STATUS OF HIGHLY HAZARDOUS PESTICIDES IN INDIA

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PAN INDIA

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March 2023

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The Savitri Waney Charitable Foundation is a philanthropic organisation working with some of the poorest and marginalised rural communities in India, with a desire to transform their lives. We work with local communities on aspects like the relief of poverty, education, and medical relief. Poverty reduction is at the core of what we do. Through this project, we wish to raise awareness among farmers, consumers and other stakeholders about the adverse effects of Highly Hazardous Pesticides which will not only benefit the farming community to ensure their health and safety but also will ensure a reduction in polluting the environment

Developed and designed by

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Thanal Conservation Action facilitates Sustainable Solutions for Environment. Its objective is to carry on the business of undertaking studies and projects, developing and running communication projects for institutions, companies, Government Organizations, and Individuals, contributing to better understanding of environment problems, conservation and protection of environment and wildlife

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Pesticide Action Network India (PAN India) is a non-profit, public interest, research and advocacy organisation formed in 2013. Its objective is to help communities and governments to reduce dependence on toxic agrochemicals for pest control in agriculture, household as well as public health and to increase the use of sustainable alternatives. PAN India is working to empower farming communities to keep away from toxic pesticides and agrochemicals, and to take up non-chemical methods of farming practices based on agroecology.

Table of Contents

PREFACE

In India, information on pesticides is very low. Studies on pesticides are far and rare. Data and basic information in most studies are not found. Information and statistics on pesticides continue to be the prerogative of the government. Mandatory provisions in the Insecticide Act, 1968, to collect data from the pesticide retail network is frazzled, inefficient and discontinuous. In this scenario, discussion on Highly Hazardous Pesticides (a group of pesticides identified for their harm potential among hundreds of pesticides) is at best rudimentary. Not many people in India are aware of this kind of pesticides whose potential harm, when used indiscriminately is under-studied and under-reported.

As part of its core work to educate Indian people, especially farmers, consumers and policy makers on pesticide, Pesticide Action Network (PAN) India has joined the effort of bringing out this report. This report on Highly Hazardous Pesticides (HHPs) is strewn with data collected from different sources. Official data has been used extensively. However, there are lot of gaps in the available statistics, which sometimes hinders decision-making. These gaps are sometimes designed as well, especially by the pesticide companies, which want to prevent unnecessary and scholarly attention to HHPs.

The use of HHPs have to be regulated. Government of India has to acknowledge and recognize the hazardous potential of pesticides. Legislation needs to be attuned as per the harm caused by these pesticides to ecology and environment. The pesticide management bill 2020 (draft) does not refer to HHPs and their usage, even while there is international attention on reining in HHPs. Regulation has to be tighter, even while monitoring the usage of HHPs more closely. Evaluation of impact of HHPs on human health, especially on farmers and their families, has to be scheduled to be done periodically. Horribly, agricultural extension systems continue to recommend HHPs, on crops, without reference to the registered use. This is patently illegal. The gap between extension and registration is huge, with either of them not making efforts to bridge this gap. This is probably because the process of regulation is heavily influenced by pesticide industry, which is afraid of review, evaluation and scientific studies. Most of the HHPs have been registered without data, or rudimentary information generated elsewhere. Effectiveness of HHPs is not demonstrated fully. Field data on the impact of HHPs on the targeted pests is completely absent. There is no independent verification process either. Meanwhile, residues of HHPs were detected in food and vegetables. No further steps are initiated by the regulators whenever such residues are detected, indicating flaws in regulation.

With this effort, PAN India has added one more study to its slew of reports that give primary information as well as directions for public policy. The objective is to educate India on HHPs and bring attention of the policy makers to these pesticides. This report it is hoped will be precursor for more scientific studies on HHPs in terms of economics, environment and ecology.

Dr. Narasimha Reddy Donthi
Public Policy Expert and Advisor to PAN India

EXECUTIVE SUMMARY

India has registered about 318 pesticides (including biopesticides) for commercial use. Among them are a group of pesticides that are severely toxic, environmentally affecting, extremely hazardous to humans and lifeforms and highly restricted for use in other countries. These Pesticides are called, Highly Hazardous Pesticides or HHPs. PAN India has developed an HHP list (Highly Hazardous Pesticides) from the registered pesticides in India. These HHPs are a group of pesticides that have grievous impacts and added toxicity, compared to other chemical pesticides. Out of 318 pesticides registered in India as of 1st October, 2022, under Insecticides / Pesticides Registered under section 9(3) of the Insecticides Act, 120 are HHPs. This number is 38 per cent of the registered pesticides.

This report is developed from secondary data accessed from reliable and verified sources. This report contains detailed statistics on HHPs in India. It provides insight into Highly Hazardous Pesticides (HHPs), identified from the current approved list of registered pesticides in India. Eighty-one of these HHPs are banned in different countries. Among these 81, 68 HHPs are banned in more than 10 countries. The usage of such HHPs in India is a matter of grave concern. These pesticides are the leading class of chemicals, used in self-poisonings and other sets of accidental poisonings in India. Indian law does not have any provision for these registered pesticides which differentiates them from other pesticides. PAN India has developed this list, based on internationally accepted criteria, related to their toxicity.

A major share of these HHPs belongs to the category of organophosphorus insecticides. More than half of these HHPs are banned in other countries. These are highly impactful to the ecosystem and human health. Out of 62 deemed to be registered pesticides (DRPs) in India, which have not undergone the mandatory scientific scrutiny process for safety and efficacy under Indian law, 26 are HHPs. These HHPs are also among the highly produced and used pesticides in India. Some of these HHPs are listed in International conventions and summits on sustainable development. Yet, they are imported and exported in large quantities, as part of the international pesticide trade. There seems to be a regulatory underhand in allowing such HHPs without closer scrutiny of their bio-efficacy and toxic impacts.

Several of these HHPs were studied for their impacts and have been named to cause serious health issues, environmental degeneration, and contamination of resources and have trans-generational implications. Cancer, reproductive disorders, endocrine disruption, neurotoxicity, genotoxicity, immunotoxicity and teratogenicity are the results of indiscriminate pesticide use. Among these pesticides are 27 HHPs, that are JMPM acknowledged.

FAO Joint Committee on Pesticide Management (JMPM) in 2013, formulated a set of criteria and definition for defining Highly Hazardous Pesticides (HHPs). This definition was adopted and extended by PAN International, to develop this list of HHPs based on JMPM criteria as well as newly added PAN criteria. This list is referred to in this study. In 2015, the SAICM’s Fourth International Conference of Chemicals Management (ICCM4), adopted a resolution that recognizes HHPs as an issue of international concern and calls for concerted action to address HHPs and has urged stakeholders to reduce reliance on HHPs. However stringent regulations over regulating HHPs are not taken in India, even in 2022.

More than half of the HHPs (78) in India are recommended by the registry for use on different crops . Information collected from agricultural extension systems from 10 States of India, and analysed in this report, reveals a shocking scenario, wherein several HHPs are being recommended and used contrary to nationally approved usage. These hazardous agrochemicals are available in Indian markets, under different brand names, variant forms, and formulations and are excessively manufactured, limitlessly stored, and carelessly applied to the fields.

Statistical data confirming its abundant production, consumption, import, and export is provided in this study. The percentage HHPs in total pesticide production and consumption is significantly high. This report tries to bring attention to these gaps and the potential harm of these HHPs to farmers, food and nature.

HHPs are annihilating biodiversity and are causing ecosystem disruptions. Evidence of environmental disruption and ecotoxicity by most of the registered HHPs in India are cited in multiple studies across the world. Poisonings and toxicology studies from India inform us about the large contribution of HHPs in such happenings. HHPs have been named in suicides and in episodes of pesticide poisoning. For this reason at least, HHPs need to be regulated, if not phased out. Regulation of HHPs in many countries has resulted in a decreasing trend of suicides, establishing direct relation between HHPs and suicides.

However India does not have an adequate regulatory provision to safeguard citizens and environment from hazardous effects of HHPs. HHPs are not strictly regulated and are not contained within the framework of Indian legislation. The Insecticides Act and the new pesticide management bill 2020 (draft) fails to address the key issues arising out of HHPs usage. The lack of availability of information on many HHPs and discrepancies in statistical data adds to severe concerns. The current situation highlights the slackened regulatory control over pesticide usage in India. Absence of stringent regulations and low public awareness about Highly Hazardous Pesticides adds to the sad state of sad affairs. This report argues for strengthening of HHPs regulation, greater coordination with agricultural extension, stricter implementation of registration conditions, and ultimately a plan which does not allow production, export/import and use of identified 120 Highly Hazardous Pesticides. Given the direct relationship between Highly Hazardous Pesticides and human and environmental toxicity, these pesticides have to be eliminated from our lands.

Chapter 1

INTRODUCTION

Pesticides are a broad spectrum of chemicals used primarily in agriculture/farming for pest control and weed removal, and can be classified, based on their diverse function into classes like herbicides, rodenticides, fungicides etc. They are made integral components in modern agricultural practices, with a purported purpose of reducing harvest-losses from weeds, diseases, and insect pests. Over the period, pesticides have become a necessary agricultural input, spiking its production and consumption. Increased addiction to chemical pesticide usage, has, however, led to acute diseases, poisoning, natural resource contamination etc. HHPs are masked among other chemical pesticides and knowingly or unknowingly, we are using them in our fields, our homes, markets and premises.

DDT (an HHP) was the first pesticide used in India in 1948, for malaria control and its large-scale production began in 1952. Ever since, Agrochemicals have become a key input in agriculture for crop protection. According to the latest government sources, India is the 4th largest producer of agrochemicals in the world and 3 rd largest producer of chemicals in Asia. India is also the 12th largest exporter of pesticides to the world where India exports to more than 175 countries. Large-scale production, import, export, and consumption of these chemical pesticides throughout the years, without stricter monitoring and regulation has presented a catastrophic scenario in the Indian context. HHPs are the leading share of pesticids included in all these set of datas.

FAO/WHO International Code of Conduct on Pesticide Management, (2013) defined HHPs as 'Pesticides that are acknowledged to present particularly high levels of acute or chronic hazards to health or environment according to internationally accepted classification systems such as the World Health Organization (WHO) or the Globally Harmonized System of Classification and Labelling of Chemicals (GHS) or their listing in relevant binding international agreements or conventions and in addition, pesticides that appear to cause severe or irreversible harm to health or the environment under conditions of use in a country may be considered to be and treated as highly hazardous'[1].

International regulatory bodies like ICCM and FAO are addressing key issues of HHP use at global level. HHP regulation at national level is lenient and meagerly addressed. HHPs are invariably linked in most of the pesticide poisonings within the country. The first report of poisoning due to pesticides in India came from Kerala in 1958 where, over 100 people died after consuming wheat flour contaminated with parathion (HHP). Years after, many distressing cases on adverse effects of pesticides are being reported from several parts of India and ceaseless reports on poisoning fill in every day. Yet, production and consumption of these hazardous pesticides continues. The evils of pesticide use are not addressed and advocated intensively. Pragmatic solutions and immediate actions are required to end this slow kill by pesticides.

The phaseout of Highly Hazardous Pesticides is undermined by inferior data on pesticide use available for farmers and policymakers. There is a shocking dearth of Highly Hazardous Pesticide usage data that could take years to address and solve. There is not enough research data to determine correct pesticide use and economic thresholds for HHPs. Complicating this is the fact that, standards for pesticides and other chemicals are also heavily influenced by lobbying from industry. This report is published in an effort to broaden the spectrum of potential planning strategies that could help in phasing off these HHPs. Notably, scientific use of these pesticides is impossible, given field circumstances and business practices. This is based on the SAICM statement that, 'Highly Hazardous Pesticides are pesticides that must be handled differently, given their high toxicity. They are considered too dangerous for common risk measures, such as labelling and wearing Personal Protective

[1] **Definition of HHPs, provided by FAO/WHO International code of conduct on Pesticide management (2013)**

Equipment' (SAICM, 2022). International code of conduct on pesticide management in 2013 stipulated, 'Prohibition of the importation, distribution, sale and purchase of Highly Hazardous Pesticides may be considered if, based on risk assessment, risk mitigation measures or good marketing practices are insufficient to ensure that the product can be handled without unacceptable risk to humans and the environment'. This should be considered and applied in the Indian context, where scientific handling of HHPs using protective gears and PPE are lacking and ineffective in general (Highly Hazardous Pesticide Series-State of Chlorpyrifos, Fipronil, Atrazine, and Paraquat Dichloride in India, PAN INDIA, February 2022)

This report is an effort to understand the vast multitude of problems and complexities posed by Highly Hazardous Pesticides in India. This work presents statistical data on HHPs in India and also presented here is numerous long-term and short- term health effects of HHPs, as obtained from GHS, IARC, EU, US EPA and WHO toxicity classifications along with environmental toxicity and toxicity to bees as proposed by USEPA. Various toxicological studies related to these HHPs and Case reports of health disruptions from cited sources, available and studied mechanisms of these disruptions, individual pesticides and their effect are also discussed in this report. Other informations like list of bans of HHPs in other countries, effect on animals, poisonings by HHPs in India are added to substantiate the evidences needed for its phasing off. This work can provide an adequate independent support to the future efforts in tightening the legal framework for registration, manufacture, use and import of these Highly Hazardous Pesticides in India.

Chapter 2

METHODOLOGY

MOTIVE OF THE STUDY

This specific study is a comprehensive analysis, which focuses on the prevalence of Highly Hazardous Pesticides (HHPs) in India and their possible consequences on people and the environment. It also elaborates the present state regulation protocols, both national and international, as well addresses its context in Indian legislation. The Study also discusses, the statistics of these chemical pesticides as well as lists HHPs by the relevant criteria developed by FAO-WHO Joint Meeting on Pesticides Management (JMPM) and Pesticide Action Network (PAN) International. The study also analyses the approved and recommeded use of HHPs in India, as, most of which are banned in many countries but are still in use in India.

SCOPE OF THE STUDY

The scope of this report is centered upon conducting a detailed study which helps in analysing the present situation, wherein considerable number of Highly hazardous pesticides are registered in India. The possible health consequences of these pesticides are also discussed in this study. This study contributes to raising immediate awareness of the implications of HHP use and its non-strict regulations. It can be a helpful tool for decision-making bodies to take necessary actions and formulate new legislation. This report can help in raising awareness of people, act as a study material for pesticide-based studies and a helping aid for environmental protection by State governments, central government and NGOs.

MATERIALS AND METHODS

The study used reliable secondary data sources. Based on PAN HHP list updated in March 2021 and Insecticides / Pesticides Registered under section 9(3) of the Insecticides Act, 1968 for use in India, October, 2022 the current list of HHPs in India was developed. PAN HHP list (2021) was analysed and pesticides grouped for clarity, with emphasis given to different toxicicological parameters. Classification of these pesticides into different classes of toxicity, was done using WHO Classification of Pesticides by Hazard, 2019. Chemical class, Use type, Drift prone, Cholinesterase inhibitor and Endocrine disruptor status of each of these pesticides, which were obtained from the pesticide information database (https://www.pesticideinfo.org) by Pesticide Action Network North America, and PAN HHP list. Classification of these pesticides to different classes of acute toxicity was based on the WHO Classification of pesticides by Hazard, 2019.

Various statistical data of HHPs listed in this study was obtained from Statistical database of Directorate of Plant Protection, Quarantine and Storage, under the division of Pesticide Monitoring & Documentation, which is available in their website. Pesticide-wise consumption of imported pesticides 2021, and Pesticide-wise consumption of indigenous pesticides 2021, were obtained from this statistical database. A compilation list of this data into the total volume of pesticides used in 2021 was also made. Production data of HHPs was collected from the production of key pesticides 2021-22 (http://ppqs.gov.in/statistical-database). Export and Import data of HHPs was also obtained for 2021-22. Pesticides banned in various countries were obtained from PAN International Colsolidated list of Banned Pesticides (https://pan-international.org/pan-international consolidated-list-of-banned-pesticides/), May 2022.

Long-term health effects of studied HHPs were obtained from the PAN HHP list, which has a compiled dataset of information on health effects from GHS, EU, IARC and USEPA. The health consequences and mechanisms of different Highly Hazardous Pesticides were compiled from numerous papers, articles, publications, and books. Recommended use of pesticides for crop-pest combination from 10 States of India, which are classified as HHPs, were summed up and analyzed. States selected for these studies are Kerala, Tamil Nadu, Telangana, Andhra Pradesh, Orissa, Punjab, Haryana, Himachal Pradesh, Assam and Jammu Kashmir. These states were selected based purely on the availability of online resources. Pesticides, crops and their corresponding pests, and recommended dosage of Pesticides are also tabulated in this study. These were collected from crop recommendation packages of the above-mentioned states. They were analyzed and encapsulated in a table format and compared to national approved usage of these pesticides. Contradictions from comparing this to national approved usage are also noted in this study. Guides and Package of Practices (POP) of 10 States were analysed in this study are given in the following table.

Guides and POPs	Studied States
Package of Practices Recommendations, 2016	Kerala
Crop Production Guide Agriculture, 2020	Tamil Nādu
Package of Practice for Horticultural Crops, 2010	Assam
Guidelines for Crop Diversification, 2015	Himachal Pradesh
Farmers Handbook on Basic Agriculture, 2016	Andhra Pradesh
Package of Practice of Vegetable Crops, 2020	Jammu Kashmir
Package of Practice of Crops, 2005	Haryana
Package of Practices for the Crops of Kharif and Package of Practices for Cultivation of Vegetables, 2022	Punjab
Agricultural Action Plan, 2021	Telangana
Manual of Agricultural Production Technology, kharif crops, 2008	Orissa

Chapter 3

HIGHLY HAZARDOUS PESTICIDES

Toxicity of some chemical pesticides exceeds others considerably. This has led to the classification and grouping of pesticides into high-risk categories by international bodies such as the Food and Agricultural Organization (FAO) and World Health Organization (WHO). This group of chemical pesticides, known as HHPs, are highly detrimental to organisms and ecosystems, hinder life processes and create transgenerational implications, causing irreversible vandalizations. UNEP has stated that, 'Pesticides are inherently hazardous, and among them, a relatively small number of Highly Hazardous Pesticides (HHPs) cause disproportionate harm to environment and human health including: severe environmental hazards, high acute and chronic toxicity'[2]. Humans are majorly exposed to these pesticides through their dietary supply, natural resources (air, soil & water), accidental exposure (eg: breastfeeding) and the working environment which has resulted in casualities over the years. Consequently, it is imperative to concentrate on the detrimental impacts of these pesticides that outweigh their ability to control weeds and pests.

Worldwide attention to the toxicity of pesticides began with the publication of **Rachel Carson's book —Silent Spring (1962)**. This publication resulted in modifications of some national policies on pesticides and the introduction of a national ban on DDT (since its commercialization in 1939) in the US. Later, many studies were conducted in different parts of the world to examine the toxicities of these pesticides. Recognition of this class of pesticides as Highly hazardous Pesticides by the World Health Organization (WHO) was an action in itself by the publication of the guideline, Recommended Classification of Pesticides by Hazard, 1975. This document classified pesticides into 5 hazard classes according to their acute toxicity. Much later, the introduction of the Globally Harmonized System of Classification and Labelling of Chemicals (GHS) in 2002, resulted in a broader system of classification which in addition to acute toxicity also provides classification of chemicals according to their chronic health hazards and environmental hazards. Continued international concerns about Pesticides and other chemicals which cause health and environmental hazards led to the Stockholm Convention on Persistent Organic Pollutants, the Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade and the Montreal Protocol on ozone depletion by harmful chemicals.

In 2006, the FAO Council endorsed FAO participation in the Strategic Approach to International Chemicals Management (SAICM) and noted that the International Code of Conduct on the Distribution and Use of Pesticides is to be considered as an important element of the SAICM process with emphasis given to pesticide risk reduction and progressive banning of Highly Hazardous Pesticides (HHPs). This resulted in the formulation of criteria that define HHPs by the Joint FAO/WHO Meeting on Pesticide Management (JMPM) and led to a definition for HHPs in the International Code of Conduct on Pesticide Management when it was revised in 2013. They have formulated **eight criteria**, based on which HHPs are to be categorized. The definition for HHP proposed by WHO-FAO JMPM is the following

'Pesticides that are acknowledged to present particularly high levels of acute or chronic hazards to health or environment according to internationally accepted classification systems such as the World Health Organization (WHO) or the Globally Harmonized System of Classification and Labelling of Chemicals (GHS) or their listing in relevant binding international agreements or conventions and in addition, pesticides that appear to cause severe

[2] **Highly Hazardous Pesticides (HHPs) | UNEP - UN Environment Programme**

or irreversible harm to health or the environment under conditions of use in a country may be considered to be and treated as highly hazardous'[3].

3.1. JMPM Criteria for identifying HHPs

HHPs are characterized by the criteria formulated by FAO/WHO Joint Meeting on Pesticide Management [2008], These are given in the following table.

Table 3.1. Criteria applied for identifying HHPs, JMPM

Criterion 1: Pesticide formulations that meet the criteria of classes Ia or Ib of the WHO Recommended Classification of Pesticides by Hazard; or
Criterion 2: Pesticide active ingredients and their formulations that meet the criteria of carcinogenicity Categories 1A and 1B of the Globally Harmonized System of Classification and Labelling of Chemicals (GHS); or
Criterion 3: Pesticide active ingredients and their formulations that meet the criteria of mutagenicity Categories 1A and 1B of the Globally Harmonized System of Classification and Labelling of Chemicals (GHS); or
Criterion 4: Pesticide active ingredients and their formulations that meet the criteria of reproductive toxicity Categories 1A and 1B of the Globally Harmonized System of Classification and Labelling of Chemicals (GHS); or
Criterion 5: Pesticide active ingredients listed by the Stockholm Convention in its Annexes A and B, and those meeting all the criteria in paragraph 1 of Annex D of the Convention; or
Criterion 6: Pesticide active ingredients and formulations listed by the Rotterdam Convention in its Annex III; or
Criterion 7: Pesticides listed under the Montreal Protocol; or
Criterion 8: Pesticide active ingredients and formulations that have shown a high incidence of severe or irreversible adverse effects on human health or the environment

(Source: International Code of Conduct on Pesticide Management Guidelines on Highly Hazardous Pesticides, WHO, 2016)

[3] **Definition of HHPs, provided by FAO/WHO International code of conduct on Pesticide management (2013), taken from PAN HHP list, 2021**

3.1.1. Elaboration of JMPM criteria

1. Criterion 1: Pesticides are classified as extremely hazardous (1a) and highly hazardous (1b) based on oral and dermal toxicity of active ingredients, in terms of LD50 values. According to WHO hazard classification (2009), an oral concentration toxicity value <5 (LD50-mg/kg body weight, bw) and dermal toxicity value <50 (LD50-mg/kg bw) is identified as extremely hazardous (class 1 a) and oral concentration toxicity ranging from 5-50 (LD50-mg/kg bw) and dermal toxicity ranging from 50-200 (LD50-mg/kg bw) are classified as highly hazardous (class 1b).

2. Criterion 2: Pesticides that meet the 1A and 1B criteria of carcinogenicity under the Globally Harmonized System of Classification and Labelling of Chemicals (GHS) (6th revised edition 2015) are mentioned in criterion 2. Pesticides that have active ingredients/formulations which are known to have carcinogenic effect on humans, where the placing of a substance is largely based on human evidence are classified into category 1A and Pesticides that have active ingredients/formulations which are presumed to have carcinogenic impact on humans, with large basis on animal evidence falls under category 1B of criteria 2 GHS carcinogenicity.

3. Criterion 3 : Pesticides which cause germ cell mutagenicity according to categories 1A and 1B of criteria 3-mutagenicity of Globally Harmonized System of Classification and Labelling of Chemicals (GHS) (6th revised edition 2015) , where category 1A includes substances known to induce or regarded as if they induce heritable mutations in germ cells of humans from positive studies from human and category 1B are substances known to induce or regarded as if they induce heritable mutations in germ cells of humans from invivo heritable germcell mutagenicity tests.

4. Criterion 4: Pesticides which fall into categories 1A and 1B of criteria 4-reproductive toxicity in Globally Harmonized System of Classification and Labelling of Chemicals (GHS) (6th revised edition 2015) regarded where category 1A are substances known to be a human reproductive toxicant and 1B are substances presumed as a human reproductive toxicant.

5. Criterion 5: These include chemicals included under Annex A, Annex B and Annex D in the text of the Stockholm Convention. The text of the Stockholm Convention was adopted by the Conference of the Plenipotentiaries (Stockholm, 22 May 2001) and entered into force on,17 May 2004 and was later amended. Chemicals listed in annexure A are agreed to be eliminated by signing parties while the production of chemicals listed in Annex B must be regulated,

6. Criterion 6:. Pesticides in Annex III have been banned or severely restricted in at least two countries in different regions, or have been identified as severely hazardous pesticide formulations, decision for their inclusion in the list along with technical information, support and Decision Guidance Document is available in annex 3 of this convention.

7. Criterion 7: Pesticides included under the Montreal Protocol on Substances that deplete the Ozone Layer are included under criterion 7. Currently, Methyl bromide is the only pesticide included.

8. Criterion 8: This is done based on the assessment of national regulatory authorities where possible indicators and surveillance of hazardous impacts of pesticides that are used.

Criteria for HHP identification used in the study

HHPs are standardly identified using criteria formulated by WHO-FAO JMPM. However, a list of HHPs based on these criteria is not developed and made available by WHO. Pesticide Action Network initiated efforts to address this lacuna and developed a list of HHPs complying with the criteria developed by JMPM. However, the criteria recommended by JMPM do not consider critical parameters such as endocrine-disrupting properties, eco-toxicological effects and inhalation toxicity. For this reason, PAN International surpasses this shortcomings, and incorporates data sets from the EU and the US Environmental Protection Agency (EPA) along with data from WHO sources and brings additional criteria on the endocrine disruption, ecotoxicology and inhalation toxicity in its HHP list, which is used in this study.

3.2. Criteria used in developing HHP list, India

Criteria for the classification of hazardous chemicals, in this study, are based on the above-mentioned JMPM criteria which consider acute toxicity, long-term (chronic) health effects, environmental effects and international regulations (global pesticide-related conventions) formulated by FAO/WHO Joint Meeting on Pesticide Management, 2008 as well as the newer system of classification incorporated to this list by PAN International.

Newer terms and Systems used in PAN HHP classification

- H330 = ‘Fatal if inhaled’ (EU or the Japan Globally Harmonized System)
- Carcinogenic according to IARC, US EPA or probably/likely carcinogenic at High Doses according to EPA
- EU interim criteria as laid down in Reg. (EC) No 1107/2009 ‘Suspected human reproductive toxicant’ (Category 2) AND ‘Suspected human carcinogen’ (Category 2) according to the EU or the Japan Globally Harmonized System (GHS) or Pesticides identified as endocrine disrupters in the EU according to Reg. (EU) 2018/605
- High environmental concern where it can be
  1. very persistent(P) with a half-life > 60 days in marine- or freshwater or half-life > 180 days in soil (‘typical’ half-life), marine or freshwater sediment
  2. Very bioaccumulative (B) (BCF >5000) or Kow logP > 5 (Indicators and thresholds according to the Stockholm Convention)
  3. Very toxic(T) to aquatic organisms (LC/EC 50 [48h] of < 0,1 mg/l)
  4. ‘Highly toxic for bees’ according to U.S. EPA (LD50 <2 microgram/bee) where pesticide properties database is the reference site used

(Source: PAN International list of Highly Hazardous Pesticides, March 2021, Pesticide Action Network International)

3.2.1. Acute toxicity

WHO HHP classification is based primarily on the determination of acute oral and dermal toxicity in rats. Apparently, these determinations are standard procedures in toxicology. PAN HHP classification by acute toxicity also includes GHS (Globally Harmonized System) classification criterion for pesticides in their identification as HHPs now followed by WHO. Acute Toxic Hazard Category according to the GHS criteria rely on the acute toxicity estimate value for a substance which in the majority of cases, is an experimentally-derived LD50 value for oral exposure. LD50 values of the technical ingredient or ingredients is determined according to the following formula:

LD50 active ingredient × 100/ Percentage of active ingredient in formulation

Table 3.2: GHS classification criterion for chemicals[4]

LD50 for the rat (mg/kg body weight)	Oral (mg/kg body weight)	Dermal (mg/kg bodyweight)
Extremely hazardous	< 5	<5
Highly hazardous	5-50	50-200
Moderately hazardous	50-2000	200-2000
Slightly hazardous Over 2000	Over 2000	Over 2000
Unlikely to present acute hazard 5000 or higher	Above 50000	Above 50000

3.2.2 Long term effects

Long term effects (Carcinogenicity, Reproductive toxicity, Endocrine disruption and Mutagenicity) used in PAN HHP list is taken from GHS, EU and USEPA.

Globally Harmonized System of Classification (GHS)

Globally harmonized system for the classification and labelling of chemicals was adopted by the World Summit on Sustainable Development (WSSD), held in Johannesburg in 2002. Globally Harmonized System of Classification and Labelling of Chemicals (GHS) addresses the classification of chemicals by types of hazards and proposes harmonized hazard communication elements, including labels and safety data sheets. It aims to ensure that, information on physical hazards and toxicity of chemicals is available to everyone, to enhance the protection of human health and the environment, during the handling, transport, and use of these chemicals. The GHS also provides a platform for harmonization of rules and regulations on chemicals at the national, regional, and worldwide levels, an important factor for trade facilitation. The first edition of the GHS, was published in 2003 and the ninth revised edition of the GHS (GHS Rev.9), published in 2021, is the most recent published edition. GHS system has integrated long-term effects by retrieving data and studies on chronic health effects such as carcinogenicity, reproductive toxicity and mutagenicity (given in criteria 2, 3 and 4).

[4] GHS Classification Criteria for Acute Toxicity (chemsafetypro.com)

Integrated Risk Information System (IRIS, US-EPA)

The Integrated Risk Information System of the US-EPA also provides information on the carcinogenicity of pesticides. The results of reviews for carcinogenicity by USEPA are published in the List of 28 Chemicals evaluated for Carcinogenic Potential. This list is made available on the website of the National Pesticide Information Center. An annually updated list of chemicals with carcinogenic potential is maintained by the U.S. Environmental Protection Agency (USEPA). Another list of pesticides that are "likely to be carcinogenic to humans at high doses" is maintained by EPA. PAN HHP list has expanded it over the years and offers precise and capsulated technical data on HHPs.

International Agency for Research on Cancer (IARC)

International Agency for Research on Cancer (IARC), which is a part of the World Health Organization along with the assistance of international working groups of experts, critical reviews and evaluates the evidence of carcinogenicity. It has published monographs on pesticide toxicity and cancer. This series of monographs that started in 1972 has almost 900 works reviewed. IARC (2018): Agents reviews by the IARC Monographs, Volumes 1-123 (by CAS Numbers), is the source used in the PAN HHP list for IARC Carcinogenicity

EU categorisation of endocrine disruptors[5]: Other than the GHS classification for carcinogenicity, PAN list of HHPs also draws on "EU GHS List" and "EU Endocrine Disruptor list" based on the GHS criteria formulated for pesticides, as laid down as EU Regulation 1272/2008/EC on classification, labelling and packaging of substances and mixtures (so-called "CLP-Regulation") and Pesticides categorised as endocrine disruptors by European Union according to EU Regulation 2018/605.

Endocrine disruptors are chemicals which can disrupt the balance of the endocrine system (hormone system) and thereby alter the physiology, growth, metabolism and reproduction were it have a deteriorating effect on the foetus in the womb and can affect generations. Endocrine disruptors (EDs) are exogenous chemicals that can mimic the activity of a functional hormone and can have an agonist effect or antagonistic effect, and can also bind with transporter protein which affects the natural metabolism and functioning of hormones. Most of them significantly affect oestrogen, androgen and thyroid metabolism. Such effects were first noted in molluscs, crustaceans, fishes, reptiles, birds, and mammals in various parts of the world. The effect of endocrine disruptors in humans was first noted in the 1950s when diethylstilbesterol (DES), a synthetic oestrogen, whose early exposure in the uterus resulted in developmental abnormalities and vaginal cancer in girls on attaining puberty. The European Union has taken advanced measures on identifying, studying and phasing out chemicals that are hormonally disruptive.

In 2020, the first pesticide that was officially identified as an endocrine disrupter by EFSA was Mancozeb. Yet, a system on sets of definite criteria is not laid, for classifying endocrine disruptors. The Endocrine Disrupters Expert Advisory Group, set up by the Directorate General Environment (DG) and chaired by the Commission's Joint Research Centre (JRC) identified and submitted a list of EDs in 2013. JRC decided upon a road map for defining criteria for EDs, holding public consultations and monitoring the responses on defining criteria for identifying endocrine disruptors.

3.2.3 Environmental effects

Environmental effects of HHP use are mainly explained in terms of high bioaccumulation and very persistent half-life (based on indicators and thresholds according to the Stockholm Convention) and based on aquatic toxicity and bee toxicity, obtained from U.S. EPA.

[5] Chemicals - Environment - European Commission (europa.eu)

U.S. Environmental Protection Agency (U.S. EPA)[6]

The US EPA also defines categories for the environmental toxicity of pesticides. US EPA defines a pesticide, as highly toxic to bees, if the LD50 is lower than 2 micrograms per bee (µg/bee). The U.S. EPA Office of Pesticide Programs summarises the toxicity of pesticides to certain species groups. Pesticides characterised as very highly toxic to aquatic organisms, have a lethal or environmental concentration LC/EC50 [48h] of < 0.1mg/l[7]. A pesticide is considered bio-accumulative if bio accumulative factor BCF >5000) or Kow logP > 5 (Indicators and thresholds according to the Stockholm Convention).

