Course Title with Credit Load
M.Sc. (Ag) in Agricultural Chemicals

Course Code	Course Title	Credit Hours
AC 501	Introduction to Agrochemicals	2+0
AC 502	Chemical Laboratory Techniques	1+2
AC 503*	Basic Chemistry	3+1
AC 504*	Natural Product Chemistry	2+1
AC 505*	Agrochemical Regulation, Quality Control and Management	2+0
AC 506*	Agrochemicals for Insect Mite and Termite Management	2+1
AC 507	Agrochemicals for Disease Management	2+1
AC 508	Agrochemicals for Weed and Crop Management	2+1
AC 509	Chromatographic and Spectroscopic Techniques	2+1
AC 510*	Pesticide Residue Chemistry	2+1
AC 591	Master's Seminar	1+0
AC 599	Master's Research	30

*Core courses

Course Contents
M.Sc. (Ag) in Agricultural Chemicals

I. Course Title : Introduction to Agrochemicals
II. Course Code : AC 501
III. Credit Hours : 2+0

IV. Why this Course?

Pesticides and allied agrochemicals are required for the management of pests of agriculture, veterinary and public health importance. Since pesticides are inherently toxic, their excessive use has led to the residues detrimental to human health and the environment. This interdisciplinary course provides introductory knowledge to students about the use of crop protection chemicals in pest control.

V. Aim of the Course

To provide basic information about crop protection chemicals, their production/ consumption and trade statistics, and adverse impact of these chemicals on human health and the environment.

The course is organized as follows:

No.	Blocks	Units
1.	Agrochemical use and Trade Statistics	1. Agrochemicals and Pest Management 2. Pesticide Production, Consumption and Trade Statistics
2.	Different Group Pesticides	1. Botanical and Biopesticides 2. Synthetic Pesticides
3.	Pesticides Formulation	1. Solid and Liquid Formulations 2. Role of Adjuvants in Pesticide Formulations
4.	Pesticide Residues, their Adverse Effects and Safe Disposal	1. Pesticide Residues in Food and the Environment 2. Adverse Effect of Pesticides on Non-target Organisms 3. Safe Disposal of Pesticides

VI. Theory

Block 1: Agrochemicals and Trade Statistics

Unit 1: Agrochemicals and Pest Management

Definition of pests and pesticides, Synthetic and natural plant protection chemicals – history and classification, House-hold pesticides, Non-pesticidal agrochemicals like nitrification inhibitors, chemical hybridizing agents, hydrogels, soil conditioners, and plant growth stimulants, Pesticide toxicity ($LD_{50,}$ $LD_{90,}$ LC_{50}, EC_{50}, I_{50}),Pesticide antidotes. Safety precautions in pesticide application, Introduction to integrated pest management (IPM).

Unit 2: Pesticide Production, Consumption and Trade Statistics

Pesticide production and consumption in India and other countries, Pesticide export and import

Block 2: Pesticide Groups

Unit 1: Botanical and Biopesticides

History of botanical and biopesticide use, Structure, properties, and use of conventional botanical insecticides - nicotine, pyrethrins, rotenones and neem limonoids. Plant allelochemicals, Biopesticides and bioagents.

Unit 2: Synthetic Pesticides

History of synthetic pesticide use, Structure, properties, and uses of insecticides-organochlorines, organophosphates, carbamates, synthetic pyrethroids, fungicides (inorganic and organic), nematicides, rodenticides, herbicides, and plant growth regulators (PGR)

Block 3: Pesticide Formulation

Unit 1: Solid and Liquid Formulations

Formulation of pesticides- objective and classification, Conventional solid and liquid formulations such as EC, WP, Dust, Granule etc. Physico-chemical properties of formulations

Unit 2: Role of Adjuvants in Pesticide Formulations

Pesticide adjuvants like synergists, stabilizers and surfactants, Pesticide carriers and diluents General methods of preparation of solid and liquid formulations

Block 4: Pesticide Residues, Their Adverse Effects And Safe Disposal

Unit 1: Pesticide Residues in Food and the Environment

Pesticide residue - definition and significance, Pesticide residues in food commodities and in water, air and in soil environment

Unit 2: Adverse Effect of Pesticides on Non-target Organisms

Adverse effect of pesticides on human health, soil health, and on non-target organisms

Unit 3: Safe Disposal of Pesticides

Various techniques for disposal of unused, obsolete, and expired pesticides and their solid and liquid formulations, Disposal of pesticide containers

VII. Teaching methods/activities

- Lectures assignments
- Review of research documents and its presentation
- Periodical quizzes
- Mid-term and final examination

VIII. Learning outcome

After successful completion of the course, student will acquire basic knowledge about agrochemicals, their formulations and safe use in crop protection. Student will also know about the adverse effects of pesticides and ways to dispose obsolete, expired and unused pesticides and pesticide containers/packaging

IX. Suggsted Reading

- DC Buchel KH. (Ed.). 1992. *Chemistry of Pesticides*. John Wiley & Sons.
- Marrs TC & Bryan BT. (Eds.). 2004. *Pesticide Toxicology and International Regulation*. John Wiley & Sons.
- Parmar BS and Tomar SS. 2004. *Pesticide Formulation Theory and Practice*, CBS Publishers & Distributors-New Delhi, ISBN: 9788123911243, 8123911246
- Tomar SS and Parmar BS. 1992. *Dictionary of Agricultural Chemicals*. Academic India Publ.
- Handa SK 2004. *Principles of Pesticide Chemistry*. Publisher Agrobios (India), Jodhpur (ISBN 10: 8177542168 ISBN 13: 9788177542165)
- Pimentel D. *Encyclopedia of Pest Management* (1st Edition), CRC Press, 931 pp. ISBN 9780824706326.
- Pimentel and Lehman H (Eds.). 1993. The Pesticide Question, Environment, Economics and Ethics, pp442.DOI 10.1007/b102353, Springer US.
- Hassall KA. 2013. *The Chemistry of pesticides, their metabolism, mode of action and uses in Crop Protection* (ISBN: 9789386237118, 9386237113) Scientific Publishers India, pp 372.
- FICCI-TSMG (2016). *Next Generation Indian Agriculture: Role of Crop Protection Solution, A report on Indian Agrochemical Industry*. pp 45.

I. Course Title : Chemical Laboratory Techniques

II. Course Code : AC 502

III. Credit Hours : 1+2

IV. Why this Course?

Students desirous of pursuing research in agrochemicals and crop protectionare expected to know about the safe handling of laboratory chemicals and instruments. They need to be well versed with extraction, purification and separation techniques commonly employed in a chemical laboratory.

