Sun-synchronous Polar orbit - Multi spectral scanning, Scanning Systems (Push broom and Whiskbroom etc) - Indian remote sensing and sensors	15
UNIT 2: GIS - Introduction, History Of GIS, Components - Shape of Earth-Geoid Spheroid Ellipsoid - Datum and projections: Conical, Azimuthal and Cylindrical. LCC Projection, UTM and Polyconic projections. Types of Datum. - Types of GIS data: Spatial, Attribute; Vector-point, line, polygon, Raster - Data structures in GIS: Spatial: Raster data, Vector data, comparative overview. Non-spatial data - Hierarchical, Network and relational data. - Acquisition of spatial data: Scanning, Geo referencing, concept of layer, digitizing, error detection and correction, concept of topology. - Spatial Analysis: Vector based: Overlays operations, point in polygon, line in polygon, polygon in polygon; single layer operations and Multilayer operations. - Raster based: Buffering, Network Analysis, generation of Thematic maps.	15

UNIT 3: Applications in RS and GIS - Aerial photography: Basic geometric characteristics of aerial photographs, Photo interpretation elements for visual interpretation - Satellite image processing and interpretation: Factors governing Interpretability, Elements of image interpretation. Image correction, rectification techniques. - Remote sensing products widely used and their features-sensors, uses, etc: LANDSAT, CARTOSAT, LISS, etc. - Global Positioning System (GPS), GLONASS, GAGAN: principles, applications - DEM, DTM, Terrain Analysis - RS GIS applications: Landuse - land cover changes; Natural hazards and hazard management; hydrology; monitoring water quality and soil quality; geology, forestry, agriculture, etc. - Use of GIS to represent environmental status and highlight environmental issues. - Latest trends in RS GIS: web GIS, drone mapping and surveying, wearable GIS, LIDAR	15

Suggested Reading:

1. Lillesand T. M., Keifer, R. W. & Chipman. Remote Sensing and Image Interpretation. John Wiley, 7th Edition, 2015
2. Burrough P.A. and McDonnell R.A., Principles of Geographical Information Systems. 2nd Edition, Oxford University Press, 2006.
3. Joseph G. (2003): Fundamentals of Remote Sensing, Universities Press, Hyderabad.
4. Haywood, Ian (2000): Geographical Information Systems, Longman
5. Chang, Kang-taung (2002): Introduction to Geographic Information Systems, Tata McGraw-Hill.
6. Gupta, R. P. 2003. Remote sensing geology, Springer, New York
7. Ramsay : Trends in Geological Remote Sensing
8. Pandey : Photogeology
9. Paine D.P.: 1981, Aerial Photography and Image Interpretation for Resource Management, John Wiley and Sons, New York, 571 p.
10. Jense J. R., Remote Sensing of the Environment – An earth resource perspective. Pearson Education, 2nd Edition, 2013

EVSB 604 - Solid Waste Management	
Topic	**Lectures**

Introduction Definitions, Historical development, Source and type-based classification, chemical and physical composition, Factors affecting solid waste management: Climate, financial, cultural constraint, quality and quantity of waste. Environmental and health impacts due to solid waste and handling of it. Characterization: physical & chemical characteristics, implications for solid waste management.	6
Municipal Solid Waste, Industrial Solid Waste, Hazardous Waste, Biomedical & E-waste: Generation, Collection, segregation, Transportation	8
Treatments and disposal characterization, UN classification, Waste processing, Recovery of biological and chemical conversion products composting, bio-methanation, RDF system, hydrolysis, Pyrolysis, plasma gasification, incineration, sanitary landfills.	4
Introduction to Solid Waste Management Rules (Solid Waste Management Rules, 2016; Plastic Waste Management Rules 2016; Biomedical Waste Management Rules 2016, etc.)	4
Case Studies	8
Student work - Assignments / Tutorials - Reviews of various research papers, reports, books - Presentations - Field Visits	15

Suggested Readings

1. M.S. Bhatt and Asheref Illiyan. 2012. Solid Waste Management: An Indian Perspective.
2. S. Bhatia. 2007. Solid and Hazardous Waste Management. Atlantic publication.
3. Goel, Sudha (Ed.). 2017. Advances in Solid and Hazardous Waste Management
4. M.N.Rao & Razia Sultana. Solid and Hazardous Waste Management
5. M.N. Rao, Razia Sultana, Sri Harsha Kota, Anil Shah, Naresh Davergave. 2016. Solid and Hazardous Waste Management: Science and Engineering. 1st Edition. Butterworth-Heinemann publication.
6. Handbook of Solid Waste Management, by George Tchobanoglous & Frank Kreith, 2nd Edition, Publisher McGRAW-HILL. DOI: 10.1036/0071356231
7. Integrated Solid Waste Management: Engineering Principles and Management Issues First Edition by George Tchobanoglous (Author), Hilary Theisen (Author), Samuel Vigil (Author). ISBN-13: 978-0070632370

