CURRICULUM OF DOCTORAL ACADEMIC PROGRAMME

School of Environment & Natural Resources (SENR)

Doon University
Kedarpur, P.O- Ajabpur, Dehradun – 248001

PROGRAMME OUTCOME OF PH.D. ENVIRONMENTAL SCIENCE

The Ph.D. in Environmental Science is designed to provide students with advanced knowledge and research experience to enter the workforce or academia. Environmental Science involves diverse areas that include biological sciences, ecology, chemistry, geology as well as studies specific to air/water pollution and hazardous wastes, environment monitoring, biodiversity conservation and natural resource management. While it is expected that graduates of the program to possess diverse skills that meet their career interests, it is expected that they will exhibit or engage in the following:

- Academic Excellence: Advanced understanding of biological, geological, chemical and Physical processes, as well as environmental regulations and other scientific issues related to the environment.
- Excellence in Research: The doctoral dissertation requires extensive work leading to publications. Ph.D. candidates will aspire to be at the forefront of an evolving field to solve problems that are highly relevant in present and future political environments.
- Professional Skills: The students develop professional skills by taking courses where the stress is on real-world environmental problems.

COURSE WORK PH.D. ENVIRONMENTAL SCIENCE-COURSE OUTCOMES

Paper 1: Research Methodology-Core Course

This course will enable the Ph.D. students to:

- Acquire tools to mine literature, extract the data and identify the research gap
- Identify the research question, develop a hypothesis and evolve the experimental design
- Develop skill for statistical analyses, to present data, and write a research paper

Paper 2: Research & Publication Ethics-Core Course

This course will enable the Ph.D. students to:

- Understand basic philosophy of science and ethics, research integrity, publication ethics.
- Identify research misconduct and predatory publications indexing and citation database, open access publication, research matrix and plagiarism tools.

Paper 3: Basic Tools & Techniques in Environmental Science-Elective 1

This course will enable the Ph.D. students to:

- Recognize the role of various analytical techniques in environmental monitoring.
- Understand the basic principles behind common analytical techniques and some important instruments.
- To perform qualitative and quantitative analysis of air, soil, and water samples.
- To perform basic GIS mapping, basic reading and analyzing satellite data, Computational Techniques, Data Modelling

Paper 4: Specialization Course as Elective 2I

This course will enable the Ph.D. students to:

- Develop a review using a systematic search, and develop a research proposal on the target topic
- Identify the research objectives and develop a roadmap for the Ph.D. programme
- Conduct pilot research study and develop a suitable hypothesis for Ph.D. programme

SEMESTER WISE CREDIT REQUIREMENT for Pre- Ph. D Course Work

FIRST SEMESTER

Total Credits: 14

S.No	Course Type	Course code	Course Title	Credit	L-T-P
1	Core	EES-710	Research Methodology	4	3-0-1
2	Core	EES-715	Research & Publication Ethics	2	1-0-1
3	Elective I	EES-720	Basic Tools & Techniques in Environmental Science	4	2-0-2
Elective II			Course on area of Specialization Students have to select any one Elective		
4	Elective II	EES-725	Atmospheric Modelling	4	3-0-1
5	--- do ----	EES-730	Ecosystem Restoration	4	3-1-0
6	--- do ----	EES-735	Elements of Data Analytics & Time Series Modelling	4	3-0-1
7	--- do ----	EES-740	Environmental Pollution	4	3-0-1
8	--- do ----	EES-745	Water & Wastewater Treatment	4	3-0-1
9	--- do ----	EES-750	Freshwater System and Processes	4	3-0-1
10	--- do ----	EES-755	Nanomaterials: Properties, Synthesis, Characterization and Applications	4	3-0-1
11	---do----	EES-760	Air Pollution & Its Control	4	3-0-1
12	-do--	EES-765	Disaster Management	4	3-1-0
13	-d0-	EES-770		4	3-0-1

DETAILED Ph.D. SYLLABUS

EES-710: Research Methodology **Credits 4 (3-1-0)**

Unit 1. Research and Research Methodology
Introduction to Research and Research Methodology; types of research; Overview of research process, Designing Research**:** Meaning, Elements and Need of research design, Features of a good design, Different types of research design; Developing a research plan, Literature review; Defining the research problem and hypothesis, selecting a problem, Necessity of defining the problem, Techniques involved in defining a problem

Unit 2. Hypothesis and Sampling
Types of hypotheses, Differences between hypothesis and research problem, Central limit Theorem; parameter and statistic, tests of significance, null hypothesis, errors in sampling, critical region and level of significance, tests of significance for large samples, sampling of attributes and sampling of variables, Chi-square, students t, F and Z tests

Unit 3. Correlation and Regression
Karl Pearson Coefficient of Correlation, Rank Correlation, Lines of regression, regression coefficients standard error of estimates, Partial and multiple correlations, coefficient of determination; Data visualization and performing statistical analysis on R software.

Unit 4. Scientific Communications and Writing Thesis & Research Paper
Communicating Scientific Results: Importance of research communication in science, Overview of research communication process in science, Role of scientific journals – quality of journals, citation index, Journal Impact factor; Other options for communicating results- Books/Book chapter, conferences, workshops and symposiums; Improving scientific writing, Writing Thesis & Research Paper, Reference management tools (Zotero, Mendeley), Introduction to LaTex.

