ENVIRONMENTAL SCIENCE AND ENGINEERING DEPARTMENT

Bulletin on Courses of Study, 2025-26

M.Tech. / M.Sc. – Ph.D. / Ph.D. Programmes

(July’ 2025 – July’ 2026)

IIT Bombay

The post-graduate programmes and activities of the Environmental Science and Engineering Department (ESED) at IIT Bombay are designed to prepare the students for a better understanding of various aspects of Environmental Science and Engineering. The curriculum is focused towards addressing the needs and challenges of major industrial sectors, governmental sectors, such as MHRD, MoEFCC, MoES, MoWR, CSIR, DST, SERB, AICTE, and international agencies such as WB, UNDP/UNEP, UNIDO, OECD and various other funding institutions.

The Department has a dedicated group of sixteen regular faculty members with multi-disciplinary background and interests. The department offers B.Tech.-M.Tech. (Dual Degree), M.Sc.-Ph.D., M.Tech. and Ph.D. in Environmental Science and Engineering. All the programmes are interdisciplinary in nature and consist of course work followed by research project. The course credit requirement in the Ph.D. programme varies depending upon the background of the candidate.

Major ongoing research deals with contemporary topics such as (a) clean technologies and industrial pollution prevention, (b) integrated treatment and disposal of hazardous waste (c) bio-medical waste management (d) biodegradation of complex industrial wastewater (fertilizer, food, paper, coke oven, diary, distillery, petrochemicals) and wastewater containing halogenated aromatics, nitro-aromatics and other mixed substrates (e) biodegradation of complex non-aqueous liquid pollutants (NAPLs, e.g., oil and tar) (f) development and application of toxicity/mutagenicity tests for emissions and effluents (g) development of novel bioreactors (RBC, UASB) (h) air pollution monitoring, modeling and human health risk analysis (i) aerosol and PAH emission factors, aerosol inventory, transport modeling and source apportionment (j) environmental impact assessment of developmental projects (k) in-situ and ex-situ remediation of contaminated groundwater and aquatic environments (l) environmental systems simulation and optimization, (m) risk, frequency and vulnerability assessment to natural/environmental hazards and (n) analysis and mapping of hydroclimatic extremes and flood modeling. Research projects are currently funded by agencies such as DBT, DST, MHRD, AICTE, MoWR, MoES, MoEFCC, CPCB, DPCC, MPCB, TSPCB, MCGM and MNES.

The Department has computing facilities and well-equipped laboratory for environmental monitoring and analysis. Some of the sophisticated instruments available include: High Performance Liquid Chromatography (HPLC), Gas Chromatograph (GC), Ion Chromatograph (IC), Carbonaceous Aerosol Speciation System (CASS) Particle Size Analysers and Indoor Air Quality Monitor,
Luminometer, Total Organic Carbon (TOC) Analyzer, UV-Vis Spectrophotometer, Gel Imaging Systems and Respirable Dust Sampler, Ultra -high Performance Liquid Chromatography (UPHLCMS), Thermogravimetric Analyser (TGA), Respirometer.

The Department has ongoing research on Aerosol and Air Quality; Water Quality and Water and Wastewater Treatment; Environmental Biotechnology; Clean Technology; Environmental Impact Assessment; Novel Technologies for Industrial/Hazardous Waste Management; Environmental Systems Modelling and Optimization; Risk, Frequency and Vulnerability Assessment and Mapping. The Department has established strong links and collaboration with leading industries, academic institutions and national/international agencies by conducting sponsored research projects and offering consultancy and technical services.

FACULTY

PROFESSOR

Munish K. Chandel, Ph.D. (IIT Delhi)
(Head of the Department)

Virendra Sethi, Ph.D. (Univ. of Cincinnati, OH)
Anil Kumar Dikshit, Ph.D. (Cornell Univ., NY)
Sanjeev Chaudhari, Ph.D. (IIT Kanpur)
Suparna Mukherji, Ph.D. (Univ. of Michigan-Ann Arbor, MI)
Anurag Garg, Ph.D. (IIT Roorkee)
Subhankar Karmakar, Ph.D. (IISc Bangalore)

ASSOCIATE PROFESSOR

Harish C. Phuleria, Ph.D. (Univ. of Southern California, LA)
Amritanshu Shriwastav, Ph.D. (IIT Kanpur)
Pradip Kalbar, Ph.D. (IIT Bombay)
Manoranjan Sahu, Ph.D. (Washington Univ., St. Louis, MO)
Swatantra Pratap Singh, Ph. D. (IIT Kanpur)

ASSISTANT PROFESSOR

Abhishek Chakraborty, Ph.D. (IIT Kanpur)
V. S. Vamsi Botlaguduru, Ph.D. (Texas A&M University, TX)
Tabish Nawaz, Ph.D. (University of Massachusetts Dartmouth, MA)
Srinidhi Balasubramanian, Ph.D. (University of Illinois at Urbana-Champaign, IL)
Indrajit Chakraborty, Ph.D. (IIT Kharagpur)
Renuka Verma, Ph.D. (IIT Roorkee)

2-Year M.Tech. Programme

ENVIRONMENTAL SCIENCE AND ENGINEERING DEPARTMENT

COURSE STRUCTURE

Credits	Sem. I	Sem. II	Sem. III	Sem. IV	Total
Core Courses	36	12	-	-	48
Elective Courses	-	18	6	-	24
Institute Elective	-	6/0	0/6	-	6
Lab Course	6	3	-	-	9
Seminar	4	-	-	-	4
Communication (PP/NP)	-	-	6	-	6
R & D Project	-	-	-	-	-
GC 101: Gender in the workplace	0	-	-	-	-
TA 101 (TASET)	0				
Training (P/NP)	-	-	-	-	-
Course Total	46	39/33	12/18	-	97
Project	-	-	42*	38@	80
Total Credits	46	39/33	54/60*	38	**177**

***** Registration for the I stage project (ES 797) will be made in II Semester (in January) @ Registration for the II stage project (ES 798) will be made in III Semester (in November) **
The student can opt for outside department elective in second semester only in lieu of one Department Elective.

COURSE CURRICULA (M.Tech. / Ph.D.)

FIRST YEAR: First Semester (2025 entrants)

ES 631	Environmental Chemistry	3 0 0 6
ES 633	Environmental Microbiology and Ecology	3 0 0 6
ES 635	Air Pollution Science and Engineering	3 0 0 6
ES 637	Municipal Water and Wastewater Systems	3 0 0 6
ES 639	Physico-Chemical Treatment Technologies	3 0 0 6
ES 647	Municipal Solid and Biomedical Waste Management	3 0 0 6
ES 694	Seminar for M.Tech. programme	0 0 0 4
ES 651	Environmental Monitoring Laboratory	0 0 6 6
GC 101	Gender in the workplace	
TA 101	TASET	

		46

ESS 801	*Seminar for PhD. Programme (for Ph.D. prog)*	0 0 0 4

FIRST YEAR: Second Semester (2025 entrants)

ES 664	Environmental Systems Modelling	3 0 0 6
ES 666	Biological Treatment Technologies	3 0 0 6
ES 668	Environmental Computation Lab	0 0 3 3

List of Electives:

Elective-I

ES 607	Environmental Informatics	2 1 0 6
ES 670	Environmental Statistics	3 0 0 6
ES 682	Numerical Methods for Environmental Systems	2 0 2 6
ES 701	Urban Water Management	2 1 0 6

Elective II

ES 602	Aerosol Measurements: Principles, Techniques and Data Analysis	2 1 0 6
ES 616	Energy Conversion and Environment	3 0 0 6
ES 624	Hazardous Waste Management	3 0 0 6
ES 642	Industrial Wastewater Management and Reuse	3 0 0 6
ES 644	Industrial Pollution Prevention and Clean Technologies	3 0 0 6
ES 658[a]	Environmental Change and Sustainable Development	3 0 0 6
(or)		
ES 644[a]	Industrial Pollution Prevention and Clean Technologies	3 0 0 6

[a] offered in alternative years

Elective III

ES 654	Groundwater Flow and Contaminant Transport through Porous Media	3 0 0 6
ES 656	Bioremediation - Principles and Applications	3 0 0 6
ES 672	Air Pollution Control Technologies	3 0 0 6
ES 674	Aerosol Science and Engineering	3 0 0 6
ES 676	Membrane Processes	3 0 0 6
ES 680	GIS for Environmental Planning and Management	1 0 4 6
ES 684	Design of Water and Wastewater Systems	3 0 0 6

Either Elective II/Elective III can be replaced by an outside Department Elective 3 0 0 6

Institute Elective 3 0 0 6

(To be opted either in this semester or the next)

39/33

SECOND YEAR: First Semester (2024 and 2025 entrants)

Elective-IV

ES 645	Environmental Law and Policy	3 0 0 6
ES 653	Environmental Impact Assessment	3 0 0 6
ES 655	Environmental Management	3 0 0 6

INSTITUTE ELECTIVE 3 0 0 6

(To be opted either in this semester or the previous)

ES 797 I stage Project* 0 0 0 42*

[* Registration for the I stage project (ES 797) will be made in II semester (in January), but the credit will be added to third semester]

ES 899 Communication Skills (β) 1 2 0 6

54/60

SECOND YEAR: Second Semester (2024 and 2025 entrants)

ES 798 II Stage Project[@] 0 0 0 38[@]

[[@] Registration for the II stage project (ES 798) will be made in III semester (in November), but the credit will be added to fourth semester]

38

6-Year Post - B.Sc. Dual Degree Programme with M.Sc. - Ph.D.
(M.Sc. in 2-years)

ENVIRONMENTAL SCIENCE AND ENGINEERING DEPARTMENT

For the 2024 and 2025 Entrants

COURSE STRUCTURE

Semester	ESED Core	ESED Elective	Institute Elective	GC 101: Gender in the workplace & TA 101 (TASET)	Lab.	Seminar	R&D project	Commu-nication (PP/NP)	Project	Total Credits
I	30	-	-	0	6	4	-	-	-	40
II	18	6	6	-	3	0	-	-	6	39
III	24	6	-	-	3	-	-	6	18	57
IV	6	12	-	-	-	-	-	-	24	42
V	**Ph.D. Research**									
VI										
VII										
VIII										
IX										
X										
XI										
XII										
Total	**78**	**24**	**6**	**0**	**12**	**4**	**0**	6	**48**	**178**

