B.Sc. Microbiology V and VI Semester Syllabus as per NEP 2020.

SEMESTER V

Discipline Specific Elective (DSE) and Vocational Courses

1. DSE 1- Industrial Microbiology (Theory and Practical)
2. DSE 2 - Microbial bioremediation (Theory and Practical)
3. DSE 3 - Microbial Ecology (Theory and Practical)
4. VC 1- Pharmaceutical microbiology
5. VC 2- Laboratory accreditation and quality control
6. VC 3- Fermented foods

SEMESTER VI

Discipline Specific Elective (DSE) and Vocational Courses

1. DSE 1-Biostatistics & Computer applications (Theory and Practical)
2. DSE 2-Fundamentals of Metabolomics (Theory and Practical)
3. DSE 3 - Microbial Biotechnology (Theory and Practical)
4. VC 1-Microbial Enzyme Production and Applications
5. VC 2-Biosafety and IPR
6. VC 3- Soil Microbiology

SEMESTER –V
DSE 1-INDUSTRIAL MICROBIOLOGY (THEORY)

TOTAL HOURS: 60 **CREDITS: 04**

Unit 1: Introduction to Industrial Microbiology Microbial growth (12 hours)

Traditional fermentation processes (e.g., bread, beer, wine); Discovery of penicillin and antibiotics; Contribution of key scientists (Louis Pasteur: Fermentation and pasteurization; Alexander Fleming: Discovery of antibiotics; Carl Neuberg: Enzyme fermentation); Overview and significance of various industries (Pharmaceuticals: Antibiotics, vaccines, and bio-therapeutics; Food and Beverages: Fermented foods, additives, and enzymes; Agriculture: Bio-fertilizers, bio-pesticides; Environment: Bioremediation and waste treatment; Energy: Biofuels and biogas production).

Unit 2: Fermentation Technology (12 hours)

Principles of fermentation; Types of fermentations: Submerged and solid-state; types of cultures: batch, fed-batch and continuous; Inoculum development; basic design and functions of different part of fermenter/bioreactor; Types of bioreactors; Scale-up and scale-down processes; Downstream processing and product recovery.

Unit 3: Microbiology for Industrial production (15 hours)

Overview of microorganisms (Bacteria: *Bacillus, Escherichia coli, Streptomyces*; Fungi: *Aspergillus, Penicillium*; Yeasts: *Saccharomyces cerevisiae*; Algae: *Chlorella, Spirulina*; Viruses: Bacteriophages in biotechnology) and cell-lines used in industry; Characteristics of industrially important microorganisms; Sources and isolation of industrial microorganisms; Preservation and maintenance of industrial strains; Primary and secondary screening techniques; use of recombinant DNA technology for strain improvement and industrial production.

Unit 4: Production of Industrial Products (15 hours)

Production of antibiotics (Penicillin & Streptomycin), alcohols (Ethanol & Butanol), enzymes (Amylase & Lipase), organic acids (Citric acid & lactic acid) and vitamins (B-12 & C); Introduction and industrial production of Biopolymers and bioplastics.

Unit 5: Regulatory and Quality Control (06 hours)

Overview of regulatory bodies; Regulatory frameworks and Guidelines; Compliance with Environmental and Safety Standards; Principles of Quality Control; Quality Assurance Systems; Testing and Validation Procedures; Fundamentals of GMP; Implementation of GMP in Bioprocessing; Documentation and Record-Keeping.

SEMESTER –V

DSE-1: INDUSTRIAL MICROBIOLOGY(PRACTICAL)

TOTAL HOURS: 60 **CREDITS: 02**

1. Isolationofmicroorganismsfrom natural sources.
2. ScreeningofbacterialculturesforAmylase production.
3. Quantitativeestimationofamylaseproductionbybacterialculture.
4. Screening of bacterial cultures for lipase production.
5. Quantitativeestimationoflipaseproductionbybacterialculture.
6. Glucose fermentation and Ethanol production using yeast
7. Penicillumsp culture and microscopic identification
8. Demonstration of antibiotic production and activity on agar plate
9. Demonstration of centrifugation, filtration and precipitation as part of downstream processes.
10. Display of fermentor/bioreactor design
11. Demonstration of Recombinant DNA technology using chart/models.
12. Documents and record keeping in GMP

