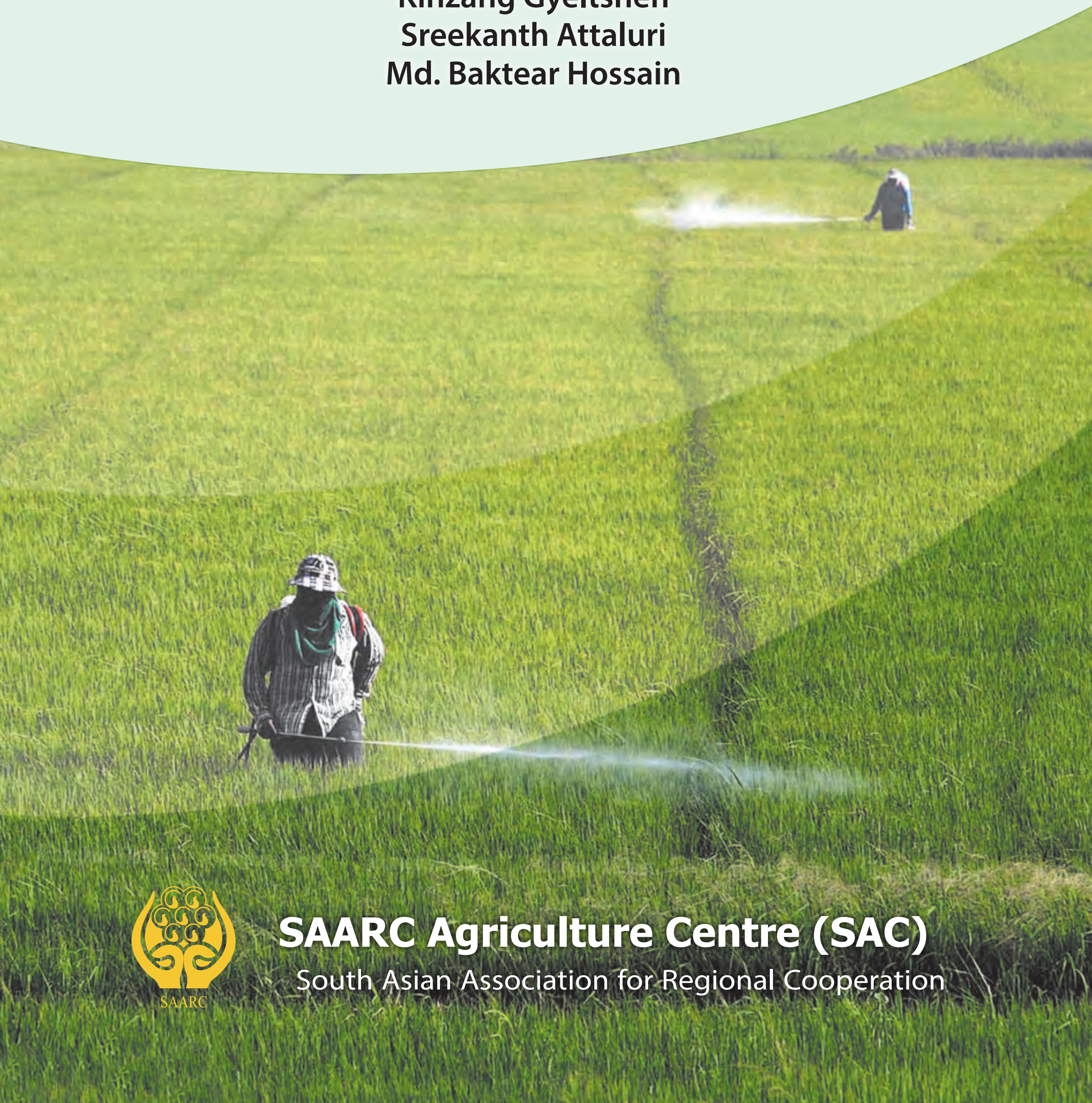
# Agricultural Chemical Inputs
## Impact and Management Strategies in South Asia

Edited by
Kinzang Gyeltshen
Sreekanth Attaluri
Md. Baktear Hossain



SAARC Agriculture Centre (SAC)
South Asian Association for Regional Cooperation

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SAARC Agriculture Centre, regional expert consultation meeting on Impact of Agricultural Chemical Inputs on the Environment and Human Health in South Asia (virtual), 21-22 April, 2021.

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# Foreword

South Asia has 43.28% of arable land available for food production with 0.11 hectare per person to meet the demand of food for over 1.8 billion populations. It is estimated that 279 million populations are undernourished with prevalence of undernourishment and food insecurity of 14.7% and 14.4% respectively. To meet the demands of agricultural goods for growing population adequately, intensification of agriculture with advanced technologies have been implemented in the region to overcome continual food scarcity by increasing the use of agricultural chemicals inputs. But the increased use of these agrochemicals like pesticides and fertilizers have adversely affected the environment and human health in the region.

A large amount of chemicals in the form of fertilizers and pesticides is applied every year in soils to increase agricultural production. Farmers view pesticides as the best means to protect their crops against pests and prevent economic loss. The use of pesticides in South Asia significantly increased from 51,901 tonnes in 2009 to 86,536 tonnes in 2019. It is reported that increased used of these agrochemicals has resulted in number of adverse impacts on the environment and human health in the region. Given the importance of agrochemicals use and its impacts in the region, SAARC Agriculture Centre organized the Virtual Regional Expert Consultation Meeting on *"Impact of Agricultural Chemical Inputs on the Environment and Human Health in South Asia"* to assess the impacts of agricultural chemical inputs on the environment and human health, and the management strategies implemented to minimize its impacts. The country status papers presented during the meeting are incorporated in this book.

This book **'Agricultural Chemical Inputs: Impact and Management Strategies in South Asia'** is published to share information on the impacts of agricultural chemical inputs on the environment and human health, policies and legislations put in place to regulate the use of agrochemicals, and effective management strategies implemented in the region to reduce its adverse impacts. This publication also contains the recommendations of the meeting, which covers policy, strategy, management and capacity development aspects of agricultural chemicals use and its strategies to minimize adverse impacts. Finally, I would like to thank Mr. Kinzang Gyeltshen Senior Program Specialist (NRM) and Dr. Sreekanth Attaluri, Senior Program Specialist (Crops) for their commitment and dedication in publishing this important book.

**Dr. Md. Baktear Hossain**
Director
SAARC Agriculture Centre
Dhaka, Bangladesh

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Chapter 1

# Impact of Agricultural Chemical Inputs on Human Health and Environment in South Asia

**Kinzang Gyeltshen**
SAARC Agriculture Centre
Dhaka, Bangladesh
*kinzang@sac.org.bd; kingyel@hotmail.com*

## 1. Introduction

Agricultural chemical inputs are pesticides, herbicides, fungicides, insecticides, and fertilizers used in agriculture for controlling pests and disease, or controlling and promoting growth of crops. In South Asia, 43.28 percent of arable land is available for food production with 0.11 hectare per person to meet the demand of food for 1.8 billion populations (World Bank, 2019a). World Bank (2019c) revealed that 35 percent of the world's poor live in South Asia and 16 percent of its population live below the extreme poverty line. Further, 279 million people are undernourished with prevalence of undernourishment and food insecurity of 14.7 percent and 14.4 percent respectively (FAO, 2019). High population growth and increasing demand on agriculture for food security and livelihoods are posing serious threats in South Asia, where soils have been affected by intensive agriculture and a heavy reliance on agricultural chemical inputs. To meet the demands of agricultural goods adequately, intensification of agriculture with advanced technologies have been implemented in the region to overcome continual food scarcity by producing more food and other agricultural products using high-yield varieties of seeds, modifying farm equipment and substantially increasing the use of agricultural chemical inputs. Applications of chemicals like fertilizers and pesticides have become necessary for optimizing agriculture production and to feed the growing population. But these agricultural chemical inputs adversely affect the environment and human health in a process of increasing agricultural production.

Over 64 percent of the population in South Asia lives in rural areas and the majority of the population make their livelihoods on surrounding natural resources, triggering rapid degradation of natural resources. The ongoing degradation of soils and ecosystems in the region threaten the sustainability of food production. Further, the use of various chemicals has been a boon for the farmers in increasing agricultural yield although the efficiency rate of these chemicals has been declining over time. This has led to an increased use of these chemicals, which adversely affect soil fertility, water and air qualities, and increased greenhouse gas emissions. The remaining chemicals not used by crop uptake and for intended purpose get accumulated in soil, where it filters into ground or surface water, thereby affecting the health of microorganisms, aquatic animals and humans. Farmers in the region are experiencing either short-term or long-term health effects from exposures to agricultural chemicals, including severe symptoms like headaches, skin rashes, eye irritations and some chronic effects.

A large amount of chemicals in the form of fertilizers and pesticides is applied every year in soils to increase agricultural production. Policy makers recognized that applying excessive and unsystematic agrochemical inputs is a problem in developing a sustainable agriculture, besides posing threat to environment and human health. South Asian countries have enacted policies to regulate the use of agricultural chemicals, including volume and types of chemicals. However, farmers do not follow appropriate chemical usage and safety precautions, and inappropriate use of these chemicals in large amounts is leading to several negative impacts on human health and environment. This chapter is prepared based on the country papers submitted by respective national focal experts of eight South Asian countries for virtual consultation meeting on impacts of agricultural chemical inputs on the environment and human health in South Asia. It also drew on the discussions and recommendations of the consultation.

## 2. Policies and Regulatory Frameworks

The green revolution has resulted in high productivity of crops through a number of adapted measures and helped countries in the region in overcoming major problems of food insecurity and alleviating poverty. However, the green revolution significantly increased the use of inorganic fertilizers and pesticides. After repeated use of these chemical inputs over the years in the agricultural production systems, several unintended and harmful effects on human health and environment have emerged. To counteract these challenges in agriculture, South Asian countries had developed policies and regulations to manage the use of agricultural chemicals appropriately and judiciously. Policies and legislations are key to minimizing adverse impacts on soils, water, air, biodiversity and health of agricultural farming communities by regulating judiciously use of chemical inputs and enhancing sustainable agriculture systems.

All countries in the region have agricultural policies in place to guide the agriculture sector to produce safe and sustainable agricultural food through balanced and cautious use of chemical inputs. These policies are supported by legal instruments, guidelines and standards to achieve the policy objectives. Every country in the region has established policy and regulatory frameworks for managing chemical inputs and producing safe food with minimal impacts on human health and environment. Bangladesh's National Agricultural Policy 2018 provides a set of guidelines relating to fertilizers and pesticides management. This policy encompasses optimum use of chemicals inputs, pest management, monitoring, research, strategies and other control measures applicable in the country. The Pesticides (Amendment) Act, 2009 regulates the use of pesticides in Bangladesh agriculture system. Good Agricultural Practices Policy 2020 was also developed to ensure safe and quality agricultural products in Bangladesh. In Bhutan the Pesticides Act 2000 ensures integrated pest management, and limits the use of pesticides as the last resort in control of pests. Only appropriate types and quality of pesticides are permitted in the country. Moreover, National Framework for Organic Farming 2006 provides a sustainable agriculture strategy and Integrated Pest Management (IPM) promotes safe and efficient use of pesticides to protect the environment and prevent pollution through their indiscriminate use.

India is the major producer and consumer of agricultural chemical inputs in South Asia. The Government of India (GoI) has been regulating the sale, price, and quality of fertilizers under an essential commodity act, called Fertilizer Control Order 1957, which was revised several times till 1985, called Fertilizer Control Order 1985. India has the Insecticides Act 1968, the Insecticides Rules 1971, and Pesticides Management Bill 2008. Maldives has the Act number: 21/2019: Agricultural Pesticide Control Act and Regulation number: 2021/R-12; Agricultural Pesticide Control Regulation endorsed in 2019 and 2021 respectively. The main aims of the agricultural pesticides control legislations are to regulate the agricultural pesticide use, manufacture, import, export, sale, and disposal. Nepal has Agriculture Policy 2004 which emphasized on eco-friendly production system, organic farming and Integrated Pest Management practice for sustainable agriculture development and food safety. Furthermore, Nepal has Plant Protection Act, No. 2064 and Rules, No.2066; Pesticide Management Act, No. 2076; Food Act, No. 2023 (1966) and Food Rules, No. 2027 (1970); Aquatic Life Protection Act, 1961 and Rules; National Fertilizer Policy No. 2058. In Pakistan, the pesticides business is managed by the Ministry of National Food Security and Research under Pakistan Agricultural Pesticides Ordinance 1971 and Pakistan Agricultural Pesticides Rules 1973 through the Department of Plant Protection. Sri Lanka has two separate Acts to manage and control the use of agrochemicals: Pesticides Act No. 33 of 1980 and Fertilizer Act No. 69 of 1988. The Fertilizer Act regulates the importation, manufacture, formulation and distribution of fertilizer. Stringent regulations are provided by the Control of Pesticides (Amendment) Act No. 06 of 1994 for licensing of traders, appointment of authorized officers to seize pesticides outlets by conducting inspections, empowered and entrusted on the functions related to the registration and regulation of pesticides in Sri Lanka.

## 3. International Conventions

The Basel, Rotterdam and Stockholm Conventions are multilateral environmental agreements, which share the common objective of protecting human health and the environment from hazardous chemicals and wastes. These conventions are part of the international actions to promote the sound management of chemicals throughout their life cycle and waste, and prevent and minimize adverse effects on human health and the environment (United Nations, 2015). The Conventions contribute to making consumption and production patterns and waste management more sustainable and hence reduce direct discharge or land runoff of hazardous pollutants or wastes into the environment.

These three international conventions govern the manufacture, trade, transboundary movement and other aspects of hazardous chemicals that include a number of pesticides. The Stockholm Convention aims to eliminate or reduce the release of twelve Persistent Organic Pollutants (POPs) which is also called as 'Dirty Dozen'. Out of twelve POPs, nine are pesticides. Further, through an amendment in 2009, nine more POPs have been added to the list, of which five are pesticides. The Rotterdam Convention on the Prior Informed Consent Procedure has thirty certain hazardous chemicals and pesticides in international trade. These conventions play an important role in controlling and preventing hazardous chemicals and pesticides effects on human health and environment. Almost all countries in South Asia have ratified three conventions which will eventually lead to safe use of pesticides and abide by the conventions on the use of banned pesticides as shown in table 1.