COURSE CURRICULA (M.Sc. - Ph.D.): For the 2024 and 2025 Entrants

FIRST YEAR: First Semester					
Code	**Name of the Course**	**Lectures**	**Tutorials**	**Practicals**	**Credits**
ES 631	Environmental Chemistry	3	0	0	6
ES 657	Water Resources and Environmental Hydraulics	3	0	0	6
ES 659	Mathematics and Statistics for Environmental Engineering	3	0	0	6
ES 633	Environmental Microbiology and Ecology	3	0	0	6
ES 635	Air Pollution Science and Engineering	3	0	0	6
ES 651	Environmental Monitoring Laboratory	0	0	6	6
ES 296	Seminar	0	0	0	4
GC 101	Gender in the workplace				
TA 101	TASET				
		15	**0**	6	**40**
					Formal Contact Hours: 21
					Total Credits : 40

FIRST YEAR: Second Semester					
Code	**Name of the Course**	**Lectures**	**Tutorials**	**Practicals**	**Credits**
ES 672	Air Pollution Control Technologies	3	0	0	6
ES 208	Mass Transfer Process in Environmental Systems	3	0	6	6
	Institute Elective	3	0	0	6
	ESED ELECTIVE-I (may be taken from Group I & II)	3	0	0	6
ES 668	Environmental Computational Laboratory	0	0	3	3
ES 664	Environmental Systems Modelling	3	0	0	6
ES 493	M.Sc.-Ph.D. Project I	0	0	0	6
		16	**2**	**9**	**39**
					Formal Contact Hours: 27
					Total Credits : **39**

SECOND YEAR: First Semester					
Code	**Name of the Course**	**Lectures**	**Tutorials**	**Practicals**	**Credits**
ES 451	Environmental Field Studies	0	0	3	3
ES 637	Municipal Water and Wastewater Systems	3	0	0	6
ES 639	Physico-Chemical Treatment Technologies	3	0	0	6
ES 645	Environmental Law and Policy	3	0	0	6
ES 647	Municipal Solid and Biomedical Waste Management	3	0	0	6
ES 899	Communication Skills	1	2	0	6 (PP/NP)
	ESED ELECTIVE II	3	0	0	6
ES 653	Environmental Impact Assessment				
ES 655	Environmental Management				
ES 649	Atmospheric Processes and Climate Change				
ES 601	Environmental Health and Safety				
ES 494	M.Sc.-Ph.D. Project II	0	0	0	18
		15	**0**	**3**	**57**
Formal Contact Hours : 18					
Total Credits : **57**					

SECOND YEAR: Second Semester					
Code	**Name of the Course**	**Lectures**	**Tutorials**	**Practicals**	**Credits**
ES 666	Biological Treatment Technologies	3	0	0	6
	ESED ELECTIVE III	3	0	0	6
	Group-I				
EN 648	Combustion Engineering				
ES 682	Numerical Methods for Environmental Systems	2	0	2	
ES 624	Hazardous Waste Management	3	0	0	
ES 642	Industrial Wastewater Management and Reuse	3	0	0	
ES 658	Environmental Change and Sustainable Development	3	0	0	
ES 644	Industrial Pollution Prevention and Clean Technologies	3	0	0	
CM 801	Introduction to Risk Analysis	3	0	0	
	ESED ELECTIVE IV	3	0	0	6
	Group-II				
ES 674	Aerosol Science and Engineering	3	0	0	
ES 680	GIS for Environmental Planning and Management	1	0	4	
ES 616	Energy Conversion and Environment	3	0	0	
ES 654	Groundwater Flow and Contaminant Transport through Porous Media	3	0	0	
ES 656	Bioremediation Principles and Applications	3	0	0	
ES 676	Membrane Processes	3	0	0	
ES 684	Design for Water and Wastewater Systems	3	0	0	
~~ES 678~~	~~Soil Science~~	~~3~~	~~0~~	~~0~~	
ELECTIVE III and ELECTIVE IV are ESED electives to be chosen from group- I and II, respectively					
ES 495	M.Sc.-Ph.D. Project III	0	0	0	24
		9	**0**	**0**	**42**
					Formal Contact Hours: 9
					Total Credits: **42**

6-Year Post - B.Sc. Dual Degree Programme with M.Sc. - Ph.D.

ENVIRONMENTAL SCIENCE AND ENGINEERING DEPARTMENT

For the 2025 Entrants

COURSE STRUCTURE

Semester	ESED Core	ESED Elective	Institute Elective	Course Outside ESED	Lab.	Seminar	R&D project	Commu-nication (PP/NP)	Project	Total Credits
I	36	-	-	-	-	4	-	-	-	40
II	12	6	6	-	9	-	-	β (+6)	6	39+β
III	24	6	-	-	3	-	-	-	18	51
IV	6	12	-	-	-	-	-	-	24	42
VI	**Ph.D. Research**									
VII										
VIII										
IX										
X										
XI										
XII										
Total	**78**	**24**	**6**	**0**	**12**	**4**	**0**	β (+6)	**48**	**172+ β**

β credits not counted

COURSE CURRICULA (M.Sc. - Ph.D.): For the 2025 Entrants

FIRST YEAR : First Semester					
Code	**Name of the Course**	**Lectures**	**Tutorials**	**Practicals**	**Credits**
ES 631	Environmental Chemistry	3	0	0	6
ES 657	Water Resources and Environmental Hydraulics	3	0	0	6
ES 659	Mathematics and Statistics for Environmental Engineering	3	0	0	6
ES 633	Environmental Microbiology and Ecology	3	0	0	6
ES 635	Air Pollution Science and Engineering	3	0	0	6
ES 651	Environmental Monitoring Laboratory	0	0	6	6
ES 296	Seminar	0	0	0	4
		18	**0**	**0**	40
					Formal Contact Hours : 18
					Total Credits : **40**

FIRST YEAR: Second Semester					
Code	**Name of the Course**	**Lectures**	**Tutorials**	**Practicals**	**Credits**
ES 672	Air Pollution Control Technologies	3	0	0	6
ES 664	Environmental Systems Modelling	3	0	0	6
ES 668	Environmental Computational Laboratory	0	0	3	3
ES 208	Mass Transfer Process in Environmental Systems	3	0	0	6
ESED ELECTIVE-I	May be taken from Group I & II	3	0	0	6
	Institute Elective	3	0	0	6
ES 493	MSc-PhD Project I	0	0	0	6
		13	**2**	**9**	**39+β**
					Formal Contact Hours : 13
					Total Credits : **39+β**

SECOND YEAR : First Semester					
Code	**Name of the Course**	**Lectures**	**Tutorials**	**Practicals**	**Credits**
ES 637	Municipal Water and Wastewater Systems	3	0	0	6
ES 639	Physico-Chemical Treatment Technologies	3	0	0	6
ES 645	Environmental Law and Policy	3	0	0	6
ES 647	Municipal Solid and Biomedical Waste Management	3	0	0	6
ES 451	Environmental Field Studies	0	0	3	3
ESED Elective II		3	0	0	6
ES 653	Environmental Impact Assessment	3	0	0	
ES 655	Environmental Management	3	0	0	
ES 649	Atmospheric Processes and Climate Change	3	0	0	
ES 601	Environmental Health and Safety	3	0	0	
ES 494	M.Sc.-Ph.D. Project II	0	0	0	18
		15	**0**	**3**	**36**
					Formal Contact Hours : 18
					Total Credits : **51**

SECOND YEAR : Second Semester					
Code	**Name of the Course**	**Lectures**	**Tutorials**	**Practicals**	**Credits**
ES 666	Biological Treatment Technologies	3	0	0	6
	ESED ELECTIVE III	3	0	0	6
	Group-I				
EN 648	Combustion Engineering	3	0	0	
ES 682	Numerical Methods for Environmental Systems	2	0	2	
ES 624	Hazardous Waste Management	3	0	0	
ES 642	Industrial Wastewater Management and Reuse	3	0	0	
ES 658	Environmental Change and Sustainable Development	3	0	0	
ES 644	Industrial Pollution Prevention and Clean Technologies	3	0	0	
CM 801	Introduction to Risk Analysis	3	0	0	
	ESED ELECTIVE IV	3	0	0	6
	Group-II				
ES 674	Aerosol Science and Engineering	3	0	0	
ES 680	GIS for Environmental Planning and Management	1	0	4	
ES 616	Energy Conversion and Environment	3	0	0	
ES 654	Groundwater Flow and Contaminant Transport through Porous Media	3	0	0	
ES 656	Bioremediation Principles and Applications	3	0	0	
ES 676	Membrane Processes	3	0	0	
ES 684	Design for Water and Wastewater Systems	3	0	0	
ES 678	Soil Science	3	0	0	
One ESED Elective is to be taken from either of the two groups					
ES 495	M.Sc.-Ph.D. Project III	0	0	0	24
		9	**0**	**0**	**42**
Formal Contact Hours: 9					
Total Credits: **42**					

Course Details

ES 208 MASS TRANSFER PROCESS IN ENVIRONMENTAL SYSTEMS 3 0 0 6
(M.Sc.-Ph.D.)

Environmental systems and processes: natural and engineered systems of environmental significance, character and scale, quantification, reactions, reactors, material balance relationship, initial and boundary conditions, mass balance-based process models.
Macro transport and micro transport processes: advective and dispersive transport mass & momentum balance, Reynolds number, Prandtl hypothesis, dispersion coefficient and flux expressions, diffusive mass transfer, Ficks Law, diffusivity estimation, interphones mass transfer, boundary layers, mass transfer coefficients, film Model, penetration and surface renewal model, development of mass transfer correlations.
Energetics in homogeneous and heterogenous system: reaction concepts, equilibrium vs ateadystate, thermodynamic relationships and functions, reaction feasibility, fugacity and chemical potential
, Henry's Law, Raoult's Law, phase exchange equilibria, absorption and adsorption processes, isotherm models, species distribution among phases in environmental eystems.
Rate concepts in homogenous system: mass law relationship, reaction order, rate data analysis and choice of rate expression, activation energy, complex reaction kinetics,
Reactor engineering in steady state homogenous systems: ideal reactions, CMBR, CMFR, PFR, PFDR, nonideal reactors, residence time distribution analysis.

