DEPARTMENT OF CIVIL ENGINEERING

Course Book for
M. Tech. in Environmental
Engineering

Visvesvaraya National Institute of Technology, Nagpur

JULY 2017

Brief about Civil Engg Department:

Civil Engineering Department is the oldest department in this institute right from the establishment of Government College of Engineering in Nagpur 1956. The department offers the undergraduate course of B.Tech in Civil Engineering and Four Postgraduate Courses of M.Tech as given below.

Program	Description
UG in Civil Engineering	Started with 60 seats in 1956 Intake increased to 71 in 2008 Intake increase to 82 in 2009 Intake increase to 92 in 2010
PG in Civil Engineering Department	
1. Environmental Engineering	Started in 1966 (32 seats)
2. Water Resources Engineering	Started in 2005 (20 seats)
3. Construction Technology and Management	Started in 2010 (20 seats)
4. Transportation Engineering	Started in 2012 (20 seats)

VISION:

To contribute effectively to the National Endeavour of producing quality human resource of world class standard in Civil Engineering by developing a sustainable technical education system to meet the changing technological needs of the Country incorporating relevant of social concerns and to build an environment to create and propagate innovative technologies for the economic development of Nation.

MISSION:

The Mission of the undergraduate Civil Engineering program is to develop students into capable civil engineering graduates by imparting appropriate high quality education in Civil Engineering so that they could be readily adapted by the service sector to meet the challenges faced by the Nation. The program strives for excellence in engineering education and profession. It also aims to promote all round development of the personality of students by suitably involving them in Co-curricular and extra-curricular activities.

TABLE 1. CREDIT REQUIREMENTS FOR POST GRADUTE STUDIES

Postgraduate Core (PC)		**Postgraduate Elective (PE)**	
Category	Credit	Category	Credit
Departmental Core (DC)	37	Departmental Electives (DE)	15
Basic Science (BS)		Other Courses (OC)	00
Grand Total PC + PE			52

The number of credits attached to a subject depends on number of classes in a week. For example a subject with 3-1-0 (L-T-P) means it has 3 Lectures, 1 Tutorial and 0 Practical in a week. This subject will have eight credits (3x2 + 1x1 + 0x1 = 8). If a student is declared pass in a subject, then he/she gets the credits associated with that subject. Depending on marks scored in a subject, student is given a Grade. Each grade has got certain grade points as follows:

Grades	AA	AB	BB	BC	CC	CD	DD	FF
Grade Points	10	09	08	07	06	05	04	Fail

The performance of a student will be evaluated in terms of two indices, viz. the Semester Grade Point Average (SGPA) which is the Grade Point Average for a semester and Cumulative Grade Point Average (CGPA) which is the Grade Point Average for all the completed semesters at any point in time. SGPA and CGPA are:

$$SGPA = \frac{\sum_{semester}(Course\ credits \times Grade\ points)\ for\ all\ cources\ except\ audit}{\sum_{semester}(Course\ credits)\ for\ all\ cources\ except\ audit}$$

$$CGPA = \frac{\sum_{all\ semester}(Course\ credits \times Grade\ points)\ for\ all\ courses\ with\ pass\ grade\ except\ audit}{\sum_{all\ semester}(Course\ credits)\ for\ all\ courses\ except\ audit}$$

Students can Audit a few subjects. i.e., they can attend the classes and do home work and give exam also, but they will not get any credit for that subject. Audit subjects are for self enhancement of students.

Details about Faculty members of Civil Engineering Department

Name of Faculty Member	Designation	Qualifications	Areas of specialization
Mhaisalkar V.A.	Professor	B.E, M.Tech , Ph.D	Environmental Engg
Gupta R.	Professor	B. E, M.Tech., Ph.D	Environmental Engg.
Katpatal Y.B.	Professor	B.Sc, M.Tech, MBA, Ph.D	Remote Sensing and GIS
Tembhurkar A.R.	Professor	B.E, M.Tech , Ph.D	Environmental Engg
Ghare A.D.	Professor	B.E, M.Tech, Ph.D	Hydraulic Engg
Latkar M.V.	Associate Professor	B.Sc., M.Sc, Ph.D	Environmental Biochemistry
Lataye D.H.	Associate Professor	B.E, M.Tech, Ph.D	Environmental Engg
Ralegaonkar R.V.	Associate Professor	B.E, M.E, Ph.D	Energy Efficient Building, Disaster Management, Construction Technology & Management
Landge V.S.	Associate Professor	B. E., M.E, Ph.D	Traffic Engineering
Mandal A.	Associate Professor	B. E., M.E, Ph.D	Soil Mechanics and Foundation Engg
Vasudeo A.D.	Assistant. Professor	B.E, M.Tech , Ph.D	Water Resources Engg
Patel A.	Assistant. Professor	B.E, M.Tech , Ph.D	Soil Mechanics and Foundation Engg
Dongre S.R.	Assistant. Professor	B.E., M.Tech, Ph.D	Environmental Engg.
Wanjari S. P.	Assistant. Professor	B.E., M.Tech, Ph.D	Construction Technology and Management, Concrete Technology
Tawalare A.G.	Assistant. Professor	B.E., M.Tech	Structural Engg, Construction Technology & Mgt.
Mirajkar A.B.	Assistant Professor	B.E, M.E, Ph.D	Water Resources Engg.
Madurwar M.	Assistant Professor	B.E, M.E, Ph.D	Building Materials
Adhikary S.	Assistant Professor	B.E, M.Tech, Ph.D	Soil Dynamics

VISION:

To contribute effectively to the national endeavor of producing quality human resource by keeping the graduates abreast of the latest technological development in the world and developing necessary skills to resolve real life problems with application of innovative and appropriate technologies in the field of Environmental Engineering.

MISSION:

The mission of the PG program in Environmental Engineering is to develop human resource with necessary knowledge and skills to meet challenges in Environmental Engineering for sustainable development.

Program Educational Objectives (PEOs)

The main objectives of Environmental Engineering program are:

1. To develop qualified engineers who will achieve a high level of technical expertise to be able to succeed in various positions in the area of Environmental engineering such as research, teaching, design and consultancy practices and in other fields they choose to pursue.
2. To develop engineers who are capable of producing engineering designs that are functional & cost effective and are based on sound principles of sustainability.
3. To enhance analytical skills so as to enable resolving complex industrial and social problems with recourse to the principles of resource conservation, recycle, reuse and recovery.
4. To make overall development through providing opportunity of participating in R&D projects with state-of-art facility laboratories, consultancy and professional society activities in the area of Environmental Engineering.