Suggested Readings:

1. Chadda, A. (1989) *Agricultural Statistics in India*, Suman Book House, New Delhi.
2. Date, C. J. (1986). *An Introduction to database system*, Addision Wesley, U.K.
3. Dear, K.J.B., Mead, R and Rilay, J. (1987) *Statistical Tools for Agroforestry Research*,
4. ICRAF, Kenya.
5. Medhi, J. (1992) *Statistical Methods*. Wiley Eastern, New Delhi.
6. Gurumani, N. (2006) *Research Methodology for Biological Sciences*, MJP Publishers,
7. Barnett, Vic (2006) *Environmental Statistics: Methods and Applications*, John Wiley and
8. Sons, New Delhi.1. An introduction to mathematical statistics and its applications- Larsen Richard J, prentice Hall, 2012
9. Zar, Jerrold H. (1998). Biostatistical Analysis. Prentice Hall, N.J.
10. Sokal, Robert and James Rohlf (1997). Biometry, Freeman Press, N.Y.
11. Wayne, R. Ott (1995). Environmental Statistics and Data Analysis, CRC Press.
12. Manly (2001) Statistics for environmental science and management, Chapman and Hall / CRC.
13. Ramsay and Schafer (1997). The Statistical Sleuth, Duxbury Press.

EES- 715: Research & Publication Ethics **Credit 2(2-0-1)**

- RPE 01: PHILOSOPHY AND ETHICS (3 hrs.)
  1. Introduction to philosophy: definition, nature and scope, concept, branches
  2. Ethics: definition, moral philosophy, nature of moral judgements and reactions
- RPE 02: SCIENTIFIC CONDUCT (5hrs.)
  1. Ethics with respect to science and research
  2. Intellectual honesty and research integrity
  3. Scientific misconducts: Falsification, Fabrication, and Plagiarism (FFP)
  4. Redundant publications: duplicate and overlapping publications, salami slicing
  5. Selective reporting and misrepresentation of data

- RPE 03: PUBLICATION ETHICS (7 hrs.)
  1. Publication ethics: definition, introduction and importance
  2. Best practices / standards setting initiatives and guidelines: COPE, WAME, etc.
  3. Conflicts of interest
  4. Publication misconduct: definition, concept, problems that lead to unethical behavior and vice versa, types
  5. Violation of publication ethics, authorship and contributorship
  6. Identification of publication misconduct, complaints and appeals
  7. Predatory publishers and journals

PRACTICE

- RPE 04: OPEN ACCESS PUBLISHING (4 hrs.)
  1. Open access publications and initiatives
  2. SHERPA/RoMEO online resource to check publisher copyright & self-archiving policies
  3. Software tool to identify predatory publications developed by SPPU
  4. Journal finder / journal suggestion tools viz. JANE, Elsevier Journal Finder, Springer Journal Suggester, etc.
- RPE 05: PUBLICATION MISCONDUCT (4hrs.)
  A. Group Discussions (2 hrs.)
     1. Subject specific ethical issues, FFP, authorship
     2. Conflicts of interest
     3. Complaints and appeals: examples and fraud from India and abroad

  B. Software tools (2 hrs.)

Use of plagiarism software like Turnitin, Urkund and other open source software tools

- RPE 06: DATABASES AND RESEARCH METRICS (7hrs.)

  A. Databases (4 hrs.)

1. Indexing databases
2. Citation databases: Web of Science, Scopus, etc.

B. Research Metrics (3 hrs.)

1. Impact Factor of journal as per Journal Citation Report, SNIP, SJR, IPP, Cite Score
2. Metrics: h-index, g index, i10 index, altmetrics

References

Bird, A. (2006). Philosophy of Science. Routledge.

MacIntyre, Alasdair (1967) A Short History of Ethics. London.

P. Chaddah, (2018) Ethics in Competitive Research: Do not get scooped; do not get plagiarized, ISBN:9789387480865

National Academy of Sciences, National Academy of Engineering and Institute of Medicine. (2009). On Being a Scientist: A Guide to Responsible Conduct in Research: Third Edition. National Academies Press. Resnik, D. B. (2011). What is ethics in research & why is it important. National Institute of Environmental Health Sciences, 1—10. Retrieved from https://www.niehs.nih.gov/research/resources/bioethics/whatis/index.cfin

Beall, J. (2012). Predatory publishers are corrupting open access. Nature, 489(7415), 179—179. https://doi.org/10.1038/489179a

Indian National Science Academy (INSA), Ethics in Science Education, Research and Governance (2019), ISBN:978-81-939482-1-7. http://www.insaindia.res.in/pdffEthics Book.pdf

Course Code: EES-720 **Credit 4(3-0-1)**
Course Title: Basic tools and techniques in environmental Science

Unit 1 - Sampling and sample preparation
Sampling, Preservation, Storage, and processing of air, water and soil samples, Laboratory Safety, sample preparation, solvent extraction, solid-phase extraction, microextraction.

Unit 2. Analytical Techniques
Gravimetric Methods of Analysis. Determination of total, dissolved, suspended, volatile and fixed solids, Estimation of moisture content of soil, phytomass, and compost/ vermicompost;
Volumetric Methods. Importance of volumetric analysis, Standardization of reagent using volumetric reactions, Acid-based titrations, Complexometric titrations. pH meter, Electrical conductivity meters,

Unit 3. Instrumentation
UV-Vis Spectrophotometry, Flame photometry, Atomic absorption spectrophotometry, Chromatography, Theory and principles, Paper chromatography, Thin layer chromatography, Column Chromatography, Gas Chromatography, High Performance Liquid Chromatography (HPLC, FPLC), Gel Electrophoresis, PCR, RT-PCR

Unit 4. Water Quality Analysis
Water quality sampling and analysis; Key factors for water analysis; Analysis of physical, chemical, and biological methods (Solids, turbidity, hardness, alkalinity, DO, BOD, COD, ammonia, TKN, nitrate, phosphate, sulfate, chloride, heavy metals, Bacteriological and Limnological analysis); Water quality standards.

