

Status of Highly Hazardous Pesticides and Their Mitigation Measures in Asia

Yubak Dhoj GC¹, Bhakta R. Palikhe², Baogen Gu², Grenier Beatrice²

¹Regional Office for Asia and the Pacific, Food and Agriculture Organization of the United Nations (FAO), Bangkok, Thailand

²Pest and Pesticide Management, Plant Production and Protection Division, Food and Agriculture Organization of the United Nations (FAO), Rome, Italy

Email: Yubak.GC@fao.org, brpalikhe@gmail.com, Baogen.Gu@fao.org, Beatrice.Grenier@fao.org

How to cite this paper: GC, Y.D., Palikhe, B.R., Gu, B. and Beatrice, G. (2022) Status of Highly Hazardous Pesticides and Their Mitigation Measures in Asia. *Advances in Entomology*, 10, 14-33.
<https://doi.org/10.4236/ae.2022.101002>

Received: May 19, 2021

Accepted: November 16, 2021

Published: November 19, 2021

Copyright © 2022 by author(s) and

Scientific Research Publishing Inc.

This work is licensed under the Creative

Commons Attribution International

License (CC BY 4.0).

<http://creativecommons.org/licenses/by/4.0/>



Open Access

Abstract

Pesticide is one of the major inputs in modern agriculture and its uses are increasing annually. Pesticides are seen as inherently benign, in the same way that medicines are. Many local languages even use the same word for “pesticide” and “medicine”. Along with the increasing consumption of pesticides, Highly Hazardous Pesticides (HHPs), which are more toxic are still in widespread use in Asia and constitute a substantial challenge to human health and the environment especially in low- and middle-income countries with less resources, training and capacities to deal with them. Reducing the risks posed by HHPs has become a priority in various international chemicals management policies, and many countries have started taking action accordingly. The objective of the paper is to establish the national status of the use of HHPs in Asia in line with FAO/WHO criteria for HHPs and encourage deliberate consideration of mitigation options for effective management of HHPs. This report is based on the nationally registered pesticide active ingredients and other related information obtained from Pesticide Registration Authorities of 13 Asian countries and research reports of different national and international journals. There are currently about 3557 pesticide products (active ingredients) registered in 13 Asian countries to control pests on crops and for public health uses, and 214 HHPs among the list of registered pesticides still in use in these Asian countries. An analysis of the list of registered formulated products revealed that 61 different active ingredients are included in these 214 registered HHPs in Asian countries. Considering the global concern of HHPs, there is thus every reason to develop mass awareness raising programmes based on knowledge, aptitude and practices and to disseminate them within the community in order to inform about the risks of HHPs and to replace HHPs and mitigate human risk and exposure to HHPs. It is concluded that detailed surveys and studies should be formulated with help of experts

from academia and research organizations to construct a baseline data which may be helpful to tone down the HHP situation in the country.

Keywords

HHPs, Health, Environment, Risk, Mitigation

1. Introduction

A survey on situation of HHPs was carried out by FAO in 13 Asian countries: Afghanistan, Bhutan, China, India, Japan, Lebanon, Malaysia, Mongolia, Myanmar, Nepal, Pakistan, Philippines and Singapore, covering the research period of Dec 15, 2020-April 2021 [1]. The review was done by evaluating the registered pesticides against the 1 - 7 criteria for HHPs established by FAO and WHO along with national identification of HHPs. The objective of the study is to establish the national status of HHPs in Asia according to the FAO/WHO criteria and encourage deliberate consideration of mitigation options for effective management of HHPs. Today, global pesticide consumption is more than four million tonnes per year [2]. Most of which are herbicides (50%), followed by insecticides (30%), fungicides (18%) and other types such as rodenticides and nematocides [3]. Since 2020 until now, the COVID-19 pandemic has added another factor to the situation by pushing up costs for the production and post harvest operations for farmers while reducing income. The pandemic has also made it harder to get farm labor and more complicated to get crops to a functioning market. The COVID-19 pandemic is disrupting food systems worldwide, posing a number of challenges for national, international and local governments that are obliged to deal with rapid changes in food availability, accessibility and affordability—which strongly impact the food security and nutrition situation of urban and peri urban populations. The use of pesticides in agriculture is increasing rapidly in developing countries, especially in Southeast Asia. Worldwide, 62% of out of 54 countries that took part in a FAO/WHO survey have identified HHPs among registered pesticides or HHPs in use, indicating that many remaining countries still have to start addressing the problem of HHPs. And 41% of the 54 responding countries have assessed the needs and risks associated with HHPs in use [4].

International organizations, through declarations and international agreements, are encouraging all countries to develop the institutional set-up or infrastructure to manage pesticides without any unacceptable risks. At the same time, however, resources are limited and the necessary information and expertise may not be readily available, thereby constraining the ability of low-income countries (LICs) and middle-income countries (MICs) to effectively manage pesticides and HHPs in particular, and protect the environment and the public health. The shift to alternatives (less hazardous alternatives or non-chemical methods and products

over chemical pesticides) is also complicated by shocks such as climate events and pandemics, and the challenges of the alternatives themselves. Government regulatory agencies of the developing countries have encouraged a variety of methods to reduce exposure risk to, pesticide handlers, agricultural workers, bystanders, consumers and the environment. The government is the only entity that regulates and can decide to ban HHPs; moreover, its duty is to carry out general educational programs about toxic pesticides. The article published in *Land and Human to Advocate Progress* [5], has suggested that governments need to develop and frequently update a list of HHPs for ban and phase-out and carry out comprehensive awareness-raising activities. Risk mitigation measures are the tools that reduce the transfer of a product, such as pesticide, into a particular environmental compartment, and thus mitigate both exposure and risk to organisms and ecosystems.

2. Statement of the Problem

The importance of agricultural pesticides for developing countries is undeniable. However, the issue of human health and environmental risks has emerged as a key problem for these countries. Public health concerns regarding the improper use of HHPs and poison have increased in recent years. The problems can be summarized as follows.