Program Outcomes (PO)

The qualified engineers are

1. Capable of analyzing and resolving Environmental Engineering problems in real life situation with full knowledge and consideration. (a, b, e, i)
2. Able to develop appropriate engineering designs using principle of theory and practice. (c)
3. Able to apply the skills acquired in planning for sustainable development. (d, h, j)
4. Able to contribute effectively in environmental engineering profession. (f, g, h, k)

Scheme of Instructions for M Tech (Environmental Engineering)

Program Core(PC)		**Program Elective (PE)**	
Category	Credit	Category	Credit
Departmental Core(DC)	37	Departmental Elective(DE)	15
Grand total PC+PE			52

I Semester				**II Semester**			
CORE				**CORE**			
Code	**Course**	**L-T-P**	**Cr**	**Code**	**Course**	**L-T-P**	**Cr**
CEL501	Environmental Chemistry and Microbiology	3-0-0	3	MAL 407	Statistics and optimization Technique	3-0-0	3
CEL 502	Municipal and Industrial Water Treatment	3-0-0	3	CEL505	Municipal Solid Waste Management	3-0-0	3
CEP 501	Environmental Chemistry and Microbiology	0-0-2	1	CEL540	Industrial Waste Water Treatment, Recycle and Reuse	3-0-0	3
CEL 503	Municipal Wastewater Treatment	3-0-0	3				
CEL 504	Water Supply and Wastewater Collection Systems	3-0-0	3				
CEL 506	Air Pollution Control	3-0-0	3				
	Core Credits =16				Core Credits = 9		
ELECTIVE				**ELECTIVE (Any Three)**			
				CEL510	Environmental Management	3-0-0	3
				CEL 422	Hazardous Waste Management	3-0-0	3
				CEL512	Environmental Biotechnology	3-0-0	3
				CEL511	Environmental Engineering Systems Optimization	3-0-0	3
				CEL 509	Bioremediation : Principles and Applications	3-0-0	3
				CEL 561	Risk Analysis and Decision making	3-0-0	3
				CEL 507	Environmental Engineering System Design	Audit	0
				CEL 542	Introduction to Climate Change	3-0-0	3
	5 DC = 16 Credits		**16**		**3DC + 3 DE = 18 Credits**		**18**
III Semester				**IV Semester**			
CED501	Project Phase-I	-	3	CED502	Project Phase-II	-	9
ELECTIVE (Any Two)							
CEL 508	Environmental Geotechnics	3-0-0	3				
CEL 513	Environmental Systems Modeling	3-0-0	3				
CEL559	Energy Efficient Buildings	3-0-0	3				
CEL 531	Spatial Analyses for Resources Management	3-0-0	3				
CEP 531	Spatial Analyses for Resources Management*	0-0-2	1				
CEL 418	Energy Conversion & Environment	3-0-0	3				
CEL 432	Environmental Impact Assessment	3-0-0	3				
CEL 541	Water Distribution System Design	3-0-0	3				
	1 DC + 2 DE = 9/10 Credits				**1 DC = 9 Credits**		

* Student must register both for practical and Theory of a course.

MAL 407 STATISTICS & OPTIMIZATION TECHNIQUE [(3-0-0); Credits: 3]

Course Outcomes:
The students will be able to design experiments and analyze the data using various statistical methods.

Syllabus:
Sampling Theory: Population Parameter, Sample Statistics, Sampling distributions, Sample mean, Sampling distribution of means, the sample variance, the sampling distribution of variance.

Estimation Theory: Point estimate and interval estimates, reliability, confidence interval estimates of population parameters, confidence intervals for means, proportions and variance.

Tests of Hypothesis and Significance: Statistical decisions, tests of hypotheses and significance, Type I and Type II errors, level of significance, one tailed and two tailed tests. Tests involving small samples and large samples, fitting theoretical distributions to sample frequency distribution, The chi-square test for goodness of fit.

O. R. Techniques: Linear Programming: Formulation of linear programming problem, Graphical solution-simplex method (including Big M method and two phase method), dual problem- duality theory, dual simplex method, revised simplex method.

Transportation problem: existence of solution-degeneracy- MODI method; Assignment problem- traveling salesman problem

Nonlinear programming problem (NLPP): Constrained NLPP, Lagrange's multipliers method – convex NLPP, Kuhn-Tucker conditions.

REFERRENCES:

1. M.R. Speigel, Probability and Statistics, McGraw Hill,
2. H.A. Taha, Operation Research, Prentice Hall of India Pvt. Ltd.
3. J.C. Pant, Introduction to Optimisation: Operations Research, Jain Brothers, New Delhi.
4. Miller and Freund, Probability and Statistics for Engineers.

CEL 418 ENERGY CONVERSION AND ENVIRONMENT [(3-0-0); Credits: 3]

Course Outcomes:

1. Understand and apply basic concept of waste to energy technology and environmental protection.
2. Capable to conduct environmental appraisal, perform energy audit and assessment of energy potential of energy sources
3. Capable to design energy conversion systems
4. Understand contemporary environmental and social issues related to energy conversion

Syllabus:

Significance of Energy Conversion and Environment, Overview of Global and Indian Energy Scenario; Environmental Impacts of Energy Conversion, Principles of Waste Minimization and Energy Recovery, Renewable and Non- Renewable Energy Sources; Estimation of Potential of Energy Recovery from various Sources, Energy economics; Energy Conversion Methods: Thermal, hydro, nuclear, solar, wind, tidaletc their principles and application, Waste to Energy options: physical, thermo chemical and bio chemical processes: pelletization, bricquetiation, Combustion, Gasification, pyrolysis; Fuels Derived anaerobic digestion , Biogas Technology, Future Technologies for Waste to Energy Systems; Introduction to Microbial Fuel cell, Gas generations and collection in landfills, Measurements and Control; Energy and Resources Conservation Strategies and Policies; Environmental Appraisal, Energy audit, Carbon Foot prints, Sustainable Energy-Efficient systems, Intelligent Green Building, Case studies of sustainable Energy Projects in the field of Water Resources, Infrastructure and Environmental System.

