M. Tech. DEGREE

ENVIRONMENTAL ENGINEERING

SYLLABUS

FOR

CREDIT BASED CURRICULUM

(2009 -2010)

DEPARTMENT OF CIVIL ENGINEERING

NATIONAL INSTITUTE OF TECHNOLOGY

TIRUCHIRAPPALLI – 620 015, INDIA.

M. Tech. (ENVIRONMENTAL ENGINEERING)

The total minimum credits required for completing the M. Tech. Programme in Environmental Engineering is 64.

SEMESTER – I

Code	Course of Study	L	T	P	C
MA601	Numerical Methods and Applied Statistics	3	0	0	3
CE701	Environmental Chemistry and Microbiology	3	0	0	3
CE702	Physico-chemical Process for Water and Wastewater Treatment	3	0	0	3
CE703	Solid and Hazardous Waste Management	3	0	0	3
	Elective I	3	0	0	3
	Elective II	3	0	0	3
CE704	Environmental Quality Measurements Laboratory	0	0	3	2
		18	0	3	20

SEMESTER – II

Code	Course of Study	L	T	P	C
CE705	Biological Process Design for Wastewater Treatment	3	0	0	3
CE706	Transport of Water and Wastewater	3	0	0	3
CE707	Air Quality Management	3	0	0	3
	Elective III	3	0	0	3
	Elective IV	3	0	0	3
	Elective V	3	0	0	3
CE708	Environmental Microbiology and Engineering Laboratory	1	0	3	2
		19	0	3	20

SEMESTER III

Code	Course of Study	L	T	P	C
CE747	Project Work	0	0	24	12

SEMESTER IV

Code	Course of Study	L	T	P	C
CE748	Project Work	0	0	24	12

ELECTIVES (I Semester)

Code	Course of Study	L	T	P	C
CE611	Geographical Information Systems and Remote Sensing	3	0	0	3
CE711	Water and Air Quality Models	3	0	0	3
CE712	Industrial Wastewater Management	3	0	0	3
CE713	Environmental Systems Analysis	3	0	0	3
EN601	Environmental Engineering and Pollution	3	0	0	3
	Any one elective from other department				

ELECTIVES (II Semester)

Code	Course of Study	L	T	P	C
CE714	Environmental Impact Assessment	3	0	0	3
CE716	Ecological and Ecosystems Engineering	3	0	0	3
CE717	Environmental Geotechnology	3	0	0	3
EE778	Analysis and Design of Artificial Neural Networks	3	0	0	3
	Any one elective from other department				

ELECTIVES (To be substituted whenever needed)

Code	Course of Study	L	T	P	C
1.	Indoor Air Quality	3	0	0	3
2.	Environmental Engineering Structures	3	0	0	3
3.	Contaminant Transport Modeling	3	0	0	3
4.	Environmental Biotechnology	3	0	0	3
5.	Design of Air Pollution Control Systems	3	0	0	3
6.	Surface and Ground Water Modeling	3	0	0	3
7.	River Engineering	3	0	0	3
8.	Water Resource Systems Management	3	0	0	3

Note: Student may also choose any other elective courses relevant to their degree with the consent of the course coordinator

SEMESTER I

MA601 NUMERICAL METHODS AND APPLIED STATISTICS

Linear system – Gaussian elimination and Gauss – Jordan methods – matrix inversion – Gauss seidel method – Nonlinear equations – Regula falsi and Newton- Raphson methods – interpolation – Newton's and Lagrange's interpolation

Linear Programming – Graphical and Simplex methods – Measures of central tendency, dispersion, skewness and Kurtosis – Probability – conditional probability – Bayes' theorem

Random variable – two dimensional random variables – standard probability distributions – Binomial Poisson and normal distributions - moment generating function

Sampling distributions – confidence interval estimation of population parameters – testing of hypotheses – Large sample tests for mean and proportion – t-test, F-test and Chi-square test – curve fitting-method of least squares

Regression and correlation – rank correlation – multiple and partial correlation – analysis of variance-one way and two way classifications – experimental design – Latin square design – Time series analysis.

1. Bowker and Liberman, *Engineering Statistics,* Prentice-Hall, 1972.
2. Venkatraman, M.K., *Numerical Methods in Science and Engineering*, National Publisher Company.