Text/References

Weber, W.J. Jr., Process Dynamics in Environmental Systems, John Wiley & Sons Inc, 1996. Fogler, H.S., Elements of Chemical Reaction Engg., 2nd Ed., Prentice-Hall India, 2001.

Maximum Registered Students

Prerequisites

None

(This course will not be permitted as elective for students outside ESED)

ES 451 ENVIRONMENTAL FIELD STUDIES 0 0 3 3

Environmental Quality Assessment: Measurement of various environmental quality parameters for selected area/matrix to determine the environmental quality status.

Ecology: Measurement and calculation of biodiversity indices based on plants and animals; Net and gross primary productivity, community respiration rate; Field Trips.
Socio-economic Survey: Population distribution, health status, perception of environment.

Visit to industrial units or treatment schemes to understand and undertake assessment to relate basic principles, Preparation of field study report.

Text/References

Artiola, Janick F. (Ed.), Environmental Monitoring and Characterization, Elsevier Academic Press, 2004.
Khopkar, S.M., Environmental Pollution, Monitoring and Control, New Age Intl., New Delhi, 2004.
Standard Methods for the Examination of Water and Wastewater, 20th ed., Washington, D.C., American Public Health Association, 1998.
Lodge, J.P., Jr., (Ed.) Methods of Air Sampling and Analysis, 3rd ed., Lewis Publishers, 1988.
Smith, R. L. (1996), Study guide to accompany ecology and field biology, 5th edition, Menlo Park, California, USA, Benjamin Cummings
Krebs C.J. (1999), Ecological methodology, 2nd edition, Menlo Park, California, USA, Benjamin Cummings

Maximum Registered Students

Prerequisites

None

3 0 0 6

ES 601 ENVIRONMENTAL HEALTH AND SAFETY

Regulations for Environment, Health and Safety**:** Factories Act and Rules, Environmental Pollution Act, Oil Industry Safety Directorate (OISD), Indian Electricity Acts and Rules, Mines Acts and Rules. Workmen Compensation Act, OSHA Standards, IS & BS Standards, API standards Occupational Health and Hygiene: Physical Hazards: Noise and vibration, Instrumentation, Surveying procedure, Health effects, Control measures (stress, exposure and radiation effects).
Chemical Hazards: Recognition of hazards, TLV for air, gas and chemical contaminants. Demonstration of equipment for the assessment of physical and chemical hazards.
Occupational Health: Concept and spectrum of health, industrial toxicology, toxicity

Safety Management
Safety performance: As per Indian and International standards
Hazard analysis: Cost effectiveness in hazard elimination – logical analysis – HAZOP
Probabilistic reliability considerations, estimating probability in time, mathematical calculation of probability, reliability determination.
Safety management techniques: Safety inspection – safety action, safety survey disaster control.

Environmental Pollution Control
Air pollution: Classification and properties of air pollutants, sources, control, dispersion of air pollutants.
Water pollution: Classification – effect on receiving bodies, chemical, physical and biological treatment method.
Solid Waste Management: Method of collection, disposal, land filling.

Text/References

IS codes: IS 5903, IS 807, IS 2760, IS 14469, IS 13367-1, IS 5324, IS 7167, IS 7155, IS1800, IS 3521.
Handbook of Occupational Health and Safety, NIC, Chicago, 1982.
Encyclopedia of Occupational Health and Safety, Vol. I and II. International Labour Organisation, Geneva, 1985.
McCornick, E.J. and Sanders, M.S., Human Factors in Engineering and Design, Tata McGraw Hill, 1982.
Accident Preventional Manual, NSC Chicago, 1982.
Henrich, H.W., Industrial Accident Prevention, McGraw Hill, 1980.
Less, F.P., Loss Prevention in Process Industries, Butterworth, New Delhi, 1986.

Maximum Registered Students

Prerequisites
None

(Only for students of ESED)

ES 600 (Institute Elective) ENVIRONMENTAL SCIENCE AND ENGINEERING

Introduction to Environmental Science and Engineering - Nature and scope of environmental problems, Ecosystem effects through bio-geochemical cycles, Environmental awareness and sustainable development; Water Pollution Fundamentals and Control Strategies; Water quality - physical and chemical characteristics, Drinking water standards; Effluent water quality requirements; Water and wastewater treatment processes - treatment train, physical, chemical and biological unit operations; Air pollution fundamentals; Sources and classifications; particulate and gaseous emissions; health effects; Particulate pollution control; Gaseous pollution control; Hazardous Waste and Pollution Prevention - Industrial sources and regulations, Toxicity measurement and human health risk assessment, Treatment and disposal methods, Pollution prevention approach.

Text/References

Stern, A.C., Air Pollution, Elsevier.
Glynn Henry, J. and Heinke, G.W., Environmental Science and Engineering, Prentice Hall.
Jackson, A.R.W. and Jackson, J.M., Environmental Sciences: The Environment and Human Impact, Longman Publishers.
de Nevers, N., Air Pollution Control Engineering, McGraw-Hill, New York.
Masters, G.M., Introduction to Environmental Engineering and Science, Prentice Hall, 2008, New Delhi.
Nathanson, J. A., Basic Environmental Technology – Water supply, Waste Management and Pollution Control. Prentice Hall, 2002 New Delhi.
Cunningham W.P. and Cunningham M.A. (2002), Principles of Environmental Science, Tata McGrawHill Publishing Company, New Delhi.
Metcalf and Eddy, Wastewater Engineering, Treatment, Disposal and Reuse, Tata McGraw Hill, 1995.
Davis, M. L. and Cornwell D. A. (1998), Introduction to Environmental Engineering, 2nd Ed., McGraw Hill, Singapore.
Supplementary Reading Materials (Selected Book Chapters and Papers)

Maximum Registered Students 60

Prerequisites

None

ES 602 AEROSOL MEASUREMENTS: PRINCIPLES, TECHNIQUES AND DATA ANALYSIS 2 1 0 6

❖ Introduction: • Aerosol definition and types in the troposphere, aerosol fundamentals, size distribution, composition, formation, transport and removal of atmospheric aerosol particles, Climate and health effects of tropospheric aerosol.

❖ Important aerosol characteristics and measurement parameters: • Aerosol physicochemical characteristics: Number, mass, size, morphology, surface area, hygroscopicity, volatility, composition and optical properties. • Measurement parameters: Number conc., mass/number/size distribution, SSA, MAC, MAE, volatile fractions, mobility diameter, hygroscopicity parameter, CCN, shape factor, agglomerates, aggregates, elements, ions, organics, MP, POPs and PAHs

❖ Sampling techniques: • Offline techniques: Samplers (Inertial, Gravitational, Centrifugal) and filters, Electrostatic and Thermal Collection Techniques, advantages and disadvantages of different techniques and filters, fog, cloud, rainwater collection, dust and other types of collection for specialized analysis • Online techniques: Aerodynamic lens, pToF, in-line sampling, filter deposition based techniques, utility, advantages and disadvantages

❖ Measurement Principles: • Off-line analysis/measurement principles: Chromatography (gas and liquid), microscopy (optical and electron), X-ray diffraction, mass spectrometry (gas and liquid). Sample preparation, analysis methods and instrument parameters, pros and cons of each technique, uncertainty, and detection limits. • On-line analysis/measurement principles: Ionization/vaporization (EI, ESI, CI, Laser) and Mass spectrometry (different types), single particle analysis, optical scattering and absorbance, electrical mobility, CCN, instrument parameters, pros and cons of each technique, uncertainty, and detection limits.

❖ Data analysis and interpretation: • Data analysis: Checking for data robustness, errors, data cleaning, time series, diurnal/seasonal patterns, calculation and interpretation of different diagnostic ratios and factors, source identification, and application of advanced techniques and tools for data analysis.

❖ Applications: • Nanoparticle and Nonspherical particle measurements: Shape factors with different diameter definitions fractals and fibres, Aerosol measurements in the workplace, Ambient aerosol sampling, Indoor Aerosols, Personal exposure assessment, Aerosol measurements in the defence sector, source apportionment and air quality related policy making.