2.1. Wide Use of HHPs

While developed countries introduced thorough registration of pesticides, requiring detailed scientific data on which to base a risk analysis, many other developing countries did not have the resources needed to operate a detailed registration system. In consequence, highly toxic pesticides have been authorized and are still widely used in many Asian countries due to the current system of crop production, which prioritizes high agricultural yields. The demand is increasing in many developing countries, which together account for a quarter of global pesticide use [6]. They will continue to contribute to part of the solution to providing food security. The use of HHPs is still a serious concern and substantial challenge in many parts of the Asia.

2.2. Distribution and Sales

The Article 8 of the Code of Conduct on Pesticide Management [7] deals with distribution and trade, and Article 11 with advertising. There are guidelines on tender procedures for the procurement of pesticides, for retail distribution and on advertising. A number of countries allow the sale of identical products under different trade names which might confuse farmers and encourage excessive use.

2.3. Stocks of Obsolete Pesticides

Stocks of obsolete pesticides are a huge threat to health and environment in many developing countries. Preventing the accumulation of surplus quantities of

pesticides in the first place is of prime importance. Countries with obsolete stock problems often lack disposal facilities and disposal abroad is extremely costly. Accumulation and eventual disposal of pesticides puts a tremendous burden on scarce resources.

2.4. Health and Environmental Problems of HHPs

Pesticide use and the resulting impacts on human health, life of rural communities, the sustainability of food production, biodiversity and the environment is an immense problem that does not get addressed comprehensively at regional level or adequately at a local level. In many developing countries, most pesticides are associated with adverse effects on human health and environment due to inappropriate use and handling of pesticides by inadequately trained farm workers [8]. Majority of pesticides users, being unaware of HHP types, their mode of action, potential hazards and safety measures, and the problem is becoming more havoc. Although the developed countries consume more pesticides, the pesticide poisoning cases are observed more in developing countries. Excessive use of pesticides, lack of education and the discomfort of using protective clothing increase poisoning risks in agricultural workers, but the country has no regular system of data collection on poisoning cases, and there is no regular program for monitoring the health of the workers involved in handling the pesticides.

2.5. Regulatory Problems

There is a lack of appropriate HHPs control legislation and lack of a modern pesticides approval/registration procedure and/or inadequate resources to implement and enforce existing schemes, lack of legislation on working conditions and lack of post-registration monitoring of HHPs. An efficiently regulated and managed pesticide registration scheme is a prerequisite for ensuring that HHPs used in the country are useful for controlling pests and would not cause effects on humans and the environment. A full understanding of the regulations involved in the registration and release of biological control agents (BCAs) is critical to their successful deployment. The approval and registration procedures differ between countries, but typically require a large dossier of scientific data on expected benefits, risks, bio-safety considerations, and impact on the environment. The process generally involves different agencies, and decision-making is usually a slow process. The Governments should harmonize the regulatory procedures for import, production and release of BCAs across countries of a region.

2.6. Inadequate Promotion and Adoption of Low-Risk Alternative and IPM

Attempts to replace the use of pesticides with alternative approaches such as IPM and IVM have been tried in a number of Asian countries. Lack of harmonized regulatory standards also results in more toxic, and even banned, pesticides being used extensively in developing countries because they are cheaper

than the less toxic alternatives. In many cases, HHPs that are not or no longer permitted for use in some high income countries are exported to developing countries. Government policies still favor chemical pesticides and high subsidies exist, while newer IPM products such as bio-pesticides and pheromone traps are taxed at high rates. The Government should foster IPM by removing subsidies on the least desirable pesticides while removing taxes from IPM products. The goal of the pesticide related program is to quickly register commercially viable alternatives to riskier conventional pesticides such as neurotoxins, carcinogens, reproductive and developmental toxicants, and groundwater contaminants.

2.7. Weak Capacity

There are serious data gaps observed due to lack of capability and capacity in monitoring data relating to health, environmental contamination and specific incidents. The government also lacks capacity to regulate the sale of illegal, unapproved, and unlabelled pesticides in rural markets. Assessing the human and environmental risks of pesticides in a comprehensive, science-based manner is a complex and expensive task for which many developing countries lack the expertise and resources. However, phasing out internationally recognized HHPs is a first step toward reducing pesticide risks which every country can take [9]. Such a situation requires effective national pesticide management capacities.

2.8. Infrastructural Problems

Developing countries lack adequate infrastructures needed to take up research. There are inadequate laboratory facilities to take up analysis of HHPs. There is also lack of safe storage and packaging of obsolete HHPs and non-HHPs pesticides.

2.9. Awareness Problems

As concerns over carcinogenic chemicals among growers and consumers, increasing awareness of potential health issues and consumer demand for stricter regulations is the only way to potentially change the future of pesticides in farming. Many pesticide dealers take up intensive and aggressive marketing strategies to sell their products with the perception that there are no other alternatives for farmers except the use of chemical pesticides. Due to public perception, a large number of farmers still recognize pesticides as medicine, a notion implanted in the mind of the farmers [10]. There is a lack of awareness among the consumers/general public about harmful effects of pesticides and HHPs. There is a misconception among the general public that HHPs are good. Lack of any local data on the ill effects makes the situation worse. People therefore continue to use HHPs. Any control system, no matter how well crafted, will not be effective without rigorous enforcement. Governments therefore need to develop and frequently update a list of HHPs for risk mitigation, ban and/or phase-out and carry out comprehensive awareness-raising activities. Many biological control options are, how-

ever, not being deployed because of poor awareness of adoption procedures and misplaced concerns about risks associated with BCAs. Imagine a village where there are no alternatives to HHPs. In response, governments or donors are encouraged to fund bio-pesticide promoters to explain the benefits of alternatives to the villagers. As a result, some villagers are keen to try using alternatives to HHPs.

2.10. Coordination Problems

There is clearly a lack of coordinated effort on the part of the governments to eliminate HHPs. Because of an open and porous border in Asian countries, there is a considerable, but unknown quantity of trade between farmers close to the borders. Hence, illicit/illegal import of pesticides issue needs to be addressed in regional approach with neighboring countries to prevent potential infiltration of banned/ unregistered pesticides [11].