Suggested Readings

1. Industrial Microbiology by L.E. Casida
2. Industrial Microbiology by Reed,G. Prescott and Dunn.
3. Industrial Microbiology: An Introduction by Michael J. Waites, Neil L. Morgan, John S. Rockey, Gary Higton
4. Principles of Fermentation Technology by Peter F. Stanbury, Allan Whitaker, Stephen J. Hall
5. Microbial Biotechnology: Fundamentals of Applied Microbiology by Alexander N. Glazer, Hiroshi Nikaido
6. Fermentation Microbiology and Biotechnology by E. M. T. El-Mansi, C. F. A. Bryce, Arnold L. Demain, A. R. Allman
7. Bioprocess Engineering: Basic Concepts by Michael L. Shuler, Fikret Kargi
8. Biotechnology: A Textbook of Industrial Microbiology by Wulf Crueger, Anneliese Crueger, Kazuo A. Nonomura
9. Industrial Biotechnology: Sustainable Growth and Economic Success edited by Wim Soetaert, Erick J. Vandamme
10. Biotechnology for Beginners by Reinhard Renneberg
11. Modern Industrial Microbiology and Biotechnology by Nduka Okafor
12. Practical Fermentation Technology Edited by Brain McNeil and Linda M. Harvey

SEMESTER –V
DSE 2 - MICROBIAL BIOREMEDIATION (THEORY)

Total Hours: 60 **Credits:04**

Unit 1: Introduction to Bioremediation (08 Hours)
Definition and importance of bioremediation, Historical perspectives and current trends, Role of microbes including *Pseudomonas, Bacillus, Rhodococcus, Deinococcus radiodurans, Phanerocheaete chrysosporium*.

Unit 2: Environmental pollutants and microbes (20 Hours)
Major pollutants – Polyaromatic hydrocarbons, Organic pollutants, Heavy metals, xenobiotics, Petroleum waste and oil spills, and Radioactive waste. Microbial communities abundant in sites polluted with specific pollutants.

Unit 3: Microbe mediated bioremediation mechanisms (16 Hours)
Microbial metabolism of pollutants. Aerobic and anaerobic degradation pathways. Microbial consortia and their roles in bioremediation. Advances in genetic engineering and synthetic biology for Bioremediation.

Unit 4: Monitoring and Assessment of Bioremediation (08 Hours)
Environment impact assessment. Remote sensing technologies for field applications of microbial bioremediation techniques. Molecular techniques for monitoring in situ bioremediation – qPCR (Quantitative PCR) for measuring gene expression and FISH (Fluorescent in situ hybridization). Biosensors for pollutant bioremediation.

Unit 5: Techniques and Technologies in Bioremediation (08 Hours)
Biostimulation, bioaugmentation, phytoremediation, Natural attenuation, microbe-based bioreactors for bioremediation.

SEMESTER –V
DSE 2 - MICROBIAL BIOREMEDIATION (PRACTICAL)

TOTAL HOURS: 60 **CREDITS: 02**

1. Isolation and Identification of Bioremediation Microbes from the polluted environmental sites.
2. Growth profiling and biochemical of the microbes isolated from the polluted sites.
3. Degradation of oil by Bacillus species or the microorganisms isolated from the oil contaminated sites.
4. Compare the aerobic and anaerobic degradation of pollutants or xenobiotic compounds.
5. Biostimulation demonstration by adding nutrients to the selected microbial cultures and examining its effect on bioremediation.

Suggested Readings

1. "Bioremediation Principles and Applications" by Ronald L. Crawford and Don L. Crawford.
2. "Environmental Biotechnology: Principles and Applications" by Bruce E. Rittmann and

Perry L. McCarty.
3. "Microbial Ecology: Fundamentals and Applications" by Ronald M. Atlas and Richard Bartha.

SEMESTER –V
DSE 3 - MICROBIAL ECOLOGY (THEORY)

TOTAL HOURS: 60 **CREDITS: 04**

Unit 1: Microbial Ecology **No. of Hours: 10**

Types of microorganism based on oxygen requirement (Aerophiles, Microaerophiles, Anaerobic bacteria); based on carbon requirement (Methanotrophs, Methylotrophs, Capnophiles); Microbial niche.

Unit 2: Microbe–Microbe Interactions **No. of Hours: 10**

Mutualism, Synergism, Commensalism, Neutralism, Competition, Amensalism, Parasitism, Predation, Antagonism, Population within biofilm

Unit 3: Soil-Microbe Interactions **No. of Hours: 15**

Soil as a habitat for microorganisms. Microorganisms in soil and their significance: bacteria, fungi, algae, protozoa, rhizosphere and rhizoplane. Biogeochemical cycles: C, N and role of microorganisms.

