Course Title with Credit Load
Ph.D. in Agricultural Chemicals

Course Code	Course Title	Credit Hours
AC 601*	Agrochemical Formulation Technology	2+2
AC 602*	Chemistry of Biopesticides	2+1
AC 603	Advanced Organic Chemistry	2+1
AC 604	Pesticide Metabolism, Persistence, and Decontamination	2+1
AC 605	Term Paper (Special Topics In Agrochemicals)	1+0
AC 691	Doctoral Seminar-I	1+0
AC 692	Doctoral Seminar-II	1+0
AC 699	Doctoral Research	75

*Core courses

Course Contents
Ph.D. in Agricultural chemicals

I. Course Title : Agrochemical Formulation Technology
II. Course Code : AC 601*
III. Credit Hours : 2+2

IV. Why this course?

Several advancements have been reported in pesticide formulation technology. The course intends to cover recent developments on the subject and will be useful to students interested in pursuing research in R & D of pesticide formulation technology

V. Aim of the course

To apprise the students about the recent developments in formulation technology and delivery systems.

The course is organized as follows:

No.	Blocks	Units
1.	Conventional Pesticide Formulations	1. Overview of Conventional Pesticide Formulations 2. Selection of Adjuvants and Synergists in Formulation Chemistry 3. Physico-Chemical Properties of Pesticide Formulations
2.	New Generation Pesticide Formulations	1. Water and Oil Based Novel Formulation 2. Dry, Controlled Release, and Other Novel Formulations 3. Pesticide Application and Delivery 4. Systems
3.	Nanotechnology and its Application in Pesticide Formulation	1. Production and Characterization of Nano-Materials 2. Application of Nanotechnology in Pesticide Formulation and Delivery

VI. Theory

Block 1: Conventional Pesticide Formulations

Unit 1: Overview of Conventional Pesticide Formulations

Solid and liquid formulation, Conventional pesticide formulations such as Dust (D), Granule, pallet (P), Wettable Powder (WP), Emulsifiable Concentrate (EC), and Solution (S). Biopesticide formulations-specifications and types, Limitations of conventional formulations

Unit 2: Selection of Adjuvants and Synergists in Formulation Chemistry

Role of adjuvants (carriers, diluents, surfactants, emulsifiers, dispersing agent, wetting agents, stickers and spreaders, penetrants,safeners, encapsulants etc.),

synergists,antioxidants, stabilizers etc. in formulation chemistry.

Unit 3: Physico-chemical Properties of Pesticide Formulations

Physico-chemical properties (solubility, octanol-water partition coefficient, vapor pressure, soil adsorption coefficient, emulsion stability, half-life, shelf-life etc.) and their testing, Formulant-toxicant interactions.

Block 2: New Generation Pesticide Formulations

Unit 1: Water and Oil Based Novel Formulation

Water soluble concentrates (WSC), Suspension concentrates (SC), Oil-in-water emulsion (EW), suspo-emulsion (SE), Micro-emulsion (ME), Water soluble bags and packets(WSB/WSP), Oil dispersion (OD), Aqueous flowable (AF).

Unit 2: Dry, Controlled Release, and Other Novel Formulations

Water soluble powder, liquid and dispersible granules, Dispersion concentrates, Effervescent tablets, Control/time release formulations. Aerosols, baits, fumigants, and formulations of pesticide mixtures, Seed treatment formulations, Seed dressing.

Unit 3: Pesticide Application and Delivery Systems

Packaging and labelling of pesticide formulations, Machinery and equipment for pesticide formulation, Pesticide application and delivery systems - principles, distribution and coverage.

Block 3: Nanotechnology and its Application in Pesticide Formulation

Unit 1: Production and Characterization of Nanomaterials

Development of nanomaterials – bottom up and top-down approach, nano-sizing of inorganic materials, Techniques for characterization of nanomaterials [Zeta sizer, Dynamic light scattering (DLS), X-ray diffraction (XRD), Scanning electron microscopy (SEM), Transmission electron microscopy (TEM), Atomic force microscopy (AFM), and Scanning tunneling microscopy (STM)].

Unit 2: Application of Nanotechnology in Pesticide Formulation and Delivery

Production and use of nano-enabled pesticide formulation (nanoemulsions, nanodispersions, nanoencapsulation, and other polymer based formulations), Nanocarriers for targeted and controlled release, Benefits and environmental risks of nanopesticides.