3. Materials and Methods

The findings of the study were mainly from reviewing nationally registered pesticide active ingredients. And the sources of secondary data were government publications, websites, FAO reports, books, journal articles, internal records, annual reports, study report, conference proceedings, published articles, papers and records of governmental and NGOs/INGOs and existing success stories on alternatives to HHPs. Data was collected based on the specially developed Data Collection Tool. Quantitative and qualitative data were collected, organized and analyzed, guided by the study objectives. The country information on nationally registered pesticides was arranged in order to collate the data for development of current status of HHP report based on the criteria developed by FAO/WHO [12] and the PAN International List of HHPs compiled in 2019 [13]. Any pesticide meeting one or more of the 1 - 8 criteria is considered to be an HHP. Identification of active ingredient (a.i.) which is HHP under criteria 5, 6 and 7 is unambiguous as these chemicals are listed in international agreements or environmental conventions such as the Rotterdam or Stockholm Conventions or the Montreal Protocol. Identification of a.i. and their formulations under criteria 2, 3, 4, is not as clear-cut, as categorization of the a.i. and their formulations depends on national classification, if available for pesticides, or on classifications by reputable authorities. According to the WHO recommended classification of pesticides by hazard, the determination of an active ingredient (a.i) as belonging to a particular class (Ia, Ib, II, III, U) depends on the amount of that a.i in the final formulation.

4. Results and Discussion

This section of a scientific paper represents the core findings of a study derived from the methods applied to gather and analyze information. The present study is completely original work. It is expected that the findings are also useful to other

countries of similar context since HHP is being used in most countries of Asia.

4.1. Status of Pesticide Registration

All countries in the region have legal arrangements for pesticide registration and management. Registrations have been designed to deal effectively with specific problems applicable in the country, taking into account the economic and social conditions of the country as well as any specific technical requirements such as the crops grown, pest problems, dietary patterns, toxicity of the required pesticides, level of literacy, and climatic and environmental considerations. The situation is quite different from one country to another mainly due to different agricultural needs, pesticide legislative framework and technical capacities. The study has shown that 3557 active ingredients of pesticides are currently registered in Asia. The number of pesticide registrations ranges from 24 to more than 554 active ingredients. Such a large difference can be explained by country-specific needs and obviously different registration strategies and philosophies are applied. The average number of registrations was more than 250 products. Insecticides are the dominant form of pesticides used followed by Fungicides and Herbicides.

4.2. Situation on HHPs

In the interpretation of the results of this study, the weight of nationally registered pesticide active ingredients were analyzed for the following type of HHPs based on FAO/WHO criteria. The study revealed that 214 HHPs (active ingredients) were in use in the 13 Asian countries in the formulation of Insecticides, Fungicides, Herbicides, Rodenticides, Acaricides, and Nematicide. The number of registered HHPs ranges from 2 to 34 Each country is different, and each country is unique.

As can be seen in **Figure 1**, an analysis of the list of registered products showed that there are 214 HHPs products containing 61 different active ingredients of different use types (Insecticides: 33-, Abamectin, Abamectin + Triazophos, Aldicarb,

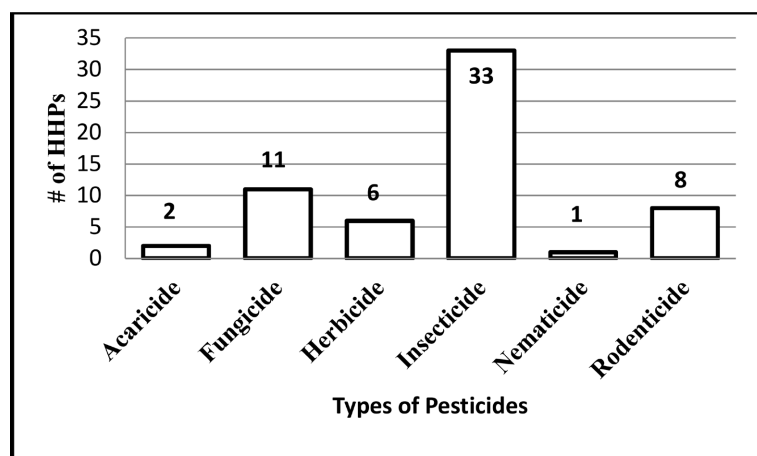


Figure 1. # of HHPs (a.i. as of types).

Azinphos methyl, Beta cyfluthrin, Cadusafos, Carbofuran, Carbosulfan*, Cyfluthrin, Dichloro Diphenyl Trichloroethane (DDT), Dichlorvos, Dicofol, Ethoprophos, Flucythrinate, Furathiocarb, Isoxathion, Methamidophos, Methidathion, Methyl bromide, Monocrotophos, Nicotine, Omethoate, Oxamyl, Oxydemeton-methyl, Phorate, Phorate + Carbofuran, Propetamphos, Silafluofen, Spirodiclofen, Tefluthrin, Thiacloprid, Trichlorfon and Zeta-Cypermethrin), (Fungicides: 11-Benomyl, Carbendazim, Cyproconazole, Dinocap, Edifenphos, Epoxiconazole, Flusilazole, Methomyl, Propiconazole, Triadimenol and Triflumizole), (Herbicides: 6-Alachlor, Fluazifop-p-butyl, Flumioxazin, Glufosinate Ammonium, Linuron and Paraquat/Paraquat dichloride**), (Rodenticides: 8-Brodifacoum, Bromadiolone, Chlorophacinone, Coumatetralyl, Diphacinone, Flocoumafen, Warfarin and Zinc Phosphide), (Acaricides: 2-Formetanate Hydrochloride and Triazophos) and (Nematicide: 1-Fenamiphos). About 33 (54%) HHP a.i. pesticides were used in the form of Insecticides in Asia [1]. The share of Fungicides, Rodenticides, Herbicides, Acaricides and Nematicide is very low as compared to Insecticides and account for 11 (18%), 8 (13%), 6 (10%), 2 (3%) and 1 (2%) respectively (See **Figure 2**).

*Cabosulfan: Agreed by the Rotterdam Convention's CRC and the COP as meeting of the criteria of the but not Convention formally listed.

**Paraquat dichloride more than 276 g/L: Formulations at or above the specified concentration have been agreed by Rotterdam COP to meet the criteria for listing, but are not formally listed.