**Table 1: Status of International Conventions ratified by South Asian Countries.**

| Country | International Conventions and Date of Ratification | | |
|---|---|---|---|
| | Basel Convention | Rotterdam Convention | Stockholm Convention |
| Afghanistan | 25/03/2013 | 06/03/2013 | 20/02/2013 |
| Bangladesh | 01/04/1993 | ----- | 12/03/2007 |
| Bhutan | 26/08/2002 | ----- | ------ |
| India | 24/06/1992 | 24/05/2005 | 13/01/2006 |
| Maldives | 28/04/1992 | 17/10/2006 | 17/10/2006 |
| Nepal | 15/10/1996 | 09/02/2007 | 06/03/2007 |
| Pakistan | 26/07/1994 | 09/09/1999 | 17/04/2008 |
| Sri Lanka | 28/08/1992 | 19/01/2006 | 22/12/2005 |

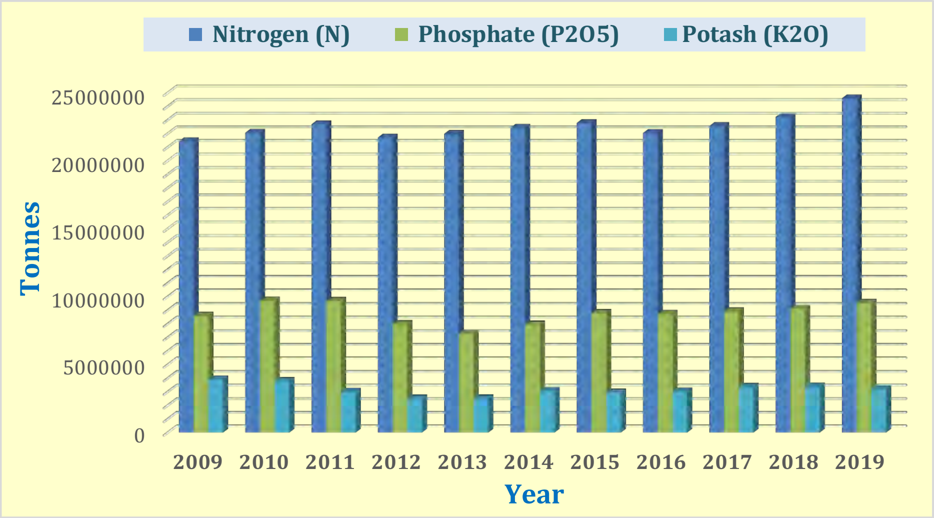
*Source: brsmeas, 2021. (www.brsmeas.org)*

## 4. Agricultural Chemicals Use

The use of agricultural chemicals intensified after the Green Revolution in developing countries, especially in South Asia, to feed the growing populations and reduce poverty and malnourishment. The agrochemical use has correspondingly increased agricultural yields and lifted millions of populations out of poverty in the region.

### *4.1. Fertilizers*

South Asia is the second largest fertilizer consumer in the world with 149 percent of fertilizer consumption and 160 kilograms per hectare consumption in arable land (World Bank, 2019b). Chemical fertilizer use is highly beneficial to plants in supplying deficient nutrients; it also provides several other conveniences such as cheaper source of nutrient, higher nutrient content, immediate availability, and more responsive than organic fertilizer. It is evident that chemical fertilizer can significantly increase crop yield and improve soil fertility. Further, based on site-specific soil tests, deficient nutrients can be supplemented with chemical fertilizer with the right quantity depending upon the need and type of crops. However, on the other hand, there is evidence that conventional agriculture practices of applying high quantities of chemical fertilizers over the years leads to low fertilizer use efficiency, decline in crop yield, degrade arable land, and pollute the environment. There are also reports of excessive use of chemical fertilizers and low economic return due to low crop responses to fertilizers and undermined food security. Fertilizers like Nitrogen, Phosphate and Potash use in agriculture in South Asia from 2009 to 2019 is shown in figure 1.




*Source: FAOSTAT, 2021*

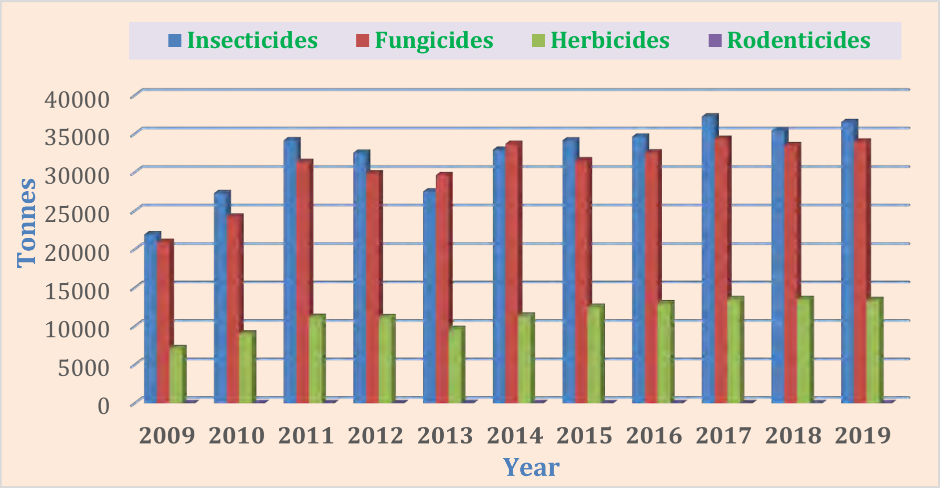
**Figure 1: Fertilizers Use in South Asia**

The brief highlight of fertilizer use in South Asian countries is as under:

In Bangladesh, fertilizer use has increased over time due to expansion of irrigation facilities and depletion of soil fertility induced by high cropping intensity and cultivation of high yielding crop varieties. The chemical fertilizer consumption was three million metric tonnes in 2008-2009, but it increased to 5.6 million metric tonnes in 2019-20. Bhutan's import of chemical fertilizers increased from about 319 metric tonnes in 1976-77 to 3,015 metric tonnes in 2018. The highest quantity of chemical fertilizer (3,398.28 metric tonnes) was distributed in 2015 which corresponds to about 42.1 kg of fertilizer per hectare of cropped land and these fertilizers are mostly applied to cash crops such as potatoes and apples. In India, the annual fertilizer consumption increased many folds, from consumption of 2.26 million tonnes in1970-71 to 28.97 million tonnes in 2019-20. The overall NPK consumption in India has grown 11.84 times from 1970 to 2018-19. In Maldives, the import of chemical fertilizer gradually decreased from 2017 to 2020; however, import of organic fertilizers like manure and compost steadily increased over the same period. Despite the fact that chemical fertilizers are imported at a small scale, Maldivian farmers give equal importance to using chemical fertilizers with organic ones. Nepal has targeted to increase the use of chemical fertilizer up to 131 kilogrammes per hectare. The import and distribution of chemical fertilizer is managed by corporations and the allocation of subsidized and managerial budgets were provided to those corporations through the Ministry of Agriculture and Livestock Development. The average consumption of fertilizer in Nepal is about 19.65kg/ha. Pakistan's consumption of chemical fertilizers in 2018-2019 was 8 million metric tonnes and about 52 percent were used in Rabi season while 48 percent in Kharif season when cotton, rice, maize and sugarcane are planted. Most of the demand for fertilizers was met domestically and small quantities were imported. Since 1950s, Sri Lanka started to use inorganic fertilizers such as Urea, Triple Super Phosphate and Muriate of Potash etc. to enhance the crop yields. Currently, the use of inorganic fertilizer is widespread in agriculture. Urea is the most widely used fertilizer, followed by muriate of potash and triple super phosphate. The consumption of chemical fertilizer in paddy is highest among the crop sector followed by tea in Sri Lanka.

### *4.2 Pesticides*

Pesticides used in agriculture are mainly insecticides, fungicides, herbicides, rodenticides etc. The use of pesticides in South Asia increased after the Green Revolution and it is now widely used in the crop production system. Farmers consider pesticides as the best means to protect their crops from pests. Pesticides are now considered an integral part of modern life as they continue to be used to protect agricultural land, granaries, and backyard gardens as well as to eradicate pests that transmit infectious diseases. It is also considered to contribute to food security and alleviate poverty. Although the application of pesticides has lots of benefits as highlighted above, it also has negative impacts on human health and environment. In general, it has been estimated that only about 0.01 percent of the pesticides reach the target organisms and the remaining bulk ends up contaminating the surrounding environment (Carriger *et al.*, 2006). The pesticide consumption in South Asia increased from 51,901 tonnes in 2009 to 86,563 tonnes in 2019 (FAOSTAT, 2021). The trends of the use of insecticides, fungicides, herbicides and rodenticides in South Asia from 2009 to 2019 is shown in Figure 2.




*Source: FAOSTAT, 2021*

**Figure 2: Pesticides Use in Agriculture - South Asia**

The brief highlight of pesticides use in South Asian countries is as under:

Pesticides use in Bangladesh started from the mid-50s and gained momentum in early 1970s with the beginning of the Green Revolution through the use of high yielding varieties of rice. In 1979, pesticide subsidy was totally withdrawn and sale of pesticides were left to the private sector. In 2009, more than 45 thousand metric tonnes of pesticides were used. After 2011, the consumption decreased, but again from 2017 it slightly increased. However, pesticide consumption in 2019 was around 38 thousand metric tonnes, which was around 15 percent less than 2009's consumption. Bhutan promoted the use of chemical pesticides in the 1980s by providing subsidies to the farmers. However, after realizing their negative impacts on human health and environment, the subsidy was withdrawn in a phase-wise manner (15% yearly) from 1990 to 1995, and simultaneously the cash and carry system was introduced as an important part of pesticide reduction strategy. India is the fourth largest producer of pesticides in the world. Domestic production has not only enabled India to become self-sufficient but also an important exporter of pesticides. The use of pesticide in India has been less than 0.5 kg $ha^{-1}$.

In Maldives, pesticides from different classes, uses, mode of action, concentrations to different formulations are being used. The import data for these chemical pesticides shows that insecticides represent the bulk of annual pesticide imports. Fungicides, herbicides and plant growth regulators are also imported in comparatively low quantities. The negligible quantity of rodenticide and molluscicide are being imported for use in domestic pest management. Pesticides gained popularity during the transitional stages from traditional to conventional farming and when farmers believed that the use of chemical pesticides are effective and economically efficient as a pest management strategy. Most of the pesticides used in Nepal are imported from India, some from China and other countries on the basis of registration. The use of chemical pesticides in Nepal is 0.396 a.i.kg/ha. Pesticide use is higher in fruits and vegetable production and in areas having greater access to markets. However, market-oriented production and agricultural intensification led to increased use of pesticide in Nepal.

In Pakistan, pesticides were introduced in 1954, but ironically Pesticide Ordinance and Rules were adopted almost 17 years later in 1971 and 1973 respectively. There was a major shift in pesticide policy in 1980 which resulted many folds increased in pesticide consumption. Pakistan does not manufacture active ingredient (a.i.) of pesticide rather imports pesticides under different registration schemes. Over the past few decades, the share of insecticides in the total pesticides' consumption has been decreased from 74 percent to 56 percent, while that of herbicides has increased from 14 percent to 29 percent and acaracides has been increased from 1 percent to 4 percent. The share of fungicides and fumigants remain constant at 9 percent and 2 percent respectively. Major chunk of the pesticides (65-70%) go to cotton crop followed by other crops that are mainly horticulture crops (30-35%). In Sri Lanka, registered pesticides published by the extraordinary gazette no 1994/71 issued on 24.11.2016 are 126 active substances including 47 insecticides, 32 herbicides and 47 fungicides representing nearly 440 agricultural pesticides for commercial use. Sri Lanka is moving towards further reduction of highly hazardous pesticide formulations in agriculture. Pesticide classifications are done according to the WHO hazard classifications and it is highly encouraged to use class III pesticides with blue label and class IV pesticide with green label.

## 5. Impact of Agricultural Chemical Inputs on Human Health

Farmers in the region face either short-term or long-term health effects from exposures to agricultural chemicals, and suffer from severe symptoms like headaches, skin rashes, eye irritations and some chronic effects. Usage of pesticides, insecticides and various chemicals in agriculture is a very easy, quick and inexpensive solution for controlling weeds and insect pests. But its use comes with a significant cost as they contaminate almost every part of the environment and affect human health. The impacts of agricultural chemicals on human health are as under:

### *5.1 Acute illness*

Pesticides drift from agricultural fields, exposure to pesticides during application and intentional or unintentional poisoning leads to the acute illness in humans (Dawson *et al.,* 2010). Several symptoms such as headache, body aches, skin rashes, poor concentration, nausea, dizziness, impaired vision, cramp, panic attacks and severe cases of coma and death could occur due to pesticides poisoning (Pan-Germany, 2012). This acute illness mainly occurs because farmers do not use safety masks, gloves and other protective gears while spraying pesticides. Exposure to pesticides affects eyes, skin and respiratory system. Farmers in Bhopal, Madhya Pradesh, who have been exposed to pesticides for eighteen months through spraying reported acute signs and symptoms of burning and stinging of eyes, blurred vision, skin redness and itching, shortness of breath, dry sore throat and burning of nose (Sharma and Singhvi, 2017).

### *5.2 Chronic illness*

Farmers have higher risk of getting chronic illness as they are exposed to agricultural chemicals over many years. It is reported that farmers in the region do not use protective gears due to hot and humid climatic conditions and lack of awareness about the risk of pesticide exposure. They are directly exposed to pesticides resulting in a number of acute as well as chronic diseases. The general populations also get exposed through contaminated food and water from agricultural fields. Incidences of chronic illness grow as more and more pesticides are applied in the field leading to the increased content of pesticides in the ecosystems. There is a link between pesticides exposure and the incidence of human chronic disease affecting nervous, reproductive, renal, cardiovascular, and respiratory systems (Mostafalou and Abdollahi, 2012).