CE701 ENVIRONMENTAL CHEMISTRY AND MICROBIOLOGY

Colloids – Redox potentials – partition co-efficient – Beer – Lambert's Law – Limitations – UV visible spectroscopy – basic principles – application – Atomic absorption spectroscopy – Principles – applications Gas chromatograph – Principles and applications – Principles of green chemistry – Error Analysis of Environmental Data

Transport and transformation of chemicals – DO, BOD and COD – Photo catalysis - Degradation of food stuffs, detergents, pesticides and hydrocarbons. Soil chemistry- acid-base and ion-exchange reactions in soil - salt affected soil and its remediation.Classification of microorganisms- prokaryotic, eukaryotic, structure, characteristics, nucleic acids-DNA, RNA, replication. Culturing of microorganisms-Environmental factors influencing microbial growth

Distribution of microorganisms—Water, Air and Soil, Indicator organisms, coliforms—fecal coliforms, E. coli, Streptococcus, Clostridium, Significance in water. Algae in water supplies—problems and control.MPN and MFT.

Ecotoxicology—toxicants and toxicity, factors influencing toxicity, effects—acute, chronic, concentration response relationships, test organisms, toxicity testing, bio concentration, bioaccumulation, bio magnification, bioassay, bio monitoring.

1. C.N. Sawyer, P.L. MacCarty and G.F. Parkin, Chemistry for Environmental Engineering and Science, Tata McGraw-Hill, Fifth edition, New Delhi, 2003.
2. G.W. Vanloon and S.J. Duffy 'Environmental chemistry – a global perspective, Oxford University press, New York., 2000.
3. Tortora. G.J, B.R. Furke, and C.L. Case, "Microbiology-An Introduction" (4th Ed.), Benjamin/Cummings Publ. Co., Inc., California, 1992.
4. Pelczar,M.J.,Chan E.C.S. and Krieg,N.R.Microbiology,Tata Mcgraw Hill,New Delhi,1993

CE702 PHYSICO-CHEMICAL PROCESS FOR WATER AND WASTEWATER TREATMENT

Water Quality-Physical, chemical and biological parameters of water- Water Quality requirement - Potable water standards -Wastewater Effluent standards -Water quality indices. Water purification systems in natural systems-Physical processes-chemical processes and biological processes-Primary, Secondary and tertiary treatment-Unit operations-unit processes.

Mixing, Clarification - Sedimentation; Types; Aeration and gas transfer – Coagulation and flocculation, coagulation processes - stability of colloids - destabilization of colloids-transport of colloidal particles, Clariflocculation.

Filtration - theory of granular media filtration; Classification of of filters; slow sand filter and rapid sand filter; mechanism of filtration; modes of operation and operational problems; negative head and air binding; dual and multimedia filtration.

Adsorption, adsorption equilibria- adsorption isotherms, Disinfection - chlorine dioxide; chloramines; ozonation; UV radiation

Ion Exchange-processes, Application Membrane Processes, Reverse osmosis, Ultrafiltration, Electrodyalisis.

1. Weber, W.J. *Physicochemical processes for water quality control*, John Wiley and sons, Newyork, 1983.
2. Peavy, H.S., Rowe, D.R., Tchobanoglous, G. *Environmental Engineering*, McGraw Hills, New York 1985.
3. Metcalf and Eddy, *Wastewater engineering, Treatment and Reuse*, Tata McGraw-Hill, New Delhi, 2003.

CE703 SOLID AND HAZARDOUS WASTE MANAGEMENT

Types and Sources of solid and hazardous wastes - Need for solid and hazardous waste management - Legislations on management and handling of municipal solid wastes, hazardous wastes, and biomedical wastes.

Waste generation rates – Composition - Hazardous Characteristics – TCLP tests – waste sampling- Source reduction of wastes – Recycling and reuse.
Handling and segregation of wastes at source – storage and collection of municipal solid wastes – Analysis of Collection systems - Need for transfer and transport – Transfer stations - labeling and handling of hazardous wastes.

Waste processing – processing technologies – biological and chemical conversion technologies – Composting - thermal conversion technologies - energy recovery – incineration – solidification and stabilization of hazardous wastes - treatment of biomedical wastes.