3.2.4. International conventions listing HHPs

Stockholm Convention[8]

Stockholm Convention on Persistent Organic Pollutants (POPs), was held on 22 May 2001, in Stockholm, Sweden on Sustainable Development. Annex A of the Stockholm conference document Prohibits and/or eliminates the production and use, as well as the import and export, of the intentionally produced POPs that are listed in Annex A. Annex B restricts the production and use, as well as the import and export, of the intentionally, produced POPs. Annex D (Information Requirements And Screening Criteria) lists the criterion for classification and safe storage & transport of chemicals based on Chemical identity, Persistence, Bio-accumulation, Adverse effects, and Potential for long-range environmental transport. The convention entered into force on May 17th, 2004.

Persistent Organic Pollutants (POPs) listed in this convention are known for their persistence in the environment and having long half-lives in soils, sediments, air, or biota. They are lipophilic in nature and can bioaccumulate in fatty tissues of living organisms and magnify in the food chain. U.S EPA has found links between POPs exposure and the increased frequency of diseases in wildlife species. POPs are also found to affect coral reef communities and marine ecosystem

In 1995, United Nations Environment Programme identified 12 highly persistent Pesticides known as “Dirty Dozen”, of which many are no longer used for agricultural purposes but a few continue to be used in developing countries. This includes **DDT and Dicofol** (it is identified as an industrial chemical rather than pesticide in Annex A) which are presently registered in India.

Rotterdam Convention[9]

The text of the Rotterdam Convention was adopted by the Conference of the Plenipotentiaries (Rotterdam, 10 September 1998). Rotterdam Convention was held to address strategic decisions regarding trade of hazardous chemicals and to facilitate informed decision-making by countries with regard to trade. The chemicals listed in Annex III include pesticides and industrial chemicals, that have been banned or severely restricted for health or environmental reasons by two or more Parties, and which the Conference of the Parties has decided to subject to the PIC procedure. About 73% of the chemicals covered by Rotterdam Convention are pesticides. A total of 52 chemicals are listed in Annex III, in which 35 are pesticides (including 3 severely hazardous pesticide formulations), 16 are industrial chemicals, and 1 is both a pesticide and an industrial chemical. The convention text has stated that “Some pesticides are so dangerous that they cannot be used safely under normal and affordable developing country conditions”.

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[6] **About EPA | US EPA**
[7]**Source used: Lewis KA, Tzilivakis J, Warner D & Green A (2020): An international database for pesticide risk assessments and management. Human and Ecological Risk Assessment: An International Journal, In Press.**
[8] **UN Conference on the Human Environment .:. Sustainable Development Knowledge Platform**
[9] **Rotterdam Convention Home Page (pic.int)**

Of these 35 pesticides, many are currently banned in India for agricultural use. Five pesticides which are still registered in India are subjected to PIC procedure according to this convention. These are Carbofuran, Carbosulfan, Dichloro Diphenyl Trichloroethane (DDT), Monocrotophos and Paraquat dichloride. For these pesticides, there is a decision guidance document (DGD), which is intended to help governments to assess the risks connected with the handling and use of the chemical and decisions about future import. Parties are also informed prior to an export as to whether there will be consent to import.

Montreal protocol[10]

The Montreal Protocol (1987) is an international agreement to protect the stratospheric ozone layer by phasing out the production and consumption of ozone-depleting substances (ODS). Signed in 1987, and amended several times since, the Protocol aims to control ozone-depleting chemicals and replace them with safer alternatives and India has been a signatory to Montreal Protocol since June 1992.

Presently, Methyl bromide is the only pesticide included in this list (since 1992). Methyl bromide is a Class I ozone-depleting substance (ODS) and it releases halogens, which can deplete the ozone layer. 2002 report of the 'Methyl bromide Technical Options Committee' has provided alternatives for methyl bromide in agriculture[11]. All developed countries agreed to a complete phase-out of this pesticide by 2005 and by 2015 for developing countries. Unfortunately, it is still registered in India and produced, exported and imported. It is recommended for stored cereals, milled products, and for dry fruits and oil seeds (Major Uses of Insecticides, 2022, PPQS)

End notes

This chapter elaborates on the general definition of HHPs and the criteria used for classifying them by FAO/WHO Joint Meeting On Pesticide Management, 2013 in detail. The need for a broader set of criteria for identifying and classifying HHPs is highlighted in this chapter. PAN International has bridged this gap and in addition to having criteria by JMPM, they have incorporated information on Endocrine disruption, ecotoxicity and inhalation toxicity from the EU, USEPA along with data from WHO sources in its HHP list. The international conventions in which these HHPs are listed and the PAN system of HHP classification are also explained in this chapter. Few of the HHPs registered in India are listed in the conventions of Monteral Protocol, Stockholm Convention and Rotterdam Convention. The purpose of this chapter is to strengthen public knowledge about HHPs.

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[10] The Montreal Protocol on Substances That Deplete the Ozone Layer - United States Department of State
[11] 2002 report of the methyl bromide: technical options committee (MBTOC) | UNEP - UN Environment Programme

Chapter 4

HIGHLY HAZARDOUS PESTICIDES(HHPs) IN INDIA

Highly Hazardous Pesticides are a group of synthetic pesticides which cause deleterious effects on humans, other life forms and the environment, and whose production must be supervised, regulated, and controlled. This study analysed registered pesticides in India and developed an HHP list using this. **Out of 318 pesticides registered in 2022, 120 are found to comply with the criteria of HHPs, as per the PAN list of 2021.** These are registered for commercial use, production, import and export purposes under section 9(3) of the Insecticides Act of 1968 in the list of registered pesticides, 01-10-2022.

Table 4.1 List of 120 Highly Hazardous Pesticides (HHPs) in India, 2022

S.No.	PESTICIDES	CHEMICAL CLASS	USE TYPE
1.	Milbemectin	-	Insecticide and acaricide (information from PubChem)
2.	Carbendazim	Benzimidazole	Breakdown product, Fungicide
3.	Methomyl	N-Methyl Carbamate	Breakdown product, Insecticide
4.	Ziram	Dithiocarbamate, Inorganic-Zinc	Fungicide, Microbiocide, Dog and cat repellent
5.	Methyl Bromide	Halogenated organic	Fumigant, Herbicide, Insecticide, Nematicide
6.	Magnesium Phosphide Plates	Inorganic	Fumigant, Rodenticide
7.	Aluminium Phosphide	-	Fumigant, Fungicide
8.	Captan	Thiophthalimide	Fungicide
9.	Chlorothalonil	Substituted Benzene	Fungicide
10.	Cyproconanzole	Azole	fungicide
11.	Edifenphos	Organophosphorus	Fungicide
12.	Epoxyconazole	-	Fungicide
13.	Flusilazole	Azole	Fungicide
14.	Iprodione	Dicarboximide	Fungicide
15.	Kresoxim Methyl	Strobin	Fungicide
16.	Mancozeb	Dithiocarbamate-ETU, Inorganic-Zinc	Fungicide
17.	Metiram	Dithiocarbamate-ETU, Inorganic-Zinc	Fungicide
18.	Propiconazole	Azole	Fungicide
19.	Tebuconazole	Azole	Fungicide
20.	Tetraconazole (FI)	Azole	Fungicide
21.	Thiophanate methyl	Benzimidazole precursor	Fungicide
22.	Triflumizole (FI-WRT)	Azole	Fungicide
23.	Validamycin	Antibiotic	Fungicide
24.	Amisulbrom	-	Fungicide (information from PubChem)
25.	Iprovalicarb	-	Fungicide (information from PubChem)
26.	Dinocap	Dinitrophenol derivative	Fungicide, Insecticide
27.	Dodine	Guanidine	Fungicide, Microbiocide
28.	Propineb	Dithiocarbamate, Inorganic-Zinc	Fungicide, Microbiocide
29.	Copper Hydroxide	Inorganic-Copper	Fungicide, Microbiocide, Nematicide
30.	Butachlor	Chloroacetanilide	Herbicide

31.	Diclofop-methyl	Chlorophenoxy acid, salt, or ester, Aryloxyphenoxy propionic acid	Herbicide
32.	Diuron	Urea	Herbicide
33.	Flumioxazin	-	Herbicide
34.	Fluazifop p butyl	Aryloxyphenoxy propionic acid	Herbicide
35.	Fluthiacet methyl	-	Herbicide
36.	Glufosinate Ammonium	Phosphonoglycine	Herbicide
37.	Glyphosate	Phosphonoglycine	Herbicide
38.	Methabenzthiazuron	Urea	Herbicide
39.	Metribuzin	Triazinone	Herbicide
40.	Oxadiazon	-	Herbicide
41.	Oxyfluorfen	Diphenyl ether	Herbicide
42.	Paraquat dichloride	Bipyridylium	Herbicide
43.	Pendimethalin	2,6-Dinitroaniline	Herbicide
44.	Quizalofop P-tefuryl	Aryloxyphenoxy propionic acid	Herbicide
45.	Triallate	Thiocarbamate	Herbicide
46.	Trifluralin	2,6-Dinitroaniline	Herbicide
47.	2,4-Dichlorophenoxy Acetic Acid	-	Herbicide, Plant Growth Regulator
48.	Chlorpropham	Other Carbamate	Herbicide, Plant Growth Regulator
49.	Hexythiazox	-	Insect Growth Regulator
50.	Chlorfluazuron	-	Insect Growth Regulator, Insecticide
51.	Abamectin	Macrocyclic Lactone,	Insecticide
52.	Acephate	Organophosphorus	Insecticide
53.	Bendiocarb	N-Methyl Carbamate	Insecticide
54.	Benfuracarb	Other Carbamate	Insecticide
55.	Beta Cyfluthritrialn	Pyrethroid	Insecticide
56.	Bifenthrin	Pyrethroid	Insecticide
57.	Carbosulfan	N-Methyl Carbamate	Insecticide
58.	Chlorantraniliprole	Anthranilic diamide	Insecticide
59.	Chlorfenapyr	Pyrazole	Insecticide
60.	Chlorpyriphos Methyl	Organophosphorus	Insecticide
61.	Clothianidin (FI-WRT)	Neonicotinoid	Insecticide
62.	Cyfluthrin	Pyrethroid	Insecticide
63.	Cypermethrin	Pyrethroid	Insecticide
64.	Deltamethrin (Decamethrin)	Pyrethroid	Insecticide
65.	Diafenthiuron	-	Insecticide
66.	Dichloro Diphenyl Trichloroethane (DDT)	Organochlorine	Insecticide
67.	Dicofol	Organochlorine	Insecticide
68.	Dimethoate	Organophosphorus	Insecticide
69.	Dinotefuron	Neonicotinoid, Guanidine	Insecticide
70.	Emamectin Benzoate	Macrocyclic Lactone	Insecticide
71.	Ethion	Organophosphorus	Insecticide
72.	Ethofenprox (Etofenprox)	Pyrethroid Ether	Insecticide
73.	Fenazaquin	-	Insecticide
74.	Fenitrothion	Organophosphorus	Insecticide
75.	Fenpropathrin	Pyrethroid	Insecticide
76.	Fenpyroximate	Pyrazole	Insecticide
77.	Fenvalerate	pyrethroid	Insecticide
78.	Fipronil	Pyrazole	Insecticide
79.	Flubendiamide	Anthranilic diamide	Insecticide
80.	Flufenoxuron	Benzoylurea	Insecticide
81.	Flupyradifurone	Neonicotinoid	Insecticide
82.	Imidacloprid	Neonicotinoid	Insecticide
83.	Imiprothrin	Pyrethroid	Insecticide

84.	Indoxacarb	-	Insecticide
85.	Lufenuron	Benzoylurea	Insecticide
86.	Malathion	Organophosphorus	Insecticide
87.	Metaflumizone	-	insecticide
88.	Monocrotophos	Organophosphorus	Insecticide
89.	Oxydemeton-Methyl	Organophosphorus	Insecticide
90.	Permethrin	Pyrethroid	Insecticide
91.	Phenthoate	Organophosphorus	Insecticide
92.	Prallethrin	Pyrethroid	Insecticide
93.	Profenophos	Organophosphorus	Insecticide
94.	Propargite	-	Insecticide
95.	Propetamphos	Organophosphorus	Insecticide
96.	Propoxur	N-Methyl Carbamate	Insecticide
97.	Pymetrozin (FI), TIM	Triazine	Insecticide
98.	Pyrethrin (pyrethrum)	Botanical	Insecticide
99.	Pyridaben (FI- WRT)	-	Insecticide
100.	Pyridalyl	-	Insecticide
101.	Quinalphos	Organophosphorus	Insecticide
102.	Spinetoram	Spinosyn	Insecticide
103.	Spinosad	Spinosyn, Macrocyclic Lactone	Insecticide
104.	Sulfoxaflor	Neonicotinoid	Insecticide
105.	Temephos	Organophosphorus	Insecticide
106.	Thiacloprid	Neonicotinoid	Insecticide
107.	Thiomethoxam	Neonicotinoid	Insecticide
108.	Tolfenpyrad (TIM)	Pyrazole	Insecticide
109.	Fluvalinate	-	Insecticide (information from PubChem)
110.	Lambdacyhalothrin	-	Insecticide and acaricide (information from PubChem)
111.	Meptyl Dinocap	-	Insecticide and acaricide (information from PubChem)
112.	Thiodicarb	N-Methyl Carbamate	Insecticide, Molluscicide
113.	Carbofuran	N-Methyl Carbamate	Insecticide, Nematicide
114.	Chlorpyriphos	Organophosphorus	Insecticide, Nematicide
115.	Forchlorfenuron	Urea	Plant Growth Regulator
116.	Brodifacoum	Coumarin	Rodenticide
117.	Bromadiolone	Coumarin	Rodenticide
118.	Coumatetralyl	Coumarin	Rodenticide
119.	Flocoumafen	Coumarin	Rodenticide
120.	Zinc Phosphide	Inorganic-Zinc	Rodenticide

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4.2 HHPs in Indian legislation

There is no legal recognition of Highly Hazardous Pesticides in India as well as in different parts of the world. In India, **38 per cent** of all the chemical pesticides registered are HHPs which are currently regulated under the Insecticides Act 1968 and Insecticides Rules, 1971. These Acts and Rules do not dwell upon the characteristics of HHPs. The draft of the Pesticide Management Bill in 2020 also does not have a provision to classify pesticides as per their toxic impacts.

The Insecticides Act, of 1968, includes many provisions and has facilitated the setting up of multiple institutions like Central Insecticides Board, Registration Committee and Central Laboratory at National and State levels for manufacturing, registering, monitoring and licensing of pesticides. Since HHPs are not regarded as a unique class of pesticide, they are subjected to the same regulations as other registered pesticides

Insecticides Rules 1971

The only set of rules governing pesticides in India is the Insecticide Rules, 1971. It has a total of nine chapters

- ❖ Chapter I; 1, consists of short titles and definitions of the terms used in the Rules
- ❖ Chapter II; 3, 4, 5 deals with the functions of the Board, Registration Committee and Laboratory
- ❖ Chapter III deals with the registration of insecticides
- ❖ Chapter IV deals with the granting of licences
- ❖ Chapter V discusses packing and labelling
- ❖ Chapter V deals with the roles of Insecticide Analysts and Insecticide Inspectors
- ❖ Chapter VII deals with the manner of packing and storage while in transit by rail
- ❖ Chapter VIII is about protective clothing, equipment, and other facilities for workers during the manufacture of insecticides
- ❖ Chapter IX is the Miscellaneous part

Pesticide Management Bill, 2020 (draft)

A new draft of Pesticide Management Bill was approved by the Union Cabinet of India in 2020. The Preamble says that "it will regulate pesticides, including their manufacture, import, packaging, labelling, pricing, storage, advertisement, sale, transport, distribution, use and disposal in order to ensure availability of safe and effective pesticides, and to strive to minimise risk to human beings, animals, living organisms other than pests, and the environment with an endeavour to promote pesticides that are biological and based on traditional knowledge and for matters connected therewith or incidental thereto"[12].

The bill fails to address critical problems posed by pesticides, from the regulatory experience of the last 54 years. The new bill does not consider the mitigation of pesticides which are deleterious to human health and the environment and many prevailing issues (commentary by A.D Dileep Kumar and D. Narasimha Reddy)[13]

However, the bill includes an important aspect stating that extremely and highly hazardous pesticides — considered Class I pesticides by the WHO due to acute toxicity — are to be used only after prescription. As per the bill, the State Government may prescribe qualifications for the licencing officer, pesticide inspector and pesticide analyst and their appointment. The State Government may also notify a person for sale by prescription of the extremely toxic or highly toxic category of Pesticides. The accountability and conditions with respect to such prescriptions are not elaborated in the bill and Guidelines for this are yet again not elaborated.

It is apparent that the Bill is not based on scientific knowledge available on various pesticides in general and HHPs in particular. Therefore, amendments to include broader changes are needed in this new bill. The bill should create provisions to enable the phase-out of HHPs by re-evaluating already registered pesticides and developing a phase-out plan.

Similarly, Chapter 5 (Pesticide Surveillance and prohibition in the public interest) has stated that the Central Government may, by notification, ban a molecule or formulation of a pesticide in respect of which registration has been granted if— (a) such ban is necessary to comply with the orders of a court of competent jurisdiction, or (b) such molecule or formulation has been banned under any international treaty or agreement relating to pesticides to which India is a party.

If this clause of the bill be implemented, Carbofuran, Carbosulfan, Dichloro Diphenyl Trichloroethane (DDT), Monocrotophos, Dicofol and Paraquat dichloride listed in POP Stockholm Convention and PIC of Rotterdam Convention will have to face an immediate ban following the enactment of the bill. However, it is noted that

[12] 164.100.47.193/lsscommittee/Agriculture, Animal Husbandry and Food Processing/17_Agriculture_Animal_Husbandry_and_Food_Processing_36.pdf
[13] https://www.currentscience.ac.in/Volumes/121/03/0348.pdf

there has not been an effective action in enacting this Bill, even in 2022. The Bill needs improvement with the objective of tightening the regulation, integrating scientific knowledge with pesticide regulation and building a robust review mechanism.

End notes

This chapter provides the list of HHPs registered in India. A list of 120 HHPs along with their chemical class and use type is listed in this chapter, which accounts for a major portion of pesticides registered in India. In the Indian context, there is currently no dedicated law governing the use and regulation of Highly Hazardous Pesticides. The latest Pesticide Management Bill, which also fails to include HHPs is discussed in this chapter. This chapter highlights how relatively unstringed is Indian regulation of HHPs and demand urgency for government to act to regulate the use of HHPs in India.

Chapter 5

STATISTICS OF HHPs IN INDIA

In this report, 120 HHPs are classified based on general characteristics, health effects, consolidated ban in other countries, Deemed to be Registered Pesticides, volume consumption (both imported and indigenous), production, export, WHO criteria of Hazard Classification and PAN HHP classification. A comparative analysis of state-wise recommended use and national-approved usage is done for 10 States of India, which is also explored in this study.

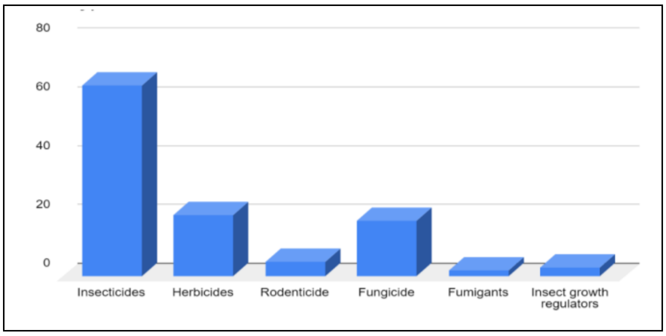
5.1. Use Type of HHPs

Insecticides make up the majority of HHPs, in India. More than 60% of the HHPs, from the 120 identified, are insecticides. This information is consistent with India's chemical pesticide usage statistics, which deviate from the worldwide trend. In India, 51% of pesticides used are **insecticides** compared to the global average of 19 % [14] according to FAOSTAT, 2018. This study finds that, of the 120 HHPs in India, 65 are insecticides, 21 are herbicides and 19 are fungicides. Other classes included in the list are plant growth regulators, fumigants, and dog repellents (Source: Pesticide info of PANNA and PubChem).

Because of India's humid climate, which is conducive to insect growth, farmers are increasingly concerned about the higher incidence of insect pests on their crops. This is contrary to the situation in developed countries, where the use of herbicides is high. However, in recent years, the use of herbicides in India has increased. Fungicides are also used extensively in India. They are used to kill parasitic spores and fungi and are also used in early seed treatments. A Technical Bulletin on Current Status and Guidelines for Safe Use of Pesticides in Agriculture, 2020, by ICAR, has reported that 50 % of the total insecticides produced in the country are for cotton pest management[15] and, chlorpyrifos is the most used insecticide in India.[16](2019-20)

Chlorpyrifos is an organophosphorous insecticide which is registered for use in six different formulations (Chlorpyrifos 01.50 % DP 59, Chlorpyrifos 10 % Granules 60, Chlorpyrifos 20 % EC 61, Chlorpyrifos 50 % EC 62, Chlorpyriphos 02 % w/w EC 63 and Chlorpyriphos 75 % w/w WG) and in combination with other Pesticide (1-Acetamiprid 00.40 % + Chlorpyriphos 20 % EC). As per field information collected from 7 states of India, there is a lot of unregulated usage of Chlorpyrifos, in violation of national approved usage, while it was approved for 18 crops, its use in 23 crops was found in the same study[17].

Fig 1: Use type of the HHPs in India



[14] FAO, (2018). Pesticide Use Data-FAOSTAT. Retrieved from http://www.fao.org/faostat/en/#data/RP

[15] P. Mooventhan et al (2020), Technical bulletin on Current Status and Guidelines For Safte Use of Pesticides in Agriculture. Bulletin.cdr (icar.gov.in)

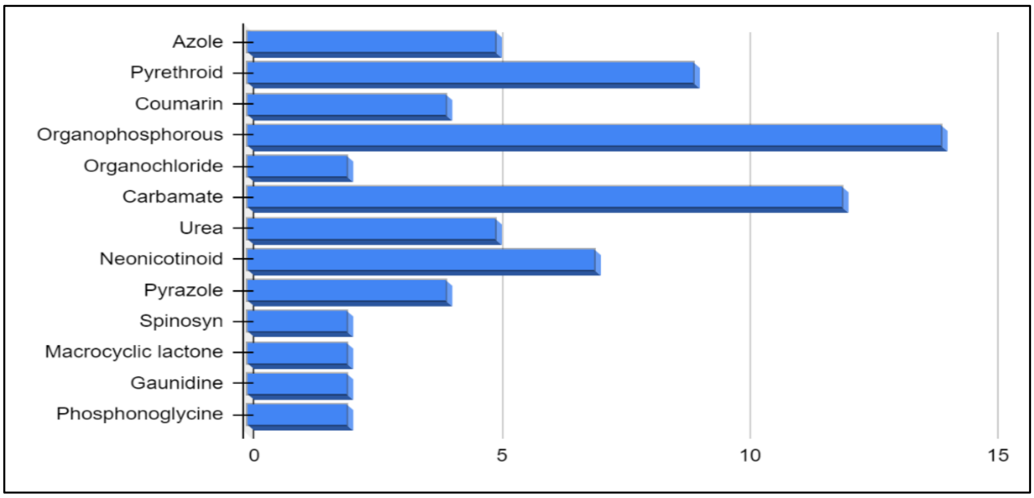
[16] Nayak, P, & Solanki, H (2021). Pesticides and indian agriculture- a review. *International Journal of Research - GRANTHAALAYAH*, *9*(5), 250

[17] https://pan-india.org/wp-content/uploads/2022/08/HHP_Chl-Fip-Atr-Pqt_Report-Final-web_PAN-India.pdf

5.2. Chemical classes of HHPs

Organophosphate chemical class of pesticides are the most abundant type of HHPs in India. They constitute the highest share of HHPs registered in India, followed by carbamate and pyrethroids. As per USEPA, organophosphates are the most used insecticides along with pyrethroids and carbamates in the US. In India, in the 2000s, organochlorine pesticides accounted for 40% of the total pesticides used[18]. **Organophosphate** insecticides have overtaken organochlorine compounds as the most used insecticides, in the recent decade. The other chemical classes of pesticides noted for HHPs in the study include pyrethroids, neonicotinoids, macro lactones, azole, carbamate, urea etc., (Fig 2). The chemical class of each studied pesticide, obtained from pesticide info database by PANNA and WHO Hazardous classification are also noted in table 4.1.

Fig 2: Chemical class of registered HHPs



5.3. Physical and chemical attributes of HHPs

The use type and drift-proneness are the two general characteristics that were examined for the registered HHPs in this study. Drift-prone characteristics of pesticides are based on the volatility of active ingredients which increases with temperature.

Pesticide-drift is measured in terms of the vapour pressure of chemicals, noted in units of millimetres of mercury (mm Hg) and this is directly proportional to volatility. Higher drifting pesticides volatilise easily from soil and plant surfaces and can reach non-target surfaces. Pesticides with vapour pressure higher than 10-6 mm Hg are considered high drift-prone pesticides. These pesticides can harm vegetation, animals, and non-target crops. It should be highlighted that only 0.1 percent of these pesticides are thought to reach the intended organisms; the remainder contaminate water sources, drift to nearby fields, and cause negative environmental effects (Carriger, J. F. et al., 2006)

Of these 120 HHPs, 28 have low drift-prone values, 18 have very low drift-prone values, 21 have moderate drift-prone values, and 3 have high drift-prone values (Annexure 2). Three high drift-prone HHPs are Dodine, Triallate and Trifluralin. Dodine is a fungicide recommended for treatment of scab disease and leaf blight in apples. Triallate is a herbicide used in wheat to get rid of herb, *Avena fatua* and Trifluralin is a herbicide without national recommendation.

[18] **Dr Agnihotri N P, Pesticide consumption in Agriculture in India-an Update. *Journal of Pesticide Research*, 31 October,2011**

5.4. Deemed to be registered pesticides (DRPs)

Certain pesticides were in use in India prior to the 1968 passage of the Insecticide Act. Due to their existing use, these pesticides were exempt from the registration scrutiny process. The safety information for these pesticides has not yet been fully submitted to the Registration Committee and was not thoroughly examined. Such pesticides are known as Deemed to be registered pesticides.[19] About 17% of pesticides registered in India falls under Deemed to be registered pesticides. It appears that DRPs increased subsequently, after 1968. By comparing the current list of HHPs to DRPs in India, the following observations were noted.

- By 2018, 62 registered pesticides in India are DRPs. Out of these 62 DRPs, 26 are HHPs (Table 1).
- It was observed that, these 26 HHPs have higher production and consumption rate in the country (Eg; Mancozeb has the highest production rate in India followed by 2,4-D. Both of them are DRPs)
- These HHPs are among the most commonly used pesticides in India and have not undergone formal registration scrutiny.
- Many of these pesticides are hazardous to health. Among them, **7** HHPs are carcinogenic (Butachlor, Captan, DDT, Diuron, Malathion, Mancozeb and Propoxur), **4** are endocrine disrupting HHPs (2,4-D, DDT, Mancozeb and Quinalphos) and **Dinocap** exhibits reproductive toxicity.
- **Eleven** of these HHPs are known to cause environmental toxicity (Aluminium Phosphide, Carbofuran, DDT, Dimethoate, Malathion, Monocrotophos, Oxydemeton-methyl, Phenthoate, Propoxur, Quinalphos and Triallate)
- Several of them are listed in International Conventions; **2** of them are POPs according to Stockholm convention (DDT and Dicofol) and **4** are subjected to PIC under Rotterdam convention (Carbofuran, DDT, Monocrotophos and Paraquat dichloride). **Methyl bromide** is also an ozone depleting chemical, under Montreal Protocol.

Table 1: List of HHPs which are DRPs

Sl No	HHPs
1	2,4-Dichlorophenoxy Acetic Acid
2	Aluminium Phosphide
3	Butachlor
4	Captan
5	Carbofuran
6	Dichloro Diphenyl Trichloroethane (DDT)
7	Dicofol
8	Dimethoate
9	Dinocap
10	Diuron
11	Edifenphos
12	Ethion
13	Fenitrothion
14	Malathion
15	Mancozeb
16	Methyl Bromide
17	Monocrotophos
18	Oxydemeton-Methyl
19	Paraquat dichloride
20	Phenthoate
21	Propoxur
22	Pyrethrin (pyrethrum)
23	Quinalphos
24	Triallate
25	Zinc Phosphide
26	Ziram

[19] **More details in the PAN India report: Deemed-to-be-Registered-Pesticides_report_PAN-India-Web.pdf**

5.5. Production of HHPs in India

Production statistics of pesticides in India comes from the Statistical database maintained Pesticide Monitoring Unit of the Directorate of Plant Protection Quarantine and Storage. It gives data only on 41 pesticides (denoted as key pesticides in India)[20], of which 27 are HHPs (66 percent of key pesticides). These 27 are tabulated below.

Table 2: HHPs and their production in metric ton in year 2021 and 2022

Sl No	Pesticides	Production (2020-2021)	Production (2021-2022)
1	Acephate	29,588	29,556
2	Chlorpyriphos	8,529	7,494
3	Cypermethrin	12,291	16,480
4	DDT	569	658
5	Deltamethrin	590	707
6	Dimethoate	1,452	1,391
7	Ethion	2,220	2,794
8	Fenvalerate	493	678
9	Imidachloroprid	29	26
10	Lambda cyhalothrin	1,677	2,696
11	Malathion	3,838	3,286
12	Metribuzin	3,191	1.999
13	Monocrotophos	7,917	7,487
14	Pendimethalin	3,639	4,764
15	Permethrin	1,656	2,485
16	Phenthoate	1,349	1,830
17	Profenofos	16,080	16,247
18	Quinalphos	1,056	2,454
19	Temephos	148	-
20	Thiamethoxam	5,211	6,562
21	Mancozeb	97,428	117,831
22	Ziram	881	673
23	2,4-D	27,050	39,996
24	Diuron	3,423	2,325
25	Glyphosate	6,129	5,722
26	Aluminium phosphide	7,614	9,350
27	Zinc phosphide	1,468	1,979
	Total	**245, 516**	**287,470**

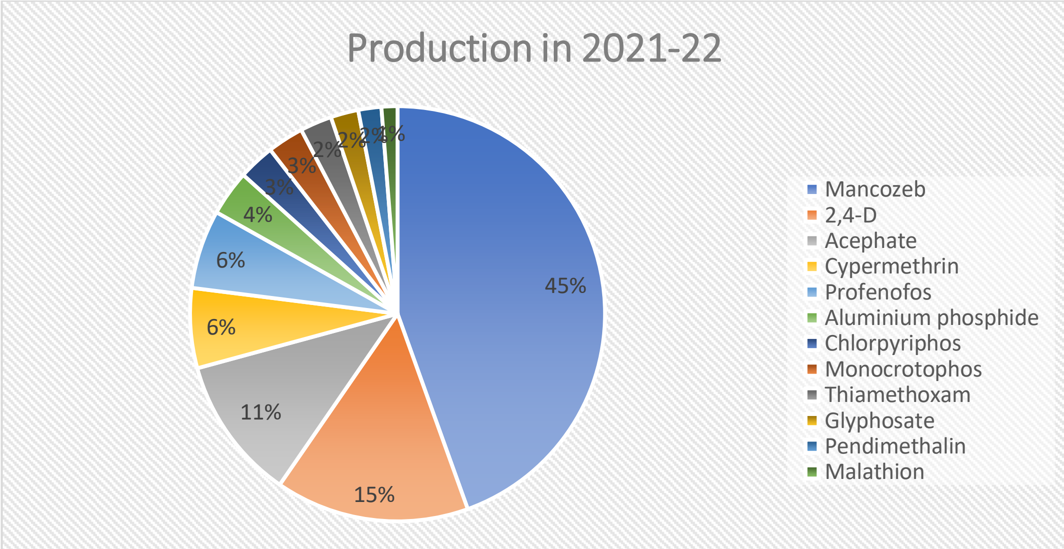
When comparing the production of HHPs in the last two years, it was noted that production of 17 HHPs have spiked in 2022 compared to the previous year. Production of Mancozeb, 2,4-D, Cypermethrin, Lambda cyhalothrin and Thiamethoxam has increased marginally in the past year. As given in Table 3, Total production of 41 key pesticides has gone up from 255,090 Metric tons in 2021 to 297,783 Metric tons of production in 2022[21]. Of these 41 pesticides listed, 27 are HHPs and their total Production has also increased from 245,516 metric tonnes in 2021 to 287,470 metric tonnes in 2022. **Production of these 27 HHPs has increased by 44,189 metric ton within one year – 18 percent rise**. Analysis of this data shows that **96.24%** of the key pesticide production is of HHPs, in 2021 and **96.53%** in 2022.

Table 3: Total Production of pesticides

	2021	**2022**
Total HHP production (27 HHPs)	2,45,516	2,87,470
Total key Pesticide production (41)	2,55,090	2,97,783

[20] http://ppqs.gov.in/statistical-database
[21] Production of key pesticides, 2022, Statistical database, PPQS

Fig 3: Pie chart of HHP production in 2021-22



From figure 3, in comparison to other HHPs, Mancozeb's production share is unquestionably higher than others. India's high consumption of this pesticide is another factor driving up its production. According to Pesticide Manufacturers and Formulators Associstion of India (PMFAI), 2020, India is the largest producer of Mancozeb for both domestic as well as world markets (Agribusiness global). Mancozeb was also included in the draft ban notification of 27 pesticides in May 2020.

2,4-D has the second highest production in the country. It is a hazardous herbicide, whose production, export, import and volume consumption are rising in the last few years. Use of herbicides is increasing, in agricultural as well as non-agricultural sectors for weed removal as a replacement for manual weeding and tilling practices. 2,4-D is an R2 and C2 categorized chemical (Pesticides classified into GHS Carcinogen Category 2 And Reproductive Category 2) as well as a suspected endocrine disruptive agent. The third largest produced HHP, Acephate, is another hazardous contact and systemic insecticide, which is recommended for use in cotton and rice against bollworms, stemborers etc., (Major uses of pesticides, PPQS). Acephate is also used as a combination pesticide with other HHPs. Its intermediate product, Methamidiphos is more toxic than the parent compound. The past year has seen a significant increase in the production of HHP and other chemical pesticides. which is now a serious cause for concern.

