School of Earth Science Systems

Department of Environmental Science

PhD Programme - Coursework

Programme Structure

(Applicable for 2020 batch onwards)

Ph.D Environmental Science Course Work Programme Structure

Course Code	Title	L	T	P	Credits
Course 1	Research Methodology	3	1	0	4
Course 2	*Research and Publication Ethics*	1	1	0	2
Course 3	Course from Basket 1 (Courses related to specific area of research)	3	1	0	4
Course 4	Courses related to specific research proposal	2	2	2	6

Programme Outcomes

After the successful completion of Ph. D. course in Environmental Science, the students will acquire the following:

(i) The ability to critically think and instil scientific temper to objectively carry out one's research without bias but with a clear mind.

(ii)Necessary skills to understand problems, prepare a hypothesis methodically, assessment and analysis of the results, and reach a solid conclusion that follows the premise of the research question logically.

(iii) To efficiently communicate the modern advances in science and address the drawbacks of the findings after comprehensive analysis of the available literature.

(iv) Scheme and undertake authentic investigation to address the necessary questions in a specific topic of Environmental Science and similar subject areas.

(v) Undertake postdoctoral research and/or professions in industrial or academic origin.

(vi) Articulating philosophical underpinnings of scientific and technical research orally and on paper.

(vii) Up-to-date information, knowledge and hands-on skills adequate for employment that can set an example in scientific and technical ethics.

(viii) Basic awareness as a responsible citizen who has compassion and empathy to carry out their duties within the jurisdiction of conferred rights and entitlements.

Programme Specific Outcomes

The Environmental Science Department's Ph.D. program would enable the students the following when they are conferred their Ph.D. Degree:

(i) Mastery of theoretical and applied knowledge in environmental science and related fields.

(ii) Discern, and methodically create solutions to rising environmental problems.

(iii) Understand, sketch and evolve low cost solutions plaguing the global society.

(iv) A comprehensive knowledge about employment, moral, law, safety and larger issues with one's responsibilities towards them.

(v) Articulating and working together with various stakeholders in an environmental context when formulating a viable solution to an environmental problem.

(vi) Expertise on statistical, mathematical, chemical and experimental basics for formulating viable designs to complex environmental problems such as climate change, air pollution, water pollution, soil pollution and ecological risks.

Course Code	*Course 1*		
Course Title	*Research Methodology*		
Credits	4	Type	Core

Course Description

Research methodology is a course designed to inculcate research skill and an understanding of various aspects of research.

Course Objectives:

(i) The course aims to give theoretical and practical knowledge for the methodical creation of reasonable research questions.

(ii) And also to draw up and perform logical research

Course outcomes:

1. Mastery in: (i) discerning the research problem (ii) formulating the research question and hypothesis (iii) developing a viable research design (iv) sample and/or data collection (iv) practical laboratory work and experimentation.

2. Development of specific skills in (v) sample collection design (vi) conceptualizing research results (vii) adequate representation of data (vii) interpretation of experimental data and results

. 3. Proficiency gain in: (viii) articulating research results in writing and presentation.

Course Structure

The syllabus of the course is given in detail below:

Unit I – Research Hypothesis and Experimental design

Literature Review and its importance, Research questions and objectives and methodology. Hypothesis - Null Hypothesis and Alternative Hypothesis. Hypothesis Testing; Logic and Importance; Research design - Exploratory Research Design and concept, types and uses; Descriptive Research Designs and concept, types and uses; Experimental Design, concept of Independent and Dependent variables, types and uses; Population and sampling design in environmental research.

Unit II – Data Collection and Analysis

Collection, classification, tabulation and diagrammatic representation of data; Measures of central tendency and dispersion; Normal, Poisson and Binominal Distributions; Tests of significance, error level of significance; Regression and Correlationanalysis, simple and multiple; t-test,z-test, ANOVA, Chi-square; Cluster analysis – PCA

Unit III – Environmental Informatics

Environmental modelling – systemidentification theory and practice, model conception, model integration and evaluation; Decision support systems and environmental information systems; Modeling environmental dynamics; Environmental prediction and assessment modeling, Ecological modeling; Sustainability and climate change modeling.

Unit IV: Laboratory Techniques for Environmental Samples

Environmental sampling techniques - Water, Air, and Soil - Quality and Quantitative Analysis. Instrumentation - concept and principle - Volumetric, gravimetric and potentiometric analysis. Good laboratory practice and Laboratory safety.