Unit 5. Computational Techniques
Elements of programming with python, Data Modelling, Basics of GIS mapping with geopandas, Fundamentals of Satellite Image processing using python, Simple applications : creating NDVI maps, Reading and analysing weather/climate models data (netCDF)

Text Book

1. *Quantitative Chemical Analysis*, *8th Edition*, by Daniel C. Harris, W. H. Freeman and Co., 2006, ISBN: 9781429218153.
2. The *Solutions Manual for Quantitative Chemical Analysis 8th Ed.* (ISBN 9781429231237).
3. *Principles of Instrumental Analysis*, Fifth Edition, Skoog, Holler, Nieman. Analytical Chemistry by Gary D. Christian.
4. *Learning Geospatial Analysis with Python*, 3rd Edition, Joel Lawhead, 2019, Packt Publishing
5. *Geoprocessing with Python*, Chris Garrard, Manning Publication
6. *Environmental Modelling Using Satellite Imaging and Dataset Re-processing*, Moses Esterigho Emetere, Springer
7. NCAR Climate Data Guide, https://climatedataguide.ucar.edu/climate-data-tools-and-analysis/netcdf-overview
8. Wastewater Engineering : Treatment and Reuse, G. Tchobanoglous, F. L. Burton, H. David Stensel, Metcalf & Eddy, Inc., McGraw Hill
9. Standard Methods for the Examination of Water**,** 23rd Edition**,** APHA Press

Course Code: EES-725 **Credit 4(3-0-1)**
Course Title: Atmospheric Modelling

Atmospheric modeling is the core subject required for a researcher to pursue research in the field of weather/climate modelling. This course equips students with the skill of weather/climate modelling, chemical transport models for air quality forecasts/reanalyses, and modelling the climate change impacts. Unit 1 to 4 builds the theoretical framework, Unit 5 to 6 provides the practical components of the same.

Unit 1. Atmospheric Structure, composition and thermodynamics: Pressure, density, and composition, Temperature structure, Equation of state, Change of pressure with altitude, Water in the atmosphere, First law of thermodynamics, Continuity equations for air, gas and particle, Thermodynamic energy equations

Unit 2. Momentum equations in Cartesian and spherical coordinate: Local acceleration, Coriolis force, Gravitational force, Pressure Gradient Force, Viscous force, Turbulent flux divergence, Complete Momentum equation, Application of the momentum equations: Geostrophic wind, gradient wind, Surface-layer wind, surface winds around highs and lows

Unit 3. Hydrostatic and nonhydrostatic models, Vertical coordinate conversions, Altitude coordinate, Pressure coordinate, Sigma-pressure coordinate, Numerical solutions to partial differential equations: operator splitting, Advection-diffusion equations, Finite-difference approximations, Advection schemes used in air-quality models

Unit 4. Boundary-layer and surface processes: Turbulent fluxes of momentum, energy, and moisture, Friction wind speed, Surface roughness lengths, Parameterization of kinematic turbulent fluxes, Eddy diffusion above surface layer, Ground surface temperature and soil moisture.

Unit 5. Model design, application and testing: Determining scales of interest, dimension of the model, selecting processes, variables, computer architecture, coding and optimizing the model, Time steps and intervals, Initial conditions, Boundary conditions, Input and ambient data, Simulations and Sensitivity tests; Example Model Simulations.

Unit 6. Model runs on UNIX systems : Basic UNIX commands, UNIX shell (Bash, csh), Basic Shell scripting (Bash), Linux Cluster System and High Performance Computing (HPC), Configuring and running WRF model ideal and real cases on HPC cluster

Suggested Readings:

1. Fundamentals of Atmospheric Modelling: Mark Z. Jacobson
2. Atmospheric Modelling, Data Assimilation and Predictability: E. Kalnay
3. Fundamentals of Numerical Weather Prediction: Jean Coiffieer
4. Linux Command Line : A complete Introduction, William E. Shotts
5. *NCAR Technical Note : A Description of the Advanced Research WRF Model Version 4*, 2019, William C. Skamarock, Joseph B. Klemp, Jimy Dudhia, David O. Gill, Zhiquan Liu, Judith Berner, Wei Wang, Jordan G. Powers, Michael G. Duda, Dale M. Barker, Xiang-Yu Huang

Course Code: EES-730 **Credit 4(3-1-0)**
Course Title: Ecosystem Restoration

Course highlights and outcomes

- Gain the skills needed to create a blueprint for ecosystem restoration
- Join a community-of-practice committed to preventing, halting, and reversing the trend of ecosystem degradation
- Explore rich learning materials, diving into detailed content based on your needs
- Learn how to select the most appropriate interventions for your context from a range of restorative practices
- Receive a certificate of completion from the course partners

Learning objectives

- Define ecosystem restoration and explain its importance
- Outline the types of ecosystems and ecosystem services
- Explain approaches to and principles of restoration
- Understand how stakeholder participation and inclusive and gender-responsive planning are critical to your restoration project
- Place restoration in the context of large-scale initiatives and agreements
- Understand the steps and activities involved in developing a plan for ecosystem restoration
- Tailor your restoration plan based on real-world examples
- Conceptualize the application of the Short-Term Action Plan on Ecosystem Restoration in your context

The course will cover the following topics:

Unit 1: Land Degradation and rehabilitation: Global, Regional and Local importance; Causes and Process of Degradation: Natural hazards, Population growth, forest-agriculture interface, Mining and waste disposal, Ecological and economic indicators of ecosystem degradation.