Disposal in landfills - site selection - design and operation of sanitary landfills- secure landfills and landfill bioreactors – leachate and landfill gas management – landfill closure and environmental monitoring – landfill remediation

Elements of integrated waste management

1. George Tchobanoglous, Hilary Theisen and Samuel A, Vigil, Integrated *Solid Waste Management,* McGraw- Hill, New York, 1993
2. CPHEEO, *Manual on Municipal Solid waste management, Central Public Health and Environmental Engineering Organization*, Government of India, New Delhi, 2000.

CE704 ENVIRONMENTAL QUALITY MEASUREMENT LABORATORY

Physical and chemical characteristics of water – pH, Electrical conductivity, Turbidity, Alkalinity, Acidity, Hardness, Sulphates, Fluorides, Nitrates. Analysis of solids content of water: Total solids, suspended solids, volatile solids, non volatile solids, Residual chlorine analysis, Optimum coagulant dose, Break point Chlorination.

Test on dissolved oxygen, BOD and COD

Ambient air quality Analysis: Determination of SPM, CO, NO_x and SO_x.

Soil Analysis**:** pH, Conductivity, Cation exchange capacity, Sodium Adsorption ratio

SEMESTER II

CE705 BIOLOGICAL PROCESS DESIGN FOR WASTEWATER TREATMENT

Constituents of wastewaters - Sources –Significant parameter - Fundamentals of Process Kinetics, Zero order, First order, Second order Reactions, Enzyme reactions – Bio reactors-Types-Classification – Design principles.

Design of wastewater treatment systems-Primary, secondary and tertiary treatments- - Evaluation of Biokinetic Parameters- Activated Sludge and its process - Modifications, Biological Nitrification and denitrification.

Aeration- Fundamentals of gas transfer- Attached Growth Biological Treatment Systems-Trickling Filters- Rotating Biological Contactors- Activated Biofilters.

Waste stabilization Ponds and Lagoons: Aerobic pond, facultative pond, anaerobic ponds-polishing ponds, aerated Lagoons

Anaerobic processes-Process fundamentals-Standard, high rate and hybrid reactors, Anaerobic filters-Expanded /fluidized bed reactors-Upflow anaerobic sludge blanket reactors, - Expanded granular bed reactors- Two stage/phase anaerobic reactors, Sludge Digestion, Sludge disposal

1. Benefield, L.D. and Randall C.W. *Biological Processes Design for wastewaters*, Prentice-Hall, Inc. Eaglewood Cliffs, 1982.
2. Grady Jr. C.P.L and Lin H.C. *Biological wastewater treatment: Theory and Applications*, Marcel Dekker, Inc New York, 1980.
3. Metcalf & Eddy, Inc. *Wastewater Engineering, Treatment and Reuse*. 3rd Edition, Tata McGraw-Hill, New Delhi, 2003.

CE706 TRANSPORT OF WATER AND WASTEWATER

Water storage – Impounding reservoirs – Intakes – pressure conduits – pumps – Economic design of pumps and pumping mains – Pipes – Pipe appurtenances – Water hammer.

Water Distribution systems – Hardy cross, Equivalent pipe and Newton Rapson methods, Distribution network analysis- methods of control and prevention of corrosion.

Sanitary sewage flow estimation – Sewer materials – Hydraulics of flow in sanitary sewers –

Partial flow – Sewer designs – Sewer layouts – Storm drainage.

Storm runoff estimation – Hydraulics of flow in storm water drains – hydraulics of flow in storm water drains-storm water drain materials and section-design of storm water drains.

Maintenance of sanitary sewerage and storm drainage – equipments – corrosion in sewers – prevention and control – Wastewater pumping networks, Application of software in design of water supply networks.

1. *Manual on water supply and Treatment,* CPHEEO, Ministry of Urban Development, GOI, New Delhi, 2000.
2. *Manual on Sewerage and Sewage Treatment,* CPHEEO, Ministry of Urban Development, GOI, New Delhi, 2000.

CE707 AIR QUALITY MANAGEMENT

Air pollutants – Sources and classification of pollutants and their effect on human health vegetation and property- Effects - Reactions of pollutants and their effects-Smoke, smog and ozone layer disturbance - Greenhouse effect – Ambient and stack sampling.