Unit 4: Microbe–Plant/animal Interactions **No. of Hours: 15**

Microbe–Plant Interactions: Roots, Aerial Plant surfaces, Biological Nitrogen fixation (symbiotic/nonsymbiotic- biofertilizers)

Microbe–Animal Interactions: Role of Microbes in Ruminants, Nematophagus fungi, Luminescent bacteria as symbiont. Microbes in/on human body

Unit 5: Extremophiles **No. of Hours: 10**

Acidophiles, Alkaliphiles, Psychrophiles, Thermophiles, Hyperthemrophiles, Barophiles, Osmophiles, Application of extremophiles, Biogas production

SEMESTER –V

DSE 3 - MICROBIAL ECOLOGY (PRACTICAL)

TOTAL HOURS: 30 **CREDITS: 02**

1. To study the effect of pH on the growth of E. coli.
2. Effect of different carbon sources on growth of *E. coli*.
3. Isolation of anaerobic bacteria from soil.
4. Analysis of soil – pH, moisture content, water holding capacity, percolation, capillary action
5. Visit any ecosystems and understand the role of microorganisms.

Suggested readings

1. R.C. Dubey and D. K. Maheshwari (2023) A Text book of Microbiology, S. Chand, ISBN: 978-93-550-1186-2, Delhi.
2. Madigan Michael T., Martinko John M., Bender Kelly S., Buckley Daniel H., and Stahl David A. (2017) Brock Biology of Microorganisms, Microbiology, Fourteenth Edition, Pearson Education, ISBN:978-9332586864
3. R.M. Atlas and R. Bartha, Microbial Ecology (Fourth Edition), Pearson Education, ISBN:9788131713846
4. R. C. Dubey and P. Kumar (2022), Rhizosphere Engineering, Academic Press, Elsevier, USA, ISBN- 9780323899734

SEMESTER V

VC 1: PHARMACEUTICAL MICROBIOLOGY

TOTAL HOURS: 30 **CREDITS: 02**

Unit 1: Introduction to Pharmaceutical Microbiology (6 hours)

Scope and Importance: Overview of pharmaceutical microbiology, its role in drug development, production, and quality control; Microbial Contaminants in Pharmaceuticals: Sources of microbial contamination, types of contaminants, and their impact on product quality and safety; Good Microbiological Laboratory Practices (GMLP): Introduction to GMLP principles and guidelines for microbiological testing in pharmaceuticals.

Unit 2: Microbial Control in Pharmaceutical Manufacturing (8 hours)

Sterilization Methods: Principles and methods of sterilization, including heat, filtration, radiation, and chemical sterilants; Aseptic Processing: Techniques for maintaining sterility during pharmaceutical manufacturing, including cleanroom design, personnel training, and gowning procedures; Disinfection and Sanitization: Methods for disinfecting pharmaceutical facilities, equipment, and surfaces to control microbial contamination.

Practical: (i) Sterility Testing: Perform sterility tests on pharmaceutical products using membrane filtration and direct inoculation methods. (ii) Microbial Limits Testing: Conduct microbial limits tests on pharmaceutical formulations and raw materials. (iii)Aseptic Technique: Practice aseptic techniques in a simulated cleanroom environment, including gowning, hand hygiene, and aseptic manipulations.

Unit 3: Microbial Testing and Assays (8 hours)

Sterility Testing: Principles, procedures, and regulatory requirements for sterility testing of pharmaceutical products; Microbial Limits Testing: Methods for determining the microbial

content of pharmaceutical products and raw materials; Microbial Assays: Techniques for assessing the potency of antimicrobial agents, antibiotics, and vaccines using microbial bioassays.

Practical: (iv) Microbial Assays: Perform microbial assays to determine the potency of antimicrobial agents or antibiotics.

Unit 4: Environmental Monitoring and Quality Control (8 hours)

Environmental Monitoring: Importance of monitoring microbial contamination in pharmaceutical manufacturing environments, sampling techniques, and data interpretation; Quality Control in Pharmaceutical Microbiology: Regulatory requirements, quality assurance practices, and documentation in pharmaceutical microbiology laboratories.

Practical: (v) Environmental Monitoring: Set up and analyze environmental monitoring samples from pharmaceutical manufacturing areas.

Suggested readings:

1. Pharmaceutical Microbiology, by Tim Sandle
2. Microbiological Quality Assurance in Pharmaceuticals, Cosmetics, and Toiletries, by Rosamund M. Baird
3. Microbial Limit and Bioburden Tests: Validation Approaches and Global Requirements, by Phil Geis and Tim Sandle
4. Microbial Control in Pharmaceuticals and Medical Devices, by Kenneth S. Thornhill
5. Microbial Limits Testing: A Practical Approach, by Scott Sutton
6. Environmental Monitoring in Pharmaceutical Facilities, by PDA (Parenteral Drug Association)

Practical Books:

1. 1. Practical Microbiology, by R.C. Dubey and D.K. Maheshwari (2023), S. Chand & co., P., Ltd, ISBN: 978-93-550-1745-1, Delhi
2. Practical Sterility Testing, by Trevor Deeks
3. Aseptic Processing and Packaging of Particulate Foods, by C.J. Doona and F.E. Feeherry
4. Microbial Assays: Methods and Applications, edited by Richard R. King
5. Environmental Monitoring for Cleanrooms and Controlled Environments, by Tim Sandles

SEMESTER V

VC 2: LABORATORY ACCREDITATION AND QUALITY CONTROL

Total Hours: 30 **Credits:02**

Unit I: Introduction to laboratory accreditation. (06 Hours)

Definition and importance of laboratory accreditation, overview of accreditation bodies at national (NABL – National Accreditation Board for Testing and Calibration Laboratories; BIS – Bureau of Indian Standards) and international levels (ILAC – International Laboratory Accreditation Cooperation; ISO/IEC 17025). The role and importance of accreditation in ensuring quality and reliability.

Practical: (i) Filling mock accreditation application.

Unit II: Quality Management System (06 Hours)

Components of QMS (Quality Management System), Development and implementation of QMS in microbiology labs. Quality assurance guidelines from relevant regulatory agencies. Standard operating procedures (SOPs) for specific microbiological tests in soil, water, and food samples.

Practical: (i) SOP Writing Exercise for Microbiological tests on soil, water, and food samples.

Unit III: Quality Control (QC) Techniques (06 Hours)

Routine QC practices in microbiology. Use of reference materials and calibration standards. Internal quality control protocols. Conducting internal and external audits – Checklist, procedures, and reporting.

Practical: (i) Internal audit simulation – Making a checklist to review QC protocols and practices. (ii) Data reporting exercise using the raw data available from different sources.

Unit IV: Safety and Compliance in Laboratory Procedures (06 Hours)

Safety Protocols and emergency procedures. Regulatory compliance requirements for microbiology laboratory at different biosafety levels. Environmental and ethical considerations associated with different laboratories.

Unit V: Laboratory Information Management System (06 Hours)

Data reporting and traceability, ensuring data accuracy and security, Databases for sharing and comparison of inter-laboratory protocols and data.

Practical: (i) LIMS software demonstration – Entering data and generating reports.

Suggested Readings

1. "Laboratory Quality Management System: Handbook" by World Health Organization (WHO).
2. "Quality Control in Microbiology: A Practical Approach" by B. M. Miller and B. A. Miller.
3. "Biosafety in Microbiological and Biomedical Laboratories (BMBL)" by Centers for Disease Control and Prevention (CDC) and National Institutes of Health (NIH)

SEMESTER –V
VC 3 - FERMENTED FOODS (THEORY)

TOTAL HOURS: 30 **CREDITS: 02**

Unit I: Fermented foods **No. of Hours: 6**
Concept of fermented foods, history, advantage and disadvantage of fermented foods, nutritive value of fermented foods, microbial changes in fermented foods (proteolytic, lipolytic and fermentative bacteria)

Unit II: Importance of fermented foods: **No. of Hours: 6**
Traditional fermented foods, Organisms used for production of fermented food products, Environmental parameters for fermentation process; Classification of fermentation processes for fermented foods; safety criteria of fermented foods.

Unit III: Fermented food products **No. of Hours: 6**
Production of bread, fermented dairy products: acidophilus milk, cheese (Mozzarella and Cheddar) and yoghurt; Fermented meat and fishery products.
Practical: (i) Microbial production of yoghurt. (ii) Isolation and identification of *Lactobacillus* from fermented dairy products.

Unit IV: Fermented vegetables **No. of Hours: 6**
Production methods and benefits of Sauerkraut, Kimchi, olives, cucumber, Coffee, Sufu, Poi.
Practical: (i) Production of sauerkraut, (ii) Determination of Lactic acid in sauerkraut

Unit V: Oriental foods: **No. of Hours: 6**
Mycoprotein, miso, soya sauce, idli, natto; beverages: vinegar, cider and sake; Alcoholic beverages of Himalayan region (Jann, Kacchi, Sez).
Practical: Preparation of Kacchi.

Suggested readings

1. Adams, M.R., and Moss, M.O. Food microbiology. Royal Society of Chemistry Publication, Cambridge.
2. Frazier, W.C. and Westhoff, D.C. Food microbiology. Tata McGraw Hill, New Delhi.
3. Stanbuty, P.F. and Hall, S.J. Principles of fermentation technology. Pergamon Press, Oxford.
4. R.C. Dubey and D. K. Maheshwari (2022) A Textbook of Microbiology, S. Chand, New Delhi, ISBN: 978-93-550-1186-2.