Unit 2: Concepts of Ecological Restoration: International Principles and standards for Ecological restoration, Legal policy and governance aspects, Ecological Basis of Ecosystem Restoration

Unit 3: Strategic planning processes of ecological restoration, selection and intervention of restoration projects, projects. Monitoring & evaluation, Forest Landscape Restoration, Case studies of successful Ecological restoration

Unit 4: Socio-economic Considerations in Ecosystem Restoration, **Relationships** between environmental, economic and social opportunities and constraints in restoration Ecosystem restoration – research needs and priorities

Suggested Readings:

1. Andel, J. V.& Aronson, J. (Eds). (2005). Restoration Ecology: The New Frontier. Blackwell Publishing.
2. Bradshaw, A. D. (1987). Restoration: An acid test for ecology. In W. R. Jordan, M. E. Gilpin, and J. D. Aber (Eds.), Restoration Ecology: A Synthetic Approach to Ecological Research (pp. 23–30). Cambridge, UK: Cambridge University Press.
3. Chapin III, F. S., P. A. Matson, & Mooney. A. (Eds.). (2002). Principles of Terrestrial Ecosystem Ecology. New York: Springer-Verlag.
4. Gann et.al (2019). International principles and standards for the practice of ecological restoration, second edition. Restoration Ecology, Vol 27, No. S1, pp S1-S46
5. Roberts, L., Stone, R.& Sugden, A. (2009). The rise of restoration ecology. Science, 325, 355.
6. David Lamb & Don Gilmour. 2003. Rehabilitation & Restoration of degraded Forests,IUCN & WWF 122 pp.
7. J.S Singh et al. 1997, Restoration of Degraded Lands, concepts & strategies, RastogiPublication, 321pp.
8. Restoration Ecology Journal.

Course Code: EES-735 **Credit 4(3-0-1)**

Course Title: Elements of Data Analytics & Time Series Modelling

This syllabus has been designed mainly with applied science perspective. A researcher working in the field of environmental science has to deal with plethora of data coming out of Atmospheric, Aquatic, Lithospheric, and Biotic systems. To analyze these data sets thoroughly in order to assess, e.g., climate change impacts or making future predictions for the state of the atmosphere, the researcher need to equip himself/herself with different modelling techniques so as to make meaningful inferences. This course aims exactly the same to equip researcher with different statistical/time-series modelling techniques both theoretically as well as practically.

Prerequisites : Basic Statistics, Graduate with Mathematics/Statistics/Physics or any of the applied science with strong quantitative discipline

Unit 1 : **Simple and Multiple Linear Regression :** Introduction and Least Squares Estimate, Simple Linear Regression Model, Inferences about the slope and intercept, R^2, Confidence Intervals for population regression, Diagnostics and transformation for simple linear regression, Multiple linear regression, Polynomial regression, Analysis of Covariance, Diagnostics and transformations for Multiple linear regression

Unit 2 : Applied Logistic Regression : Introduction, Fitting the logistic regression model, testing for significance of coefficients, confidence interval estimation, Multiple logistic regression, Testing the

significance of model, dichotomous independent variable, polychotomous independent variable, odds ratio interpretation, measures of Goodness-of-Fit, Pearson Chi-Square Statistic and Deviance, Hosmer-Lemeshow tests, Logistic Regression diagnostics, Interpretation and Presentation of Results from a fitted Logistic Regression Model

Unit 3 : Univariate Time Series Analysis : Introduction and Examples of Time Series, Stationary models and autocorrelation function, Estimation and elimination of trend and seasonal components, Basic properties and linear processes, Introduction to ARMA models, properties of sample mean and autocorrelation function, ARMA(p, q) processes, ACF and PACF, Forecasting stationary time series, Spectral Analysis, The Spectral density of ARMA Process, Unit roots in times series, ARIMA Models, Identification Techniques, Forecasting ARIMA models, Seasonal ARIMA Models

Unit 4 : Multivariate Time Series Analysis : Vector Autoregressive Models (VAR), Specification, Assumptions, and Estimation, Diagnostic Tests, Causality Analysis, Forecasting, Impulse Response Function, Forecast Error Variance Decomposition, Structural Vector Autoregressive Models, Spurious regression, Concept of Cointegration and Error-Correction Models, System of Cointegrated variables

Unit 5 : Nonlinear Modelling Techniques : GARCH Nonlinear Models, Model Typology, Feed forward Neural Network, squasher functions, Radial Basis Functions, Multilayered feed Forward Networks, Recurrent Networks

Unit 6 : Practicals with R : Introduction to R, vectors, array, Matrix, Data Frame, , Control Flow in R, Data input output with R, Data management with R using dplyr package, plotting and visualization using R, ggplot to create beautiful graphs, Regression analysis with R, Logistic regression with R, tsa and astsa packages for time series analysis, nnet package for neural networks

Suggested Readings :

1. *Time Series Modelling of Water Resources and Environmental Systems*, Keith W. Hipel, A. Ian. McLeod
2. *A Modern Approach to Regression with R*, Simon J S Sheather, Springer
3. *Linear Regression Analysis*, D. C. Montgomery, E. A. Peck, G. G. Vining, Wile Publication
4. *Analysis of Categorical Data with R*, Christopher R. Bilder, Thomas M. Loughin, 2015, CRC Press
5. *Applied Logistic Regression*, Hosmer and Lemenshow, 2nd Edition, 2000, John Wiley and Sons
6. *Introduction to Time Series Analysis and Forecasting*, Brockwell and Davis
7. *Time Series Analysis and its Applications with R examples*, R. Shumway, D. Stoffer, Springer
8. *Time Series Analysis with R*, J. D. Cryer, Kung-Sik Chan
9. *Time Series Analysis*, James D. Hamilton
10. *New Introduction to Multiple Time Series*, Helmut Lutkepohl, Springer
11. *Analysis of Integrated & Cointegrated Time Series with R*, Bernhard Pfaff
12. *Guide to Create Beautiful Graphics in R*, Alboukadel Kassambara, published by STHDA (http://www.sthda.com)