Atmospheric diffusion of pollutants - Transport, transformation and deposition of air contaminants - Air sampling & pollution measurement methods - Ambient air quality and emission standards - Air pollution indices - Air Act

Control principles – Removal of gaseous pollutants by adsorption, absorption, reaction and other methods.

Particulate emission control- settling chambers, cyclone separation, Wet collectors, fabric filters, electrostatic precipitators and other removal methods like absorption, adsorption, precipitation.

Biological air pollution control technologies - bioscrubers, biofilters, and Indoor air quality.

1. Wark Kenneth and Warner C.F, *Air pollution its origin and control.* Harper and Row Publishers, New York, 1981.
2. Rao C.S., *Environmental pollution control Engineering*, New age international Ltd, New Delhi, 1995.
3. Peavy, H.S., Rowe, D.R., Tchobanoglous, G. *Environmental Engineering*, McGraw Hills, New York 1985.

CE708 ENVIRONMENTAL MICROBIOLOGY AND ENGINEERING LABORATORY

Microscopic Examination of Microorganisms: Preparation of bacterial smear - staining - Hanging drop technique - plate count test, MPN tests and MFT Tests. Determination of MLSS and MLVSS in ASP - Coagulation and flocculation of water – Optimization of dose / pH / time of flocculation. Color removal from wastewater by adsorption - Estimation of suspended particulate matter / SPM, NO_x, SO_x.

ELECTIVES (I Semester)

CE711 WATER AND AIR QUALITY MODELS

Modeling approaches to water quality - classification – Mathematical Models for water quality.

DO. Models for Streams - Streeter Phelps model - oxygen 'sag' curve - deoxygenation and reaeration coefficients - Benthal oxygen demand - mass transport mechanisms –

Advective and diffusive mass transport - Models for Estuary and Lakes - Physical chemical and biological processes - water quality distribution - dispersion coefficient - temperature models.

Models for microorganisms decay.

Air quality models - Micrometeorological processes - wind rose – dispersion - stability classes - Gaussian dispersion model - Regional air quality models, Line source models, Noise – Decibel – Decibel Addition – Octave band spectrum.

1. Chapra, Steven C., *Surface water quality modeling*, McGraw Hill International Edition, 1997.

CE712 INDUSTRIAL WASTEWATER MANAGEMENT

Sources and types of industrial wastewater – Environmental impacts – Regulatory requirements – generation rates – characterization – Toxicity and Bioassay tests.

Prevention vs Control of Industrial Pollution– Source reduction techniques – Waste Audit- Evaluation of pollution prevention options.

Waste minimization - Equalization - Neutralization – Oil separation – Flotation – Precipitation – Heavy metal Removal – adsorption – Aerobic and anaerobic biological treatment – Sequencing batch reactors – High Rate reactors - Chemical oxidation – Ozonation – Photocatalysis – Wet Air Oxidation – Evaporation – Ion Exchange – Membrane Technologies – Nutrient removal

Individual and Common Effluent Treatment Plants – Zero effluent discharge systems - Wastewater reuse – Disposal of effluent on land – Quantification, characteristics and disposal of Sludge.
Industrial manufacturing process description, wastewater characteristics, source reduction options and waste treatment flow sheet for Textiles – Tanneries – Pulp and paper – metal finishing – Petrochemical -Pharmaceuticals – Sugar and Distilleries – Food Processing – fertilizers – Thermal Power Plants and Industrial Estates, ISO 14000:2003 – Waste Audit.

1. Eckenfelder, W.W., *Industrial Water Pollution Control*, McGraw-Hill, 1999.
2. Arceivala, S.J., *Wastewater Treatment for Pollution Control*, McGraw-Hill, 1998.
3. Frank Woodard, *Industrial waste treatment Handbook*, Butterworth Heinemann, New Delhi, 2001.

CE713 ENVIRONMENTAL SYSTEMS ANALYSIS

Systems Engineering – Analysis - Design – synthesis - applications to environmental engineering Systems.

Role of optimization models - Deterministic models/Linear programming, Dynamic programming, Separable and Nonlinear programming models.