SEMESTER –VI

DSE 1-BIOSTATISTICS AND COMPUTER APPLICATIONS (THEORY)

TOTAL HOURS: 60 **CREDITS: 04**

Unit I: Introduction to Statistical Methods (10 hours)

Biostatistics: An Introduction, Aim, scope, definition and elementary idea of Statistics in Biology; Principles of statistical analysis of biological data, Types of data, data collection methods, methods of data representation; Difference between sample and population; Sampling parameters and types; Difference between parametric and non-parametric statistics.

Unit II: Central Tendencies (15 hours)

Measures of central tendency: Mean, median, mode and their relationship; Measures of dispersion: Mean deviation, Standard deviation and standard error; Standard distributions: Binomial, Poison, Normal distribution and their application; Properties of Normal distribution curve, Skewness and kurtosis.

Unit III: Probability and Correlations (10 hours)

Probability: Random experiments, Discrete and continuous variables, Sample space, Mutually exclusive events, Independent and dependent events, definition of probability, Addition and multiplication theorems of probability (only statement); Correlation and Regression analysis with emphasis on examples from biological sciences.

Unit IV: Statistical Tests (15 hours)

Concepts of Null and Alternative hypothesis, level of significance, Degree of freedom, steps in testing; Large sample test based on normal distribution; Small sample test based on t-test, Z- test and F-test; Distribution-free test: Chi-square test; Analysis of variance (ANOVA), Introduction, Procedure and problems based on one way ANOVA.

Unit V: Computer and its Applications (10 hours)

Introduction to the basic components and their functions of the computer; Memory types (Primary and secondary) and memory storing devices; Software types (system software and application software), an introduction to DOS, Windows and Linux OS; Introduction to MS-Office, MS-Excel and MS-Power point; Internet: Introduction, network and types of Network: Types of network, Local Area Network (LAN), Wide Area Network (WAN), Metropolitan Air Network (MAN), devices, hub, router and switch; advantages and disadvantages of networks.

BIOSTATISTICS AND COMPUTER APPLICATIONS (PRACTICAL)

TOTAL HOURS: 60 **CREDITS: 02**

1. Mean, median and mode from grouped and ungrouped data set.
2. Standard deviation and Coefficient of variation.
3. Skewness and Kurtosis.
4. Curve fitting.
5. Correlation and Regression.
6. Finding area under the curve using normal probability.
7. Forming and testing of hypothesis using *t*-test and Chi-Square-test.
8. Knowledge about web browsing, sending email, attaching and downloading files to an email.

Suggested Readings

1. Biostatistics: A Foundation for Analysis in the Health Sciences, by Wayne W. Daniel and Chad L. Cross
2. Introduction to Biostatistics, by Robert R. Sokal and F. James Rohlf
3. Principles of Biostatistics, by Marcello Pagano and Kimberlee Gauvreau
4. Fundamentals of Biostatistics, by Bernard Rosner
5. Biostatistics for the Biological and Health Sciences, by Marc M. Triola and Mario F. Triola
6. Applied Biostatistics, by P. N. Arora and P. K. Malhan
7. Introductory Biostatistics, by Chap T. Le
8. Biostatistics: An Applied Introduction for the Public Health Practitioner, by Heather M. Bush and S. E. Polansky
9. Methods in Biostatistics for Medical Students and Research Workers, by B. K. Mahajan
10. Fundamentals of Biostatistics, by P. Hanmanth Rao & K. Janardhan.
11. Elements Of Biostatistics, by Satguru Prasad
12. Fundamentals of Computers, by V. Rajaraman

SEMESTER - VI

DSE 2 - FUNDAMENTALS OF METABOLOMICS (THEORY)

Total Hours: 60 **Credits:04**

Unit 1: Introduction to Metabolomics (10 Hours)
Metabolomics as important tool of omics-studies. Qualitative and quantitative metabolomics. Application of metabolomics in food technology, nutrition, medicine, health sciences, agriculture, environment, and Industry.

Unit 2: Sample Preparations and Extraction (15 Hours)
Sample preparation – Harvest, quenching, and purification (solvent extraction) of protein samples, Intracellular metabolites (sugars, amino acids, and lipids), and secreted metabolites. Importance and application of Internal Standard compounds in untargeted and targeted metabolomics.

Unit 3: Techniques and Modern Instrumentation (10 Hours)
Working mechanisms, instrumentation, and data analysis – NMR, GC-MS, MALDI-TOF-MS, and LC-MS (HILIC and Reverse Phase) variants in metabolomics.