REFERRENCE:

1. Fowler J. M. Energy and the Environment McGraw Hill New York 2nd edition.
2. B.H. Khan, Non-Conventional Energy Resources, 2nd Edition, McGraw Hill Companies.
3. G. D. Rai, Non-Conventional Energy Source, Standard Publishers Distributors.
4. D. O. Hall, G. W. Barnard and P. A. Moss, Biomass for Energy in the Developing Countries, Current Roles, Potentials, Problems, Prospects, Pergamon Press Ltd, 1st edition.
5. W. C. Turner, Energy Management Handbook Wiley Newyork 1st edition.
6. P. Meier, Energy System Analysis for Developing countries, Sringer Verlag 1st edition.
7. Dorthy J De Renzo, Energy from Bioconversion of Waste materials, Noyes data Corporation USA 1st edition.
8. Francis A. Domino Energy from Solid Waste – Recent Development, Noyes data Corporation USA 1st edition.
9. Oliver S. Owen, Daniel D. Chiras, Natural Resource Conservation – Management for Sustainable Future Prentice Hall Publications 6th edition.
10. McGraw Hill George Tachonobanoglous, Hilary Thesin, Samuel Vigil 1st International Edn.

CEL 422 HAZARDOUS WASTE MANAGEMENT [(3-0-0); Credits: 3]

Course Outcomes:

1. To introduce hazardous waste materials.
2. Teach about the generation, classification and categories and sources of hazardous waste.
3. Teach about the methods of treatment and management of hazardous waste.
4. Various rules about the management and handling of hazardous waste.

Syllabus:

Generation, storage, transportation, treatment, disposal, exchanges and minimization, legislative and technical aspects, current management practices; Environmental audits, pollution prevention, facility development and operations, treatment and disposal methods; physical, chemical, thermal, biological processes, land disposal with general applications to the industrial and energy-producing sectors, Site remediation. Special wastes, such as, infectious and radioactive waste.

REFERENCES:

1. M. D. LaGrega, P. L. Buckingham and J. C. Evans, Hazardous Waste Management, McGraw-Hill, Inc., New York, 1994.
2. W. S. Forester and J. H. Skinner, International Perspective on Hazardous Waste Management, Mudra Offset Printers, Bajaj Nagar Nagpur, 2001.
3. G. W. Dawson and B. W. Mercer, Hazardous Waste Management, Academic Press, Inc., London, England 1987.
4. H. M. Freeman, Standard Handbook of Hazardous Waste Treatment and Disposal, McGraw-Hill, Inc., New York, 1989.
5. E. J. Martin and J. H. Johnson, Jr., Hazardous Waste Management Engineering Van Nostrand Reinhold Co. Inc. New York, 1987.

CEL 432 ENVIRONMENTAL IMPACT ASSESSMENTS [(3-0-0); Credits: 3]

Course Outcomes:
The students will be able to assess the impact on the environment of various environment management techniques. The students will be able to analyze the impact on environment due to some new developmental activities.

Syllabus:
Evolution of EIA; EIA at project; Regional and policy levels; EIA process in India and other countries; EIA methodologies; Screening and scoping criteria; Rapid and Comprehensive EIA; Environmental health impact assessment, Environment risk analysis; Uncertainties; Practical Applications of EIA; Baseline collection of data; Prediction and assessment of impacts of physical biological and socio-economic environment; Development of environment management plan; Post project monitoring; EIA report and EIS; Review process. Case histories of applications for industrial; Water resources and irrigation projects; ports and harbours, Mining, Transportation and other projects sectors

REFERENCES:

1. Canter, L. Environmental Impact Assessment, McGraw Hill 1977
2. Rau, GJ. And Wooten, C.D., Environmental Impact Analysis Handbook, McGraw Hill 1980
3. Ministry of Environment and Forests, GoI, Current Documents on Guidelines for EIA.

CEL 501 ENVIRONMENTAL CHEMISTRY & MICROBIOLOGY [(3-0-0); Credits: 3]

Course Outcomes:
To interpret various fundamentals of the subject & use them in the field of Environmental Engineering.

Syllabus:
Basic concepts of oxidation and reduction reactions, Gas laws and their application in Environmental Engineering, Osmosis, Dialysis, Principles of solvent extraction, Amphoteric hydroxides.

Concept of pH, and its application in Environmental Engineering, Definitions and basic concepts of acids, bases and buffers, colloid chemistry, Basic concepts of carbohydrates, proteins, lipids and enzymes, Definition and concept of Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD) and Total Organic Carbon (TOC).

Chemistry of water treatment processes like coagulation, disinfection, water softening and demineralization.

Definitions of Ecology and ecosystem, structure and components of ecosystem, concepts of trophic levels, food chain and food web, types of ecosystem, productivity, Sulphur cycle, nitrogen cycle.

Introduction to Microbiology, Haeckel's classification, Morphology and structure of bacteria, nutritional requirement and nutritional classification of bacteria, Growth of bacteria, Indicator bacteria, Multiple Tube Dilution (MTD) and Membrane Filter (MF) techniques, Definition and characteristics of viruses.

REFERENCES:

1. C. N. Sawyer and P. L. McCarty, Chemistry for Environmental Engineers, McGraw Hill, Latest.
2. Pelezar Reid & Chan, Microbiology Tata McGraw Hill, Latest.
3. Powar & Daginawala, General Microbiology Vol. I &II, Himalaya Publishing House, Latest.

CEP 501 ENVIRONMENTAL MONITORING LABORATORY- I [(0-0-2); Credits: 1]

Course Outcomes:
To acquire skill to test the various physical, chemical & bacteriological parameters of water and wastewater.

1. Determination of following parameters in water
    a. Alkalinity
    b. Chloride
    c. Hardness
    d. Sulphate
    e. Turbidity
    f. Dissolved oxygen
    g. Kjeldahl nitrogen
    h. Iron
    i. Manganese
    j. Heavy metals
2. Determination of COD and BOD of wastewater
3. MTD method for enumeration of indicator bacteria in water
4. Heterotrophic plate count for enumeration of bacteria.

REFERENCES:

1. Standard Methods for the Examination of Water & Wastewater, APHA, AWWA, WEF, Latest.

CEL 502 MUNICIPAL AND INDUSTRIAL WATER TREATMENT [(3-0-0); Credits: 3]

Course Outcomes:
Student obtains detailed theoretical knowledge about obtaining of quality water for drinking and industry purposes, obtain knowledge not only about present technologic processes and facilities, equipment for water treatment, but about new methods used in water treatment, materials and equipment too.