5.6. Import of HHPs to India

Table 4: HHPs and their import quantity in 2020-21

#	HHPs	Import quantity in 2021-22 (unit:MT)
1	Cypermethrin	19,820.21
2	DDT	72.24
3	Dimethoate	96.18
4	Malathion	2,771.83
5	Quinalphos	810.83
6	Aluminium Phosphide	1,029.46
7	Methyl Bromide	2,213.79

Import data of only 7 pesticides are available from official sources. Among these 7 HHPs, Cypermethrin is the top most imported HHP when compared with others. However, there are discrepancies in the data as some of these HHPs have the same, exact export values.

5.7. Export of HHPs from India

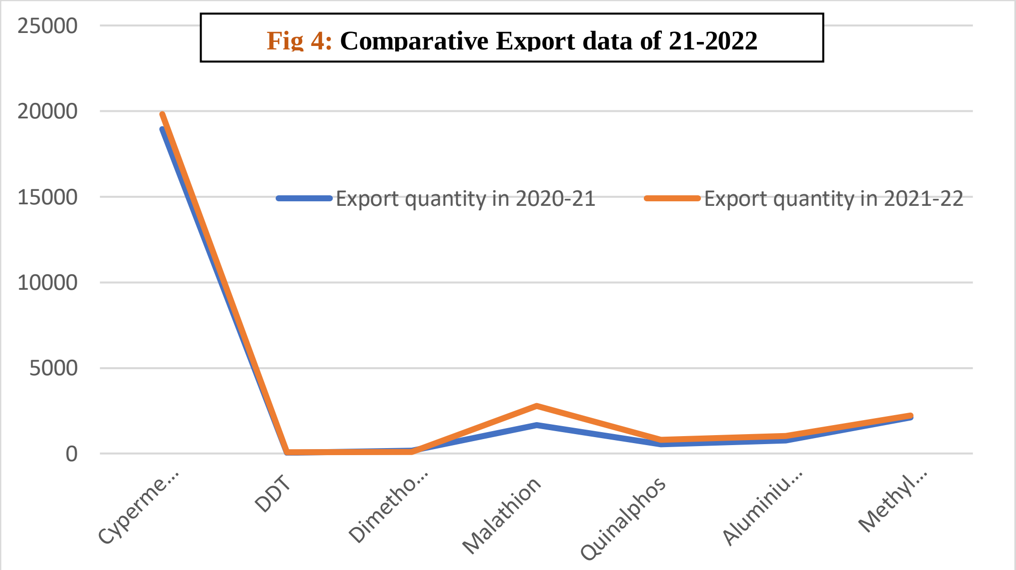
Export of HHPs from India increased in the last two years. An increased export of pesticides has ensured a profitable outcome for the companies in India in the past decade. Interestingly, in general, pesticides were the world's 85th most traded product in 2020, with a total trade worth of $40.8B. **India is the 4th largest exporter of pesticides in the world[22].**

Table 5: HHPs Export quantity 2020-22

Sl No	HHPs (unit:MT)	2020-21	2021-22
1	**Cypermethrin**	18,945	19,820
2	**DDT**	42	72
3	**Dimethoate**	154	96
4	**Malathion**	1,673	2,772
5	**Quinalphos**	522	811
6	**Aluminium Phosphide**	764	1,029
7	**Methyl Bromide**	2,089	2,214

In quantitative terms, Cypermethrin is the topmost HHP exported (largest share for a single pesticide in the total list of exported pesticide). Cypermethrin is a Class II, Moderately Hazardous pesticide exhibiting ecotoxicity. India is also the chief exporter of cypermethrin to the world market[23]. Cypermethrin 3% smoke generator is banned for public use in India. Aluminium phosphide is banned in India for public spraying without supervision from government authorities and DDT use in agriculture is banned in India. These banned and retricted pesticides in India are heavily exported from India to the world market.

Fig 4: **Comparative Export data of 21-2022**



[22] Pesticides | OEC - The Observatory of Economic Complexity
[23] Cypermethrin,free Exports from India to United States - Export data with price, buyer, supplier, HSN code (volza.com)

A total of 6,48,317 million tonnes of chemical pesticides were exported from India in 2020-21, worth a an enormous sum of Rs.36,497.87 crores. Brazil is the largest market for pesticide exports from India (129,942 Metric Ton, Rs.9,259.66 crores) followed by USA, Bangladesh, and Vietnam[24]. The above figure shows trends in export of 7 HHPs in the last two years. There is a hike in export of HHPs in 2022, except for dimethoate. Cypermethrin export shows a steep climb compared to other HHPs, implying a larger gap between its export and other HHPs. Export of malathion, which is a choline esterase inhibitor, suspected endocrine disruptor and an IARC carcinogen, has increased from 1,673 to 2,772 million tonnes.

5.8. Volume Consumption of HHPs in India

Table 6: HHPs and their local, import and total volume consumption in 2021

S. No.	Name of pesticides	Consumption of locally produced pesticides	Consumption of imported pesticides	Total volume of pesticide used
	FUNGICIDES			
1)	Aluminium Phosphide	103.57	-	103.57
2)	Carbendazim	541.37	-	541.37
3)	Chlorothalonil	32	19	51
4)	Copper Hydroxide	6.62	-	6.62
5)	Dinocap	8	-	8
6)	Dodine	166.79	17	183.79
7)	Epoxyconazole	7	-	7
8)	Flusilazole	2	-	2
9)	Iprodione	-	-	
10)	Iprovalicarb	3	-	3
11)	Mancozeb	1877.43	-	1187.43
12)	Propiconazole	112.46	3	115.46
13)	Propineb	-	42	42
14)	Tebuconazole	89.68		89.68
15)	Thiophanate methyl	201.19		201.19
16)	Validamycin	17	-	17
17)	Ziram	475.54	-	475.54
	Total	**3,643.65**	**81**	**3724.65**
	HERBICIDES			
18)	Butachlor	209.17	-	209.17
19)	Diuron	11.54	-	11.54
20)	Glyphosate	505.19	-	505.19
21)	Methyl Bromide	28	-	28
22)	Metribuzin	68.2	19	87.2
23)	Oxyfluorfen	34.16	6	40.16
24)	Paraquat dichloride	74.49	-	74.49
25)	Pendimethalin	149	-	149
	Total	**1079.75**	**25**	**1106.75**
	INSECTICIDES			
26)	Acephate	356.9	-	356.9

[24] **https://ppqs.gov.in/statistical-database**

27)	Abamectin	-	-	
28)	Bendiocarb	-	6	6
29)	Beta Cyfluthrin	9	4	13
30)	Bifenthrin	47.48	-	47.48
31)	Carbofuran	214.75	23	237.75
32)	Carbosulfan	31.13	12	43.13
33)	Chlorantriliniprole	135.34	-	135.34
34)	Chlorfenopyr	1	-	1
35)	Chlorfluazuron	0.19	-	0.19
36)	Chlorpyriphos	1036.69	-	1036.69
37)	Clothianidin (FI-WRT)	14	-	14
38)	Cypermethrin	343.91	-	343.91
39)	Deltamethrin (Decamethrin)	24.59	-	24.59
40)	Diafenthiuron	30	-	30
41)	Dicofol	7.18	-	7.18
42)	Dimethoate	209.593	-	209.593
43)	Emamectin Benzoate	124.73	-	124.73
44)	Ethion	79.14	-	79.14
45)	Ethofenprox (Etofenprox)	3	-	3
46)	Fenazaquin	4	-	4
47)	Fenitrothion	16.45	-	16.45
48)	Fenpropathrin	7	1	8
49)	Fenpyroximate	5.27	-	5.27
50)	Fenvalerate	149.73	-	149.73
51)	Fipronil	256.83	-	256.83
52)	Flubendiamide	11.15	-	11.15
53)	Flufenoxuron	7	2	9
54)	Fluvalinate	-	-	-
55)	Hexythiazox	-	3.5	3.5
56)	Imidacloprid	317.17	39	356.17
57)	Imiprothrin	-	39	39
58)	Indoxacarb	112	16	128
59)	Lambdacyhalothrin	161.09	29	190.09
60)	Malathion	305.41	-	305.41
61)	Methomyl	14	3	17
62)	Monocrotophos	351.91	-	351.91
63)	Permethrin	6	1	7
64)	Phenthoate	26.9	-	26.9
65)	Profenophos	433.4	53	486.4
66)	Propargite	20	-	20
67)	Propoxur	3	3	6
68)	Pymetrozin (FI), TIM	10	-	10
69)	Pyrethrin (pyrethrum)	12	-	12
70)	Quinalphos	412.6	-	412.6
71)	Spinetoram	12	-	12
72)	Spinosad	20	-	20

73)	Temephos	10.8	-	10.8
74)	Thiacloprid	23.66	-	23.66
75)	Thiodicarb	35	-	35
76)	Thiamethoxam	214.54	-	214.54
77)	Tolfenpyrad (TIM)	-	15	15
	Total	**5,627.533**	**210.5**	**5,838.033**
	RODENTICIDES			
78)	Bromadiolone	56.08	8	64.08
79)	Flocoumafen (FI-WRT)	-	4	4
80)	Zinc Phosphide	89.25	-	89.25
	Total	**145.33**	**12**	**157.33**
	Grand Total	**10,496. 263**	**328.5**	**10,824.763**

PPQS provides lists 80 HHPs of which consumption data of only 74 HHPs were made available in 2021 (Pesticide wise consumption of Indigenous Pesticide and Pesticide wise consumption of Imported pesticides). However, the data is incomplete as it lacks consumption volume of 50 HHPs (of the total 120). Volume consumption of a total of 25 imported HHPs and 71 locally produced HHPs are available from this source. It was also noted from the study that consumption of imported HHPs is very low compared to its indigenous use. Data of many imported HHPs are also not available. Statistics of consumption is given as two independent dataset titled ‘Consumption of imported pesticides’ and ‘Consumption of indigenously produced pesticides’ in PPQS. This study creates a total volume consumption of individual HHPs by compiling the "Consumption of imported pesticides" and "Consumption of indigenously produced pesticides."

Based on this analysis, in terms of volume consumption within **HHPs, Insecticides constitute the greatest proportion by volume**. Total consumption of 52 Insecticides, which are HHPs, is 5,627.533 metric tons, making it the largest segment in the net volume of consumption. However, total insecticide usage (including non-HHPs) has gone up from 7,027.52 (6669+358.52) metric ton in 2020 to 8176.2 (7858+318.20) metric ton in 2021, marking an increased use of 1,148.68 metric ton of insecticides in one year. Chlorpyrifos (an HHP) is the most consumed insecticide in India (1036.69 MT).

Even though, volume consumption data of only few fungicides in the studied list of HHPs are available from statistical database of PPQs, their total consumption adds to a total of 2,087.95 Metric ton in 2021, making it second largest class of HHPs consumed, followed by herbicides. Among all the HHPs listed, the fungicide **Mancozeb**, has the highest volume consumption.

Indigenos volume consumption of a total of 272 chemical pesticides and Imported volume consumption of 119 pesticides are available ftom PPQS. According to the same source, in terms of volume consumption of all **chemical pesticides , fungicides have the highest volume consumption**. This contrasts with the HHP consumption data, as noted in this study, where insecticides are the most consumed. Fungicides are applied to commercial and staple crops to combat fungal diseases. The most widely used fungicides are foliar fungicides and seed treatment fungicides. In India, fungi-related crop losses are increasing annually, leading to a rise in the application of fungicides. It is estimated that, crop losses due to pests and diseases exceed INR 290 billion annually and approximately 5 million tons of crop yield are lost annually in India as a result of these fungal infections[25].

[25] Shukla, S., Upadhyay, D., Mishra, A., Jindal, T., & Shukla, K. (2022). Challenges faced by farmers in crops production due to fungal pathogens and their effect on Indian economy. In *Fungal diversity, ecology and control management* (pp. 495-505). Singapore: Springer Nature Singapore.

Fig 5: Total volume consumption of HHPs in 2021

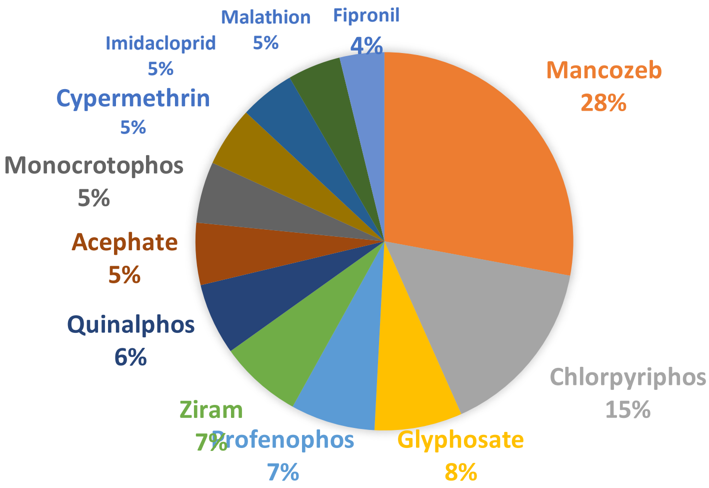


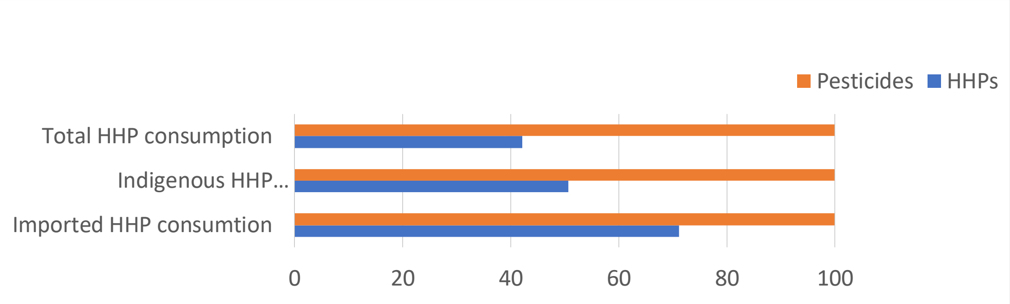
Fig 10 shows that, Mancozeb constitutes the largest share of HHPs used in India, where 1877.43 metric ton of Mancozeb was used in 2021 and 2194.51 metric ton was used in 2022. There is an increased usage of 317.08 metric tonne in the last year. Mancozeb is an HHP according to JMPM criteria and is banned in 29 countries. It is recommended for 14 crops in India and thereby widely consumed. Its production is followed by chlorpyriphos, an organophosphate insecticide, which is an HHP according to JMPM criteria (banned in 35 countries). Glyphosate, a herbicide has the third largest volume consumption, whose consumption rate has increased from 505.19 metric ton in 2021 to 571.06 metric ton in 2022 (Statistical database, PPQS). Total HHP consumption (combined volume consumption of imported and indigenous HHPs) to total chemical pesticide consumption in the year 2020-2021 was analysed in this study. Results from this analysis is noted in table 7.

Table 7: Data of volume consumption of pesticides in the year 2020-2021

#		Total chemical pesticide consumption, 2021	Total HHP consumption, 2021	% Volume of consumed HHPs to chemical pesticides
1	Volume consumption of imported pesticides	461.70	328.5	71.15
2	Volume consumption of indigenous pesticides	20,697	10,496.263	50.71
3	Combined volume consumption of pesticides	21,158.7	10,824.263	-

It was noted from the study that, HHPs constitute major share of the total volume of imported and locally produced pesticides used in India. This is a critical issue considering the increased usage of chemical pesticides in India every year. About 50.71 % of the locally produced pesticides consumed are HHPs, showing the abundance of HHPs in the Indian agriculture. Of the imported pesticides, 71.15 % volume is constituted by HHPs. This is a serious concern, given that most of the imported pesticides are HHPs and possibly banned in other countries, which is surprisingly true. Investigative studies conducted by Unearthed and Public Eye reported that companies in UK and some European countries are exporting massive amounts of pesticides banned in their countries to Low- or Middle-income countries, including India.[26]

Fig 6: Comparative Graph of HHP consumption with other pesticides in 2020-21



Discrepancies in official data (2022)

	Import (2022)	**Export (2022)**	**Production (2022)**	**Consumption of indigenousHHPs in 2022**
Cypermethrin	19820.21	19820.21	16480	340.98
DDT	72.24	72.24	658	-
Dimethoate	96.18	96.18	1391	216.36
Malathion	2771.83	2771.83	3286	516.18
Quinalphos	810.83	810.83	2454	442.29
Aluminium Phosphide	1,029.46	1,029.46	9350	148.54
Methyl Bromide	2,213.79	2,213.79	-	88.48

The statistical database of the Directorate of Plant Protection, Quarantine, and Storage contains the complete dataset (import, export, production, and consumption data) for only seven HHPs. Further, it was noted that, import and export values of these 7 HHPs are exactly same. This can possible be an inaccurate representation of statistical data provided by PPQS. Conversely, PPQS only provides volume consumption data for 80 registered HHPs, suggesting that data for a large number of other HHPs are still lacking. Additionally, the statistical database only provides the production value of 41 pesticides in total.

It can also be observed from the data that, production of some HHPs is low, which cannot meet the demands for a higher pesticide use. It is seen that, consumption of cypermethrin is far less, than many other HHPs questioning their need to import. This is same for many HHPs whose import is high, however their indigenous consumption is not high that demand a need for import. Also it was noted while analysing imported volume consumtion of 2021 (data for 2022 is not available) that volume consumption of imported pesticides are very small (less than 20 Metric tonnes) for all the pesticides given in this list and import consumption of only few HHPs are available. There is no information about the volume consumption of large share of imported HHPs. It can be seen that, DDT is shown to have a higher production and lower export; however, their indigenous consumption is not available, adding to the doubt of where these produced DDT is applied.

Apart from this, there are HHPs without national recommendations. For example, Trifluralin is registered as herbicide as of 01-10-2022, however its recommended use is not provided in Major uses of herbicides, 2022 (PPQS). All these points out a need for suitable and properly functional regulatiory measures which can enable common people to access unbiased data.

[26] https://unearthed.greenpeace.org/2022/02/22/bees-syngenta-paraquat-uk-exports/

5.9. Comparative analysis of state level HHP recommendations to national approved usage

This study summarized and examined the HHPs that currently exist alongside to other registered pesticides that are advised for different crop-pest combinations from ten Indian states. States selected for this assessment are Kerala, Tamil Nadu, Telangana, Andhra Pradesh, Orissa, Punjab, Haryana, Himachal Pradesh, Assam, and Jammu Kashmir. Information on pesticides, crops and their corresponding pests, and recommended dosage of pesticides were gathered and tabulated from recommended package of practices/crop production guides of these states in India, available online. (Annexure 6-14).

It was found that from the recommended pesticides in these 10 States, there are 78 HHPs. Most of these are banned in other countries due to their adverse effects on human health and ecosystem. It was noted from the study that, over 40 HHPs are included in the Recommended Package of Practice of Punjab and Kerala. They are recommended for staple crops, pulses, cereals, millets, oil seeds, and vegetables. HHPs such as **carbofuran, monocrotophos, thiamethoxam, dimethoate and 2,4-D** were recommended in almost all the Package of Practice recommendations, signifying their availability and wider use.

Further, this study compared the recommended use of these 78 HHPs in the 10 States of India with national approved usage of pesticides[27] (Major Uses of Pesticides, Directorate of Plant Protection, Quarantine & Storage). It was noted that, **29 HHPs, used in 10 States in India, were recommended in violation to national approved use.**

Dicofol and Thiamethoxam are the two HHPs which showed the most violations of national approved use. When compared to the national approved usage, these two HHPs have the most contradictions in their recommended use in crops by the states. **Dicofol,** with an annual consumption of 7.17 metric ton is recommended for 7 crops; cotton, okra, tea, litchi, citrus, brinjal and bitter gourd under one formulation 18.50% EC. However, it is recommended for use in rice, mushroom, potato, sugarcane and jute in Orissa, Kerala, and Jammu Kashmir. **Thiamethoxam** is recommended for 19 crops including cotton, rice, maize, wheat, sunflower, ground nut, sugarcane, and tea. However, it is recommended for use in pea, banana, coconut, and other non-recommended crops such as black pepper, brinjal, cashew & banana in Kerala and recommended for banana and coconut in Assam.

The Crop Production Guide (2020) of Tamil Nadu shows the largest set of violation of national recommendations followed by Jammu Kashmir's 'Package of Practice for vegetable crops-2020', However these recommendation guides are from previous years and there is a possibility for different observations based on current time frame. The results of this study follows web-published, non-updated package of practices of these States which was available for only 10 States of India.

Table 8: Variance in recommended use and approved use of pesticides

S. No	HHP	National approved usage	Contradictions in approved use
1	Abamectin	Rose, Grapes	Orissa-Vegetables
2	Bifenthrin	Tea, Rice, Cotton, Apple	Assam-Coconut
3	Carbofuran	Potato, Tomato, Citrus, Maize, Rice, Oilseeds, Wheat, Cabbage	Andhra Pradesh and Punjab-Jowar, Sugarcane
4	Carbosulfan	Rice	Jammu& Kashmir- Potato
5	Chlorpyrifos	Rice, Pulses, Cotton, Weeds Sugarcane, Groundnut, Litchi Ber, Cabbage	Orissa, Himachal Pradesh, and Jammu Kashmir-Potato, Maize

[27] Major Uses of Pesticides | Directorate of Plant Protection, Quarantine & Storage | GOI (ppqs.gov.in)

6	Dimethoate	Rice, Sugarcane, Vegetables Groundnut, Ber, Citrus	Tamil Nadu, Orissa, and Jammu Kashmir-Potato, coconut, and ragi
7	Ethion	Pulses	Assam and Orissa-vegetables
8	Clothianidin	Cotton	Assam and Tamil Nadu - oil seeds, vegetables
9	Chlorantriniprole	Rice, Cotton, Brinjal, Okra Pulses	Punjab and Tamil Nadu- Maize and sugarcane
10	Dicofol	Cotton, Vegetables, Tea, Citrus	Orissa, Kerala, and Jammu Kashmir-Rice, jute, mushroom, potato, and sugarcane
11	Diafenthiuron	Cotton, Vegetables	Haryana-Mushroom
12	Fipronil	Rice, Sugarcane	Jammu Kashmir-Potato
12	Flubendiamide	Rice, Pulses	Assam and Tamil Nādu-Maize and cauliflower
14	Imidacloprid	Oilseed, Wheat, Vegetables, Rice, Sugaracane	Assam and Himachal Pradesh- Capsicum and Banana
15	Emamectin benzoate	Cauliflower, Brinjal, Rice Pulses	Tamil Nadu and Telangana-Maize
16	Chlorothalonil	Potato, Oilseed, Cauliflower	Assam and Haryana- Fruits and vegetables
17	Oxyflurofen	Weed in Rice	Telangana-Sugarcane
18	Malathion	Rice, Mango, Cabbage, Brinjal, Grape	Tamil Nadu, Himachal Pradesh, and Jammu Kashmir-coconut, pulses, potato, and carrot
19	Monocrotophos	Pulses, Maize, Citrus	Haryana and Orissa- oilseeds and guava
20	Lambda-cyhalothrin	Cotton	Telangana-Tea
21	Fenvalerate	Cotton, Brinjal	Orissa, Haryana, and Jammu Kashmir- Oilseeds, grapes, and cabbage
22	Spinosad	Cotton, Cauliflower, Pulses	Kerala and Jammu Kashmir- vegetables and Rice
23	Propargite	Chilli, Tea	Jammu Kashmir and Himachal Pradesh- vegetables and potato
24	Thiodicarb	Cotton, Vegetables	Tamil Nadu and Telangana-Maize
25	Spinetoram	Cotton	Tamil Nadu and Punjab-maize
26	Thiamethoxam	Rice, Cotton, Okra, Groundnut, Potato, Mango	Jammu Kashmir, Assam, Punjab, and Kerala- vegetables, pulses banana and coconut
27	Quinalphos	Rice, Pulses, Oilseeds	Jammu Kashmir, Haryana, and Kerala- vegetables, Ber, and potato
28	Fenpyroximate	Chilli	Himachal Pradesh and Kerala-Vegetables
29	Profenofos	Cotton, Chilli	Assam and Jammu Kashmir- potato and vegetable

This study also reveals that the recommended use of pesticides by States are not in harmony with the use of pesticides approved nationally, which is serious indication of non-regulation, lack of coordination, communication and monitoring. Given this, there is a possibility of violations in other agrarian states of India, where chemical pesticide usage is high. This comparative study can be extrapolated to other states to infer this conclusion that there may be variations in use of non-recommended HHPs for crops as stated by national recommendations.

Variance in the State level recommended use and approved use of pesticides as noted in the table 8 is of grave concern, as violated use can compromise food safety and affect the food security of the nation. Pesticides recommended have a definite set of waiting period and interval, only after which it is to be harvested. A waiting period denotes the interval to be followed between the last pesticide spray and harvest. However, when pesticides are used for non approved food crops, these parameters of waiting period and others are violated. Apart from this Maximum residue limit or MRL are not set for such non-approved crops. These pesticide-bearing crops when subjected to residue tests gives an impartial result, as permissible levels of pesticide or MRL are not set for these crops and this may leave many of the non-approved crops not monitored for food safety standards and thereby putting consumers at risk of exposure to such pesticides unknowingly.

Chemical pesticide consumption in different States of India

The statistical database of the Directorate of Plant Protection, Quarantine, and Storage has state-level data on the total chemical pesticide consumption from each state, titled "State-wise pesticide consumption," but individual HHP use from different states in India is not available. There can be a positive correlation between HHP consumption and overall chemical pesticide consumption, where HHP consumption can be proportional to the total chemical pesticide consumed in the state. States which have higher chemical pesticide usage can have higher HHP consumption based on this assumption.

Pesticide consumption data of 21 states of India, in the year 2021-22, when analysed (Annexure 15) showed that total pesticide consumption is the highest in Maharashtra (13,175 MT), followed by Uttar Pradesh (11,688 MT), Punjab (5,193 MT) and Telangana (5,090 MT). According to this data, Pesticide consumption is the highest in States with an agrarian background. Maharashtra has the largest share of cotton growing land (39.41 lakh ha) as of 2021. Uttar Pradesh is the chief producer of principal crop, wheat, in India (35.50 million tons) and contributing 32.42 percent share of wheat production. West Bengal (16.65 million tons) and Uttar Pradesh (15.66) are the largest producers of Rice in India. A set of data obtained from Ministry of Chemicals and Fertilizers on Pesticide consumption per hectare in different states of India, 2016, has shown that Punjab has highest per hectare consumption of pesticide exceeding the national average of 0.29 kg per hectare(Annexure 16). This was followed by states of Haryana, Maharashtra, Kerala, Uttar Pradesh, and Tamil Nadu, where all the five states showed a consumption greater than national average.

Increased cultivation of crops in these states have also resulted in the increase of chemical pesticides, adopting inorganic methods of cultivation in the last decade. Pesticide consumption for most states were very high compared to previous years showing the increased reliance on chemical pesticides in agriculture over the past years.

End points

This chapter underlines the statistics of the increased usage of HHPs in India. Statistics on the production, import, export and consumption of registered HHPs as well their use type, Deemd to be Registered pesticides, and drift characters are discussed in this chapter. As we analyse the data, it was noted that HHPs constitute the greatest share in the production, consumption and export of all the pesticides in India. There is a shocking incline, driven by widespread HHP use in the last years. However, sufficient data is not available for most of the registered HHPs to reach a plausible inference.

A very similar gap in the regulatory system is seen with HHP recommendations by the agricultural extension system of each states of India. There is variance in national and state level recommendations for HHP usage.

These faulty recommendations are a leading cause for the erroneous use and exploitation of HHPs among farmer communities. The purpose of this chapter is to reveal the inconceivable statistics of HHPs in India that needs to be regulated.

Chapter 6

HHPs AND REGULATION

6.1. International regulations of HHPs

FAO, WHO and International Convention on Chemical Management (ICCM) are the international bodies that oversees issues on HHP regulations.

FAO & WHO

The Food and Agriculture Organization (FAO) and the World Health Organization (WHO) Code of conduct (FAO and WHO in 2013) and the Guidelines on Highly Hazardous Pesticides (FAO and WHO 2016) adopted the following definition:

"Highly Hazardous Pesticides means pesticides that are acknowledged to present particularly high levels of acute or chronic hazards to health or environment according to internationally accepted classification systems such as WHO or Global Harmonized System (GHS) or their listing in relevant binding international agreements or conventions. In addition, pesticides that appear to cause severe or irreversible harm to health or the environment under conditions of use in a country may be considered to be and treated as highly hazardous".

[28]FAO has stated that 'HHPs are of concern due to severe adverse effects, and it is estimated that, most pesticide poisoning are caused by relatively small amount of HHPs, particularly in low and middle income countries'. FAO has provided The FAO Pesticide Registration Toolkit that can be used for HHP identification process and helps in providing ways for the needs and risks assessment and for mitigation options.

FAO also provides support to countries on HHP management by

- Creating awareness on HHPs and their risks, by producing videos, communication materials and organizing webinars.
- Building capacities of National and Regional authorities to carry out the three steps approach.
- Collecting data on poisoning incidences, and identifying severely hazardous pesticide formulations.
- Promoting alternatives to HHPs and preventing HHPs use.
- Coordinating all relevant stakeholders and ongoing efforts to reduce harms associated HHPs.

ICCM

In 2015, the Fourth International Conference of Chemicals Management (ICCM4) under the Strategic Approach to International Chemicals Management (SAICM) adopted a resolution that recognizes HHPs as an issue of international concern and calls for concerted action to address HHPs. SAICM is a Multi-Stakeholder framework reviewed by ICCM that unites governments, industries, and civil societies to develop and implement integrated strategies for the safe use of chemicals. This is supported by stakeholder groups including Intergovernmental Organizations (IGOs), National Governments, Non-Governmental Organizations (NGOs), academia and the private sector, which in some cases have collaborated regionally through their respective Regional Economic Communities (RECs). SAICM stakeholders are encouraged to undertake concerted efforts to implement the HHP Strategy at the local, national, regional, and international levels, with emphasis on promoting agroecological alternatives. [29]SAICM has published a factsheet, 'The Potential Role of SAICM National Focal Points in Reducing Harm from HHPs,' to ensure information about highly hazardous pesticides (HHPs) reaches all SAICM National Focal Points (NFPs) and other stakeholders so they can make effective and

[28] **Addressing Highly Hazardous Pesticides (HHPs) | Pest and Pesticide Management | Food and Agriculture Organization of the United Nations | IPM and Pesticide Risk Reduction | Food and Agriculture Organization of the United Nations (fao.org)**
[29] **NFPs Can Help Reduce Harm from Highly Hazardous Pesticides: SAICM Paper | News | SDG Knowledge Hub | IISD**

informed decisions, as well as play an active role in reducing the health and environmental risks associated with HHPs.

The factsheet describes the role of SAICM NFPs in, among others:

- Informing policymakers which HHPs used nationally are banned in high-income countries;
- Promoting national systems, such as poison centers, for undertaking surveys and establishing pesticide use registers, and collecting pesticide health and environmental data;
- Promoting and supporting national stakeholder engagement on HHPs;
- Promoting the Globally Harmonized System of Classification and Labelling of Chemicals (GHS) for HHP identification and sharing relevant information to support national implementation; and
- Establishing collective targets and milestones for removing exposures to HHPs, and monitoring systems.

India is a party to SAICM. SAICM report of India, 2020[30], India has only outlined the reasoning for its 2018 pesticide ban and the guidelines it follows in accordance with the 1968 Insecticide Act. The SAICM report also acknowledges the Pesticide Management Bill and the Indian draft of the Chemical Management and Safety Rule. However, Pesticide ban that can be largely based on simple strategy of phased removal of Hazardous Pesticides is not discussed in this report and much attention is not given to the toxic perils caused by these pesticides.

6.2. HHP regulations in different countries

American countries: US EPA[31] is the organization that oversees pesticide use in the US. The EPA Office of Pesticide Programs handles most of the regulatory issues pertaining to pesticides. The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) gives the EPA authority to determine which pesticides can be used in the United States, and how they can be used. Like the European Union, they have opted for higher standards of pesticide use regulations, however The US being one of the dominant pesticide markets of pesticides, HHP regulation is merely managed because of lobbying by chemical industries[32] and other giant lobbies of the country.

California has imposed a ban on Highly Hazardous Rodenticides on October, 2020 under the provision of the Ecosystems Protection Act of 2020, AB 1788. Legislative body joins in banning second-generation anticoagulant rodenticides like bromadiolone, brodifacoum, difenacoum and difethialone which cause blood thinning and are hard to excrete, making them lethargic and vulnerable to other predators.[33]

African countries: Mozambique cancelled registration of 79 HHPs in 2012.[34] No other nation has attempted to regulate HHPs in Africa. Studies by IPEN (International Pollutants Elimination Network) on 6 African countries (Cameroon, Ethiopia, Kenya, Mozambique, Tanzania and Zambias) has showed that large amount of HHPs are used in all the six countries[35]. Studies from Nigeria also produced the same results.