VII. Practicals

- Study of liquid carriers for the determination of (i) flash point, (ii) specific gravity, (iii) viscosity, and (iv) micelle formation with the surfactants
- Study of solid carriers: Determination of (i) Surface acidity by volumetric method, (ii), surface area, (iii) Sorptivity, and (iv)particle size, of the solid carriers
- Preparation of solid formulations: wettable powder (WP)/granules (G)/WDG/WSG
- Physico-chemical analysis of solid formulations based on BIS/CIPAC/FAO guidelines.
- Physico-chemical analysis of liquid/gel formulations based on BIS/CIPAC/FAO guidelines
- Preparation of toxicant based insect repellent formulations.
- Preparation of liquid and gel formulations: EC/SC/SL/OD/EW/gel, etc.
- Preparation and characterization of a nanopesticide formulation

- Preparation of controlled release (CR) formulation and the release of active ingredient in soil and water

VI. Teaching methods/activities

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

VII. Learning outcome

After successful completion of the course, student will acquire knowledge about new generation pesticide formulation and their use in pest control

VIII. Suggested Reading

- Chester L. Foy, David W. 1996. Pritchard Pesticide Formulation and Adjuvant Technology. ISBN-13: 978-0849376788. CRC Press, 384 pages
- Knowles DA. 1998. *Chemistry and technology of Agrochemical Formulations* DOI https://doi.org/10.1007/978-94-011-4956-3 Kluwer Academic Publishers, Springer Nature Switzerland AG.
- Alan K. Viets, Jane C. Mueninghoff (Editors). 2001. *Pesticide Formulations and Application Systems*, 20 ASTM International, 2001, 196 pages.
- Jane C. Mueninghoff, Alan K. Viets (Editors) Pesticide Formulations and Application Systems: A New Century for Agricultural Formulations. 21, (1414), ASTM publication. *Journal of ASTM International: Selected technical papers*, ISSN 1040-1695, 260 pages.
- Parmar BS and Tomar SS. 2004. *Pesticide Formulation Theory and Practice*, CBS Publishers & Distributors-New Delhi, ISBN: 9788123911243, 8123911246
- Valkenburg WV. 2008. *Pesticide Formulation: Recent Developments and Their Applications in Developing Countries* (ISBN-13: 978-8122410693) New Age International (P) Limited, Publishers; First edition (2008) pp 488.
- Goss GR (Editor). 2014. *Pesticide Formulation and Delivery Systems*: 35th Volume, Pesticide Formulations, Adjuvants, and Spray Characterization. ISBN-13: 978-0803176195 (Publisher: ASTM International 2016), 93 pages .
- Teicher HB. 2017. *Pesticides and Biopesticides: Formulation and Mode of Action* (Publisher: BioComm Press) pp 166.
- Practical Manual on Pesticide Formulation Technology developed by the ICAR Institute/ SAU.

I. Course Title : Chemistry of Biopesticides

II. Course Code : AC 602*

III. Credit Hours : 2+1

IV. Why this course?

Biopesticides derived from natural sources (plant, animal, nematodes, bacteria, fungi, virus, natural minerals) are considered as safer alternative to chemical pesticides. In view of their safety, such ecologically sound products are increasingly sought after for use in agriculture, veterinary and public health.

V. Aim of the course

To apprise the students about the usefulness of phytochemical biopesticides, microbial pesticides insect behaviour modifying chemicals, and role of biotechnology in pest management.

The course is organized as follows:

No.	Blocks	Units
1.	Phytochemical Biopesticides	1. Conventional Botanical Pesticides 2. New Generation Botanical Pesticides
2.	Insect Behaviour Modifying Chemicals	1. Insect Hormones and Related Products 2. Pheromones and Allelochemicals 3. Insect Feeding Deterrents and Repellents
3.	Microbial Pesticides and Bioagents	1. Microbial Insecticides 2. Microbial Fungicides and Herbicides 3. Entomopathogenic Nematodes, Fungi, and Plant Inhabiting Fungal Endophytes 4. Application of Biotechnology in Pest Management

VI. Theory

Block 1: Phytochemical Biopesticides

Unit 1: Conventional botanical pesticides

Isolation, characterization, use and mode of action of natural pyrethrins, rotenones,nicotine and neem based azadirachtiniods