Course Code: EES-740 **Credit 4(3-0-1)**
Course Title: Environmental Pollution

Unit 1: Air Pollution: Air pollutants, transport, diffusion and reactions of pollutants in the atmosphere, Impact of air pollutants on human beings, animals and climate, plants, materials, buildings, water bodies, Methods of monitoring and control of air pollutants; Ambient Air quality standards. Noise Pollution

Unit 2: Water Pollution: Types, source and impacts- surface and ground water, Domestic, Industrial, Agricultural and Natural sources, Impact on plants, human, animals and environment, Water quality studies-quality parameters, sampling, analysis, Water quality standards; **Water pollution control:** Pollution due to municipal severage dumping, industrial effluent discharge, solid waste dumping – leachate, infiltration, Assessment of level of pollution, Waste water treatment: an overview

Unit 3: Soil Pollution: Sources of soil pollution- natural, Anthropogenic; Soil pollution monitoring, Remediation of polluted soil

Unit 4: Pollution due to plastic & Solid waste: Types of plastic waste, quantity and its source, pollution of water bodies, drains, sewage; Soil pollution- assessment of level of pollution, Impact on soil quality, Control measures- Role of society and civic bodies. Solid waste disposal and its effects on surrounding environment.

Unit 5: Environment and Sustainability: *The concept of Planetary Boundaries • Growth Dynamics • Case of Energy • Population Dynamics*

Suggested Readings:
The following book will be the key course reference book:

Marquita .K. Hill. Understanding Environmental Pollution. Cambridge University Press, 3rd Edition, 2010.

Other recommended books that cover particular elements of the course are:
- C. Baird and M. Cann. Environmental Chemistry. W.H. Freeman, 4th Edition, 2008.

- M.Z. Jacobson. Atmospheric Pollution, History, Science and Regulation. Cambridge University Press, 2002.

- J. Houghton. Global Warming, the Complete Briefing. Cambridge University Press, 3rd Edition, 2004.

A book covering relevant basic chemical concepts:
- C.V.A. Duke and C.D. Williams, Chemistry for Environmental and Earth Sciences. Cambridge University Press, 2008.
Rockstrom et al., "Planetary Boundaries: Exploring the Safe Operating Space for Humanity" Steffen, "How defining Planetary Boundaries can Transform our Approach to Growth"
Atmospheric chemistry and Physics : Seinfeld & Pandis ., John wiley & sons
Trace elements in the Terrestrial Env (D C Adriano) Springer –Verlag)
Environmental science, technology, and chemistry: Manahan, S: CRC

Course Code: EES-745 **Credit 4(3-0-1)**
Course Title: Water & Wastewater Treatment

Unit-I

Characterization of water and wastewater: Key factors for Water Analysis such as selection of parameters, sampling, preservation etc., Characteristics of water: Physical, chemical and biological.

Wastewater treatment concepts; pretreatment, primary treatment, secondary treatment, tertiary treatment.

Unit-II

Physicochemical unit operations: screening, grit removal, equalization, sedimentation. Filtration: Slow and rapid gravity filter, Membrane filtration. Disinfection: theory and application of chlorine. Coagulation and Flocculation for water treatment. Adsorption.

Unit-III

Aerobic unit operations for organic carbon removal such as activated sludge, trickling filter, Constructed wetland systems. Anaerobic operations for organic carbon removal (UASB). Sequencing Batch Reactor. Biological Nutrients (nitrogen and phosphorus) removal.

Unit-IV

Tricking filters classification, Design parameters, NRC formula, Recirculation in tricking filter merits and demerits, Operation problem encountered in tricking filters and Corresponding remedial measures. Theory and Design of Rotatory biological contactors**.**

Suggested readings

1. Metcalf and Eddy (2003) *Wastewater Engineering: Treatment and Reuse*, (4th Edition), Tata McGraw-Hills Comp. Inc., New York.
2. Qasim, S.R., Motley, E.M., Zhu, G. (2000) *Water Works Engineering: Planning Design and Operation*, Prentice Hall, New Jersey.
3. Birde, G.S., Birde, J.S. (2004) *Water Supply and sanitary Engineering*, 7th Ed., Dhanpat Rai Publishing, New Delhi.
4. Viessman, W., Hammer, M.J., Perez, E.M., Chadik, P.A. (2009) *Water supply and pollution Control*, PHI learning Pvt. Ltd., New Delhi.
5. Hammer, M.J., Hammer, M.J. Jr. (2008) *Water and wastewater Technology*. 6th Ed. PHI learning Pvt. Ltd., New Delhi.
6. Punmia, B.C., Jain, A. (2005) *Environmental Engineering.* Laksmi Pub. Pvt. Ltd, New Delhi.
7. Davis, M. (2010) *Water and Wastewater Engineering*. McGraw Hills, New York.
8. Fair, Geyer,Okun's Water and Wastewater Engineering: Water Supply and Wastewater Removal

(2010) (3rd Edition). John Wiley and Sons, New York.