The study result has shown that the situation is completely different in Bhutan, a small country in the Southern Asia. A very small number of HHPs (2) are registered in Bhutan. In 2013 the government announced the aspiration that Bhutan will become the first country in the world with 100 percent organic farming [14] [15]. Some agricultural areas in Nepal (in hills and mountains) have never used chemical fertilizers and pesticides for farming and by default these areas can well support the organic farming [16]. Jumla district of Nepal is

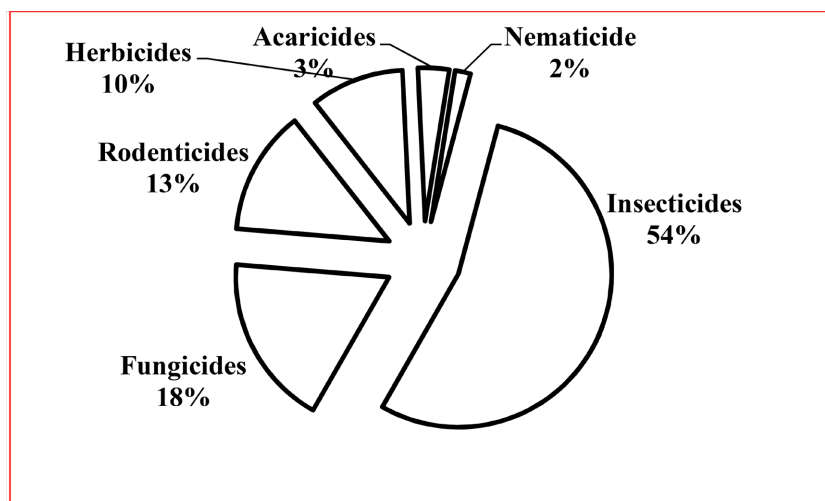


Figure 2. Percentage of HHPs (a.i. as of types).

the first “Organic District” officially declared in 2007 for the implementation of organic agriculture in Nepal. As an organic district the district administration has banned the import and use of chemical pesticides and fertilizers for production of fruits, vegetables and food crops [17].

4.2.1. HHPs Category and Toxicity

As stated at the beginning of this study, the sums for these three groups (Acute Toxicity, Chronic toxicity and PIC/POPs/Montreal) amount to sixty-one and some active ingredients meet the criteria of more than one group. The finding is that the active ingredients Aldicarb, Azinphos methyl, Brodifacoum, Bromadiolone, Carbofuran, Coumatetralyl, Flocoumafen, Methamidophos, Monocrotophos, Phorate and Warfarin appear in two criteria and are therefore particularly problematic as shown in **Table 1**. They may be very serious and cause the death of the human. However, all kinds of HHPs are potentially hazardous to humans, animals, and the environment.

Based on toxicity pesticides, of the total number of 13 Asian countries, 119 products (WHO Ia-31 and WHO Ib-88) are registered for group one: Acute Toxicity, 109 active ingredients (GHC Carc. -5, GHC Muta-13 and GHC Repro. Toxicity-91) for group two: chronic toxicity and a further 41 active ingredients (POPs-4, PIC-34 and Mont. Prot-3) products registered for group three: Environmental Conventions (Stockholm and Rotterdam Conventions and Montreal Protocol). Of the total number, 44% active ingredients are registered for group one: Acute Toxicity, for group two: Chronic Toxicity (41%) and further products registered for group three: Environmental Convention (15%). Based on FAO/WHO criteria, 5 HHPs used have classified in carcinogenic category Ia Ib, 13 in mutagenicity category Ia Ib and 91 in reproductive toxicant category Ia Ib. The

Table 1. Active ingredients in groups.

SN	Pesticide a.i	Group 1: Acute Toxicity		Group 2: Chronic toxicity		Group 3: (PIC/POP/ Montreal) PIC	Total
		WHO Ia	WHO Ib	GHS Muta. (Ia, Ib)	GHS Repr. Toxicity (Ia, Ib)		
1	Aldicarb	✓				✓	2
2	Azinphos methyl		✓			✓	2
3	Brodifacoum	✓			✓		2
4	Bromadiolone	✓			✓		2
5	Carbofuran		✓			✓	2
6	Coumatetralyl		✓		✓		2
7	Flocoumafen	✓			✓		2
8	Methamidophos		✓			✓	2
9	Monocrotophos		✓			✓	2
10	Phorate	✓				✓	2
11	Warfarin		✓		✓		2

present assessment identified 109 pesticide active ingredients that contribute 40.5% of the total chronic hazard.

Following the FAO/WHO criteria, the analysis further found that 1% HHPs are categorized as POP, 13% HHPs are categorized as having PIC, 1% HHP is categorized as being Montreal Protocol, 11% are categorized as WHO Extremely Hazardous Class Ia, 33% are categorized as WHO Highly Hazardous Class Ib, 2% is categorized as GHC Carcinogen Ia, Ib, 5% are categorized as GHC Mutagenic Ia, Ib and 34% of the HHP having been listed for Reproductive Toxicity Ia, Ib as shown in **Figure 3** below.

An analysis of the Asian data set of registered pesticides showed that four countries had registrations of a very few active ingredients (Dicofol and DD) that belong to POP pesticides listed in Annexes A and B (or meeting the Conventions' criteria), PIC pesticides (Carbofuran, Carbosulfan, Paraquat/Paraquat Dichloride -> 276 g/L, Phorate, Trichlorfon, Aldicarb, Monocrotophos, Alachlor, Methamidophos, Azinphos methyl and Benoml) listed in Annex III (or meeting the Convention criteria) and Pesticides (Methyl bromide) listed in Montreal Protocol. With regard to the pesticides regulated under the Environmental Conventions, only three countries have banned or restricted all Conventional products. One pesticide (Methyl Bromide) listed in the Montreal Protocol is being used in three countries. With regard to international treaties, all countries had signed the Stockholm Convention, one country still needed to join the Stockholm Convention and two countries had not yet ratified the Rotterdam Convention.