Formulation of objective functions and constraints for environmental engineering planning and design.

Probabilistic models - fuzzy models - Simulation models.

Modern tools - Expert systems - Neural networks - Genetic Algorithm - Case studies.

1. Rich L.G., *Environmental Systems Engineering*, McGraw Hill, 1973.
2. Thoman R.V., *Systems Analysis & water Quality control*, McGraw Hill, 1978.

ELECTIVES (II Semester)

CE714 ENVIRONMENTAL IMPACT ASSESSMENT

Evolution of EIA – Concepts – Methodologies – Screening – Scoping – Base line studies - Mitigation – Matrices – Check list.

Rapid and Comprehensive EIA – Legislative and Environmental clearance procedures in India – Prediction tools for EIA.

Assessment of impacts – Air – Water – Soil – Noise – Biological.

Socio cultural environment – Public participation – resettlement and rehabilitation.

Documentation of EIA – Environmental Management plan – Post project monitoring – Environmental Audit – Life cycle assessment – EMS - Case studies in EIA.

1. Canter R.L., *Environmental Impact Assessment*, Mc Graw Hill International Edition, 1997.
2. John G. Rau and David C. Wooten (Ed), *Environmental Impact Analysis Handbook*, McGraw Hill Book Company.

CE716 ECOLOGICAL AND ECO SYSTEMS ENGINEERING

Development and evolution of ecosystems – Principles and concepts – Energy flow and material cycling – productivity – Classification of ecotechnology – ecological engineering.

Classification of systems – Structural and functional interactions of environmental systems – Mechanisms of steady-state maintenance in open and closed systems.

Modeling and ecotechnology – Classification of ecological models – Applications- Ecological economics- Self-organizing design and processes – Multi seeded microcosms.

Interface coupling in ecological systems – Concept of energy – Determination of sustainable loading of ecosystems.

Ecosanitation – soil infiltration systems – Wetlands and ponds – Source separation systems – Aqua cultural systems – Agro ecosystems – Detritus based treatment for solid wastes – marine systems- Case studies.

1. Kangas, P.C. and Kangas, P., *Ecological Engineering: Principles and Practice*, Lewis Publishers, New York, 2003.
2. Etnier, C. and Guterstam, B., *Ecological Engineering for Wastewater Treatment*, Lewis Publishers, New York, 1997.

CE 717 ENVIRONMENTAL GEOTECHNOLOGY

Soil as a multiphase system; Soil-environment interaction; Properties of water in relation to the porous media; Water cycle with special reference to soil medium.

Soil mineralogy; significance of mineralogy in determining soil behaviour; Mineralogical characterization.

Mechanisms of soil-water interaction: Diffuse double layer models; Force of attraction and repulsion; Soil-water-contaminant interaction; Theories of ion exchange; Influence of organic and inorganic chemical interaction.

Introduction to unsaturated soil mechanics; water retention property and soil-water characteristic curve; flow of water in unsaturated soil.

Concepts of waste containment facilities; desirable properties of soil; contaminant transport and retention; contaminated site remediation.

Introduction to advanced soil characterization techniques; volumetric water content; gas permeation in soil; electrical and thermal properties; pore-size distribution; contaminant analysis.

1. Mitchell, J. K and Soga, K Fundamentals of Soil Behavior, John Wiley and Sons Inc., 2005.
2. Fang, H-Y, Introduction to Environmental Geotechnology, CRC Press, 1997.
3. Daniel, D. E, Geotechnical Practice for Waste Disposal, Chapman and Hall, 1993.
4. Rowe, R. K., Quigley, R. M. and Booker, Clay Barrier Systems for Waste Disposal Facilities, J. R., E & FN Spon, 1995.
5. Rowe, R. K, Geotechnical and Geoenvironmental Engineering Handbook, Kluwer Academic Publishers, 2001.
6. Reddi, L. N. and Inyang, H. F, Geoenvironmental Engineering - Principles and Applications, Marcel Dekker Inc, 2000.
7. Sharma, H. D. and Lewis, S. P, Waste Containment Systems, Waste Stabilization and Landfills: Design and Evaluation, John Wiley & Sons Inc., 1994

ELECTIVES (To be substituted whenever needed)

1. INDOOR AIR QUALITY

Indoor activities of inhabitants - Levels of pollutants in indoor and outdoor air- Design and operation of buildings for improvements of public health- IAQ policy issues- sustainability.