V. Aim of the Course

To acquaint students with laboratory hygiene, upkeep and maintenance of laboratory, handling of chemicals/solvents/glassware, as well as distillation and chromatographic techniques:

No.	Blocks	Units
1.	Laboratory Hygiene and Safe Laboratory Practices	1. Safe Storage and Handling of Chemicals 2. Safety Practices in Chemical Laboratory
2.	Distillation, Extraction and Separation Techniques	1. Theory and Practice of Distillation and Drying of Solvents 2. Theory and Practice of Extraction and Other Techniques 3. Theory and Practice of Chromatographic Techniques

VI. Theory

Block 1: Laboratory Hygiene and Safe Laboratory Practices

Unit 1: Safe Storage and Handling of Chemicals

Laboratory hygiene and safety, Handling and storage of hazardous (flammable, volatile, and corrosive) chemicals, Accurate weighing of chemicals, Maintenance of lab-wares, Maintenance of lab notebooks and records of laboratory chemicals/solvents

Unit 2: Safety Practices in Chemical Laboratory

Precautions while carrying out lab experiments, Use of safety gadgets, Safe disposal of reaction wastes and used solvents, Laboratory accidents and their management

Block 2: Distillation, Extractionand Separation Techniques

Unit 1: Theory and Practice of Distillation and Drying of Solvents

Solvent distillation, Fractional distillation, Steam distillation, Hydro-distillation, Drying of solvents,

Unit 2: Theory and Practice of Extraction and Other Techniques

Different extraction techniques, Cold extraction, Soxhlet extraction, liquid-liquid partitioning, Crystallization and sublimation, Determination of melting point, boiling point, and density of organic compounds

Unit 3: Theory and Practice of Chromatographic Techniques

Chromatography - principle and practice, Partition and adsorption chromatography (TLC, Preparative TLC, HPTLC, Paper chromatography, Column chromatography), Chromatography solvents and chromogenic reagents.

VII. Practicals

- Simple distillation, vacuum distillation, and fractional distillation of solvents/ volatile materials (e.g. essential oils)
- Determination of melting point, boiling point, density, etc.
- Purification and drying of organic solvents
- Crystallization and sublimation techniques.
- Solvent extraction techniques (cold extraction, Soxhlet extraction, percolation, accelerated solvent extraction), and refluxing a reaction
- Chromatographic separation of organic compounds by paper chromatography and thin layer chromatography (TLC)
- Separation of compounds by preparative TLC, HP-TLC and column chromatography

VIII. Teaching methods/activities

- Lectures assignments
- Review of research documents
- Presentation of review
- Periodical quizzes
- Mid-term and final examination

IX. Learning outcome

After successful completion of the course, student will acquire knowledge aboutsafe handling of chemicals, lab safety and basic laboratory techniques

X. Suggested Reading

- Fessenden RJ, Fessenden JS, Feist P. 2001. *Organic Laboratory Techniques* 3rd Edition, Publisher: Cengage Learning, 256 pages
- Feist P. 2002. *Handbook for Organic Chemistry Lab*. 6th Ed. Brooks/Cole
- Vogel AI. 1996. *Vogel's Textbook of Practical Organic Chemistry*. 5th Ed. Prentice Hall.
- Pavia DL, Kriz GS, Engel UJF. 2006. *Organic Chemistry: A Lab Manual*, Thomson and Brooks/Cole 972 pages.
- Brown SL. 2012. *Laboratory Techniques for General Chemistry*, Hayden McNeil; 208 pages
- ICAR Institute/SAU, *Practical Manual on Chemical Laboratory Techniques*

I. Course Title : Basic Chemistry

II. Course Code : AC 503*

III. Credit Hours : 3+1

IV. Why this Course?

Basic knowledge of physical, inorganic and organic chemistry is fundamental for understanding various aspects of pesticides and allied agrochemicals, pesticide residue analysis, and dynamics in the environment. This course empower the students with important aspects of chemistry.

V. Aim of the Course

To acquaint the students about the basics of inorganic, physical and organic chemistry

The course is organized as follows:

No.	Blocks	Units
1.	Basics of Inorganic Chemistry	1. Properties of Atoms, Molecules And Basic Elements 2. Chemical Bonding and Electronic Effects
2.	Basics of Physical Chemistry	1. Chemical Kinetics 2. Chemical Thermodynamics 3. Surface Chemistry 4. Solution and Electrochemistry
3.	Basics of Organic Chemistry	1. Reactive Intermediates in Chemical Reactions 2. Introduction to Stereochemistry 3. Chemistry of Aliphatic and Aromatic Compounds 4. Chemistry of Heterocyclic Compounds

VI. Theory

Block 1: Basics of Inorganic Chemistry

Unit 1: Properties of Atoms, Molecules and Basic Elements

Modern periodic law and periodic table, Properties of atoms, molecules and basic elements like C, H, O, S, and N, Atmospheric pollutants (oxides of C, N, and S), Atomic and ionic radii, Oxidation states and chemical reactivity, Acid-base chemistry, Introduction to organometallic and coordinated compounds

Unit 2: Chemical Bonding and Electronic effects

Nature of chemical bonding, hydrogen bonding, Van der Waals forces, Inductive effect, electromeric effect, Resonance effect, Hyperconjugation, Electronegativity and Dipole moment

Block 2: Basics of Physical Chemistry

Unit 1: Chemical Kinetics

Kinetic theory of gases, Collision theory, Maxwell - Boltzmann distribution law, Order and molecularity of reactions, First order and second order reactions, Effect of concentration, temperature, pressure and catalyst on rate of reaction, Arrhenius equation, Enzyme kinetics, Catalysis.

Unit 2: Chemical Thermodynamics

First law of thermodynamics, concept of work, internal energy and enthalpy, Second law of thermodynamics, entropy and free energy, Third law of thermodynamics

Unit 3: Surface Chemistry

Introduction to surface chemistry, Adsorption, physi-sorption, and chemisorption, Factors affecting adsorption of gases on solids- Freundlich and Langmuir adsorption isotherm

Unit 4: Solution and Electrochemistry

Colligative properties of solutions, law of mass action, Ionic equilibria in solutions, Phase rule and its application to one- and two- component systems, Hydrolysis, Solubility product, pH and buffer solutions, True solutions, colloid and suspensions, Electrochemistry, Redox reactions, Potentiometric analyses, Conductance in electrolytic solutions, Laws of electrolysis, Nernst equation, Metal corrosion

Block 3: Basics of Organic Chemistry

Unit 1: Reactive Intermediates in Chemical Reactions

Carbenes, carbanions, carbonium ion, free radicals and their role in organic reactions

Unit 2: Introduction to Stereochemistry

Chirality and optical isomerism, Geometric isomerism, Designation of configuration (D-L and R-S system), Conformations of acyclic and cyclic systems

Unit 3: Chemistry of Aliphatic and Aromatic Compounds

Preparation, properties and uses of some important aliphatic, alicyclic and aromatic compounds (halogenated, nitro, amino-compounds, diazonium salts, aromatic sulphonic acids, phenols, quinones and aromatic acids, naphthalene and naphthaquinone).

Unit 4: Chemistry of Heterocyclic Compounds

Preparation, properties and uses of some important heterocyclic compounds (furan, thiophene, pyrrole, pyrazole, imidazole, oxazole, thiazole, pyridine, piperidine, quinnoline, isoquinnoline etc.)