The Convention limits trade in extremely hazardous chemicals that should not be exported unless agreed by importing countries participating in the PIC procedure. All countries have been recommended for regulation of POP and PIC pesticides under the Stockholm and Rotterdam Conventions, indicating a growing international concern over their safety. After the Stockholm and Rotterdam

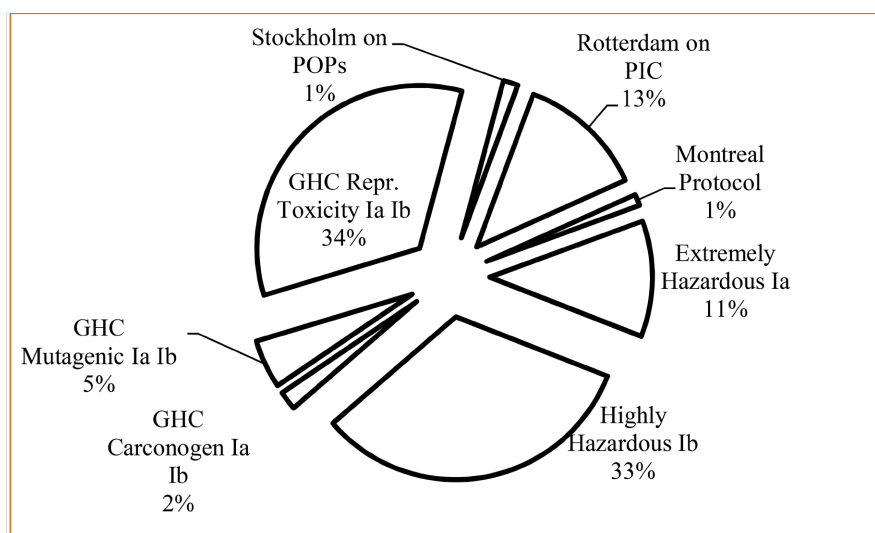


Figure 3. Categories of the a.i. by their impacts.

Conventions; many countries have banned various pesticides because of their health and environmental effects. The national implementation plan (NIP) of certain Asian countries related to the Stockholm Convention on Persistent Organic Pollutants (POPs) includes pesticides classified as POPs and can be considered as a first step to phase out HHPs. The remaining Asian countries have been underway for identification of HHPs. This task is still ongoing. In this review, the results also showed that the use of registered HHP pesticides in general is much less percentage of HHPs (6%) in Asia. But the situation in Asia is becoming a little alarming (Figure 4).

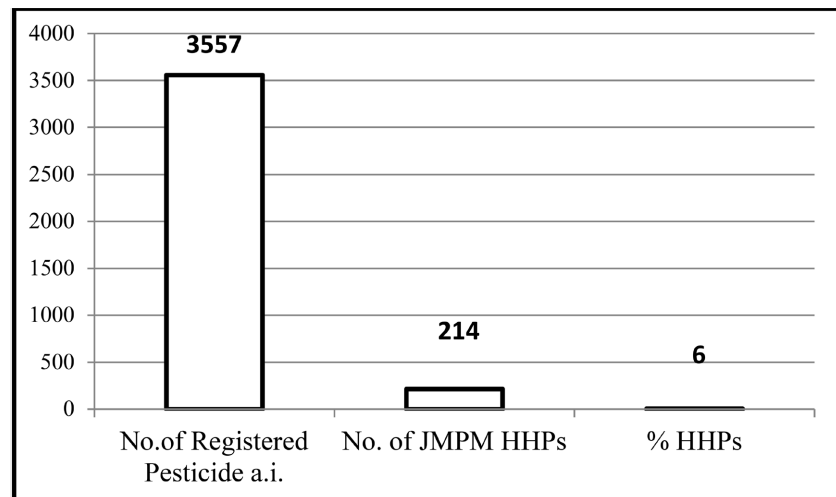


Figure 4. % of HHP among the country list of Registered Pesticide a.i.

4.2.2. Pests and Crops

Pests continue to present a major challenge in crop production. Consequently pest management is one of the major aspects of crop management. The application of HHPs in the agricultural sector in Asia covers various crops. The analysis has shown that HHPs are used in about major 50 commodity crops (Cereals, Fruits, Cash Crops, Vegetables, Orchid/Ornamental plants and others and Public Health) as, Insecticides, Fungicides, Rodenticide, Herbicide or Acaricide. Anticoagulant Rodenticides are poisons used to kill rats. Active ingredients of pesticides are also used for household and public health in Asia. The Asian countries have inadequate regular system of collection of data on HHPs and information regarding in this field is wanting. Data are very rarely generated in developing countries and, therefore, few HHPs data are established for use in crops. Therefore, there are serious data gaps observed due to lack of capability and capacity in monitoring HHPs use. In addition, no systematic studies have so far been made on HHPs in different crops in Asia. In order to adequately evaluate HHPs use, a database is needed which contains: current situation, accurate, current usage data for agricultural and public health HHPs. This suggests that much remains to be done to reduce risks from HHPs.

The increased quantity and frequency of HHP applications have posed a major challenge to the targeted pests causing them to either disperse to new environment

and/or adapt to the novel conditions [18]. It highlights the potential to grow enough healthy, sustainable food without using HHPs, and calls for the national and regional community to develop a comprehensive, binding treaty to regulate HHPs based on principles of human rights. Injudicious and indiscriminate use of pesticides and presence of HHPs residues in food, fruits, vegetables and environment is a matter of grave-concerns in our context. Pesticide use and risk reduction is a necessity because most consumers expect that their food and environments are free from pesticide residues. When planning to replace or phase out a specific HHP, it is important not to assume that use of a particular HHP (e.g., carbosulfan use to control whitefly in tomato and carbendazim use in coffee), can always be simply substituted by either using a less toxic chemical or by a single nonchemical method. Trapping and use of *Beauveria* biopesticides can be cheaper than endosulfan application or similar in cost. Effective and long-lasting control strategies often combine a range of preventative and direct intervention methods—this is the essence of Integrated Pest Management. Replacing HHP fungicides with non-HHP synthetic products appears to be a feasible option, technically and economically [19]. Considering the results of this review, it must be taken into account that there is a need of continuous monitoring and strict regulations should be implemented by the Government agencies regarding safe doses of pesticide residues in food commodities.