European countries: Pesticide regulation is under the purview of European Commission, European Food Safety Authority (EFSA), and European Chemical Agency (ECHA). They have some of the stringent regulations on HHPs like MRL limit regulation, toxic analysis etc. However, export of HHPs from EU, as well as their use, is

[30] SAICM Report Pages.pdf (toxicslink.org)
[31] https://www.epa.gov/pesticides
[32] The USA lags behind other agricultural nations in banning harmful pesticides | Environmental Health | Full Text (biomedcentral.com)
[33] Second-Generation Anticoagulant Rodenticides (SGARs) (ca.gov)
[34] Mozambique prohibits Highly Hazardous Pesticides | FAO | Food and Agriculture Organization of the United Nations
[35] Update on the use of highly hazardous pesticides in six African countries: Cameroon, Ethiopia, Kenya, Mozambique, Tanzania and Zambia | IPEN

a challenge. PAN Europe in 2020, has reported the heavy use of banned hazardous pesticides and has detected HHP residues in food in European market[36]

Asian countries: A study on HHP use in Asian countries revealed that around 214 HHPs were in use in 13 Asian countries in 2021.[37] The number of HHPs among the registered list has drastically increased over the years. Temporary bans on pesticides, especially HHPs are noted in Asian countries over the last decade. Southeast Asian countries such as Cambodia, Laos, Malaysia, and Vietnam have banned the use of paraquat. Furthermore, Thailand imposed a ban on the insecticide chlorpyrifos, and the herbicide paraquat from the beginning of June 2020 and kept glyphosate a restricted use pesticide. Vietnam has allowed the use of glyphosate-based herbicides until 30th June 2021. Indonesia and Philippines banned chlorpyrifos, but paraquat remains a restricted pesticide. In India, considering the innumerable cases of advere effects, Endosulfan was banned by the Supreme Court of India in May 2011, with the final stocks disposed of or exported by January 2017.

6.3. HHPs and Indian regulations

There is no exclusive legislation for regulating HHPs in India. They are not legislated independently. In India, Product liability (Consumer Protection Act, 2019) is the only legal provision in providing legal support to consumers.

Many HHPs that are prohibited elsewhere are registered for use in India. In 2013, an expert committee headed by **Dr Anupam Verma** was set up to examine the continued use of neo-nicotinoid pesticides registered in India. This Committee was given an additonal mandate of reviewing 66 pesticides used in India that are banned in other countries. The committee reviewed these sixty-six pesticides, and after detailed examination submitted a report to the Central Government on the 9th December, 2015. The Registration Committee deliberated this report in its 365th special meeting, 2015 and submitted its observations to Central government. Union government in turn, in exercise of power conferred by Section 27 and 28 of Insecticides Act, 1968, banned 18 pesticides for registration, use import and export purposes in 2018, of which 12 were banned with immediate effect on August 2018, and six were to be banned by December 31, 2020.

PAN India finds that all these 18 pesticides are HHPs[38]. Of the 66 pesticides reviewed by Anupam Verma, all except nine pesticides registered in India as of October 1, 2022 are HHPs. Based on this study, it was also observed that, out of the 66 pesticides that the Anupam Verma committee reviewed, 10 HHPs that are currently registered meet JMPM criteria for HHPs. Government India had proposed ban on 27 pesticides in 2020, however a final decision is yet to come, as on the end of 2022.

6.3.1 Product liability

"Product liability can be defined as a doctrine that gives plaintiffs a cause of action if they encounter a defective consumer item. This doctrine can fall under negligence but it is generally associated with strict liability meaning that defendants can be held liable regardless of their intent or knowledge. It can include manufacturing, design defect, defect product and breach of warranty"[39]. In India, this provision is provided by the Consumer Protection Act, 2019 (Chapter VI, Sections 82 to 87). This Act recognizes product liability claims such that it can help the victims of pesticide imperilments to act and claim their right and also file for compensation for damages before Consumer Courts.

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[36] ***https*://www.pan-europe.info/sites/pan-europe.info/files/Report_Banned%20pesticides%20in%20EU%20food_Final.pdf**
[37] **Southeast Asia Regulatory Update: Food Production, Nutrition Security Bolster Need for AgChem - Agribusiness Global**
[38] **HHPs at the time of ban, currently some of them are non-HHPs**
[39] **product liability | Wex | US Law | LII / Legal Information Institute (cornell.edu)**

Endosulfan disaster in Kasaragod district of Kerala is the only highlighted case in India, where in 2012 the Kerala government has issued an order taking over the liability to pay compensation to the victims of Endosulfan, recommended by the National Human Rights Commission, and absolving the Plantation Corporation of Kerala (PCK) of the liability [40]. The honorable Supreme Court in India, in 2017, had addressed the issue of liability in an order related to compensations to Endosulfan victims and directed the State government to recover the amount of compensation either from the concerned industry or from the Government of India, but this is still not been explored.

6.4. HHPs and State level regulations in India

HHPs have not been subjected to separate State level regulation. However, there are cases of independent pesticide bans in some Indian states in which most pesticides are HHPs. It has to be noted that State governments in India do not have powers to ban pesticides permanently, but can prohibit pesticides for a period of two months. **Some examples of State level efforts to regulate pesticides in India are given below.**

Kerala state imposed ban on endosulfan in 2005 and 14 other pesticides in 2011 due to potential adverse effects. Among them, 3 were later banned nationally. All these pesticides were HHPs. In 2019, Kerala State government prohibited the sale and distribution of Glyphosate and all associated products citing its potential threatening effects on both human health and the environment[41], and recommended to ban it nationally. The action was based on a report put forward by Kerala Agricultural University (KAU) and a recommendation by the Agriculture Director. Additonally, some restriction was also brought on chlorpyrifos in Kerala since 2015, stating that it can be sold only with the recommendation/prescription by agriculture officers[42].

Punjab has imposed a ban on the sale, stock and distribution of Acephate, Buprofezin, Chloropyriphos, Methamidophos, Propiconazole, Thiamethoxam, Profenofos , Isoprothiolane, Carbendazim Tricyclazole (most are HHPs) for 2 months during rice growing season in 2022.[43] Punjab also refused renewal of 20 pesticides in 2018 including carbosulfan, fenitrothion, methomyl, monocrotophos, phorate and phosphmidon

Maharashtra has gone for a ban of five pesticides and formulations; Acephate, monocrotophos, diafenthiuron, fipronil+ imidacloprid, cypermethrin+profenofos for a period of 60 days after the incident of inhalation toxicity in the state followed by nearly 60 deaths in 2017.[44]

Karnataka also banned endosulfan in 2011 for 60 days on February 2011. **Sikkim** has banned all inorganic inputs, including HHPs in 2014 under the Sikkim Agricultural, Horticultural Input and Livestock Feed Regulatory Act, 2014.

6.5. Status of HHPs in India, that are banned in other countries

A comparative analysis of pesticides registered for use in India as on 01.10.2022 with the PAN International Consoldiated List of Banned Pesticides (6th Edition, May 2022), shows that **81 among 120 HHPs** are banned elsewhere or listed in International Conventions (Table 8). Among them, **27** HHPs meet the HHP criteria set by, JMPM. It was noted that **68 out of 120 HHPs** are banned in more than 10 countries (Table 9).

The 361st special meeting of registration committee (held on 22/12/2015) considered the report of the Expert Committee under the Chairmanship of Dr Anupam Verma that reviewed 66 pesticides which were

[40] https://www.thehindu.com/news/national/kerala/endosulfan-pck-absolved-from-liability/article2939089.ece
[41] Order issued restricting the use of weed killer Glyphosate - The Hindu
[42] Directorate of Agriculture Development and farners Welfare, Kerala Government Circular number TQ(01)35006/16, dated 22.08.2016
[43] http://timesofindia.indiatimes.com/articleshow/93552697.cms?utm_source=contentofinterest&utm_medium=text&utm_campaign=cppst
[44] http://timesofindia.indiatimes.com/articleshow/64034941.cms?utm_source=contentofinterest&utm_medium=text&utm_campaign=cppst

banned/restricted/withdrawn in one or more countries but continued to be registered in India. (for more details refer section, HHPs and Indian regulation)

6.5.1 HHPs that are listed in international conventions

DDT is the most banned pesticide in the world, which is a Highly Hazardous Pesticide by JMPM criteria. This is however still registered in India (for non-agricultural use) and is exported to different parts of the world. India opposed the 2020 deadline on Worldwide ban of DDT, at the sixth conference of parties of Stockholm convention, as India is one the largest producer of DDT [45]. DDT is used for mosquito and other vector control across the world. It is a Persistent organic Pollutant (POP) listed by Stockholm convention. DDT is also subjected to PIC consent for import and export, and is produced in India in large scale (569 metric ton annually). DDT was yet again not included in the list of pesticides considered for the recently(2020) proposed ban in India.

Monocrotophos, is registered in India but banned for use in vegetables as per the order dated 10, October, 2005[46]. Monocrotophos is recommended for 13 crops nationally which are rice, cotton, green gram, maize, red gram, black gram, pea, sugarcane, citrus, mango, coconut, coffee and cardamom against insect pests like Aphids, Jassids, Thrips, Whiteflies, Green leaf hopper, Leaf roller/folder, shoot borer, Pod borer, etc. (Obtained from Major uses of insecticides, PPQS). It has one of the highest indigenous volume consumptions in India, 351.91 metric tonne in 2021 and is banned in 129 countries. It is also listed in Rotterdam Convention (PIC consent)[47]. This is the second most banned HHP in the world.

Carbofuran, banned in 87 countries is an HHP and is subjected to PIC procedure as a part of Rotterdam convention is currently registered in India.

Carbosulfan (banned in 44 countries), is approved for 25 crops - Barley, Bajra, Sorghum, Jute, Groundnut, French bean. Potato, Tomato, Apple, Citrus, Maize, Paddy. Mustard, Soybean, Sugarcane, Okra, Chilli, Cabbage, Wheat, Brinjal, Banana, Peach, Mandarins, Pea and Tea against multiple pests

Paraquat dichloride (banned in 58 countries), approved for weeds in Tea, Potato, Cotton, Rubber, Coffee, Rice, Wheat, Maize, Grapes, Apple and for aquatic weed control, is also included under the provision of annex III, of Rotterdam convention.

Dicofol is another POP listed in Stockholm convention, banned in 50 countries including Latin American countries, European union and China. It is registered and approved for 7 crops including Tea, Okra, Citrus, Litchi, Cotton, Brinjal, Bottle&Bittergourd and has a volume consumption of 7 metric ton in India.

[45]India opposes 2020 deadline for DDT ban (downtoearth.org.in):
[46] (S.O.1482 (E) dated 10th Oct, 2005)
[47] PIC consent of Rotterdam convention is a procedure to ensure tha restriced hazardous chemicals are not exported to countries without their consent.

Notably, few HHPs which are banned in a particular dosage, form or formulations in India are registered for use in different concentrations or in different physical state within the country. However, the chronic effects from these active ingredients and the toxicity exerted by these HHPs remain the same. A brief account of such HHPs are given below.

Trifluralin, a herbicide which was prohibited for use by the Ministry of Agriculture and Farmers Welfare on eighth august, 2018 still finds its place in the registered pesticides under section 9(3) of the Insecticides Act, 1968 for use in the Country as of 01.04.2022. The prohibitory statement includes that '*the Registration, import, manufacture, formulation, transport, sell and its all uses except use in wheat shall be prohibited and completely banned'*. Its use in crops is not defined by CIB&RC, but the package of practice (2020) for vegetable crops of Jammu Kashmir, recommends trifluralin for weed management with an application unit of 0.4-0.8 kg /acre area while sowing common methi, kasuri methi, watermelon and muskmelon. Even when it is not used for wheat, the health consequences it can cause remains the same for applicators.

Cypermethrin, an insecticide, is banned for use as a 3% smoke generator by the Order of Hon'ble High Court of Delhi in WP(C) 10052 of 2009 dated 14-07-2009. It is registered in India in 3 different formulations in 2022 (00.25% SC of cypermethrin is recommended for use in brinjal against fruit and shoot borer and 10 % EC cypermethrin application is recommended to eradicate Spotted bollworm, American bollworm, Pink bollworm, Diamond back moth, Fruit borer, Shoot fly, Bihar hairy caterpillar in crops of cotton, cabbage, okra, brinjal, wheat and sunflower and 25% EC is recommended for use in cotton, okra, brinjal in mitigating bollworms, Jassids, thirps, shoot and fruit borer and Epilachna grub)

Aluminium Phosphide is a respiratory irritant, which is also used in quarantine purposes (pest-free export). Registration committee decision on this compound in 2015 was that, the Pest Control Operations with Aluminium Phosphide may be undertaken only by Govt./ Govt. undertakings/ Govt.Organizations/ pest control operators under the strict supervision of Govt. Experts or experts whose expertise is approved by the Plant Protection Advisor, except Aluminium Phosphide 15% 12 g tablet and Aluminium Phosphide 6% tablet[48]. Aluminium phosphide 77.50% GR is recommended for use in stored grain against Red Rust Flour Beetle, Lesser Grain Borer, Rice Weevil, Khapra Beetle according to PPQS, Major uses of pesticides, 2022.

Methyl bromide, the only chemical listed in Montreal protocol, being an HHP (both JMPM and PAN criteria) is restricted for use in nation, where it states that Methyl Bromide may be used only by Govt./ Govt.undertakings/ Govt. Organizations/ Pest control operators under the strict supervision of Govt. Experts or Experts whose expertise is approved by the Plant Protection Advisors to Govt. of India.[49]. Methyl bromide 98% w/w is registered for use in Stored Whole Cereals and Seed, Millet, Pulses, Milled Products: Flour, Dry Fruits, Nuts Spices & Oil Seeds to mitigate Rice Weevil, Lesser Grain Bore, Khapra Beetle, Rust Red Flour Beetle, Saw Drug Store Beetle, Khapra Beetle, Rust Red Flour , Beetle, Lesser grain borer, Rust Red Flour Beetle. It has an indigenous volume consumption of 28 metric tonnes in 2021.

48 [RC decision circular F No. 14-11(2)-CIR-II (Vol. II) dated 21-09-1984 and G.S.R. 371(E) dated 20th may 1999] .Decision of 282nd RC held on 02-11-2007 and, Decision of 326th RC held on 15-02-2012.

49 [G.S.R.371 (E) dated 20th May, 1999 and earlier RC decision]

Table 9: 81 HHPs and number of countries with these HHP bans

HHPs according to PAN criteria	Number of countries with a ban
2,4-Dichlorophenoxy Acetic Acid	5
Acephate	38
Aluminium Phosphide	2
Bendiocarb	31
Benfuracarb	31
Bifenthrin	30
Brodifacoum	33
Bromadiolone	30
Butachlor	32
Captan	6
Carbendazim	34
Carbofuran	87
Carbosulfan	48
Chlorfenapyr	32
Chlorfluazuron	29
Chlorothalonil	34
Chlorpropham (TI), TIM	30
Chlorpyriphos	39
Chlorpyriphos Methyl	33
Clothianidin (FI-WRT)	29
Coumatetralyl	28
Cyfluthrin	31
Cypermethrin	29
Diafenthiuron	32
Dichloro Diphenyl Trichloroethane (DDT)	147
Diclofop-methyl	3
Dicofol	52
Dimethoate	33
Dinocap	32
Dinotefuron	28
Diuron	31
Edifenphos	32
Epoxyconazole	30
Ethion	34
Fenitrothion	32
Fenpropathrin	32
Fenvalerate	32
Fipronil	38
Flocoumafen (FI-WRT)	32
Flufenoxuron	30
Fluazifop p butyl	1
Flusilazole	32
Fluvalinate	1
Glufosinate Ammonium	29
Glyphosate	4
Imidacloprid	29
Iprodione	32
Lufenuron	28
Magnesium Phosphide Plates	1
Malathion	32
Mancozeb	31
Methabenzthiazuron	30
Methomyl	47
Methyl Bromide	38
Monocrotophos	129
Oxadiazon	29
Oxydemeton-Methyl	34
Oxyfluorfen	1
Paraquat dichloride	58
Pendimethalin	1
Permethrin	33
Phenthoate	37
Profenophos	34
Propergite	33
Propetamphos	29
Propiconazole	29
Propineb	31
Propoxur	33
Pymetrozin (FI), TIM	32
Quinalphos	32
Tebuconazole	1
Temephos	30
Thiacloprid	31
Thiodicarb	33
Thiophanate methyl	29
Tolfenpyrad (TIM)	29
Triflumizole (FI-WRT)	29
Trifluralin	31
Validamycin	28
Zinc Phosphide	6
Ziram	3

Note: Pesticides marked in dark blue background colour are HHPs by JMPM criteria.

Twenty seven of the 120 pesticides identified as HHPs by PAN India meet the JMPM criteria set by FAO JMPM. These 27 HHPs are in compliance with the criterion formulated by JMPM and are banned in different countries as per their acute toxicity, long term effects, listed in conventions or based on national monitoring**.**

Table 10: Consolidated List of HHPs banned other countries

1	**Number of HHPs banned in less than 10 countries**	**13**
2	**Number of HHPs banned between 10-50 countries**	**63**
3	**Number of HHPs banned in more than 50 countries**	**5**

(Source: PAN international consolidated list of banned pesticides, March 2022)

Major share of HHPs in India are banned in more than 10 countries. 13 HHPs are banned in less than 10 countries in which Fluvalinate, Fluazifop p butyl, Pendmethalin, Tebuconazole, Oxyfluorfen and Magnesium phosphide are banned in only one country. There are 5 HHPs which arch are banned in more than 50 countries; DDT (banned in 147 countries), Monocrotophos (banned in 129 countries), Carbofuran banned in (87 countries), Paraquat Dichloride (banned in 58 countries) and Dicofol (banned in 52 countries). These pesticides are high risk pesticides, known to cause severe damages to health and environment which resulted in their bans in most countries. Therefore, their continued use in India is a major concern.

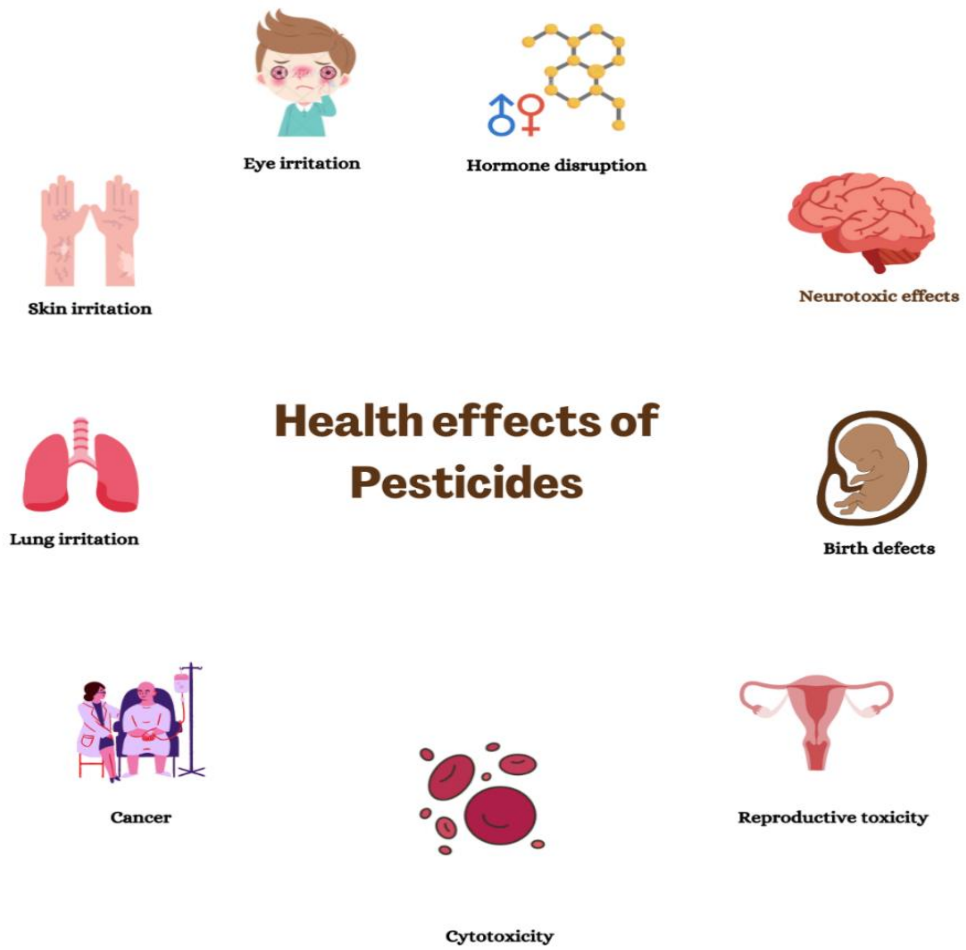
End points

This chapter scrutinises the regulations of HHPs in international platforms, other countries and in Indian context. ICCM, and FAO are the international bodies which has addressed the key issues on HHP regulation. Insecticides Act, 1968 forms the basic framework for pesticide regulation in India. Indian regulations on pesticides are panned by activists and experts, as India has not regulated Hazardous Pesticides, that have inadmissible harmful evidences on health. In India, there is no statutory regulation of HHPs. The list of HHPs which are banned elsewhere is given in this chapter. This chapter highlight the need for a reframed policy work that focuses on pesticide regulation, environmental protection, workforce safety, and integrated pest management.

Chapter 7

HHPs AND HEALTH EFFECTS

Pesticides are chemicals, used for irradiating pest infestations from fields and other human-dwelling places. Pesticides, however, has contributed to countless diseases and abnormalities in humans as shown in a number of studies over the past years. These ranges from small rashes to chronic illnesses, which has intergenerational impacts. Most of these pesticides, can cause contact dermatitis and can enter the body through any route of transmission. They can bind with other functional molecules in the body, can be absorbed into blood and lymphatic system, can lodge in organs, can act as hormone analogues and can even induce mutations. This, in turn, can lead to a wide array of diseases. Long term exposure to pesticides increases risk, by many folds and increases the chance of confronting multiple disorders and system failures. Changes induced in germ cells and other reproductive cells, can affect the next generation and thereby, become a heritable change. Reduced immunity and reproductive fitness, loss of motion coordination are the most common side effects of pesticide use. Cancer is one of the most studied effects of pesticide use. Another common health defect, endocrine disruption, can lead to altered biological hormone function and thereby affect homeostasis. In the following section, health impacts such as cancer, endocrine disruption, reproductive toxicity, neurotoxicity, genotoxicity, immunotoxicity and teratogenicity are explained in detail along with case studies and reports from different parts of the world, where the emphasis is given to studies on women and children, and studies from India.



7.1. Health effects of the studied HHPs used in India

Health effects of these HHPs are of varying degrees ranging from acute toxicity to long term effects. Acute toxicity is the ability of a substance to cause harmful effects, which develop rapidly following exposure. A pesticide with a high acute toxicity (Low LD50) is fatal, even if only a tiny quantity is absorbed into body. The immediate health effects following pesticide exposure may include skin irritation which may then cause itching and burning sensations as well as blisters and rashes, headache, dizziness, vomiting, diarhoea, convulsion etc. Acute toxicity classification put forth by GHS classify pesticides based on LD50 into four classes; Class 1, class 2 or Moderately Hazardous, class 3 or Slightly Hazardous and class U or Unlikely to Present Hazards. Class 1 is subdivided into two classes; class WHO 1a (Extremely Hazardous) and WHO 1b (Highly Hazardous). As per the JMPM criteria for HHP identification, pesticides falling under class 1a and class 1b are regarded as HHPs, alongside to the other pesticides that comply with the eight listed criteria. Apart from this, a newer classification for acute toxicity is also used in this report, which is H330 (H330 is a newer adaptation in the PAN list indicating inhalation toxicity). The effects of repeated or prolonged lower level exposures to a toxic substance is referred to as Chronic toxicity. Long-term toxicities analysed in this report are carcinogenicity, mutagenicity, reproductive toxicity, endocrine disruption and neurotoxicity.

7.1.1. WHO classification of pesticides by Hazard

WHO classification of pesticides, by hazard, 2019 is an updated classification system which is in compliance with the GHS recommended classification of chemicals, used to distinguish between the more and the less hazardous forms of selected pesticides based on acute toxicity of the technical active substance.[50] Toxicological profile of an active ingredient is primarily based on acute oral and dermal toxicities in rats. Analysis of the HHP listed in India as identified in this report has shown that, **three of these HHPs belong to WHO class1a or are Extremely Hazardous. Eleven HHPs belong to WHO class 1b or are Highly Hazardous and twenty three HHPs belong to H330 subclass (inhalation toxicity).**

Of the three Extremely Hazardous Pesticides, Bromadiolone, is recommended for use in more than 8 crops and for use in the residential area. Brodifacoum and Flocoumafen are recommended for use as rat-bait in residential, commercial, and other institutional areas. These three pesticides are also included in the H330 list (Inhalation Toxicity). Bromadiolone has an annual consumption of 64.6 metric tonne while flocoumafen has an annual consumption of 15.15 metric tonnes in India in the year 2021 (Consumption data of Brodifacoum is not available). This represents the severity of the case where these pesticides, despite their toxic nature are used on a large scale in agricultural and other prominent sectors. Six of the pesticides of WHO 1b class are also included in H330 classification, highlighting their acute toxicity and inhalation toxicity.

Fifty five Highly Hazardous Pesticides noted in this study belong to class 2 or are Moderately Hazardous. This is the category to which largest number of HHPs registered in India falls into. It is to note that, some HHPs which belong to lesser classes of toxicity are still toxic at a concentrated amount or even through other routes of entry. For example, Paraquat chloride belonging to this category, registered in India, is stated as a relatively low hazardous chemical in oral use, however, is considered fatal if exposed to its concentrated product taken by skin (WHO classification by Hazard, 2019)[*]. **Twenty one HHPs registered in India belong to Class 3 or are Slightly Hazardous and Twenty two HHPs belong to the ClassU or Unlikely to cause Hazardous effect** (Annexure 1).

[50] The WHO Recommended Classification of Pesticides by Hazard and guidelines to classification, 2019 edition
[*]This is an HHP by PAN criteria due to several other health effects but not an HHP by JMPM standards

7.1.2 Long term toxicity

Cancer: Twenty-five HHPs registered in India, exhibit carcinogenic toxicity according to U.S EPA (Annexure 3) (Refer criterion 2, chapter 1)**. Three** of these HHPs are IARC probably/likely cancer-causing pesticides**. DDT**, is a carcinogen according to both IARC and U.S EPA recommendations. Case studies from different parts of India elaborates the carcinogenic potential of these pesticides (For case studies, refer section HHPs and cancer). The 2005 EPA guidelines of EPA classification for carcinogenicity describes a chemical's human carcinogenic potential in the "weight-of-evidence narrative" that gives a summary of available evidence relevant to cancer for carcinogenicity. IARC evaluation of evidence of carcinogenicity considers three types of data: animal, human, and mechanistic. Based on these two system for evaluation of carcinogenicity of pesticides, the above mentioned HHPs are classified.

Mutagenicity: One of the HHPs in India, **carbendazim** exhibit mutagenic effect (Refer criterion 3, chapter 1). Carbendazim, a mutagenic fungicide (volume consumption of 1567.86 metric tonnes in 2019) is found to cause embryotoxicity, apoptosis, teratogenicity, infertility, hepatocellular dysfunction, endocrine disrupting effects, disruption of haematological functions, mitotic spindle abnormalities, mutagenic and aneugenic effects[51]. It can also disrupt the microbial community structure in various ecosystems and caused micronuclear abnormalities in milkfish, *Chanos chanos* at a higher concentration[52]**.** There are currently no studies available on human culture.

Reproductive Toxicants: Twenty of the studied HHPs in India are reproductive toxicants (Refer HHPs and reproductive toxicity) according to GHS criteria (Refer, criterion 4, chapter 1). List of these toxicants are given in annexure 3. Chlorpyrifos (insecticide recorded with highest rate of production), carbendazim, glufossinate ammonium, and mancozeb (highest production and consumption) are all categorized as reproductive toxicant. USEPA Guidelines for Reproductive Risk Assement use data evidences to evaluate potential toxicity of chemicals to human reproductive system. In absence of adequate human studies, data derived from experimental animals are used. HHPs which falls under this evaluation guidelines of USEPA are used in this study.

Neurotoxicants: Neurotoxicity (Refer HHPs and neurotoxicity) in terms of acetyl cholinesterase inhibition is considered in this study. It was noted that **21 of the HHPs in India cause cholinesterase inhibition**. Cholinesterase inhibition is a major repercussion of pesticide use. Acetyl choline esterase is the primary choline esterase in human body, which is involved in the breakdown of the neurotransmitter acetyl choline released in the neural junctions. Acetylcholine accumulation in neural junctions can cause synaptic toxicity and can ultimately result in death.

Endocrine Disruptors: The European Chemicals Agency (ECHA) and the European Food Safety Authority (EFSA) released guidelines in June 2018, regarding the identification of substances that have the potential to disrupt the reproductive system in pesticides and biocides. Since then, the EPA has evaluated a number of pesticides for potential endocrine disruption; nonetheless, no pesticide has ever been outlawed due to this concern. Mancozeb was identified as the first pesticide known to cause endocrine disruption in humans (EFSA). Endocrine disruption (Refer HHPs and Endocrine Disruption) is caused when endocrine disrupting chemicals, like pesticide, alters the normal hormone titre and their activity in human body and thereby results in abnormal hormonal action. There are **33 HHPs suspected of having endocrine disruption effects in India** which include Acephate (third largest produced insecticide), cypermethrin (highest exported chemical, with a CIF value of 126617 lakhs in the year 2021-22) DDT (most banned pesticide) and paraquat. These pesticides can interfere with the normal hormone balance. (Annexure 3)

[51] Singh, S., Singh, N., Kumar, V., Datta, S., Wani, A. B., Singh, D., ... & Singh, J. (2016). Toxicity, monitoring and biodegradation of the fungicide carbendazim. *Environmental chemistry letters*, *14*(3), 317-329.
[52] Palanikumar, L., Kumaraguru, A. K., Ramakritinan, C. M., & Anand, M. (2014). Toxicity, biochemical and clastogenic response of chlorpyrifos and carbendazim in milkfish Chanos chanos. *International Journal of Environmental Science and Technology*, *11*(3), 765-774.

7.2. HHPs AND REPRODUCTIVE TOXICITY

One among the major detrimental effect of pesticides is the reproductive damage that they pose to the reproductive systems of both sexes of humans and animals. Reports from different parts of the world substantiate this statement. Craine et al., (2008), discussed various aspects of reproductive dysfunctions, caused by pesticides, which range from birth defects, early onset of puberty and sexual maturation to infertility and abortions in human females. Testicular dysfunctions, prostate cancer and infertility are also noted in male children of people exposed to pesticides in multiple studies. However, the explicit mechanism for such defects are not well studied. Reproductive dysfunctions resulting from chemical pesticide use are presumed to be mostly caused by oxidative stress (imbalance of reactive oxygen species (ROS) and antioxidants, where excess ROS production or decreased antioxidant production occurs), hormonal imbalance & endocrine disruption, and epigenetic factors (heritable changes in gene expression that occur without a change in the DNA sequence, like methylation, histone modifications, and microRNA expression). HHP Analysis for reproductive toxicity in this study has shown that, **20 HHPs registered in India are Reproductive Toxicants (Annexure 3).**

The study "Poisoning our future: Children and Pesticides" (Meriel Watts, 2013) addressed the detrimental impact of pesticides on both male and female reproduction in great depth. By putting together research studies on children, this book highlights the major ways that exposure to pesticides during pregnancy, during critical developmental stages after birth, and throughout adolescence negatively affects children's long-term health, reproductive potential, intelligence, and overall well-being. The early onset of puberty in girls is a noteworthy change, attributed to pesticide exposure. Gaspari et al., (2011) had noted that precocious puberty in a 4-month-old girl marked with increased breast size, uterine length and 3 sets of the menstrual cycle can be due to parental exposure to multiple pesticides. Studies by Guillette et al., (2006), showed the correlation between increased breast size in women and exposure to pesticides, however mammary tissue development remained the same. In males, anti-androgenic and oestrogenic effects are observed due to heavy exposure to pesticides. It includes hypospadias (irregular penis opening), undescended testis, smaller testis, testicular cancer, lowered sperm count, and poor fertility (Toppari et al., 1996). Boys born to women exposed to pesticides, had smaller penis and testis (Andersen et al., 2008).

Pesticide exposure among Indian farmers working in the cotton fields has been linked to a significant decrease in the number of fertile males when compared to controls (Rupa et al., 1990). The same study also pointed to the the increasing incidence of stillbirths and neonatal deaths, congenital defects like anencephaly (a baby is born without parts of the brain and skull), cleft palate, club foot, limb and eye deformation and polydactyly among children of these farmers, who manually mix and spray pesticides. It further reports, abortion percentile of 26.04% was noted in women of the exposed population, in comparison to 14.95% in the control group. The alarming increase of deformities in male workers (90.75%) compared to males in the control group (31.08%) show the extent of the damaging effect of pesticide. They were similar to studies from working men in agriculture from California (Whorton et al., 1977).

Substantial adverse consequences of pesticides were also established through animal studies. Administration of pesticides like DDT to male mice resulted in dominant lethal sperm head abnormalities, and chromosomal aberrations (Lobdell and Johnston, 1966) and its oral administration resulted in dominant lethal mutations. Ingestion of cypermethrin has resulted in a significant decrease in number of cell layers of the seminiferous tubules affecting fertility and reproduction in male rats (Elbetieha, A. et al., 2001)

Damgaard et al., (2006) observed that, residues of organochlorine pesticides in the breast milk of exposed women when passed on to male children resulted in cryptorchidism or undescended testes. Garry et al., (1996) in their studies from Minessota, US observed that there is an increased chance of birth defects in children of couples who conceived in the months of spring when herbicides are typically applied. Similarly decreased fertility in both sexes, demasculinization (antiandrogenic effects), elevated rate of miscarriage, altered sex ratio, and change in the pattern of maturity are reported as some of the severe side effects of pesticide use (Frazier, 2007). Farmworkers in Southern Italy who used atrazine, benomyl, carbendazim, carbaryl, and DDT reported a higher incidence of spontaneous abortion in their spouses (G Petrelli, 2003).