VII. Practicals

- Micro-weighing of compounds and preparation of different concentration of solutions Preparation of different pH solutions and buffer solutions
- Detection of elements (C, H, O, N, S Halogens) in organic compounds
- Detection of functional groups
- Experiments to demonstrate adsorption of a chemical on solid substrate
- Separation and identification of organic compounds in binary mixtures.
- Rate kinetics and Colligative properties.

VIII. Teaching methods/activities

– Lectures assignments
– Review of research documents
– Presentation of review
– Periodical quizzes
– Mid-term and final examination

IX. Learning outcome

After successful completion of the course, student will acquire knowledge about the fundamental aspects and concepts of basic chemistry

X. Suggested Reading

- Eliel EL and Wilen SH. 1994. *Stereochemistry of Organic Compounds*. Wiley-Interscience.
- Finar IL. 1989. *Organic Chemistry*. Vols. I, II. Longmans.
- Hendrickson JB, Cram DJ and Hammond GS. 1970. *Organic Chemistry*. McGraw-Hill.
- Morrison RT and Boyd RN. 1992. *Organic Chemistry*. 6th Ed. Prentice Hall.
- Vogel AI, Tatchell AR, Furnis BS and Hannaford AJ. 1996. *Vogel Textbook of Practical Organic Chemistry*. Forestmillbooks,UK.
- Negi AS and Anand SC. 2003. *A Text Book of Physical Chemistry*. Wiley Eastern.
- Moore WJ. 1987. *Basic Physical Chemistry*. Prentice Hall of India
- Alberty RA and Silbey RJ. 1996. *Physical Chemistry*. 2nd Ed. John Wiley & Sons.
- Moore WJ. 1987. *Basic Physical Chemistry*. Prentice Hall of India
- ICAR Institute/SAU *Practical Manual on Basic Chemistry*

I. Course Title : Natural Product Chemistry

II. Course code : AC 504*

III. Credit Hours : 2+1

IV. Why this Course?

Natural Product Chemistry course is useful to multidisciplinary students of chemistry, agricultural chemicals, entomology, pathology, and biochemistry. The course is designed to improve the student's understanding of bioactive natural products and their role in human welfare.

V. Aim of the Course

To apprise the students about the extraction, purification, and characterization of bioactive natural products and their use in human health, medicines and agriculture The course is organized as follows:

No.	Blocks	Units
1.	Natural Products: Chemistry and Uses	1. Chemistry and Uses of Fats, Lipids, Terpenoids, and Carotenoids 2. Chemistry and Uses f Alkaloids, Flavonoids, Steroids, and Triterpenoids 3. Chemistry and Uses of Carbohydrates, Amino Acids, Proteins, and Nucleic Acids 4. Introduction to Metabolomics
2.	Natural Antioxidants and Food Colorants from Food and Non-Food Sources	1. Natural Antioxidants and Food Colorants from Food Crops 2. Nutraceuticals and Phytoceuticals from Non-Food Sources
3.	Natural Polymers And Enzymes	1. Natural Polymers and their Application 2. Enzymes and Their Industrial Applications

VI. Theory

Block 1: Natural Products: Chemistry and Uses

Unit 1: Chemistry of Fats, Lipids, Terpenoids, and Carotenoid

Introduction to natural products, Structure, chemistry, properties and function of

fats, lipids, terpenoids, and carotenoid group of natural products

Unit 2: Chemistry of Alkaloids, Flavonoids, Steroids, and Triterpenoids

Structure, chemistry, properties and function alkaloids (berberine, morphine, caffeine, atropine), flavonoids (Luteolin, quercetin, catechin, naringin, anthocyanins, theaflavins) and phenolic acids (benzoic acid and cinnamic acid derivatives), steroids (cholesterol, cortisone, testosterone, progesterone), and saponin (steroidal, triterpenic and steroid-alkaloidal) group of natural products.

Unit 3: Chemistry of Carbohydrates, Amino Acids, Proteins, and Nucleic Acids

Structure, chemistry, properties and function of carbohydrates, amino acids, proteins, and nucleic acids

Unit 4: Introduction to Metabolomics

Definition, Plant and microbial metabolomics, Metabolome analysis (profiling of secondary metabolites) by GC-MS, LC-MS and NMR spectrometery, Application of metabolomics in different fields

Block 2: Natural Antioxidants and Food Colorants From Food and Non-food Sources

Unit 1: Natural Antioxidants and Food Colorants from Food Crops

Natural oxidants and their mode of action, Different types of natural oxidants from vegetable, fruit and cereal crops (Examples: carotene, lycopene, betanaine, capsanthins, capsicinoids, anthocyanins, curcuminoids etc.)

Unit 2: Nutraceuticals and Phytoceuticals from Non-Food Sources

Nutraceuticals and phytoceuticals from microalgae (e.g. phycocyanins), seabuckthorn (phenolics and flavonoids), medicinal plants (boswellic acid, artemisinin, andrographinolides, withanolides, taxol, forskolinetc.) and marine products

Block 3: Natural Polymers and Enzymes

Unit 1: Natural Polymers and their Application

Different types of natural polymers, Chemistry of natural polymers (Starch, cellulose, Agar, inulin, chitosan, alginate, dextran, guar gum, gum Arabic, gum tragacanthin, xanthan gum, pectin, psyllium etc.). Application of polymers in agrochemical, food and other industries

Unit 2: Enzymes and their Industrial Application

Major classes of enzymes, Enzymes in food industry, industrial enzymes and their application in pharma, leather, textile, detergent and other industries

VII. Practicals

- Extraction of essential oil from mint leaves, lemon and orange peel etc.
- Extraction and purification of bioactive natural products like lycopene, from tomato or watermelon
- Extraction and purification of curcuminoids from turmeric rhizome
- Extraction and purification of anthocyanins from black carrot, purple cabbage, grapes or jamun etc
- Extraction and purification of bioactive natural products namely capsanthin and capsaicinoids from chili/paprika.

- Identification and characterization of the phytochemicals by GC-MS/LC-MS

VIII. Teaching methods/activities

- Lectures assignments
- Review of research documents
- Presentation of review
- Periodical quizzes
- Mid-term and final examination

IX. Learning outcome

After successful completion of the course, student will acquire knowledge about the bioactive natural products and their use in medicines, crop protection and other industrial applications

X. Suggested Reading

- Thomson RH (Ed). 1993. *The Chemistry of Natural Products*, DOI 10.1007/978-94-011-2144-6, Springer Netherlands, 453 pages
- Sujata V. Bhat, B.A. Nagasampagi, Meenakshi Sivakumar. 2005. *Chemistry of Natural Products* Springer Science & Business Media, 840 pages
- Rensheng Xu, Yang Ye, Weimin Zhao. 2011. *Introduction to Natural Products Chemistry*, CRC Press, 381 Pages
- Bernd Schaefer. 2014. *Natural Products in the Chemical Industry*, Springer-Verlag Berlin Heidelberg, 831 pages.
- Talapatra SK and Talapatra B. 2015. Chemistry of Plant Natural Products, Springer-Verlag Berlin Heidelberg, 1180 pages
- ICAR Institute/SAU. *Practical Manual on Natural Product Chemistry*