Testing & Evaluation

- Seminar
- Assignment
- Written Exam

References:

1. Khan, L.A. and Kanum, A. (1994) Fundamentals of Biostatistics, Ukaaz Publication, Hyderabad.
2. Gupta, S.P. (1996) Statistical Methods, Sultan Chand & Sons Publications, New Delhi.
3. Miller, J. (1989) Statistics for Advanced Level, Cambridge University Press, Cambridge.
4. Kothari, C.R. (2004) Research Methodology – Methods and Techniques, New Age Publishers, New Delhi
5. Haynes, R. (1982) Environmental Science Methods, Chapman & Hall, London.
6. Garg, B.L., Karadia, R., Agarwal, F. and Agarwal, U.K. (2002) An introduction to Research Methodology, RBSA Publishers, Rajasthan.
7. Down, R.D. and Lehr, J.H. (2004) Environmental Instrumentation and Analysis Handbook, John Wiley & Sons, Inc., New Jersey, United States.
8. Dunnivant, F.M. (2004) Environmental laboratory exercises for instrumental analysis and environmental chemistry, John Wiley & Sons, Inc., New Jersey, United States

Course Code	*Course 2*		
Course Title	*Research and Publication Ethics*		
Credits	4	Type	Core

Course Description

Research ethics course concentrates on philosophy of science, ethics required for research integrity and publication. It also consists of training to point out misconduct in research and to identify predatory publications. The course also delves into topics of indexing/citation databases, open access publications, research metrics (citations, h-index, impact factor, etc.) and tools used to find out plagiarism.

Course Objectives:

(i) The course aims to create awareness about the misconducts in research and publication, ethical standards to be followed by researchers for research integrity.

(ii) And to impart knowledge on indexing, research metrics and plagiarism.

Course Outcome

Upon the completion of the course, students are expected to gain the following outcomes:

1. Mastery in: (i) research ethics and philosophy (ii) ethical conduct and scientific temper (iii) misconducts in publication of scientific work and ethical standards to follow (iv) tools used by researchers, databases available and various types of research metrics.

2. Development of necessary skills in: (v) the identification of research misconduct and predatory publications

3. Proficiency gain in: (vi) research ethics and standards to follow for fruitful scientific investigation

Course Structure

The syllabus of the course is given in detail below:

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

misrepresentation of data.

Unit 03: PUBLICATION ETHICS (7 hrs.)

Publication ethics: definition, introduction and importance. Best practices/ standards setting initiatives and guidelines: COPE, WAME, etc. Conflicts of interest. Publication misconduct: definition, concept, problems that lead to unethical behaviour and vice versa, types. Violation of publication ethics, authorship and contributorship. Identification of publication misconduct, complaints and appeals. Predatory publishers and journals

Unit 04: OPEN ACCESS PUBLISHING (4 hrs.)

Open access publications and initiatives. SHERPA/RoMEO online resource to check publisher copyright and self-archiving policies. Software tool to identify predatory publications developed by SPPU. Journal finder /journal suggestion tools viz. JANE, Elsevier Journal finder, Springer
Journal suggested., etc

Unit 05: PUBLICATION MISCONDUCT (4 hrs)

A. Group Discussions (2 hrs.)

Subject specific ethical issues, FFP, authorship, Conflicts of interest, 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

Unit 06 : DATABASES AND RESEARCH METRICS (7 hrs .)

A. Databases (4 hrs.)

Indexing databases, Citation databases: Web of Science, Scopus, etc

B. Research Metrics (3 hrs)

Impact Factor of journal Citation report, SNIP, SJR, IPP, Cite Score. Metrics: h-index, g index, i10 index, altmetrics.

Testing & Evaluation

- Seminar
- Assignment
- Written Exam

References

Bird, A (2006), *Philosophy of Science* .Routledge
Maclntyre,Alasdair (1967) *A short History of Ethics* . London
P . Chaddah, (2018) Ethics in Competitive Research : Do not get scooped : do not get plagiarized. ISBN : 978-9387480865
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.Reteieved from https://www.niehs.nih.gov/research/resources/bioethics/whatis/index.cfm
Bealll,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,
https://www.insaindia.res.in/pdf/Ethics_Book.pdf

Course Code	*Course 3*		
Course Title	**Oxidation techniques for Water Management**		
Credits	4	Type	Core

Course Description

The course concentrates on the importance of the application of oxidation techniques for water management. The course assists in instilling awareness about water recovery and wastewater remediation using oxidation techniques for the removals of organic contaminants and microbes without sludge production. This course focuses on identifying the specific oxidation techniques applicable for a particular type of water and wastewater, taking into consideration the cost-benefit scenario and the type of pollutants present in the water or wastewater source.

Course Outcome

Upon completion of the course, the students are anticipated to be capable of:

- Discerning various aspects of water quality standards, techniques, principles and their significance to mitigate the harmful effects of pollutants in water and wastewater.
- Making out the fundamentals of Electrochemistry, its basic concepts, various types of techniques in use and their significance to wastewater remediation and pollutant removals from water.
- Applying electrochemical techniques in varying conditions of water and wastewater environment by identification and preparation of electrodes for electro-oxidation and eletro-coagulation.
- Analysing the various fundamentals of Ozone chemistry, ozone reactivity and ozone generation for remediation purposes.
- Understanding the nuances of various Advanced Oxidation Processes including but not restricted to Ultra-violet Radiation, Hydrogen peroxide and Photo Catalysis; the analysis of degradation and mineralization using various chromatographic and spectroscopic techniques.

Course Structure

The syllabus of the course is given in detail below:

Unit I

Water quality standards- sampling, preservation techniques for water and wastewater, Basic Principles and their significance with special reference to colour, turbidity , alkalinity, acidity, chemical coagulation, hardness, water softening, BOD, COD, Nitrogen, Phosphate and Sulphate.