Journals

Water Research - Elsevier

Water Science & Technology - IWA *Water Science & Engineering*

Water Practice & Technology - IWA

Journal of Water, Sanitation and Hygiene for Development - IWA *Applied Water Science* - Springer

Ecological Engineering - Elsevier

Course Code: EES-750 **Credit 4(3-0-1)**
Course Title: Freshwater System and Processes

Unit 1: Introduction: Definition, scope, and history, types of freshwater bodies lentic, lotic; Physicochemical properties of water; Morphometry and water movement; Light in water; Heat budget of water bodies; Oxygen and other dissolved gases; Sediments, Sediment-water interface and redox potential; Nitrogen in water; Phosphorus, Sulphur, Calcium and other nutrients; Heavy metals and organic compounds in water

Unit 2: Life in water: Life forms and adaptations, Microbiology of freshwaters; Primary and Secondary production, Production Processes and factors influencing them; Food-chain dynamics and energetic; Detritus and Carbon cycle; land-water interaction

Unit 3: Chemical processes in the aquatic environment : Chemical nature of water; sources, pathways and reservoirs of contaminants in aquatic systems. organic chemicals in aquatic systems, specific groups and their fate in water bodies, impact on aquatic biota. Analytical methodologies for chemical speciation studies,. Radionuclides in the aquatic environment.
Unit 4: Applied Limnology: Water Pollution, Eutrophication; Wastewater treatment and techniques, Water quality management and modeling; Water quality standards; Methods of water and waste-water analysis.

Unit 5:Water Quality Modeling: River hydrology,surface water pollutants,Physical laws and their use in modeling; Surface Water Quality Modeling:water quality in rivers, estuaries and lakes, measurements and evaluation of DO and BOD in rivers, Eutrophication process and basic mechanisms and its significance in surface water; Water Quality Model Equations**:** Model set-up, calibration, and validation procedures, selection, Case studies, Application of water quality model; Oxygen Sag Model.

Suggested Readings:

1. Limnology: Lake and River Ecosystems. Wetzel, R.G.,. Academic Press,.
2. Introduction to Limnology: Dodson, Stanley; McGraw Hill.
3. The Biology of Streams and Rivers. Giller, Paul & Bjorn Malmqvist. Oxford University Press.
4. Introduction Environmental Engineering ans Science. Gilbert M. Masters
5. Chemical and Biological Regulation of Aquatic Systems, J. Buffle and Richard R DeVitre
6. Surface Water Quality Modelling: Steven C. Chapra, Waveland Press.

Course Code: EES-755 **Credit 4(3-0-1)**
Course Title: Nanomaterials: Properties, Synthesis, Characterization and Applications

Unit I. Properties at Nanoscale
Comparison of properties at bulk and Nano - Nanomaterials – nanostructures, chemical and physical properties- surface-to-volume ratio, density of states - Quantum confinement and Bohr exciton radius - Quantum size effects, electrical, optical & magnetic properties. Origin of Surface Plasmon resonance in metallic nanoparticles – Absorption and emission properties of semiconductor nanocrystals. Carbon-based nanomaterials.

Unit II. Nanomaterials by Physical and Chemical Methods
Top-down and bottom up approaches - Physical methods: Inert gas condensation – Arc discharge sputtering - Laser ablation. Chemical methods: reduction-precipitation – hydrothermal solvothermal processes - sol-gel, micelle and micro emulsions – thermolysis - chemical vapor deposition methods - electrochemical synthesis - chemical modification of nanomaterials –functionalization.

Unit III. Green Synthesis of Nanomaterials
General approach for green synthesis – principles - Green synthesis of metals and alloys – use of natural resources and biosynthesis of nanomaterials. Microwave synthesis of nanomaterials.

Unit IV. Structural and Morphological Characterization
Powder XRD and crystallite size–light scattering and particle size – surface area and porosity – UV and IR studies. Microscopy techniques - Scanning Electron Microscopy (SEM) – Transmission Electron Microscopy (TEM) – Scanning Tunneling Microscopy (STM) - Atomic Force Microscopy (AFM) – Principle and analysis.

Unit V. Applications of Nanomaterials and Societal Implications
Nanomaterials and Nanotechnology General Applications – green technology and green energy applications - Industrial manufacturing, materials and products, medicine and clean environment -implications for philosophy, ethics and society.

References:
1. Guozhong Cao, Nanostructures and Nanomaterials, Imperial College Press, 2004, London.
2. Charles P. Poole, Frank J. Owens, Introduction to Nanotechnology, A John Wiley & Sons, inc.
3. Pradeep T., Nano:The Essentials: Understanding Nanoscience and Nanotechnology, Tata McGraw-Hill Publishing Company Limited, New Delhi,2008.
4. Rao C.N.R, Müller, Cheetham, The Chemistry of Nanomaterials, Vol 1 and 2, Wiley-VCH VerlagGmBH& Co., Weinheim, 2004.
5. Nanotechnology: assessment and perspectives, H. Brune et al., New York, Springer, 2006.
6. Nano-hype: the truth behind the nanotechnology buzz, David M. Berube; Amherst, N.Y., Prometheus Books,2006.
7. Edelstin A.S. and CammarataR.C..Nanomaterials: Synthesis, Properties and applications, Institute of Physics Publishing 1996.
8. M.C. Roco and W.S Bainbridge, Nanotechnology: Societal Implications II – individual Perspectives, Springer publishers, sponsored by National Science Foundation, Netherlands.