Text/References

• Pramod Kulkarni, Paul Baron, E. Willeke; Aerosol Measurements: Principles, Techniques, Applications and Significance. Wiley, 3rd Edition, 2011

• Mihalis Lazaridis, Ian Colbeck; Aerosol Science: Technology and Applications. Wiley, February 2014 Edition

• Yifang Zhu, William C. Hinds; Aerosol Technology: Properties, Behavior, and Measurement of Airborne Particles. Wiley, 3rd Edition, 2022

• James H. Vincent; Aerosol Sampling: Science, Standards, Instrumentation and Applications. Wiley, April 2007

• Kvetoslav Rudolf Spumy; Analytical Chemistry of Atmospheric Aerosols; CRC Press Inc; 1st edition (23 April 1999)

• Roy M. Harrison, Roger Perry, R. Young; Handbook of Air Pollution Analysis; Chapman and Hall; 2nd edition (24 July 1986)

• Several review papers

Prerequisites : None

ES 607 ENVIRONMENTAL INFORMATICS **2 1 0 6**

Module 1: Background and History of Informatics and Computational thinking; Characteristics of environmental information; Various Applications using emerging technologies; exploratory data analysis notably diagnostic testing, detection of outliers and methods to impute missing data, data processing techniques including singular value decomposition, principal component analysis, Ordinary least squares regression and related topics.
Module 2: Nonlinear regression, and regularization models including ridge regression. Generalized linear models follow, emphasizing logistic regression, Variable subsetting is addressed through stepwise procedures and the LASSO.
Module 3: Supervised machine learning topics include the basic concepts of resampling, boosting and bagging and several techniques: Decision Trees, Classification and Regression Trees, Random Forests, Support Vector Machines and Neural Networks.
Module 4: Unsupervised Machine Learning approaches are addressed through applications using principal component analysis, k-means Clustering, k-fold Cross-Validation and Environmental applications with modelling techniques and analysis tools implemented in Python.
Module 5: Geospatial Data Analysis: Properties of spatial data, Interpolation techniques, Pattern and clustering analysis of spatial data
Module 6: Case studies for application to Environmental engineering problems: Use Air Pollution case study as example (for regression, clustering); water quality analysis; energy analysis (Note: mathematical exercises will be supported with environmental data to demonstrate application)

Text/References

1. The Elements of Statistical Learning: Data Mining, Inference, and Prediction, Second Edition, by Trevor Hastie and Robert Tibshirani 2016
2. Pattern Recognition and Machine Learning, by Christopher Bishop, Springer 2011
3. Introduction to Probability and Statistics for Engineers and Scientists 5th Edition by Sheldon M. Ross, 2014.
4. Statistical Methods in the Atmospheric Sciences by 4 th Edition by Daniel S. Wilks, 2019.
5. Machine Learning Methods in the Environmental Sciences, 1 st Edition by William W. Hsieh, 2009
6. Python for data analysis, Wes Mckinney, O Reilly, 2013

Prerequisites

Any prior course in Statistics or data analysis and Interpretation is essential

ES 616 ENERGY CONVERSION AND ENVIRONMENT 3 0 0 6

Interlinkages of energy and environment.
Principles of energy conversion methods: thermal, nuclear, hydro, solar.
An introduction to fuels, combustion fundamentals, thermodynamics, kinetics and properties of combustion products; combustion principles for gases, liquids and solids.
Formation of pollutants, measurements and control.
Automobile engines, operation and design, emissions. Power production and emissions from waste incineration.
Energy policies, economics related to energy along with cost factor, the renewable energy sources and conversion processes and sustainable energy.
Energy externalities, Energy and climate change global issues. Alternative
energy sources, economics, sustainability.

Text/References

International Energy Markets: Understanding Pricing, Policies and Profits by Carol A.Dahl, PennWell Corporation (2004) ISBN:
978-0-87814-799-1
Energy: Technology and directions for the future by John R. Franchi, Elsevier Academic Press (2004). ISBN: 0-12-248-291-3
Principles of Sustainable Energy by Frank Keith and Jan F Kreider, CRC press (Taylor and Francis group) (2011), ISBN: 978-1-4398-1407-9 Energy Economics: A Modern Introduction by Ferdinand E Banks.
Kluwer Academic Publishers. 2nd ed. (2003), ISBN: 0-7923-7700-1 Flagan,
R.C., Seinfeld, J.H., Fundamentals of Air Pollution Engineering, Prentice Hall, New Jersey, 1988.
Kanury, A.M., Introduction to Combustion Phenomena, Gordon and Breach Science Publishers, New York, 1992.

Maximum Registered Students

Prerequisites
None

ES 624 HAZARDOUS WASTE MANAGEMENT

Hazardous Waste Fundamentals: Definition; Landmark episodes; Classification; Generation.
Regulatory process: Hazardous Waste (Management and Handling) Rules and Amendments, Guidelines for HWM from MoEF, New Delhi, Regulatory framework in the USA and EU, Basal Convention and other international statutes.
Process: Physicochemical properties; Energy and mass balances; Fate and transport of contaminants; Toxicology
Current Management Practices: Environmental audit; Pollution prevention; Facility development and operations.
Treatment and Disposal Methods: Physicochemical processes; Biological processes; Stabilization and solidification; Thermal methods; Land disposal.
Remediation of Contaminated Sites: Quantitative risk assessment; Site and subsurface characterization; Containment, Remedial alternatives.

Text/References

LaGrega, M.D., Buckingham, P.L., and Evans, J.C., Hazardous Waste Management, McGraw-Hill International Editions, New York. 1994.
Freeman, H.W., Standard Handbook of Hazardous Waste Treatment and Disposal, McGraw Hill, New York, 1989.
Martin, E.J. and Johnson, J.H., Hazardous Waste Management Engineering, van Nostrand-Reinhold, New York, 1987.
Wentz, C.A., Hazardous Waste Management, 2nd Edition, McGraw Hill, New York, 1995

Maximum Registered Students

Prerequisites

For all UG and DD students: ES 200 and only for students from Civil, Chemical, Metallurgy and Energy Department.

ES 631 ENVIRONMENTAL CHEMISTRY

Aquatic Chemistry: Chemical equilibria and kinetics fundamentals; Acids and bases; Titrations; Acidity; Alkalinity; Buffers and buffer intensity; Chemical equilibrium calculations; pC-pH diagram. Precipitation and dissolution; Water softening and water conditioning; Langelier index; Solubility diagram; Coexistence of phases in equilibrium; Complexation of metal ions and organic complexes in natural water.
Oxidation and reduction reactions stoichiometry; Redox couples; pE-pH diagrams; Redox control in natural systems; Basic concepts of organic and colloid chemistry.
Soil Chemistry: Weathering reactions; Structure and surface reactions of clays and oxides; Forces at soil-water interfaces.
Atmospheric Chemistry: Chemical equilibria and kinetics; Photo-dissociation and free radical reactions; Chemistry of precipitation; Acid rain.

Text/References

Sawyer, C.N., McCarty, P.L., and Parkin, G.F., Chemistry for Environmental Engineering, 5th Edition, McGraw-Hill, Inc., New York, 2003.
Manahan, S.E., Fundamentals of Environmental Chemistry, Lewis Publishers, Inc., Boca Raton, 1993.
Sposito, G., Surface Chemistry of Soils, Oxford University Press, New York, 1984.
Stumm, W., and Morgan, J.J., Aquatic Chemistry : An introduction Emphasizing Chemical Equilibria in Natural Waters, 2nd Edition, Wiley Intersciences, New York, 1981.

Maximum Registered Students

Prerequisites

None

ES 633 ENVIRONMENTAL MICROBIOLOGY AND ECOLOGY

Structure of prokaryotic and eukaryotic cells; Types of microorganisms; Metabolic classification of microorganisms.
Microbial metabolism; Respiration and energy generation; Microbial growth; Enzyme kinetics and regulation; Bacterial genetics; Structure of DNA and RNA; Transcription and translation; Gene expression and regulation; Gene transfer and recombinant DNA technology.
Ecology; Ecosystem structure; Energy flow and material cycling in an ecosystem; Biogeochemical cycling of carbon, nitrogen, phosphorous and sulphur; Biodiversity and conservation of wild genetic resources.
Microbiological aspects of drinking water and water distribution systems.

Texts/References

Bitton, G., Wastewater Microbiology, Wiley-Liss Inc., New York, 1994.
Pelczar Jr., M.J., Chan, E.C.S. and Kreig, N.R., Microbiology, 5th Edition, McGraw- Hill Publishing Co. Ltd., New Delhi, 1993.
Odum, E.P., Fundamentals of Ecology, W.B. Saunders Pub. Co., Philadelphia, 1971.

Maximum Registered Students

Prerequisites

This course is not permitted as elective for students outside ESED. ES 633 is offered for M.Sc., MTech and PhD students.

ES 635 AIR POLLUTION SCIENCE AND ENGINEERING

Air Pollutants and their Effects: The air pollution system; Gases and particulate; Atmospheric sources, sinks, transport; Effects of health and environment; Criterial pollutants, ambient and source standards. Aerosols: Characterisation of aerosols, size distributions, measurement methods; Transport behaviour: diffusion, sedimentation, inertial, electrical and thermal; Aerosol Dynamics: nucleation, condensation and coagulation, Radiation properties – visibility, climate effects; principles of particulate control systems.
Gaseous Pollutants: Vapour-liquid and vapour-solid equilibria; Diffusion and Interfacial mass-transfer; Control systems.
Air quality management: dispersion modeling, source apportionment methods.

Texts/References

Cheremisinoff, P., Encyclopaedia of Environmental Control Systems, Vol 2, Gulf Publishing Company, Houston, 1989.
de Nevers, N., Air Pollution Control Engineering, McGraw Hill, New Delhi, 1995 Friedlander,
S. K., Smoke Dust and Haze, Oxford University Press, New York, 2000.
Hinds, W.C., Aerosol Technology: Principles, Behaviour and Measurements of Airborne Particles, Wiley: NY, 1982.
Seinfeld, J. H. and Pandis, S N., Atmospheric Chemistry and Physics: from Air Pollution to Climate Change, John Wiley, New York, 1998.

Maximum Registered Students

Prerequisites

This course is not permitted as elective for students outside ESED.

ES 637 MUNICIPAL WATER AND WASTEWATER SYSTEMS

Introduction to urban and metropolitan regional planning; Water quality and effluent standards; Issues related to water supply and disposal of wastewater; Water demand forecasting and management.

Environmental hydraulics: Flow in pipes; Multiport diffuser outfalls; Flow in open channels; Pumpssystem-head curve and pump head curve; Hydraulic profile computations of water and wastewater treatment plant.

Water treatment and distribution systems; Network design; Municipal wastewater collection; Computer packages for the design of water distribution and wastewater collection system.

Text and References

Manual on Sewerage and Sewage Treatment, 2nd Edition, Ministry of Urban Development, New Delhi, 1993.
Manual on Water Supply and Treatment, 3rd Edition, Ministry of Urban Development, New Delhi, 1991.
Walski, T.M., Gessler, J., and Sjostorm, J.W., Water Distribution Systems: Simulation and Sizing, Lewis Publisher, Michigan, 1990.
Peavy, H. S., Rowe, D. R., and Tchobanoglous, G., Environmental Engineering, McGraw Hill Book Company, Singapore, 1985.
Benefield, L.D., Judkins, J.F., and Parr, A.D., Treatment Plant Hydraulics for Environmental Engineers, Prentice-Hall Inc, New Jersey, 1984.