I. Course Title : Agrochemical Regulation, Quality Control and Management

II. Course Code : AC 505*

III. Credit Hours : 2+0

IV. Why this course?

Agricultural chemicals being inherently toxic need to be handled with caution during their production, transport, storage, usage and disposal. The national and international regulations and guidelines ensure their safe distribution and use. Students need to be aware of such regulations and guidelines

V. Aim of the course

To acquaint students about the provisions of Insecticide Act 1968, Food Safety and Standard Act 2006, pesticide registration process, and guidelines for their safe use. The course is organized as follows:

No.	Blocks	Units
1.	Pesticide Regulation and Food Safety	1. The Insecticides Act (1968) and Rules (1971) 2. Food Safety and Standard Act (2006) & Rules (2011) 3. Pesticide Registration in India
2.	National/ International Guidelines for Safe Use of Pesticides	1. Good Agricultural Practices (GAP) and Good Laboratory Practices (GLP)

No.	Blocks	Units
		2. International Guidelines for Safe Use of Pesticides
3.	Quality Control, Quality Assurance and Accreditation	1. Quality *Assurance* and *Quality Control* in Pesticide Analysis 2. Accreditation of *Laboratories*

VI. Theory

Block 1: Pesticide Registration in India

Unit 1: The Insecticides Act (1968) and Rules (1971)

Provisions of the Insecticides Act 1968 and Insecticides Rules 1971, Schedule of the Insecticide Act. Directorate of Plant Protection, Quarantine & Storage (DPPQ&S), Central Insecticide Board and Registration Committee (CIB&RC),Guidelines for production and use of pesticides

Unit 2: Food Safety and Standard Act (2006) & Rules (2011)

Provisions of the Food Safety and Standard Act (2006) & rules (2011), Acts relating to protection of air, water and the general environment

Unit 3: Pesticide Registration in India

Requirement of data (Chemistry, Bioefficacy, Residue, Toxicology, Packaging etc) for pesticide registration in the country, Guidelines for pesticide export and import**,** Current status of registered, restricted, and banned pesticides in India

Block 2: National/ International Guidelines for Safe Use of Pesticides

Unit 1: Good Agricultural Practices (GAP) and Good Laboratory Practices (GLP)

Definition of GAP and GLP, National and international guidelines for GAP, and GLP.

Unit-2: International Guidelines for Safe Use of Pesticides

WHO/FAO Joint Meeting on Pesticide Residues (JMPR), Codex Alimentarius Commission (CAC) EU and EPA guidelines for food safety, Sanitary and phytosanitary (SPS) measures and food safety

Block 3: Quality Control, Quality Assurance and Accreditation

Unit 1: Quality Assurance and Quality Control in Pesticide Analysis

Spurious/ fake pesticides and pesticide formulations, Quality Assurance (QA) and Quality Control (QC) Quality control procedures for pesticide residue analysis, Problems related to pesticide residue analysis in a regulatory laboratory.

Unit 2: Accreditation of Laboratories

Accreditation and its importance, General criteria for accreditation of chemical and food laboratories, Introduction to ISO/IEC 17025. NABL and GLP compliance of laboratories, Role of International Laboratory Accreditation Cooperation (ILAC) and Asia Pacific Laboratory Accreditation Cooperation (APLAC) in promoting accreditation recognition arrangements (MRAs) and practices

VII. Teaching methods/activities

- Lectures assignments
- Review of research documents
- Presentation of review
- Periodical quizzes
- Mid-term and final examination

VIII. Learning outcome

After successful completion of the course, student will acquire knowledge about the agrochemical regulation, quality control, management, and need for accreditation of chemical laboratory as per ISO/IEC 17025

IX. Suggested Reading

- EU.http://ec.europa.eu/food/plant/pesticides/eu-pesticides-database/public/?event=pesticide.residue.CurentMRL&language=EN&pestResidueID=69.
- Pest Management Regulatory Agency Canada. 21 May 2014. ISSN: 1925-0843 (PDF version), Catalogue number: H113-24/2014-25E-PDF. Cucurbit vegetables (Crop group 9). http://www.hc-sc.gc.ca/cps-spc/pest/part/consultations/_pmrl2014-25/pmrl2014-25-eng.php.
- OECD (Organization for Economic Co-operation and Development), 2011. *OECD MRL calculator: spreadsheet for single data set and spreadsheet for multiple data set*, 2 March 2011. In: Pesticide Publications/Publications on Pesticide Residues. http://www.oecd.org.
- SANTE. 2017. *Guidance document on analytical quality control and validation procedures for pesticide residues analysis in food and feed.* European Commission Health and Consumer Protection Directorate–General. SANTE/11813/2017 Supersedes SANCO/11945/2015.
- USEPA (2016). https://www.epa.gov/sites/production/files/2016-03/documents/flubendiamide_ noic_published_03-04-16.pdf. (accessed 18 May 2016).
- USEPA 2016 United States Environmental Protection Agency https://www.epa.gov/sites / production/files/2016-03/documents/flubendiamide_noic_published_03-04-16.pdf.
- Gnther Voss, Gerardo Ramos &GüNther Voss. 2003. *Chemistry of Crop Protection: Progress and Prospects in Science and Regulation*. Wiley-vch Verlag Gmbh.

I. Course Title : Agrochemicals for Insect, Mite and Termite Management

II. Course Code : AC 506*

III. Credit Hours : 2+1

IV. Why this course?

Insect pests, mites and termites are the major destroyer of the agricultural crops, food commodities as well as buildings and wooden structures. Since synthetic insecticides are used to control such pests, students must learn about the chemistry, mode of action and safe use of such pest control chemicals

V. Aim of the course

To understandchemistry, synthesis, mode of action, and use of insecticides, acaricides and termiticides in agriculture and protection of buildings and wooden structures. The course is organized as follows:

No.	Blocks	Units
1.	Organochlorine, Carbamate and Organophosphorus Group Insecticides	1. Chemistry and Use of Organochlorine Insecticides 2. Chemistry and Use of Carbamate Insecticides

No.	Blocks	Units
		3. Chemistry and Use of Organophosphorus Insecticides
2.	Synthetic Pyrethroid and Neonicotinoid Group Insecticides	1. Chemistry and Use of Synthetic Pyrethroid Insecticides 2. Chemistry and Use of Neonicotinoid Insecticides
3.	Acaricides, Termiticides, Insect Growth Regulators and Newly Discovered Insecticidal Molecules	1. Chemistry and Use of Acaricides 2. Chemistry and Use of Termiticides 3. Chemistry and Use of IGRs and Newly Discovered Insecticidal Molecules
4.	Insecticide resistance	1. Insecticide Resistance and its Management