Unit 4: Data Processing (10 Hours)
Data retrieval, File conversions, and Data processing (alignment and normalization). Statistical projections of the metabolomics data and Multivariate analysis (ANOVA, PCA, PLS-DA, OPLS- DA).

Unit 5: Metabolite identification and Annotation (15 Hours)
Databases utilization – KEGG, HMDB, MoNA (Mass Bank of North America), MS-DIAL, MetaboAnalyst. Use of Spectral libraries for compound identification. Stable isotope labeling and tracing the metabolic pathways.

DSE4-FUNDAMENTALS OF METABOLOMICS (PRACTICAL)

Total Hours: 60 **Credits:02**

1. Hands-on sample preparation for untargeted and targeted metabolomics.
2. Application and importance of suitable internal standard compounds while Sample preparation in Metabolomics.
3. Data acquisition, file conversions, and data pre-processing using the freely available web-based software packages.
4. Data processing and multivariate analysis on Metabo Analyst platform.
5. Metabolite identification and annotations based on MS-DIAL/MASS Bank/Spectral libraries.

Suggested Readings

1. Metabolomics: “Methods and Protocols" edited by Wolfram Weckwerth.
2. "Computational Methods for Mass Spectrometry Proteomics" edited by Ingvar Eidhammer, Kristian Flikka, and Lennart Martens.
3. "Metabolome Analysis: An Introduction" by Silas G. Villas-Boas, Ute Roessner, Michael A.
   E. Hansen, John Smedsgaard, and Jeremy S. F. Hansen.

SEMESTER –VI
DSE 3 - MICROBIAL BIOTECHNOLOGY (THEORY)

TOTAL HOURS: 60 **CREDITS: 04**

Unit 1: Microbial Biotechnology **No. of Hours: 12**
Scopes and challenges; Industrial microorganisms: Growth metabolism regulation, Isolation and preservation of industrially important microorganisms. Production of metabolites: Microbial production and applications of primary metabolites: Citric acid, Ethanol, L Glutamic acid, L Lysine,Vitamins B; Industrially important microbial enzymes: Types, mode of action and industrial applications of microbial amylases and proteases

Unit II: Production of important microbial products **No. of Hours: 12**
Antibiotics (Penicillin and Streptomycin), Ergot alkaloids; Biotransformations of steroids: Hydroxylations and dehydrogenation, Sterol biotransformations; Probiotics, prebiotics and synbiotics: Products of Probiotics, health benefits, Vaccines production by bacteria.

Unit III: Microbes and society: **No. of Hours: 12**
Microbes in agrobiotechnology; microbial pesticides; integrated pest management, nano fertilizers, environmental biotechnology; food production involving microorganisms andtheir products, microbes in medical biotechnology, microbes in alternative energy, microbes indetergent, textile industries.

Unit IV: Bioplastics and Bioweapons **No. of Hours: 12**
Plastics vs. Bioplastics; History, chemical nature and production of bioplastics, health benefits of bioplastics; Microplastics: Microbial degradation of microplastics; Bioterrorism/bioweapons – History, microbes used an bioterrorism, threats and policy to control bioterrorism.

Unit V: Biosurfactants and Biosensors **No. of Hours: 12**
Biosurfactants: History, Characteristics, Sources, types and production, application in Agriculture, food, medical and paper industries; Biosensors: History, types, characteristics and Application in food quality monitoring, soil quality monitoring, water quality monitoring, environmental monitoring and environmental monitoring.

SEMESTER –VI
DSE 3 - MICROBIAL BIOTECHNOLOGY (PRACTICAL)

TOTAL HOURS: 30 **CREDITS: 02**

1. Isolation of amylase producing bacteria from soil.
2. Isolation of plastic degrading microbes
3. Isolation and screening of bioplastic producing microorganisms.
4. Demonstration of isolation and production of microbial pesticides
5. Demonstration of vaccine production by bacteria.

Suggested readings

1. R.C. Dubey (2014), Advanced Biotechnology, S. Chand, New Delhi, ISBN: 9788121942904
2. Alexander N. Glazer (2012), Microbial Biotechnology: Fundamentals of Applied Microbiology, Cambridge University Press, ISBN : 9780511811227
3. Relevant research articles

SEMESTER - VI

VC 1 -MICROBIAL ENZYMES (PRODUCTION AND APPLICATIONS)

TOTAL HOURS: 30 **CREDITS: 02**

Unit 1: Introduction to Microbial Enzymes (6 hours)