8. Handbook of Solid Waste Management and Waste Minimization Technologies. 2002. by, Nicholas P Cheremisinoff Hardcover ISBN: 9780750675079
9. Industrial Waste Treatment Handbook. 2005. by Woodard & Curran, Inc. Hardcover ISBN: 9780750679633 Paperback ISBN: 9781493303199
10. Thermal Processing of Wastes 2010 By J. C. Jones ISBN: 978-87-7681-590-5
11. Transport and Chemical Rate Phenomena.1995. [Hardcover] By N. Themelis. Publisher: Taylor & Francis (July 17, 1995) ASIN: B00SB1MD32
12. Waste Management Practices - Municipal, Hazardous, and Industrial. 2014. By John Pichtel. ISBN - 13: 978-1-4665-8519-5
13. Industrial Waste Management Hardcover 2017 by Zander Ellis (Editor). ISBN-13: 978-1635491494.
14. Manual on Municipal Solid Waste Management, CPHEEO, Ministry of Urban Development, Govt. of India, New Delhi, 2000.
15. White P.R. et al, Integrated Solid Waste Management, Lewis Publisher, 1989.
16. David L.H.F. and Liptak D. G., Hazardous waste and solid waste, Lewis Publisher, 2000
17. Oberoi N.K, Environmental Management, (2nd Edition) Excel Books, New Delhi, 2003.

Elective Course 3 - Environmental Economics	
Topic Details	**Lectures**
Basics of Environmental Economics • Overview of environmental problems in India • What is environmental economics – Interlinkages between the economy and the environment. • Economic aspects of making Environmental Policy.	2
Introduction to Economic Instruments • Regulatory tools versus Incentives and Subsidies. • Charges/Taxes; Subsidies; Deposit-refund systems; Market Creation; Enforcement incentives, etc. • Effectiveness of economic instruments.	3
The Theory of Externalities • Pareto optimality and market failure in the presence of externalities; property rights and the Coase theorem.	4
Overview to the Design and Implementation of Environmental Policy • Pigouvian taxes and effluent fees; tradable permits; choice between taxes and quotas under uncertainty; implementation of environmental policy	3

International Environmental Problems Trans-boundary environmental problems; economics of climate change; trade and environment.	2
Introduction to the measuring of Benefits of Environmental Improvements Non-market values and measurement methods; risk assessment and perception.	2
Sustainable Development Concepts; measurement.	2
Student Work • Case Studies • Review - Books, Scientific Journals • Group Discussions, etc.	6

Suggested readings:

1. John V. Krutilla; Anthony C. Fisher.1985. The Economics of Natural Environments: Studies in the Valuation of Commodity and Amenity Resources. The Johns Hopkins Press.
2. Alan Gilpin. 2000. Environmental Economics: A Critical Overview. Wiley.
3. Hanley, Nick, Jason F. Shogren& Ben White: Environmental Economics in Theory and Practice, New Delhi: Macmillan –India, 1997.
4. James, D.E., Economic Approaches to Environmental Problems: Techniques and Results of Empirical Analysis, Elsevier Scientific Publishing Co., 1978.
5. Nash, R.F., The Rights of Nature: A History of Environmental Ethics, University of Wisconsin, 1989.
6. Whytte, Anne, V. and Ian Burton (eds), Environmental Risk Assessment, John Wiley & Sons, 1980.
7. Arrow, K.J. and Scitovsky, T., Readings in Welfare Economics Part III, 1969.
8. Coase, R.H., The Problem of Social Cost in Readings in Micro Economics by Breit and Hochman, 1951.
9. Allen V. Kneese and James L. Sweeney, eds. Handbook of Natural Resource and Energy Economics, Chapters 2,12,14,17, North Holland, 1985.
10. Fisher, A.C., Environment and Resource Economics, Selected readings, New Horizon in Environmental Economics, Ed. W.E. Oates, 1995
11. Oates, W.E., Economics of the Environment, 1992.
12. Field, B.C., Environmental Economics: An Introduction, McGraw Hill, 1994
13. Baumol, W.J. and W.E. Oates, `The Theory of Environmental Policy', Cambridge University Press, 1988.
14. Bohm, P. and Russell, C., `Comparative Analysis of Alternative Policy Instruments'
15. Handbook of Natural Resource and Energy Economics, Vol.I Ed. A.V. Kneese and J.L. Sweeney, 1985.
16. Mehta, S., S. Mundle and U. Sankar, `Incentives and Regulation for Pollution Control',

Sage, 1997.
17. Sankar, U. (ed.) Environmental Economics, New Delhi: Oxford University Press, 2001.