VI. Theory

Block 1: Organochlorine, Carbamate and Organophosphorus Insecticides

Unit 1: Chemistry and Use Of Organochlorine Insecticides

Introduction and classification of synthetic insecticides, Chemistry, use and mode of action of some important conventional organochlorine and cyclodiene insecticides, Present status of organochlorine pesticides

Unit 2: Chemistry and Use of Carbamate Insecticides

Chemistry, use, and mode of action of carbamate insecticides, Present status of carbamate pesticides

Unit 3: Chemistry and Use of Organophosphorus Insecticides

Chemistry, use and mode of action of some important organophosphorus insecticides. Important reactions namely Michaelis- Arbuzov reaction, Perkow reaction, Thiono-thiolo rearrangement. Present status of OP pesticides

Block 2: Synthetic Pyrethroid and Neonicotenoid Insecticides

Unit 1: Chemistry and Use of Synthetic Pyrethroid Insecticides

History and evolution of synthetic pyrethroid insecticides, Synthesis, properties, structure activity relationships, and mode of action of some important ester and non-ester synthetic pyrethroids. Current status of synthetic pyrethroids insecticides

Unit 2: Chemistry and Use of Neonicotinoid Insecticides

Neonicotinoids: Chemistry, classification, mode of action and uses, Preparation, properties anduses of some important neonicotinoids, Current status of neonicotinid insecticides

Block 3: Acaricides, Termiticides, Insect Growth Regulatorsand Newly Discovered Insecticidal Molecules

Unit 1: Chemistry and Use of Acaricides

Chemistry, classification, mode of action of some important acaricidal molecules.

Unit 2: Chemistry and Use of Termiticides

Termites of different types infesting crops and building materials, Chemistry, mode of action and uses of some important termiticides

Unit 3: Chemistry and Use of Igrs and Newly Discovered Insecticidal Molecules

Chemistry of insect growth regulators: Juvenile hormone mimics, anti-JH, Chitin synthesis inhibitors. Chemosterilants, Mode of action of IGRs, Endocrine disruptor compounds, Chemistry of newly discovered insecticidal molecules

Block 4: Insecticde Resistance

Unit 1: Insecticide Resistance and its Management

Definition, types and mechanism of insecticide resistance, Insecticide Resistance Action Committee (IRAC) guidelines for resistance management, Status of resistance to neo-nicotinoid, synthetic pyrethroids, and other group insecticides

VII. Practicals

- Preparation and characterization of organochlorine insecticides and their intermediates, metabolites and degradation products
- Preparation of representative organochlorine insecticide like dicofol
- Preparation of representative organophosphorus insecticide
- Preparation and characterization of a pesticide intermediate (oxime/oxime ether/ ester etc.)
- Phytotoxicity evaluation of insecticides through germination and growth inhibition study
- Bioefficacy of insecticides against stored grain insect pests

VIII. Teaching methods/activities

– Lectures assignments
– Review of research documents
– Presentation of review
– Periodical quizzes
– Mid-term and final examination

IX. Learning outcome

After successful completion of the course, student will stand exposed to recent developments in agrochemicals and their use in insect, mite and termite management in crops, food commodities as well as buildings and wooden structures

X. Suggested Reading

- Melnikov NN. 1971. *Chemistry of Pesticides* (Ed: Gunther, F. A., Gunther, J. D. (Eds.), Springer Nature, Springer-Verlag New York, 480 pp
- Eto M. 1979. *Organophosphorus Pesticides: Organic and Biological Chemistry*. CRC Press.
- Kuhr RJ &Dorough HW. (1979). *Carbamate Insecticide Chemistry and Biochemistry*. CRC Press
- Fest C, Schmidt KJ. 1982. *The Chemistry of Organophosphorus Pesticides*, pp 362, DOI10.1007/978-3-642-68441-8, Springer-Verlag Berlin Heidelber
- Leahey JP. 1985. *The Pyrethroid Insecticides*. Taylor & Francis.
- Matolcsy G, Nadasy M and Andriska V. 1988. *Pesticide Chemistry*. Elsevier.
- Matolcsy M, Nádasy V Andriska. 1989. *Pesticide Chemistry*, Volume 32 (1st Edition) G. eBook ISBN: 9780080874913, Elsevier Science, 1989, pp 805
- Buchel KH. (Ed.). 1992. *Chemistry of Pesticides*. John Wiley & Sons.
- Cremlyn RJ. 1990. *Pesticides: Preparation and Mode of Action*. Wiley.
- Stenersen J. 2004. *Chemical Pesticides Mode of Action and Toxicology*. (ISBN-13: 978-0748409105), CRC Press; 1 edition., 296 pages.
- Ohkawa H, Miyagawa H and Lee PW. (Ed). 2007. *Pesticide Chemistry: Crop Protection,*

Public Health, Environmental Safety. DOI: 10.1002/9783527611249 Wiley VCH Verlag GmbH & Co. KGaA., pp 489.
- Singh DK. 2012. *Pesticide Chemistry and Toxicology* (*Book Series: Toxicology: Agriculture and Environment) Volume 1, pp 142*. DOI: 10.2174/9781608051373 1120101 (Benntham eBook)
- Hassall KA. 2013. *The Chemistry Of Pesticides Their Metabolism, Mode Of Action And Uses In Crop Protection* (ISBN: 9789386237118, 9386237113), Scientific Publishers India, pp 372.
- ICAR Institute/SAU *Practical Manual on Agrochemicals for Insect, Mite and Termite Management*

I. Course Title : Agrochemicals for Disease Management

II. Course Code : AC 507

III. Credit Hours : 2+1

IV. Why this course?

Plant diseases are caused by a diverse group of microorganisms which include fungi, bacteria, viruses, plant parasitic nematodes, etc. Besides reducing crop yield, they also reduce quality of the crop produce. Students must learn about diverse range of fungicidal and nematicidal products and their use in plant disease control

V. Aim of the course

To teach students about the chemistry and use of synthetic fungicides and nematicides and their role in plant diseases and nematode management.
The course is organized as follows:

No.	Blocks	Units
1.	Introduction to Fungicides and Plant Disease Management	1. Important Plant Pathogenic Fungi, Diseases and Fungicides 2. Classification of Fungicides
2.	Chemical Control of Plant Diseases	1. Inorganic and Dithiocarbamate Fungicides 2. Heterocyclic and Organophosphorus Fungicides 3. Strobilurin (β-Methoxy-Acrylate) Group Fungicides 4. Miscellaneousand New Emerging Fungicides
3.	Chemical Control of Plant Parasitic Nematodes	1. Chemistry, Use and Mode of Action of Chemical Nematicides
4.	Fungicide Resistance	1. Fungicide Resistance and its Management

VI. Theory

Block 1: Introduction to Fungicides and Plant Disease Management

Unit 1: Important Fungicides, Plant Pathogenic Fungi and Diseases

Historical development of fungicides, Some important plant pathogenic fungi and crop diseases, Fungicide movement (translocation) in plant

Unit 2: Classification of Fungicides

Fungicide classification based on chemical nature, Fungicide classification based on mode of action.