Definition and Classification of Enzymes: Overview of enzymes, classification based on reaction type and substrate specificity; Microbial Sources of Enzymes: Bacteria, fungi, yeast, and algae as enzyme producers; Industrial Applications of Enzymes: Use of microbial enzymes in pharmaceuticals, food processing, detergents, textiles, biofuels, medical and genetic engineering (lipase, protease, amylase, cellulose, pectinase, xylanase, Urokinase, L-asparaginase, streptokinase, polymerases and restriction endonucleases)

Unit 2: Enzyme Production Techniques (8 hours)

Microorganism Screening and Selection: Isolation and screening of enzyme-producing microorganisms from natural sources; Fermentation Processes: Submerged and solid-state fermentation for enzyme production; Optimization of Culture Conditions: Factors affecting enzyme production (pH, temperature, oxygen, nutrient supplementation).
Practical: (i) Isolation of microorganisms from soil or water samples, screening for enzyme activity (e.g., amylase, protease) on agar plates. (ii) Setup and monitoring of submerged fermentation of selected microorganisms for enzyme production at laboratory-scale.

Unit 3: Downstream processing (8 hours)

Enzyme Extraction and Recovery: Methods for extracting enzymes from microbial cultures (cell disruption, solvent extraction); Purification Techniques: Filtration, centrifugation, chromatography (ion exchange, affinity, size exclusion) for enzyme purification; Enzyme Assays and Characterization: Methods for measuring enzyme activity, stability, and specificity.
Practical: (iii) Extraction of enzymes from fermented broth, quantification of enzyme activity using colorimetric or titration assays. (iv) Purification of enzymes using different chromatography techniques (e.g., ion exchange, size exclusion) and measurement of purity and yield.

Unit 4: Industrial Applications of Enzymes (8 hours)

Food and Beverage Industry: Use of enzymes in starch processing, brewing, baking, dairy, and fruit juice production; Pharmaceutical Industry: Enzymes in drug formulation diagnostics, and biocatalysis; Textile Industry: Enzymes in fabric Desing, bio finishing, and denim stone washing; Biofuel Production: Enzymatic hydrolysis of biomass for bioethanol and biodiesel production.
Practical: (v) Practical demonstrations of enzyme applications in food processing (e.g., starch hydrolysis, cheese-making, fruit juice clarification). (vi) Visit to a local enzyme production facility or guest lecture by industry experts on enzyme production and applications.

Suggested readings:

1. Industrial Enzymes: Structure, Function and Applications, by Julio Polaina and Andrew P. MacCabe
2. Enzyme Technology, by Martin F. Chaplin and Christopher Bucke
3. Principles of Fermentation Technology, by Peter F. Stanbury, Allan Whitaker, and Stephen J. Hall

4. Microbial Enzymes in Bioconversions of Renewable Resources, edited by Vijai Kumar Gupta, Maria G. Tuohy, and Anthonia O'Donovan
5. Enzyme Technology, by Martin F. Chaplin and Christopher Bucke
6. Biotechnology: A Textbook of Industrial Microbiology, by Wulf Crueger, Anneliese Crueger
7. Biotechnology for Beginners, by Reinhard Renneberg

Practical Books:

1. Enzymes in Industry: Production and Applications, by Wolfgang Aehle.
2. Practical Enzymology, by Hans Bisswanger
3. Microbial Enzyme Technology in Food Applications, edited by Ramesh C. Ray
4. Enzyme Technology: Application and Commercial Production, by Gregory J. Zylstra and Arthur M. Klibanov.

SEMESTER - VI

VC 2 - Biosafety and IPR

Total Hours: 30 **Credits:02**

Unit I: Introduction to Biosafety (04 Hours)

Understanding biosafety and its significance in research and industry. Biosafety levels and associated requirements of BSL-1, BS-2, BSL-3, and BSL-4. Identifying hazards and risk assessments protocols.

Unit II: Laboratory Biosafety (08 Hours)

Standard operating procedures (SOPs), containment practices, personal protective equipment (PPE). Safe handling, transportation, and disposal of biohazardous materials. Emergency procedures -Response plans for spills, exposures, and other emergencies.
Practical: (i) Analyse real-life biosafety incidents from recent history and their causes. (ii) Emergency response drill under simulated conditions.

Unit III: Regulatory Framework for Biosafety (08 Hours)

GMO's and associated Biosafety concerns & Regulations. GEAC (Genetic Engineering Approval Committee), RCGM (Regional Committee on Genetic Manipulation), and IBC (Institutional Biosafety Committee). International treaties regulating Biosafety from potential biological hazards – Cartagena Protocol, Nagoya-Kuala Lumpur Supplementary Protocol, IPPC – International Plant Protection Convention, and the EU regulation (No. 1829/2003).
Practical: (i) International treaty reviews and presentation by students. (ii) Drafting a typical patent application.