4.2.3. Risks of HHPs Use in Crops

Almost all countries consider risk during the registration procedure; in most cases, they assess the pesticide hazard based on a review of toxicological data. HHPs are both persistent and bio-accumulative. After each application or spraying, one should leave crops for a period of time for the chemicals specially HHPs to dissolve before harvesting for the safety of consumers. If growers quickly harvest their yields and distribute crops for immediate consumption, the toxic residues in agricultural products may be highly hazardous to consumers. The greatest exposure to HHPs is for agricultural and public health workers during handling, dilution, mixing and application. But more must be done, by all stakeholders, to ensure the safe and responsible use of pesticides, especially highly hazardous pesticides in low income countries as another way of saying “higher the hazard ratio the greater the hazard”. The effect of pesticides on non-target organisms has been a source of worldwide attention and concern for decades. In the current scenario, optimized use of pesticides is important to reduce environmental contamination while increasing their effectiveness against target pest.

4.3. Discussions

The increasing Asian population has put a tremendous amount of pressure on the existing agricultural system so that food needs can be met from the same current resources like land, water etc. Although chemical pesticides safeguard crops and improve farm productivity, they are increasingly feared for their potentially dangerous residues and their effects on ecosystems. The above men-

tioned results indicate that many pesticides banned in the developed countries end up being sold cheaply in developing countries where safer alternative chemicals are not always available. A very high share percentage of total active ingredients of HHPs are available in Insecticide category compared to other pesticide types, which is of considerable concern. However, regional differences are still distinct. Most developing nations use greater quantities of insecticidal chemicals, given that insect pests create the greatest problems. Insecticides constitute a large number of chemical classes as Insecticides are used in a wide range of settings with the most important areas being in agriculture and public health. Many countries in South-East Asia lack the capacity to handle chemicals management issues and are in great need to develop institutions, legislation, knowledge and general awareness [20]. Most farmers lack knowledge and skills and Personal Protection Equipment to meet safety requirements for HHPs during application. The capabilities, expertise and resources to fully implement the regulation are limited in most of the developing countries in the region. Our research suggests that capacity building of lifecycle management of pesticides should be strengthened with focus on identification, assessment and mitigation of HHPs.

Many agro-biologicals represent safe and effective alternatives to HHPs, but systems of registration and regulation in the present situation tend not to favor them. This is particularly challenging since adaptations are influenced by many factors including government policy, technology R & D and agricultural extension services. Therefore, the rate of success of effective adoption of alternative chemical options through awareness and promotion is minimal in developing countries. The perception of farmers is that pesticides were considered as “Silver Bullets” technology for managing pests. Thus, other pest management tactics were relegated to the background. Application technology has largely been ignored. No segment of the population is completely protected against exposure to HHPs and the potentially serious health effects, though a disproportionate burden is shouldered by the people of developing countries and by high-risk groups in each country. Most urgently, Asia needs to ban use of HHPs which are very toxic; many of these are banned in developed countries. Considering the results of this review, this is the time that necessitates the proper use of HHPs to protect our environment and eventually health hazards associated with it.

5. Mitigating Risks from HHPs

Risk management is a key component especially when alternatives are not available and during transition to alternative technologies. The gap on HHPs calls for regional action by all relevant stakeholders on addressing HHPs, including a progressive elimination of HHPs and contamination caused by HHPs and a progressive phase-in of alternative measures. It outlines the need for concerted efforts to mainstream the regulation and sound management of HHPs and contribute to the achievement of the Sustainable Development Agenda 2030.

In particular in developing countries, HHPs may pose significant risks to hu-

man health or the environment, because risk reduction measures such as the use of personal protective equipment or maintenance and calibration of pesticide application equipment are not easily implemented or are not effective. In this respect, the Code of Conduct, in Article 7.5, stipulates that: Prohibition of the importation, distribution, sale and purchase of HHPs 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. Pesticide risk reduction is therefore one of the priority areas in pesticide management programme. Pesticides like Phorate, Brodifocoum, Aldicarb, Ethoprophos, Bromadiolone, Carbofuran, Chlorophacinone, Diphacinone, Oxamyl and Flocoumafen are considered class I pesticides by the World Health Organization (WHO), which are further categorized into extremely hazardous (WHO class Ia). The classification is based on acute toxicity of pesticide active ingredient and since WHO class I pesticides can be fatal at a very low dose, many of these are banned in several countries. Asia urgently needs to address pesticide mismanagement from several aspects; the most urgent step needed is to ban use of WHO Group 1 (Acute Toxicity) HHPs including Group 2 (Chronic Toxicity) and Group 3 (Environmental Conventions: POP, PIC and Montreal Protocol). Effective risk reduction from HHPs is mainly carried out at the national level, thus have the prime responsibility in this respect.

The study offers a roadmap to help developing countries identify and deal with HHPs. This involves inventory taking, assessing risks and actual needs, and then taking appropriate mitigation measures. In many cases, this will be phasing out of the HHPs, but in cases where there are no good alternatives, other mitigation actions may be considered. Pesticide packaging improvements, formulation changes, restriction to some of its uses, appropriate training in appropriate pesticide use, integrated pest management, integrated vector management and the appropriate disposal of empty pesticide containers are examples of risk mitigation measures. This is the time that necessitates the proper use of pesticides to protect our environment and eventually health hazards associated with it.

The threshold requirements for mitigation measures vary from country to country. Guidelines on HHPs expand upon the articles that address HHPs in the Code of Conduct (Box 1) with the objective of helping countries to interpret and apply these articles effectively in order to reduce risks posed by HHPs. Based on results of the study, several measures have been identified to prevent and mitigate (minimize) the adverse impacts of a HHP and replace HHPs, where appropriate. However, these are not standard mitigation measures that can be used everywhere and for all in Asian countries. Finally, a judgment about the extent of the mitigation measures was made based on the current available data and status of the HHPs in Asia.

1) Identifying HHPs

Mitigation of HHPs risks could be started by identifying them. This can be done with support from existing data, primarily data already available, and col-

lecting new data on incidences of targeted HHPs on plant health, human health and the environment within country authority. Information generated within different approval schemes and information regarding classification and labeling in other countries could add valuable information, especially if data is scarce in your own country. FAO and WHO Guidelines on developing a reporting system for health and environmental incidents resulting from exposure to pesticides could help to developing the information collection scheme.