Block 2: Chemical Control of Plant Diseases

Unit 1: Inorganic and Dithiocarbamate Fungicides

Chemistry, use and mode of action of inorganic fungicides (S, Cu, Hg, Sn, As), Dithiocarbamate fungicides.

Unit 2: Heterocyclic and Organophosphorus Fungicides

Chemistry, use and mode of action of heterocyclic fungicides (Imidazole, benzimidazole, triazole, oxazole, thiazole, pyridine, pyrimidine, quinoline, quinoxaline, morpholine etc.), Organophosphorus fungicides.

Unit 3: Strobilurin (â-methoxy-acrylate) Group Fungicides

Chemistry, use and mode of action of strobilurin (-methoxyacrylaye) group synthetic fungicides e.g. azoxystrobin, kresoximmethyl, picoxystrobin, fluoxastrobin, pyraclostrobin and trifloxystrobin.

Unit 4: Miscellaneous and New Emerging Fungicidal Molecules

Chemistry, use and mode of action of phenol, quinone, polyhalogen, alkane sulfenyl group, formamide, alkane, alkane carboxylic acid carboxamide and dicarboximide group of fungicides, Chemistry of newly discovered fungicide molecules

Block 3: Chemical Control of Plant Parasuitic Nematodes

Unit 1: Chemical Nematicides

Plant parasitic nematodes, Historical development of nematicides. Preparation, properties and uses of aliphatic halogen compounds, methyl isocyanate liberators, organophosphates and carbamates for nematode control.

Block 4: Fungicide Resistance

Unit 1: Fungicide Resistance and its Management

Definition and development of fungicide resistance in crop pathogens, Fungicide Resistance Action Committee (FRAC) guidelines for resistance management, Fungicide resistance status in India

VII. Practicals

- Preparation of chemical fungicide intermediate(s) like triazoles/ benzimidazoles
- Preparation and characterization of some important fungicides (e.g. Zineb, Bordeaux mixture, Burgundy mixture, dichlorophen, Glyodin, DBCP (nematicide), and an organophosphorus fungicide
- Determination of antifungal activity of the representative test agrochemical (bioassay)
- Characterization of the select fungicides by spectral (IR, UV, NMR or MS) analysis

VIII. Teaching methods/activities

- Lectures assignments
- Review of research documents
- Presentation of review
- Periodical quizzes
- Mid-term and final examination

IX. Learning outcome

After successful completion of the course, student will acquire knowledge about the recent developments in agrochemicals and their use in plant disease and nematode

management in agricultural crops

X. Suggested Reading

- Matolcsy M, Nádasy V, Andriska. 1989. *Pesticide Chemistry*, Volume 32 (1st Edition) G. eBook ISBN: 9780080874913, Elsevier Science, 1989, pp 805
- Buchel KH. (Ed.). 1992. *Chemistry of Pesticides*. John Wiley & Sons.
- Cremlyn RJ. 1990. *Pesticides: Preparation and Mode of Action*. Wiley.
- Dehne HW, Deising HB, Gisi U, Kuck KH, Russell PE, Lyr H. (Eds.). 2008. *Modern Fungicides and Antifungal Compounds V*. Proceedings of the 15th International Reinhardsbrunn Symposium on Modern Fungicides and Antifungal Compounds. Friedrichroda, Germany (May 06 – 10, 2007), Deutsche Phytomedizinische Gesellschaft, Braunschweig, Germany, 2008 - ISBN 978-3-941261-02-0
- Ohkawa H, Miyagawa H and Lee PW. (Ed). 2007. *Pesticide Chemistry: Crop Protection, Public Health, Environmental Safety*. DOI: 10.1002/9783527611249 Wiley VCH Verlag GmbH & Co. KGaA., pp 489.
- Carisse O. 2010. (Ed) Fungicides, (ISBN 978-953-307-266-1) Publisher: InTechJanezaTrdine 9, 51000 Rijeka, Croatia. pp 538. (A free online edition of this book is available at www.intechopen.com)
- Lukens RJ. *Chemistry of Fungicidal Action* (ISBN: 9783662113134, 3662113139). Springer-Verlag, Berlin, Heidelberg, Germany.
- Singh DK. 2012. *Pesticide Chemistry and Toxicology* (*Book Series: Toxicology: Agriculture and Environment) Volume 1, pp 142*. DOI: 10.2174/97816080513731120101 (Benntham eBook)
- Hassall KA. 2013. *The Chemistry of pesticides, their metabolism, mode of action and uses in Crop Protection* (ISBN: 9789386237118, 9386237113) Scientific Publishers India, pp 372.
- Oliver and Hewitt H. (Eds). 2014. *Fungicides in Crop Protection*, CABI, Oxfordshire, OX10 8DE, UK pp 200 Pages
- ICAR Institute/SAU. *Practical Manual on Agrochemicals for Fungi and Nematode Management*

I. Course Title : Agrochemicals for Weed and Crop Management

II. Course Code : AC 508

III. Credit Hours : 2+1

IV. Why this Course?

Weeds compete with the crop plant for light, space, water and nutrients and hamper the overall growth of the desired crop. Chemical herbicides are employed to kill or control such weeds. This course provides detailed information about the chemistryand mode of action of diverse group of herbicides for weed management and PGRs for crop growth

V. Aim of the Course

To apprise the students about the chemistry, mode of action and use of different classes of herbicides for weed management, and plant growth regulators for crop growth.

The course is organized as follows:

No.	Blocks	Units
1.	Herbicides and Weed Management	1. Introduction to Herbicides and Weed Management
2.	Aliphatic, Aromatic, and other Group Herbicides	1. Aliphatic and Aromatic Acid Group Herbicides

No.	Blocks	Units
		2. Carbamate, Substituted phenyl urea, and s-Triazine 3. group Herbicides 4. Diphenyl Ethers, Dinitroanilines, Amide, and 5. Anilide Group Herbicides
3.	Heterocyclic and Sulfonyl Urea Herbicides	1. Chemistry and Use of Heterocyclic and Sulfonyl Urea Group Herbicides
4.	Plant growth regulators, herbicide safeners, and newly discovered herbicidal molecules	1. Chemistry and Use of Plant Growth Regulators and Herbicide Safeners 2. Newly Discovered Herbicidal Molecules
5.	Herbicide resistance	1. Herbicide resistance and its management

VI. Theory

Block 1: Herbicides and Weed Management

Unit 1: Introduction to Herbicides and Weed Management

Important crop weeds, Introduction to synthetic herbicides, Classification of herbicides based on time of application, mode of action and selectivity, Herbicide resistance and its management

Block 2: Aliphatic and Aromatic Group Herbicides

Unit 1: Aliphatic Acid and Aromatic Acid Group Herbicides

Chemistry, mode of action, and factors governing structure activity relationship of aliphatic and benzoic acid herbicides, phenoxy acid herbicides, phenoxy-phenoxy acid and phenoxy-phenoxy alkanoic acid herbicides