The study conducted by Riaz *et al.,* 2017 found a correlation between pesticide exposure, physical health and susceptibility towards tuberculosis along with alterations in hematological indices liver enzymes in pesticide operators in Punjab, India. In Nepal, nearly 51 percent of farmers experienced an acute toxicity syndrome of pesticides and one of ten farmers reported several kinds of chronic diseases of which 24 percent of farmers had chronic neuropathic disease (Aryal *et al*., 2016). The study conducted by Shammi *et al.,* 2020 in Bangladesh has revealed that farmers exposed to pesticides suffer from acute as well as chronic illness. Farmers reported to have experienced headache, vomiting, feelings of unconsciousness, stomach ache, weakness, skin and eyes problems after exposure to pesticides.

## 6. Impact of Agricultural Chemicals Inputs on the Environment

Pesticides and fertilizers applications play a vital role in increasing agricultural production and ensuring the supply of agricultural products. Spraying pesticides can significantly reduce or offset the economic costs from plant diseases, insect pests, and weeds on agricultural production. Similarly, fertilizer application can provide a variety of nutrients required for the growth of crops and for an increased crop yield. However, there are reports from South Asian countries about the alarming residues of agricultural chemicals in soil, water, air, agricultural products, and even in the human body. Pesticides have contaminated our environment and pose significant risks to the environment and non-target organisms ranging from beneficial soil microorganisms to insects, plants, fish, and birds. The issue of hazards posed by agricultural chemicals to human health and environment has raised concerns in the region. The impacts of agricultural chemicals on the environment are as under:

### *6.1 Water contamination*

Farmers in South Asia apply much more chemical fertilizers than what is actually required by crops and in unfavourable environmental condition. The excess nutrients, especially N nutrient, get lost to surface and groundwater through leaching, drainage and surface runoff. One of the main parameters of the pollution of water is the nitrate, which is the key component of fertilizer. Nitrate is also the most common form of dissolved nitrogen present in groundwater or other water bodies. When nitrate concentration exceeds the safe standard in drinking water or high nitrate accumulation leads to health complications like gastric cancer, 'blue baby syndrome' and other diseases. The intensive use of nitrogen and phosphorus fertilizer led to eutrophication, which resulted in increased growth of aquatic plants and algae in water bodies leading to the loss of other aquatic lives due to reduced supply of oxygen.

Application of pesticides in agricultural fields reach to various water bodies by runoff or drainage induced by rain and irrigation. Pesticides residues in water bodies are harmful to fishes and non-targeted aquatic lives and its biodiversity. Pesticides also reach ground water through drainage of degraded surface water and improper disposal and spills. Aquatic ecosystems are seriously being affected by pesticides residues in lakes, streams and other water bodies. These pesticides residues in water cause fish and other amphibian mortality and also kill aquatic plants.

### *6.2 Soil Contamination*

Soils in the South Asian region are contaminated by overuse of agrochemicals in agricultural fields where uptake of nutrients by plants is far less than the fertilizer applied. This leads to toxic build-up of heavy metals such as arsenic, cadmium, and uranium in the soil and in the process get into vegetables. Repeated use of fertilizer over time also leads to soil acidification, soil degradation, nutrients imbalance, reducing soil organic matter, and changing soil properties and functions, thereby declining soil productivity.

Pesticides used for agriculture get accumulated in soil due to indiscriminate and repeated use by farmers. Pesticides in soil alter the soil microbial diversity and microbial biomass eventually leads to the disturbance in the soil ecosystem and loss of soil fertility (Gill and Gaur, 2014). It also adversely affects the growth, microbial diversity or microbial biomass of soil microflora. Further, pesticides affect the soils vital chemical reactions such as nitrogen fixation, nitrification, and ammonification by activating or deactivating specific soil microorganisms.

### *6.3 Impact on non-targeted organisms*

It has been estimated that only about 0.01 percent of the pesticides reach the targeted pests and the remaining percent of pesticides affect the non-targeted organism and surrounding environment (Carriger *et al.,* 2006). With the use of pesticides over time, even the targeted organism develops more resistance which is the most serious hindrance for effective use of pesticides. There is also a case of secondary pest resurgence because pesticides kill the beneficial natural enemies which control the pest population.

Indiscriminate application of pesticides in agricultural systems severely affects soil invertebrates like nematodes, springtails, mites, micro-arthropods, earthworms, spiders, insects and other organism which make up the soil food web and enable the decomposition of organic compound (Gill and Gaur, 2014). Pesticides also affect predators which prey on pests making it difficult to control pests through biological means. Further, application of pesticides affects various activities of pollinators including foraging behaviour and pollen collecting efficiency resulting in decline of crop productivity.

### *6.4 Air pollution*

Application of chemical fertilizer for increasing agricultural production generates greenhouse gases that contribute to depleting the ozone layer. Agriculture accounts for 60 percent of anthropogenic $N_2O$ emission and agricultural soils are the dominant source (Shoji *et al.,* 2001). Nitrogen fertilizer is converted into nitrous oxide by soil bacteria and it is responsible for air pollution, ozone depletion, global warming etc. Ammonia emitted from agricultural fields because of fertilizer application gets into the atmosphere and oxidized to become nitric acid and sulfuric acid thereby creating acid rain damaging vegetation and contaminating lakes and reservoirs. Spraying of pesticides also causes air pollution as chemicals escape into the atmosphere directly or through volatilization.

## 7. Management Strategies to Minimize Impact of Agricultural Chemicals

Agricultural chemicals are considered as a quick, easy, inexpensive and effective means to control weeds and pests and enhance agriculture productivity. However, the country papers of the region report serious environmental and health hazards affecting the human endocrine and immune systems and contaminating every part of the environment. Agricultural chemical residues found in soil, air, and surface and groundwater across the region are posing significant risks to the environment and non-target organisms ranging from beneficial soil microorganisms, to insects, plants, fish, and birds (Kumar *et al.,* 2013). Therefore, it is imperative to have a management strategy for the region to minimize these adverse impacts from agricultural food production systems. The following are the strategies gathered from country papers of region and also drew from discussions and recommendations of the regional consultation meeting:

### *7.1 Review and strengthen agricultural chemical policies and legislations*

All countries in the region have policies and legislations regulating the availability, distribution and use of agricultural chemicals and ensuring the allocation of adequate resources for overall management of these chemicals. These policies and legislations have been implemented in respective countries, but there are reports of a number of adverse impacts associated with agrochemicals on human health and environment. Consequently, the strong need for reviewing and fine-tuning existing policies and legislations emerged from regional consultation meeting to create an enabling environment for managing new challenges of agrochemicals impacts.

Existing policies and legislations must be reviewed by considering current issues and challenges of agricultural chemicals management, and reduce health and environmental risks by fine-tuning them. The following points should be incorporated and integrated in policies and regulations to create enabling environment for minimizing adverse impacts of agricultural chemicals inputs:

- Incorporate provisions for regular reviews of fertilizers and pesticides which are marketed, their acceptable uses and availability, carry out health surveillance programmes of those who are occupationally exposed to pesticides;
- Strengthen regulations on providing extension services, agricultural and public health advisory services to farmers and public health workers;
- Incorporate provisions to strictly restrict the sale of pesticides to the general public through unregistered or non-specialized outlets and ensure each pesticide product is adequately and effectively tested by recognized bodies and publicize the dangers and direction of pesticides use;
- Integrate provisions to regulate pesticide residues in food, feed, drinking water, and the environment; the need for collecting reliable data, maintaining statistics on environmental contamination and adverse effects; reporting specific incidents related to pesticides to relevant authorities;
- Strengthen regulations on the use of personal protective equipment and make provisions for safe storage of pesticides at wholesale, retail, warehouse and farm levels;
- Incorporate provisions, which create an ideal environment for research and development, and promote and adopt technologies like Integrated Plant Nutrient Management, Integrated Pest Management, Good Agriculture Practices and other emerging approaches contributing to reducing adverse impacts on human health and environment.

### *7.2 Integrated Plant Nutrient Management*

Integrated Plant Nutrient Management (IPNM) is an approach to enhance soil productivity through a balanced use of chemical fertilizers in combination with organic and biological sources of plant nutrients. While it ensures sustainable food production and protects the environment, it is not widely practiced by the farming communities in South Asia. Blanket use of chemical fertilizers without implementing IPNM technology has led to surface water and groundwater pollution from the excess load of nutrients through leaching and run-off. Eutrophication in rivers, lakes and inlets take place due to high concentration of nutrients in water, which in turn promotes algal growth. Through adoption of IPNM by farmers, the rate of land degradation can be slowed down, soil fertility can be maintained, and emission of greenhouse gases minimized, which in turn will contribute to sustainable management of natural resources and mitigate climate change for sustainable food production (Gyeltshen, 2020).

Adoption of IPNM by the farming communities in South Asia will significantly reduce adverse environmental impacts and contribute to environmental sustainability. Practicing IPNM will induce balanced use of chemical fertilizers and organic manures. Bio-fertilizers will enhance soil productivity for sustainable crop production and maintaining environmental quality. Most of the countries in the region have developed IPNM modules for major crops and cropping systems for different agroecological zones. It is important to create an ideal and enabling environment for farmers to practice IPNM widely for their better livelihoods and for sustainable crop production without compromising the quality of the environment for future generations. IPNM addresses environmental concerns by optimizing fertilizers applications according to the needs of the crops and soil conditions in order to avoid excessive applications and prevent potential nutrients loss to water or air. Adoption of IPNM can reduce or prevent adverse environmental impacts like soil erosion, land degradation, soil contamination, degradation of soil properties, water pollution, eutrophication, acid rain and greenhouse gas emission (Kurbah, 2016).

### *7.3 Integrated Pest Management*

Integrated Pest Management (IPM) has considered all available pest control techniques and integration of appropriate measures that discourage the development of pest populations and keep pesticides and other interventions to levels that are economically justified and reduce risks to human and animal health and to the environment (FAO and WHO, 2014). IPM emphasizes the growth of a healthy crop with the least possible disruption to agroecosystems and encourages natural pest control mechanisms in agricultural fields. In South Asia, it is reported that vigorous research on IPM has been carried out in most of the countries and adopted viable IPM technologies to reduce use of harmful pesticides and promote use of biopesticides. However, there is a need for continuous research on developing IPM technologies with the changing environment and promote adopting IPM technologies widely with support from extension agents. Concerted efforts should be made by governments to develop and promote the use of IPM technologies to reduce adverse impacts on human health and environment.

The international code of conduct on pesticide management 2014 recommends the development of national IPM policies and improved IPM concepts and practices with support from lending institutions, donor agencies and governments. These should be based on strategies that promote increased participation of farmers including women's groups, extension agents and on-farm researchers, communities, and relevant entities from the public health and other sectors (FAO and WHO, 2014). All stakeholders, including farmers and farmer associations, IPM researchers, extension agents, food processing industries, manufacturers of biological and chemical pesticides, public health workers, environmentalists and representatives of public interest groups should play a proactive role in the development and promotion of IPM technologies.

## *7.4 Good Agricultural Practices*

Good Agricultural Practices (GAP), as defined by FAO (2016), is a "collection of principles to apply for on-farm production and post-production processes, resulting in safe and healthy food and non-food agriculture products, while taking into account economic, social and environmental sustainability". Adoption of GAP by farmers will improve the safety and quality of their produce while at the same time protecting the environment and safeguarding the health and safety of farmers themselves (FAO, 2016). GAP encompasses a range of levels of pesticides and fertilizers applications, up to the highest authorized use, applied in a manner which leaves a residue which is the smallest amount practicable.

In South Asia, SAARC-GAP was introduced by FAO, first in four SAARC Member States of Bangladesh, Bhutan, Maldives and Nepal through a Technical Cooperation Project (TCP) in 2015-2016. During this period, FAO in collaboration with governments of implementing countries adopted the SAARC-GAP through several processes and adopted it with required modifications. These countries adopted SAARC-GAP as their own GAP and named it Bhutan-GAP, Bangladesh-GAP, Maldives-GAP and Nepal-GAP. Later, FAO also introduced SAARC-GAP to Sri Lanka as SL-GAP and Afghanistan as Afghan-GAP and accordingly developed a certification system in line with the SAARC-GAP Scheme requirements. Although GAP was introduced in most of the countries in the region, its adoption rate is very low. It is important for the governments to promote and support farming communities to adopt GAP by providing incentives and effective extension services, impart training and awareness to minimize the adverse impacts of agricultural chemicals impacts.

## *7.5 Organic Farming*

Organic farming is one of the strategies to minimize adverse impacts of agricultural chemical inputs on human health and environment in South Asia. It is an efficient and promising agricultural approach, which ensures stable yield, improves soil fertility, does not pose environmental problems, and reduces the use of pesticides and inorganic fertilizers. Organic agriculture provides benefits in terms of environmental protection and safety of human health, conservation of non-renewable resources, improved food quality, and reorientation of agriculture towards areas of market demand (Shrestha *et al.,* 2021). Organic farming avoids the use of inorganic fertilizers and pesticides as well as traditional methods of agricultural farming. The environmental and economic benefits of organic farming can be increased through introduction of policies that bring prices of inputs in line with their full economic costs, including externalities; improvement in product standards, certification and labelling to give consumers confidence (Norse, 2003).

In South Asia, organic farming has been promoted and adopted in most of the countries. There are organic farming policies and regulations put in place in most of the countries to guide and encourage farmers to practice organic farming, but still, it is not widely practiced as envisaged. The governments of the region should provide assistance to farmers wishing to switch to organic farming, enact favourable regulations to encourage organic farming, increase research to widen the range of organic agricultural techniques, improve access to organic inputs, increase capacity building in extension systems, and remove barriers to the expansion of organic farming. Further, governments should facilitate marketing of organic products, which have short shelf-life and the prices are comparatively higher than the normal produce. With the development and improvement of living standard of general populations in the region, demand for organic products will steadily increase and gradually organic farming will be a sort of consumer-driven agricultural practices. If organic farming spearheads in the region as envisaged, then it will significantly contribute in reducing adverse impacts of agricultural chemicals on human health and environment.