2) Pesticide Formulations

Risks of pesticide to humans, other non-target species, and the environment are primarily influenced by a pesticide's toxicity and formulation. Some pesticide formulations can lower the risk for people and other non-target organisms, by reduced product toxicity with lower concentration, changed formulations and application methods, if they are applied as directed by the label. Methods of application will vary with pesticide formulation. Risks of some HHPs could be achieved by changing formulations. It is important to apply pesticides in the quantities and concentrations that are specified on the pesticide label. Applying pesticides in greater amounts or higher concentrations than recommended on the label is illegal, usually not cost effective, and increases the risks to humans, other non-target species, and the environment.

3) Restricting Use

Where a specific need is identified for a HHP and no viable alternatives are available, national governments should be advised to take all the necessary precautions, mitigation measures and apply restrictions, which may include the use only under certain conditions such as under recommendations of the authorized persons (plant protection officers/pesticide inspectors) or by specifically certified users, severe restrictions, or a possible phase-out.

4) Truth in Advertising

Advertisements should not make claims outside of the information presented at registration. It should be unlawful to advertise false, misleading, and deceptive information and not to claim that any pesticide especially HHPs are safe, non-poisonous, non-injurious, or harmless.

5) IPM/IVM Extension Programs

The challenge to find safer, more sustainable, community-based strategies led the research to support pilot activities on Integrated Pest Management (IPM) and Integrated Vector Management (IVM). IPM and IVM are general strategies of pesticide use-reduction in agriculture and public health and would be an effective approach of reducing HHPs use. Research recommendations and farmer knowledge both exist but availability and adoption of appropriate options appears weak, or at best sporadic. Developing countries have seen low adoption rates of IPM strategies [21]. There is widespread international consensus on the need to implement alternative strategies that reduce or even eliminate the reliance on chemical pesticides, notably IPM in agriculture and IVM in public health. Pest and vector management based on IPM and IVM would be preferred.

Successful IPM is driven by the actual users—mainly farmers. It is not a service provided from “above”—by a government service, a private company, a donor, or a foreign NGO. Full participation of the users is a prerequisite. Women have a crucial role to play—in many developing countries, the majority of farmers are women—and their training needs and other priorities are important. UNEP, FAO and WHO are committed to promote integrated strategies for more sustainable pest and vector management.

6) Promoting Bio-Pesticides

When pesticides are used—as a “last resort”—their toxicity to non-target organisms should be as low as possible and they should be as selective as possible. Certain pesticides of natural origin are compatible with IPM, causing minimum disturbance of natural control mechanisms. While phasing out HHPs, Governments should replace them with the rapid deployment of ecosystem-based approaches to crop production such as bio-pesticides, biological controls and other safer pest management options and share information on alternatives to HHPs with farmers and the public. It is in this context that biological pesticides are being considered as environmentally safe, selective, biodegradable, economic and renewable alternatives to HHPs for use in farming systems and public health. However, they lack position in crop protection market and represent only 3.5% of global pesticides market [22]. The successful market for bio-pesticides can be achieved through understanding the major challenges and constraints faced by them and developing new strategies such as optimizing delivery system; screening new and better strains; educating farmers and others to cope up with encountering hurdles.

7) Implementation of International Conventions and Agreements

A number of countries have made progress towards implementation of international convention and agreements dealing with chemicals, such as Stockholm Convention on POP, Rotterdam Convention on PIC and Montreal Protocol on Substances that Deplete the Ozone Layer. The convention could also help to reduce the illegal trade of HHPs. The Convention also assists Parties to reduce risks from HHPs and provides the necessary guidance and technical assistance for sound pesticides management, including the identification of safer alternatives.

8) Collaborative Efforts

Successful achievement of phasing out HHPs requires a multi-stakeholder approach. These stakeholders include governments, academics and scientists, the pesticide industry, the food industry, farmers’ organisations, civil society and media. They would play relevant roles of assessment and deregistration, development and phasing in alternatives, awareness raising and education etc. Inter-sectoral collaboration including agriculture, health, environment and customs is essential for effective results. The engagement of industry, retailers, extension units and farmers and their organizations are crucial for adopting low risk alternatives. Custom is an authority or agency in a country responsible for collecting tariffs and for controlling the flow of goods, including hazardous items, into and

out of a country. Each country has its own laws and regulations for the import and export of goods into and out of a country, enforced by their respective customs authorities; the import/export of some pesticides may be restricted or forbidden entirely. Customs departments must be regularly advised of those products which are registered and gazette and which can be imported so that checks on imports can be made by their officers, it is very important that customs officers are vigilant in checking at the borders that only notified pesticides are introduced into the country. A system must be developed to ensure that custom office is aware of the registration status of all products and moreover that this information is transmitted to the various customs posts at the points of entry into country. There is a need for the engagement of customs for trade management of banned HHPs. Close collaboration and frequent communication must be ensured between institutions responsible for health, environment and agriculture. Any ongoing or proposed control strategy will have implications for all these sectors, and it is vital that policies and strategies are consistent and mutually supportive. Effective collaborative arrangements are important for institutions and organizations at all levels, from local to international.

9) Regional Collaboration

Many Asian countries lack adequate capacity and enough human resource and expertise to conduct complex risk assessment of HHPs. In fact, some countries in Asia have only one or two available staff. Countries with similar pesticide application scenarios in Asia can support each other by sharing data from monitoring and reporting systems for health and environmental impacts of pesticides and sharing experiences on successful phasing out of particular chemicals, including information about alternatives. Some countries such as China and Bhutan have banned most HHPs identified and shared expertise with others. A close cooperation among countries would be a strong continual driving force for achieving progress in strengthening regulatory management at both country and regional levels. As a mitigating measure, countries in Asia should establish regional collaboration on pesticide registration to reduce workload, share available resources, and improve quality of the assessment. Therefore, countries with limited human capacity for pesticide registration should establish or strengthen (sub-) regional collaboration, where applicable, to share their registration procedures, data and decisions. In addition, regional collaboration could effectively deal with the illegal trade of banned pesticides.

10) Awareness-Raising Campaigns

Awareness raising requires strategies of effective communication to reach the desired outcome. We need to raise the awareness of pesticide regulators and other relevant Government authorities, farmers, the private sector, consumers, workers, trade unions, health-care providers, research and development institutions, academia and the press (mass media) about the risks of HHPs, the availability of low risk alternatives and the desirability of making a transition to more sustainable agro-ecological approaches to pest management. Therefore, it is high time governments should raise public awareness through the use of various in-

formation and communications technology (ICT) materials available at country.