Unit 2: New generation botanical pesticides

Isolation, characterization, use and mode of action of toosendanin, ryanodine, rocaglamides, annonins, isobutylamides, quassinoids, and sugar esters from plant sources, Plant essential oils and their constituents as botanical pesticides, Photo-activated pesticides like á-terthieyl, acetylenes and acetylenic thiophenes

Block 2: Insect Behaviour Modifying Chemicals

Unit 1: Insect hormones and related products

Insect hormones (Juvenile hormones, Moulting hormones, Brain hormones), their chemistry, mode of action and use in insect pest control)

Unit 2: Pheromones and allelochemicals

Pheromones (sex, alarm, trail, territorial, aggregation, etc.), Semiochemicals, Allelochemicals – allomones, kairomones, synomones, apneumones, Phytoalexins

Unit 3: Insect feeding deterrents and repellents

Sources, chemistry and mode of action of feeding deterrent and insect repellents

Block 3: Microbial Pesticides And Bioagents

Unit 1: Microbial Insecticides

Pesticides of microbial origin, Bacillus (*Bt, Bs*) and NPV based Insecticides. Chemistry and mode of action of macrolides such as avermectins, milbimycins and spinosyns

Unit 2: Microbial Fungicides and Herbicides

Natural fungicides like strobilurins and other methoxyacrylates, Bioherbicides like biolaphos and phosphonothricin

Unit 3: Entomopathogenic Nematodes, Fungi, and Plant Inhabiting Fungal Endophytes

Entomopathogenic nematodes and entomopathogenic fungi in insect control, Pesticidal secondary metabolites (biotoxins) from EPN (*Photorhabdus* and *Xenorhabdus)* and EPF (Metarrahiza etc.), Plant inhabiting fungal endophytes and their role in plant protection

Unit 4: Application of Biotechnology in Pest Management

Plant incorporated protectants, Recombinant DNA technology, **Genetically-modified** (GM) herbicide resistant crops, **Genetically-modified**insect resistant crops, Potential benefits and risks of GM crops

VII. Practicals

- Isolation of curcuminoids from turmeric rhizome and their characterization,
- Extraction of tobacco leaves, isolation of nicotine and its identification,
- Extraction of neem seed kernels to isolate neem oil
- Saponification of neem oil
- Isolation of azadirachtin concentrate from neem seed kernel powder
- Quantification of azadirachtin content in isolated azadirachtin powder
- Characterization of biopesticides by chromatographic and spectral 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 get acquainted with production of biopesticides from natural sources and their use in crop protection as safer alternative to chemical pesticides.

X. Suggested Reading

- Jacobson M. 1970. *Naturally Occurring Insecticides*. Wiley Khan SU. 1980. Pesticides in the Soil Environment. Elsevier.
- Parmar BS and Devakumar C. 1990. *Botanical and Biopesticides*. Westvill Publ. House
- Copping LG. 1996. *Crop Protection Agents from Nature: Natural Products and Analogues*. Royal Soc. Chem., London.
- Dev S and Koul O. 1997. *Insecticides of Natural Origin*. Harwood Acad. Publ. Godfrey CRA. 1995. Agrochemicals from Natural Products. Marcel Dekker.
- Schmutterer H. 2002. *The Neem Tree: Source of unique natural products for integrated pest management, medicine, industry and other purposes*. (2nd edition) Neem Foundation, Mumbai-400 049, India
- Parmar BS, Walia S, Anupama and Kumar J. 2008. *Neem Pesticides in India, An update of the recent developments*. SPS Publication No. 15, Society of Pesticide Science, India 50pp
- Parmar BS and Walia S. 2001. *Prospects and problems of phytochemical pesticides*. In: O. Koul and G.S. Dhaliwal (eds) Phytochemical Biopesticides, Harwood Academic Publishers Gmbh. Netherlands pp 133-210.
- Koul. 2004. *Insect antifeedants*. CRC Press LLC Boca Raton, Florida 33431, USA, pp 1005
- Franklin R. Hall and Julius J. Menn (Ed) *Biopesticides: Use and Delivery*. DOI 10.1385/0896035158, 2010 edition, 626 pages. Humana Press, Springer Nature. Switzerland. AG
- Singh D. 2014. *Advances in Plant Biopesticides*, Springer Nature India Private Limited, DOI 10.1007/978-81-322-2006-0. Pages 421.