### *7.6 Research and development*

Research and Development (R&D) are key to the developing agriculture sector and to feed millions of populations in the region. Agriculture research is well-established in all countries of the region, but to meet the emerging needs and develop the latest agricultural technologies, R&D should be strengthened. There should be vigorous research programmes to develop agricultural technologies which contribute to reducing agrochemicals use and minimizing its adverse impacts on environment and human health. National governments, with the support of relevant international and regional organizations, and donor agencies, should encourage and promote research on developing alternatives such as biological control agents and techniques, non-chemical pesticides and pest control methods, pesticides that are of low risk to human health, and environment that as far as possible or desirable, are target-specific, and that degrade into innocuous constituent parts or metabolites after use (FAO & WHO, 2014).

Governments should collaborate with international organizations and other interested bodies to consider assisting in the establishment of analytical laboratories, or strengthening existing laboratories from time to time to meet the needs of testing pesticides and fertilizers as well as to test pesticides residues in food, water, air and the environment. All such laboratories should be set up in a manner that assures their economic and technical sustainability. These laboratories should adhere to sound scientific procedures and guidelines for good laboratory practice, possess the necessary expertise and adequate analytical equipment and supplies of certified analytical standards, solvents, reagents and appropriate, up-to-date analytical methods (FAO & WHO, 2014). These laboratories should be able to detect and control counterfeiting and illegal trade in pesticides and fertilizers through national and intergovernmental cooperation and information sharing. It will also provide services to regulate and monitor pesticide residues in food in accordance with the national or regional standards.

### *7.7 Capacity development*

Capacity development is one of the important management strategies to minimize adverse impacts of agricultural chemicals on the environment and human health. It is crucial to develop the capacity of stakeholders at various stages of agricultural production systems to minimize negative impacts of agrochemical usage in agriculture. Capacity building is vital for agrochemicals regulators, researchers, managers, extension agents, farmers, community groups, retailers, producers to reduce health and environmental risks. Capacity of researchers and managers should be developed with the latest available technologies at the international level to ensure regular testing and analysis of agrochemicals and its residues. It is also equally important to build the capacity of stakeholders involved in the supply chain of agricultural chemicals inputs, so that industries produce the right agrochemicals in consultation with researchers and regulators.

Farmers in South Asia, most of whom are smallholders, are at the forefront of using agricultural chemicals. They can play a major role in minimizing negative impacts. As the region consists of least developed and developing countries, most farmers are illiterate and semi-literate. Thus, governments should plan massive capacity building programmes. It is reported that smallholder farmers without much knowledge of agrochemicals apply excessive quantities of fertilizers and pesticides to protect their crops and increase crops yield. This blanket application of pesticides and fertilizers is causing a number of health hazards and serious adverse impacts on the environment. Therefore, it is imperative to educate and train farmers through Farmers' Field School on using personal protective equipment, storing agrochemicals safely, application methods, preparation, and disposal. Farmers should be trained and made aware of a series of adverse impacts on their health and surrounding environment caused by irresponsible use of pesticides and fertilizers, and the role they will have to play in preventing these impacts. Further, they should be trained on IPNM, IPM, GAP, and organic farming so that they will be able to adopt these technologies to minimize adverse impacts of agricultural chemicals impacts on the environment and human health.

## 8. Conclusion

Is it possible to feed the populations of the region without agricultural chemicals? This is a critical question we all should ponder and contemplate ourselves to shape the future agricultural production systems in South Asia. The answer to this important question is NO since it was the Green Revolution which significantly increased food production through massive use of agrochemicals and lifted millions of populations in the region out of poverty. But at the same time, we cannot afford to be complacent about the adverse effects of agricultural chemicals on the environment and human health. There are well-documented evidences and reports from all countries of the region that the use of agricultural chemicals like fertilizers and pesticides has resulted in number of adverse impacts like water and air pollutions, soil contamination, greenhouse gas emissions, loss of aquatic and terrestrial species, change of species compositions, and degraded ecosystems of the surrounding environment. Moreover, use of these agrochemicals also has caused serious human health hazards like headache, body aches, skin rashes, poor concentration, nausea, dizziness, impaired vision, and chronic disease affecting nervous, reproductive, renal, cardiovascular, and respiratory systems. As a result, pertinent questions arise again on how agricultural chemicals can be used for food production without compromising the quality of the environment and safety of human health. It is, therefore, crucial for the region to carefully study and strategize ways and means for judicious and responsible use of agricultural chemicals without affecting the agricultural production system.

A number of policies and legislations were enacted and strategies developed in the region to avoid or minimize the use of chemicals. However, the existing policies, legislations and strategies have not actually reduced or minimized their adverse impacts on human health and environment in the region. There are still reports of indiscriminate and excessive use of these chemicals by the farmers to protect crops and get higher yields. The governments should vigorously promote agricultural technologies like IPNM, IPM, GAP, organic farming, and other emerging technologies through awareness and farmer's training programs and also by creating an enabling environment for adoptions of these technologies widely. Continuous research should be carried out to improve existing technologies and develop new agricultural technologies to avoid or reduce the use of pesticides and fertilizers in agricultural production systems. Capacity building of extension agents and farmers will significantly reduce adverse impacts on human health and environment by using the agrochemicals judiciously after the training. Further, concerted and coordinated efforts of other stakeholders is also essential for safe production of food and maintaining environmental quality. It is also felt the need to strengthen existing laboratories in the region and share information and expertise among the countries through a common platform managed by concerned regional agencies.

The governments in the region are trying hard to balance food production and environment conservation. Land and water resources of the surrounding environment form the basis of all farming systems, and their preservation is crucial to sustained and improved food production. Unless the environment is preserved and managed sustainably and safety of public health is taken care of, South Asia's aspiration for sustainable agriculture to feed ever growing populations would be a challenge for the region.

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Chapter 2

# Impact of Agricultural Chemical Inputs on Human Health and Environment in Bangladesh

**Nirmal Kumar Dutta[1]; Ranjit Sen[2]; Md. Iqbal Faruk[3]**
Bangladesh Agricultural Research Institute (BARI), Gazipur, Bangladesh
*[1]nkdutta83@yahoo.com; [2]senranjitbdgmail.com; [3]mifaruk2012@yahoo.com*
&
**Md. Aminur Islam**
Plant Protection Wing, Department of Agricultural Extension
Khamarbari, Dhaka, Bangladesh.
*iaminsau@gmail.com*

## 1. Introduction

Agriculture is one the most important sectors of Bangladesh economy for its significant role in food security, employment generation and livelihood support. Around eighty percent people of Bangladesh depend directly or indirectly on agriculture. The current share of agriculture to Gross Domestic Product (GDP) is 14.23% and employs about 40.60% of the labor force. Due to its very fertile land and favorable weather, varieties of crop grow abundantly in this country. The total cropped area of the country is about 15.93 million hectares with 197% cropping intensity. Bangladesh grows a variety of crops and rice is the predominant one that accounts for about 72.32% of the total cropped area. The second most important cereal crop is maize that accounts for about 2.82 % of the total cropped area, which is followed by wheat (2.07%). Jute (4.71%), potato (2.95%), vegetables (2.72%), pulses (2.22%), oil seeds (2.78%), spices & condiments (2.52%), fruits (2.82%), sugar crops (1.17%) etc. also occupy considerable acreage of the total cropped area. The rest of the area is covered by tea, tobacco and other crops (Figure 1).

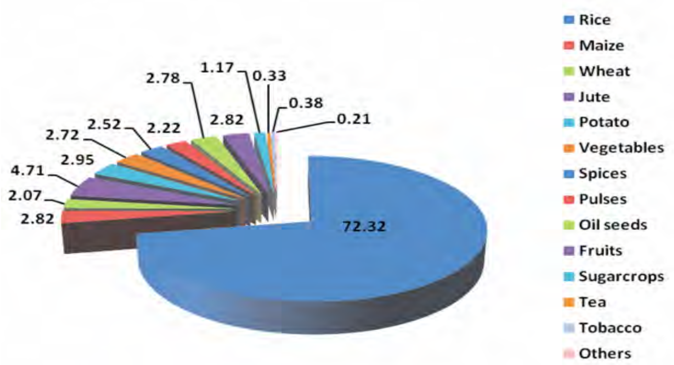


**Fig. 1 Area occepied by major crops in Bangladesh during 2018-19**

*Source: BBS 2020*

Bangladesh has made commendable progress in achieving food security, despite frequent natural disasters and population growth. The country is self-sufficient in food grain production. Bangladesh has also made tremendous success in production of many other crops. The revolution that Bangladesh is now witnessing in the agriculture sector is the outcome of the epoch-making steps that Father of the Nation Bangabandhu Sheikh Mujibur Rahman initiated after the independence. Bangladesh's agricultural sector has benefited from a sound and consistent policy framework followed by present agriculture-friendly Government. Agriculture of Bangladesh is now in the process of transforming from subsistence to commercial farming.

However, Bangladesh Agriculture is facing some challenges too. The population is increasing at an alarming rate and about 1% of the cultivable land is going out of agricultural use annually. Bangladesh is among the most vulnerable countries to climate change, which poses a long-term threat to the country's agricultural sector, particularly in areas affected by flooding, salinity intrusion, and drought. To meet the demand of ever-increasing population, intensified agricultural land use accompanied by increased use of modern crop varieties has contributed to increased use of chemical inputs thereby affecting environment and human health.

In modern agriculture, pesticides and fertilizers application play a vital role in increasing production and ensuring the supply of agricultural products. Pesticide spraying can significantly reduce or offset the economic costs from plant diseases, insect pests and weeds on agricultural production, and fertilizer application can provide a variety of nutrients required for the growth of crops for an increased yield and production. However, continuous application of synthetic fertilizers and indiscriminate use of toxic chemical pesticides are posing serious threat to our agro-ecology and human health. This paper describes in brief, the adverse impacts of different chemical inputs especially fertilizers and pesticides on agro-ecology, human health and environment of Bangladesh along with the policy framework and the strategies of the Government, and technologies developed to monitor and control excessive use of agrochemicals.

## 2. National Agricultural Policy 2018

### *2.1 Fertilizer management*

The section 5.2 of National Agricultural Policy 2018 provides a set of guidelines relating to fertilizer management. Some of the priority areas relating to optimum use of fertilizers include:

i) Arrangement for intensive monitoring at each level to ensure strict control and supply, warehousing, price and quality of the approved standards of fertilizer;

ii) Encourage farmers to use balanced fertilizer, especially containing multiple nutrient elements;
iii) Encourage the use of green fertilizer/organic fertilizers to increase the fertility of the soil and the use of bacterial fertilizers in pulses;
iv) Encourage marketing and use of microbial fertilizers invented through research;
v) Encourage farmers to participate in training programs in the use of organic and chemical fertilizers in balanced manner;
vi) Increase the availability of organic fertilizers and encourage farmers to rear cattle in the household for increasing supply of renewable energy;
vii) Encourage manufacturing of organic, green and microbial fertilizers and provide incentives to the users.

### *2.2 Pesticide management*

The section 3.3.13 of National Agricultural Policy 2018 provides a set of guidelines relating to pest management. Some of the priority areas relating to pest management and judicious use of pesticides include:

viii) Undertake research activities to identify new pest and environment friendly pesticides;
ix) Encourage research for developing methods for bio-control of pests;
x) Take steps to ensure the safe use of pesticides.

The Section 5.3 of National Agricultural Policy 2018 also provides clear guidelines about pest control and pesticide management. The major approaches include:

xi) Strengthen pesticides registration, marketing and monitoring activities;
xii) Discourage import & use of pesticides that are harmful to beneficial insects;
xiii) Encourage the farmers to use organic pesticides;
xiv) Promote use of environment-friendly, safe and effective pesticides categorized as class 3, by World Health Organization.

## 3. Good Agricultural Practices Policy (GAP) 2020

### *3.1 Agrochemicals management*

Bangladesh Government in 2020 approved Good Agricultural Practices Policy (GAP) in order to ensure safe and quality agricultural products by applying good practices in the entire production-to-consumption chain. GAP encourages the optimum use of agricultural inputs such as pesticides and chemical fertilizers etc. and environment friendly management options. GAP also emphasizes that the health safety of workers engaged in agricultural activities must be ensured from the faulty use of the pesticides and various chemicals.

## 4. Chemical Fertilizer Use

Fertilizer is a major input for crop production and it was introduced in early 1950s when nitrogen deficiency was first identified. Since then, as time advanced, new nutrient deficiencies have appeared (Table 1). Eventually, the farmers started to use other fertilizes such as TSP, MoP and gypsum. Micronutrient fertilizers such as zinc sulphate was introduced in early 1980s and boric acid in early 1990s when zinc deficiency in rice and boron deficiency in wheat were identified. However, fertilizers that are most commonly used by the farmers of Bangladesh are urea, TSP and MoP. The fertilizer demand in Bangladesh is met by domestic production and import. For urea, a significant portion of the demand is met from local production and for non-urea fertilizers, a significant demand is met by import (about 90% import for TSP, 100% for MoP and about 50% for DAP) which is largely done by the private sector and a small portion by BADC.

**Table 1. Nutrient deficiency identified in Bangladesh**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Nutrient deficiency | | | | | | | Mg+Mo |
| | | | | | | B | B |
| | | | | | Zn | Zn | Zn |
| | | | | S | S | S | S |
| | | | K | K | K | K | K |
| | | P | P | P | P | P | P |
| | N | N | N | N | N | N | N |
| Identifying year | 1951 | 1957 | 1960 | 1980 | 1982 | 1995 | 2000 |

*Source: Khan, 2010*

Fertilizer use in this country has increased over time due to expansion of irrigation facilities and depletion of soil fertility induced by higher cropping intensity and cultivation of high yielding crop varieties. Around 56.14 lac metric tons of chemical fertilizers was used during 2019-20, while it was 30.05 lac metric tons during 2008-2009 (Figure 2).