6. Conclusions

Looking into the aforementioned constraints, the use of HHPs is still a serious concern in many parts of Asia posing threats to human health and the environment. There are still many products that are harmful to humans or the environment in various modes of actions. Therefore, risk assessment and phasing out of HHP are highly relevant topics for Asian countries, both for the present situation and challenges of the future. However, an analysis of the pesticides registered in Asian countries showed that substances of WHO Classes IA and IB were registered in 13 countries, as well as POP in 3 countries, PIC in 10 countries, Mont. Prot in 3 countries, GHC Carc. in 5 countries, GHC Muta. in 9 countries and GHC Repro. Toxicity in 12 countries. Considering toxicity hazards, these pesticides may be given priority for phasing out in Asia, and this could be done without a full risk assessment procedure since their unacceptable risk is well documented and internationally agreed. Despite the environmental legislation on POPs in the country, there is still a huge gap between legislation and implementation. In this scenario, both government regulatory bodies and private sector should take initiatives for proper implementation of environmental legislation regarding POPs, PIC and Montreal Protocol chemicals in the country. Concrete actions are certainly needed to phasing out them and phasing in low risk alternatives to support achieving sustainable and resilient agri-food systems and UN sustainable development goals by 2030. This suggests a big challenge in substituting HHPs in agricultural production and public health in Asia, which needs time and greater efforts. Therefore, priority actions by national agencies, with targeted interventions and a strategy of resource mobilization are urgently needed for structural improvement of pesticide lifecycle management especially for HHPs. Actions need the support not only of governments, but also of the whole supply chain: particularly producers, traders and consumers of agricultural goods. As noted previously, these findings appeal for the development of effective public health strategies to improve farmers' awareness and provide information to IPM and IVM. IPM and IVM are both driven at the local level. The key elements of an IPM and IVM strategies include promotion and inclusion of IPM/IVM principles in public policies, empowerment of communities for community action for sustainability, collaboration within the health sector and with other sectors, such as agriculture and agriculture development projects; strong operational and implementation research support and developing tools and guidelines in local languages and training of personnel responsible for pest and vector control. At the field level, knowledge and understanding of the ecology of agricultural production systems is needed to make informed decisions on management. This knowledge needs to be decentralized to local levels. It has to be in the hands of farmers and health workers who are responsible for management of their own systems. Increasing local people participation in the development and imple-

mentation of IPM and IVM programs has emerged as a strategy for increasing the application of IPM and IVM.

In principle, Asian countries have interest in harmonizing pesticide registration and phyto-sanitary procedures and regulations through the implementation of a regional integrated production and pest management programme as a reformed strategy in pest management. Countries were encouraged to take appropriate actions in reviewing the use of HHPs and in conducting basic risk assessment when considering registration of new compounds. In conclusion phasing out HHPs in Asia is essential and achievable through governmental commitment, enhanced capacity, engagement of stakeholders and strengthened national and regional cooperation. It could start with governmental identification of HHPs based on HHPs criteria of FAO/WHO.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

- [1] FAO Survey (2021) Status of Highly Hazardous Pesticides in Asia.
- [2] FAOSTAT (2019) Pesticide Use.
- [3] Sharma, A., Kumar, V., Shahzad, B. and Tanveer, M. (2019) Worldwide Pesticide Usage and Its Impacts on Ecosystem. *SN Applied Sciences*, **1**, 1446. <https://doi.org/10.1007/s42452-019-1485-1>
- [4] WHO-FAO Survey (2018) Global Situation of Pesticide Management in Agriculture and Public Health.
- [5] Land and Human to Advocate Progress (LHAP) (2020) Jordan National Situation Report on Highly Hazardous Pesticides (HHPs).
- [6] UNICEF (2018) Understanding the Impacts of Pesticides on Children: A Discussion Paper.
- [7] FAO (2014) The International Code of Conduct on Pesticide Management.
- [8] Naidoo, S., London, L. and Rother, H.A. (2010) Pesticide Safety Training and Practices in Women Working in Small-Scale Agriculture in South Africa. *Journal of Occupational Environment Medicine*, **67**, 823-828. <https://doi.org/10.1136/oem.2010.055863>
- [9] FAO (2015) Regional Office for Asia and the Pacific. Progress in Pesticide Risk Assessment and Phasing-Out of Highly Hazardous Pesticides in Asia.
- [10] Palikhe, B.R. (2002) Challenges and Options of Pesticide Use: In the Context of Nepal.
- [11] Palikhe, B.R. (2005) Pesticide Management in Nepal: In View of Code of Conduct.
- [12] FAO and WHO (2016) Guidelines on Highly Hazardous Pesticides.
- [13] Pesticide Action Network International (2019) PAN International List of Highly Hazardous Pesticides (PAN List of HHPs).
- [14] Guardian (2013) Bhutan Set to Plough Ione Furrow as World's First Wholly Organic Country.
- [15] Paul, J. (2017) Four New Strategies to Grow the Organic Agriculture Sector. *AGRO-*

FOR, **2**, 61-70. <https://doi.org/10.7251/AGRENG1703061P>

- [16] Yubak Dhoj, G.C. (2015) Biopesticides: Effective Alternative to Organic Nepal.
- [17] Gauchan, D., *et al.* (2020) Organic Farming and Marketing of Traditional Crops in Nepal Mountains: Gaps, Issues and Opportunities for Improvement.
- [18] Meyers and Bull (2002) Pesticides: Environmental Impacts and Management Strategies.
- [19] Stephanie, W. (2017) A Short Guide Alternatives to Highly Hazardous Pesticides.
- [20] Food and Agriculture Organization of the United Nations (FAO) and KEMI (2017) Regional Programme: Towards a Non-Toxic Environment in South-East Asia Phase II.
- [21] Alwang, J., Norton, G. and Larochelle, C. (2019) Obstacles to Widespread Diffusion of IPM in Developing Countries: Lessons from the Field. *Journal of Integrated Pest Management*, **10**, 1-8. <https://doi.org/10.1093/jipm/pmz008>
- [22] Swati, *et al.* (2016) Current Challenges Constraints and Future Strategies for Development of Successful Market for Biopesticides.