Unit IV: IPR and its different types (05 Hours)

Types of Intellectual property and their significance. Patents, Trademarks, Copyrights, Trade secrets, Industrial designs, Geographical Indicators, Plant breeder's rights, Traditional

knowledge; Importance of IPR; Patentable and non-patentable IPs; Legal protection of biotechnological inventions; World Intellectual Property Organization (WIPO).

Unit V: Patents and Patent Laws **(05 Hours)**

Types of patent applications: Ordinary, PCT, Conventional, Divisional. Agreements and Treaties: GATT, TRIPS agreement, Role of Madrid agreement, Hague agreement, WIPO treaties, Budapest treaty on international recognition of the deposit of microorganisms, UPOV, Berne convention, Patent Co- operation Treaty (PCT), Indian Patent Act 1970 and recent amendments.
Practical: (i) Patent search exercise.

Suggested Readings

1. "Biosafety in Microbiological and Biomedical Laboratories" (BMBL) by Centers for Disease Controland Prevention (CDC) and National Institutes of Health (NIH).
2. "Intellectual Property: Patents, Trademarks, and Copyright in a Nutshell" by Arthur R. Miller andMichael H. Davis
3. "Patent Law and Policy: Cases and Materials" by Robert P. Merges and John F. Duffy.
4. Bare Act, 2007. Indian Patent Act 1970 Acts and Rules. Universal Law Publishing Co. Pvt. Ltd.,New Delhi.

SEMESTER –VI
VC 3 - SOIL MICROBIOLOGY (THEORY)

TOTAL HOURS: 30 **CREDITS: 02**

Unit I: Soil Microorganism **No. of Hours: 6**
Microorganisms in soil: bacteria (including cyanobacteria and actinobacteria), algae, fungi, protozoans, nematodes and viruses, factors affecting distribution and activities of microflora in soils.

Unit II: Microbial associations and organic matter decomposition **No. of Hours: 6**
Microbial associations in phytosphere, rhizosphere, phyllosphere, spermosphere; Mycorrhiza – types and importance in agriculture, role of soilmicroorganisms in decomposition of plant and animal matter, soil fertility.

Unit III: Biofertilizers **No. of Hours: 6**
Biofertilizers types of biofertilizers; Characterstic features of the microorganisms: *Azospirillium*, *Azotobacter*, *Bacillus*, *Pseudomonas*, *Rhizobium*, *Frankia*, and *Anabaena;* Plant growth promoting rhizobacteria (PGPR), Mechanisms of action of different bio-inoculants for plant growth, Significance of biofertilizers, Biofertilizer inoculation and microbial communities in the soil.
Practical: (i) Isolation of plant growth promoting rhizobacteria from rhizosphere. (ii) Isolation and identification of Rhizobium from root nodules.

Unit IV: Organic manures and Biogeochemical cycles **No. of Hours: 6**
Preparation, properties, and use in crop production, nutrient enriched compost, green manure; Composting, vermicomposting, biochar. Biogeochemical cycles – carbon, nitrogen,

phosphorus, sulphur cycles; nitrogen fixers – root nodule formation.
Practical: (i) Preparation of vermicompost, (ii) Preparation of biochar.

Unit V: Biological control of phytopathogens **No. of Hours: 6**

Mechanism of control – *Bacillus* spp. and *Pseudomonas spp.* as biocontrol agents; Disease suppressive soils – Biopesticide and their importance: Bacterial, fungal and viral; Effects of synthetic pesticides on soil microorganisms and environment
Practical: (i) Isolation of biocontrol agents (bacteria) from soil.

Suggested readings

1. Subba Rao, N.S. (2001) Soil microorganisms and plant growth. Oxford and IBH Publishing Company, New Delhi.
2. Kononova, M.M. (1996), Soil organic matter: Nature, its role in soil formation and in soil fertility. Pergamon, Oxford.
3. R.C. Dubey and P. Kumar (2022), Rhizosphere Engineering, Academic Press, Elsevier, USA, ISBN- 9780323899734
4. Glick B.R. (2015) Beneficial Plant Bacterial Interactions, Springer.
5. Paul E.A. (Ed.) (2015) Soil Microbiology, Ecology and Biochemistry, 4th Edn, Academic Press.
6. Madigan Michael T., Martinko John M., Bender Kelly S., Buckley Daniel H., and Stahl David A. (2017) Brock Biology of Microorganisms, Microbiology, Fourteenth Edition, Pearson Education, ISBN: 978-9332586864.
7. R.C. Dubey & D.K. Maheshwari (2022) A Textbook of microbiology, S. Chand & Co. P. Ltd, Delhi, ISBN: 978-93-550-1186-2.