Unit II

Fundamentals of Electrochemistry; Basic concepts – Galvanic Cells- Standard Potentials- The Nernst Equation – Reference Electrodes – Indicator Electrodes – Ion selective electrodes – Polarography in chemical analysis – Cyclic Voltammetry.

Unit III

Electrochemical Techniques, Types of Electrodes, Preparation of Electrodes- Electro Oxidation – Titanium Electrodes – Graphite Electrodes – Triple Oxide coated Electrodes- Boron Doped Diamond Electrodes- Evolution of Chlorine, Oxygen and Ozone during electrolysis, Mechanisms of oxidation of organic compounds by chlorine, oxygen and ozone . Electro Coagulation – Iron Electrodes – Aluminium Electrodes – Kinetics and Mechanisms of Reactions.

Unit IV

Fundamental aspects of Ozone Chemistry- Molecular Ozone Reactivity- Decomposition of Ozone- Ozone Measurements in the Aqueous Phase (Ozone Residual) – Gas Phase Measurements – Ozone Generation – By Corona Discharge – Alternative Methods- Ozone Gas Transfer – Solubility of Ozone in Water – Contacting of Ozone with water.

Unit V

Advanced Oxidation Process; Ultra-Violet Radiation, Hydrogen Peroxide – Titanium Oxides – Photo catalysis – Chlorination- Analysis of the products by UV-Visible Spectroscopy, FTIR, AAS, HPLC, GC-MS-Mechanisms of Mineralization.

Testing & Evaluation

- Seminar
- Assignment
- Written Exam

REFERENCE:

1. Ozone in Water Treatment Application and Engineering. Bruno Langlias, D.A. Reckhow and D.R. Brink, (1997) Lewis Publishers, USA.

2. Ozone and its Reactions with Organic Compounds. S.D. Razumovskii and G.E. Zaikov, (1984) Elsevier science publishers, The Netherlands.

3. Quantitative Chemical Analysis. Daniel C. Harris, W.H. (1995) Freeman and Company, New York.

4. Handbook of Analytical Instruments. R.S. Khandpur, (2000) Tata McGraw-Hill Publishing Company, Limited, New Delhi.

Course Code	*Course 3*		
Course Title	**BIODIVERSITY AND CONSERVATION**		
Credits	4	Type	Core

Course Description

This course has been designed to introduce the students to the concepts of biodiversity, its components such as ecosystem, species and genetic diversity, pattern of global diversity with special focus on Western Ghats.The course provides students with essential knowledge and values of biodiversity, anthropogenic effects on biodiversity and the importance of conserving the biodiversity through sustainable management practices. This course also introduces the concept ofextinction, threatened organisms, conservation organizations and various conservation practices that will be help them to understand the importance of environmental protection.

Course Outcome

Upon completion of the course, the students are anticipated to be capable of:

- Understanding the fundamental concepts of biodiversity and conservation
- Understanding the major threats to biological diversity, as well as the ability to assess the effects of human influences on biodiversity, such as global warming and climate change, environmental pollution, etc...
- Applying various theoretical models, tools, and techniques to develop strategies and methods for current conservation issues
- Understanding the IUCN Red List Category and Criteria Guidelines.
- Understanding biodiversity values, including methods for valuing biodiversity and their relevance for management of natural resources and a sustainable development
- Understanding the foundations of environmental ethics and apply them to current issues.

Course Structure

The syllabus of the course is given in detail below:

UNIT I

Biological Diversity: Species – Origin of new species, Community and ecosystem diversity, Genetic diversity, Systematics in Diversity – Environment and Genetic Variations – Biological Classification – Phylogenetic Relationship – Ecological Biodiversity –Species Concept – Biological and Phylogenetic Concepts; Species Inventory – Biodiversity hot spots. IUCN categories– Red data book.

UNIT II

Species Diversity – Global Distribution of Species - Tropical species diversity – Diversity in terrestrial, marine and freshwater –Micro-organisms-lower and higher plants – lower and higher invertebrates and vertebrates; Species extinction and Endangered species; Monitoring indicator

species and habitats; Threats to biodiversity: Extinction – Past rate of Extinction – Human Caused Extinctions – Endemic species - Extinction rates - Man and animal conflicts.

UNIT III

Habitats and Ecosystem – Classification – Ecosystem mapping, tropical forests, grasslands, wetlands, coral reefs, mangroves; Habitat lass: Habitat destruction – Fragmentation and degradation – desertification, Green Revolution, Food Plants, medicinal and ornamental plants, animal uses – livestock and fisheries;

UNIT IV

Conservation and Management – National Legislation – Protection of Wild flora and Fauna - Protection of National Habitats - National and International Protected Areas – Current Practices in Conservation - in *situ* Conservation and *ex situ* Conservation of Threatened Species – Biodiversity Bill 2002 – Agenda 21 – Multilateral Treaties – Biodiversity Conventions.

UNIT V

Species Diversity – Case Studies – Deciduous Forests - Desert Lizard communities – Coral Reef - Fish Communities -Island species – Environmental ethics – Biodiversity – a Socio – Political Perspective – Western Ghats.