Course Code: EES-760 **Credit 4(3-0-1)**
Course Title: Air Pollution & Its Control

Unit 1: Air pollutants, their sources and harmful effects and on the environment: Meteorology as applied to air

pollution and dispersion of air pollutants; Atmospheric physics and air quality; Mobile air pollution sources, Indoor air quality

Unit 2: Air quality and emission standards (India and international); Combustion fundamentals (Stoichiometry, thermodynamics, Kinetics);

Unit 3: Lapse Rate, Plume Behaviour, and Air Quality Monitoring, Air Quality Index (AQI) , Air Quality Modelling, Gaussian dispersion models: point, line and area source models, Emissions Inventory: Transport, Industrial, Agricultural, Residential and Commercial sectors

Unit4: Air pollution legislation; Methods for monitoring and control; Indian policy and programme for air quality management (NAMP, NCAP, Urban forestry),

Unit 5: Selection of control equipments, Engineering control concepts; Process change, Fuel change, Pollutant removal and disposal of pollutants; control devices and systems (Fabrications, cyclones, Electrostatic precipitation, wet and dry scrubbing, Condensation, flare processes, thermal and catalytic oxidation, other emerging air pollution control devices etc), Removal of dry particulate matter, liquid droplets and mist removal, gaseous pollutants and odor removal. Control of stationary and mobile sources; optimal air pollution control strategies.

Suggested Readings:

1. Introduction to Environmental Engineeringand science (Third edition): Masters & Ela (PHI)
2. Atmospheric chemistry and Physics: Seinfeld & Pandis ., John wiley & sons
3. Introduction to aerosol science, P C Reist (Macmillan pub)
4. Environmental science, technology, and chemistry: Manahan, S: CRC
5. Chemistry of the upper & Lower Atmosphere: Pitts & pitts., Academic press

EES 765: Disaster Management Credits 4 (3-1-0)

Unit 1: Introduction to Disasters: Concepts and definitions (disaster, hazard, vulnerability, and resilience risks), disaster: classification, causes, impacts (including social, economic, political, environmental, health, psychological, etc.) differential impacts- in terms of caste, class, gender, age location, disability. Global trends in disaster, urban disaster, pandemics, complex emergencies, climate change.

Unit 2 Approaches to Disaster Risk Reduction Disaster cycle- its analysis, phases, culture of safety, prevention, mitigation and preparedness, community bases DRR, structural- non-structural measures, roles and responsibilities of community, Panchayati Raj Institutions/ urban local bodies (PRIs/ULBs). States, centre, and other stake holders.

Unit 3: Inter-Relationships between Disasters and Development Factors affecting vulnerabilities, differential impacts, impact of developmental projects such as dams, embankments, changes in landslides, etc. climate change adaptation, relevance of indigenous knowledge, appropriate technology and local recourses.

Unit 4: Disaster Risk Management in India Hazards and vulnerability profile of India, components of disasters relief: water, food, sanitation, shelter, health, waste management. Institutional arrangements (mitigation, response and preparedness, DM Act and policy, other related policies, plans programmes and legislation) Preparation of onsite and off-site disaster management Plans, Pre-disaster, Actual disaster, Post-disaster relief camp organization, Role of voluntary organizations and Armed Forces, Mitigating natural disasters through preparedness measures. Community based Disaster Management Post Disaster Survival University/School Disaster Management Disaster Management Act Institutional Arrangement for disaster Management and Mitigation, Technology intervention for disaster Management Disaster Management in Himalayas Incident command system for disaster management Table

top simulation exercise for disaster management Case study on forest fire.

Unit 5: Training and Capacity Building Using Disaster Management Games; Games to connect culture and disasters**;** an initial approach to a decision-making support for disaster managers interacting across cultural boundaries, Table top simulation exercise; for policy planning and implementation, Communication exercise for better coordination during disaster. The Telephone game allows improving the communication flow in early warning systems, Basic skill development; for rescue operation by the first responders during golden hours, Flood Preparedness Simulation**;** game helps identify the actions that can be taken by local communities in response to a flood risk in their neighborhood. Evacuation challenge game, Formation of Self-Help group and community mapping; Conduct of gaming workshop, Cultural memory game, The climate and gender game, About that forest, Lords of the valley, Ready, Stop disasters and Earth Quake awareness ludo etc.

Suggested Readings

1. Krynine, D.S. and Judd, W.R. (1998) Principles of Engineering Geology, CBS, New Delhi.
2. Smith, K. (1992) Environmental Hazards, Routledge, London.
3. Bell, F.G. (1999) Geological Hazards, Routledge, London.
4. Bryant, E. (1985) Natural Hazards, Cambridge University Press. London.
5. Nagarajan, R. (2001) Lanslide Disaster – Assessment and Monitoring, Anmol Publications, New Delhi. 6. Cutter, Susan L. (1999) Environmental risks and hazards, Prentice Hall of India, New.
7. V. Clerveaux, B. Spence, T. Katada- Using game technique as a strategy in promoting disaster awareness in caribbean multicultural societies: the disaster awareness game, J. Disaster Res., 3 (5) (2008), p. 2008.
8. K. Yamori,-Disaster risk sense in Japan and gaming approach to risk communication**,** Int. J. Mass Emergencies Disaster, 25 (2) (2007).
9. K. Yamori. Narrative mode of thought in disaster damage reduction. a crossroad for narrative and gaming approaches, in: T. Sugiman, K. Gergen, W. Wagner, Y. Yamada (Eds.) *Meaning in action: constructions, narratives and representations*, Springer: Tokyo 2008, pp. 241–252, https://doi.org/10.1007/978-4-431-74680-5_14.
10. C. Bachofen, P. Suarez, M. Steenbergen, N. Grist- Can games help people manage the climate risks they face? The participatory design of educational games, Red Cross Red Crescent Climate Centre (2012)
11. O. Barreteau, C. Le Page, P. Perez- Contribution of simulation and gaming to natural resource management issues: an introduction, Simul. Gaming: Interdiscip. J., 38 (2007), pp. 185-194
12. Ł. Jarząbek, How game can help flood-prone communities, 2016. 〈https://games4sustainability.org/2016/08/18/flood-resilience-game-for-flood-prone-communities/〉(Accessed online in October 2017).
13. A. Keating. Playing at flood resilience: using games to help vulnerable communities. 〈http://blog.iiasa.ac.at/2016/08/03/playing-at-flood-resilience-using-games-to-help-vulnerable-communities/〉 (Accessed online in October 2017).
14. N. Keung, 'Dissolving Disasters' in Madagascar: Climate games for a vulnerable nation, Climate Centre, Madagascar', 2017.
15. C. Macklin, Ready! Lessons in the design of humanitarian game, Red Cross Red Crescent Climate Centre, 2014, Working Paper Series No. 3.
16. J. Mendler de Suarez, P. Suarez, C. Bachofen-Games for a New Climate: Experiencing the Complexity of Future Risks, Boston University Frederick S. Pardee Center for the Study of the Longer-Range Future, Boston (2012)
17. D. Rumore, T. Schenk, L. Susskind-Role-play simulations for climate change adaptation education and engagement, Nat. Clim. Change, 6 (2016), pp. 745-750