- Leo ML. Nollet and Rathore HS. 2017. *Green Pesticides Handbook: Essential Oils for Pest Control* (ISBN-13: 978-1498759380), CRC Press pp 570.
- ICAR Institute/SAU. *Practical Manual on Chemistry of Biopesticides.*

I. Course Title : Advanced Organic Chemistry

II. Course code : AC 603

III. Credit Hours : 2+1

IV. Why this course?

This course provides a deeper understanding of organic chemistry and covers advanced topics of stereochemistry, photochemistry, pericyclic reactions, name reactions, chemical reagents etc. The knowledge of advanced organic chemistry is essential to students interested in synthesis and technology development of organic compounds including pesticides

V. Aim of the course

The course aims to equip the students with the advanced knowledge about stereochemistry, chemical reactions, chemical reagents in organic synthesis, and photochemistry.

The course is organized as follows:

No.	Blocks	Units
1.	Stereochemistry	1. Understanding Spatial Arrangement of Organic Molecules 2. Application Of Stereochemistry
2.	Important Chemical Reactions and their Mechanisms	1. Electrophilic and Nucleophilic Substitution Reactions 2. Elimination and Addition Reactions 3. Pericyclic Reactions 4. Organic Name Reactions
3.	Reagents in Organic Synthesis	1. Different Reagents and their Application in Organic Synthesis 2. Protection and Deprotection of Functional Groups
4.	Photochemistry	1. Basic Principles and Application of of Photochemistry

VI. Theory

Block 1: Stereochemistry

Unit 1: Understanding Spatial Arrangement of Organic Molecules

Enantimerism and diastereoisomerism, mesomers, Racemic mixture (racemate), Different methods of resolution of enantiomers (optical resolution), Walden inversion, Asymmetric synthesis of stereoisomers

Unit 2: Application of Stereochemistry

Nomenclature of stereo-chemicals with particular reference to agrochemical molecules, Stereospecific and stereoselective reactions, Chiral synthesis

Block 2: Important Chemical Reactions and their Mechanisms

Unit 1: Electrophilic and Nucleophilic Substitution Reactions

Electrophilic aromatic and Electrophilic aliphatic substitution reactions, Nucleophilic substitution reactions, (SN1, SN2 and SNi), Reactions involving carbonium ion, carbanion, carbene and free radicals.

Unit 2: Elimination and Addition Reactions

Elimination reactions (*syn* vs. *anti*-elimination, orientation in elimination reaction, molecular rearrangement, decarboxylation reactions, etc.). Addition reactions. Electrophilic addition of bromine. hydrogenation, hydroboration

Unit 3: Pericyclic Reactions

Cyclic transition states, Types of pericyclic reactions - cycloadditions, sigmatropic rearrangements, and electrocyclic reactions.

Unit 4: Organic Name Reactions

(i) Diels Alder reaction, (ii) Grignard reaction, (iii) Aldol, condensation, (iv) Perkin reaction, (v) Benzoin condensation, (vi) Friedel Craft alkylation and acylation reaction, (vii) Fries rearrangement (viii) Reformatsky reaction, (ix) Wittig Reaction and Sandmeyer reaction (x) Oppenaeur oxidation, (xi) Ziegler Natta reaction

Block 3: Reagents in Organic Synthesis

Unit 1: Different Reagents and their Application in Organic Synthesis

Reagents in organic synthesis: complex metal hydrides, Gilman's reagent, lithium dimethyl curparate, lithium di-isopropyl amide (LDA), dicyclohexylcarbodimide, 1,3-di-thiane, trimethyl selyl iodide, triselenium dioxide, tri-butyl tin hydride, osmium tetroxide, dichlorodicyano quinone etc. Organometallic reagents in organic synthesis, phase transfer catalysis, crown ethers and Merrifield resins

Unit 2: Protection and Deprotection of Functional Groups

Different methods of protection of functional groups in organic synthesis with examples, Deprotection to release the functionality

Block 4: Photochemistry

Unit 1: Basic Principles and Application of Photochemistry

Definition and laws of photochemistry, Light-induced excitation of organic molecules, Singlet and triplet state of oxygen, Application of photochemistry in biological systems, agriculture and industry. Role of light in degradation of pesticides and related xenobiotics