Testing & Evaluation

- Seminar
- Assignment
- Written Exam

REFERENCES:

1. Global Biodiversity – Status of the Earths Living Resources, Brian Groombridge (1992) Chapman & Hall, London.
2. Biodiversity, Science and Development, Francesco di castri (1996), Backhuys Publishers, The Netherlands.
3. The Biology of Biodiversity, Kato, M (1999), Springer Verlag, Tokyo
4. Biodiversity Conservation – In Managed forest and Protected areas, Kotwal, P.C. and S. Banerjee (2002). Agrobios, India.
5. Global Biodiversity, Sinha, R. K(1997), INA Shree Publishers, Jaipur.
6. Mega diversity Conservation, flora, Fauna and Medicinal Plants of India's hot spots, Chaudhuri, A. B. and D. D. Sarkar (2003), Daya Publishing House, Delhi.
7. Conservation of Biodiversity and Natural Resources. Singh, M.P., B.S. Singh and Soma S.

Dey (2004), Daya Publishing House, Delhi.

Course Code	*Course 3*		
Course Title	*Limnology*		
Credits	4	Type	Core

Course Description

The course outlines the different aspects of Limnology in 5 units. The unit 1 deals with the introductory aspects of Limnology. The Unit 2 emphasises on the various aspects of limnetic ecosystems. Unit 3 covers the biogeochemical cycles in the lakes and the aspects of microbial limnology and unit 4 deals with limnetic environmental problems. Unit 5 presents insights into sampling and analytical techniques used in limnology.

Course Outcome

At the end of the course, the participants are expected to be:

- Well versed with the different theoretical aspects of limnology
- Able to understand how to sample and analyse limnetic samples
- Able to understand and analyse the different environmental problems in the limnetic ecosystems

Course Structure

The syllabus of the course is given in detail below:

Unit I:

Introduction to limnology, Inland water: types, distribution, morphology, zonation. Hydrologic cycle. Origin of lakes, morphometry, thermal stratification, lake mixing. Limnetic ecosystem: physical and chemical features – Light, colour, temperature, pressure, density, buoyancy, movement of water, surface film, turbidity, pH, conductivity, dissolved and suspended matter: gases, solids, organic matter.

Unit II:

Limnetic ecosystems: biological features, diversity, ecology. Limnetic communities: phytoplanktons, zooplanktons, macrophytes, macrozoans, benthic communities, microorganisms. Productivity: primary and secondary productivity. Food chains and food webs, trophic interactions, positive and negative ecological interactions. Adaptations to limnetic environment.

Unit III:

Biogeochemical cycles in lakes: Carbon, Nitrogen, phosphorus, nutrient use and remineralization. Microbial limnology, diversity, ecology, aerobic and anaerobic microbial processes in water and in sediments of lakes, decomposers. Interaction of microbes with other communities of lakes.

Unit IV:

Limnetic environmental problems: eutrophication, acidification, pollution, toxic substances, invasive species – Causes, sources, effects on ecosystem, remediation processes. Biomonitoring, bioindicators, biomass utilization, Use of Duckweeds as a case study.

Unit V:

Sampling and analyses. Sampling techniques – types, requirements and procedures. Analytical methods and techniques – water quality testing, light microscopy, phase contrast microscopy, confocal microscopy, scanning electron microscopy, transmission electron microscopy, UV-VIS spectroscopy, atomic absorption spectroscopy, GC-MS, chromatographic techniques.

Testing & Evaluation

- Seminar
- Assignment
- Written Exam

REFERENCE:

1. Likens, G.E. 2009. Encyclopedia of Inland Waters. Amsterdam: Elsevier/Academic Press.

2. Wetzel, R.G. 2001. Limnology: Lake and River Ecosystems. Third Edition. Academic Press.

3. Khandpur, R.S. 2015. Handbook of analytical instruments, 3rd Edition. Mcgrawhill publishers.

4. Agrawal, S.C. 1999. Limnology. APH publishers.

5. Cole, G.A. 2015. Textbook of Limnology, 4 th edition. CBS publication.

6. Settle, F.A. 1997. Handbook of instrumental techniques for analytical chemistry. Prentice Hall publishers.

7. Cole, G.A. and Weihe, P. 2015. Textbook of Limnology, 5th edition. Waveland press.

8. Munshi, J.D. and Munshi, J.D. 2015. Fundamentals of Limnology. Astral publisher.

9. Wetzel, R.G. and Likens, G.E. 2000. Limnological analyses. Springer-Verlag.

Course Code	Course 3		
Course Title	ENVIRONMENTAL MICROBIOLOGY AND ENVIRONMENTAL BIOTECHNOLOGY		
Credits	6	Type	Core

Course Description

The objective of the course is to cover the important topics that comes under environmental toxicology, microbiology, biotechnology, genomics and statistical analysis which will be required for performing various analysis during the research work carried out by the scholar.