Syllabus:
Water quality criteria and standards, Requirement of water treatment facilities, Unit operation & Unit process, Synthesizing water treatment system, Site selection, Process selection, Theory and Application of water treatment process- aeration, coagulation, flocculation, sedimentation, filtration, disinfection. Hydraulic design of water treatment plant, Advances/ modification/ moderndevelopment in water treatment, Control of water treatment process, O&M of water treatment plant, Water treatment plant residuals management. Industrial Water Quality requirement, Specific treatment for industrial purpose; Softening, Lime Soda and Ion Exchange, Desalination- Distillation processes, Reverse Osmosis, Electrodialysis; Flouride Removal, Arsenic Removal, Fe and Mn removal, Taste and Odor and color Removal, Adsorption, Ultrafiltration, Water treatment for Swimming Pool.

REFERENCES:

1. Fair Geyer & Okun, Water and Waste Water Engineering Vol I and II, John Wiley & Sons 1st.
2. W. J. Weber Physiochemical process for water quality control, John Wiley & Sons 2nd.
3. ASCE, AWWA Water treatment plant design
4. CPHEEO, Manual on Water supply and Treatment, Govt. of India Publication.
5. R. L. Sank, Water treatment plant for practicing engineers, Ann Arbor Science.

CEP 502 ENVIRONMENTAL MONITORING LABORATORY- II [(0-0-1); Credits: 1]

Course Outcome:

The students will be able to:

1. Acquire the practical knowledge on sampling and analysis of various air pollutants viz. SO_2, NO_2, SPM, RSPM etc. They will also able get the knowledge on sampling and analysis of solid waste.
2. Collection, preservation and analysis of samples from water treatment plants, municipal wastewater treatment plants or industrial wastewater treatment plants, Collection and analysis of air samples for SPM, RSPM, SO_2, NO_x, etc. Characterization of municipal solid wastes

Minimum ten practical shall be performed from the list given below:

1. Study of various sampling and analytical equipment in air pollution
2. Determination of wind speed and direction
3. Preparation of wind rose diagram
4. Modeling of air pollution concentration
5. Determination of Particulate (SPM and RSPM) matter concentration in atmosphere by using high volume sampler
6. Determination of dust fall in atmosphere
7. Sampling and analysis of SO_2 in atmosphere
8. Sampling and analysis of NO_2 in atmosphere
9. Sampling and analysis of CO in atmosphere
10. Analysis of VOCs in air
11. Analysis of hazardous air pollutants
12. Characteristics and composition of solid waste
13. Proximate analysis of solid waste
14. Determination of calorific value of solid waste
15. Elemental analysis (CHNOS) of solid waste
16. Heavy metal analysis of solid waste
17. Toxicity characteristic leaching procedure (TCLP) for solid waste samples
18. Extractions of samples for pesticides

REFERENCES:

1. Standard Methods for the Examination of Water & Wastewater, APHA, AWWA, WEF.
2. IS Code No. 5182 Parts 1 to 20.
3. IS Code No. 10158, 9234 & 9235

CEL 503-MUNICIPAL WASTEWATER TREATMENT [(3-0-0); Credits: 3]

Course Outcomes:

1. Understand and apply basic concepts of industrial wastewater treatment.
2. Apply principle of waste minimization for reuse recycling and recovery.
3. Synthesize treatment system, component or processes for industrial wastewater treatment.
4. Formulate and design treatment units using hydraulic principles and calculation techniques for industrial wastewater treatment process.
5. Development of treatment flowsheet based on wastewater characteristics for various industries.
6. Analyze and evaluate treatment alternative flow sheets through case studies.

Syllabus:

Constituent of sewage and sewage characteristics, conventional municipal wastewater treatment flow sheet, functions of different unit processes, treatment requirements. Process analysis: Reaction and reaction kinetics, mass balance analysis, reactors and hydraulic characteristics, reactor selection, practical aspects of reactor design.

Preliminary treatment: Screening grit removal; Primary Treatment: Principles of sedimentation

Biological treatment: Principles of biological treatment, Role of microorganisms in WWT, types of biological processes for WWT, introduction to microbial metabolism, kinetics of biological growth, aerobic and anaerobic treatment of sewage, suspended and attached growth biological treatment processes Activated sludge, tricking filters, rotating biological disc. Packed bed and fluidized bed treatment, stabilization ponds, design aspects of Wastewater Treatment Units.

Biological phosphorus and nitrogen removal

Sludge treatment: Sludge treatment flowsheet, sludge quality and quantity, various methods of sludge treatment, aerobic and anaerobic sludge digestion, sludge conditioning, dewatering of sludge, conveyance, storage and disposal. Water reclamation technologies

Advanced waste water treatment: Principles of tertiary treatment, Reuse and resource recovery. Recent developments in Wastewater Treatment

REFERENCES:

1. Metcalf and Eddy, Wastewater Engineering, Treatment, Disposal and Reuse, McGraw Hill, Fourth Edition,2002.
2. S.J. Arceivala, Wastewater Treatment and Disposal, Marcel Dekker, 1981.
3. Davis & Cornwell, Introduction to Environmental Engineering, McGraw Hill, International, 1998.
4. Qasim S.R, Wastewater Treatment Plant Planning, Design and Operation, Holt Rinehart & Winston, N. Y, 1990.

CEL 504 WATER SUPPLY AND WASTEWATER COLLECTION SYSTEMS [(3-0-0); Credits: 3]

Course Outcomes:

1. Capable of using various methodologies for hydraulic analysis of various components of water distribution and wastewater collection system.
2. Capable of designing of various components of water distribution systems and wastewater collection system.

Syllabus:

Analysis of flow in pipe network using Hardy Cross, Newton-Raphson and Linear Theory method, Reservoirs, Pumps and Valves in Water distribution systems, Pumps and Pumping Stations, Pipe Appurtenances, Pipe material selection, laying and jointing of pipes, Water supply to multi-storeyed buildings, Water supply during fairs, festivals and emergencies. Maintenance of distribution system.

Design of pumping main including water hammer consideration, Critical path method for design of water distribution networks.

Objectives, Type of systems and sewers, requisites for sewerage system design, Hydraulics of sewers, Velocity of equal cleansing, Sewer shape vis-a-vis their usefulness, sewer invert drop.