Maximum Registered Students

Prerequisites

None

Remarks: This course should not be permitted as elective for students outside ESED

ES 639 PHYSICO-CHEMICAL TREATMENT TECHNOLOGIES

Overview of mass transfer and reactor concepts; Mass transport mechanisms; Ideal reactors, nonidealities, Mass balance in various reactor configurations.

Particle separation processes; Coagulation and flocculation processes, Particle surface charge, surface potential and stability of colloidal dispersions; Sedimentation and flotation processes, Gravity thickeners, clarifiers and flotation systems; Filtration and Ultrafiltration Processes, Modelling approaches for rapid sand filters.

Solute separation processes; Gas transfer processes, Diffused and surface Aeration and Air stripping of volatile contaminants in packed tower; Adsorption and ion exchange processes, sorption isotherm models and rates considerations, Sorption in completely mixed and packed bed reactors; Precipitation processes; Reverse osmosis and electrodialysis.
Species transformation processes; Chemical oxidation / reduction processes, disinfection using chlorine and UV.

Texts/References

Weber, W. J. Jr., Environmental Systems and Processes: Principles, Modeling and Design, John Wiley and Sons Inc., New York, 2001
Weber, W. J. Jr., and DiGiano, F.A., Process Dynamics in Environmental Systems, John Wiley and Sons Inc., New York, 1996
Weber, W. J. Jr., Physicochemical Processes for Water Quality Control, John Wiley and Sons Inc., New York, 1972
Metcalf & Eddy, Inc, Tchobanoglous G. and Burton, F.L., Wastewater Engineering: Treatment, Disposal and Reuse, 4th ed., Tata McGraw Hill, New Delhi, 2003

Maximum Registered Students

Prerequisites

None

Remarks: This course should not be permitted as elective for students outside ESED

ES 642 INDUSTRIAL WASTEWATER MANAGEMENT AND REUSE 3 0 0 6

Tertiary treatment of industrial wastewater including removal of nitrate, sulphate, phosphorous, pathogens, colour, Odor, TDS, COD and residual BOD; Sector specific issues in management of industrial wastewater including petrochemical, textile, food processing, pharmaceutical, fertilizer, pesticides etc.; Policy and legislation including challenges posed by various sectors of industries and legislation framework and regulation in India; Case studies.

Text/References

Asolekar, S.R., Ecocentric Technologies for Recycle and Reuse of Municipal and Industrial Effluents. A monograph published by the QIP-CDP Office of IIT, Bombay, 2005.
Eckenfelder, W.W. Jr., Industrial Water Pollution Control, 3rd Edition, McGraw Hill International Edition, Singapore, 2000.
Metcalf & Eddy, Inc, Tchobanoglous G. and Burton, F.L., Wastewater Engineering: Treatment, Disposal and Reuse, 4th Edition, Tata McGraw Hill, New Delhi, 2003.
Arceivala, S. J. and Asolekar, S. R., Wastewater Treatment for Pollution Control, 3rd Edition, McGraw Hill Education (India) Pvt. Ltd., New Delhi, 2006.
Various review papers and selected readings prescribed by the instructor.

Maximum Registered Students

Prerequisites

For all UG and DD students: ES 200 and only for students from Civil, Chemical, Metallurgy and Energy Department.

ES 644 INDUSTRIAL POLLUTION PREVENTION AND CLEAN TECHNOLOGIES 3 0 0 6

Principles and techniques for industrial pollution prevention and waste minimization; Nature and characteristics of industrial wastes; Prevention versus control of industrial pollution; Source reduction tools and techniques: raw material substitution, toxic use reduction and elimination, process modification and procedural changes; Recycling and reuse; Opportunities and barriers to cleaner technologies; Pollution prevention economics.

Waste audits, emission inventories and waste management hierarchy for process industries; Material balance approach; Material and process mapping approach; Emission sources; Estimation of fugitive emissions; Environmental impact of VOCs; Energy and resource (material and water) audits for efficient usage and conservation.

Unit operations in separation technology; Pollution prevention for unit operations: Boilers and Heat Exchangers; Storage tanks; Distillation columns; Application of separation technologies for pollution prevention; Process optimization for cleaner industrial processes: Flowsheet analysis—qualitative and quantitative approaches using mass exchange networks; Thermodynamic constraints to waste minimization; Holistic and critical technology assessment; Environmental performance indicators; Concept of industrial ecology and symbiosis of eco-parks.

Case studies on industrial applications of cleaner technologies in chemical, metallurgical, pulp and paper, textile, electroplating, leather, dairy, cement and other industries.

Texts/ References

Bishop, P.E., Pollution Prevention: Fundamentals and Practice, McGraw Hill, 2000.
Freeman, H. M., Industrial Pollution Prevention Handbook, McGraw Hill, 1995.
Allen, D.T., and Rosselot, K.S., Pollution Prevention for Chemical Processes, John Wiley, 1997.
Allen, D.T., Bakshani, N., and Rosselot, K.S., Pollution Prevention: Homework and Design Problems for Engineering Curricula, American Institute for Pollution Prevention.
Johansson, A., Clean Technology, Lewis Publishers, 1992.
Theodore, L., and McGuinn, Y. C., Pollution prevention, Van Nostrand Reinhold, NewYork, 1992.
Asolekar, S. R. and Gopichandran, R. Preventive Environmental Management - An Indian Perspective., Foundation Books Pvt. Ltd., New Delhi (the Indian association of Cambridge University Press, UK), 2005.

Maximum Registered Students

Prerequisites

For all UG and DD students: ES 200 and only for students from Civil, Chemical, Metallurgy and Energy Department

ES 645 ENVIRONMENTAL LAW AND POLICY **3 0 0 6**
(both M.Sc.-Ph.D. and M.Tech. components)

Models of environmental management; Incentives; Context; Theories of corporate strategy and environmental policy; Environmental guidelines and charters; Auditing, Monitoring; Reporting, economics and accounting; Local economic development and environmental management; Role of government; Law and policies beyond environmentalism; Sustainability issues; Role of government and non-government organizations and citizens.

Text/References

Hawken, P., Ecology and Commerce, Harper Business, New York, 1993.
Rosencranz, A., Divan, S. and Noble, M.L., Environmental Law and Policy in India : Cases, Materials and Statutes, Tripathi Pvt. Ltd, Bombay, 1992.
Welford, R., Corporate Environmental Management, Earthscan Publications Ltd., London, 1988.
Asolekar, S. R. and Gopichandran, R. Preventive Environmental Management - An Indian Perspective Foundation Books Pvt. Ltd., New Delhi (the Indian association of Cambridge University Press, UK), 2005.
Various policy statements and Laws of the Government of India

Maximum Registered Students

Prerequisites

For all UG and DD students: ES 200 and only for students from Civil, Chemical, Metallurgy, Humanities and Social Sciences, and Energy Department.

ES 647 MUNICIPAL SOLID AND BIOMEDICAL WASTE MANAGEMENT 3 0 0 6

Solid waste management: Sources, Composition and Properties of Municipal Solid Waste, Engineering principles; Generation of solid waste; Onsite handling, storage and processing including segregation; Collection of solid waste; Transfer and transport; Processing technique and equipment; Recovery of resources; Conversion products and energy; Composting; Recycling; Incineration and pyrolysis; Disposal of solid waste including sanitary landfill, planning, siting, design, closure and postclosure monitoring; Regional/Integrated solid waste management related issues.
Biomedical waste: Regulatory framework, categorization; generation, collection, transport, treatment and disposal.

Text/References

Tchobanoglous, G., Theisen, H., and Vigil, S.A., Integrated Solid Waste Management: Principles and Management Issues, McGraw Hill Book Company, Singapore, 1993.
Powes, P.W., How to Dispose of Toxic Substances and Industrial Waste, Noyes Data Corporation, England, 1976.
Pavoni, J.L., Handbook of Solid Waste Disposal, Solid Waste Management, Van Nostrand-Reinhold Co., 1975.
Mantell, C.L., Solid Waste Management, John Wiley, New York, 1975.

Maximum Registered Students

Prerequisites None

ES 649 ATMOSPHERIC PROCESSES AND CLIMATE CHANGE

Structure of atmosphere, composition, global cycles and lifetimes; Atmospheric chemistry: troposphere and stratospheric; Atmospheric aerosols : properties, chemistry and processes. Meso and macro scale atmospheric and meteorological processes; Global circulation models. Radiation balance, direct and indirect effects of pollutants; climate change implications; policies and international protocols.

Text/References

Seinfeld, J. H., and Pandis, S N., Atmospheric Chemistry and Physics : from Air Pollution to Climate Change, John Wiley, New York, 1998.
Almeida, G.A., Koepke, P., and Shettle, E.P., Atmospheric Aerosols : Global Climatoloty and Radiative Characteristics, A. Deepak Publishing, Virginia, 1981.
Charlson, R.J., and Heintzenberg, O.J. (Eds.), Aerosol Forcing of Climate, John Wiley and Sons, N.Y., 1995.

Maximum Registered Students

Prerequisites

None

ES 651 ENVIRONMENTAL MONITORING LABORATORY 0 0 6 6

Air pollution measurement: Measurement design and methods; Principles and instruments for particulate and gaseous pollutant measurements; Meteorological measurements; Collection efficiency of control devices.
Water quality monitoring*:* Cation/anion analysis; BOD; COD; Residual chlorine analysis; Metal analysis; Instrumental methods of pollutant analysis; Characterisation of sludge sample.
Microbiology: Microscopy; Staining and detection of microbes; Methods of enumerating microbes; Multiple tube fermentation technique; Membrane filter technique.

Text/References

ESED Lab Manuals.
Standard Methods for the Examination of Water and Wastewater, 19th Edition, APHA/AWWA/WPCF Publishing, Washington D.C., 1995.
Ramp, H.H., and Krist, H., Laboratory Manual for the Examination of Water, Wastewater and Soil, VCH Publishers, Weinheim, 1988.
Willard, H.H., Merritt, L.L. Jr., Dean, J.A., and Settle, F.A., Jr., Instrumental Methods of Analysis, 6th Edition, C.B.S. Publishers, New Delhi, 1986.
I.S. Codes: IS 5182, IS 11255, IS 8829, IS 3028.