Course Outcome

In the end of the course scholar is expected to:

- Gain knowledge about various aspects of environmental toxicology, microbiology, biotechnology and genomics
- Learn how to use statistical analysis for the research work

Course Structure

The syllabus of the course is given in detail below:

Unit I: Environmental toxicology

Toxic chemicals in the environment - organic and inorganic toxicants. Acute and chronic toxic effects. Dose effect, dose response relationships. Toxicity of pesticides, herbicides, fertilizer, hydrocarbons, phenolic compounds, radioactive wastes. Translocation of xenobiotics.

Unit II: Environmental microbiology

Bioconcentration, bioaccumulation and biomagnification of toxicants. Biodegradation of xenobiotics, bioremediation of heavy metals, first generation and second generation biofuels. Impact of pollutants on microbial diversity in various ecosystems.

Unit III: Environmental biotechnology

Genetically modified organisms (GMO's), role of recombinant DNA technology in environmental sustainability, gene shuffling for remediation of xenobiotics.

Unit IV: Environmental genomics

Shortgun metagenomics, 16S rRNA sequencing, microbial whole genome sequencing - GC fraction, meta proteomics, proteogenomics, metatranscriptomics, partial genome sequencing – Gene finger printing techniques - RFLP, DGGE, RISA, RAPD, clone library method, real time PCR, FISH, DNA Microarrays.

Unit V: Statistical Analysis

Arithmatic mean, median, range, variance, standard deviation, standard error, confidence interval, regression, correlation, chi-square test, t-test, ANOVA, Tukey Kramer test, Bartlett's test

Testing and evaluation

- Continuous assessment for 40% will be carried out with internal assessment tests, seminars, assignments etc.
- End semester examination for 60% will be conducted at the end of the course work.

REFERENCE:

1. Cockerham L.G., Shane B.S. Basic Environmental Toxicology. Boca Raton, CRC Press, 1994.
2. Evano, G.H., Furlong, J.C. Environmental Biotechnology - Theory and Application. USA, John Wiley and Sons, 2004.
3. Kuhad R.C., Singh A. Biotechnology for Environmental Management and Resource Recovery. New York, Springer-Verlag, 2013.
4. Laws E.A. Environmental Toxicology: Selected entries from the encyclopedia of sustainability science and technology. New York, Springer-Verlag, 2013.
5. Madsen E.L. Environmental Microbiology: From Genomes to Biogeochemistry. Denmark, Wiley-Blackwell, 2008.
6. Maier R.M., Pepper I.L., Gerba C.P. Environmental Microbiology. California, Elsevier, 2009.
7. Martin C.C. Environmental Genomics. Totowa, NJ, USA, Humana Press, 2008.
8. Reimann C., Filzmoser P., Garett R., Dutter R. Statistical Data Analysis Explained. USA, Wiley, 2008.
9. Rose J. Environmental Toxicology Current Developments, Boca Raton, CRC Press, 2003.
10. Sangeetha J, Thangadurai D, David M, Abdullah MA. Environmental Biotechnology: Biodegradation, Bioremediation and Bioconversion of Xenobiotics for Sustainable Development, Canada, Apple Academic Press, 2016.
11. Thangadurai D, Sangeetha J. Biotechnology and Bioinformatics: Advances and Applications for Bioenergy, Bioremediation and Biopharmaceutical Research. Boca Raton, CRC Press, 2014.
12. Thangadurai D, Sangeetha J. Genomics and Proteomics: Principles, Technologies and Applications. Boca Raton, CRC Press, 2015.

Course Code	Course 3		
Course Title	ENVIRONMENTAL MICROBIOLOGY AND BIOTECHNOLOGY		
Credits	6	Type	Core

Course Description

The course covers the basic concepts of Environmental Microbiology, applied aspects of Environmental Biotechnology, Marine ecosystem and Extremophiles. The course presents an insight into the diverse roles, functions and applications of microbesin biotechnology.

Course Outcome

- Gain insight into the basics of microbiology.
- Apply the diverse uses and roles of microbes in their further study.
- Gain experience in environmental biotechnology and industrial applications for future prospects.

Course Structure

The syllabus of the course is given in detail below:

UNIT I: Fundamentals of Environmental Microbiology

Introduction - autotrophs and heterotrophs,cultivation of microorganisms, Microbial growth, factors affecting microbial growth,sampling techniques- air, water ad soil, bioconcentration, bioaccumulation and biomagnification, importance of microorganisms in environment, microbial mats and biofilms.

UNIT II: Environmental Biotechnology

Microbial diversity – culturable and non-culturable microorganisms- physiological and molecular methods, role of recombinant DNA technology in microbial ecology, genetically modified organisms, bioindicators, biosensors, environmental applications and implications of biotechnological tools.

UNIT III: Extremophiles

Extreme microbial habitats, extremophiles- acidophiles, alkaliphiles, halophiles, psychrophiles, thermophiles, barophiles, xerophiles, anaerobs, endoliths, hypoliths, osmophiles, radioresistant, biomolecules from extremophiles, applications of extremophiles in various aspects.

UNIT IV: Marine Ecosystem

Marine ecosystem- estuaries, rocky and sandy shores, continental shelf, pelagic zone, seabed, deep sea, seagrass meadows, coral reefs, mangrove forests- habitat and characteristics, ecological importance, impact on mangroves.