VII. Practicals

- One experiment each of methylation, acetylation, elimination, oxidation, reduction, and hydrolysis
- Preparation of acid chlorides, amides, esters,
- Friedal craft reaction (Alkylation/Acylation),
- Aldol/Claisen/Schmidt reaction,
- Pechmann condensation/Perkin reaction,
- Characterisation of prepared organic compounds by NMR and IR spectroscopy

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 get familiar with advanced organic chemistry and its application for planning, understanding and conducting organic reactions

X. Suggested Reading

- Finar IL. *Organic Chemistry*, Longman Publishing Group
- Corey FA and Sundberg RJ. 1983. *Advanced Organic Chemistry. Subseries:* Part A. *Structure & Mechanism*. Part B. *Reaction and Synthesis.* 2nd Ed. Plenum Press,
- Morrison RT, and Boyd RN. 1992. *Organic Chemistry*, 6th edition, ISBN 0136400612 (ISBN13: 9780136436690) Prentice Hall, 1278 pages.
- Eliel EL and Wilen SH. 1994. *Stereochemistry of Organic Compounds.* John Wiley & Sons. Finar IL. 1959. *Text book of Organic Chemistry*. Vols. I, II. 25th Ed. Pearson Edu.
- Kalsi PS. 1996. *Stereochemistry and Mechanism through Solved Problems.* 2nd Ed. New Age International Publ.
- Peter Sykes. 1996. *Organic Chemistry. Guidebook to Mechanism in Organic Chemistry*. 6th Ed. Prentice Hall.
- Vogel AI. 1996. *Vogel's Textbook of Practical Organic Chemistry*. 5th Ed. Printice Hall.
- Ahluwalia VK and Aggarwal R. *Comprehensive Practical Organic Chemistry - Preparation and Quantitative Analysis*. Universities Press.
- Bahl A and Bahl BS. 2005. *A Textbook of Organic Chemistry*, S Chand and Company, New Delhi, India, 1074 pages.
- Smith MB and March J. 2007. *March's Advanced Organic Chemistry Reactions, Mechanisms, And Structure*, John Wiley & Sons, Inc., Hoboken, New Jersey, 2190 pages
- Clayden J, Geeves N, Warren S. 2012. *Organic Chemistry* 2nd Edition (ISBN: 978-0199270293), Oxford University Press, Pages 1234.
- ICAR Institute/SAU *Practical Manual on Advanced Organic Chemistry*

I. Course Title : Pesticide Metabolism, Persistence and Decontamination

II. Course Code : AC 604

III. Credit Hours : 2+1

IV. Why this ourse?

The study of pesticide metabolism and dynamics is necessary to understand behaviour of pesticides in the biological systems and the environment. The course is designed to provide deep understanding of the biotic and abiotic transformations affecting fate of the pesticides in the environment

V. Aim of the ourse

To acquaint the students about the persistence, dissipation, and fate of pesticides in the crops and the environment. and about bio-remedial measures to decontaminate pesticide residues.

The course is organized as follows:

No.	Blocks	Units
1	Pesticide Movement in the Environment	1. Translocation of Pesticides in the Plant, Soil and Aquatic Environment 2. Different Phases of Pesticide Metabolism
2	Abiotic and Biotic Transformations of Pesticides	1. Abiotic Transformation of Pesticides 2. Microbial Degradation of Pesticides 3. Metabolism of Pesticides in the Living Systems
3	Pesticide Persistence and Dissipation Kinetics	1. Persistence of Pesticides in the Environment (Soil, Water and Crops) 2. Pesticide Dissipation and Fate in the Environment
4.	Decontamination and Bioremediation Measures	1. Decontamination of Pesticide Residues 2. Bioremediation of Pesticides and Pesticide Contaminated Sites

VI. Theory

Block 1: Pesticide Movement in the Environment

Unit 1: Translocation of Pesticides in the Plant, Soil and Aquatic Environment

Introduction to pesticide metabolism, penetration, uptake, translocation, excretion, and mineralization etc. (Highlight the role of physico-chemical parameters). Uptake, bio-accumulation, bio-concentration, and biomagnifications of pesticides in the plant and the environment.

Unit 2: Different Phases of Pesticide Metabolism

Fate of pesticides in the plant, animal and other living systems, Phase I metabolism (oxidation, reduction, hydrolysis, enzymatic degradation, etc.), Phase II metabolism (conjugation with sugar, amino acid, glutathione, etc.), Phase III metabolism (further conjugation of phase II metabolites), Non-extractable (Bound) residues.