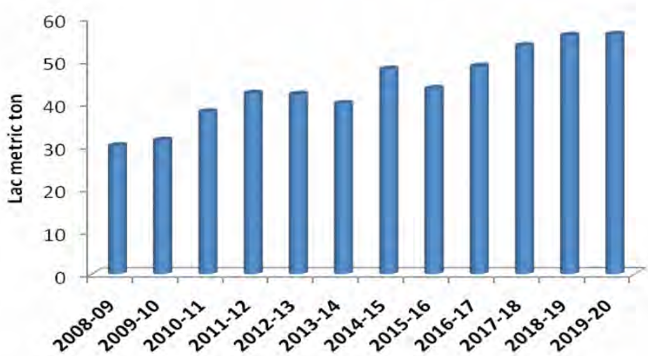


**Figure 2. Year wise chemical fertilizer consumption in Bangladesh**

*Source: AIS, 2017 & 2021*

Figures 3 & 4, represent a comparison of share of major fertilizers used during 2008-09 and 2018-19. Of the total fertilizers used during 2008-09, share of urea was approximately 80%, while it was approximately 45% in 2018-19. On the other hand, usage of TSP, MoP and DAP increased to a considerable percentage in 2018-19 as compared to 2008-09. The reason behind the scenario is that, the price of non-urea fertilizers was quite high in 2008, the Government during 2009 drastically reduced the prices of non urea fertilizers. As a result, farmers started to use balanced fertilizers instead of using more urea in the field thereby increasing higher productivity of different crops.

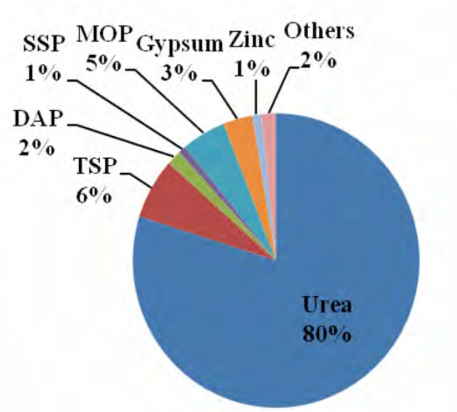


**Fig. 3 Share of chemical fertilizers (%); 2008-2009**

*Source: AIS, 2017*

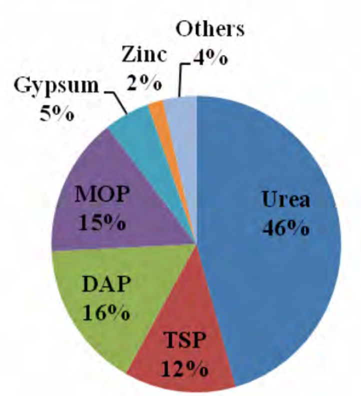


**Fig. 4 Share of chemical fertilizers (%); 2018-19**

*Source: AIS, 2021*

## 5. Impacts of Chemical Fertilizers on Human Health and Environment

Continuous and overuse of chemical fertilizers creating several problems like air and water pollutions, land degradation, and depletion of soil fertility. Some of the adverse impacts are described below:

### *5.1 Nitrate pollution in ground and surface water*

Massive use of nitrogenous fertilizer increases nitrate pollution in ground and surface water. For example, farmers use two to three times more urea in potato field to get higher yield without thinking of environmental impacts on soil, water and air. Excess urea leach down into water body in a form of nitrate which is highly soluble. Excessive use of urea is also causing hollow heart disease of potato. Nitrate contamination in surface water and groundwater occurs through surface run-off and leaching from various agricultural fields. The acute health hazard associated with nitrate contaminated drinking water occurs when bacteria in the digestive system transform nitrate to nitrite. The nitrite reacts with iron in the hemoglobin of red blood cells to form methemoglobin, condition called methemoglobinemia which lacks the oxygen-carrying ability of hemoglobin, also known as blue baby syndrome.

### *5.2 Eutrophication*

Over use of fertilizer causes eutrophication in the water body. Eutrophication is a condition when the water body becomes enriched with nutrients. This can be a problem in aquatic habitats such as lakes as it can cause algal blooms and development of different weeds. Some algae even produce toxins that are harmful to higher forms of life. This can cause problems along the food chain and affect any animal that feeds on them.

### *5.3 Greenhouse gas emission*

Increased use of nitrogenous fertilizers increases emission of nitrous oxide, a green house gas. Nitrous oxide is produced in soils through the processes of nitrification and denitrification. Nitrification is the aerobic microbial oxidation of ammonium to nitrate, and denitrification is the anaerobic microbial reduction of nitrate to nitrous oxide to nitrogen gas ($N_2$). Nitrous oxide is a gaseous intermediate in the reaction sequence of denitrification and a by-product of nitrification that leaks from microbial cells into the soil and ultimately into atmosphere. Release of nitrous oxide from excess use of urea or other nitrogenous fertilizers, accumulate in stratosphere and deplete ozone layer. As a result, ultra violet radiations come into earth surface and cause several types of cancer in human, animal etc.

### *Acid rain*

Unsafe gases like nitrous oxide from excess use of fertilizers are discharged into air. When it rains, the water beads or droplets react with these air contaminants and become acidic (nitric acid) and fall on the ground as acid rain which is corrosive in nature.

### *Heavy metal pollution in soil*

Massive use of inorganic fertilizers is associated with the accumulation of contaminants, e.g. arsenic (As), cadmium (Cd), fluorine (F), lead (Pb) and mercury (Hg) in agricultural soils (Naser *et al*., 2017). The maximum acceptable limit of toxic heavy metals in the chemical fertilizer in Bangladesh is: arsenic-50 ppm, chromium-500 ppm, cadmium-10 ppm, lead-100 ppm and mercury-0.1 ppm (MOA, 2007). Some TSP sample containing more Cd than the acceptable limit. Sometimes adulterated fertilizers like zinc sulphate and boric acid contain substantial quantity of toxic heavy metal which contaminates soil and affect plant and animal.

*Destruction of beneficial organisms*

Excess use of chemical fertilizers destroys soil born beneficial organisms. For example, earth worm which is called natural plough was found abundantly in Bangladesh earlier. Due to massive use of chemical fertilizer, it is now rare in Bangladesh soil. Chemical fertilizer also destroys beneficial micro-organisms which increases soil fertility and crop productivity.

## 6. Strategies to Minimize Adverse Impacts of Chemical Fertilizers

### *6.1 Integrated Plant Nutrition System (IPNS) Approach*

Bangladesh is one of the most densely populated countries in world with very low per capita cultivable land. It has to produce huge quantity of food from small piece of land to feed large number of populations. Hence, it is very important to restore soil fertility and increase crop productivity. Chemical fertilizer alone cannot restore soil fertility and provide sustainable crop production without the use of organic fertilizers. On the other hand, it is not possible to increase crop production by applying only organic manures. Therefore, integration of organic manure with chemical fertilizer can improve soil fertility and sustain crop productivity. Integrated Plant Nutrition System is the management of all available plant nutrient sources, organic and inorganic, to provide optimum and sustainable crop production conditions within the prevailing farming system. Therefore, an appropriate combination of mineral fertilizers, organic manures, crop residues, compost, N-fixing crops and bio-fertilizers are used according to the local ecological conditions, land use systems and the individual farmer's social and economical conditions. Several IPNS based fertilizer recommendations for different crops and cropping systems are now being pursued in Bangladesh (Sen, 2019). IPNS approach prevent excessive use of chemical fertilizers thereby minimize its adverse impacts on the environment and human health.

In Bangladesh cowdung, poultry manure and Farm Yard Manure are widely used organic fertilizers. However, attempts are being made to popularize the following organic/bio-fertilizers as suitable components of IPNS technology.

#### *6.1.1 Use of biochar as a soil amendment*

Biochar is a carbon-rich stable substance, defined as charred organic matter, produced during biomass thermochemical decomposition, and its application is currently considered as a mean of enhancing soil productivity, which is an important requirement for increasing crop yields. Simultaneously, it also improves the quality of contaminated soil and water. Biochar provides ecosystem services such as immobilization and transformation of contaminants and mitigation of climate change by sequestering carbon and reducing the release of greenhouse gases such as nitrous oxide and methane.

Bangladesh Agricultural Research Institute (BARI) has developed sustainable technology for preparing biochar at farm level. Application of biochar obtained from poultry litter @ 9 t $ha^{-1}$ can be used for effectively amending acidic soil and to increase crop yield. About 36% yield increase of BARI Khoi Bhutta was obtained by applying 9 t $ha^{-1}$ poultry litter biochar compared to un-amended soil (Masud *et al.*, 2020).

### *6.1.2 Use of vermicompost as an effective organic fertilizer*

Vermicompost is an ideal organic manure for better growth and yield of many plants. It can increase the production of crops and prevent them from harmful pests without polluting the environment. Vermicompost has higher nutritional value than traditional composts. This is due to increased rate of mineralization and degree of humification by the action of earthworms. Vermicomposting is gaining popularity in rural Bangladesh as the technology is simple, viable and cost effective. More than ten thousand vermicompost producing industries of both small and large are running in the country.

BARI has developed sustainable technology for preparing vermicompost at farm level. Application of 5 ton vermicompost/ha along with 75% chemical fertilizer reduced 25% demand of chemical fertilizer and increased 31% yield of vegetables (Akhter *et al.*, 2014).

### *6.1.3 Use of rhizobial biofertilizer*

Bio-fertilizer technology is inexpensive and environmentally sound. Rhizobial inoculants could be the cheapest and easiest way to increase legume production through their unique capability to fix atmospheric nitrogen. In Bangladesh, significant progress has been made in the development of rhizobial biofertilizers that provided yield increases of 15–30% in lentil, 20–45% in chickpea, 18–35% in mungbean, 25–45% in cowpea, 20–40% in groundnut and 75–200% in soybean (Satter *et al.*, 1996). Application of rhizobial biofertlizer in various legume crop adds 50-85 kg N/ha in soil and increases yield of about 31- 42% (Ali *et al.*, 2020).

### *6.1.4 Green manuring*

Raising of quick growing leguminous plants and burying them after 45 to 60 days has been practiced to improve soil fertility. A leguminous green manure crop contributes about 30 to 40 kg N/ha for the succeeding crop.

### 6.1.5 *Blue Green Algae and Azolla*

Blue Green Algae (BGA) and Azolla are used in water logged rice fields for nitrogen fixation. If 12-15 tons of Azolla biomass per hectare is incorporated, 30-40 kg N/ha may be reduced for rice. BGA can add 20-30 kg N/ha for rice crop.

### 6.1.6 *Other Micro-organisms*

Azotobacter, Azospirillum, Mycorrhizae, etc. are also gaining importance. However, much more is yet to be known about them before their use can be advocated to the farmers.

### 6.2 *Increase chemical fertilizers use efficiency*

Chemical fertilizers use efficiency is low. For example, roughly the efficiency of prilled urea when broadcasted in rice field ranges from 30-40% (depends upon the rate of hydrolysis of urea to $NH_3$ to $NH_4$ to $NO_3$ to $NO_2$ to $N_2$). The efficiency of urea super granule is 10-15% higher than prilled urea. Neem oil coated urea is another option for increasing nitrogen use efficiency. Pattern based fertilizer application can reduce the requirement of fertilizer than single crop-based fertilizer application as most of phosphatic and potasic fertilizers have residual effect. Fertilizers should be applied following 4 R principal (right form, right method, right rate and right time) which will increase the use efficiency of chemical fertilizers (Ahmmed *et al*., 2018).

## 7. Pesticide Use Pattern

Pesticide use in Bangladesh started from mid fifties and gained momentum in early 1970's with the introduction of green revolution through the use of HYV rice. Through the import of 3 metric tons (MT) of insecticides in 1956, Bangladesh entered into the era of the synthetic chemical pesticides for pest control. During that time, pesticides were procured by the government and supplied to the farmers free of cost (100% subsidy). Subsidies were halved in 1974 and withdrawn entirely in 1979. In 1979, pesticide subsidy was totally withdrawn and sale of pesticides were left to the private sector. After withdrawal of the subsidies, the use of pesticides declined. However, the consumption began to rise again as agriculture activities expanded. Figure 5 represents year wise pesticide consumption in Bangladesh during the period 2009-2019. During 2009, more than 45 thousand metric tons or kilolitres of pesticides were used. After 2011, the consumption trend decreased, but from 2017 onwards it slightly increased. However, pesticide consumption in 2019 was around 38 thousand metric tons or kilolitres, which was around 15% less compared to 2009.

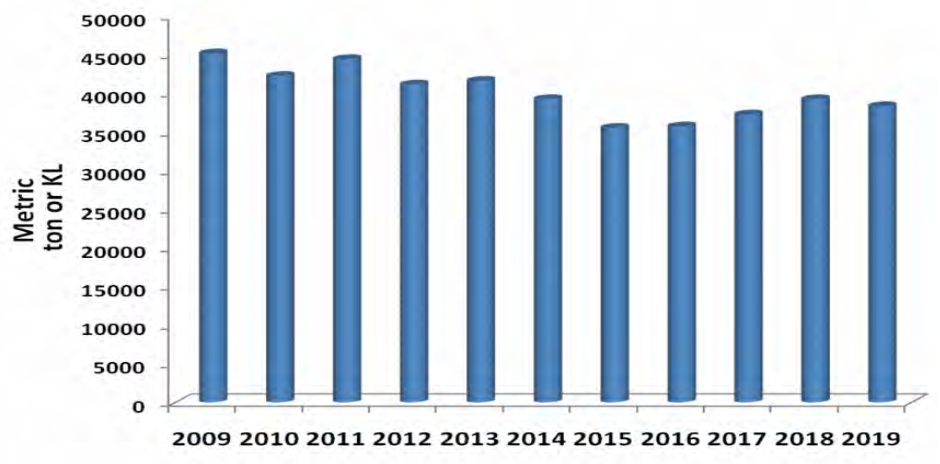


**Figure 5: Year-wise pesticide consumption in Bangladesh (2009-2019)**

*Source: AIS, 2020 & 2021*

As indicated in Figure 6, during 2009, 60% of the total pesticide used was insecticide, while share of fungicide and herbicide was 32% and 8%, respectively. In contrast, Figure 7 indicates that during 2019, 35% of the pesticide used was insecticide, while share of fungicide and herbicide was 46% and 18%, respectively. So, over the last 11 years, there has been considerable increase in use of chemical herbicides and fungicides in Bangladesh.