Testing and evaluation

- Continuous assessment for 40% will be carried out with internal assessment tests, seminars, assignments etc.
- End semester examination for 60% will be conducted at the end of the course work.

REFERENCE:

1. Evano, G.H., Furlong, J.C. Environmental Biotechnology- Theory and Application. USA, John Wiley and Sons, 2004.
2. Kuhad R.C., Singh A. Biotechnology for Environmental Management and Resouces Recovery. New York, Springer- Verlag, 2013.
3. Madsen E.L, Environmental Microbiology: From Genomics to Biochemistry. Denmark, Wiley-Blackwell, 2008.
4. Maier R. M., Pepper I. L., Gerba C. P. Environmental Microbiology. California, Elsevier, 2009.
5. Martin C.C. Environmental Genomics. Totowa, NJ, USA, Humana Press, 2008.
6. Sangeetha J, Thangadurai D, David M, Abdullah MA. Environmental biotechnology: Biodegradation, Bioremediation and Bioconversion of Xenobiotics for Sustainable Development, Canada, Apple Academic Press, 2016.
7. Thangadurai D, Sangeetha J. Biotechnology and Bioinformatics: Advanced and Applications for Bioenergy, Bioremediation and Biopharmaceutical Research. Boca Raton, CRC Press, 2008.
8. Durvasula R.V., Subba Rao D.V. Extremophiles: From Biology to Biotechnology. Boca Raton, CRC Press,2018.
9. Polunin V.C. Aquatic Ecosystems: Trends and Global Prospects. Cambridge, Cambridge University Press, 2008.
10. Kaiser M.J., Attrill M.J. Marine Ecology: Process, System and Impacts. Oxford, Oxford University Press, 2011.

Course Code	Course 3		
Course Title	SUSTAINABLE AGRICULTURE		
Credits	4	Type	Core

Course Description
Course provides introduction about sustainable agriculture and also covers other topics like soil health and nutrient management, water resource management and modern technologies in sustainable agriculture in order to provide better understanding of these topics to the scholar.

Course Outcome
By the end of the course research scholar will be to:

- Understand the various aspects of sustainable agriculture, their role and importance in the present scenario.
- Understand the management of natural resources like soil and water.
- Analyze the applications of biotechnology in sustainable agriculture and other modern technologies in agriculture.
- Analyze the importance of nanotechnology in agriculture.
- Able to implement the knowledge gained through the syllabus for research as well as social work.

Course Structure
The syllabus of the course is given in detail below:

Unit I: Introduction to Sustainable Agriculture
Overview of sustainable agriculture - definitions and goals, background, importance and need of sustainable agriculture, management of natural resources, economics of sustainable agriculture, indicators of sustainable agriculture, impact of weed, modernization of agriculture with reference to sustainability, factors affecting sustainable agriculture, National Mission for Sustainable Agriculture (NMSA), climate change and sustainable agriculture – agricultural practices to mitigate the climate change

Unit II: Soil Health and Nutrient Management
Soil fertility, micro and macro nutrients, organic matter, soil pH, soil moisture and aeration. Role of organic manures in soil health, integrated nutrient management, cropping rotations, soil conservation, nutrient cycles, impact of chemical pesticides and fertilizers on soil, biopesticides and bioherbicides – role, importance and commercialization

Unit III: Water Resource Management
Water resources of India and their utilization for irrigation, effect of water quality on soil and plants, water harvesting techniques, watershed management, irrigation – small scale and large scale irrigation systems, irrigation methods, drainage – importance and types of drainage systems, environmental concerns and water management practices in agriculture

Unit IV: Modern technologies in sustainable agriculture

Application of biotechnological tools in sustainable agriculture, seed enhancement technologies, green manures, biocontrol agents, vertical farming, farm automation, rainfed farming, live stock farming, precision agriculture, flood-based farming system, drought-proof farming system, artificial intelligence and nanotechnology in agriculture

Testing and evaluation

- Continuous assessment for 40% will be carried out with internal assessment tests, seminars, assignments etc.
- End semester examination for 60% will be conducted at the end of the course work.

REFERENCE:

1. Chatterjee, A., & Clay, D. (2016). Soil fertility management in agroecosystems, Madison, USA: American Society of Agronomy.
2. Coleman, D.C., Crossley, Jr. D.A., & Hendrix, P.F. (2004). Fundamentals of soil ecology (2nd ed.). Burlington, MA: Elsevier Academic Press.
3. Drinkwater, L.E., Friedman, D., & Buck, L. (2016). Systems research for agriculture: Innovative solutions to complex challenges, Brentwood, California: SARE Outreach Publications.
4. Gugino, B. K., Idowu, O.J., Schindelbeck, R.R., van Es, H.M., Moebius-Clune, B.N., Wolfe, D.W., Thies, J.E., &Abawi, G.S. (2009). Cornell soil health assessment training manual (2nd ed.). Ithaca: Cornell University.
5. Kumar, S. (2013). Modern technologies for sustainable agriculture, New Delhi, India: New India Publishing Agency.
6. Lichtfouse, E., Hamelin, M., Navarrete, M., &Debaeke, P. (2011). Sustainable Agriculture, Netherlands: Springer
7. Magdoff F., &Es, H.V. (2009). Building soils for better crops: Sustainable soil management (3rd ed.). Bretwood, California: SARE Outreach Publications.
8. Poonia, R.C., Gao, X-Z., Raja, L., Sharma, S., & Vyas, S. (2019). Smart farming technologies for sustainable agricultural development, Hershey, USA: IGI Global.
9. Reicosky, D. (2018). Managing soil health for sustainable agriculture: Monitoring and management, Cambridge, UK: Burleigh Dodds Science Publishing.