Maximum Registered Students

Prerequisites

Only for the PG students of ESED. Not permitted for students outside ESED because this is a lab course and we cannot handle more number of students.

ES 653 ENVIRONMENTAL IMPACT ASSESSMENT

Evolution of EIA; EIA at project; Regional and policy levels; Strategic EIA; EIA process; Screening and scoping criteria; Rapid and comprehensive EIA.
Legislative and environmental clearance procedures in India and other countries, Siting criteria; CRZ; Public participation; Resettlement and rehabilitation.
Practical applications of EIA; EIA methodologies; Baseline data collection; Prediction and assessment of impacts on physical, biological and socio-economic environment; Environmental management plan; Post project monitoring, EIA report and EIS; Review process.
Case studies on project, regional and sectoral EIA.
Specialised areas like environmental health impact assessment; Environmental risk analysis; Economic valuation methods; Cost-benefit analysis; Expert system and GIS applications; Uncertainties.

Text/References

World Bank, 'Environmental Assessment Source Book', Environment Dept., Washington D.C., 1991.
Rau, G.J. and Wooten, C.D., Environmental Impact Analysis Handbook, McGraw Hill, New York, 1980.
Canter, L., Environmental Impact Assessment, McGraw Hill, New York, 1996.

Maximum Registered Students

Prerequisites

None

ES 654 GROUNDWATER FLOW AND CONTAMINANT TRANSPORT THROUGH POROUS MEDIA

Water movement in the subsurface; Groundwater and the hydrologic cycle; The groundwater environment; Types of aquifers; Sources of contamination; Saturated flow: continuity equation; Darcy's Law; Equation of flow; Analytical solutions and numerical modelling; Unsaturated flow; Ground water sampling methods and analyses.
Transport of contaminants; Transport equation; Dispersion and diffusion in porous media; Reaction terms; Analytical solutions; Soil chemistry; Groundwater quality; Common soil minerals and components; Forces at soil-water interfaces; Adsorption and surface complexation models; Interaction of non-polar compounds with soils; Soil chemical kinetics; Modelling Groundwater Pollution; Coupling of contaminant-soil interactions with transport; Reaction and transport of trace metals, ligands and nonpolar organic solutes.

Texts/ References

Todd, D.K., Groundwater Geology, 2nd Ed., John Wiley, NY, 2001
Domenico, P.A., and Schwartz, F.W., Physical and Chemical Hydrogeology, John Wiley and Sons, New York, 1990.
Grathwohl, P., Diffusion in Natural Porous Media: Contaminant Transport, Sorption-desorption and Dissolution Kinetics, Kluwer Academic, Boston, 1998
Appelo, C.A.J., and Postma, D., Geochemistry, Groundwater and Pollution, A.A. Balkema Publishers, Rotterdam, 1993.
Freeze, R.A., and Cherry, J.A., Groundwater, Prentice Hall, Englewood Cliffs, New Jersey, 1979.

Maximum Registered Students

Prerequisites
Knowledge of Mathematics fundamentals is essential. Programming knowledge desirable (with permission of instructor).

ES 655 ENVIRONMENTAL MANAGEMENT

Environmental regulations and policies; Environmental protection laws and acts; Corporate and international charters and protocols; Environment Risk assessment; Industrial ecology, Pollution prevention and Waste minimization; Sustainable development; Life cycle assessment; Environmental auditing; Eco-labelling of products; Performance indicators. Environmental management systems particularly IS 14000 series.

Texts and References

Welford, R., Corporate Environmental Management, Earthscan Publications Limited, London, 1996.
Sayre, D., Inside ISO 14000: Competitive Advantage of Environmental Management, St. Louis Press, Florida, 1996.
Graedel, T.E. and Allenby, B.R., Industrial Ecology, Englewood Cliffs: Prentice Hall, New Jersey, 1995.
Rosencranz, A., Divan, S. and Noble, M.L., Environmental Law and Policy in India : Cases, Materials and Statutes, Tripathi Pvt. Ltd, Bombay, 1992.
Asolekar, S. R. and Gopichandran, R. Preventive Environmental Management - An Indian Perspective Foundation Books Pvt. Ltd., New Delhi (the Indian association of Cambridge University Press, UK), 2005.

Maximum Registered Students

Prerequisites

For ESED students ONLY. Should not be included in ‘outside department’ electives.

ES 656 BIOREMEDIATION – PRINCIPLES AND APPLICATIONS 3 0 0 6

Current bioremediation practice and applications; Microbial systems of bioremediation; Factors influencing bioremediation (environmental factors, physical factors and chemical factors); Genetic responses of microorganisms to the presence of pollutants (plasmid coded inducible degradative enzymes); Application of genetically engineered microorganisms for hazardous waste management; Microbial transformation reactions (aerobic and anaerobic biotransformations); Microbial detoxification of specialty chemicals (insecticides, herbicides, fungicides, polychlorinated biphenyls, heavy metals); Bioremediation systems and processes (solid, liquid and slurry phase bioremediation); Microbial cleaning of gases (biofiltration and bioscrubbing); In situ bioremediation; Laboratory scale biotreatability studies for bioremediation; Management of bioremediation project.

Text/References

Baker, K H., and Herson, D. S., Bioremediation**,** McGraw-Hill Publishing Company, New York, 1994
Eweis, J. B., Ergas, S. J., Chang D. P. Y., and Schroeder E. D., Bioremediation Principles, McGraw-Hill Publishing Company, Singapore, 1998.
Cookson, J.T. Jr., Bioremediation Engineering – Design and Application, McGraw Hill Publishing Company, New York, USA, 1995
Young, L.Y., and Cerniglia, C.E., Microbial Transformation and Degradation of Toxic Organic Chemicals, Wiley–liss Publishers, New York, USA, 1995

Maximum Registered Students

Prerequisites

ES 633 Environmental Microbiology and Ecology

ES 657 WATER RESOURCES AND EVIRONMENTAL HYDRAULICS 3 0 0 6
(M.Sc.- Ph.D.)

Global water resources; Precipitation; Streamflow measurement; Runoff; Hydrographs; Floods and flood routing; Design of open channels; Concepts of specific energy, Hydraulic jump; Groundwater hydrology.

Definition and properties of fluids; Fluid statistics, fluid pressure and its measurement, hydrostatic force on plane, inclined and curved submerged surfaces, buoyancy and floatation; Kinematics of fluid flow; Fluid dynamics: Continuity, Momentum and energy equations, Flow through orifices, Weir and notches, Flow through pipes.

Text/References

Chaudhry, M. H., Open channel flow, Englewood Cliffs: Prentice Hall, 1993.
French, R.H., Open Channel Hydraulics, McGraw Hill Book Co., New York 1986.
Linsley, R.K. and Paulhus, J.L.H., Water Resources Engineering, McGraw Hill Book Co., 1992.
Streeter, V.L. and Wylie, E. B., Fluid Mechanics, McGraw Hill Book Co.,1983.
Subramanya, K., 2013. Engineering Hydrology, 4e. Tata McGraw-Hill Education.

Maximum Registered Students

Prerequisites: None

This course is exclusively for M.Sc.-Ph.D. students in ESED.

ES 658 ENVIRONMENTAL CHANGE AND SUSTAINABLE DEVELOPMENT 3 0 0 6
(M.Sc.-Ph.D. and M.Tech. components)

Issues of sustainability: food, materials and energy resources, demands, policies, ethics; Paradigms of agricultural/industrial age, population, limits to growth; Current debates on the issues of sustainability; Relationships of ecological, economic and social systems; Engineering tools for assessment and design for environment and sustainability; Relevance of traditional paradigms for rural India.

Text/References

LEAD India (Editor) Rio to Johannesburg: India's Experience in Sustainable Development, Orient Longman, Hyderabad, 2002.
Lee, N., and Kirkpatrick, C., (Eds), Sustainable Development and Integrated Appraisal in a Developing World, Edward, Elgar, UK, 2000.
Chopra, K., and Kadekodi, G.K., Operationalisting Sustainable Development, Sage Publication, New Delhi, 1999.
Roy, K.C., Sen R.K. and Tisdell, C.A., Environment and Sustainable Agricultural Development (Volumes I and II), New Age International Pvt. Ltd., New Delhi, 1996.
Kirkby, J., O'Keefe, P., and Timberlake, L. (Eds.), The Earthscan Reader in Sustainable Development, Earthscan Publications, London, 1995.
Asolekar, S. R. and Gopichandran, R. Preventive Environmental Management - An Indian
Perspective Foundation Books Pvt. Ltd., New Delhi (the Indian association of Cambridge University Press, UK), 2005.

Maximum Registered Students

Prerequisites

For all UG and DD students: ES 200 and only for students from Civil, Chemical, Mechanical, Metallurgy and Energy Department.

ES 659 MATHEMATICS AND STATISTICS FOR ENVIRONMENTAL ENGINEERING 3 0 0 6
(M.Sc.-Ph.D.)

Differential and Integral calculus; Linear algebra: Eigenvalues and Eigenvectors, Systems of linear equations – Properties of determinants and matrices, Solution of linear simultaneous equations; Systems of nonlinear equations; Ordinary differential equations: First order, Ordinary linear differential equations of nth order, Systems of differential equations; Introduction to partial differential equations.

Overview of statistics and probability; Probability concepts and probability distributions; Conditional probability and Bayes' theorem; Fundamentals of data analysis; Experiment design and analysis of variance; Regression analyses.