Air pollutants in indoor environments- private residences- offices- schools-public buildings- ventilation.

Control of several pollutant classes- radon- toxic organic gases- combustion byproducts- microorganisms such as molds and infectious bacteria.

Concepts and tools- exposure- material balance models- statistical models.

Indoor air pollution from outdoor sources- particulate matter and ozone- Combustion byproducts- Radon and its decay products- Volatile organic compounds- odors and sick-building syndrome- Humidity- Bio aerosols- infectious disease transmission- Special indoor environments- A/C units in indoor- Measurement methods- Control technologies- Control strategies.

1. Thaddes Godish, *Indoor air and Environmental Quality*, CRC press, 2000.
2. Nazaroff W.W. and L. Alvarez-Cohen, *Environmental Engineering Science*, Wiley sons, Newyork, 2001.

2. ENVIRONMENTAL ENGINEERING STRUCTURES

Structural design of Concrete- Prestressed Concrete - anchorage for pipes - massive outfalls.

Design of concrete roofing systems a) Cylindrical b) Spherical and c) Conical shapes using membrane theory.
Design of water retaining structures- Design of circular, rectangular, spherical and Intze type of tanks- Design of prestressed concrete cylindrical tanks.

Underground reservoirs and swimming pools- Intake towers- Structural design of settling tanks- clarifloculators- aeration tanks - effect of earth pressure and uplift considerations.

Identification of different types of structural and non-structural cracks – repair and rehabilitation methods for Masonry, Concrete and Steel Structures.

1. Krishna Raju, *Prestressed Concrete*, Tata McGraw Hill, 1988.
2. Sinha N.C., Roy S.K., *Reinforced Concrete*, S. Chand and Co, 1985.

3. CONTAMINANT TRANSPORT MODELING

Transport phenomenon – diffusion – dispersion – advection – adsorption - conservative and non-conservative pollutants.

Governing Equations for flow and transport in surface and subsurface waters - chemical and biological process models - simplified models for lakes, streams, and estuaries.

Model complexity - model resolution - coupled and uncoupled models - linear and nonlinear models - Solution techniques – calibration - application and evaluation of environmental control – bioremediation –

Numerical models: FDM, FEM and Finite volume techniques - explicit vs. implicit methods - numerical errors - High resolution techniques –

Stream quality modeling using QUAL2K - Groundwater transport modeling using VISULA MODFLOW.

1. Martin, L.J. and McCucheon, S.C, *Hydrodynamics of transport for water quality modeling*, Lewis Publishers, Boca Raton, 1999.
2. Freeze, R.A. and Cherry. J.A. *Groundwater*, Prentice Hall, 1979.

4. ENVIRONMENTAL BIOTECHNOLOGY

Environmental Biotechnology -Principles and concepts - usefulness to mankind.

Degradation of high concentrated toxic pollutants- halogenated, non halogenated, petroleum hydrocarbons, metals - Mechanisms of detoxification – oxidation - dehalogenation - biotransformation of metals - biodegradation of solid wastes.

Biotechnological remedies for environmental pollution - decontamination of groundwater – bioremediation - Production of proteins – biofertilizers - Physical, chemical and microbiological factors of composting – health risk – pathogens – odor management – Microbial cell/enzyme technology – adapted microorganisms – biological removal of nutrients – algal biotechnology– extra cellular polymers - Biogas technology.

Concept of rDNA technology – expression vectors – cloning of DNA – mutation – construction of microbial strains - radioactive probes - protoplast fusion technology – applications.

Environmental effects and ethics of microbial technology – genetically engineered organisms- Microbial containment-Risk assessment.

1. Chaudhury, G.R., *Biological degradation and Bioremediation of toxic chemicals*, Dioscorides Press, Oregon, 1994.
2. Martin.A.M, *Biological degradation of wastes*, Elsevier Applied Science, London, 1991.
3. Blaine Metting.F (Jr.,) *Soil Microbiology Ecology*, Marcel Dekker Inc., 1993

5. DESIGN OF AIR POLLUTION CONTROL SYSTEMS

Industrial sources of air pollution- Emission factors-regulations- control strategies-policies.