Course Code	Course 3		
Course Title	MARINE MICROBIOLOGY		
Credits	4	Type	Core

Course Description
Course provides introduction about marine microbiology especially on marine ecosystem, marine microbial ecology, downstream processing and instrumentation in order to provide better understanding of these topics and techniques to the scholar.

Course Outcome
By the end of the course the scholar will beable to:

- Understand the different types of marine ecosystem
- Understand the microbial life in marine environment and techniques to cultivate microbial organisms from marine sources.
- Gain knowledge on different processing technology and various instrumental techniques which are essential for the research work.
- Able to implement the knowledge gained through the syllabus for further research work.

Course Structure
The syllabus of the course is given in detail below:

Unit I: Marine Ecosystem
Estuary, shores, continental shelf, pelagic and benthic zones, deep sea, sea bed, seagrass meadows, mangrove forests, wetlands, coral reefs, sea lagoons; exclusive economic zone; biological productivity; marine protected areas; marine ecosystem services

Unit II: Marine Microbial Ecology
Marine prokaryotes and eukaryotes – cell structure and functions; marine extremophiles; microbial diversity – culturable - isolation of marine microorganisms - sample collection, culture media, inoculation techniques; non-culturable microorganisms - role of recombinant DNA technology; role of marine microorganisms – nutrient cycling and carbon sequestration; applications of marine microorganisms

Unit III: Marine Actinomycetes
Origin and distribution; sampling techniques for different marine environment; isolation and identification; molecular tools in the identification; marine physiological adaptations; hypersaline actinomycetes and its ecological importance

Unit IV: Downstream Processing and Instrumentation
Fermentation, downstream processing of bioactive compounds from actinomycetes - screening, extraction, purification and characterization of bioactive compounds, novel metabolites from actinomycetes, applications of metabolites in different sectors.

Chromatography, mass spectrometry, HPLC, NMR and FTIR for purification and identification of bioactive compounds.

Testing & Evaluation

- Continuous assessment for 40% will be carried out with internal assessment tests, seminars, assignments etc.
- End semester examination for 60% will be conducted at the end of the course work.

Reference Books

1. Evano, G.H., Furlong, J.C. (2004). Environmental biotechnology: Theory and application, Hoboken, New Jersey: John Wiley and Sons.
2. Kuhad, R.C., Singh, A. (2013). Biotechnology for environmental management and resource recovery. New York: Springer-Verlag.
3. Kim, S. (2013). Marine microbiology: Bioactive compounds and biotechnological applications, Hoboken, New Jersey: John Wiley and Sons.
4. Madsen, E.L. (2008). Environmental microbiology: From genomes to biogeochemistry, Denmark: Wiley-Blackwell.
5. Kim, S. (2015). Handbook of marine biotechnology, Berlin Heidelberg: Springer -Verlag.
6. Maier, R.M., Pepper, I.L., Gerba, C.P. (2009). Environmental microbiology. California: Elsevier.
7. Polunin, V.C. (2008). Aquatic ecosystems: Trends and global prospects. Cambridge: Cambridge University Press, 2008.
8. Kaiser, M.J., Attrill, M.J. (2011). Marine ecology: Process, systems and impacts. Oxford: Oxford University Press, 2011.

Course Code	*Course 3*		
Course Title	**Waste Management and Pollution Control**		
Credits	4	Type	Core

Course Description

The course focuses on the importance of having a waste recycling and management. The course helps to raise awareness of environmental issues including benefits of reducing, re-using, and recycling of general environmental waste materials. This course helps to identify items which can be recycled through a recycling management program with a special focus on plastic waste.

Course Outcome

By the end of the course, students are expected to be able to:

- The components of solid waste management infrastructure systems, to minimize these effects.
- Recycling, reuse and reclamation of solid wastes.
- Relationships between inappropriate waste management practices and impacts on water, soil and sediment quality.
- Current practices prominent in plastic waste management.
- Assessing environmental guidelines, human activities, and environmental quality due to waste pollution.
- Recovery of Waste and their future management.

Course Structure

The following is a detailed syllabus.

Unit I

Sustainable Waste Management

Waste Management Policies, Best practice Environmental risks and their management and control Managing Pollution in the Environment Understanding the Life Cycle of Waste.

Unit II

Waste Prevention with Special reference to Plastics

Introduction of Plastic pollution as a global problem today, plastic in ocean and impact on sea life and economy, best way to manage the plastic waste and how to mitigate the risk from plastic waste, Plastic Waste Management Rules, Waste management - state of the art technologies and best practices.