REFERENCES:

1. Bhave P. R. And Gupta R, Analysis of Water Distribution Networks, Narosa Publishing Co., New Delhi (2006).
2. Fair G. M., Geyer J. C. & Okun D. A., Water & Wastewater Engg. Vol. I & II, John-Willey & Sons, New York.
3. McGhee N. J. & Steel E. W., Water supply and sewerage, McGraw hill publications, 1991.
4. CPHEEO, Manual on water supply and treatment, Ministry of urban development, GoI.
5. CPHEEO, Manual on Sewerage and Sewage Treatment, Ministry of urban development, GoI.
6. Bhave P.R, Optimal design of water distribution networks, Narosa Publishing Co., New Delhi (2003).

CEL 505 MUNICIPAL SOLID WASTE MANAGEMENT [(3-0-0); Credits: 3]

Course Outcomes:
The students will be able to understand the concept of municipal solid waste management, various classifications of solid waste, characteristics of solid waste, methods of collection of solid waste and method of management of solid waste.

Syllabus:
Sources, Classification, Composition – Quality – characteristics-Physical, Chemical and microbiology involved, Quantity-generation of municipal refuse, per capita contribution, Density, Sampling;
Collection and transportation of waste-refuse transportation vehicles ; optimization of routes, maintenance of vehicles; industrial waste management; reduction, Recycle, Reuse, Recovery and Reporting; hazardous waste management;

Disposal of waste by land filling, site selection, leachate and gas collection, lining; composting of waste, methods, factors affecting, Incineration, types, energy recovery and products of incineration; Processing of waste for useful products-pyrolysis, RDF; Legislation and regulatory trends

REFERENCES:

1. Bhide A.D., Sundaresan B.B, Solid Waste Management, Collection, Processing and Disposal, Mundrashilp offset printers, Nagpur, 2001.
2. Vesilind A. P., Worrell W., Reinhart Solid Waste Engineering Thomson Books Cole. 2002.
3. Techobanoglous G., Theisen H, Vigil S.A., Integrated Solid Waste Management Engineering Principles and Management Issues, Tata McGraw Hill International Editions Civil Engg. Series, 1993.
4. CPHEEO, MoUD, CPHEEO manual on municipal solid waste management, GoI, New Delhi.
5. Syed R. Qasim, Walterchiang Sanitary landfill leachate generation control and treatment, Techromic publishing co. Inc. 1994.
6. Amalendubagchi, Design of landfills & integrated solid waste management John wiley & sons. Inc.
7. S. S. Dara A text book of environmental chemistry and pollution control S. Chand & Co. Ltd. 2002
8. American public works association Municipal refuse disposal Public administration service, Chicago 1970.

CEL 506 AIR POLLUTION CONTROL **[(3-0-0); Credits: 3]**

Course Outcomes:

1. Gain a broad understanding of air pollution sources and classification
2. Knowledge on meteorological parameters, modelling, methods of sampling and analysis of air pollutants
3. Effects of air pollutants on human, animals, plants and materials
4. Knowledge about Control of various air pollutants and Design of control equipment.

Syllabus:

Sources, Classification, Causes and effects of air pollution; Metrological parameters of dilution, dispersion, distribution of emission of stack pollutants, Air quality monitoring, sampling and analysis of air from ambient and other sources of pollutants, Monitoring Instrumentation and principles of operation, Exhaust pollution, Control equipment for gaseous and particulate pollutants, Legislation and regulatory trends, Impacts of air pollution.

REFERENCES:

1. Rao M.N. and Rao H.V. N, Air Pollution, Tata Mc-Graw Hill Publishing Co. New Delhi, Third Edition, 1992.
2. Y. Anjaneyulu, A textbook of air pollution & control technology, Allied publishers.
3. Nevers N.D, Air Pollution control Engineering, Editions Civil Engineering series, 1995.
4. Rao C.S., Environmental Pollution Control Engg, New Age International Pvt. Ltd. Publishers, 2006.
5. Stern A. C, Air pollution, Tata McGraw Hill International, Vol I to IX.
6. Kudesia v. P., Air Pollution, Pragatiprakashan, meerut 2nd 1980.

CEL 507 ENVIRONMENTAL ENGINEERING SYSTEMS DESIGN [(0-0-2); Credits: 1]

Course Outcomes:
The students will be able to make functional hydraulic design of water supply and wastewater engineering systems with full knowledge and understanding

Syllabus:
Design aspects of water and waste water systems ranging from pipeline to treatment plant; sanitary landfill; a detailed design of at least one unit will be completed as either an individual or class project.

REFERENCES:

1. Qasim S.R Wastewater Treatment Plant Planning, Design and Operation Holt Rinehart & Winston, N. Y 1990.
2. Dr. A.G. Bhole, Water Treatment Plant Design Indian Water works Association 1st edition.
3. AmalenduBagchi, Design of landfill & Integrated Solid Waste Management, John Willey & Sons, Inc.2nd edition.

CEL 508 ENVIRONMENTAL GEOTECHNICS [(0-0-3); Credits: 3]

Course Outcomes:
The students will be able to make functional hydraulic design of water supply and wastewater engineering systems with full knowledge and understanding

Syllabus:
Source, Production and Classification of Wastes. Soil Pollution Processes; Physical-chemical and Biological Interactions in Soil. Effects on Geotechnical Properties and Case Studies. Waste Disposal Facilities such as Landfills and Impoundments, Slurry walls, etc. Barrier Systems- Basic concepts, Stability, compatibility and performance, Geo- membranes. Monitoring Sub surface contamination; Stabilization/ Solidification of Wastes. Remediation Methods.

REFERENCES:

1. Daniel, D. E., Geotechnical Practice for Waste Disposal, Chapman and Hall, London 1993.
2. Reddi, L. N., and Inyang, H. F., Geoenvironmental Engineering - Principles and Applications, Marcel Dekker, Inc., 2000.
3. Hsai-Yang Fang, Introduction to Environmental Geotechnology, CRC Press, 1997.

CEL 509 BIOREMEDIATION: PRINCIPLES & APPLICATIONS [(3-0-0); Credits: 3]

Course Outcomes:
Application of knowledge of bioremediation techniques to treat contaminated air, water and land.

Syllabus:
Introduction to biotransformation, biodegradation and bioremediation, history of bioremediation, xenobiotics and their structures and persistence in the environment, *in situ* and *ex situ* bioremediation technologies and their merits and demerits.

An overview of the current bio remedial practices and its application, factors affecting bioremediation (physical, chemical and biological), bio stimulation and bioaugmentation, bioconcentration and biomagnifications.