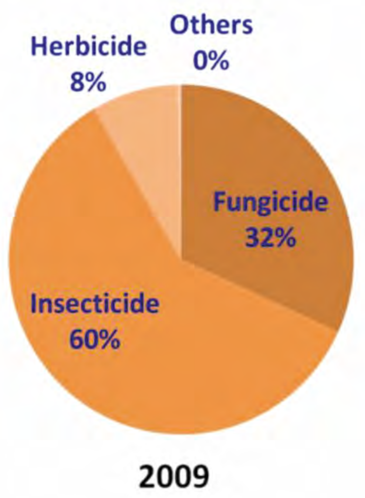


**Figure 6: Share of synthetic pesticide use by type (%) during 2009**

*(Source: AIS, 2020)*

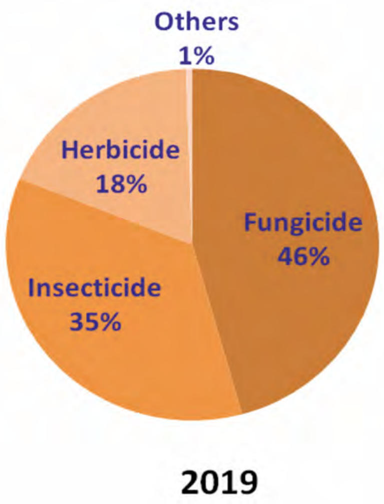


**Figure 7: Share of synthetic pesticide use by type (%) during 2019**

*(Source: AIS, 2021)*

List of registered pesticides as approved up to 81st PTAC meeting, held on 14 May 2020 is given in Table 2. Insecticides having 363 different formulations (insecticide 160, miticide 7, bio-pesticide 20, fungicide 103, stored grain pest 3, rodenticide 2 and herbicide 68) with a total of 4782 brands were registered for agricultural purposes. However, the government has already banned all “dirty dozen” products along with extremely hazardous (Ia) and highly hazardous pesticides (Ib). It is to be noted here that in 2010, the Pesticide Rules 1985 was amended with the incorporation of the provisions of bio-pesticide registration and from 2012 registration of bio-pesticides have been opened. Before that several bio-pesticides were registered as insecticides. The actual number of bio-pesticide formulations/brands would be higher than those included in the Table 2 because previously registered products (bio-pesticides those were registered as insecticides) are not included here.

**Table 2. List of registered pesticides in Bangladesh**

| SL. No. | Type of Pesticides | Total Registered Pesticides | |
|---|---|---|---|
| | | No. of Formulations | No. of Brands |
| 1 | Miticides | 7 | 204 |
| 2 | Fungicides | 103 | 1050 |
| 3 | Insecticides | 160 | 2502 |
| 4 | Herbicides | 68 | 888 |
| 5 | Stored Gain Pesticides | 3 | 88 |
| 6 | Rodenticides | 2 | 15 |
| 7 | Biopesticides | 20 | 35 |
| 8 | Public Health Pesticides | 77 | 665 |
| Total | | 440 | 5447 |

*Source: BCPA 2020*

## 8. Impacts of Chemical Pesticides on Human Health and Environment

Tremendous benefits have been derived from the use of pesticides in agriculture. On the other hand, there is overwhelming evidence that indiscriminate use of these chemicals poses a potential risk to humans and other life forms and unwanted side effects to the environment (Aktar *et al*., 2009). More than 98% of sprayed insecticides and 95% of herbicides reach a destination other than their target species, because they are sprayed or spread across entire agricultural fields (Miller, 2004). There are adverse impacts of using these pesticides on the environment and its components. On the other hand, since majority of the farmers in Bangladesh do not maintain any waiting period for chemical pesticide spraying before crop harvest, the consumers become inevitably exposed to high levels of pesticide residues in their diets. Indiscriminate use of synthetic toxic chemical pesticides (misuse and overuse, use of impure and improper, non-registered or sometimes banned pesticides) is a common scenario in Bangladesh.

The potential hazards associated with chemical pesticide use in Bangladesh are described below:

### *8.1 Pesticide resistance, pest resurgence and secondary pest outbreak*

Insecticide resistance, resurgence and secondary pest outbreaks are frequent problems associated with insecticide use against arthropod pest species in Bangladesh. Repeated applications of insecticides have induced multiple resistances of different pests against pesticides (Alam & Rahman, 2017). Resistance of brinjal shoot and fruit borer population to the commonly used pesticides in Bangladesh has been reported by several authors (Kabir & Prodhan, 2011; Alam, 2013). Severe outbreak of several devastating pests occurred in recent past. Resurgence is one of the major causes for these outbreaks. Rice crops worth at least US$ 8.1 million were lost due to brown planthopper (BPH) attack during the widespread outbreaks in 1976, 1978 and 1983 (Alam & Karim, 1986). Nowadays, its outbreak is occurring frequently in different areas of Bangladesh (Ali *et al*., 2017).

During 2008-09, a serious outbreak of common cutworm, *Spodoptera litura* occurred at Tarash, Sirajgonj. Around 200 ha of mustard field were severely infested with the pest. Farmers applied different insecticides at 2-3 times higher dose and even at alternate days but could not check the outbreak (Alam, 2013). During 2011-12 winter, a serious outbreak of the same pest, common cutworm, *Spodoptera litura* occurred at Kamlakanda, Netrokona areas (north-eastern part of the country) on cabbage. Around 40 ha of cabbage cultivated land was severely infested with the pest. Farmers applied different insecticides at 2-3 times higher dose and even at alternate days but could not check the outbreak (Alam, 2013). Severe outbreak of common cutworm, *Spodoptera litura* also occurred at Nalchhity, Jhalokathi on Mungbean during 2019. Around 10 ha of Mungbean crop were severely infested with the pest. Farmers were helpless because they failed to control this pest with repeated spraying of toxic chemical insecticides.

**Severe infestation of mungbean with *S. litura* at Nalchhity, Jhalokathi, March 2019**

Another outbreak of common cutworm, *Spodoptera litura* occurred at Badalgachi, Naogao areas on potato during December 2020. Around 20 ha of potato field were severely infested with the pest. Farmers applied different insecticides but failed to control this pest.

**Severe infestation of potato with *S. litura* at Badalgachi, Naogao, December 2020**

During January-February 2021, serious infestation of *Spodoptera litura* caused havoc at Kashiani, Gopalganj to brinjal, onion and other crops in about 5-6 ha of land. Farmers were helpless because no chemical insecticides were working against this pest.

**Severe infestation of brinjal and onion with *S. litura,* Gopalganj, Jan-Feb, 2021**

Very recently, serious infestation of leaf miner, *Liriomyza sativae* occurred at Shibpur, Norsingdi areas on cucumber during March 2021. Around 7-8 ha of cucumber fields were severely infested with the pest. Farmers applied different insecticides but failed to control this pest. Actually, before the outbreak, leaf miner was a minor pest of cucumber in that area. Frequent and indiscriminate spraying of toxic chemical insecticides by farmers to control fruit fly in cucumber in that area could be held responsible for the secondary outbreak of leaf miner in that locality.

Further, frequent use of toxic pesticide has boost up the population of many minor pests like whitefly, jassid, red mite, spiraling whitefly, jack fruit borer, mango fruit borer etc. (Alam & Rahman, 2017). Kabir & Prodhan, 2011, also reported that due to over use of pesticides several minor pests such as *Spodoptera* in mustard, whitefly in guava, jassid in brinjal and cotton, mealy bug in papaya etc. became major pests. Serious red mite resurgence in brinjal field at BARI, Gazipur occurred due to regular spraying of Thiamethoxam (Dutta *et al.*, 2018). Recent serious outbreak of rugose spiraling whitefly in coconut and other crops in different parts of the country could partly be attributed to the indiscriminate use of chemical pesticides in crop fields.

### *8.2 Pesticide residues in food commodity*

Recent research findings of Pesticide Analytical Laboratory of Entomology Division, BARI revealed that 30-40% marketed vegetable samples were contaminated with left over pesticide residues and of these samples, 10-12% contained residues above Maximum Residue Limit (MRL). It is also revealed that 8-10% marketed fruit samples were contaminated with left over pesticide residues and of these samples, 3-4% contained residues above Maximum Residue Limit (MRL) (Prodhan *et al*., 2018).

In Bangladesh, dry fish is a low-cost dietary protein source and every year a significant portion of fresh fish is sun dried due to high market demand and a substitute of scarcity of fresh fish. Unfortunately, there are recurrent concerns regarding traditionally dried fish quality. Rahman *et al*., (2019) in a review work on pesticide residues in dry fishes observed that dry fish samples of different locations of Bangladesh were contaminated with different concentrations of DDT, heptachlor, aldrin, dieldrin, endrin, endrin ketone and heptachlor epoxide indicating unrestricted and unplanned use of them without considering their health hazards. Begum *et al.,* (2017) observed that 30% of marketed dry fish samples were contaminated with different organochlorine insecticides such as endrin, heptachlor epoxide and endrin ketone. Among those, 15% samples contained residues above MRL. Recently, marketed dry fish samples collected from Gazipur, Bangladesh were analyzed at Pesticide Analytical Laboratory of Entomology Division, BARI. It was observed that around 13% samples were contaminated with different organophosphorus insecticides and around 11% of those contaminated samples contained residues above MRL (Begum *et al., 2020*). All these are no doubt alarming signs considering food safety issues in Bangladesh. The most vulnerable vegetables and food commodities having left over pesticide residues are red amamranth, chilli, summer bean, summer cabbage, yard long bean, bitter gourd, brinjal, betel leaf, dry fish etc. (Alam & Rahman, 2017).

### *8.3 Pesticide residues in soil and water*

Organophosphorus and carbamate pesticide residues were detected beyond acceptable levels in water samples collected from paddy and vegetable fields of the Savar and Dhamrai Upazilas in Bangladesh (Chowdhury *et al*., 2012). Hassanzaman *et al*., (2016) also reported presence of different organophosphorus insecticide residues at an alarming level in water samples collected from fish pond and cultivated land of Dhamrai Upazila, Bangladesh.

Uddin, *et al*., (2016) studied the residual pesticides in soils of Narsingdi district and revealed that out of 9 samples, only two contained organochlorines, namely DDT and DDE ranging from 0 - 0.726 and 0.404 - 0.563 μg/kg, respectively. While, organophosphorous, carbamate and pyrethroid residues were found below the detection limit. However, the contamination level of DDT and its metabolites was lower as compared to the IAEA/FAO/Codex Alimentarious Guideline value. In a similar study, soil samples from vegetables and paddy fields in the coastal district of Feni were collected. It was revealed that some samples out of 21 samples were found to be contaminated with organophosphorus (OP) pesticide namely diazinon; carbamate pesticide namely carbofuran and carbaryl. However, the contamination level of organophosphorous and carbamate was relatively low compared to the IAEA/FAO/Codex Alimentarious Guideline value (Uddin *et al.*, 2018).

### *8.4 Human health*

No segment of the population is completely protected against exposure to pesticides and other serious health effects of pesticides. Disproportionate burden is shouldered by the people of developing countries and by high-risk groups in each country (WHO, 1990). The world-wide deaths and chronic diseases due to pesticides poisoning number about 1 million per year (Environews Forum, 1999). There are many studies linking chemical pesticides exposure to infertility, cancer, birth defects, damage to brain, as well as nervous system. Additionally, exposure to chemical pesticides can exacerbate allergies and asthma. In Bangladesh, a survey on brinjal growers in Jashore region revealed that almost all farmers experienced sickness (physical weakness or eye infection or dizziness etc.) related to pesticide application, but only 3% were hospitalized due to complications related to pesticide use (Alam *et al*., 2003). Dasgupta *et al.*, (2007) conducted a survey in different regions of Bangladesh reported that farmers' exposure to toxic pesticides was quite serious. They observed that, among conventional farmers, 37% reported frequent health problems such as eye irritation, headaches, dizziness, vomiting, shortness of breath, skin effects and convulsions due to exposure to toxic pesticides. The outbreak of illness and deaths among children living near lychee orchards in northern Bangladesh in 2012 was due to poisoning, likely from pesticides used in nearby lychee orchards (ICDDR,B 2012). Self-poisoning by pesticide is a serious health problem in Bangladesh responsible for about 40% of poisoning cases admitted to hospital (Dewan, 2014). In Bangladesh, pesticide poisoning related deaths represented 8% of all hospital deaths for people aged 15-49 years in 2009 (Ministry of Health and Family Welfare, GOB, 2009).

## 9. Strategies to Minimize Adverse Impacts of Chemical Pesticides

Considering the above-mentioned negative impacts, it is of utmost importance to ensure the proper use of pesticides to protect our environment and eventually health hazards associated with it. Alternative pest control strategies such as

Integrated Pest Management (IPM) that deploys a combination of different control measures such as cultural control, use of resistant variety, physical and mechanical control, and rational use of pesticide could reduce the number and amount of pesticide applications. At present, different bio-pesticides are rapidly gaining popularity. Development and popularization of bio-pesticide based IPM packages could be important steps towards reducing abuse of chemical pesticides. Furthermore, advanced approaches such as biotechnology and nanotechnology could facilitate in developing resistant genotype or pesticides with fewer adverse effects. Additionally, pesticide resistance management; prevention of marketing of adulterated pesticides; strengthening pesticide analytical and residue research for residue detection and monitoring etc. are also very much important in this context. Training on the safe use and handling of pesticides, related community development, and extension programs to educate farmers to adopt the innovative and environment friendly management strategies are key to reduce the deleterious impact of pesticides on our environment. The present agriculture friendly Government of Bangladesh is well aware of the problems associated with misuse of pesticides and committed to ensure safe and nutritious food for the nation. The Government has already taken various steps and implementing various projects to this end.

Bangladesh has made significant achievement in developing and popularizing bio-pesticide based IPM/IDM technologies at the farm level for managing insect pests and diseases of different crops. In many areas of the country, the farmers are being benefitted using those technologies. These technologies are safe, cheap, environment friendly, easy to apply and have the high yield potential. Some of the noteworthy and popular bio-pesticide based insect pest and disease management technologies are outlined below:

## *9.1 Biopesticide based management practices against major pests*

### *9.1.1 Biopesticide based management of fruit fly*

Cucurbit fruit fly, *Bactrocera cucurbitae*, is a devastating pest of different cucurbit vegetables. This pest has been a major problem for the farmers as they invade the crops in high populations and devastate the cucurbit crops. Due to its nature of damage, it is very difficult to control this pest with chemical insecticide. However, an effective and cheap management strategy against this pest has already been developed by BARI, which comprises of sanitation and sex pheromone mass trapping. This technology has got widespread popularity among the farming community across Bangladesh.