Unit 2: Carbamate, Substituted phenyl urea, and s-Triazine group Herbicides

Chemistry, mode of action, and factors governing structure activity relationship of carbamate, thiocarbamate, biscarbamate, oxime carbamate, sulfonyl carbamate, Substitutred phenyl urea herbicides, s-Triazine group herbicides

Unit 3: Diphenyl Ethers, Dinitroanilines, Amide, and Anilide Group Herbicides

Chemistry, mode of action, and factors governing structure activity relationship ofdiphenyl ethers, dinitroanilines, amide, and anilide group herbicides

Block 3: Heterocyclic and Sulfonyl Urea Herbicides

Unit 1: Chemistry and Use of Heterocyclic and Sulfonyl Urea Group Herbicides

Chemistry, use, mode of action and factors governing structure activity relationship of triazine, pyridine, bipyridylium, pyridazine, pyrimidine, oxadiazole, imidazolinoneand sulfonylurea and sulfonylamides herbicides

Block 4: Plant Growth Regulators, Herbicide Safeners, and Newly Discovered Herbicidal Molecules

Unit 2: Chemistry and Use of Plant Growth Regulators and Herbicide Safeners

Chemistry and use of plant growth regulators (auxins, gibberallin, cytokinins,

brassionosteroids, triacontanol, protein hydrolysates), Synthesis, structure activity relationships of auxins and gibberellins, Herbicide safeners and pro-safeners

Unit 3: Newly discovered Herbicidal Molecules

Structure and herbicidal activity of newly discovered herbicidal molecules

Block 5: Herbicide Resistance

Unit 1: Herbicide resistance and its management

History and types of herbicide resistance, Factors and mechanism of herbicide resistance, Management of herbicide resistance

VII. Practicals

- Synthesis and characterization of 2,4-D by m.p, TLC, and NMR,
- Identification and collection of weed samples from Institute research farm.
- Preparation of propionyl chloride and its use in the synthesis of the propanil herbicide
- Synthesis of maleic hydrazide and its characterization by TLC, NMR,
- Estimation of 2,4-D, alachlor, propanil, simazine and/or other available herbicides by HPLC and spectrophotometry.

VIII. Teaching methods/activities

- Lectures assignments
- Review of research documents
- Presentation of review
- Periodical quizzes
- Mid-term and final examination

IX. Learning outcome

After successful completion of the course, student will be well versed with safe use of herbicides for weed management and PGR for crop growth

X. Suggested Reading

- Kearnay PC and Kaufman DD. 1975. *Herbicides: Chemistry, Degradation and Mode of Action*. Vols. I, II. Marcel Dekker.
- Matolcsy G, Nadasy M and Andriska V. 1989. *Pesticide Chemistry*, Volume 32 (1st Edition) G. eBook ISBN: 9780080874913, Elsevier Science, pp 805
- Cremlyn RJ. 1990. *Pesticides: Preparation and Mode of Action*. Wiley
- Kramer WK and Ulrich Schirmer. 2007. *Modern Crop Protection Compounds*. Wiley-vch Verlag Gmbh.
- Ohkawa H, Miyagawa H and Lee PW. (Ed). 2007. *Pesticide Chemistry: Crop Protection, Public Health, Environmental Safety*. DOI: 10.1002/9783527611249 Wiley VCH Verlag GmbH & Co. KGaA., pp 489.
- Sondhia S and Varshney JG. 2010. Herbicides. Satish Serial Publication House, New Delhi. P 567.
- Rao VS. CRC Press, 2000. *Principles of Weed Science*, 2nd Edition, 566 pp, ISBN 9781578080694 - CAT# N00115
- ICAR Institute/SAU. *Practical Manual on Agrochemicals for Weed and Crop Management*

I. Course Code : Chromatographic and Spectroscopic Techniques
II. Course Title : AC 509
III. Credit Hours : 2+1

IV. Why this course?

The chromatographic (GC, HPLC) and spectroscopic (IR, UV, NMR) methods are necessary tools for the detection, identification, and quantitation of organic molecules. The knowledge of such analytical techniques is necessary for the students pursuing research in R & D of pesticides and allied agrochemicals

V. Aim of the course

To acquaint the students with the chromatographic and spectroscopic techniques and their use in analysis and characterization of organic compounds.
The course is organized as follows:

No.	Blocks	Units
1.	Chromatographic Techniques	1. Introduction to Separation Science Techniques 2. Gas Chromatography (GC) and its Application 3. High Performance Liquid Chromatography (HPLC) and Its Application
2.	Spectroscopic Techniques	1. UV, Visible and IR Spectrophotometry, and its Application 2. NMR (^{1}H, ^{13}C) Spectroscopy and its Application 3. Mass Spectroscopy (MS) and its Application 4. Tandem Chromatographic and Spectroscopic Techniques

VI. Theory

Block 1: Chromatographic Techniques

Unit 1: Introduction to Separation Science Techniques

Principles of separation science, GC, GPC, and LC chromatography, Super critical fluid chromatograph (SCFC), and Ion exchange chromatography (IEC)

Unit 2: Gas Chromatography and its Application

Theory, principle and instrumentation of GC, GC detectors and columns of different types, Application of GC in analysis of organic compounds, Advantages and limitations of GC

Unit 3: High Performance Liquid Chromatography (HPLC) and its Application

Theory, principle and instrumentation of HPLC, LC detectors and columns of different types, Mobile phase, Application of HPLC in separation and analysis of organic compounds. Advantages and limitations of HPLC

Block 2: Spectroscopic Techniques

Unit 1: UV, Visible and IR Spectrophotometry and its Application

Theory, principle, and instrumentationof absorption (UV, Visible and IR)

spectroscopy, Application of UV and IR in structure elucidation of organic compounds

Unit 2: NMR (^{1}H, ^{13}C) Spectroscopy and its Application

Theory, principal and instrumentation of NMR (^{1}H, ^{13}C) spectroscopy, Application of NMR spectroscopy in characterization of organic compounds

Unit 3: Mass Spectroscopy (MS) and its Application

Theory, principal, instrumentation of mass spectroscopy, Mass fragmentation pattern, Application of MS in structure elucidation and confirmation

Unit 4: Tandem GC-MS and LC-MS Techniques

Tandem chromatographic and spectroscopic techniques (GCMS-MS/LCMS-MS), Application of tandem techniques for confirmation of the chemical structure of the analyte constituents.

VII. Practicals

- Separation of organic compound mixture by GC and HPLC
- Application of UV and IR spectrophotometry for detection of organic compounds
- Identification and structure elucidation of organic compounds by NMR (^{1}H, ^{13}C) and MS
- Identification and structure elucidation of organic compounds by GC-MS, LC-MS and MS fragmentation pattern

VIII. Teaching methods/activities

– Lectures assignments
– Review of research documents
– Presentation of review
– Periodical quizzes
– Mid-term and final examination

IX. Learning outcome

After successful completion of the course, student will acquire working knowledge of chromatographic and spectroscopic methods for detection, identification, and quantitation of organic molecules.