Developmental toxicities in terms of feotal development are also noted in many studies. In a Systematic review titled, 'Non-cancer health effects of pesticides' (Sanborn et al, 2007), ten studies, mainly from Europe and North America, were compiled and examined for pesticide induced effects on foetal growth. Out of which, seven showed positive associations between agricultural pesticide exposure and altered foetal development. Two pesticides, noted for consistent implications in the above studies were **pyrethroids and chlorpyrifos.** In the same systematic review, foetal damage reported from different parts of the world were analysed, in which the Ontario Farm Study results suggested that, pre-conception exposure to pesticides were directly linked to early first-trimester abortions, and post-conception exposure were directly linked to late spontaneous abortions (Arbuckle TE et al.,1999).

Table 7.2.1 Some of the registered HHPs in India and their reproductive toxicity effects according to studies

Sl No	Pesticide	Reproductive toxicity effects
1	**2,4 D**	Exposure of 2,4-D on 32 male farm sprayers after 4 days of sexual inactivity showed significantly high levels of asthenospermia, necrospermia, and teratozoospermia (Lerda D and Rizzi R, 1999)
2	**Dimethoate**	Histopathological examination of the treated rats revealed that dimethoate caused dose-dependent testicular damage characterized by moderate to severe seminiferous tubule degeneration as sloughing, atrophy, germ cell degeneration, and partial arrest of spermatogenesis (Sayy´m F, 2007)
3	**Malathion**	Chronic malathion administration in Wistar rats was reported to reduce the weight of testes, epididymis, seminal vesicle, and ventral prostate (Choudhary N et al, 2003).
4	**Mancozeb.**	Oral administration of this fungicide in male Wistar rats for 30 days resulted in the reduction of weight of testis, epididymis, seminal vesicle, and ventral prostate
5	**Organophosphates**	Decrease in serum total protein, sperm density and motility, and fertility was observed in male rats on administration (Ngoula et al, 2007).
6	**pyrethroids**	Pyrethroid insecticides can reduce sperm count and motility, cause deformity of the sperm head, increase the count of abnormal sperm, damage sperm DNA and induce its aneuploidy rate, as well as affect sex hormone levels and produce reproductive toxicity

(Source: Table made from the information given in Article, Pesticides: A review of the male reproductive toxicity.Mathur, N., Pandey, G., & Jain, G. C. 2010).

7.3. HHPs AS ENDOCRINE DISRUPTORS

Endocrine Disruptors are small exogenous lipophilic chemicals which mimic, inhibit, or lower the activity of hormones by interacting with more than one component of the endocrine system[53] and thereby affect, the metabolism and survival status of humans and other life forms. The term endocrine disruptors, was first used by **Ana Soto** and co-workers on their work in animal and human endocrine disruption during the famous workshop by Colborn, et al. 1993 at Wingspread Conference Centre in Racine, Wisconsin. Pesticides can act as endocrine disrupting chemicals that affect the reproductive balance in humans, where they alter hormone synthesis patterns, mimic hormone function or block it by occupying the receptor site, modulate the number of the receptors and their affinities for specific molecules, and alter hormone clearances (Gore A, 2007). Their effect on the female reproductive system is evident and well-studied, where pesticides can cause changes in hormonal activities, hormone synthesis, hormone release and storage, hormone transport and clearance, hormone receptor recognition and binding, hormone post-receptor activation, thyroid function, and central nervous system. **This study identified thirty-three HHPs in India, which potentially causes endocrine disruption (Annex 1)**

Balanced hormone levels and functions are important for normal growth and development, metabolism, reproduction and influence neonatal development. Animal studies have demonstrated that, 50 pg/ml increase in total circulating oestradiol can permanently alter the prostate size in mice (Sal et al., 1997) and differentiation of cranial tissue of the urogenital sinus into prostatic tissue as opposed to vaginal tissue is aided by a higher circulating level of testosterone (by 2-3 ng/ml) in male mouse foetuses (Sal et al., 1989). Therefore, endocrine disruption at this stage can significantly affect the development and sexual characteristics of an organism. Endocrine disruptors mostly bind strongly to androgenic/oestrogenic receptors and mimic their action (agonist) resulting in hyperactivity or they can inactivate a receptor by acting as an antagonist. They can also interfere with the natural biochemical synthesis of a hormone. E.g., Thyroid synthesis is disrupted by Mancozeb, ziram, zineb etc. This can result in numerous neurological, behavioural, and reproductive changes in offspring. Endocrine disruption can affect and alter other systems of the body as they are heavily dependant on hormone functions. Thereby they disrupt normal functioning of these systems and cause irreversible damages.

Neurological and behavioural disorders

Endocrine disruptors are believed to interfere with neurotransmitter activity, synaptic organization and neuron visibility in children. Correlation between pesticide exposure and Parkinson's disease is noted in certain studies (Paule et al., 2012). Examples of neuroendocrine disruptors include some PCBs, dioxins, DDT and related chlorinated pesticides and its metabolites, and triazine herbicides.

Metabolic disorders

Increasing incidence of metabolic disorders with an increase in global chemical consumption of pesticides add doubts to the possible effect of EDs on metabolic disruption. Estrogen receptors (ER) and estrogen have a direct metabolic effect on glucose transport, glycolysis, mitochondrial structure and activity, and fatty acid oxidation. Endocrine disruptors which bind with these receptors, therefore, have a direct effect on metabolism. EDCs may also modulate other hormone nuclear receptors, particularly thyroid hormone receptor (TR) and glucocorticoid receptor (GR). This can cause metabolic side effects such as diabetes, muscle wasting, and growth retardation in children upon interaction with ED.

[53] Endocrine system consists of glands and organs that make hormones and release them directly into the blood so they can travel to tissues and organs all over the body. The hormones released by the endocrine system control many important functions in the body, including growth and development, metabolism, and reproduction. The endocrine system includes the hypothalamus, pineal gland, pituitary gland, thyroid gland, parathyroid glands, thymus, adrenal glands, pancreas, testes in males and the ovaries and placenta (during pregnancy) in females.

Reproductive disorders

Reproductive disorders are often caused by the antagonistic interaction of EDs with androgen and oestrogen receptors (Diamanti Kandarakis et al., 2009). Abnormalities of the female reproductive system that might be associated with EDC include; precocious puberty, polycystic ovary syndrome and premature ovarian failure (Costa, et al., 2014). Apart from this, increased growth of the endometrium, uterine fibroids, menstrual irregularities, infertility, higher risk of breast cancer and vaginal cancer can also occur due to exposure to EDs. Studies on wildlife showed that, Wild American alligators on exposure to dicofol, exhibited genital malformations (Gore et al., 2014). Estrogenicity of monocrotophos is also documenterd in mice (Rao et al., 2002).

The increased incidence of prostate cancer in human males can also be associated with EDs. For example, pesticides (in particular DDT) were associated with a statistically significant higher rate of prostate cancer among farmers (exposed to organochloride pesticides) in a multi-site case-control study carried out in five rural areas between 1990–92 in Italy (Settimi et al., 2003).

Factors affecting Endocrine Disruption

Age

Endocrine disruptors have a huge impact on neonatal development. Much of the damage caused by EDC occurs during gametogenesis and the early development of the foetus and symptoms are presented during early adulthood. Exposure to chemicals can begin as early as in the womb through placental transfer or in infants through breastfeeding, where fat mobilization from the mother is high (Bouman H,1993). Infants and children are more susceptible to EDs because of their low immunity, high exposure to pesticide-contaminated resources per body volume, and dynamic body metabolism. This was reaffirmed by the statement 'children today are sicker than they were a generation ago' from the book, 'A Generation in Jeopardy: How pesticides are undermining our children's health and intelligence' (PANAP, 2013). Children are exposed to pesticides, where child labour is still operational. According to the PANAP report, around 215 million children are engaged in child labour around the globe. In India, the cottonseed production sector employed nearly 17000 children below the age of 14 in the years 2009-2010 (PANAP, 2013).

Elderly people have a higher ratio of bio accumulative pesticides in their bodies, from the past year exposures. They are susceptible to more chronic diseases due to their age, lowered immunity and pesticide accumulation and its associated defects add a burden to this.

Gender and Economic Conditions

Bioaccumulation of pesticides is higher in women because of higher fat deposition, higher dermal absorption and a higher level of hormone-sensitive tissue. This situation is worsened and heightened in women in developing countries, where women make up to 85% of pesticide applicators in the field. They manually mix and apply pesticides to crops without proper safety gear and their poor educational and financial status complicates the situation. In a study report of 72 female workers in 17 plantations in Malaysia by Tenaganita and PAN titled, 'Poisoned and Silenced'(2002), all women exhibited symptoms of acute poisoning like nausea, headache, vomiting etc upon pesticide application.

Multiple studies report that people who have direct pesticide exposure to pesticides have a higher incidence of pesticide in blood serum than non-exposed people. Residential proximity to agricultural activity is another factor which is often used to describe developmental abnormalities in epidemiological studies. Low birth weight, foetal death, childhood cancers and a higher prevalence of cryptorchidism (undescended testicles) and hypospadias (Abnormally placed urinary opening in the penis) at birth are noted in children of pesticide applicators (Generation in Jeopardy, PANAP, 2013)

Environmental Effect

Endocrine disruption is observed in wildlife as well. The first published evidence for environmental disruptors appeared more than a decade earlier, when it was reported that consumption of a certain type of clover disrupted reproduction in sheep. A study on *Daphnia magna* has shown that Endosulfan sulphate disrupts the ecdysteroid system (regulating processes such as moulting and embryonic development) of crustaceans (Palma et al., 2009)

Table 7.3.1: Some of the registered HHPs in India and their endocrine disruptive functions from studies

Sl No	PESTICIDES	ENDOCRINE DISRUPTING EFFECT
1.	**2,4-D**	Synergistic androgenic effects when combined with testosterone
2.	**Acephate**	Disruption of hormone expression in the hypothalamus
3.	**Bendiocarb**	Weak estrogen effect
4.	**Captan**	Inhibition of estrogen action
5.	**Carbendazim**	Increase in estrogen production and aromatase activity
6.	**Carbofuran**	Increase in progesterone, cortisol and estradiol level and decrease of testosterone
7.	**Chlorothalonil**	Activation of androgen-sensitive cells proliferation
8.	**Chlorpyrifos methyl**	Antagonist to androgen activity
9.	**Cypermethrin**	Estrogenic effect
10.	**Cyproconazole**	Decrease of estrogen production and increase of androgen availability
11.	**DDT and metabolites**	Competitive binding to androgen receptors, activation of androgen-sensitive cells proliferation. Stimulation of estrogen receptor production, estrogen receptor agonist and PR antagonist
12.	**Deltamethrin**	Weak estrogenic activity
13.	**Dicofol**	Inhibition of androgen synthesis, an increase of estrogens synthesis, binding to estrogen receptor
14.	**Dimethoate**	Disruption of thyroid hormone action. Increase of insulin and LH blood concentration
15.	**Diuron**	Inhibition of androgen action
16.	**Epoxiconazole**	Inhibition of aromatase activity, decrease of estrogen production and increase of available androgens
17.	**Fenvalerate**	Inhibition of estrogen-sensitive cells proliferation, antagonist of the progesterone action
18.	**Fluvalinate**	Binding to human sex hormone, inhibition of progesterone production
19.	**Flusilazole**	Inhibition of aromatase activity, decrease of estrogen production, increase of available androgens
20.	**Glyphosate**	Disruption of aromatase activity, preventing the production of estrogens
21.	**Iprodione**	Increase weakly aromatase activity, and estrogen production
22.	**Malathion**	Inhibition of catecholamine secretion, binding to thyroid hormone receptors
23.	**Methomyl**	Weak increase of aromatase activity and estrogen production
24.	**Metribuzin**	Hyperthyroidism, alteration of somatotropin levels, weak increase of aromatase activity and estrogen production

25.	**Permethrin**	Inhibition of estrogen-sensitive cells proliferation
26.	**Propiconazole**	Decrease estrogens production and increase of androgens availability
27.	**Propoxur**	Weak estrogenic effect
28.	**Trifluralin**	Interaction with pregnane X cellular receptor, interference steroid hormone metabolism

(Source: Table made from the information given in Article, Environmental toxins: alarming impacts of pesticides on male fertility by Pallav Sengupta and Rajdeb Banerjee, 2013)

7.4. HHPs AND CANCER

One of the major effects associated with pesticide use is increased susceptibility to multiple kinds of cancer. Cancer, according to WHO, is a collection of diseases which results from an uncontrollable and unconditional growth of cells in any part of the body. They can be benign (stagnant) or malignant (invasive) in nature and can be acute, chronic, severe or deadly based on the type, location, stage and health condition of a person. Farmers and occupational workers in the fields with direct exposure to pesticides tend to have a higher risk of cancer than others (Blair et al., 1990). They have higher rates of cancers in the lymphatic and hematopoietic systems, sarcoma, melanoma, cancers on the lip, stomach, breast, prostate etc. A scientific literature analysis by the Federal University of Goias, Brazil, finds occupational (work-related) exposure to agricultural pesticides increases the risk for **45 different types of cancer**. The general public is also exposed to pesticides through the indoor application, use of pesticide-applied food, agricultural runoff, contamination of natural resources etc. Mechanism for cancer induction by pesticide is not thoroughly studied. **This study shows that twenty-six HHPs registered in India, shows carcinogenic toxicity.**

Classes of Pesticides showing Carcinogenic Toxicity

Phenoxy Herbicides like 2,4-D, 2,4,5-T and formulations were reported to cause high malignancy and Hodgkin Lymphoma (Hodgkin disease/lymphoma -HD/HL- is a malignancy involving lymph nodes and the lymphatic system). Studies, confirming association between Non-Hodgkin lymphoma (NHL) and 2,4-D use were conducted in Nebraska, Canada and Australia (Goodman, J. E et al., 2015)

Triazine herbicides like Atrazine, had been linked to increased mammary tumours and uterine adenocarcinoma in rats, and lymphomas in mice. Research on women working in Italian corn fields exposed to triazine has shown a 2-to 4-fold increase in ovarian cancer risk (Donna et al., 1984).

Arsenical insecticides: International Agency for Research on Cancer (IARC) had classified arsenical insecticides as pesticides with enough evidence of causing lung and skin cancer.

Organochlorine insecticides: These are among the most used insecticides in the world. In Washington State (US), a population-based study revealed that individuals with reported use of DDT had an 80% increased risk of NHL.

Organophosphate insecticides: Organophosphorous pesticides are found to increase the chance of colorectal cancer (Abolhassani, M et al., 2019) and breast cancer in applicators (Yang, K. J., Lee, J., & Park, H. L. 2020)

Others: Exposure to nicotine and pyrethrin results in an increased chance of leukaemia after a time period (Brown.et.al,1990)

Aside from these active chemicals, are **inert ingredients** which are present along with pesticide formulations in the commercial products, that can cause perilous effects on humans. Inert ingredients mostly act as adjuvants which helps in fixing pesticides or chemicals to a substratum, stabilize the product and extend shelf-life, help the pesticide dissolve in water an help prevent caking or foaming. However, inert substances can raise human exposure by enhancing skin absorption, reducing the effectiveness of protective gear or by enhancing environmental mobility and persistence. Most common examples of adjuvants used in market-bought pesticides are Dioxin, a chemical which is also used in the bleaching of sanitary pads, and Nonyl phenol, also used in shampoos and detergents, which are both known to be carcinogenic and endocrine disruptive in function via dermal absorption

Table 7.4.1: Some of the registered HHPs in India and their carcinogenic potential from studies

Sl no	Pesticide	Cancer type
1.	**Diclofop-methyl**	Bladder
2.	**DDT**	Bladder
3.	**2,4-D**	Bladder
4.	**Trifluralin**	Colon
5.	**Carbofuran**	Colon
6.	**Mancozeb**	Cutaneous Melanoma
7.	**Chlorpyrifos**	Hodgkin lymphoma
8.	**Permethrin**	Leukemia
9.	**Imiprothrin**	Leukemia
10.	**Metribuzin**	LHC
11.	**Captan**	Multiple Myeloma
12.	**Paraquat**	NHL
13.	**Pendimethalin**	Pancreatic
14.	**Methyl bromide**	Prostate
15.	**Malathion**	Prostate
16.	**Ziram**	Prostate

(Source: Table taken from Pesticide exposure and cancer; An integrative literature review, Pluth T B et al., 2019)

Children and Cancer

Research on the association between childhood cancer and pesticide exposure started as early as 1970, when neuroblastoma and leukemia were observed in prenatal and postnatal development following exposure to chlordane. Acute lymphocytic leukaemia was noted in children of pregnant women who were exposed to pesticides, in China (Shu et al., 1988). Acute myeloid leukaemia was noted in children, of parents exposed to pesticide and their continual use throughout childhood in a US based study (Buckley et al.,1989). Studies by Holly et al., (1992), revealed an increased incidence of Ewings sarcoma (Ewing sarcoma is a rare type of cancer in children, high incidence in males, that affects bones or the tissue around bones) among children whose parents had occupational exposure to pesticides. Similar study by Kristensen et al., (1996), also concluded the increasing incidence of Wilms tumour (Wilms tumour, also known as nephroblastoma, is the most common form of kidney cancer in children) in children of pesticide applicators.

Breast Cancer

Research on the use of pesticides has demonstrated a stronger link between the use of DDT and other organochlorine pesticides and breast cancer. Sommer S.S., et al, (1992) observed that p53 mutation[54] patterns for female workers in Midwest, an agricultural area, differ from locals used as control. A technical report titled 'Breast Cancer: A Wake Up Call' by PANAP (2007) concluded the same results were the contribution of pesticides to cancer noted includes;

- Mammary carcinogen by causing mutation in the gene. Animal evidence has shown that 2,4-D, Malathion, and Paraquat cause breast cancer
- DDT can act as tumour promoter where they promote the growth of breast cancer cells
- By affecting mammary gland development. E.g., DDT, Malathion
- Decreasing immune responses e.g., DDT which reduces the ability of natural T cells to kill tumour cells
- By interfering with transport at junctions, eg: Deltamethrin.

[54] **P[53] gene is a tumor suppressor gene. A defective gene or presence of only one set of gene can increase the chance of cancer .**

MALWA,The Cancer Capital Of India

Malwa is a region in the west central India, located in Punjab. This place has historical significance in the past and is an epitome of green revolutionary efforts in Punjab. However they also have high incidence of cancer and other health problems reported with pesticide use. Malwa region has reported over 21% of death due to pesticide poisoning in 2001-2002. A recent report from the Department of Health and Family Welfare (DHFW, 2013), Government of India, indicates that the cancer prevalence (per million) in the Malwa region is 1089, which is higher than India's national average cancer prevalence (800/million), giving it the name, Cancer Capital Of India. The survey by DHFW also reported 34,430 cancer deaths in Punjab and of this, the Malwa region alone comprised 46% of the cases (Mittal S et al., 2014).

Other than this, India witnessed Bhopal tragedy, in 1984, where the Union Carbide plant began leaking 27 tons of the deadly gas methyl isocyanate (an intermediate product of pesticide carbamate). Half a million people were exposed to the gas and 20,000 have died and more than 120,000 people still suffer from ailments, cancer and other serious conditions caused by the accident and the subsequent pollution at the plant site. In terms of human health, DDT is the cause of many kinds of cancer, acute and persistent injury to the nervous system, lung damage, injury to the reproductive organs, dysfunction of the immune and endocrine systems and birth defects.

7.5. HHPs AND GENOTOXICITY

Genotoxicity refers to the change in the genetic constitution of the cell by any agent. Pesticides induce genetic change, which can alter cell functioning drastically. Henceforth multiple tests and assays, each relying on unique characteristics are used to measure genotoxicity. Genotoxicity screening has been made mandatory in U.S.EPA and other developed nations where leverage is given to screening in mammalian cell lines and eukaryotic cell cultures.

Genotoxicity is measured mostly in terms of Chromosomal Aberrations (CA), Micronuclei frequency (MN) and Sister-chromatid exchanges (SCE). Chromosomal aberrations mainly consist of alteration in either chromosome number or chromosome structure. Micronuclei are smaller fragments of acentric nuclei, which are formed during mitotic cellular division due to irregularities and appear as small addition nuclei in the cytoplasm of cells during interphase (resting period before mitotic division). Sister chromatid exchange refers to the exchange of the homologous part of the chromosome although the correlation between its frequency and genotoxicity is not known in detail. Several studies have reported an increase in MN frequency in buccal epithelial cells (BECs) (Benedetti et al., 2013; Khayat et al., 2013) upon pesticide exposure. Micronuclei frequency, Chromosomal abberations, and sister chromatid exchange frequency was also noted to be higher in farmers exposed to a complex mixture of pesticides (Gentile et al., 2012; Bortoli et al., 2009).

Genotoxicity can be the primary contributor to carcinogenicity and reproductive toxicology. Genotoxicity of a single compound is usually low, but a dose-dependent relation is noted in several studies. Thereby farmers and occupational workers, who are exposed to a mixture of pesticides are more vulnerable to this. Van Bao and co-workers in 1974, noted an increase in chromosomal damage in 31 workers intoxicated by organophosphorus insecticides.

Studies from India

Studies from different parts of India are also in agreement with the general effects of pesticide-induced genotoxicity. In an investigative study on 210 male workers exposed to pesticides in Punjab, all of them displayed significant DNA damage (Kaur M S et al, 2011). Cotton workers of Andhra Pradesh also presented higher chromosomal aberration frequency upon long term pesticide exposure (Jonnalagadda et al, 2012). Organophosphate, with its inhibitory action on cholinesterase enzyme, affects neural regulation, induces significant DNA damage as noted in a study on 230 subjects by Singh et al., 2011 in Indian farmers. A study conducted in cotton fields from India in 106 female agricultural workers (mostly around age 18) by Perumalla Venkata R and associates (2016), showed that there is prominent DNA damage, increased frequency of micronuclei and chromosomal aberrations in the exposed subjects. RBC Acetylcholinesterase (AChE) was significantly reduced in pesticide exposed populations and a higher rate of lipid peroxidation was also observed. This is an exclusive study on women workers to study genotoxic implications of pesticides in India.

In another study titled ‘Genotoxic Evaluation of Workers Employed in Pesticide Production’ by N Sailaja and co-workers, (2006), an increased frequency of micronucleus (1.24 % in exposed vs 0.32 % in control), and higher chromosomal aberration percentage (8.43% in exposed vs 3.32 in control) was observed. In cytological studies, LC50 values of monocrotophos, carbofuran and endosulfan (7.5, 4.18, and 5.76 μM respectively) were calculated using probit analysis, and it was found that the percent viability of the cells decreased with an increase in the concentration of the pesticide (PP Das et al., 2007). Impact of pesticide in food upon consumption by the general public is not much studied along with other in vivo studies.

Table 7.5.1:Some of the registered HHPs in India and their genotoxic effects from studies

Sl No	Pesticides	Generation of mutation	Chromosomal aberration (a) /micronuclei (b) In vitro	Chromosomal aberration (a)/micronuclei In vivo(b)	Sister chromosome exchange (SSC)
1.	Acephate	Positive in salmonella test			+
2.	Arsenic compounds		a	a, b	
3.	Captan	Positive in salmonella test			
4.	DDT		a	a	
5.	Deltamethrin			a	
6.	Fenvalerate		a	a, b	
7.	Malathion		a		
8.	Methyl bromide	Positive in mammalian cell line, salmonella test		b	
9.	Propoxur			a	
10.	Trifluralin		a		

(Source: Pesticides with reported genotoxic effects (Table made from data available in Genotoxicity of Pesticides, David A. Eastmond and Sharada Balakrishnan and STUDY OF PESTICIDE GENOTOXICITY, Michael D. Waters et al)

7.6. HHPs AND NEUROTOXICITY

Neurotoxicity refers to the adverse effect on the peripheral and Central Nervous System, by any physical, chemical, or biological agents termed as neurotoxicants. Insecticides are most often responsible for neurotoxic effects in humans, as the nervous system represents their biological target in insects (Costa, L et al, 2008). Results from the Agriculture Health Study (AHS) by Dosemeci and colleagues, (2002) suggest that among 18,782 pesticide applicator subjects, those who used more insecticides were more likely to acquire neurological symptoms. Increased pesticide use was also associated with Parkinson's disease, dementia, and Alzheimer's in many studies. **21 of the 120 HHPs in India cause cholineesterase inhibition activity, and thus cause neurotoxicity effects.**

Gomes J and co-workers, (1999), in their studies on farmworkers exposed to multiple pesticides, reported increased neural disorders compared to unexposed workers. In a large population-based, case-control study, pesticide exposure was associated with Alzheimer's disease (AD) risk (McDowell et al., 1994). In a similar study on Vineyard workers in France, a two-fold increase in the risk of AD was noted (Baldi I et al., 2003). Apart from these, differences in cognitive functions, depression, memory loss and mood swings were also noted in several studies (Alavanja M.C et al, 2004). Farm workers exposed to organophosphates exhibited decreased psychomotor function (a wide range of tests on locomotor abilities and cognitive skills) in several tests, (Daniell W et al, 1992). Workers exposed to Organophosphates (Bazylewicz-Walczak B et al., 1999) and DDT (van Wendel de Joode B et al., 2001) are reported to have higher levels of tension, anger, and depression. Farahat T et al., 2003, has shown that all the pesticide applicators exposed to multiple pesticides over many years showed worse performance on tests of cognitive function (variety of tests on perception, attention, decision making, etc.).

Classes of Pesticides Inducing Neurotoxicity

Organophosphates

Organophosphates have an exceptionally high oral LD_{50} value ranging from 50 mg/kg to 500 mg/kg in rats. They act by inhibiting acetylcholinesterase (AChE), which catalyses acetylcholine into acetate and ester groups. This marks an increased accumulation of neurotransmitter acetylcholine at synapse and results in overstimulation of neurons producing various Central Nervous System effects[55]. Acute pesticide poisoning in several cases are found to be expressed in people as profound bronchial secretion, bronchoconstriction, miosis, increased gastrointestinal motility, diarrhoea, tremors and muscular twitching (Matthew C. Keifer et al., 2012). When exposed, individuals may experience organophosphate-induced delayed polyneuropathy (OPIDP), which is characterized by axonopathy (presented as tingling of the hands and feet) followed by sensory loss, progressive muscle weakness and flaccidity of the distal skeletal muscles and ataxia (neurological disorder affecting movement and coordination). In its 1992 report, "Pesticides in the Diets of Infants and Children," the National Academy of Science hypothesized that oral exposure to both dietary and non-dietary pesticides could cause OP neurotoxicity and expose young children's developing nervous systems to risk.

The classic signs of OP intoxication are often clinically termed, SLUD syndrome (salivation, lacrimation, urination, and diarrhoea), or DUMBBELS (diarrhoea, urination, miosis/muscle weakness, bronchorrhea, bradycardia, emesis or vomiting, lacrimation, salivation/ sweating).

[55] **Recognition and Management of Pesticide Poisonings: Sixth Edition: 2013: Chapter 5 Organophosphates (epa.gov)**

Carbamates

Carbamates are derivatives of carbamic acid. Cholinesterase-inhibiting carbamates include dimethylcarbamates and non-cholinesterase inhibiting pesticides consist of sulfur containing carbamates, the dithiocarbamates (used primarily as fungicides and herbicides). Exposures to high levels of dithiocarbamates lead to elevated copper level and promote lipid neurotoxicity (Aschner, M., & Toews, A. D. 2010). Carbamylated AChE is reversible unlike organophosphates, however, the signs and symptoms of carbamate poisoning are the same observed following intoxication with OPs like diarrhoea, salivation, muscle fasciculation and CNS effects (Miller D. B. 1982).

Pyrethroids

Pyrethroids are chemical components based on Pyrethrin, a constituent in the flower of *Chrysanthemum cinerariaefolium*, whose extract has 6 insecticidal compounds. They mainly act on the peripheral nervous system and bind with sodium channels and create a hyperexcitable state. Its prolonged opening and its regulation can manifest as different symptoms like mediate choreoathetosis (involuntary movement), salivation, and seizures. Similarly, long term skin exposure results in paraesthesia (burning sensation and numbness). (Soderlund, D. M et al., 2002)

Organochlorine compounds

Organochlorine insecticides like **DDT** have an LD50 of about 250 mg/kg on oral administration in rats. DDT interferes with the sodium channels in the axonal membrane similar to the action of Pyrethroids (Jason R. Richardson et al., 2019). In humans, the earliest symptom of poisoning by DDT is hyperesthesia (increased sensitivity) of the mouth and lower part of the face, followed by paraesthesia of the same area and the tongue. Other symptoms include dizziness, tremor of the extremities, vomiting and convulsions in case of severe poisoning. Recently, a study by Kim K S and associates (2015), using data from the National Health and Nutrition Examination Survey (NHANES) reported that serum DDE levels (Dichlorodiphenyldichloroethylene or DDE is a chemical compound formed by the loss of hydrogen chloride from DDT, of which is one of the most common breakdown products) were associated with decreased cognitive function in elderly people in the US, suggesting that non-occupational exposures to DDT can also cause cognitive deficits.

Others

Nicotine based insecticides exert their toxic effects in mammals and insects by activating nicotinic acetylcholine receptors and their depolarization, which results in receptor paralysis. Nicotine has a high acute toxicity in vertebrates, with LD50s usually below 50 mg/kg. Signs and symptoms of poisoning include nausea, vomiting, muscle weakness, respiratory effects, headache, lethargy, and tachycardia. Neonicotinoids are synthetic insecticides with the nicotinic acetylcholine receptors as their target and have a high degree of selectivity toward insects compared to nicotinoids. Examples include Imidacloprid, Thaimethoxam, Clothianidin etc.

Paraquat, a Bipyridylium herbicide, has high acute toxicity among others with an oral LD50 in rats of approximately 100 mg/kg. Paraquat forms superoxide free radicals inside the human body which causes lipid peroxidation. Animal studies have shown that paraquat can cause CNS effects, most notably resulting in neurodegeneration of dopaminergic neurons (McCormack et al., 2002).

Table 7.6.1 Some of the registered HHPs and their mechanism of neurotoxicity from studies

Insecticide class	**Example**	**Mechanism Effect**
Organophosphate	Chlorpyrifos, Dimethoate, Fenitrothion	Inhibition of AchE, Cholinergic syndrome, Peripheral axonopathy
Carbamate	Propineb, Mancozeb, Metiram	Inhibition of AChE, Cholinergic syndrome
Pyrethroid	Deltamethrin, Bifenthrin, Cyfluthrin	Prolonged opening of sodium channel, Hyperexcitability
Organochlorine	DDT	Prolonged opening of sodium channel, Inhibition of GABA and voltage-dependent chloride channels causing Hyperexcitability, tremors and Seizures

Source: Modified table from Neurotoxicity of pesticides: a brief review, Costa, L. G., Giordano, G., Guizzetti, M., & Vitalone, A. (2008). *Frontiers in Bioscience-Landmark*, *13*(4), 1240-1249.

7.7. HHPs AND IMMUNOTOXICITY

Immunity is the inherent or acquired property of an organism to fight against infectious agents and diseases. Xenobiotics or external chemical agents tend to affect the immune system by affecting cellular pathology, abnormal proliferation of immune clusters, and B and T lymphocytes[56]. This can be immunosuppressive or immune-potentiating in nature and can make the body susceptible to viral, bacterial, or parasitic infections. Immunosuppression in long-term, can result in prolonged infections and, immunostimulation can result in hypersensitivity reactions.

The mechanism for pesticide induced immunotoxicity is operational through ways by which chemicals can interfere with various general or immune specific signalling pathways or through adduct formation, which can induce cellular damage. This is severe in children where their immunity is compromised at a developing stage. In humans, pesticide inductive diseases are of three categories; Direct immunotoxicity (caused by the effects of chemicals on the immune system, leading to immunosuppression and subsequently reduced resistance to infectious diseases), Hypersensitivity (exaggerated or inappropriate immunologic responses occurring in response to an antigen or allergen) and Autoimmunity (the process by which the immune system makes a mistake and attacks the body's own tissues or organs) (Descotes & Vial, 1994).

Classes of Pesticides and Immunotoxicity

Organochlorine insecticides

Organochlorine insecticides are known for their ability to cross the placenta and thereby affect foetal growth. Hermanowicz and associates in 1982, concluded that neutrophil functions were depressed in 33 workers intoxicated by DDT. A high incidence of respiratory infections was also noted in the same study. Kashiap (1986) conducted a study on Indian workers in a hexachlorocyclohexane (HCH) factory. The workers whose HCH concentration differed markedly from those of non-exposed individuals in the same company had an evident effect on their IgM concentration. Schaalan et al., (2012) investigated the association between maternal milk and infant serum level of chlorinated pesticides and found a dramatic decrease in white blood cell count and lymphocytes associated with depressed cytokine secretion which affects the immunity of foetus.

Organophosphorus Compounds

A single neurotoxic dose of organophosphate pesticides decreased a wide range of immune responses in experimental models (New combe & Esa, 1992). Organophosphates can affect both in vivo and in vitro immune response, including effects on antibody production, IL-2 production, T cell proliferation, increase of autoantibodies, altered cytokine profiles, and inhibition of NK cells. O, O-5-trimethylphosphorothioate, an impurity of **malathion**, has been shown to exert marked immunosuppressive effects (Descotes, 1988). Human natural killer cell activity was also significantly suppressed after incubation of peripheral blood lymphocytes with several organophosphorus compounds (Newcombe & Esa, 1992). Thrasher et al., (1993), in their studies on 12 patients exposed to **chlorpyrifos** reported decreased lymphocyte subsets.

[56] They are white blood cells involved in atigen-specific immune response or adaptive immune response

Carbamates

An epidemiological study conducted on 23 women chronically exposed to aldicarb-contaminated groundwater showed persistent changes in the T-cell subset count (Fiore et al., 1986)

Others

In a work on the in-vitro model, Zhang and co-workers (2010) showed that synthetic pyrethroids are cytotoxic to monocytes, and affect cytokine secretion. Rats injected intraperitoneally with 20 mg/kg herbicide, **paraquat** experienced a decrease in the percentage of neutrophils (Suntres and Shek, 1995). The effect of propanil on the thymus was studied on mice by Zhao et al., 1995 and Cuff et al., 1996, and the results obtained indicate that this herbicide induces thymic atrophy with a significant decrease in the population of immature lymphocytes.