Block 2: Abioticand Biotic Transformations of Pesticides

Unit 1: Abiotic Transformations of Pesticides

Physical and chemical factors affecting fate of pesticides in the environment, Photochemical transformation of pesticides, Role of photosensitizers, quenchers, and light filters in pesticide degradation.

Unit 2: Metabolism of Pesticides in the Living Systems

Biotic transformations and metabolic pathways of different group pesticides in thecrops, insects, animal models.

Unit 3: Microbial Degradation of Pesticides

Types of pesticides-degrading microorganisms in the environment, Factors affecting microbial degradation, Microbial degradation of different group pesticides.

Block 3. Pesticide Persistence and Dissipation in the Environment

Unit 1: Persistence of Pesticides in the Environment

Low, moderate and high persistent pesticides, Persistent organic pollutants,

Physical, chemical, biochemical and environmental factors affecting pesticide persistence in the environment.

Unit 2: Pesticide Dissipation and Fate in The Environment

Various dissipation processes, Role of drift, volatilization, adsorption, desorption, runoff etc.in pesticide dissipation, Leaching and risk of groundwater pollution, Dissipation time (Half-life-DT_{50}, DT_{90}), Rate kinetics (1st order, 2nd order), Behaviour and fate of pesticides in soil and crops.

Block 4: Decontamination and Bioremediation Measures

Unit 1: Decontamination of Pesticide Residues

Decontamination of pesticide residues in water and food (vegetables and fruits) commodities, Effect of different processing/culinary methods on reduction pesticide residues, safer methods of pesticide decontamination.

Unit 2: Bioremediation of Pesticides and Pesticide Contaminated Sites

Bioremediation-advantages and applications, Biodegradation and bioremediation of pesticides and related xenobiotic compounds, Microbe-mediated bioremediation, Use of enzymes in bioremediation, bioremediation of pesticide polluted sites.

VII. Practicals

- Synthesis of a pesticide metabolite
- Photodegradation of pesticides on glass and leaf surface,
- Microbial degradation of pesticides in soil.
- Leaching of pesticides in soil columns,
- Recovery of residues from pesticide-spiked farm soil

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 pesticide metabolism and dynamics in the biological systems and the environment and get acquainted with bio-remedial measures for to decontaminating food commodities and pesticide contaminated sites

X. Suggested Reading

- Schnoor JL. (Ed). 1992. *Fate of pesticides and chemicals in the environment*. Wiley New York. 436 pages:
- Alexander M. 1999. *Biodegradation and bioremediation*. 2nd Ed. Academic Press.
- Racke KD, Skidmore MW, Hamilton DJ, Unsworth JB, Miyamoto J and Cohen SZ. 1997. *Pesticide Fate in Tropical Soils*. Pure and Appl. Chem. 69 (6): 1349-1371.
- Hall JC, Hoagland RE and Zablotowicz RM. 2001. *Pesticide Biotransformation in Plants and Microorganisms: Similarities and Divergences*. ACS Symposium Series 777. Washington, DC.
- Shahamat U Khan. 1980. *Pesticides in the Soil Environment* (Editor: R. J. Wakeman) Elsevier. 248 pages.
- Perry AS, Yamamoto I, Ishaaya I, Perry RY. 1998. Insecticides in Agriculture and Environment- Retrospects and Prospects, DOI: 10.1007/978-3-662-03656-3 pp 261. Springer-

Verlag Berlin Heidelber.
- Wheeler WB. (Ed) 2002. *Pesticides in Agriculture and the Environment* (1st Edition), CRC Press.
- Matsumura F (Ed) 2013. *Biodegradation of Pesticides* (ISBN-13: 978-1468440904) Publisher: Springer, pp 312 pages.
- ICAR Institutes/SAU. *Practical Manual on Pesticide Residues and Dynamics in the Environment*

I. Course Title : Term Paper (Special Topics in Agro Chemicals)

II. Course code : AC 605

III. Credit Hours : 1+0

IV. Aim of the course

To develop proficiency of the student in his/her area of specialization. The teacher will give a topic relevant to the area of specialization of the student as a term paper to develop proficiency in his field of research. The term paper can be based on one of the selected current topics in agrochemicals