EES-770: Solid & Hazardous Waste Management Credits 4 (2-1-1)

Unit 1: Introduction: Solid waste: Sources and types of solid wastes, material flow and waste generation in a technological society, factors affecting the generation rates. Municipal solid waste (MSW)**:** physical and chemical composition, factors affecting MSW quality and quantity, hierarchy of waste management options, RCRA, integrated solid waste management concept. R3 strategy, Overview of solid waste generation and management practices in India. Legal framework for handling and storage of municipal, medical and hazards wastes in India.

Unit 2: Waste Storage, Collection and transportation: Storage: movable bins, fixed bins. MSW Collection: home to home collection, community bin system. Container system, stationary container system, Transfer and transport, processing, waste transportation system, waste: separators, size reduction equipment, screening equipment, Material recovery facility. Electronic waste and construction/demolition waste – storage and treatment options. Waste disposal system and health and pollution issues with waste handling and disposal system.

Unit 3: Waste recycling and waste-to –energy – Waste recycling - role of formal and informal sector, community waste recycling; resource derived fuels (RDF)- concept, processing, application and limitations, waste-to-energy, waste calorific value assessment, Thermal conversion technologies: incineration and pyrolysis system, energy recovery, system, technologies-gasification, pyrolysis, biogas, fuel from wastes and char; limitation and health issues. Composting and vermicomposting –, types of composting, process description, design and operational consideration composting. Anaerobic digestion – process description, design and operational consideration of. Land-filling: Site selection criteria, landfill layout, landfill sections, Occurrence of gases and, leachate in landfills: composition and characteristics, operation control, gas control and utilization, flaring system. Incinerator technology– concept, engineering and applications, incinerator system for MSW, thermal processing system, unit operations, fuel gas controlling, air pollution control in incineration, residual management, legal, political and social issues with incineration technology.

Unit 4: Hazardous Waste management: Hazardous wastes, types, sources, composition and classification. Storage- onsite and offsite storage, hazardous waste transportation, International trade/export/ import of hazards waste, Basel Convention, hazardous waste treatment methods- criteria for treatment selection, land disposal, combustion, solidification. Medical waste storage and treatment, residues management in hazardous waste treatment.

Unit 5: Case Studies: Waste recycling operations in industrial sectors, Waste Incineration systems, Pilot projects of MSW biogas plants, Pilot projects of Recycling operation, Impact of COVID-19 on Waste management and Material recycling sectors, Global Waste Outlook, Pilot scale Sanitary Landfill Practices, Rural-scale waste biogas plants, Waste Biochar preparations, process and applications- case studies, Hazardous waste handling and management in India-Case study, Role of Informal Waste sector in Waste operation in India and worldwide.

Suggested Readings

1. EPA, 1995. *Decision-Makers' Guide to Solid Waste Management*, Vol-I & II. US EPA, Washington, D.C.
2. FAO 2003. On-farm Composting Methods. FAO, Rome.
3. *Guidelines for Management and Handling of Hazardous wastes* MOEF (1991), Govt. of India.
4. Kaily, G. 19997. *Environmental Engineering*. The McGraw-Hill Companies, New York, NY.
5. Liu, D.H.F., and Liptak, 2000. B.G. *Hazardous Waste and Solid Waste*, Lewis Publishers, Boca raton, FL.
6. Pichetel, J. 2005. *Waste management Practices – Municipal, Hazardous, and Industrial*. Taylor and Francis, Boca Raton, USA. 659 pp.
7. Reinhart, D.R., and Townsend, T.G. 19997. *Landfill Bioreactor Design and Operations*. Lewis Publishers, New York, NY.
8. Tchobanoglous, G., and Kreith, F. 2002. *Handbook of Solid Waste Management.* McGraw Hill, New York.

9. Tchobanoglous, G., Theisen, H., and Vigil, S.A; *Integrated Solid Waste Management*: McGraw Hill, New York.
10. UNEP, 2009. *Developing Integrated Solid Waste Management Plan Training Manual*. UNDP, IETC, Okasa, Japan.
11. Wang, L.K., Shammas, N.K. and Hung, Y.T. 2008. *Biosolids Engineering and Management*. Humana Press, Totowa, NJ, USA.
12. Waste Management "*Asian and Pacific Center for Transfer of Technology* (N.D.) India", September 1993.

Journals

Waste Management (Elsevier)
Waste Management & Research (Sage Publications)
Compost Science & Utilizations (Taylor & Francis)
International Journal of Environment and Waste Management (Inderscince, UK)
Journal of Waste Management (Hindwai)
Journal of Material Recycling and Waste Management (Springer)
Journal of Hazardous Materials (Elsevier)
Bioresource Technology (Elsevier)
Waste& Biomass **Valorization** (Springer**)**
Journal of the Air & Waste Management Association