BARI has recently developed another easy, effective and environment friendly technology to manage this noxious cucurbit fruit fly. This new technology attracts and kill both male and female flies. To attract male flies, small quantity of a paste/gel like substance composed of cuelure pheromone and a bio-pesticide is placed on the creeping stems or on the bamboo supporting the trellis (2-3ft above ground level) along the boundary lines of the field at 10-12 meter intervals. To attract and kill female flies, a trap containing mixture of protein hydrolysate and a bio-pesticide is hung on the trellis inside the field maintaining 10-12 meter distance. The female fly is attracted to the hydrolysed protein as it searches for protein sources to support egg maturation and get killed in contact with bio-pesticide.

#### *9.1.2 Biopesticide based management of brinjal shoot and fruit borer*

Brinjal Shoot and fruit borer, *Leucinodes orbonalis* Guen. is considered as the key pest of brinjal. Unfortunately, even after repeated insecticide spraying the farmers are unable to control the pest properly as the field populations have become resistant to the commonly used pesticides. The BARI scientists have developed effective and economic biopesticide based IPM package to combat the pest.

One of the important steps taken by Government of Bangladesh in reducing the insecticide use and promoting environment friendly options was the release of four bt brinjal varieties (BARI Bt brinjal varieties 1, 2, 3, and 4) in 2013. The varieties were developed by BARI. Bt eggplant was the first GE crop released for cultivation in Bangladesh. From a survey study, it was revealed that Bt brinjal farmers of Bangladesh saved 61% of the pesticide cost compared to non-Bt brinjal farmers, experienced no losses due to shoot and fruit borer, and received higher net returns (Shelton *et al*., 2018).

#### *9.1.3 Biopesticide based management of common cutworm*

Common cutworm, *Spidoptera litura* are becoming a destructive pest of several crops, viz. mustard, cabbage, cauliflower, tomato, aroids, chili, cotton, tobacco, potato, mungbean etc. It is difficult to control this pest with any synthetic chemical insecticides. However, BARI scientists have developed an effective and cheap management strategy against this pest.

#### *9.1.4 Biopesticide based management of Tomato leaf miner*

Tomato leaf miner, *Tuta absoluta* is a serious pest of tomato and presently causing enormous damage to the crop in different parts of country. This pest was successfully managed by applying the IPM package developed by Entomology Division, BARI.

### *9.1.5 Biopesticide based management of country bean pod borer*

Country bean cultivation in Bangladesh is seriously impeded by attack of pod borer, *Maruca vitrata*. Pod borer in country bean is successfully managed by applying the management package developed by Entomology Division, BARI.

### *9.1.6 Biopesticide based management of fruit fly in different fruit crops*

The fruit fly, *Bactrocera dorsalis* cause serious loss of different fruit crops such as mango, guava, orange etc. The pest is very difficult to control with insecticides because its larva damages boring inside the fruit. BARI Scientists have recently developed and validated an easy, effective and environment friendly technology which attracts and kills both male and female fruit flies.

### *9.1.7 Biopesticide based management package against Fall Armyworm*

Fall Armyworm (FAW), *Spodoptera frugiperda* an invasive insect pest was first reported in Bangladesh infesting maize crop during November 2018. The pest is becoming a major threat causing substantial yield losses on maize in Bangladesh. Fall armyworm in maize in Bangladesh is successfully managed by applying the IPM package developed by BARI.

### *9.1.8 Use of sticky traps in controlling different insect pests*

It is a positive sign in pest management arena of Bangladesh that sticky traps, especially yellow sticky traps are now getting popularity to the farmers for managing different insect pests. Different private companies at present are now marketing yellow sticky traps in different regions of the country. Several studies in Bangladesh revealed that sticky traps could be good component of IPM in managing different sucking insect pests (Dutta *et al.*, 2018; Sarker *et al.*, 2020). Research activities are also going on to introduce pheromone impregnated sticky traps against fruit fly pests of vegetables and fruits.

## *9.2 Biopesticide based management practices against major diseases*

### *9.2.1 Biopesticide based management on downy mildew*

Downy mildew is a serious disease of cucurbit crops. Although the disease only infects foliage, a reduction in photosynthetic activity early in plant development results in stunted plants and yield reduction. This disease is successfully managed by applying the technology developed by BARI.

### *9.2.2 Eco-friendly management of root knot nematode and bacterial wilt of tomato*

Bacterial wilt and root-knot are two soil borne diseases that cause serious damage in the production of tomato with substantial yield loss in Bangladesh.

These two diseases can be managed successfully by integration of Tricho-compost @ 2.5 t/ha with stable bleaching powder @ 25 kg/ha and Furadan 5G @ 2 g/plant.

#### *9.2.3 Management of seedling disease caused by Sclerotium rolfsii and Fusarium sp*

Seedling disease caused by *Sclerotium rolfsii* and *Fusarium* sp. of lentil, chickpea, wheat and barley is one of the major constraints for successful production of these crops. Soil amendment with Trichoderma based Tricho-compost @ 2.5-3.0 t/ha can effectively reduce seedling disease of lentil, chickpea, wheat and barley caused by soil borne fungal pathogens *Sclerotium rolfsii* and *Fusarium* sp. Seed treatment with chemical fungicide provax @ 2.5 g/kg seed and Trichoderma inocula (spore concentration $1X10^7$/ml) is also effective against seedling disease of lentil, chickpea, wheat and barley.

#### *9.2.4 Integrated management of gummosis disease in fruit trees*

Recently, gummosis caused by Phomopsis artocarpi Sydow is noticed as one of the most damaging serious diseases of jackfruit. It reduces fruit yield, timber quality and life span of the tree in Bangladesh. Recently, gummosis caused by Phomopsis artocarpi Sydow is noticed as one of the most damaging serious diseases of jackfruit. It reduces fruit yield, timber quality and life span of the tree in Bangladesh. At present, gummosis disease is recognized as one of the serious diseases of fruit trees in Bangladesh. This disease is successfully managed by applying the technology developed by BARI.

#### *9.2.5 Eco-friendly management of root knot nematode of cucurbit crops*

The root-knot nematode can severely damage cucurbit crops, especially on light, sandy-textured soils. Soil amendment with poultry refuse (PR) @ 6-8 kg/pit or Neem oil cake/Mustard oil cake (MOC) @ 1 kg/pit applied 21 days before seedling transplanting or Tricho-compost @ 2 kg/pit applied 5 days before seedling transplanting or saw dust burning along with application of Furadan 5G @ 15-20 g/pit at the time of seedling transplanting can effectively control root knot nematode in cucurbits.

## 10 Challenges of Agrochemicals Use

- Farmers in many cases are not getting desired results by spraying chemical pesticides. So, most important challenge is to develop suitable alternatives to toxic chemicals.
- Farmers still depend on agrochemical dealers for taking decision on fertilizer and pesticide usage.
- Non-availability of biopesticides at field level.

- Marketing of adulterated/low AI containing agrochemical inputs especially pesticides.
- Inadequate research and laboratories facilities.
- Inadequate awareness building and promotional activities.

## 11. Conclusion and Recommendations

In modern agriculture, pesticides and fertilizers are vital components for increasing crop production on a sustainable basis. Sustainable technologies for efficient use of agrochemicals must be developed to reduce cost and minimize risk or hazard to human health and environment. The present Government of Bangladesh is committed to ensure safe and nutritious food to the nation through judicious and balanced use of different agrochemicals at farm level. Our people have already started getting benefits from the various Government efforts to this end.

The following are the recommendations for efficient and judicious use of different agrochemicals in Bangladesh:

- Strengthening research for developing biopesticides based IPM/IDM technologies against insect pests and diseases and IPNS based fertilizer recommendations;
- Strengthen research works on pesticide resistance management, pesticide analysis, and detection of heavy metals in soil samples etc.;
- Necessary steps should be taken to popularize biopesticides and organic fertilizers at farm level;
- Strict quality control of different agrochemicals should be maintained at the market level;
- Private companies dealing with biopesticides/biofertilizers should be given necessary government assistance;
- Promotional works for effective dissemination of environment friendly management strategies should be undertaken;
- Networking of the scientists working in different SAARC countries for exchange of technical expertise on the pesticide and fertilizer management strategies;
- Develop short-term and long-term regional strategies for efficient use of agrochemicals and to enhance regional coordination and cooperation;
- Massive awareness building programs need to be taken to educate and encourage farmers to adopt the innovative IPM/IDM/IPNS strategies;
- Strengthening agrochemical policy and financial support.

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Chapter 3

# Impact of Agricultural Chemical Inputs on Human Health and Environment in Bhutan

**Pema Tshoki**[1]
**Chinta Mani Dhimal**[2]
National Plant Protection Center, Department of Agriculture
Ministry of Agriculture and Forests, Bhutan
[1]ptshoki@moaf.gov.bt; [2]cmdhimal@moaf.gov.bt

## 1. Introduction

In this modern world of farming, the use of agrochemicals is inevitable. Agrochemicals are used by all the farming communities in the world and the under developing countries of South Asia are no exception. In order to ensure the continuous production and supply of food items to feed the population and also for trade, the use of agrochemicals such as synthetic fertilizers for boosting crop growth and production and synthetic pesticides to minimize the crop loss to pests and diseases has become a must in farming practices.

The use of agrochemicals in farming enhances crop production and protect crop from pests and diseases, but it has a lot of negative effects on the human health and environment. It is revealed that the use of pesticides and synthetic fertilizers especially the nitrogen fertilizers have increased drastically over the past 30 years. The human getting exposed to agrochemicals suffer from both acute and chronic health effects, including acute and chronic neurotoxicity, lung damage, chemical burns, and infant methemoglobinemia. The exposure to various pesticides has found to be the cause of a variety of cancers particularly hematopoietic cancers. Other harmful effects of use of agrochemicals on human health such as immunologic abnormalities and adverse reproductive and developmental effects have been reported (Weisenburger 1993).

The use of agrochemicals also has negative impacts on the environment. Aktar, *et al*., (2009) stated that the diffusion of agrochemicals in the water bodies can contaminate the water making it unsafe for human and animal consumption. The soil gets contaminated with continuous use of synthetic fertilizers over the years. The use of pesticides is a cause of water, soil and air contamination beside killing beneficial soil microorganisms and insects, non-target plants, fish, birds and other wildlife. Bhutan has strong regulatory framework to prevent or minimize negative impacts of agrochemicals use on human health and the environment.

## 2. Agricultural Transition in Bhutan

Agriculture farming at backyard scale in Bhutan persisted with the advent of Bhutanese civilization. Agriculture is the backbone of livelihood for the Bhutanese people in which about 69 % of the population is engaged in farming. Rice, maize, wheat, barley, buckwheat and millets are major cereal crops cultivated among which rice is preferred and staple food. Farming existed solely in a traditional way without the use of machinery and improved technologies until the initiation of a five-year plan in 1961 (Chhogyel & Kumar 2018). Agriculture system evolved over time gradually transitioning from subsistence to commercialization (Department of Agriculture, MoAF 2019). With the execution of Five-Year Plan (FYP), agricultural development continued to progress both in terms of area and technologies contributing to increased crop productivity. Introduction of high yielding crop varieties from the outside world, involvement of foreign expertise, up-gradation of human resources and facilities contributed to transitional changes in agricultural development over the decades. Compared to the mid twentieth century, the agricultural system transformed from subsistence towards an entrepreneurial system driven by five components of urbanization, farm mechanization, community institutions, high-value products and youth aspirations (Dendup 2018). With the advent of such modern technologies, there was simultaneous incidence and outbreak of pests and diseases as well as increasing food demand for increasing population.

Conventional agriculture development started with the institution of the first FYP and the establishment of the Department of Agriculture in 1961. Improved technologies dissemination system was initiated through extension centers till second FYP (1961-1971). Agriculture development continued to fourth FYP (1976-1981) with the policy of food self-sufficiency and supply of pesticides, fertilizers and improved seeds at full subsidy. Further, in the sixth FYP (1987-1992), decentralization was extended and the input distribution system (seeds, agricultural tools and fertilizers) was taken out from extension workers and privatized to let farmers take the accountability and ownership. The subsidy for pesticides and fertilizers was lifted after the government felt that the use of pesticides and chemical fertilizers could lead to irrational and overuse, affecting human health and environment. The same trend is followed at present and the current 12 FYP (2018-2023) focuses on six major commodities; rice, maize, vegetables, fruits and nuts, citrus and potato as they have indispensable contribution to nations on food self-sufficiency, nutritional security, poverty alleviation and income generation. These commodities production is through enterprise development, organic agriculture, land development, farm mechanization, innovation and promotion of climate resilient technologies

(Department of Agriculture MoAF 2019). One of the objectives of 12 FYP is to promote organic farming for sustainable agriculture, safe food, and environment conservation and reduce agrochemicals.

The policy goal of "Food Self Sufficiency" is being pursued along with the 12 FYP. The limited agricultural land aggravated by an aging farming population along with increasing fallow land and rural to urban migration is a serious challenge faced today in Bhutan. The agriculturists and farmers play a critical role in confronting these challenges. However, the increased cost of production resulting from ever growing competitive industrialists around the world is an added challenge. As recommended by Young (1991), establishment of a system of environmental monitoring and a more holistic approach is necessary since Bhutanese traditional sustainable agricultural system is being influenced. Bhutan's social and physical environment is changing, making it concerned on displacement of hardy and resistant native varieties by high yielding and improving varieties of cereals and vegetables. With the current digitalization of technologies, the world has become closer and smaller which are mostly robotic in nature. On the other hand, there is high and increasing demand for safe, nutritious and healthy food due to climate change, reluctance of youth in taking over farming from the old aged population and overall world competition on Gross Domestic Product performance and challenges.