Natural and programmed bioremediation, inducible and degrading enzymes and their roles, Roles of electron donors and acceptors in bioremediation, anaerobic and aerobic bioremediation processes, application of bioinformatics in bioremediation.

Concept of phytoremediation, roles of phytochelatins and chemicals secreted by the plant roots, phytoremediation with trangemic plants, fungal and algal bioremediation, merits and demerits of phytoremediation.

Solid and slurry phase bioremediation (composting, land farming, slurry bioreactors and lagoons), liquid phase bioremediation, bioventing, soil-vapor extraction(SVE) and treatment.

Genetic engineering and bioremediation, regulations of GM organisms in India, biosensors and their applications in bioremediation. Case studies.

REFERENCES:

1. Baker H. and Herson D.S.Bioremediation, McGraw Hill, 1994
2. Eweis J.B., Ergas S.J., Chang D.P.Y. and Schroeder E.D., Bioremediation Principles, McGraw Hill, 1998.

CEL 511 ENVIRONMENTAL ENGINEERING SYSTEMS OPTIMIZATION [(3-0-0); Credits: 3]

Course Outcomes:
Application of knowledge of various optimisation techniques and economic principles to design various environmental engineering systems.

Syllabus:
Principles of economic analysis, mathematics of economic analysis, discounting factors and different discounting techniques. Optimization methods for environmental engineering. Systems e.g. pumping main, water transmission & distribution networks, wastewater collection systems, water treatment systems, wastewater treatment systems, solid waste management systems and air pollution control systems.

REFERENCES:

1. Haith D. A. Environmental systems optimization, John Willey, New York 1982.
2. Bhave P.R. Optimal design of eater distribution networks Narosa Publishing Co., New Delhi.
3. Kalyanmoy Deb Optimization for engineering design Practice Hall.
4. Vedula S. And Majumdar Y. P. Water resources systems-modelling techniques and analysis McGraw Hills Co.

CEL 512 ENVIRONMENTAL BIOTECHNOLOGY [(3-0-0); Credits: 3]

Course Outcomes:

1. Application of principles of biotechnology to monitor various environmental pollution problems.
2. Practice various biotechnological means to produce value added chemicals and energy.

Syllabus:

Basic concepts of Microbial Biochemistry of carbohydrates, proteins and fats; structure of nucleic acids Deoxyribose nucleic acid - DNA and Ribose nucleic acid – RNA.

Basic concepts of biodegradation, biotransformation, bioleaching and biobeneficiation; Different types of microbial associations or interactions.

Environmental monitoring – significance of monitoring bacterial, viral and protozoan pathogens; Techniques of monitoring – gene probes, biosensors and immunoassay.

Basic concepts of Genetic Engineering – genes, chromosomal DNA, plasmid DNA, replication of DNA, genetic code, transformation, transduction and conjugation processes in bacteria, mutation, recombinant DNA techniques.

Biotransformation of biomass / organic waste into value added chemicals and energy, Single cell proteins, Microorganisms involved and biochemical changes of different pollutants present in liquid wastes, Types of reactors, pathways of bioenergy production – biomethane production, bioethanol production etc.

REFERENCES:

1. Balasubramaniyan et al. Concepts in Biotechnology Sangam Books ltd. Latest.
2. Dubey, Text book of Biotechnology, Latest.

CEL 513 ENVIRONMENTAL SYSTEMS MODELLING [(0-0-3); Credits: 3]

Course Outcomes:

1. Gain knowledge of fate and transport mechanism of contaminant in water system.
2. Application of knowledge of Systems Modeling to various environmental engineering systems.

Syllabus:

Definition; Classification; Examples and Models of Environmental Systems. Introduction to Air Quality Models; Metrology; Atmospheric Stability and Turbulence; Gaussian Plume Model and Modifications; Numerical Models, Urban Diffusion Models; Introduction to river, estuarine and lake thermodynamics, Stratification of lakes, Dissolved Oxygen Model for streams, Temperature Models, Prediction of fate of organisms and toxic substances. Models for predicting water quality changes in water distribution systems. Computational methods in Environmental Modelling.

REFERRENCES:

1. Gilbert M. Masters Introduction to Env. Engg. and Science Practice hall, India.
2. Thomann R. V. And Muller J. A. Principles of surface water quality modelling and control Harper international edition 1987.
3. TechnobangolousG. ,Schroader E. D., Water quality Addison-Wesley publishing co. Reading Massachusetts.

CEL 531 SPATIAL ANALYSES FOR RESOURCES MANAGEMENT [(3-0-0); Credits: 3]

Course Outcomes:
Students will be able to apply the knowledge of remote sensing technique with proper understanding and use of customized products for management of natural resources for sustainable development

Syllabus:
Fundamentals of Geoinformatics: raster and Vector Data, Resolutions of RS data, Thermal and Radar and Lidar Sensing, spatial and non spatial information, attribute data collection, data formats, data conversions, elements of image interpretation. RS as a technology for data extraction, multithematic data extraction using multispectral sensors, thematic map generation.

Interpolation, Overlay analyses, Buffer analyses, Query shell. Spatial analysis, Modeling of spatial data, Network analysis, digital terrain elevation models, Customization and Decision Support Systems.

Applications of Geoinformatics for spatial management of resources: Run-off estimations, infiltration characteristics, groundwater potential and recharge characteristics, Watershed management, watershed prioritization, Sediment yield estimation, reservoir capacity studies, transportation design and planning, Spatial analyses for Environment Impact assessment, Monitoring and feedback, Natural indices, Concept of E-Governance using Geoinformatics, web GIS. Integrated applications using various technologies within Geoinformatics; methods and approach. Real time and temporal analysis using Geoinformatics.

Multidisciplinary applications of Geoinformatics; integration of various segments. Geoinformatics for resources management and utilities management.