Text/References

Guha, Saumyen, and Rajesh Srivastava. Numerical methods for Engineering and Science. Oxford University Press, 2010.
Chapra, Steven C., and Raymond P. Canale. Numerical methods for engineers. Boston: McGraw-Hill Higher Education, 2010.
Berthouex, P.M. and Brown, L.C., Statistics for Environmental Engineers, CRC Press, ISBN 9781566705929 - CAT# L1592, 2002.
Gilbert Strang, Introduction to Linear Algebra, 4th Ed., Pub.: Society for Industrial and Applied Mathematics (SIAM), 2009.
Erwin Kreyszig, Advanced Engineering Mathematics, 10th Ed., John Wiley & Sons, 2005. C.T.
Haan, Statistical Methods in Hydrology, C.T. Haan, 2002.
Ross, Sheldon M. Introductory Statistics. Academic Press, 2017.

Maximum Registered Students

Prerequisites

None

This course is exclusively for M.Sc.-Ph.D. students in ESED.

ES 664 ENVIRONMENTAL SYSTEMS MODELLING **3 0 0 6**

Definition; Classification; Examples of models for environmental systems.
Introduction to air quality models; Meteorology; Atmospheric stability and turbulence; Gaussian plume model and modifications; Numerical models, Urban diffusion models, Calibration and sensitivity analysis; Applications of public domain models and software, Global radiation balance and climatic changes.
Transport and fate of pollutant in aquatic systems; Introduction to river, estuarine and lake hydrodynamics; Stratification and eutrophication of lakes; Dissolved oxygen model for streams; Temperature models.
Transport and fate of pollutants in soils and ground water; Utility of environmental models for forecasting.
Computational methods in environmental modelling.

Text/References

Seinfeld, J.H., and Pandis, S.N., Atmospheric Chemistry and Physics, John Wiley and Sons, Inc., New York, 1998.
Schnoor J.L., Environmental Modelling, Inter Sc. Publ., 1996.
Boubel, R.W., Fox, D. L., Turner, D. B., and. Stern, A.C., Fundamentals of Air Pollution, Academic Press, New York, 1994.
Thomann, R.V., and Muller, J.A., Principles of Surface Water Quality Modelling and Control, Harper International Edition, N.D., 1987.
Tchobanoglous, G., Schroeder, E.D., Water Quality, Addison – Wesley Publishing Company, Reading, Massachusetts, 1987.

Maximum Registered Students

Prerequisites

Strong background in mathematics is essential and programming is desirable.
(With permission of the instructor)

ES 666 BIOLOGICAL TREATMENT TECHNOLOGIES 3 0 0 6

Classification of biochemical operations; Stoichiometry and kinetics of biochemical operations; Modelling of suspended growth systems (basic model for CSTRs; Extensions of the basic model; Methods of biomass recycle and retainment; Techniques for evaluation of kinetic and stoichiometric parameters; Multiple microbial activities in reactors); Design and evaluation of suspended growth processes (guiding principles; Iterative nature of process design and evaluation; Basic decisions during design; Levels of design; Factors to be considered during design); Biological nutrient removal (carbon, nitrogen and phosphorous removal); Anaerobic treatment (process options, components of anaerobic reactions that influence process design); Attached growth reactors (process description and applications); Biodegradation of xenobiotic organic chemicals.

Text/References

Arceivala, S. J. and Asolekar, S. R., Wastewater Treatment for Pollution Control, 3rd Edition, McGrawHill Education (India) Pvt. Ltd., New Delhi, 2006.
Metcalf & Eddy, Inc, Tchobanoglous G. and Burton, F.L., Wastewater Engineering: Treatment, Disposal and Reuse, 4th Edition, Tata McGraw Hill, New Delhi, 2003.
Gray, N. F., Biology of Wastewater Treatment, Oxford University Press, London, 1989.

Maximum Registered Students

Prerequisites

ES 201/633 or equivalent; This course is only for students in ESED

ES 668 ENVIRONMENTAL COMPUTATION LABORATORY **0 0 3 3**

Introduction to Computers and Computing, Introduction to a programming language, Applications of spreadsheet and management of software for solving environmental problem; Hands-on practice on statistical software/tools; hands-on practice on standard software in environmental science and engineering field.

Text/References

Various selected readings prescribed by the instructor.
Rudra Pratap, Getting Started with MATLAB 7: A Quick Introduction for Scientists and Engineers, Oxford University Press, 2005.

Maximum Registered Students

Prerequisites

None

Only for ESED M.Tech./M.Sc.-Ph.D. students

ES 670 ENVIRONMENTAL STATISTICS **3 0 0 6**

Overview of statistics and probability; Statistics in the context of environmental analysis; Probability concepts and probability distributions; conditional probability and Bayes' theorem

Fundamentals of data analysis; Measurement uncertainty: Precision and accuracy; Reproducibility/repeatability; Types of Error, Normal error curve; Error propagation; Quality assurance and quality control; Confidence intervals. Hypothesis testing for equality of mean and standard deviation: t-test, chi-square test and F-test; Errors in hypothesis testing.

Experiment design and analysis of variance; ANOVA concepts; Completely randomized design; Randomized block design; Two-way factorial design; Variance component analysis; Factorial and fractional factorial design; Significance of interaction between factors.

Regression versus correlation; Autocorrelation in data; Linear versus non-linear regression models; Linear least-squares regression; Precision of parameter estimates, coefficient of determination: inherent limitations; non-parametric statistics; Exercises using the statistical package SYSTAT.

Texts/References

Berthouex, P.M. and Brown, L.C., Statistics for Environmental Engineers, Lewis Publishers, CRC Press, Boca Raton, 1994.

Mendenhall, W. and Beaver, R.J., Introduction to Probability and Statistics, 8th Ed., PWS-Kent Publishing Co, Boston, 1991.

Ott, W.R. Environmental Statistics and Data Analysis, Lewis Publishers, New Jersey, 1995.

Maxwell, S.E. and Delaney, H.D. Designing Experiments and Analysing Data—A Model Comparison Perspective, Wadsworth Publishing Company, California, 1990.

Maximum Registered Students

Prerequisites

None

This course is only for students in ESED

ES 672 AIR POLLUTION CONTROL TECHNOLOGIES 3 0 0 6

Industrial sources of air pollution; Behaviour of pollutants in atmosphere; Emission factors, regulations, control strategies and policies; Choosing appropriate APC technology.
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 – field and diffusion charging; Electrical migration velocity; Cyclones – laminar and turbulent flow; Wet collectors; Design and drawing of various particle control devices.
Gaseous Pollutant Control*:* Gas absorption in tray and packed towers; Stage efficiency; Liquid/gas rates; Equilibrium number of stages/packed height; Absorption with/without chemical reaction; Adsorption in fixed beds; Breakthrough; Wet scrubbers; Condensation and combustion; Design and drawing of various pollutant control devices.
Control of specific pollutants: Control technologies for removal of SO_2, NO_x, VOC. Control technologies for motor vehicles.

Texts/References

McCabe, W. L., Smith, J.C., and Harriott, P. W. L., Unit Operations of Chemical Engineering, McGraw Hill, New York, 1993.
Buonicore, A.J., and Davis, W.T., Air Pollution Engineering Manual, van Nostrand-Reinhold, New York, 1992.
Flagan, R.C., and Seinfeld, J.H., Fundamentals of Air Pollution Engineering, Prentice Hall, New Jersey, 1988.
Reynolds, J.P., Jeris, J., and Theodore, L., Handbook of Chemical and Environmental Engineering Calculations, Wiley Interscience, New Jersey, 2007.
Mycock, J.C., McKenna, J.D. and Theodore, L., Handbook of Air Pollution Control Engineering and Technology, CRC, LEWIS Publishers, Boca Raton, Florida, 1995.
Cooper, C.D., and Alley, F.C., Air Pollution Control – A Design Approach, Waveland Press Inc., Prospect Heights, IL, 1986.

Maximum Registered Students

Prerequisites

ES 635, ES 317 or equivalent

ES 674 AEROSOL SCIENCE AND ENGINEERING 3 0 0 6

Physics of aerosols: size and size distributions, mechanics of motion, agglomeration, diffusion, electrical effects and light scattering. Applications to sampling, deposition, and visibility. Particle formation and growth dynamics, aerosol reactor design engineering, and applications to environmental aerosols, catalysis, combustion, instrumentation, pharmaceuticals and powder production.

Text / References

Friedlander, S K , Smoke Dust and Haze, Oxford University Press, New York, 2000
Hinds, W C., Aerosol Technology: Properties, Behavior and Measurement of Airborne Particles, Wiley-Interscience, New York., 1999
Seinfeld, J H and Pandis, S N., Atmospheric Chemistry and Physics: from Air Pollution to Climate Change, John Wiley, New York, 1998

Maximum Registered Students

Prerequisites

ES 635, ES 317 or equivalent

ES 676 MEMBRANE PROCESSES 3 0 0 6

Introduction to processes and materials, Phenomena governing process operation; driving forces, concentration polarization, hydrodynamics, sealing, fouling, Module configurations, Applications. Reverse Osmosis fundamentals, process design and operation: municipal and industrial applications. Desalination of sea water, pure/ultrapure water production. Fouling and pretreatment, CAD for RO design.

Electrodialysis, Definition of process operation conditions from first principles. Water and industrial wastewater applications with reference to recent case studies.

Nanofiltration and ultrafiltration applications. NF for surface water treatment. UF in ultrapure and potable water production and in membrane bioreactors.

Dead-end cartridge filtration applications in potable and pure water treatment. Choice of media: filtration mechanism, filter media structure.

Text/References

Hillis, P., Membrane technology in water and wastewater treatment edited by Royal Society of Chemistry, Cambridge, 2000.

Belfort, Georges, Synthetic membrane processes: fundamentals and water applications edited by Academic Press, Orlando, 1984.

Noble, R.D., and Stern, S.A., Membrane Separation Technology – Principles and Appliations, Amsterdam, Elsevier, 1995.

Mallevialle, J., Odendaal, P.E., and Wiesner, M.R., Water Treatment Membrane Process, New York, McGraw Hill, 1996.

Maximum Registered Students

Prerequisites

None

ES 680 GIS FOR ENVIRONMENTAL PLANNING AND MANAGEMENT 1 0 4 6
(Course credit structure is now modified to 1-0-4-6, from 2-1-0-6)

Introduction to GIS, Data input, verification, storage and output, Data structures in GIS, Data analysis and spatial modeling, DEMS, DTMS, Surfaces, TINS and Networks in GIS.