Unit III

Re-Use and Recycling of Waste

The role of Materials Recovery Facilities (MRFs) and transfer stations, the science of composting in Waste management, open windrow composting.

Unit IV

Waste Recovery

Waste recovery of Food waste, Good practice in the management of food waste. Waste incineration with energy recovery, energy from waste Incineration (EfW) EfW for municipal waste Landfill: Hazards and risks. Land waste disposal Principles of sustainable landfill in various countries Landfill: Engineering considerations Long-term storage of waste, the future of waste management.

Testing & Evaluation

- Class room MCQ assessment
- Take Home Test
- Seminar
- Assignment

References

1. Aarve, V. P., William, A. W. and Debra, R. R. (2002). Solid waste engineering. Cengage reading, USA.
2. Abbasi, S. A. (1998). Environmental Pollution and its Control. Cogent International, Pondicherry.
3. Abbasi, S. A. and Ramasamy, E. V. (1999). Biotechnological Methods of Pollution Control. Universities Press (India) Limited, Hyderabad.
4. Bhide, A. D. and Sundaresan, B. B. (2001). Solid Waste Management – Collection, Processing and disposal. Mudrashilpa Offset Printers, Nagpur.
5. Biomedical waste (Management and Handling) Rules, Ministry of Environment and Forestry (1998).
6. Charles, A. W. (1995). Hazardous waste management, Mc Graw-Hill.
7. George, T., Hilary, T. and Samuel, A. V. (1993). Integrated solid Waste Management, Engineering Principles and Management Issues, Mc Graw Hills.
8. George, T. and Frank, K. (2002). Handbook of solid waste management: (Second Edition). Mc Graw Hills.
9. Glynn, H. J., and Gary, W. H. (2004). Environmental Science and Engineering. Prentice Hall, India.
10. Kanthi, L. S. (2000). Basics of Solids and hazardous waste management Technologies. Prentice Hall.
11. Michael, D. L., Phillip, L. B. and Jeffrey C. E. (2001). Hazardous waste management. Mc Graw-Hill.
12. Scragg, A. (1999). Environmental Biotechnology, Addison Wesley Longman, Singapore.
13. Syed, E. H. (1996). Geology and Hazardous Waste Management. Prentice Hall.
14. Tammemagi, H. Y. (2000). The Waste Crisis: Landfills, Incinerators, and the Search for a Sustainable Future. Oxford University press.

Course Code	*Course 3*		
Course Title	**Energy and Environment**		
Credits	4	Type	Core

Course Description

The course covers environmental impact of energy production and consumption. Further aspects studied are energy, energy efficiency, consumption patterns and sustainability.

Course Outcome

By the end of the course, students are expected to be able to:

- Summarize the basic concepts of energy, its distribution and general Scenario.
- Explain different energy storage systems, energy management, audit and economic analysis.
- Summarize the environment eco system and its need for awareness.
- Identify the various types of environment pollution and their effects.
- Discuss the social issues of the environment with associated acts. Course Structure The following is a detailed syllabus.

UNIT I: Non renewable Energy resources

Fossil fuels-classification, composition, physico – chemical characteristics and energy content of coal, petroleum and natural gas, nuclear fuel, fission and fusion.

UNIT II: Renewable energy resources

Biomass, bio-fuel, hydroelectric power; Non-conventional energy resources: tidal energy, wind energy, geothermal energy, solar energy, solar radiation and its spectrum, solar collectors, photovoltaics, solar ponds, hydrogen energy.

UNIT III: Energy resource management

Energy crisis; Energy Conservation and Management; Energy audit; Recycling of wastes**:** Types - sources - composition of waste - recycling of waste for Industrial, Agricultural and Domestic Purposes.

UNIT IV: Energy use and its Environmental impact

Energy use pattern in different parts of the world; Environmental implication; CO_2 emissions, global warming; thermal pollution, air pollution; radioactive waste,

radioactivity from nuclear reactors, radioactivity risk assessment and criteria for safe exposure; impacts of large-scale exploitation of Solar, Hydro and Wind energy.

UNIT -V Energy and climate Change

Carbon cycle, greenhouse gases and global warming; Climate change – causes and consequences; Carbon footprint; Management of greenhouse gases at the source and at the sinks Energy policies and climate change: Carbon cycle, peak oil & global climate change; Future energy sources; Sustainable energy

Testing & Evaluation

- Seminar
- Assignment
- Written Exam

REFERENCES

Bharucha, E., T extbook of Environmental Studies, Universities Press (2005).

Chapman, J.L. and Reiss, M.J., Ecology-Principles and Application, Cambridge University Press (LPE) (1999).

Joseph, B., Environmental Studies, T ata McGraw-Hill (2006).

Eastop, T .P . and Cr oft, D.R. Energy Efficiency for Engineers and T echnologists, Longman and Harow (2006).

Miller , G.T ., Environmental Science- Working with Earth, Thomson (2006).

Wright, R.T ., Environmental Science-Towards a sustainable Future, Prentice Hall (2008) 9th ed.

O'Callagan, P .W ., Energy Management, McGraw Hill Book Co. Ltd. (1993).