X. Suggested Reading

- Sharma JM and Follweiler J. 1984. CRC. *Handbook of Chromatography: Pesticides and Related Organic Chemicals*. CRC Press
- Friebolin H and Becconsall JK. 1993. Basic One- and Two-Dimensional NMR Spectroscopy. John Wiley & Sons.
- Dyer JR. 1994. *Application of Absorption Spectroscopy of Organic Compounds*. Prentice Hall of India.
- Silverstein RM, Bassler GC and Morrill TC. 2005. *Spectrometric Identification of Organic Compounds*. 4th Ed. John Wiley & Sons. pages 512.
- Braithwaite A, Smith JF. 1999. *Chromatographic Methods* DOI 10.1007/978-94-011-0599-6, Springer Netherlands, pp 580
- Cazes J and Scott RPW. 2002. *Chromatography Theory* (Chromatographic Science, 88), CRC Press; 1 edition, 496 pages
- Williams DH and Fleming I. 2004. *Spectroscopic Methods in Organic*. Chemistry, Tata McGraw-Hill Education, New Delhi, India, pages 322.
- Nikalje. 2017. *A Handbook of Chromatography* (Editor: Marco Braga), Publisher: Scholar's Press Verlag Omniscriptam, Deutschland, Germany. (ISBN: 978-3-330-65032-9).
- *Practical Manual on Chromatographic and Spectroscopic Techniques* developed by the ICAR Institute/SAU.

I. Course Title : Pesticide Residue Chemistry

II. Course Code : AC 510*

III. Credit Hours : 2+1

IV. Why this course?

Pesticides are inherently toxic and their non-judicious use leaves behind toxic residues. Therefore it needs to be ensured that food commodities we consume are devoid of residues. This course provides exposure to analysis of pesticide residues in food commodities as well as in the soil and aquatic environment. It also provide information about consumer risk assessment and MRL fixation

V. Aim of the course

To teach the students extraction, cleanup, recovery and analysis techniques, develop and validate analytical methodology for risk assessment and MRL fixation.

The course is organized as follows:

No.	Blocks	Units
1.	Introduction to Pesticide Residue Chemistry	1. Pesticide Residue – Concept and Significance 2. Laboratory Data and Proficiency Testing
2.	Analysis of Pesticide Residues	1. Extraction, Clean Up and Recovery 2. Method Development and Validation 3. Monitoring of Pesticide Residue in Food Commodities
3.	Consumer Risk Assessment and MRL Fixation	1. Consumer Risk Assessment 2. MRL Fixation of Pesticides in Food Commodities

VI. Theory

Block 1: Introduction to Pesticide Residue Chemistry

Unit 1: Pesticide Residue – Concept and Significance

Pesticide residue definition, source, Significance of Certified Reference Materials (CRMs) in pesticide residue analysis, Planning and layout of experiments, Good agricultural practices (GAP) and experimental design, Post-harvest interval (PHI)

Unit 2: Laboratory Data Documentation and Proficiency Testing

Documentation and audit of laboratory data, Inter laboratory comparison and laboratory proficiency testing, legal implications of pesticide residue data

Block 2: Analysis of Pesticide Residues

Unit 1: Extraction, Clean Up and Recovery

Sampling, sample processing and testing, Different extraction and clean up techniques for optimum recovery

Unit 2: Method Development and Validation

Method development, Validation and performance verification through linearity, sensitivity, matrix effect, limit of quantification (LOQ), limit of detection (LOD), accuracy and precision of recovery, Measurement uncertainty (MU)

Unit 3: Monitoring of Pesticide Residue

Monitoring of pesticide residue in agricultural produce and environment, Multiresidue analysis by quick, easy, cheap, effective, rapid and safe (QuEChERS) method, GC/LC, GC-MS, LC-MS method. ELISA and Radiotracer techniques in residue analysis.

Block 3: Consumer Risk Assessmentand MRL Fixation

Unit 1: Consumer Risk Assessment

Hazard and risk, Ecological and human health risk assessment, Acceptable daily intake (ADI), theoretical maximum daily intake (TMDI),estimated daily intake, Maximum Residue Limit, No Observed Adverse Effect level (NOAEL), Food factor.

Unit 2: MRL fixation of Pesticides in Food Commodities

Safe waiting period, Lowest, highest and median residue data, OECD MRL Calculator, Significance of Codex, EU and FSSAI MRLs.

VII. Practicals

- Collection, storage and preparation of samples for pesticide residue analysis
- Extraction and clean-up of food, soil and water sample prior to analysis of pesticide residues
- Study the percent recovery of pesticide residues from vegetable, soil, and/or water samples fortified with the standard pesticide analyte
- Validation of analytical method by studying linearity, matrix effect, LOD, LOQ, accuracy (recovery) and precision as per SANTE guidelines
- Identification of organochlorine insecticides in soil and water by TLC/GC/HPLC
- Identification of Carbamate insecticides in water by TLC/GC/HPLC,
- Estimation of carbamate insecticide residues in vegetable by visible spectroscopic method and HPLC
- Estimation of OP insecticide residues in soil by spectroscopic method and HPLC.

VIII. Teaching methods/activities

- Lectures assignments
- Review of research documents
- Presentation of review
- Periodical quizzes
- Mid-term and final examination

IX. Learning outcome

After successful completion of the course, student will acquire knowledge aboutthe pesticide residue analysis, consumer risk assessment and MRL fixation

X. Suggested Reading

- Handa SK, Agnihotri NP and Kulshrestha G. 2000. *Pesticide Residue Analysis, Significance, Management and Analysis*.
- Gupta A. 2006. *Pesticide Residue in Food Commodities*. Agrobios (India).
- FAO. 2009b. *Submission and evaluation of pesticide residues data for the estimation of maximum residues levels in food and feed* (FAO Plant production and protection paper 197) <http://www.fao.org/ag/AGP/AGPP/Pesticide/p.htm>.
- FAO/WHO. 2013. *Codex Pesticides Residues in Food Online Database*. Pesticide Residues in Food and Feed, doi: http://www.codexalimentarius.net/pestres/data
- Sharma KK. 2013. *Pesticide Residue Analysis Manual* (Second edition), Directorate of

Knowledge Management in Agriculture, ICAR, KAB-I, Pusa, New Delhi-110012, India. pp 248

- Sondhia S. 2014. *Herbicides residues in soil, water, plants and non-targeted organisms and human health implications: an Indian perspective.* Indian Journal of Weed Science 46(1): 66–85.
- FSSAI. 2015. *Food Safety Standard Authority of India*, Fixation of MRL.
- Mohidus SK and Mohammad SR. (Eds.). 2017. *Pesticide Residue in Foods: Sources, Management and Control*. DOI 10.1007/978-3-319-52683-6, Springer Interntnl. Publishing, pp 200.
- SANTE. 2017. *Guidance document on analytical quality control and validation procedures for pesticide residues analysis in food and feed*. European Commission Health and Consumer Protection Directorate–General. SANTE/11813/2017 Supersedes SANCO/11945/2015.
- ICAR Institute/SAU. *Practical Manual on Pesticide Residue Chemistry*