Propanil shows immunosuppression in mice model where thymic atrophy, decreased proliferation of T- and B-cell populations and reduced NK cells cytotoxicity and reduced ability of macrophages to phagocytose and kill pathogenic bacteria were noted (Barnett et al, 1992).

Hypersensitivity Reactions to Pesticides

Pesticides are reported to cause numerous clinical responses even when the underlying mechanism remains poorly understood. A significant association between asthma and the use of carbamates has been found in a cross-sectional survey based on the self-reports of male farmers in Saskatchewan (Senthilselvan et al., 1992). Similarly, Bhargava et al., (1977) reported the occurrence of erythema multiforme (skin reaction), few hours after contact with Methyl Parathion. Contact dermatitis is reported in many cases and more than 70 substances have been incriminated in the occurrence of contact dermatitis based on studies in animal models like guinea pigs (Cronin, 1980)

Table 7.7.1: Some of the registered HHPs in India and their immunotoxic effects from studies

Sl No	Chemical group	Pesticides	Effect
1	Organophosphates (OPs)	Chlorpyriphos	Atopy and antibiotic sensitivity. CD5, proliferative response to mitogens CD26, autoantibodies and autoimmunity
2		Malathion	Allergic contact dermatitis
3		Other Organophosphates	Infections of the upper respiratory tract, Neutrophil functions, NK and CTL cells activity
4		DDT	Neutrophil functions, evident IL-2 production decrease
5	Organochlorines (OCs)	Other Organochlorines	Increase immature blood leukocytes, basophils and globulins and increase of infections, decrease T-cells, T-suppressor, T-cytotoxic, NK, lymphocyte proliferative response to mytogen
6	Dithiocarbamate Fungicides	Mancozeb	Increase Proliferative response to T-cell mitogens, IL-2 production
7		Ziram	Increase B cells and Decrease TNF production
8	Pyrethroids	Pyrethroids	Decrease IFN production, expression of STAT6, lymphocyte proliferation, monocyte antigen presentation
9		Propanil	Decrease Thymus T and bone marrow B cells, NK cells, macrophages, CTL activity, cytokine production
10	others	Paraquat	Increase Genes involved in inflammation (CXL10, CXL11 and IL-10), cell death

(Source: Table made from Table1, Table 2, and Table 3 in the article 'Pesticide induced immunotoxicity in humans: A comprehensive review of the existing evidence' by E. Corsini et al., 2012)

7.8. HHPs AND TERATOGENICITY

Teratogenicity is the ability of a chemical or a drug to cause foetal abnormalities or deformities. A teratogen is an agent that causes physical or functional defects in the development of the embryo or foetus when the pregnant parent is exposed to these agents. They can be endocrine disruptors in function, that alter hormonal balance required for the normal development of the fetus. They can also be reproductive toxicants, where they affect reproductive development in a person and can thereby affect the development of the fetus which may later manifest as disorders, abnormalities or as cancer in the developing child[57]. Pesticides can act as teratogens.

Most of the studies on teratogenicity are conducted on animal models. Reduced fetal weight was observed when **Cypermethrin** was administrated to pregnant albino rats at day 20 of gestation (Madu, E. P, 2015). **Deltamethrin** administered orally to mice at gestation day 6, caused hydrocephaly, microcephaly and micromyelia (shortness of the spinal cord), anophthalmia (baby is born without one or both eyes) or microphthalmia (one or both eyes did not develop fully, so they are small), exophthalmia, open eyelids, cryptophthalmia (total absence of eyelids), defective nasal pouch, kyphosis (excessive curve of the spine), pericranial cleft palate, degeneration of jaw muscles, sacral hygroma (lymphatic malformations), reduced lengths of forelimbs and tail, drooping wrist, tissue necrosis (brain, liver and intestine) and decreased body weight (Khan M K et al., 2013). Mixed combinations of pesticide used in nearby farmland resulted in facial malformities in young chimpanzees and baboons in Kibale National Park in Uganda (Krief et al., 2017)

Classes of Pesticides and Teratogenicity

Chlorinated Insecticides

DDT was found to be teratogenic for chick and quail embryos (David and Lutzostertag, 1972). Intra peritoneal administration of DDT has also shown increased post-implantation mortality. Endosulfan was found to induce malformations in treated chick and quail embryos (Lutz-Ostertag and Kantelip, 1971).

Organophosphorus Insecticides

Organophosphorus insecticides like ethyl parathion, fenitrothion and **malathion** are all reported to have teratogenic effects in avian embryos (Moutschen-Dahmen J and N. Degraeve, 1984).

Carbamates

In a 1979 study by Murray et al., the percutaneous injection of carbamate caused a rise in the occurrence of omphalocele, a birth defect of the abdominal wall in which the baby's liver, intestines, or other organs protrude through the belly button. Similarly, Beagle dogs when administered carbamate through food throughout the gestation period showed teratogenic effects like abdominal-thoracic fissures, brachygnathia (a deficit in mandibular length causing the incisor teeth to meet the upper dental pad behind its anterior angle), ecaudate pups (having no tail), failure of skeletal formation, and superfluous phalanges (fused hands) (Smalley et al., 1968)

[57] Teratogens/Prenatal Substance Abuse - Understanding Genetics - NCBI Bookshelf (nih.gov)

End notes

HHPs and health effects is a chapter which explores the disastrous public health consequences of the use of the pesticide and the health-related effects that persist to this day. The data described above, that are systematically collected about pesticide hazards, exposures, and health effects describe the risks experienced by agricultural communities in general. It summarizes the long listed health effects of HHPs which includes cancer, endocrine disruption, teratogenicity, reproductive toxicity, neurotoxicity, immunotoxicity and genotoxicity. Toxicities of different classes of HHPs on different sections of society are dealt in detail in this chapter. Case studies from India are highlighted to provide a detailed background introduction of HHP effects inorder to focus on strict regulation of these HHPs

Chapter 8

HHPs AND POISONINGS

“Two of every three attempted poisoning in India are attributable to pesticide use [58]”

Pesticide poisoning occurs when non-target organisms are affected by pesticide exposure. Intentional poisonings and Unintentional pesticide poisoning are the two classes of pesticide poisoning in the world, of which occupational pesticide poisoning is the most common type of unintentional poisoning (UAPP). This occurs during the preparation, mixing, decanting and application of pesticides. About 385 million cases of UAPP occur annually world-wide including around 11,000 fatalities. The greatest estimated number of non-fatal UAPP cases are in Southern Asia, followed by South-eastern Asia and East Africa. The farming/occupational population in India has the highest estimated number of non-fatal UAPP which is about 145 million based on this study.[59] Boedkar et al., 2020 in their studies on intentional poisonngs around world has stated that, **66,000 of farmers are poisoned in India in ever year**.

Other unintentional pesticide poisoning occurs when, accidentally inhaled, ingested, or consumed. Self-poisoning is the commonest form of Intentional poisoning. It is also a note of concern that a high incidence of poisoning due to household pesticides as compared to agricultural pesticides are seen in the past century, clearly emphasizing the need for creating awareness and education about proper use, storage and regulation of pesticides[60].

A 2019 submission of PANAP on pesticide poisoning in Asia has reported 1307 pesticide poisoning cases from the period of 2013 to 2018. Four hundred seventy five children in India were poisoned by toxic fumes and 9 died in the year 2017. Highly hazardous pesticides are the convicted culprits of these cases. Trends of Poisoning Cases in Tertiary Care Teaching Hospitals in Western Indian Population, has shown that of all the cases reported of intentional poisoning by use of pesticides, HHPs were involved.[61] National Crimes Record Bureau (NCRB) Accidental deaths and suicidies in India report of 2021 has stated the 7950 accidents by intake of pesticides occurred in India in 2021. Madhya Pradesh has the largest number of suicides by pesticide poisoning (1466) according to this report.

Self-poisoning by voluntary intake of pesticides shows an astonishing trend in most Asian countries. Most of the chemicals used for this purpose are highly toxic chemical pesticide belonging to HHP class. This is supported by the observation that, ban on HHPs has helped in downregulation of pesticide suicides over the past years in few countries. Studies from Sri Lanka has shown that ban of **dimethoate and fenthion**, has resulted in reduced

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[58] Toxicoepidemiology of poisoning exhibited in Indian population from 2010 to 2020: a systematic review and meta-analysis. *BMJ open*

[59] Boedeker, W., Watts, M., Clausing, P., & Marquez, E. (2020). The global distribution of acute unintentional pesticide poisoning: estimations based on a systematic review. *BMC public health*, *20*(1), 1875.

[60] Peshin, S. S., & Gupta, Y. K. (2018). Poisoning due to household products: A ten years retrospective analysis of telephone calls to the National Poisons Information Centre, All India Institute of Medical Sciences, New Delhi, India. *Journal of forensic and legal medicine*, *58*, 205–211. https://doi.org/10.1016/j.jflm.2018.07.005

[61] Sambhaji Pate, R., Vijay Rojekar, M., & Chandrakant Hire, R. (2017). Trends of Poisoning Cases in Tertiary Care Teaching Hospitals in Western Indian Population. *International Journal of Medical Toxicology and Forensic Medicine*, *7*(3(Summer), 177-184.

pesticide poisoning cases by 43%[62]. Banning of WHO Class I pesticides in Bangladesh were associated with major reductions in deaths and hospital mortality, without any apparent effect on agricultural output[63].

In India BMC report titled, 'Suicide by Pesticide poisoning in India'(2020) has investigated the trends in suicide rates nationally by analysing trends in Kerala, has shown that a decreasing trend in total suicides is seen after temporary bans of HHPs.

8.1. Poisoning studies from India

"44% of the farmer population are poisoned by pesticides every year, globally"[64]

In a systematic study on pesticide poisonings in south India, it was observed that almost all the cases of poisoning occurred were by ingestion of HHPs. Fourteen active ingredients were listed in this study from Warangal, Telangana which displayed that all the 14 chemicals were HHPs thus showing the effect of HHPs on pesticide poisoning.[65]

Malathion, Monocrotophos, Parathion, Diazinon, Fenthion, Dichlorvos, Chlorpyrifos and Ethion are reported in causing severe poisoning in Yavatmal district of Maharashtra in 2016, in which all were HHPs[66]. Following this, Maharashtra government banned Fipronil, Monocrotophos, Profenofos, Imdiacloprid, Cypermethrin, Acephate and difenthiuron in 2017. Acute poisoning of 32 school children in 2002 in Kerala was due to the use of phorate in banana plantation. Twenty three children in India aged 4 to 12, were killed after eating their mid-day meal contaminated with Monocrotophos in Bihar (The Times of India, 2013). Many incidents of pesticide poisoning in developing countries are linked to monocrotophos. Severe monocrotophos poisoning will affect the central nervous system, producing incoordination, slurred speech, loss of reflexes, weakness, fatigue, involuntary muscle contractions, and eventually paralysis of the body extremities and the respiratory muscles.

Data gathered from July 1999 to June 2000 from four Indian states (West Bengal, Tamil Nadu, Andhra Pradesh, and Karnataka) was used in a WHO-sponsored study titled "Health implications from monocrotophos use: a review of the evidence in India." The study revealed that 89 of the 1531 cases of pesticide poisoning in these states—the highest number of any insecticide—was caused by monocrotophos.

8.2 Pesticide poisoning and treatments

Patients who have been poisoned by pesticides are typically treated with general medicine as many pesticides lack an antidote. Most medical facilities do not have adequate stocks of antidotes as well. Pre-hospital care treatments, that include removing pesticide residues form body by washing, stoppage of further exposure, drinking fluids etc, are henceforth the only source of treatment in most Indian states. Primary treatment for poisoning includes termination of exposure and decontamination followed by hospital care

- Organophosphate poisoning and carbamate poisoning is dealt with IV administration of atropine sulphate, pralidoxime (severe toxification). Glycopyrrolate administration is considered an effective alternative to atropine (EPA)

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[62] **Eddleston et al, (2012). Effects of a provincial ban of two toxic organophosphorus insecticides on pesticide poisoning hospital admissions. *Clinical toxicology (Philadelphia, Pa.)***

[63] **Chowdhury, F. R et al, (2018). Bans of WHO Class I Pesticides in Bangladesh-suicide prevention without hampering agricultural output. *International journal of epidemiology***

[64] **Boedeker, W *et al.* The global distribution of acute unintentional pesticide poisoning: estimations based on a systematic review. *BMC Public Health* 20, (2020)**

[65] **Pesticide Poisoning in South India – Opportunities for Prevention and Improved Medical Management - PMC (nih.gov)**

[66] **Pesticide Poisonings in Yavatmal District in Maharashtra: Untold Realities, PAN INDIA**

- Synthetic pyrethroid poisoning is accompanied by inflammation, for which anti histamine administration is the most suggested treatment. Patients who have been poisoned by pesticides are typically treated with general medicine as many pesticides lack an antidote. Vitamin E administration may be used for paraesthesia
- Antidote phytonadione is used for the anticoagulant rodenticides (coumarin and indandione)
- Aluminium phosphide and zinc phosphide release phosphine gas upon contact with moisture for which no special antidotes are available. Serum electrolyte administration and gastric lavage are the suggested treatments.

Most of the HHP poisonings causes severe and potentially fatal respiratory distress, lack of motor co-ordinations, acute effects, paralysis and even death. Currently there is no antidote available for the symptoms of most of the HHP poisonings in India. According to NPIC, AIIMS there is only antidotes availabe for 13 HHPs in India[67].

Accrording to PAN India's report titled 'Pesticide Poisonings in Yavatmal District in Maharashtra: Untold Realities', all the cases of pesticide poisonings were considered as Medico- legal cases (MLCs), in which all accidental poisoning cases were classified as 'inhalational poisoning'cases. Treatment to inhalational poisoning cases were provided based on the symptoms they show. There is also a significant and critical information gap because both farmworkers and hospital staff typically do not know the names of pesticides. As a result, poisonings from pesticides in Yavatmal were classified as organophosphate (OP) poisoning, and patients who were poisoned with pesticides were prescribed atropine, PAM (pralidoxime: 2-pyridine aldoxime methyl chloride), and antibiotics without first being evaluated for infections. Oxygeneation is provided following atropinisation in severe cases of paralysis, however there exists a dilemma about the need for oxygenation that precede atropinisation. This describes the general condtions of hospital care for pesticide poisoning in rural India, where without appropriate diagnosis and treatment, majority of poisoned patients suffer permanent disability.

Maharashtra-pesticide consumption and poisoning studies

It is noted from the data of chemical pesticide consumption that, Maharashtra, the third largest State in India (30771330 sq km) and second largest populous state in India has the highest chemical pesticide consumption in 2020 and 2021 (State wise consumption of chemical pesticides, PPQS). Agriculture is the mainstay in the state of Maharashtra. Principal crops include rice, jowar, bajra, wheat, pulses, turmeric, onions, cotton, sugarcane, and several oil seeds including groundnut, sunflower and soybean. The state has huge areas, under fruit cultivation of which mangoes, bananas, grapes, and oranges are the main ones. Maharashtra is the largest producer of seedless Grapes (78%) banana (75%) Mandarin oranges (75%) Onion (63%), Tomatoes (42%) of the total production in India. Alphonso Mangoes accounts for 90% of India's export in mangoes.

Maharashtra marked the highest pesticide usage in the year, 2016-2017 (15,568 Metric ton, PPQS). This was followed by a decreased trend of chemical usage in the next years, and a peak usage of 13175 metric ton in the year 2021-22. Chemical pesticide use, however, has added to a vast number of cases of pesticide poisonings and accidental intoxications in the last decade from Maharashtra, where thousands of farmers suffer from acute and chronic effects of pesticide intoxication.Vidarbha region of Maharashtra, largely constituted by an agrarian society, has reported over **14,000 suicides** of farmers over the last 16 years (Pesticide Poisonings in Yavatmal District in Maharashtra: Untold Realities, PAN India, 2017). **Yavatmal**, a district of Maharashtra had witnessed more than 23 deaths and around 1000 casualties as a result of pesticide intoxication in 2017[68] (Yavatmal-Report, PAN India, 2017). Similar cases were noted from Warangal district of Maharashtra in 2002, where the post-mortem report noted multiple organ failure.[69]

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[67] **Antidotes (aiims.edu)**
[68] **Yavatmal-Report_PAN-India_Oct-2017_web.pdf**
[69] **Pesticide Poisonings in Yavatmal District in Maharashtra: Untold Realities, PAN INDIA**

End Notes

This chapter discusses an aspect of HHP use, which is poisoning. Pesticide poisonings are one of highest causes of death, accounting for just under 8000 casualties in an year in India. Unintentional Occupational Exposures constitute the highest risk of toxicity and it is severely high among farmers. These HHPs are ready availability for use at an affordable price, resulting in its use in self-poisonings. Moreover, the majority of HHPs used in India have no known counteragent or antidote for poisoning. Ban on HHPs has shown in decreasing trends of suicides in many countries. By outlawing HHPs, this operational model can be used to lower suicide rates in India.

Chapter 9

HHPs AND ENVIRONMENTAL EFFECTS

9.1 HHPs and Environmental Toxicity

Pesticides are having disproportionately large impact on functioning of our ecosystem. Biodiversity changes in terms of habitat loss and reduced species richness are prominently monitored in the past years from different parts of the world. In a study of Britain's farmland habitats where pesticides including HHPs were taken up widely, it was noted that population declines have occurred in about half of the plants, a third of insects and four-fifths of bird species (Robinson & Sutherland, 2002). Similar studies from different parts of the globe, are suggesting the severity of pesticide implications on the environment.

Many pesticides are not easily degradable, they persist in soil, leach to groundwater and surface water and contaminate wide environment. Pesticides can reach surface water through runoff from treated plants and soil. Several researches and studies from different parts of India, have shown that pesticides and heavy metals linger in detectable levels in drinking-well water and groundwater. Organochlorine and Organophosphorus pesticide residues were detected in groundwater samples from irrigation wells, domestic wells and canals used for irrigation and drinking purposes in Aligarh (Ray, 1992). These can affect the biome as the water is utilized by most species of an ecosystem.

Pesticides can affect soil fertility, diversity and microbiomes in soil. Reinecke et al., (2008), in their studies in South Africa, noted that the feeding activity of soil organisms was higher in soil from organic vineyards than from conventionally treated sites. Similar studies conducted by Mader and co-workers, 2002, showed that, the population of earthworms was 1.3-3.2 times higher in organic field compared to conventional plots, and the length of plant roots colonised by mycorrhizae was 40% higher in organic fields. Microorganisms has a higher role to play in the field fertility and its dynamics. HHPs can have a toxic effect to soil dwelling organism as well as to its fungal and algal components.

Pesticide accumulation in food chain can affect organisms directly, or by biomagnification. Dietary intake and feed intake by cattle and other herbivores, which feed on these pesticide-laden herbs are of major concern. As most of the pesticides are lipophilic, they get accumulated in their fat tissues, including milk and meat, which can affect the physiology of the animal, and is transferred to higher food trophic levels.

Endosulfan, an organochlorinated insecticide, was used in agriculture for the control of various pests in crops in India before its ban in 2011. It was reported to be present as residues in different feed concentrates and green fodders up to a concentration of 6 ppm (Dikshit et al., 1989) even before its ban. ICMR has reported of the presence of multiple organo-chlorine pesticide residues in milk samples collected from different locations of the country[70].

Herbicide application in the fields have further resulted in acute plant damages. In field tests, the herbicide, **Glyphosate** altered the composition of freshwater microbial communities by decreasing the abundance of microbial phytoplankton and increasing cyanobacteria (Pérez et al., 2007). Studies reveal that glyphosate can cause secondary habitat changes by affecting plant productivity and the distribution of biomass. This affects the abundance and reproductive success of wildlife, especially birds and mammals in spray zones (Freedman, 1990).

[70] sample of ind studies on pesticide residues-connected to PESTICIDE RESIDUES (indiaforsafefood.in)

Environmental Toxicity

According to the PAN HHP criteria, environmental toxicity effect of HHPs are divided into 4 subclasses, they are: Very bio-accumulative, Highly persistent in water, soil or sediment, Very toxic to the aquatic organisms and Highly toxic to bees (Refer section 3.3). PAN HHP list 2021 provided the toxicities data for the HHPs registered in India. From this study it was noted that, **9 HHPs** included in this study are highly bio accumulative. **Twelve** of these HHPs are very persistent in soil/water/sediment, **15 HHPs** are very toxic to the aquatic organism, and **52 HHPs** are highly toxic to bees. The present study only considered and analysed biodiversity effects of HHPs listed in PAN HHP list, 2021.

"Many pests have developed **Pesticide resistance**, due to repeated exposure to the chemical compound. In India, the pesticide resistance appeared first in insect vectors of parasitic diseases in 1952, in agricultural pests in 1963 and in insect pests of stored grains and commodities in 1971 (Mehrotra, 1989). In studies conducted in Andhra Pradesh and Maharashtra, five major insect pests of cotton were found to gather resistance against HHPs like **Cypermethrin, Chlorpyriphos and Endosulfan** (Kranthi et al., 2002)"

9.2. HHPs and Ecotoxicity

Periodic application of pesticides are negatively affecting the wildlife, that are not the targets of pesticide application. Pesticides have caused significant behavioural changes, physiological imbalances, and structural modifications in many organisms. Bees foraging behavior has been significantly impacted by pesticides such as imidacloprid (Yang et al., 2008). DDT and its metabolites have accumulated in the tissues of Bald eagles, causing physiological changes and a significant decline in the birds population in the United States (Liroff, 2000). DDT and its metabolites have also been shown to cause obstruction of Ca^{2+} metabolism in birds (Lundholm, 1994).

Fungicides can indirectly affect bird and mammal populations by killing earthworms on which they feed. **Glyphosate and chlorpyrifos** have exerted their deleterious effects like DNA damage and have affected the feeding activity and viability of earthworms (Casabé et al. 2007). Chlorinated pesticides have shown to give rise to oestrogen-dependent reproductive effects in several avian species (Fry, 1995).

Fishes

Lambda-cyhalothrin showed very high toxicity in fish followed by **fenvalerate, deltamethrin and cypermethrin** which affected cell growth differentiation and apoptosis in a study (Singh et al., 2016)

Birds

Declining population of Sarus Crane (*Grus antigone*) in Keoladeo National Park, Bharatpur, was attributed to the application of aldrin (HHP) in the agricultural fields around the park where 18 Sarus Cranes were found dead inside the park within a span of 3 years (Muralidharan 1993). Even after the ban on aldrin, the death of 15 Sarus Cranes due to **monocrotophos** poisoning was reported (Pain et al., 2004). Dhananjayan and Muralidharan, (2010) reported concentrations of Organchlorine pesticides in the blood plasma of 13 species of birds collected from Ahmedabad, India.

High levels of **DDT** and other organochlorine pesticide residues were detected in the fat depots of crow, kite, and vulture in a study by Kaphalia et al. (1981). Comparable research conducted by Misra (1989) revealed increased concentrations of DDT and its chemical equivalents in the brains of flamingos, red-wattled lapwings, and birds from the Mahala water reservoir. It was reported that 58 aquatic birds, representing six different species, had died at Okhla Bird Sanctuary in Uttar Pradesh, possibly as a result of pesticide poisoning (Sundar, 2006). Waterbird deaths at Chilika Lake's Nalaban bird sanctuary may be related to organochlorine pesticides (OCPs), according to Dhananjayan et al. (2012), who found pesticide residues in every bird tissue they examined.

Dhananjayan et al, (2012), assessed the persistent OCPs in various tissues of House Sparrow, *Passer domesticus*, from Tamil Nadu, India, between 2001 and 2006 and observed higher levels of bioaccumulation in eggs, liver, brain, and muscle tissues. Although OCPs levels detected in tissues are not indicative of toxicity, they can be considered as a positive reason for the decline of House sparrows. Eggs from specific colonial water birds breeding at Keoladeo National Park, Bharatpur, India, when studied for the presence of orgganochlorine residues also exhibited positive results (Muralidharan et al.,1993).

Amphibians

Endosulfan toxicity was observed in tadpoles of three amphibian anurans from Barak valley, Assam (Dey et al., 2015). **Malathion** in adult species of frog *F limnocharis* causes necrosis, tissue damage, cellular disintegration, and reduction in the number of ovarian follicles in the ovary. Levels of haematological parameters were also affected significantly. Blood glucose levels, enzyme SGOT levels and amylase levels were recorded high in this species (Roy and Gupta, unpublished)

Mammals

Pesticide-induced inhibition of AChE by **Quinalphos** in mice affects a secondary transmitter, especially dopamine and invariably affects gonadotropin release, which decreases fertility in adult male rats (Sarkar et al., 2000). The Forensic Science Laboratory (FSL) in Guwahati confirmed the cause of the death of a tiger cub in a tea estate near Kaziranga National Park in January, 2008 by pesticide poisoning. Elephant death trends were noted in the Coimbatore Forest division where eight jumbo deaths were recorded in 2022, 15 in 2021 and 20 in 2020, majorly at Pethikuttai reserve forest. The Regional Forensic Science Laboratory, in Coimbatore, which tested samples from two of the elephants, found traces of organophosphorus compound (OPC), indicating pesticide poisoning.

Bees

Bees are responsible for the pollination of 71% of the common crop around the world. However, bee populations have been dwindling due to pesticide use. Pesticides can act through direct spray contact, residue contact or through contaminated nesting materials. Bees can ingest the residues found in pollen and nectar of plants or drink pesticide- applied water. A single droplet of insecticide may kill a bee and can cause colony disruption.

Fifty two HHPs registered in India are found to be toxic to bees. Bees are mostly affected by neonicotinoid class of pesticides. Neonictonioids like **Imidacloprid** and **Thiamethoxam**, that are coated on seeds or sprayed on soil, can cross tissues of plants and show up in nectar and pollen, taken up be bees. They are more toxic to central nervous system of bees causing leg tremors, rapid wing motion, disoriented movement, paralysis and death[71]. Organophosphates, Neonicotinoids and Pyrethroid HHPs are studied to affect locomotor grooming, odour learning and disrupt cholinergic neurotransmission in bees. They may even affect fertility in bees.

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[71] Williamson, S. M., Willis, S. J., & Wright, G. A. (2014). Exposure to neonicotinoids influences the motor function of adult worker honeybees. *Ecotoxicology*, *23*, 1409-1418.

End notes

This chapter discusses recent studies and reports on environmental toxicities induced by HHPs and other pesticides, which fail to selectively eliminate a particular pest and thereby damage other wildlife. HHPs have a debilitating, complex and wide effect on the ecosystem. They affect the texture and composition of soil at different layers and thereby affect soil-rooted plants and soil-dwelling organism. Every species tend to have an effect on our ecosystem function that is disproportionate to its abundance or size. These species are now wiped off due to pesticide application that causes habitat destruction, poisoning of resources and disrupting their bodily functions. The widespread use of pesticides is coming under increasing pressure as their negative effects on bees and other pollinators become more apparent. This chapter discusses the need for a strategic approach to sustain reliable biological parameters in order to protect our ecosystem from harmful chemical pesticides

Consolidated list of data represented in this study

Criteria	Sub classes	Number of HHPs
Drift-prone Characteristics	Pesticides which have low drift-prone values	28
	Pesticides which have very low drift-prone values	18
	Pesticides which have moderate drift-prone values	21
	Pesticides which have high drift-prone values	3
Long term effects	Pesticides which probably cause cancer (EPA)	24
	Pesticides which probably cause cancer (IARC)	3
	Pesticides which cause mutation (GHS)	1
	Pesticides which cause reproductive disorders (GHS)	20
	Pesticides which cause Endocrine Disruption (EU)	1
	Pesticides which are Choline esterase inhibitors	21
	Pesticides which have Suspected Endocrine activity	33
	Pesticides which can cause reproductive disorders and cancer	16
Environmental Toxicity	Pesticides which are very bioaccumulative	9
	Pesticides which are very persistant in soil, water and sediment	12
	Pesticides which are very toxic to aquatic organisms	15
	Pesticides which are highly toxic to bees	52
Listed in Conventions	Pesticides which are Persitant Inorganic Pollutants (POP)	2
	Pesticides which are listed in Montreal Protocol	1
	Pesticides which are listed in Rotterdam convention on PIC	5
WHO classification based on atur toxicity	Pesticides belonging to WHO Class 1a	3
	Pesticides belonging to WHO Class 1b	11
	Pesticides belonging to WHO Class 2	55
	Pesticides belonging to WHO Class 3	21
	Pesticides belonging to WHO Class U	20
	Pesticides belonging to H330 (PAN HHP List)	23

Chapter 10

MAJOR FINDINGS & CONCLUSIONS

Major findings

- ✓ It was found that about one-third of the total pesticides registered in India are Highly hazardous Pesticides (120 out of 318 registered pesticides as on October, 2022).

- ✓ Eighty one of these HHPs are banned and/or restricted in other countries. Among the 81, 68 HHPs are found to be banned in more than 10 countries. Five HHPs registered in India are banned in more than 50 countries, which are; DDT (banned in 147 countries), Monocrotophos (banned in 129 countries), Carbofuran banned in (87 countries), Paraquat Dichloride (banned in 58 countries) and Dicofol (banned in 52 countries). Twenty seven of these HHPs are have been found to be in congruence with FAO JMPM criteria of HHPs.

- ✓ Seven HHPs (DDT listed in two conventions) currently registered in India are listed in 3 International conventions (DDT, Carbofuran, Carbosulfan, Monocrotophos and Paraquat dichloride in Stockholm Convention, DDT and Dicofol in Rotterdam convention and Methyl bromide in Montreal Protocol)

- ✓ Drift prone characteristics of HHPs were studied in which data for 70 HHPs were obtained. Of these 70 HHPs, 28 are low drift-prone, 18 are of very low drift-prone value, 21 are moderately drift-prone and 3 are highly drift-prone HHPs

- ✓ This study finds that organophosphates form the major share of 120 HHPs in India, while insecticides constitute the the major type of HHPs. Chlorpyrifos (1,036.69 MT) is the most used insecticide HHP and Mancozeb (2194.51 MT), a fungicide, is the most used HHP in India.

- ✓ HHPs constitute nearly half of the total volume of pesticide used in India. But this data pertains only to 70 HHPs, and not for all 120 HHPs. Of the imported pesticides, 71.15 % volume is constituted by HHPs.

- ✓ Production data set of 27 HHPs are available from a total of 41 pesticides. This data analysis revealed that 96.53 % of the total pesticide production is of HHPs. There is a 17 % increase in production of HHPs in 2022 compared to its production in 2021. Mancozeb was found to be the largest produced HHP (1,17,831 MT) in India.

- ✓ Export and import dataset of only 7 HHPs were available, from which cypermethrin, an HHP shows the largest import and export value for any pesticide.

- ✓ Twenty six of the registered 120 HHPs in India are Deemed to be Registered Pesticides. That means these HHPs have escaped the registration scrutiny.

- ✓ A comparative analysis of pesticides recommended by state level authorities and national approved usage is done for 10 States of India. It shows that 78 HHPs of the 120 were mentioned in crop recommendation practises from 10 States of India. 29 HHPs were recommended for crops not approved in the national approved use of pesticides.

- ✓ Health effects of these HHPs analysed are of varying degrees ranging from acute toxicity to long term effects. Acute toxicity analysis revealed that 3 of the HHPs belongs to class WHO 1a (Extremely hazardous), 11 HHPs belongs to class WHO 1b (Highly hazardous), 23 HHPs belongs to H330 (inhalation toxicity), 51HHPs bleongs to category of Moderaltely Hazardous or class 2, 21 HHPs belongs to clas 3 or Slightly Hazardous and 20 HHPs were found to be unlikely to cause hazard or belongs to class U.

- ✓ Long term effects factored in this report are carcinogenicity, mutagenicity, reproductive toxicity, endocrine disruption, and neurotoxicity. It was found that, 26 Pesticides are carcinogenic, one HHP cause mutation, 20 HHPs cause reproductive disorders, 33 HHPs are suspected of Endocrine Disruption and 16 HHPs cause combined reproductive disorders and cancer. Almost all of the 120 pesticides have shown possible multiple toxicological effects on humans in multiple studies.

- ✓ Environmental effects in terms of persistence in soil, bioaccumulation, toxicity to aquatic organisms and toxicity to bees are analysed in this study based on which 9 HHPs are found to very bioaccumulative; 12 HHPs are found to be higly persistant in soil, water, sediment; 15 HHPs are found to be verty toxic to aquatic organisms; and 52 HHPs registered in India are found to be highly toxic to bees.

Recommendations

- ✓ Ministry of Agriculture and Farmers Welfare, Government of India should immediately take measures to ban production/import/export and usage of these Highly Hazardous Pesticides considering that they are too dangerous for common risk measures, such as labelling and wearing Personal Protective Equipment (SAICM, 2022)

- ✓ Safety data sheet of all DRP HHPs along with all registered pesticides should be prepared and submitted to the Registration Committe to analyse the health risks caused by each pesticides to validate their continued registration and use.

- ✓ Ministry of Agriculture and Farmers Welfare, Government of India should withdraw the registration certificate and ban all Deemed-to-be Registered Pesticides with immediate effect and should indroduce a uniform regulatory process, without exceptions.

- ✓ The Central Insecticides Board and Registration Comittee should maximise legal compliance, by monitoring usage, sales and marketing of HHPs in India, more closely.

- ✓ The Central Sector Scheme, Monitoring of Pesticide Residues at National Level, should focus on monitoring residues of HHPs in crop products and environmental samples to understand the level and extent of contamination, as a number of non-approved uses have been found. Further, residue monitoring should be expanded to reveal and study other non-approved uses of pesticides and other aspects. Precise and accurate residue analysis techniques should be introduced to incerase the efficacy of the test system.