Introduction to remote sensing particularly for getting Input data from remote sensing.

Introduction to GIS software and hardware. Laboratory sessions with hands on practice on GIS software say ArcGIS.

Case studies on various applications of GIS for environmental planning and management.

Texts/References:

Goodchild, Michael F., Parks, Bradley O. and Steyaert, Louis T. Environmental modeling with GIS, Oxford University Press, New York, 1993.
Maguire, David J., Goodchild, Michael F. and Rhind, David W., Geographical information systems, Longman Scientific and Technical, Essex, 1991.
Burrough, Peter A. and McDonnell, Rachael A., Principles of geographical information systems, Oxford University Press, Oxford, 1998.
Delaney, Julie, Geographical information systems: an introduction, Oxford University Press, Oxford, 1999.
DeMers, Michael N., Fundamentals of geographic information systems, John Wiley, New York, 1997.

Maximum Registered Students

Prerequisites

None

ES 682 NUMERICAL METHODS FOR ENVIRONMENTAL SYSTEMS 2 0 2 6

(The credit structure is now modified to 2 0 2 6 from 3 0 0 6)

Numerical differentiation and Integration, Numerical methods and techniques for solving ordinary, partial differential equations, nonlinear equations; Matrices Eigenvalues and Eigenvectors, Finite difference method: schemes – implicit and explicit types. Accuracy, convergence and stability, method of characteristics, Finite element method- variational and weighted residual formulations; Introduction and hands-on practice on popular / available numerical tools and software; Applications to Environmental systems viz. water, air, wastewater and groundwater systems.

Texts/References:

Salvadori, Mario G. and Baron, Melvin C. Numerical methods in engineering, Prentice-Hall of India, New Delhi, 1993.

Bathe, K.J. and Wilson, E.L., Numerical methods in finite element analysis, Prentice Hall, New Jersey, 1999.

Bajpai, A.C., Numerical methods for engineers and scientists, Wiley Interscience, New York, 1977.

Rozsa 1P., Numerical methods, North-Holland Pub., Amsterdam, 1980.

Noble, Ben, Numerical methods, Oliver and Boyd, Edinburgh, 1964.

Buchanan, James L. and Turner, Peter R., Numerical methods and analysis, McGraw-Hill, New York, 1992.

Reddy, J.N., Introduction to the finite element method, McGraw-Hill, New York, 1985.

Desai, Chandrakant S. and Abel, John F., Introduction to the finite element method: a numerical method for engineering analysis, Van Nostrand Reinhold, New York, 1972.

Maximum Registered Students

Prerequisites

Strong background in mathematics is essential and programming is desirable (with permission of the instructor).

ES 684 DESIGN OF WATER AND WASTEWATER SYSTEMS 3 0 0 6

General considerations for source of drinking water; Economic sizing of pumping mains; Considerations for layout of treatment plant; Water treatment plant design, Design of water distribution network and wastewater collection system using EPANET AND LOOP program.
Design of Screens; Grit chamber; Aerated grit chamber; Communitor; Sizing of flow equalisation tank; Design of primary sedimentation tank.
Activated sludge process and its modifications; Trickling filter design along with hydraulic considerations; Rotating biological contactor; Aerated lagoons; Waste stabilisation ponds.
Anaerobic treatment Process; Design of upflow anaerobic sludge blanket reactor; Design of anaerobic sludge digester; Design of sludge drying beds.

Text/References

Eckenfelder, W. W Jr., Industrial Water Pollution Control, McGraw Hill, Singapore, 2000.
Manual on Sewerage and Sewage Treatment, 2nd Edition, Ministry of Urban Development, New Delhi, 1993.
Manual on Water Supply and Treatment, 3rd Edition, Ministry of Urban Development, New Delhi, 1991.
Metcalf and Eddy, Wastewater Engineering: Treatment, Disposal and Reuse., 3rd Edition, McGrawHill Book Company, Singapore , 1991.
Qasim, S. R., Wastewater Treatment Plant, Planning Design and Operation, CBS Publishing Japan Ltd, New York, 1985.

Maximum Registered Students

Prerequisites

ES 637: Municipal Water & Wastewater Systems

ES 630 ENVIRONMENTAL NANOTECHNOLOGY 3 0 0 6

Introduction of nanotechnology and overview of nanomaterials in the environment; Nanomaterial synthesis, fabrication, and characterization of nanomaterials; Characterization techniques for nanomaterials; Surface chemistry and colloidal aspects of nanomaterials; Catalytic behavior of nanomaterials ; Toxicity and ecotoxicity of nanomaterials; Applications of nanomaterials: Water, soil, and air purification and sensing; Case studies for Iron nanoparticle, bimetallic, and other carbonbased nanoparticles in desalination and wastewater treatment, and environmental remediation application; Ethical issues of nanotechnology

Text/References

Environmental Nanotechnology: Applications and Impacts of Nanomaterials by Wiesner and Bottero (2007),
McGraw Hill Professional, 2007
Hasselhov and Kaegi, Analysis and Characterization of Manufactured Nanoparticles in Aquatic Environments from Environmental and Human Health Impacts of Nanotechnology, 2009, eds. Lead and smith, Blackwell Publishing
Poole C P and Owens F J, Introduction to Nanotechnology, Wiley-Interscience 2003.
Cao G, Nanostructures and Nanomaterials: Synthesis, properties and applications, Imperial College Press 2004.
Thedore, l., Kunz, r.g., Nanotechnology: Environmental Implications And Solutions, John Wiley & Sons Inc. 2005.
Sellers Ve Diğ, Nanotechnology and the Environment, Crc Press, 2009.
Cloete Ve Diğ, Nanotechnology In Water Treatment Applications, Caister Academic Press, UK, 2010.
Masciangioli, T., Zhang, W., Environmental Technologies At Nanoscale. Environmental Science and Technology, March, 102-107, 2004.

Maximum Registered Students

Prerequisites

Basic Chemistry and Physics

ES 701 URBAN WATER MANAGEMENT 2 1 0 6

Missions and programs of central and state governments related to urban water
Water management connections with SDGs
Circular economy of water and related case studies
Continuous and intermittent mode of water supply
Decentralized and non-grid water networks
Sustainability assessment of water infrastructure and appropriate technology selection
Water loss and non-revenue water management
Demand side management strategies for water
Integration of Nature-based solutions for water management
Climate change adaptation and resilience building for water infrastructure
Social aspects related to water infrastructure, such as consumer behaviour and water storage practices
Economic aspects such as water tariffs, project finances, and funding mechanisms
Role of urban planning in urban water infrastructure
Effect of urbanization and different scales/typologies of cities on water infrastructure
Water and sewer network maintenance
Municipal structures and governance of water infrastructure
Retrofitting and rehabilitation of water infrastructure
Asset management, digitization and automation of water infrastructure
Innovations for improvement of infrastructure performance

Text/References

Soli J Arceivala, Shyam R Asolekar. Wastewater Treatment for Pollution Control and Reuse. Third edition. McGraw Hill Education. 2017.
David Butler, Christopher Digman, Christos Makropoulos, John W. Davies. Urban Drainage. Fourth Edition. CRC Press, Taylor & Francis Group. 2018.
Neil S. Grigg. Water, Wastewater, and Stormwater Infrastructure Management. Second Edition. IWA Publishing. CRC Press, Taylor & Francis Group. 2012.
Syed R. Qasim. Wastewater Treatment Plants. Planning, Design and Operation. Second Edition. CRC Press, Special Indian Edition. 1999.
Ron Crites and George Tchobanoglous. Small and Decentralized Wastewater Management Systems.WCB McGraw-Hill. 1998.
Stuart Hamilton and Ronnie McKenzie. Water Management and Water Loss. First edition. IWA Publishing. 2014.
Manual on sewerage and sewage treatment systems, Central Public Health and Environmental Engineering Organisation, Government of India. 2013.
Manual on Water Supply and Treatment Systems (Drink from Tap) Part A: Engineering - Planning, Design and Implementation, Part B: Operation and Maintenance and Part C: Management. 4th Edition. Central Public Health and Environmental Engineering Organization (CPHEEO). Ministry of Housing and Urban Affairs Government of India. 2024.

Maximum Registered Students

Prerequisites

None

ES 899 COMMUNICATION SKILLS **1 2 0 6**

1. Demonstration and evaluation of Scientific Reports, Note Taking Techniques 2.Discussion and Debates after Listening, Podcasts and Webcasts 3.Two pass approach to reading papers, Summary writing, literature survey and organization, Software Aids 4.Report Writing, Document Processing Software 5.Ethics and Plagiarism: practice and discussion. 6. Writing and Talking about workplace relationships, Gender Issues, Stereotypes, Biases, Labeling 7.Discussion on Contextual Viewpoint, Non-verbal Communication, Analysis of Mannerisms during interactions and presentations. 8. Evaluation of Presentations, Short and Long Talks, Timing, Visual Aids, Presentation Software

Text/References

1.Booth, W C, Colomb, G G, and Williams, J M The Craft of Research (Chicago Guides to Writing, Editing, and Publishing) Univ. of Chicago Press, 2008.2.Turabian, Kate L, Booth, Wayne C., Colomb Gregory G , Williams, Joseph M. University of Chicago Press, 20083.Monippally, M. M., Pawar, B.S. Academic Writing: A Guide for Management Students and Researchers, Response Books, (2010).4.Strunk Jr., William; E. B. White, The Elements of Style, Fourth Edition, Longman; 4th edition (1999).5.Truss, Lynne Eats, Shoots & Leaves: The Zero Tolerance Approach to Punctuation Gotham; 302240(2006).6.Alley, Michael The Craft of Scientific Presentations, Springer (2003).7.Whitesides, George M. 302223 Whitesides Group: Writing a Paper302224, Advanced Materials 16 137530222677 (2004)

Maximum Registered Students

Prerequisites

None

Further Contact:

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