V. Suggested Reading

Literature on the relevant subject of the term paper in his area of research

Journals

- *Archives of Environmental Contamination and Toxicology*
- *Biopesticide International*
- *Bulletin of Environmental Contamination and Toxicology*
- *Chemosphere*
- *Crop Protection*
- *Current Science*
- *Environment Monitoring and Assessment*
- *Environmental Toxicology and Chemistry*
- *Food Additives and Contaminants*
- *Food Chemistry*
- *Indian Journal of Agricultural Chemistry*
- *Industrial Crops and Products*
- *Integrated Pest Management Reviews*
- *International Journal of Pest Management*
- *International Journal of Pesticide Reform*
- *Journal of Agriculture and Food Chemistry*
- *Journal of AOAC*
- *Journal Environ. Science and Health Part A & B*
- *Journal of Essential Oil Bearing Plants*
- *Outlooks on Pest Management*
- *Pest Management Science*
- *Pesticide Biochemistry and Physiology*
- *Pesticide Research Journal*
- *Pesticide Science Japan*
- *Weed Research*
- *Weed Science*
- *Weed Technology*

e-Resources

- Government of India, Ministry of Agriculture & Farmers Welfare, Department of Agriculture, Cooperation & Farmers Welfare, Directorate of Plant Protection, Quarantine & Storage. http://ppqs.gov.in/about-us/about-department

- Central Insecticide Board and Registration Committee (CIB&RC) www.cibrc.nic.in; http://ppqs.gov.in/contactus/central-insecticide-board-and-registration-committee-cibrc
- The Food Safety and Standards Authority of India (FSSAI) https://www.fssai.gov.in/home
- *Insecticides in Agriculture and Environment- Retrospects and Prospects*, Authors: Perry, A.S., Yamamoto, I., Ishaaya, I., Perry, R.Y. (1998) DOI: 10.1007/978-3-662-03656-3 pp 261. Springer-Verlag Berlin Heidelber
- *CRC Handbook of pest management in agriculture, Volume 1. Author:* Pimentel, D., CRC Series in Agriculture; Editor: Hanson, A.A.]. 1981. 597 pp.
- Food and Agricultural Organization Statistics (FAOSTAT) *Pesticides Use*. http://www.fao.org/faostat/en/#data/RP
- Food and Agricultural Organization (FAO/WHO) *Codex Pesticides Residues in Food Online Database. Pesticide Residues in Food and Feed*, doi: http://www.codexalimentarius.net/pestres/data
- European Food Safety Authority: http://www.efsa.europa.eu/en/pesticides/mrls.htm
- Pest Management Regulatory Agency Canada. https://www.canada.ca/en/health-canada/corporate/about-health-canada/branches-agencies/pest-management-regulatory-agency.html
- 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.
- Bureau of Indian Standards (BIS), New Delhi, India. http://www.bis.org.in/cert/bis_proc_obt_lic.htm
- EU. http://ec.europa.eu/food/plant/pesticides/eu-pesticides-database/public/?event=pesticide.residue.CurentMRL&language=EN&pestResidueID=69. (accessed 21 October 2016).
- US Environment Protection Agency (USEPA) https://www.epa.gov, https://www.epa.gov/pesticide-registration/about-pesticide-registration

Suggested broad topics for master's/ doctoral research

- New generation pesticides (insecticides, fungicides, herbicides, nematicides), plant growth stimulants, and other allied agrochemicals from synthetic and botanical sources
- Biopesticides from natural sources (plants, fungi, bacteria, algae, nematodes, etc),
- Novel insect antifeedants and other insect behaviour modifying chemicals (pheromones and other semio-chemicals)
- Novel pesticide formulations, time-release formulations, and delivery systems for enhanced activity and stability of single and combination pesticides
- Analysis of pesticide residues (multi-class pesticides, metabolites, degradation products, impurities) in soil, water, food commodities as well as in technical materials and formulations
- Investigations on safety evaluation, fixation of MRLs and safe waiting periods, and risk assessment
- Biotechnological and nanotechnological intervention for developing ecologically sound agrochemicals
- Pesticide-environment (plant, air, water, microbes) interaction, Pesticide persistence, degradation (biotic, abiotic)
- Impact of pesticides on the non-target organisms.
- Pesticide detoxification, decontamination and disposal, Bioremediation of pesticide contaminated sites for safe environment
- Increasing agricultural input (pesticides, water, fertilizers, micronutrient etc.) use-efficiency through technological interventions.