Particulate Pollutant Control: Settling chambers - laminar and turbulent flow- Filtration – interception- Impaction- Convective diffusion- Collection of particles by cylindrical fibres and granular beds- Electrostatic precipitation - Cyclones - Wet collectors.

Gaseous Pollutant Control: Gas absorption in tray and packed towers- Absorption with/without chemical reaction- Removal of SO_2 - Adsorption in fixed beds- Breakthrough.

Removal of HCs/ VOCs- NO_X removal - Wet scrubbers.

Integrated air pollution control systems.

1. Lawrence K.Wang, Norman C Perelra, Yung-Tse Hung, *Air pollution control Engineering*, Tokyo.
2. Noel de Nevers, *Air pollution control Engineering*, McGraw Hill, New York.

6. SURFACE AND GROUND WATER MODELLING

Land Processes – Subsurface and Channel Processes- Precipitation – Rain gauge network, Abstractions, Infiltration, Evaporation, Transpiration, Process and models

Unit Hydrograph & S curve hydrograph, Dimensionless unit hydrograph, GUIH, Watershed Model and Conceptual Models.

Occurrence and Movement of Ground water, Properties of aquifer, Groundwater flow equations, Dupuit Forchheimer assumptions, Well hydraulics, Partial penetration of wells, Interference of wells, Collector wells and Infiltration galleries.

Pumping tests, Analysis for unconfined and non leaky and leaky confined aquifer and water table aquifer, Locating hydro geologic boundaries, Well design criteria.

Natural and Artificial Recharge of Ground water- Salt water intrusion, Application of Finite Difference in ground water.

1. Ven Te Chow, “Applied Hydrology”, Mc GrawHill Science Publishers, 1988
2. Singh, Vijay ., “Elementary Hydrology”, Prentice Hall,1994
3. Raghunath. “Ground Water”, Mc Graw Hill, 2007
4. Bear, J., Hydraulics of Ground water, Mc Graw Hill, 2007

7. RIVER ENGINEERING

Classification of free surface flow, velocity and pressure distributions, Uniform flow.

Dynamic equation for Gradually varied flow – Classification of flow profiles, Computational methods, Prismatic channels.

Energy and Momentum principles in open channel flow, Rapidly Varied Flow, Hydraulic jump – Analysis.

River Hydrology & Distribution of water quality in Rivers, Estuaries, Physical and Hydrological Characteristics of Lakes.

Sediment Transport, Properties, Initiation of Sediment Transport, Bed load, Bed forms, Bed roughness, Suspended load, total load, Meandering of Rivers, Scouring at different structures.

1. Garde, R.J.Rangaraju, K.G. “Mechanics of Sediment Transportation And Alluvial Stream Problems”,1978

2. Santosh Kumar Garg., "Irrigation Engineering & Hydraulic Structures" Khanna Publishers, 2006
3. Subramanya., "Flow in Open Channels", Tata Mc Graw Hill,2001

8. WATER RESOURCES SYSTEMS MANAGEMENT

Reservoir planning, Management, Multi reservoir systems, Real time operation, River basin planning, water logging, soil salinity, salinity control.

Design of Dams, Non gravity dams, Weirs and Barrages, Conjunctive use of Irrigation water, Quality of Irrigation water, Contaminants and their effects on various crops

Rainwater Harvesting and Management – Different Types and Methods of Harvesting in urban and agricultural areas.

Draught analysis, NCA classification, Direct and Indirect losses, Drought severity assessment, Drought Monitoring, Drought Management

Introduction to systems approach, Linear programming, Problem formulation, Solution by simplex method, Application to design and operation of reservoir, Non Linear Programming, Sensitivity analysis, Monte Carlo simulation.

1. Dilip Kumar Majumdar, "Irrigation Water Management (Principles & Practices)", Prentice Hall of India (P), Ltd, 2004
2. Water Resources Systems, "Vedula & Mujumdar", McGrawHill, 2005.
3. Daniel P. Loucks "Water Resources systems Planning and Management(Studies and Reports in Hydrology) ", 2006