- ✓ The pesticide industry must immediately cease sales of, and withdraw from the market, pesticides with labels not in compliance with the label requirements in India

- ✓ An accurate representation of statistics regarding import, export, production and use of every pesticides should be made available in the Plant Protection Quarantine and Storage, Government of India.
- ✓ CIB and RC should constitute independent and autonomous body for regulation of HHPs in India.
- ✓ A monitoring committee mechanism is needed at national, State and sub-State levels to oversee pesticide use and non-scientific application of pesticides etc within the country
- ✓ Build awareness, among individuals and communities, on the pathways of exposure for children, and the potential effects on their health.

Conclusion

Indian pesticide regulation masks highly hazardous characteristics of pesticides registered and used. HHPs constitute a major share in production, imports, exports and usage of pesticides in India. The impacts of these HHPs are unfocussed and under-studied. While many countries have banned these HHPs, India continues to encourage the usage of these pesticides. Agricultural extension services are also ignorant of these HHPs. Unscientific and Non-studied recommendations by extension services manned by scientists is a cause of concern. Without reference to the National registration stipulations, Scientists and Agricultural systems are found to recommend HHPs for food crops which can endanger the lives of farmers and consumers. Retail network of pesticides in markets is known to further dilute registration norms recommending HHPs to farmers, without in iota of scientific, experiential knowledge. This super structure ultimately blames farmers for pest resistance, poisonings, exposures, residues and contamination. International knowledge on HHPs should be frequently referred and utilised in HHP regulation in India. Advancing agroeological farming practices is the key to craft the change. Such farming practices need to be encouraged at the national level and need to be practised on a large scale with adequate policy and institutions as well as extension support systems.

REFERENCES

A.L. McCormack, M. Thiruchelvam, A.M. Manning Bog, C. Thiffault, J.W. Langston, D.A. Cory-Slechta and D.A. Di Monte, (2002): Environmental risk factors and Parkinson's disease: selective degeneration of nigral striatal dopaminergic neurons caused by the herbicide paraquat. Neurobiol. Dis. 10, 119-127

Alavanja, M. C., Hoppin, J. A., & Kamel, F. (2004). Health effects of chronic pesticide exposure: cancer and neurotoxicity. *Annu. Rev. Public Health*, *25*, 155-197.

Andersen, H. R., Schmidt, I. M., Grandjean, P., Jensen, T. K., Budtz-Jørgensen, E., Kjærstad, M. B., ... & Main, K. M. (2008). Impaired reproductive development in sons of women occupationally exposed to pesticides during pregnancy. *Environmental health perspectives*, *116*(4), 566-572.

Arbuckle, T. E., Lin, Z., & Mery, L. S. (2001). An exploratory analysis of the effect of pesticide exposure on the risk of spontaneous abortion in an Ontario farm population. *Environmental health perspectives*, *109*(8), 851-857.

Aschengrau, A., Ozonoff, D., Coogan, P., Vezina, R., Heeren, T., & Zhang, Y. (1996). Cancer risk and residential proximity to cranberry cultivation in Massachusetts. *American journal of public health*, *86*(9), 1289-1296.

Abolhassani, M., Asadikaram, G., Paydar, P., Fallah, H., Aghaee-Afshar, M., Moazed, V., ... & Moradi, A. (2019). Organochlorine and organophosphorous pesticides may induce colorectal cancer; A case-control study. Ecotoxicology and environmental safety, 178, 168-177

Aschner, M., & Toews, A. D. (2010). Myelin and myelination. In Nervous System and Behavioral Toxicology (pp. 181-198). Elsevier Inc..)

Baldi I, Filleul L, Mohammed-Brahim B, Fabrigoule C, Dartigues J, et al. 2001. Neuropsychologic effects of long-term exposure to pesticides: results from the French Phytoner study. *Environ. Health Perspect. 109:839–44*

Barnett, J.B., Gandy, J., Wilbourn, D., Theus, S.A., 1992. Comparison of the immunotoxicity of propanil and its metabolite, 3,4-dichloroaniline, in C57Bl/6 mice. *Fundam. Appl. Toxicol. 18, 628–631.*

Bay, K., Asklund, C., Skakkebaek, N. E., & Andersson, A. M. (2006). Testicular dysgenesis syndrome: possible role of endocrine disrupters. *Best Practice & Research Clinical Endocrinology & Metabolism*, *20*(1), 77-90.

Bazylewicz-Walczak B, Majczakowa W, Szymczak M. 1999. Behavioral effects of occupational exposure to organophosphorus pesticides in female green-house planting workers. *Neurotoxicology 20:819–26*

Benedetti D, Nunes E, Sarmento M, Porto C, Dos Santos CE, Dias JF, daSilva J. (2013). Genetic damage in soybean workers exposed to pesticides: evaluation with the comet and buccal micronucleus cytome assays. Mutat Res 752:28-33.

Bernier, J., Rola-Pleszcynski, M., Flipo, D., Krzystyniak, K., and Fournier, M. 1990. ''Immunotoxicity of aminocarb: II. Evaluation of the effect of sublethal exposure to aminocarb on bone marrow cells by flow cytometry.'' Pestic. *Biochem. Physiol. 36:35–45.*

Bhardwaj, J. K., Mittal, M., Saraf, P., & Kumari, P. (2018). Pesticides induced oxidative stress and female infertility: a review. *Toxin Reviews*.

Bhargava, R. K., Singh, V., and Soni, V. 1977. Erythema multiforme resulting from insecticide spray. *Arch. Dermatol. 113:686*.

Blair A, Axelson O, Franklin C, et al: carcinogenic effect of pesticides. In Baker SR, Wilkinson CF (eds): The effect of pesticide on Human Health (Task Force of Environmental Cancer and Heart and Lung Disease-Workshop, may 1988) Princeton, NJ, Princeton Science publishing,1990, pp 201-260

Bolognesi, C. (2003). Genotoxicity of pesticides: a review of human biomonitoring studies. *Mutation Research/Reviews in Mutation Research*, *543*(3), 251-272.

Bortoli GM, Azevedo MB, Silva LB. (2009). Cytogenetic biomonitoring of Brazilian workers exposed to pesticides: micronucleus analysis in buccal epithelial cells of soybean growers. Mutat Res 675: 1-4.

Bouwman, H., & Schutte, C. H. (1993). Effect of sibship on DDT residue levels in human serum from a malaria endemic area in northern Kwazulu. *Bulletin of environmental contamination and toxicology*, *50*(2), 300-307.

Brophy, J. T., Keith, M. M., Watterson, A., Park, R., Gilbertson, M., Maticka-Tyndale, E., ... & Luginaah, I. (2012). Breast cancer risk in relation to occupations with exposure to carcinogens and endocrine disruptors: a Canadian case–control study. *Environmental Health*, *11*(1), 1-17.

Broughton, A., Thrasher, J. D., and Madison, R. 1990. Chronic health effects and immunological alterations associated with exposure to pesticide. Comments *Toxical. 4:59-71.*

Brown, L. M., Blair, A., Gibson, R., Everett, G. D., Cantor, K. P., Schuman, L. M., ... & Dick, F. (1990). Pesticide exposures and other agricultural risk factors for leukemia among men in Iowa and Minnesota. *Cancer research*, *50*(20), 6585-6591.

Buckley, J. D., Meadows, A. T., Kadin, M. E., Le Beau, M. M., Siegel, S., & Robison, L. L. (2000). Pesticide exposures in children with non-Hodgkin lymphoma. *Cancer: Interdisciplinary International Journal of the American Cancer Society*, *89*(11), 2315-2321.

Caliman, F. A., & Gavrilescu, M. (2009). Pharmaceuticals, personal care products and endocrine disrupting agents in the environment–a review. *CLEAN–Soil, Air, Water*, *37*(4-5), 277-303.

Cannon SB, Veazey JM Jr, Jackson RS, Burse VW, Hayes C, Straub WE, Landrigan PJ, Liddle JA(1978). Epidemic kepone poisoning in chemical workers. *Am J Epidemiol. 1978 Jun;107(6):529-37*

Carriger, J. F., Rand, G. M., Gardinali, P. R., Perry, W. B., Tompkins, M. S. & Fernandez, A. M. (2006). Pesticides of Potential Ecological Concern in Sediment from South Florida Canals: An Ecological Risk Prioritization for Aquatic Arthropods. *Soil and Sediment Contamination: An International Journal* 15(1), 21–45

Cataño, H. C., Carranza, E., Huamaní, C., & Hernández, A. F. (2008). Plasma cholinesterase levels and health symptoms in Peruvian farm workers exposed to organophosphate pesticides. *Archives of environmental contamination and toxicology*, *55*(1), 153-159.

Comhaire, F. H., Mahmoud, A. M., & Schoonjans, F. (2007). Sperm quality, birth rates and the environment in Flanders (Belgium). *Reproductive Toxicology*, *23*(2), 133-137.

Cooper, G.S., Martin, S.A., Longnecker, M.P., Sandler, D.P., Germolec, D.R., 2004. Association between plasma DDE levels and immunological measures in African-American farmers in North Carolina. *Environ. Health Perspect. 112, 1080–1084*.

Costa, L. G., Giordano, G., Guizzetti, M., & Vitalone, A. (2008). Neurotoxicity of pesticides: a brief review. *Front Biosci*, *13*(4), 1240-1249.

Crain, D. A., Janssen, S. J., Edwards, T. M., Heindel, J., Ho, S. M., Hunt, P., ... & Guillette Jr, L. J. (2008). Female reproductive disorders: the roles of endocrine-disrupting compounds and developmental timing. *Fertility and sterility*, *90*(4), 911-940.

Damgaard, I. N., Skakkebæk, N. E., Toppari, J., Virtanen, H. E., Shen, H., Schramm, K. W., ... & Nordic Cryptorchidism Study Group. (2006). Persistent pesticides in human breast milk and cryptorchidism. *Environmental Health Perspectives*, *114*(7), 1133-1138.

Daniell W, Barnhart S, Demers P, Costa LG, Eaton DL, Miller M, et al. 1992. Neuropsychological performance among agricultural pesticide applicators. *Environ. Res. 59:217–28*

Das, P. P., Shaik, A. P., & Jamil, K. (2007). Genotoxicity induced by pesticide mixtures: in-vitro studies on human peripheral blood lymphocytes. *Toxicology and industrial health*, *23*(8), 449-458.

Dean, T.N., Kakkanaiah, V.N., Nagarkatti, M., and Nagarkatti, P.S. 1990. ‘‘Immunosuppression by aldicarb of T cell responses to antigen-specific and polyclonal stimuli results from defective IL-1 production by the macrophages.’’ *Toxicol. Appl. Pharmacol. 106:408–417.*

Descotes, l. 1988. Immunotoxicity of pesticides. In Immunotoxicology of drugs and chemicals, *pp. 33 7-363. Amsterdam: Elsevier*

Diamanti-Kandarakis, E., Bourguignon, J. P., Giudice, L. C., Hauser, R., Prins, G. S., Soto, A. M., ... & Gore, A. C. (2009). Endocrine-disrupting chemicals: an Endocrine Society scientific statement. *Endocrine reviews*, *30*(4), 293-342.

Dosemeci M, Alavanja MCR, Rowland AS, Mage D, Zahm SH, et al. (2002). A quantitative approach for estimating exposure to pesticides in the Agricultural Health Study. Ann. Occup. Hyg. 46:245– 60

Eastmond, D. A., & Balakrishnan, S. (2010). Genotoxicity of pesticides. In *Hayes' handbook of pesticide toxicology* (pp. 357-380). Academic Press.

Elbetieha, A., Da'as, S., Khamas, W. et al. Evaluation of the Toxic Potentials of Cypermethrin Pesticide on Some Reproductive and Fertility Parameters in the Male Rats. Arch. Environ. Contam. Toxicol. 41, 522–528 (2001)

Esa, A. H., Warr, G. A., and Newcombe, D. S. 1988. Immunotoxicity of organophosphorus compounds. Modulation of cell- mediated immune responses by inhibition of monocyte accessory functions. *Clin. Immunol. Immunopathol. 49:41-5 2.*

Farahat T, Abdelrasoul GM, Amr MM, Shebl MM, Farahat FM, Anger WK. 2003. Neurobehavioral effects among workers occupationally exposed to organophosphorus pesticides.Occup. *Environ. Med. 60:279–86*

Fiore, M.C., Anderson, H. A., Hong, R., Golubjatnikov, R., Seiser). E., Nordstrom, D., Hanrahan, L., and Belluck, D. 1986. Chronic exposure to aldicarb-contaminated groundwater and human immune function. *Environ. Res. 41:633- 645*

Frazier, L. M. 2007. Reproductive Disorders Associated with Pesticide Exposure. J. Agromedicine 12(1), 27-37

Garry, V. F., Schreinemachers, D., Harkins, M. E. and Griffith, J. 1996. Pesticide appliers, biocides, and birth defects in rural Minnesota. Environ Health Perspect 104(4), 394-399

Gaspari, L., Paris, F., Jeandel, C., & Sultan, C. (2011). Peripheral precocious puberty in a 4-month-old girl: role of pesticides? *Gynecological Endocrinology*, *27*(9), 721-724.

Gentile N, Mañas F, Bosch B, Peralta L, Gorla N, Aiassa D. (2012). Micronucleus assay as a biomarker of genotoxicity in the occupational exposure to agrochemicals in rural workers. Bull Environ Contam Toxicol 88:816-22.

Gomes J, Lloyd OL, Revitt DM. 1999. The influence of personal protection, environmental hygiene and exposure to pesticides on the health of immigrant farm workers in a desert country. *Int. Arch. Occup. Environ. Health*

Goodman, J. E., Loftus, C. T., & Zu, K. (2015). 2, 4-Dichlorophenoxyacetic acid and non-Hodgkin's lymphoma, gastric cancer, and prostate cancer: meta-analyses of the published literature. Annals of epidemiology, 25(8), 626-636.

Gore, A. C. (2007). Introduction to endocrine-disrupting chemicals. In *Endocrine-Disrupting Chemicals* (pp. 3-8). Humana Press.

Gore, A. C., Crews, D., Doan, L. L., La Merrill, M., Patisaul, H., & Zota, A. (2014). Introduction to endocrine disrupting chemicals (EDCs). *A guide for public interest organizations and policy-makers*, 21-22.

Gore, Andrea C., et al. "Introduction to endocrine disrupting chemicals (EDCs)." *A guide for public interest organizations and policy-makers* (2014): 21-22.

Guillette, E. A., Conard, C., Lares, F., Aguilar, M. G., McLachlan, J., & Guillette Jr, L. J. (2006). Altered breast development in young girls from an agricultural environment. *Environmental Health Perspectives*, *114*(3), 471-475.

H. Caksen, D. Odabas, S. Arslan, C. Akgun, B. Atas, S. Akbayram and O. Tuncer (2003): Report of eight children with amitraz intoxication. *Hum. Exp. Toxicol. 22, 95-97*

Hermanowicz, A., Nawarska, Z., Borys, D., and Maslankiewicz, A. 1982. The neutrophil function and infectious diseases in workers occupationally exposed to organochlorine insecticides. Int. Arch. *Occup. Environ. Health 50:329-340*

Hoar, S. K., Blair, A., Holmes, F. F., Boysen, C. D., Robel, R. J., Hoover, R., & Fraumeni, J. F. (1986). Agricultural herbicide use and risk of lymphoma and soft-tissue sarcoma. *Jama*, *256*(9), 1141-1147.

Holly, E. A., Aston, D. A., Ahn, D. K., & Kristiansen, J. J. (1992). Ewing's bone sarcoma, paternal occupational exposure, and other factors. *American Journal of Epidemiology*, *135*(2), 122-129.

Hoogenraad T. 1988. Dithiocarbamates and Parkinson’s disease [letter]. Lancet 1:767

Hooghe, R.J., Devos, S., Hooghe-Peters, E.L., 2000. Effects of selected herbicides on cytokine production in vitro. *Life Sci. 66, 2519–2525*

Hoshi, N., Hirano, T., Omotehara, T., Tokumoto, J., Umemura, Y., Mantani, Y., ... & Kitagawa, H. (2014). Insight into the mechanism of reproductive dysfunction caused by neonicotinoid pesticides. *Biological and Pharmaceutical Bulletin*, *37*(9), 1439-1443.

International Agency for Research on cancer: International Agency for Research on cancer Monograph on the Evaluation of Carcinogenic Risk to Human. Vol 53. Occupational Exposures in Insecticide Application and Some Pesticides. Lyon, France, IARC,1991

International Code of Conduct on Pesticide Management Guidelines on Highly Hazardous Pesticides

Janesick, A., & Blumberg, B. (2011). Endocrine disrupting chemicals and the developmental programming of adipogenesis and obesity. *Birth Defects Research Part C: Embryo Today: Reviews*, *93*(1), 34-50.

Jonnalagadda, P. R., Jahan, P., Venkatasubramanian, S., Khan, I. A., Prasad, A. Y. E., Reddy, K. A., ... & Hasan, Q. (2012). Genotoxicity in agricultural farmers from Guntur district of South India—A case study. *Human & experimental toxicology*, *31*(7), 741-747.

Kashiap, S.K., 1986. Health surveillance and biological monitoring of pesticide formulation in India. *Toxicol. Lett. 33, 1*

Kaufman, R. H., Adam, E., Hatch, E. E., Noller, K., Herbst, A. L., Palmer, J. R., & Hoover, R. N. (2000). Continued follow-up of pregnancy outcomes in diethylstilbestrol-exposed offspring. *Obstetrics & Gynecology*, *96*(4), 483-489.

Keifer, M. C., & Firestone, J. (2007). Neurotoxicity of pesticides. *Journal of agromedicine*, *12*(1), 17-25.

Khayat CB, Costa EO, Gonçalves MW, da Cruz e Cunha DM, da Cruz AS, de AraújoMelo CO, Bastos RP, da Cruz AD, de Melo e Silva D. (2013). Assessment of DNA damage in Brazilian workers occupationally exposed to pesticides: a study from Central Brazil. Environ Sci Pollut Res Int 20:7334-40.

Kim KS, Lee YM, Lee HW, Jacobs DR Jr, Lee DH (2015) Associations between organochlorine pesticides and cognition in U.S. elders: national health and nutrition examination survey 1999–2002. *Environ Int 75:87-92*

Kristensen, P., Andersen, A., Irgens, L. M., Bye, A. S., & Sundheim, L. (1996). Cancer in offspring of parents engaged in agricultural activities in Norway: incidence and risk factors in the farm environment. *International Journal of Cancer*, *65*(1), 39-50.

Lafuente A, Pereiro N (2013) Neurotoxic effects induced by endosulfan exposure during pregnancy and lactation in female and male rat striatum. Toxicology 311:35–40.

Lakroun Z, Kebieche M, Lahouel A, Zama D, Desor F, Soulimani R (2015) Oxidative stress and brain mitochondria swelling induced by endosulfan and protective role of quercetin in rat. *Environ Sci Pollut Res Int 22:7776–7781.*

Langston JW. 1996. The etiology of Parkinson's disease with emphasis on the MPTP story. *Neurology 47: S153–60*

Lee, T. P., Moscati, R., and Park, B. H. 197 9. Effects of pesticides on human leukocyte functions. *Res. Commun. Chern. Pathol. Pharmaco/. 23:597- 609*

Lobdell, B. J., & Johnston, C. D. (1966). Methyl-parathion—three generation reproduction study in the rat. *Herndon, Va, Woodard Research Corp*, 1-64.

McDowell I, Hill G, Lindsay J, Helliwell B, Costa L, et al. 1994. The Canadian study of health and aging: risk factors for Alzheimer's disease in Canada. *Neurology 44:2073–80*

Miller D. B. (1982). Neurotoxicity of the pesticidal carbamates. *Neurobehavioral toxicology and teratology, 4(6), 779–787.*

Mittal, S., Kaur, G., & Vishwakarma, G. S. (2014). Effects of environmental pesticides on the health of rural communities in the Malwa Region of Punjab, India: a review. *Human and Ecological Risk Assessment: An International Journal*, *20*(2), 366-387.

Mittal, S., Kaur, G., & Vishwakarma, G. S. (2014). Effects of environmental pesticides on the health of rural communities in the Malwa Region of Punjab, India: a review. *Human and Ecological Risk Assessment: An International Journal*, *20*(2), 366-387.

Mnif, W., Hassine, A. I. H., Bouaziz, A., Bartegi, A., Thomas, O., & Roig, B. (2011). Effect of endocrine disruptor pesticides: a review. *International journal of environmental research and public health*, *8*(6), 2265-2303.

Morgan JP, Penovich P (1978) Jamaica ginger paralysis. Fortyseven-year follow-up. Arch Neurol 35:530–532

Newcombe, D. S., and Esa, A. H. 1992. Immunotoxicity of organophosphorus compounds. In Clinical immunotoxicology, eds. D. S. New combe, N. R. Rose, and J. C. Bloom, *pp. 349- 363. New York: Raven Press*

Orphanides, G., Reinberg, D., 2002. A unified theory of gene expression. Cell 108, 439-451. Perez-Maldonado, I.N., Athanasiadou, M., Yanez, L., Gonzalez-Amaro, R., Bergman, A., DiazBarriga, F., 2006. DDE-induced apoptosis in children exposed to the DDT metabolite. Sci. Total Environ. 370, 343-351

Palma, P., Palma, V. L., Matos, C., Fernandes, R. M., Bohn, A., Soares, A. M. V. M., & Barbosa, I. R. (2009). Effects of atrazine and endosulfan sulphate on the ecdysteroid system of Daphnia magna. *Chemosphere*, *74*(5), 676-681.

PAN International List of Highly Hazardous Pesticides (PAN List of HHPs) March 2021

Paule, M. G., Green, L., Myerson, J., Alvarado, M., Bachevalier, J., Schneider, J. S., & Schantz, S. L. (2012). Behavioral toxicology of cognition: extrapolation from experimental animal models to humans: behavioral toxicology symposium overview. *Neurotoxicology and teratology*, *34*(2), 263-273.

Perumalla Venkata, R., Rahman, M. F., Mahboob, M., Indu Kumari, S., Chinde, S., Dumala, N., & Grover, P. (2017). Assessment of genotoxicity in female agricultural workers exposed to pesticides. *Biomarkers*, *22*(5), 446-454.

Petrelli, G., Figà-Talamanca, I., Lauria, L., & Mantovani, A. (2003). Spontaneous abortion in spouses of greenhouse workers exposed to pesticides. *Environmental health and preventive medicine*, *8*(3), 77-81.

Phillips, T.M., 2000. Assessing environmental exposure in children: immunotoxicology screening. *J. Expo. Anal. Environ. Epidemiol. 1*

Rani, U., & Reddy, P. P. (1986). Cytogenetic effects of aldrin and endosulfan in mice. *IRCS Medical Science. Cell and Molecular Biology*, *14*(11), 1125-1126.

Rao, R. P., & Kaliwal, B. B. (2002). Monocrotophos induced dysfunction in estrous cycle and follicular development in mice. *Industrial Health*, *40*(3), 237-244.

Remor, A. P., Totti, C. C., Moreira, D. A., Dutra, G. P., Heuser, V. D., & Boeira, J. M. (2009). Occupational exposure of farm workers to pesticides: biochemical parameters and evaluation of genotoxicity. *Environment International*, *35*(2), 273-278.

Richardson, J. R., Fitsanakis, V., Westerink, R. H., & Kanthasamy, A. G. (2019). Neurotoxicity of pesticides. *Acta neuropathologica*, *138*(3), 343-362.

Rupa, D. S., Reddy, P. P., & Reddi, O. S. (1991). Reproductive performance in the population exposed to pesticides in cotton fields in India. *Environmental Research*, *55*(2), 123-128.

Sailaja, N., Chandrasekhar, M., Rekhadevi, P. V., Mahboob, M., Rahman, M. F., Vuyyuri, S. B., ... & Grover, P. (2006). Genotoxic evaluation of workers employed in pesticide production. *Mutation Research/Genetic Toxicology and Environmental Mutagenesis*, *609*(1), 74-80.

Sanborn, M., Kerr, K. J., Sanin, L. H., Cole, D. C., Bassil, K. L., & Vakil, C. (2007). Non-cancer health effects of pesticides: systematic review and implications for family doctors. *Canadian family physician*, *53*(10), 1712-1720.

Schaalan, M.F., Abdelraouf, S.M., Mohamed, W.A., Hassanein, F.S., 2012. Correlation between maternal milk and infant serum levels of chlorinated pesticides (CP) and the impact of elevated CP on bleeding tendency and immune status in some infants in Egypt. *J. Immunotoxicol. 9, 15–24*

Schrager, S., & Potter, B. (2004). Diethylstilbestrol exposure. *American family physician*, *69*(10), 2395-2400.

Sengupta, P., & Banerjee, R. (2014). Environmental toxins: Alarming impacts of pesticides on male fertility. *Human & experimental toxicology*, *33*(10), 1017-1039.

Senthilselvan, A., McDuffie, H. H., and Dosman, J. A. 1992. Association of asthma with the use of pesticides. *Am. Rev. Respir. Dis. 146:884- 887*

Shu, X. O., Gao, Y. T., Tu, J. T., Zheng, W., Brinton, L. A., Linet, M. S., & Fraumeni Jr, J. F. (1988). A population-based case-control study of childhood leukemia in Shanghai. *Cancer*, *62*(3), 635-644.

Shutoh, Y., Takeda, M., Ohtsuka, R., Haishima, A., Yamaguchi, S., Fujie, H., Komatsu, Y., Maita, K., Harada, T., 2009. Low dose effects of dichlorodiphenyltrichloroethane (DDT) on gene transcription and DNA methylation in the hypothalamus of young male rats: implication of hormesis-like effects. J Toxicol Sci 34, 469-482.

Singh, S., Kumar, V., Thakur, S., Banerjee, B. D., Chandna, S., Rautela, R. S., ... & Rai, A. (2011). DNA damage and cholinesterase activity in occupational workers exposed to pesticides. *Environmental toxicology and pharmacology*, *31*(2), 278-285.

Singh, S., Kumar, V., Thakur, S., Banerjee, B. D., Chandna, S., Rautela, R. S., ... & Rai, A. (2011). DNA damage and cholinesterase activity in occupational workers exposed to pesticides. *Environmental toxicology and pharmacology*, *31*(2), 278-285.

Soderlund, D. M., Clark, J. M., Sheets, L. P., Mullin, L. S., Piccirillo, V. J., Sargent, D., ... & Weiner, M. L. (2002). Mechanisms of pyrethroid neurotoxicity: implications for cumulative risk assessment. Toxicology, 171(1), 3-59.

Sommer, S. S., Cunningham, J., McGovern, R. M., Saitoh, S., Schroeder, J. J., Wold, L. E., & Kovach, J. S. (1992). Pattern of p53 gene mutations in breast cancers of women of the midwestern United States. *JNCI: Journal of the National Cancer Institute*, *84*(4), 246-252.

Song, C., Kanthasamy, A., Anantharam, V., Sun, F., Kanthasamy, A.G., 2010. Environmental neurotoxic pesticide increases histone acetylation to promote apoptosis in dopaminergic neuronal cells: relevance to epigenetic mechanisms of neurodegeneration. Mol. Pharmacol. 77, 621-632.

Suntres, Z.E. and Shek, P.N. 1995. ‘‘Intratracheally administered liposomal alpha-tocopherol protects the lung against long-term toxic effects of paraquat.*’’ Biomed. Environ. Sci. 8:289–300.*

The WHO Recommended Classification of Pesticides by Hazard and Guidelines to Classification 2019

Thrasher, J. D., Madison, R., and Broughton, A. 1993. Immunologic abnormalities in humans exposed to chlorpyrifos: preliminary observations. *Arch. Environ. Health 48:89-93*

Toppari, J., Larsen, J. C., Christiansen, P., Giwercman, A., Grandjean, P., Guillette Jr, L. J., & Skakkebæk, N. E. (1996). Male reproductive health and environmental xenoestrogens. *Environmental health perspectives*, *104* (suppl 4), 741-803.

Van Bao, T., Szabó, I., Ruzicska, P., & Czeizel, A. (1974). Chromosome aberrations in patients suffering acute organic phosphate insecticide intoxication. *Humangenetik*, *24*(1), 33-57.

Van Wendel de Joode B, Wesseling C, Kromhout H, Monge P, et al. 2001. Chronic nervous-system effects of long-term occupational exposure to DDT. *Lancet 357:1014–16*

Vial, T., Nicolas, B., Descotes, J., 1996. Clinical immunotoxicity of pesticides. *J. Toxicol. Environ. Health 48, 215–229*

Vom Saal FS (1989). Sexual differentiation in litter-bearing mammals: influence of sex of adjacent fetuses in utero. *J Anim Sci 67:1824-1840.*

Vom Saal FS, Timms BF, Montano MM, Palanza P, Thayer KA, Nagel SC, Dhar MD, Ganjam VK, Parmigiani S, Welshons WV (1997). Prostate enlargement in mice due to fetal exposure to low doses of estradiol or diethylstilbestrol and opposite effects at high doses. *Proc NatI Acad Sci USA 94:2056-2061.*

Waters, M. D., Sandhu, S. S., Simmon, V. F., Mortelmans, K. E., Mitchell, A. D., Jorgenson, T. A., ... & Garrett, N. E. (1982). Study of pesticide genotoxicity. In *Genetic toxicology* (pp. 275-326). Springer, Boston, MA.

Watts, M. (2007). Pesticides and breast cancer: a wake-up call.

Whorton, D., Krauss, R., Marshall, S., & Milby, T. (1977). Infertility in male pesticide workers. *The Lancet*, *310*(8051), 1259-1261.).)..

Yang, K. J., Lee, J., & Park, H. L. (2020). Organophosphate pesticide exposure and breast cancer risk: a rapid review of human, animal, and cell-based studies. International journal of environmental research and public health, 17(14), 5030.