Elective Course 4 - Disaster Management & Mitigation	
Topic Details	**Lectures**
Disaster - Definition, Classification of hazards/disasters and its types; Natural and Man Induced Disasters: Their causes, distribution and adverse effects	3
Natural: Volcanos, Earthquake, Floods, Droughts, Landslide Tsunamis, Storm and Cyclones, Cloud Bursts, Forest Fire, etc	4
Manmade: Industrial accidents, Stampedes, Pollution, Gas leaks, Radioactive leak, Water scarcity, Salinization of soils, Epidemics, Deforestation and Desertification, Earthquakes, Extreme heat, Urban flooding & Flashfloods)	4
• Disaster Management & Mitigation- Preparedness, Response, Recovery & Mitigation • Disaster Monitoring and Warning Systems; Remote Sensing and GIS for Disaster Management • Role of community in Disaster Management • Disaster Management Planning in India	4
Vulnerability & Risk Assessment - Identification and control of hazards, Risk Analysis – Definition, Various Techniques of Risk Analysis for Industries- HAZOP, HAZAN, Fault Tree Analysis, Event Tree, Dose-Response Relationship, etc.	4
Student Work • Case Studies • Review - Books, Scientific Journals • Group Discussions, etc. • Field Visit	14

Suggested Reading:

1. Bell F.G., Geological Hazards: Their Assessment, Avoidance & Mitigation, Taylor and Francis, 2003.
2. Alexander D., Natural Disasters, ULC press Ltd, London, 1993.
3. Bryant E., Natural Hazards, 2nd Edition, Cambridge University Press
4. B. Narayan. Disaster Management - APH Publishing Corporation
5. Chakrabarty U.K. Industrial Disaster Management - Asian company, new Delhi

6. Peter K. Lagoy. Risk Assessment- An Environmental Perspective - Jaico Publishing House, Mumbai
7. National Policy on Disaster Management, NDMA, New Delhi, 2009.
8. A Global Report - Reducing Disaster Risk, A Challenge for Development; UNDP Publication, 2004
9. Websites of Government of India (e.g. https://ndma.gov.in/en/ , etc.)

EVSB 607 - Environmental Biotechnology – LAB

1. Basic molecular/ microbial/ plant/animal culture-based techniques
2. Genomic DNA Extraction of Bacteria/ plants from water/soil/ contaminated samples
3. PCR analysis of extracted genomic DNA samples
4. Electrophoresis Analysis of gDNA and PCR amplicons
5. Sequence analysis using BLAST platform

EVSB 608 - Remote Sensing and GIS – LAB

1. Aerial photographs interpretation/ stereo images: Measurement of height on aerial photograph, Principle of relative tonality, minimum mapping unit, scale.
2. Google Earth- usage, measurement, historical data, placemarks, etc
3. Browsing, Downloading satellite data from BHUVAN & LANDSAT. Installing QGIS. Familiarization with software tools, data
4. Geo referencing toposheet &/or image registration
5. Digitization of features-point, line, polygon from toposheet/satellite image
6. Satellite image interpretation of different terrains/setup
7. Collection of data on field (GPS) and plotting on toposheet, creating Base maps.
8. Case study for understanding land use land cover change using temporal satellite data
9. Satellite image processing- image enhancement, contrast, mosaic, subset.
10. Visit to institute/company or small project work in groups

EVSB 609 - Project/ Dissertation

Project-based learning offers an opportunity to the students to work independently under guidance of a supervisor. Students will be assigned to the on campus faculty/ research scientists from various

national research institutes such as NCL/ IISER/ IITM etc/ experts from NGOs working in environmental field/others; under whose guidance he or she would work on a problem keeping the focus to enhance their own ability to critical thinking, identification of research problems and research gaps, formulate research objectives, formulation of research plan, and problem solving via execution of specific experiments, and develop specialized skills to handle specific problems. This would train the students to nurture their creativity and innovative ideas, collaboration/teamwork and leadership, communications, learning self-reliance and project management.

Adequate assessment requirements for individual marking are presentations with discussions and seminars on the working process and the results.

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