REFERENCES:

1. C.P LO Albert KW Yeung Concepts and techniqes of Geographic Infromation Systems Pritince Hall of India, 2002.
2. C.S. Agrawal & P K Garg, Text Book on Remote Sensing Wheeler First.
3. Paul A. Longley, M. Goodchild, David Maguire, David Rhind, Geographic Information Systems and Science, Wiley, First.
4. Geographic Informaiton System and Enviornment Modeling, Keith C. Clerk, Bradely O Parks, Michel P Crane, Pritince Hall of India, 2002.
5. John R Jensen, Remote Sensing of the Environment. an Earth Resource Perspective, Pearson Education, 2006**.**

CEP 531 SPATIAL ANALYSES FOR RESOURCES MANAGEMENT [(0-0-1); Credits: 1]

Course Outcomes:

1. Digital Data, resolution and Formats
2. Data preparation and image registration
3. Digital Image analysis and Classification
4. Vector Data generation, topology building and attribution
5. Interpolation, Overlay, Buffer and Network analysis
6. Thematic maps generation
7. Models for Resource analysis

CEL 540 INDUSTRIAL WASTE WATER TREATMENT RECYCLE & REUSE[(3-0-0);Credits: 3]

Course Outcomes:

1. Understand and apply basic concepts of industrial wastewater treatment.
2. Apply principle of waste minimisation for reuse recycling and recovery.
3. Synthesize treatment system, component or processes for industrial wastewater treatment.
4. Formulate and design treatment units using hydraulic principles and calculation techniques for industrial wastewater treatment process.
5. Development of treatment flowsheet based on wastewater characteristics for various industries.
6. Analyse and evaluate treatment alternative flow sheets through case studies.

Syllabus:

Industrial pollution and its measurement; Generation of Industrial wastewater, Disposal standards; Quantification and characterization of wastewater and its variations; Environmental impacts due to discharge of wastewater on streams, land and sewerage system; Industrial waste survey; Stream sanitation, stream sampling, Stream survey; Principles and techniques for Industrial Pollution prevention and control; Waste minimization; recent trends in industrial waste management, Cleaner technologies; Reuse, Recycling and Resource recovery; Volume and strength reduction; Equalization and proportioning; Neutralization; Methods of Disposal and treatment for removal of organic, inorganic, solids, pathogens, heavy metals and other pollutants; Alternatives and Synthesizing industrial waste treatment system; Joint treatment of industrial waste; CETP; Pollution control measures and Treatment of wastes from various industries viz. Pulp and paper, tanning, Sugar, Dairy, Chemical, Cement, Petroleum, Fertilizers, Metal Finishing, Etc.

REFERENCES:

1. Nemerow N.L, Theories and Practices of Industrial Waste Treatment, Addison Wesley Publishing CO. NY. 2nd edition.
2. W.W.Ecenfelder, Industrial Water Pollution Control Mc-Graw Hill Book Co. 2nd edition.
3. Freeman H. M., Industrial Pollution Prevention Handbook McGraw Hill 1st.
4. Central Pollution Control Board, India, Comprehensive Industry Document Series.
5. E.B. Besselivievre, The Treatment of Industrial Waste Mc-Graw Hill Book Co. 1st.

CEL 541 WATER DISTRIBUTION SYSTEM DESIGN [(3-0-0); Credits 3]

Course Outcomes:

To develop competency in the analysis, design and optimisation of water distribution systems in using computer techniques.
To become aware of uncertainty and risk (e.g. in the estimation of peak day water demands and pipe roughnesses) and recognising limitations of engineering approaches and systems.
To become aware of the need for sustainable systems and principles of sustainable design by considering greenhouse gas emission because of construction and pumping operations of water distribution systems.

Syllabus:
Analysis of distribution networks with controlling elements, Rules for solvability of pipe networks, Unknown pipe characteristics in network analysis.

Performance of water distribution networks under deficient condition, Various models, Bhave's NFA method, Performance of primary and secondary networks under deficient condition.

Fuzzy analysis of Water Distribution Networks – Fuzzy parameters, Membership function, Methods to obtain membership functions of dependent parameters using Optimization method and Method based on Impact table.

Reliability Analysis – Factors affecting reliability, Topological and hydraulic redundancy, Concepts and measures in reliability analysis, Introduction to analytical and simulation methods, Reliability factors Uncertainty analysis – Monte Carlo simulation, FORM method etc.

Design of Water Distribution Networks

i) Minimum cost design
ii) Flexible design based on flow distribution models
iii) Reliability based design
iv) Resiliency based design

REFERENCES:

1. Bhave, P. R. Optimal design of water distribution networks, Narosa Publishing House, New Delhi.
2. Bhave, P. R. and Gupta R. Analysis of water distribution networks, Narosa Publishing House Pvt. Ltd.

CEL 559 ENERGY EFFICIENT BUILDINGS [(3-0-0); Credits: 3]

Course Outcomes:

1. Gain a broad understanding of energy efficient building designs.
2. Identify, formulate, and solve engineering problems
3. contemporary issues and development
4. use the techniques, skills, and modern engineering tools necessary for engineering practice.

Syllabus:

Conservation & energy efficiency concepts-overview of significance of energy use and energy processes in buildings.

Solar energy fundamentals & practices in building design- solar astronomical relations and radiation physics and measurements, design decision for optimal orientation of building, shadow analysis.

Heating and ventilation design- Human thermal comfort, climatological factors, material specifications and heat transfer principles, Thermal performance evaluation, Heat loss from buildings, design of artificial ventilation system, design of insulators.

Design audits & economic optimization- Concept of cost/benefit of energy conservation & carbon footprint estimation.

Energy efficient lighting system design: Basic terminologies and standards, daylighting and artificial lighting design, auditing.

Advances in computational energy conservation- implementation of computer energy simulation programs into building designs.

REFERRENCES:

1. MiliMajumdar, Energy Efficient Buildings in India Tata Energy Research Institute.
2. Lal Jayamaha Energy-Efficient Building Systems, McGraw Hill Publication.
3. H P Garg, J Prakash, Solar Energy Fundamentals & Applications Tata McGraw Hill Publishing.
4. J A Duffie & W A Beckman, Solar Energy and thermal processes John Wiley.
5. AA M Sayigh Solar Energy Applications in Buildings Academic Press
6. Energy Conservation Building Code, 2007
7. Handbook of functional requirement of buildings, SP: 41:1987.

CEL 561 RISK ANALYSIS AND DECISION MAKING [(3-0-0); Credits 3]

Course Outcomes:

1. Understand and apply basic principles of decision making and risk analysis
2. Develop cause- consequences diagram, Analyze and evaluate risk for various environmental engineering, water resources engineering and construction technology.