Zhang, Y., Zhao, M., Jin, M., Xu, C., Wang, C., Liu, W., 2010. Immunotoxicity of pyrethroid metabolites in an in vitro model. *Environ. Toxicol. Chem. 29, 2505–2510*

Zhao, W., Schafer, R., Cuff, C.F., Gandy, J., and Barnett, J.B. 1995. ‘‘Changes in primary and secondary lymphoid organ T-cell subpopulations resulting from acute exposure to propanil.’’ *J. Toxicol. Environ. Health 46:171–181*

ANNEXURE 1

Pesticides with acute toxicity, suspected endocrine activity and choline esterase inhibition

WHO 1a	WHO 1b	H330	Choline esterase inhibitor	Endocrine activity suspected
Brodifacoum	Abamectin	Abamectin	Acephate	Abamectin
Bromadiolone	Beta Cyfluthrin	Aluminium Phosphide	Bendiocarb	Acephate
Flocoumafen	Carbofuran	Beta Cyfluthrin	Benfuracarb	Bifenthrin
	Coumatetralyl	Brodifacoum	Carbofuran	Carbendazim
	Cyfluthrin	Bromadiolone	Carbosulfan	Carbofuran
	Edifenphos	Carbofuran	Chlorpyriphos	Chlorpyriphos
	Methomyl	Carbosulfan	Dimethoate	Cypermethrin
	Monocrotophos	Chlorothalonil	Edifenphos	Dichloro Diphenyl Trichloroethane (DDT)
	Oxydemeton-Methyl	Copper Hydroxide	Ethion	Dicofol
	Propetamphos	Coumatetralyl	Fenitrothion	Dimethoate
	Zinc phosphide	Cyfluthrin	Malathion	Diuron
		Dodine	Methomyl	Epoxyconazole
		Ethion	Monocrotophos	Ethofenprox (Etofenprox)
		Fenpropathrin	Oxydemeton-Methyl	Fenitrothion
		Fenpyroximate	Profenophos	Fenvalerate
		Flocoumafen (FI-WRT)	Propetamphos	Fipronil
		Fluvalinate	Propoxur	Iprodione
		Lambdacyhalothrin	Quinalphos	Malathion
		Magnesium Phosphide	Temephos	Mancozeb
		Monocrotophos	Thiodicarb	Methomyl
		Paraquat dichloride	Triallate	Methyl Bromide
		Tebuconazole		Metiram
		Ziram		Metribuzin
				Oxydemeton-Methyl
				Paraquat dichloride
				Pendimethalin
				Permethrin
				Phenthoate
				Propiconazole
				Quinalphos
				Tebuconazole
				Trifluralin
				Ziram

(Source: Pesticideinfo.org and PAN HHP list,2021)

ANNEXURE 2

Drift prone characteristics of pesticides

Low Drift prone	Moderate Drift prone	Very low Drift prone	High Drift prone
Bifenthrin Carbofuran Chlorfenopyr Chlorpyriphos Methyl Cyfluthrin Deltamethrin (Decamethrin) Dicofol Dinocap Diuron Emamectin Benzoate Fenpyroximate Glufosinate Ammonium Glyphosate Imidacloprid Iprodione Kresoxim Methyl Metribuzin Oxadiazon Oxyfluorfen Paraquat dichloride Profenophos Propetamphos Propiconazole Pymetrozin (FI), TIM Tebuconazole Temephos Thiophanate methyl Propargite	Acephate Bendiocarb Chlorothalonil Chlorpropham (TI),TIM Chlorpyriphos Diclofop-methyl Dimethoate Ethion Fenpropathrin Flumioxazin Malathion Methomyl Monocrotophos Oxydemeton-Methyl Pendimethalin Phenthoate Propoxur Pyrethrin (pyrethrum) Pyridaben (FI- WRT) Thiodicarb Triflumizole (FI-WRT)	Abamectin Carbendazim Chlorantraniliprole Clothianidin (FI-WRT) Copper Hydroxide Cypermethrin Fenvalerate Fipronil Flufenoxuron Forchlorfenuron Hexythiazox Iprovalicarb Spinetoram Spinosad Thiacloprid Zinc Phosphide Ziram Thiomethoxam	Dodine Triallate Trifluralin

(Source: pesticideinfo.org)

ANNEXURE 3: Various health effects on humans

EPA probable or likely cancer causing	**GHS mutation**	**GHS C2 & R2(carcinogenic and reproductive toxicant)**
Butachlor	Carbendazim	2,4 D
Captan	**GHS reproduction**	Bifenthrin
Chlorothalonil	Brodifacoum	Captan
Dichloro Diphenyl Trichloroethane (DDT)	Bromadiolone	Chlorpropham (TI), TIM
Diclofop-methyl	Carbendazim	Dichloro Diphenyl
Diuron	Chlorpyriphos	Trichloroethane (DDT)
Epoxyconazole	Chlorpyriphos Methyl	Epoxyconazole
Fluthiacet methyl	Coumatetralyl	Fenitrothion
Hexythiazox	Cyproconanzole	Forchlorfenuron
Iprodione	Deltamethrin (Decamethrin)	Mancozeb
Iprovalicarb	Dinocap	Metiram
Kresoxim Methyl	Epoxyconazole	Metribuzin
Mancozeb	Flocoumafen (FI-WRT)	Quinalphos
Metiram	Flumioxazin	Quizalofop P-tefuryl
Oxadiazon	Fluazifop p butyl	Tebuconazole
Oxyfluorfen	Flusilazole	Tetraconazole (FI)
Permethrin	Glufosinate Ammonium	Trifluralin
Propineb	Meptyl diinocap	
Propoxur	Mancozeb	
Pymetrozin (FI), TIM	Propiconazole	**IARC prob cancer**
Thiacloprid	Thiacloprid	Dichloro Diphenyl
Thiodicarb	Triflumizole (FI-WRT)	Trichloroethane (DDT)
Thiophanate methyl		Glyphosate
Propargite		Malathion
	EU EDC	
	Mancozeb	
	Meptyl diinocap	

(Source: PAN HHP list, 2021)

ANNEXURE 4

Environmental effects of pesticides

Very bioaccumulative	**Highly toxic to bees**	Montreal protocol
Chlorfluazuron	Abamectin	Methyl Bromide
Flufenoxuron	Acephate	
Lufenuron	Aluminium Phosphide	
Metaflumizone	Bendiocarb	
Pendimethalin	Benfuracarb	
Pyridalyl	Beta Cyfluthrin	
Tolfenpyrad (TIM)	Bifenthrin	
Trifluralin	Carbofuran	
propargate	Carbosulfan	
Very persistent in soil, water, sediment	Chlorfenopyr	**PIC**
Amisulbrom (FI-WRT)	Chlorpyriphos	Carbofuran
Chlorantraniliprole	Chlorpyriphos Methyl	Carbosulfan
Copper Hydroxide	Clothianidin (FI-WRT)	Dichloro Diphenyl Trichloroethane (DDT)
Dichloro Diphenyl Trichloroethane (DDT)	cyfluthrin	Monocrotophos
Emamectin Benzoate	Cypermethrin	Paraquat dichloride
Ethofenprox (Etofenprox)	Deltamethrin (Decamethrin)	**POP**
Flubendiamide	Diafenthiuron	Dichloro Diphenyl Trichloroethane (DDT)
Lufenuron	Dimethoate	Dicofol
Metaflumizone	Dinotefuron	
Pendimethalin	Emamectin Benzoate	
pyridalyl	Ethofenprox (Etofenprox)	
Triallate	Fenazaquin	
Very toxic to aquatic organism	Fenitrothion	
Amisulbrom (FI-WRT)	Fenpropathrin	
Chlorantraniliprole	Fenvalerate	
Chlorfluazuron	Fipronil	
Copper Hydroxide	Flupyradifurone	
Dichloro Diphenyl Trichloroethane (DDT)	Indoxacarb	
Emamectin Benzoate	Imidacloprid	
Ethofenprox (Etofenprox)	Imiprothrin	
Flubendiamide	Lambdacyhalothrin	
Flufenoxuron	Malathion	
Lufenuron	Metaflumizone	
Profenofos	Methabenzthiazuron	
Pyridalyl	Methomyl	
Tolfenpyrad	Milbemectin	
Triallate	Monocrotophos	
Propargate	Oxydemeton-Methyl	
	Permethrin	
	Phenthoate	
	Prallethrin	
	Propoxur	
	Pyrethrin	
	Pyridaben (FI- WRT)	
	Quinalphos	
	Spinetoram	
	Spinosad	
	Sulfoxaflor	
	Temephos	
	Thiodicarb	
	Validamycin	
	Thiomethoxam	

(Source: PAN HHP list, 2021)

ANNEXURE 5: WHO Hazardous classificationof pesticides, 2019

class 1 a brodifacoum bromadiolone flocoumafen **class 1b Highly Hazardous** Abamectin Beta Cyfluthrin Carbofuran Coumatetralyl cyfluthrin Edifenphos Methomyl Monocrotophos Oxydemeton-Methyl Propetamphos Zinc Phosphide **Class 2 Moderately Hazardous** 2,4-Dichlorophenoxy Acetic Acid Acephate Bendiocarb Benfuracarb Bifenthrin Carbosulfan Chlorfenopyr Chlorpyriphos Clothianidin (FI-WRT) Copper Hydroxide Cypermethrin Cyproconanzole Deltamethrin (Decamethrin)	DDT Dicofol Dimethoate Dinocap Dodine Emamectin Benzoate Ethion Fenazaquin Fenitrothion Fenpropathrin Fenpyroximate Fenvalerate Fipronil Flupyradifurone Flusilazole Fluvalinate Glufosinate Ammonium Imidacloprid Imiprothrin Indoxacarb Lambdacyhalothrin Metribuzin Paraquat dichloride Pendimethalin Permethrin Phenthoate Prallethrin Profenophos Propiconazole Propoxur Pyrethrin (pyrethrum) Pyridaben (FI-WRT)	Quinalphos Quizalofop P-tefuryl Sulfoxaflor Tebuconazole Tetraconazole (FI) Thiacloprid Thiodicarb Thiomethoxam Triflumizole ziram **Class 3 slightly Hazardous** Butachlor Chlorpyriphos Methyl Diafenthiuron Dinotefuron Diuron Flubendiamide Flufenoxuron Flumioxazin Fluazifop p butyl Glyphosate Iprodione Kresoxim Methyl Lufenuron Malathion Meptyl diinocap Methabenzthiazuron Pymetrozin (FI), TIM Spinosad Temephos Triallate propargate	**Class U unlikely to present acute Hazard** Amisulbrom (FI-WRT) Captan Carbendazim Chlorantraniliprole Chlorfluazuron Chlorothalonil Chlorpropham (TI),TIM Ethofenprox (Etofenprox) Hexythiazox Iprovalicarb Mancozeb Metaflumizone Metiram Oxadiazon Oxyfluorfen Propineb Spinetoram Thiophanate methyl Trifluralin Validamycin

(Source: WHO Hazardous Classification of Pesticides, 2019)

ANNEXURE 6

Recommended pesticides (HHPs) in Kerala

Serial no	pesticides	crops	Pests of crops	Recommended dosage in pests
1	Butachlor	Rice	Weed	25 kg
2	Petrilachlor	rice	Weed	1-1.5 kg
3	oxyflurofen	Rice	Weed	0.6kg
4	pendimethalin	Rice	Weed	3.3-5.0 kg
5	2,4-D	weed	Weed	1.4-1.7 kg
6	Acephate	Rice	Rice leaf folder Brown plant hopper	800 g of 75 sp per ha
7	carbosulfan	Rice	Rice stem borer Gall midge and leaf folder	17 kg of 6 G per ha
8	Chlorpyrifos	Rice	Gall midge	0.2% and 0.02% suspension
9	Dimethoate	Rice vegetables	rice nematode thrips	0.2% and 0.05% suspension
10	Ethofenprox	Rice		750 ml/ha
11	Flubendiamide	Rice	Rice stem borer whorl maggot leaf folder	125 g of 20 WDG per ha
12	Imidacloprid	Rice	Brown plant hopper	150 ml of 200 SL per ha
13	Indoxacarb	Rice	Rice stem borer whorl maggot leaf folder blue beetle	200 ml of 15.8 EC per ha
14	Malathion	Rice vegetables	Rice stem borer whorl maggot rice bug	1000 ml of 50 EC/ AF per ha
15	Mancozeb	Rice		2 kg/ha
16	Propineb	Rice		1.25/kg
17	Quinalphos	Rice vegetables	rice pests cardamom thrips	1000 ml of 25 EC / AF per ha
18	Spinosad	Rice	Rice stem borer whorl maggot leaf folder	100 ml of 45 SC per ha
19	Thiamethoxam	Rice vegetables	Brown plant hopper	100 g of 25 WG per ha
20	Chlorantraniliprole	Rice	Rice stem borer leaf folder whorl maggot	10 kg/ha
21	Fipronil	Rice	Rice gall midge	19 kg/ha
22	Propiconazole	Rice		500 ml/ha
23	Tebuconazole	Rice		750 ml ha-1
24	Fluzilazole	Rice		250 ml ha-1
25	Validamycin	Rice		1000 ml-1 500 l-1 ha-1
26	Paraquat	Weeds		500-600 L/ha
27	Glyphosate	Weeds		400 L/ha
28	Fenyroximate	Vegetables		Chilli mites thrips

29	Thiodicarb	Vegetables	Cucurbits Epilachna beetle	1000g/kg
30	Lambda cyalothrin	Tea	tea mosquito bug	0.009 ml/L
31	Diafenthiuron	Vegetables	Brinjal sucking pests whiteflies jassids mites	600ml/l
32	Emamectin Benzoate	Vegetables	Brinjal fruit shoot borer	200ml/l
33	Copper hydroxide	Leaf		1000-1500g/kg
34	Dinocap	Leaf		1000 ml
35	Captan	seed		1125-1500g
36	Thiophanate	Leaf		500g
37	Propiconazole	Flower of vegetables		25 EC 500 ml
38	Diuron	Fruits	Weeds	1.25-2 kg
39	Glufosinate ammonium	Weed		2.5-3.3 l
40	Carbendazim	Rice		50 WP 500g/ha
41	Tebuconazole	Rice		250 EC 750 ml
42	Propineb	Rice		1250g
43	Oxyflurofem	Rice		0.65 g

(Source: Package of Practice recommendation of crops, 2016)

ANNEXURE 7

Recommended pesticides (HHPs) in Tamil Nadu

Serial no	Pesticides	Crops	Pests of crops	Recommended dosage in pests
1	Dicofol	Rice	Mite	18.5% EC 1250 ml
2	Thiamethoxam	Rice Oil seed	Stem borer Leaf folder Gall midge Thrips Green leafhopper Termites	25% WG 100 g 75 SG@125 g/ha
3	Carbofuran	Rice Maize Oil seeds	Stem borer Spiny beetle Green leafhopper Shoot fly Thrips White grubs	3% CG 25 Kg 3CG 33.3 kg
4	Carbosulfan		Stem borer Leaf folder Brown planthopper White backed planthopper Green leaf hopper	6% G 16.7 kg 25% EC 800-1000 ml
5	chlorpyriphos	Rice Pulses	Stem borer Leaf folder Gall midge Spiny beetles Brown planthopper Grasshopper Pod fly Tobacco cutworm	20% EC 1250 ml 1.5% DP 25 kg/ha 20% EC 1250 ml
6	Acephate	Rice cotton	Stem borer Leaf folder American bollworm	75 % SP 670-1000 g 75% SP 780g/ha
7	Chlorantraniliprole	Rice pulses Maize sugarcane	Stem borer Leaf folder Brown planthopper White backed planthopper Pod fly Tobacco cut worm Blue butterflies Gram caterpillar Fall armyworm Early shoot borer Root borer	18.5% SC 150 ml 18.5 SC 4 ml/10 l 0.4% G @ 18.75 g
8	Fipronil	Rice	Stem borer Leaf folder Gall midge Whorl maggot Brown planthopper	80%WG 50- 62.5 kg

		Cotton sugarcane	White backed planthopper Green leaf hopper American ballworm Early shoot borer	5% SC 2000ml/ha 0.3% GR @ 25 kg
9	Flubendiamide	Rice Maize pulses	Stem borer Leaf folder Fall armyworm Pod fly Tobacco cutworm Blue butter flies	20% WG 125 g 480 SC 4 ml/10 l 39.35 % SC 100ml / ha
10	Thiacloprid		Stem borer	21.7% SC 500 g
111	Quinalphos	Rice Pulses Oilseeds	Gall midge Pod fly Gram caterpillar Red hairy caterpillar	5% G 5 kg 1.5%DP 23kg/ha 1.5 DP 25 kg/ha
121	Malathion	Rice Cumbu coconut	Spiny beetles Ear midge Black-headed caterpillar	5% DP 25 kg 5 D 25 kg/ha 50 EC 0.05%
13	Imidacloprid	Rice Cumbu Oil seeds	Brown planthopper White-backed planthopper Green leafhopper Shoot fly Leaf hopper	70% WG 30-35 kg 70 WS 10 g/kg of seeds 17.8 SL 100 ml
14	Phenthoate		Case worm	50% EC 1000 ml
15	Monocrotophos	Maize pulses	Shoot fly Pod fly Spotted pod borer	36SL 625 ml
16	Thiodicarb	Maize pulses	Fall armyworm Pod fly Blue butterflies Spotted pod borer Gram caterpiller	75 WP 20 g/10 l 75 WP 625g / ha
17	Emamectin benzoate	Maize Pulses cotton	Fall armyworm Pod fly American ballworm	5 SG 4g/10 l 5% SG 220 g/ha 5% SG 190-220g/ha
18	Spinetoram	Maize cotton	Fall armyworm Spotted ballworm	12 SC 5 ml/10 l 11.7 % SC @420-470 ml/ha
19	Dimethoate	Pulses coconut	Aphids Pod fly Pod bugs mealybugs	30 EC 500 ml/ha 30 EC 1 ml/lit
20	benfuracarb	pulses	Pod fly Gram caterpiller	40% EC 2.5l/ha
21	Ethion	pulses	Pod fly Gram caterpiller	50% EC 1.0 l/ha
22	Indoxacarb	pulses	Pod fly Gram caterpiller	14.5% SC 350 ml/ha
23	Lufenuron	pulses	Pod fly Blue butterflies	5.4% EC 600ml/ha
24	Methomyl	pulses	Pod fly	40%SP 750g/ha
25	Spinosad	pulses	Pod fly	45%SC 125 ml/ha

			Gram caterpillar	
26	clothianidin	oilseeds	Green leaf hopper	50WDG @ 50 g/ha
27	profenofos	cotton	American ballworm Spotted ballworm	50%EC 1500-2000ml/ha
28	pyridalyl	cotton	American bollworm	10% EC 750-1000ml/ha
29	Diafenthiuron	cotton	White fly	50%WP 600g/ha
30	Dinotefuron	cotton	White fly	20% SG 150 g/ha
31	Captan		Weed	
32	Carbendazim		Weed	
33	Tebuconazole	Rice	Sheath blight	
34	Propiconazole	Rice	Grain discoluration	
35	Flusiliazole	Rice	Sheath blight	
36	Kresoxim methyl	Maize	Rust disease	
37	Cyproconazole	Maize	Stalk rot disease	
38	Chlorothalonil	Oil seeds	Leaf spot disease	

(Source: Crop Production Guide Agriculture 2020)

ANNEXURE 8

Recommended pesticides (HHPs) in Punjab

Serial no	pesticides	crops	pests	Recommended dosage in pests
1	Butachlor		Weeds	1200 ml per acre
2	Chlorantriniprole	Rice Maize Cotton Sugarcane	Stem borer Leaf folder Stem borer Fall armyworm larvae of American bollworm Termite	18.5 SC 60 ml
3	Flubendiamide	Rice	Stem borer	20 ml 480 SC
4	Chlorpyriphos	Rice Sugarcane	Stem borer Black bug	1 l 20 EC 350 ml 20 EC
5	Dinotefuron	Rice Cotton	Planthopper White fly Jassid	20 SG 80 g 20 SG 60 g
6	Quinalphos	Rice	Planthopper Rice hispa	800 ml 25 EC
7	Propiconazole	Rice		200 ml 325 SC
8	Tebuconazole	Rice		25 EC
9	Copper hydroxide	Rice		500 g 46 DF
10	Fipronil	Rice Sugarcane	Stem borer Termite	15 g 80% WG in 100 litres of water per acre 10 kg granule 0.3 G
11	2,4-D		Weed	400 ml per acre
12	Spinetoram	Maize Cotton	Fall army worm Jassid	11.7 SC 0.5 ml per litre
13	Emamectin benzoate	Maize	Fall army worm	5 SG 0.4 g per litre
14	Pendimethalin		weed	1.0 litre per acre 30 EC
15	Paraquat		Weed	500 ml per acre 24 SL
16	Glufosinate ammonium		Weed	900 ml per acre 13.5 SL
17	Diafenthiuron	Cotton	Whitefly	200 g 500 WP
18	Clothianidin	Cotton	Whitefly	20 g 50 WG
19	Ethion	Cotton	Whitefly	50 Ec 800 ml
20	Imidacloprid	Cotton	Jassid larvae of American bollworm	70 WS 5 g/seed kg
21	Thiamethoxam	Cotton Sorghum	Jassid Shoot fly	30 FS 7 kg/kg seed 10 ml 30 FS
22	Tolfenpyrad	Cotton	Jassid	15 EC 300 ml
23	Profenofos	Cotton	Thrips	50 EC 500 ml
24	Sulfoxaflor	Cotton	Thrips	21.8 EC 150 ml

25	Fenpropathrin	Cotton	Pink and spotted bollworms	20 EC 300 ml
26	Beta cyfluthrin	Cotton	Pink and spotted bollworms	0.25 SC 300 ml
27	Cypermethrin	Cotton Brinjal	Pink and spotted bollworms Jassid	10 EC 200 ml
28	Deltamethrin	Cotton Brinjal	Pink and spotted bollworms Jassid	2.8 EC 160 ml
29	Fenvalerate	Cotton	Pink and spotted bollworms	20 EC 10 ml
30	Thiodicarb	Cotton	larvae of American bollworm	75 WP 250 g
31	Spinosad	Cotton Cauliflower	larvae of American bollworm Stem borer	48 Sc 60 ml
32	Indoxacarb	Cotton Tomato	larvae of American bollworm Fruit borer	15 EC 200 ml 200 ml 14.5 SC
33	Pyridalyl	Cotton	larvae of American bollworm	10 EC 300 ml
34	Acephate	Cotton	larvae of American bollworm	75 SP 800 g
35	Metribuzin		Weed	800g 70 WP
36	Diuron		weed	800 g 80 WP
37	Carbofuran	Sugarcane	Top borer	12 kg encapsulated 3G
38	Mancozeb	Groundnut		3 g M-45
39	Bromadiolone	Groundnut	Rodent bait	0.005%
40	Zinc phosphide	Groundnut	Rodent bait	2%
41	Dimethoate	Onion	Thrips	250 ml 30 EC
42	Malathion	Cucurbits Tomato	Fruit flies White fly	20 ml 50 EC
43	Propargite	Chilli	Thrip	57EC 200ml
44	Captan	Onion		3 g /kg seed
45	Oxydemeton methyl	Potato	Jassid	300 ml 25 EC

(Sources: Package of Practices for the Crops of Punjab ,Kharif 2022 and Package of Practices for Cultivation of Vegetables)

ANNEXURE 9

Recommended pesticides (HHPs) in Telangana

Serial no	pesticides	crops	pests	Recommended dosage in pests
1	Chlorantraniliprole	Rice	Stem borer	60 ml/200 l water
2	Acephate	Rice		1000 g/ha
3	carbofuran	Rice		25 kg/ha
4	carbosulfan	Rice		16.7 kg/ha
5	Thiodicarb	Maize	Fall army worm	
6	Emamectin benzoate	Maize	Fall armyworm	0.4 gm/l
7	Thiamethoxam	Ground nut	Fall armyworm	5 gm/l

Serial no	Pesticides	Crops	Pest	Recommended dosage
1	Pendimethalin	cotton	Weed	1 kg ai/ha
2	Butachlor	Jute		50% EC
3	Petrilachlor	Jute		50% EC
4	Oxyflurofen	Sugarcane		750 ml/ha in 5000l water
5	2,4-D	Sugarcane		1.25 kg/ha in 500 l water
6	Glyphosate	Sugarcane		2 kg/ha

(Source: Agricultural Action Plan, Telangana 2021)

ANNEXURE 10

Recommended pesticides (HHPs) in Odisha

Serial no	pesticides	crops	pests	Recommended dosage in pests
1	Butachlor	Rice Maize	Weed	1 kg/ha
2	Pendimethalin	Rice Millet pulses	Weed	1 kg/ha
3	Oxyflurofen	Rice	Weed	0.03 kg/ha
4	Petrilachlor	Rice Maize	Weed	1.25 kg/ha
5	Isoproturon	Maize	Weed	0.5 kg/ha
6	2,4-D	Maize	Weed	0.75 kg/ha
7	Oxadiazone	Pulses	Weed	0.75 kg/ha
8	Fluazifop-p-butyl	oilseeds	Weed	0.05 kg
9	Trifluralin	Niger	Pest control	2.5 kg/ha
10	Paraquat	Cotton	Weed	0.4 kh/ha
11	Glyphosate	Cotton		1 kg/ha
12	Captan	Vegetables	Seed treatment	2 g/kg
13	Thiram	vegetables	Seed treatment	2 g/kg
14	Mancozeb	Vegetables	Seed treatment	0.03%
15	carbendazim	Vegetables	Seed treatment	0.15%
16	Dinocap	Vegetables	Seed treatment	48% EC

Serial no	pesticides	crops	pests	Recommended dosage in pests
1	Fipronil	Rice	Gall midge Stem borer	0.5 kg
2	Chlorpyriphos	Rice Maize Sugarcane Groundnut	Gall midge Stem borer Caterpillar Termite Hairy caterpillar	20 EC 1.5% dust
3	Monocrotophos	Rice Castor	Gall midge Stem borer Mealy bugs	36 SL 1000ml/ha
4	Etofenprox	Rice	Brown plant hopper	10 EC/200 ml
5	Imidacloprid	Rice Vegetables	Brown plant hopper Brinjal mite	10 EC/50 ml 200 SL 50 ml
6	Malathion	Rice Maize Pulses Jute	Green leaf hopper Grasshopper Aphids Leaf eating caterpillar	5 %
7	Carbofuran	Maize Jowar Sugarcane	Grasshopper Shoot fly Early shoot borer	4 kg per acre
8	Dimethoate	Maize Pulses Ragi Sugarcane	Aphids Thrips Top shoot borer	30EC 400 ml/acre
9	Imidacloprid	Ragi	Jassids	200 SL 50 ml/acre

10	Cypermethrin	Ragi	Pule beetle	10 EC 400 ml/200 l
11	Fenvalerate	Sesame castor	Leaf Webber Semi looper	20 EC 500 ml
12	Quinalphos	Castor	Shoot borer	25 EC 1000 ml
13	Dicofol	Jute Sugarcane Vegetables	Mites Red spider mites Brinjal mite	400 ml/ha 1 l/acre 1.85 EC 1000 ml/acre
14	Ethion	Jute Vegetables	Mites Thrips	400 ml/ha 50 EC 200 ml/acre
15	Abamectin	Vegetables	Thrips	1.9 EC 400 ml/acre

(Source: Manual of Agricultural Production Technology, Kharif Crops, 2008)

ANNEXURE 11

Recommended pesticides (HHPs) in Andhra Pradesh

Serial no	pesticides	crops	pests	Recommended dosage in pests
1	Thiamethoxam	Mango	White fly	2 ml/l
2	Imidacloprid		Jassid, aphid, thrips	70 WS 10 g/ kg
3	Captan			75 WS 2 g/l
4	Chlorpyriphos		Termite	4 ml/kg
5	Tebuconazole			2 DS 1.5 g/kg
6	Pendimethalin	Rice	Weed	30 % EC
7	Glyphosate	Fruits	Weed	4 kh/ha

Recommended pesticides (HHPs) in Haryana (Source: Package of practice of crops 2004-2005)

Serial no	pesticides	crops	pests	Recommended dosage in pests
1	Dimethoate	citrus	Citrus psylla Leaf miner	625 ml/ 500 l water
2	Monocrotophos	Citrus Guava	White fly Brak eating caterpillar	500 ml/500 l water
3	Carbofuran	citrus	Nematode	13 g/sq m
4	Fenvalerate	Grape Brinjal	Thrip Jassid	20 EC/500 ml water
5	Malathion	Grape Mango cabbage	Thrips Leaf roller Mango hooper Diamond black moth	50 EC/500 ml 500 ml/ 500 l water 35 EC
6	Dimethoate	Litchi	Leaf curler	30 EC 500 l water/acre
7	chlorpyrifos	Litchi Ber	Leaf rolling caterpillar Termite	35 EC 50 l water/ acre
8	Quinalphos	Ber	Defoliating beetle	25 EC 500 l water/acre
9	Captan	Papaya		0.2%
10	Metribuzin		Weed	300 g/ acre
11	oxyflurofen		Weed	60 g/acre
12	Imidacloprid	chillies	Jassid	70 WS 5g/kg
13	Cypermethrin	Cucurbit	Red beetle	10 EC 100 l water/ acre
14	Diafenthiuron	Mushroom	Flies	1.2 g 25 EC/100 ml water
15	Dicofol	Mushroom	Mites	50 EC 1 ml/10 l water

(Source: Farmer's Handbook on Basic Agriculture, 2016)

ANNEXURE 12

Recommended pesticides (HHPs) in Assam

Serial no	pesticides	crops	pests	Recommended dosage in pests
1	chlorothalonil	Pineapple Dragon fruit		75 WP 2 g/l
2	Thiamethoxam	Banana coconut	Leaf scarring beetle Red palm weevil	25 WG 100 g/ha
3	Oxydemeton-methyl	Banana	Aphid	25 EC 0.05% g ai/ha
4	Imidacloprid	Banana citrus	Aphid Leaf miner	17.8SL 0.3ml/1 ltr of water.
5	Difenthiuron	citrus	Leaf miner	50WP 1g/ltr
6	Abamectin	citrus	Mealy bugs	1.9EC 0.0007%
7	Glyphosate	Weeds		41SL 1 ltr/ha
8	Bifenthrin	coconut	White ant	2.5 EC 0.05% ha
9	Flubendiamide	cauliflower	Caterpillar	39.35 EC 0.1%.
10	Emamectin benzoate	Cauliflower Brinjal	Caterpillar Fruit borer	5 SG 220 g/ha
11	Clothianidin	Cauliflower Brinjal	Caterpillar	50 WDG 80 g a.i./ha.
12	Lamda-cyhalothrin	Tomato		5EC 20 g ai/ha.
13	Tebuconazole	Pea		2 g/ltr of water
14	Propiconazole	Pea		2 g/ltr of water
15	Metribuzin		weed	0.75 kg/ha
16	profenofos	Vegetables	Mites	50EC 1 ml/ltr
17	Milbmectin	Rose	Red scales	1 EC 4.5 g ai/ha
18	Iprodione	Tuber rose		
19	oxyflurofen		weed	500 ml/200 ltr water
20	propargite		Tea mite pest	57EC 2.5 ml/ 2 ltr water
21	Ethion	Patchouli		5 ml/2 l water

(**Source: Package of Practices For Horticultural Crops Of Assam, 2021)**

ANNEXURE 13

Recommended pesticides (HHPs) in Jammu Kashmir which are HHPs

Serial no	pesticides	crops	pests	Recommended dosage in pests
1	Pendimethalin		Weeds	1litre/acre
2	Metribuzin		Weeds	0.3 kg/acre.
3	2,4-D		nutrition	1 ppm
4	chlorothalonil	potato		2.5 g/litre
5	chlorpyrifos	Potato Cabbage	Cutworm Mealy bugs	1.5%D 8kg/acre
6	Quinalphos	Potato Okra Pea	Cutworm maggots	5G 8-10 kg/acre
7	Oxydemeton methyl	Potato	Mealy bugs	25 EC 1 ml/litre
8	Imidacloprid	Potato Cucurbit	Mealy bugs Jassids	17.8SL 0.3 ml/litre of water
9	Dimethoate	Potato Pea	Whiteflies Jassids	2ml/litre 30 EC 2 ml/l
10	Thiamethoxam	Potato Pea Okra	Jassids Red cotton bug	70 WS 5g/kg 25 WG 0.25 g/l
11	Malathion	Potato Cucurbit Pea Carrot	Jassids Mustard sawfly	50 EC 2ml/l 5 D 8kg/acre
12	Profenofos	Potato	Slugs	50 EC 2 ml /l
13	Flubendiamide	Potato	Slugs	0.2 ml or g/l
14	Carbosulfan	Potato	Slugs	25 EC 1ml/l
15	dicofol	Potato	Spider mite	18.5EC 2.5 ml/l
16	Propargite	Potato	Spider mite	57EC 1.5-2 ml/l
17	Fipronil	Potato	Thrips	5FS 1.5 ml/ l
18	Methyl bromide		Fumigant	800g/1000cft
19	Iprovalicarb		leaf	2g/l
20	Propineb		leaf	2g/l
21	Trifluralin		weed	0.4-0.8 kg a.i/acre
22	Cypermethrin	Okra Cabbage	Shoot and fruit borer Cabbage semi looper	1 ml/l 20 EC 1 ml/l
23	Spinosad	Okra Cabbage	Shoot and fruit borer Cabbage butterfly	45SC 0.2ml/l
24	Fenvalerate	Cabbage	Cabbage semi looper	20 EC 1 ml/l
25	Carbofuran	Garlic	Maggot	3G 8-10 kg/acre
26	Indoxacarb		Borers	1 ml/l
27	Methomyl		Borers	1 ml/l
28	Beta cyfluthrin		Borers	1.5 ml/l

(Source: Package of Practices For Vegetable Crops, 2020)

ANNEXURE 14

Recommended pesticides (HHPs) in Himachal Pradesh

Serial no	pesticides	crops	pests
1	Malathion	Potato,Brinjal,Cucurbits	Fruit fly Hadda beetle Potato tuber moth red pumpkin beetle
2	Propargite	Tomato,Cucumber,Capsicum	Mites
3	Emamectin benzoate	Brinjal, Cole crops	Shoot and fruit borer tobacco caterpillar
4	Chlorantranilprole	Brinjal,okra	Shoot and fruit borer
5	Flubendamide	Brinjal,Tomato	Shoot and fruit borer
6	Indoxacarb	Pea,tomato	Pea pod borer
7	Imidacloprid	Tomato,Capsicum,okra	Aphid Whitefly Thrips jassids
8	Cypermethrin	Brinjal, cabbage	Fruit and shoot borer Epilachna beetle diamondback moth
9	Dimethoate	Tomato, capsicum	Thrips whitefly
10	Carbofuran	Tomato, cucumber	Nematodes
11	Chlorpyriphos	Potato	Cutworm white grub termites
12	Deltamethrin	Brinjal,Tomato, okra	Fruit and shoot borer fruit borer
13	Fenpyroximate	Capsicum	Yellow mite
14	Chlorothalonil	Capsicum,Tomato,Potato Cucurbits	
15	Carbendazim	Capsicum,Tomato,Capsicum	
16	Mancozeb	Tomato,Potato	
17	Propineb	Tomato,Potato	
18	Captan	Tomato,Capsicum,Cucurbit pea	

(Source: Guidelines for Crop Diversification In Himachal Pradesh, 2015)

ANNEXURE 15

Pesticide consumption in different states of India

States	Consumption volume (unit: MT) in 2021-22
Maharashtra	13175
Uttar Pradesh	11688
Telangana	5090
Jammu & Kashmir	4086
Haryana	4066
West Bengal	3630
Rajasthan	2104
Karnataka	1930
Gujarat	1869
Tamil Nadu	1851
Andhra Pradesh	1759
Chhattisgarh	1740
Orissa	1240
Jharkhand	1195
Bihar	995
Madhya Pradesh	654
Kerala	554
Himachal Pradesh	454
Uttarakhand	114
Goa	32
Punjab	NR*, 5193 (2021)

(Source: statistical database, plant protection, quarantine and storage)[72]

Pesticide consumption per hectare in different states of India	Per ha (kg) pesticide consumption 2016-17
Punjab	0.74
Haryana	0.62
Maharashtra	0.57
Kerala	0.41
Uttar Pradesh	0.39
Tamil Nadu	0.33
West Bengal	0.27
Chhattisgarh	0.26
Andhra Pradesh	0.24
Odisha	0.15
Gujarat	0.13
Bihar	0.11
Karnataka	0.10
Rajasthan	0.05
Madhya Pradesh	0.03
All India	0.29

(Source: Ministry of Chemicals and Fertilizers, Government of India, 2016-2017)

[72] Statistical Database | Directorate of Plant Protection, Quarantine & Storage | GOI (ppqs.gov.in)

STATUS OF HIGHLY HAZARDOUS PESTICIDES IN INDIA

One of the biggest challenges to our food security is the widespread use of Highly Hazardous Pesticides in our food crops. These Pesticides pose severe acute as well as chronic harm to human health and the environment. This report provides a first step in the direction of analysing the synergistic effects of HHP use and ill effects in farming communities. The potential avenues for future research stem from analysing how these HHPS affect our health and ecosystem. This report is an effort to understand the statistics, and present-day regulations of HHPs in India, where it exposes gaps in national approved uses of pesticides and recommendations for HHPs. A major share of pesticides registered in India are HHPs and they are estimated to account for the largest share because of their high usage and demand in the agriculture industry. This pesticide use scenario eventually will lead to an unpropitious outcome. The fastest way to achieve higher living standards for the nation's workers and farmers is only through producing healthy viable alternatives to these chemical pesticides and not through repeated use of potentially harmful chemicals.

This report objects to function as a helping tool to penetrate every level of stakeholders and policymakers to help in analysing the future of our farming sector, which does not compromise our health and food safety.

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