Syllabus:

Need of Decisions and Risk analysis for construction management, Strategic and integral planning, Decisions making for site selection, construction , execution and operation of projects, Documentation, Project proposals, Economic based decision, Legal Aspects of project management, Decision Models, Risk and Uncertainty, Theory and Techniques of Decision and Risk Analysis, Qualitative and Quantitative risk analysis tools /methods, Modelling Value Systems, Value Management for Construction, Competitive Bidding and Risk Sharing, Environmental appraisal, ISO 14000, Hazards identification, analysis and risk assessment, Accident and incident Analysis and control systems, IS 3786, S.H.E. Management IS15001, Training &Education Management Oversight and risk tree, Risk control and Treatment, Risk management and Internal control, Risk mitigation, Risk management plan, IT and IS for Risk management

REFERRENCES:

1. Melvin W. Lifson, Edward F. Shaifer, Decision and Risk Analysis for Construction Management, John Wiley & Sons
2. Ian Cameron, Raghu Raman, Process Systems Risk management Elseveir Academics Press 2005.
3. Chris Marrison Fundamentals of Risk Measurements Tata McGraw Hill 2002.
4. Han Buhliman, Mathematical Methods in Risk Theory Springler- Verlang Berlin Heidelberg 1970.
5. Calow P Hand book of Environmental Risk Assessment and Management Blackwell Science Ltd. Oxford, Uk 1998.
6. Risk Analysis: L&T Publication.

CEL 510 ENVIRONMENTAL MANAGEMENT [(3-0-0); Credits: 3]

Course Outcome:

1. Understand the environmental, social and economic framework in which environmental management decisions are made understand the life cycle perspective, systems approach and environmental technologies for converting process, products and service related industrial environmental problems into opportunities to improve performance
2. Anticipate, recognize, evaluate, and control environmental issues in a variety of sectors and industries and liaison with federal, state, and local agencies and officials on issues pertaining to environmental protection
3. Recognize, evaluate, and control factors in the workplace and the environment that cause health and environmental hazards and utilize quantitative knowledge and skills and modern tools and technologies to assess, analyze, plan, and implement environmental management systems
4. Obtain, update, and maintain plans, permits, and standard operating procedures.
5. Prepare, review, and update environmental monitoring and assessment Report sand Monitor progress of environmental improvement programs

Syllabus:

Environmental problems and issues at global and national level, sustainable development (SD), Indicators of sustainable development, regional carrying capacity based planning, National Environmental Policy (NEP), Climate change, its impacts, adaptation and mitigation.

Waste minimization and pollution prevention strategies – Tools of corporate environmental management; ISO 14000, TC 207 structure, Environmental Management System (ISO: 14001), General requirements; Cleaner technology (CT) of production, waste management hierarchy implementation of CT, barriers for adoption of CT.

Life cycle assessment, methodological framework. Environmental impact assessment, Methodologies for EIA, Environmental management plan (EMP), environmental monitoring plan, EIS, case studies of infrastructure and industrial projects

Indian environmental legislations and major environmental acts such as Water Act (1974), Air Act (1981), Environmental (Protection) Act (1986); International Environmental Treaties; Kyoto protocol, Montreal protocol, COP21, CDM.

Ecomark , objectives, criteria, general and specific requirements, Design for Environment(DFE), strategy, implementation Environmental audit, methodology, Benefits of EA to Industry. Overview of technologies, regulatory standards for industrial wastewaters and atmospheric emission.

REFERENCES

1. Richard Welford, Corporate Environmental Management Systems and Strategies, Universities Press (I) Ltd., Hyderabad, 1996.
2. Paul L. Bishop, Pollution Prevention: Fundamental and Practice, McGraw Hill, International, 2000. Freeman, H.M., Industrial Pollution Prevention Handbook, McGraw Hills 1995
3. Ministry of Environment, Forests and Climate Change (MoEFCC), Govt. of India web site

CEL 542 INTRODUCTION TO CLIMATE CHANGE [(3-0-0); Credits: 3]

Course Outcome: The objective of this course to provide basic understandings of climate change, the causes of climate change and its effect on environment. This course is expected to provide the basic knowledge of important climate variables and the predictions of the changes in the climate system, policy issues and mitigation strategies.

Course Syllabus:

The Basics of Climate Change Science: The Earth's Energy Balance, negative entropy and mitigation, Greenhouse Gases, Aerosols and atmospheric brown cloud, Impact of CO_2 increase on climate change, Other Drivers of Climate Change, Adaptation strategy, Recent Climate Change impact at local and global scale, Sustainable Energy for All Paleoclimatology: Glaciar Ice and Ice Core Dating, Other measurement techniques, Heinrich events, Dansgaard-Oeschger (D-O) events and their relevance in climate studies

Ecological Impacts of Climate change: Anthropogenic activities and climate change, Rising of sea level and consequences, Impact on biodiversity and extinction of endemic species, Changing of food chain, Agricultural shifts, Impact of climate change on health

Policy and Legislative issues in Climate Change: The UNFCCC, The Montreal Protocol, From Kyoto to Copenhagen, Towards COP21, ICMR, ICAR & IARI

Goal to Set Climate Change Prevention: Limiting the Mean Surface Temperature Increase Below 2-Degrees Celsius vs. Pre-Industrial Levels, Global Emissions Reduction Pathway for the 2-Degree Limit, Potential Emissions from Fossil Fuel Reserves & Resources

Mitigation Strategy: Grid Management of Power Systems with High Penetration of Renewable Energies, Carbon Capture & Sequestration, Electric Vehicles and Advanced Biofuels, The Role of Technology Roadmaps and Roundtables, Introduction to Climate Modeling (GCM and RCM Models)

REFERENCE:

1. Climate Change and India – Vulnerability Assessment and Adaptation; Edited by P. R. Shukla, Subodh K. Sharma, N. H. Ravindranath, AmitGarg, Sumana Bhattacharya, Universities Press, 2003
2. Climate Change and India – Vulnerability Assessment and Adaptation; Edited by P. R. Shukla, Subodh K. Sharma, N. H. Ravindranath, AmitGarg, Sumana Bhattacharya, Universities Press, 2003
3. Climate Change and Chemicals Environmental and Biological, aspects; Golam Kibria, A. K. Yousef Haroon, DayunthiNugegoda and Gavin Rose, Published by New India Publishing Agency, 2010
4. Global Warming – The Complete Briefing, third edition; John Honghton, Cambridge University Press, 2004,
5. Climate Change- Causes Effects and Solutions; John T. Hardy, Wiley
6. Paleoclimatology, Third Edition, Reconstructing Climate of the Quaternary; Raymond S. Bradley, Elsevier Inc.