## 3. Management of Agricultural Chemicals

As stated by Weisenburger (1993), exposure of human to agrochemical environment is the main cause resulting to acute and chronic health problems such as neurotoxicity caused by insecticides, fungicides and fumigants; damage to lungs caused by paraquat; chemical burns due to anhydrous ammonia; and infant methemoglobinemia caused by nitrate in groundwater. Besides, hematopoietic cancer is likely to be caused by exposure to pesticides. Immunologic abnormalities, adverse reproductive and developmental effects are also serious health effects of pesticides. Since the effect on human health associated with pesticides is not restricted to only a few classes, enhanced efforts are to be put into rationalizing or avoiding human exposure with all possible measures. It is also harmful for soil health, water bodies and environment at large. There is a need for research for effective characterization and quantification of agrochemical and their effect on human health. In Bhutan, there is no dedicated and responsible organization on this aspect rather the country is working towards preventive measures and organic agriculture for environmental protection.

Ministry of Agriculture and Forests manages agrochemicals, namely pesticides, fertilizers, veterinary drugs, and chemical safety in food through the National Plant Protection Centre (NPPC), National Seed Centre (NSC), Department of

Livestock (DoL), and Bhutan Agriculture Regulatory Authority (BAFRA) respectively. BAFRA is the competent authority for bio-security and food safety systems to promote the quality and safety of food and agricultural-related products. The chemical management-related mandate of BAFRA is the implementation of the Pesticide Act and the Food Act. NPPC in collaboration with BAFRA is involved in regulating all stages of the lifecycle of pesticides, carries out research and encourages the use of Integrated Pest Management (IPM) to reduce the use of chemical pesticides. The supply and distribution of pesticides including herbicides (mainly Butachlor) is looked after by NPPC. NSC is responsible for the supply and distribution of fertilizers in the country. The DoL is responsible for the supply and distribution of veterinary drugs and implements relevant provisions under the Medicine Act 2003.

With the economic development policy of Bhutan guided by the philosophy of Gross National Happiness (GNH), any development activity harmful to the environment and human health is screened out through GNH Policy and Project Screening Tools. This approach ensures a balanced economic development with environmental conservation and human health safety. It places people at the heart of development plans so as to enable them to achieve economic prosperity as well as happiness (Dorji, 2008). Thus, the Government of Bhutan has enacted Acts to regulate the use of agrochemical in the country. There are also ministries and agencies involved in managing the agrochemical use in Bhutan.

### *3.1. Ministry of Agriculture and Forests (MoAF)*

The pesticide management system is a very centralized one. NPPC is the only agency authorized to procure and distribute plant protection products, both organic and inorganic pesticides in the country. The pesticide requirement is indented by agriculture extension agents as per the needs of farmers which are compiled by the respective districts and finally sent to NPPC. As per the requirement received from the districts, the Centre procures plant protection products through the open tendering process. The Center distributes the plant protection products through the District Agriculture and extension agents to individual clients. This whole process is a regulatory mechanism to avoid stockpiling of obsolete chemicals. The pesticides types and quantities imported are regulated by the Bhutan Agriculture and Food Regulatory Authority. NPPC only procures the chemical products grouped under toxicity class II and III in the World Health Organization.

### *3.2. National Environment Commission (NEC)*

NEC was established as the highest decision-making body on all matters relating to the environment and its management. NEC is a cross-ministerial independent body, chaired by one of the Ministers with four to five Secretaries representing relevant ministries, nominated by the Chairperson, and three representatives from civil society. One of the main mandates of NEC is to mainstream the environment into the country's developmental policies, plans and programs. It is also responsible for raising awareness on environment-related issues, promoting and conducting environmental research.

## 4. Regulatory Frameworks for Management of Agricultural Chemicals

Bhutan is using minimum agricultural chemicals in agriculture farming. But still country has various enabling policies, acts and legal frameworks which guide towards preventive approach. The following are some of the Policies, Acts and Regulations for rational use of agrochemicals:

### *4.1. The Pesticides Act of Bhutan 2000*

The objectives of this Act are to ensure that integrated pest management is pursued, limiting the use of pesticides as the last resort in control of pests and that only appropriate types and quality of pesticides are introduced into Bhutan. The clause 6.1 states that "*A pesticide must only be used with regard to its authorized application and in accordance with good professional practice. Good professional practice shall include observation of the guideline provided by the Board and the principles on integrated pest management, where appropriate.*" (Ministry of Agriculture, 2000). The implementation of the act is guided by the Pesticides Rules and Regulations of Bhutan 2019. It is also to ensure that pesticides are effective when used as recommended and to minimize harmful effects of pesticides to human beings and the environment, and to enable privatization or sale of pesticides as and when required guided by the Act (Ministry of Agriculture and Forests, 2019).

The Act also serves to regulate the safe use and handling of chemicals to prevent harmful effects to public health and environmental hazards. The sole authority for the implementation of this Act is the Pesticide Board with the MoAF. The board is responsible for authorizing the import, sale, manufacture, transport, distribution of pesticides, and waste disposal. It also regulates the standard of labeling and packing, advertising, and the Maximum Residue Level (MRL) for food. The Act allows authorized officials from BAFRA to inspect, collect or seize samples, detain or remove any substance that is found to be an offensive against the Act. In line with this, in 2016, BAFRA found high pesticide residue in imported chilli, beans and cauliflower which were unsafe for human consumption and health. Since then, the imports of these three vegetables are temporarily banned. Any offenses against the Act will be punishable in the form of seizure of goods and imprisonment.

### *4.2. National Environment Protection Act 2007*

The National Environment Protection Act of 2007 (NEPA) is an umbrella Act for environmental protection and management in Bhutan. All other Acts and regulations concerning the use of land, water, forests, and other natural resources shall be consistent with this Act and those that are inconsistent with this Act are repealed. This Act provides for the establishment of an effective system to conserve and protect the environment through the National Environment Commission (NEC) or its successors, designation of competent authorities and constitution of other advisory committees, in order to independently regulate and promote sustainable development in an equitable manner.

### *4.3. Economic Development Policy (EDP) 2016*

Bhutan EDP prioritizes development of organic brand to promote Brand Bhutan and promotion of unique Bhutanese value of organic farming under Gross National Happiness social values, environmental and traditional Buddhist philosophy guided by principles of organic farming (Royal Government of Bhutan 2016). This approach can be used to conserve traditional farms attracting foreign tourists providing livelihood and income generation from commercialization of unique products having high value.

### *4.4. Bhutan's policy on environmental conservation.*

About 51% of the country's area is under Protected Areas and National Parks. This provides an opportunity to reserve the area as organic zones for organic development and organic production within 2.93 % of agricultural land. Having such protected areas provide sound conditions for cultivation with strategies in reducing hazardous agrochemicals and replacing them with organic inputs.

### *4.5. Enabling Policy and Legal Environment for Organic Farming*

Organic farming approach is widely opted by Bhutanese farmers over conventional farming. There are various negative impacts due to conventional farming such as human health issues caused by pesticides, soil and water contamination, resistance and resurgence of pests and environmental pollution. Therefore, organic farming is of paramount importance in Bhutanese context. Some policies are already in place that favors organic farming production principles, these give Bhutan a sound base for developing and promoting organic farming.

#### *4.5.1. National Framework for Organic Farming in Bhutan*

Organic agriculture in Bhutan was initiated in 2006 with the inception of National Framework for Organic Farming in Bhutan coordinated by the MoAF.

With its inception, Integrated Pest Management (IPM) strategy was strengthened and implemented towards safe and efficient use of pesticides with protection of the environment, preventing pollution due to indiscriminate use of pesticides. This initiation was a turning point and there was reduction on use of pesticides as the subsidies on pesticides were removed and many hazardous chemicals were banned from the open market for environmental safety. The framework with emphasis on biodiversity, environment protection, forest cover maintenance, and Integrated Plant and Nutrient Management (IPNM) approaches guided by the existing policies was an empowering aspect on strengthening organic farming. With this, organic farming was more focused and strategized. Due to growing health concerns, consumers are diverted more towards the value of organic farming and produce. It says that organic farming reduces external inputs mainly of synthetic fertilizers and pesticides and favors the law of nature to increase yield, protect the environment and produce healthy food. Traditional farming is still practiced by larger farming groups in Bhutan which is a boon for organic farming. The organic food product fetches higher price contributing higher income to majority of small-scale Bhutanese farmers.

The National Framework for Organic Farming in Bhutan (NFOFB) is the guiding principle in promoting organic agriculture in the country. The vision and mission as outlined in the NFOFB (2006) envisions that Bhutan will be fully organic by 2020. It envisions developing and promoting organic farming for food, produce and trade. This was framed with the aim that either alternative technology needs to be found for agrochemicals or incentives and compensation will be required for conversion. Till such time has arrived, it will be a vision to be worked towards and it will take time to develop that capacity, technology, facilities and investments to meet the goal.

### *4.5.2. Master Plan for Organic Sector Development*

Since 2012, the master plan has developed a growth strategy for the cross-cutting issues and sectors within the MOAF. This has potential to uplift the livelihood side and the commercial opportunities side of the organic sector along the value chain with the specific challenges, solutions, requirements for intervention and areas of investments. For this, a dedicated Research Development Centre at Yusipang is mandated for national organic program and coordination from 12 FYP.

### *4.5.3. The Bhutan Organic Guarantee System (BOGS)*

The BOGS is system implemented with Bhutan Organic Standards, Bhutan Agriculture and Food Regulatory Authority (BAFRA) Organic Certification Guidelines, The Local Organic Assurance System and Organic Operators' registration program which are under MoAF, managed by BAFRA and National Organic Program (NOP). This document guides in certification of organic products both at local and national levels which is already at implementation phase at ground level.

## *5. Different Agriculture Chemicals Inputs used in Bhutan*

In Bhutan, use of agrochemicals includes mainly synthetic fertilizers and pesticides by farming communities in Bhutan. With the concern on human health and environmental protection, Bhutan has screened out many of the previously imported and used pesticides which included toxic pesticides such as edifenphos and bromadiolone. Over the years, Bhutan has progressed towards the use of mild toxic chemicals. Common pesticides used in Bhutan in all six agro-ecological zones in the past as well as at present are mentioned below (Table 1).

**Table 1. List of commonly used pesticides the past and present**

| | **Pesticides used at present** |
|---|---|
| 1. Aldrin<br>2. Aluminium Phosphide<br>3. BHC<br>4. Captafol<br>5. Carbofuran<br>6. Ekalux<br>7. Agallol<br>8. Methyl Parathion<br>9. Red Lead<br>10. Thimet<br>11. Temik | **Insecticides**<br>1. Chlorpyrifos 20 EC<br>2. Cypermethrin 10 EC<br>3. Fenvelerate 0.4 % dust<br>4. Malathion 50 EC<br>5. Dimethoate30 EC<br>6. Imidacloprid 20% SL<br>**Fungicides**<br>1. Captan 50 WP<br>2. Carbendazim 50 WP<br>3. Copper Oxychloride 50 WP<br>4. Hexaconazole 5 EC<br>5. Mancozeb 75 WP<br>6. Metalaxyl 8% + Mancozeb 64 %<br>**7.** Sulphur 80 WP<br>**8.** Tricyclazole 75 WP<br>**Non-toxic**<br>1. TSO/HMO<br>**2.** Sticker<br>**3.** Protein hydrolysate<br>**Herbicides**<br>1. Butachlor 5G<br>**2.** Glyphosate 41 SL<br>**3.** Metribuzin 70 WP<br>**Rodenticide**<br>1. Zinc phosphate 80W/W<br>**Bio-pesticide**<br>Neem Oil |

*Source: NPPC*

### *5.1. Current scenario on pesticides uses in Bhutan*

Initially during 1980s the country promoted the use of chemical pesticides by providing subsidy to the farmers. However, after realizing the negative impacts of highly toxic pesticides on the human health and the environment, the subsidy for pesticides was withdrawn in a phase-wise manner (15% yearly) from 1990 to 1995, and simultaneously cash and carry system was introduced as an important part of pesticide reduction strategy. In 1995, a total of 66.5 tons of obsolete pesticides and 4.6 tons of medical chemical wastes, which includes Dichlorodiphenyltrichloroethane (DDT) were collected from all agricultural stores and health care facilities all over the country. Of these, 17 MT of pesticides were returned to the manufacturers and 22 MT pesticides were reused while the remaining 32.19 MT were re-packed under the supervision of international experts and incinerated in 2006.

Bhutan is a signatory to Basel Convention and therefore the import of highly hazardous pesticides is prohibited. From 1986 to 1995, several highly toxic and persistent pesticides like aldicarb, aldrin, aluminum phosphides, benzene hexachloride (BHC), captafol, ekaflux, agallol, methyl-parathion, red lead and thimet, endosulfan, fenitrothion, pirimiphos-methyl, carbaryl, carbofuran, 2,4-Dichlorophenoxy acetic acid, bromadiolone, and brodifacoum were banned for use in agriculture. Bhutan also bans or restricts the import of chemicals used in agriculture which are banned in other countries.

The pesticides used, especially that of insecticides and fungicides had decreased significantly after the 1990s. The insecticides and fungicides used by the farmers in the country from 1986 to 2020 only constitutes 8% and 2% respectively as shown in Figure 1A. The pesticides use trend in Bhutan excluding herbicides has stayed minimum as seen in the Figure 1B. Farmers in Bhutan use a minimum amount of pesticides with comparison to other south Asian countries.

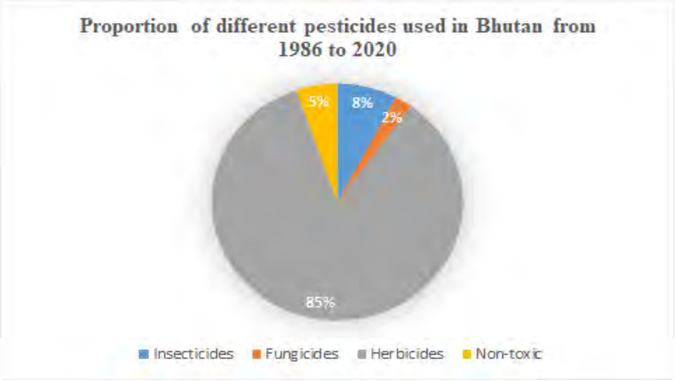



**Figure 1 A. Proportion of pesticides used in Bhutan**

*Source: NPPC year- wise pesticides sale record*

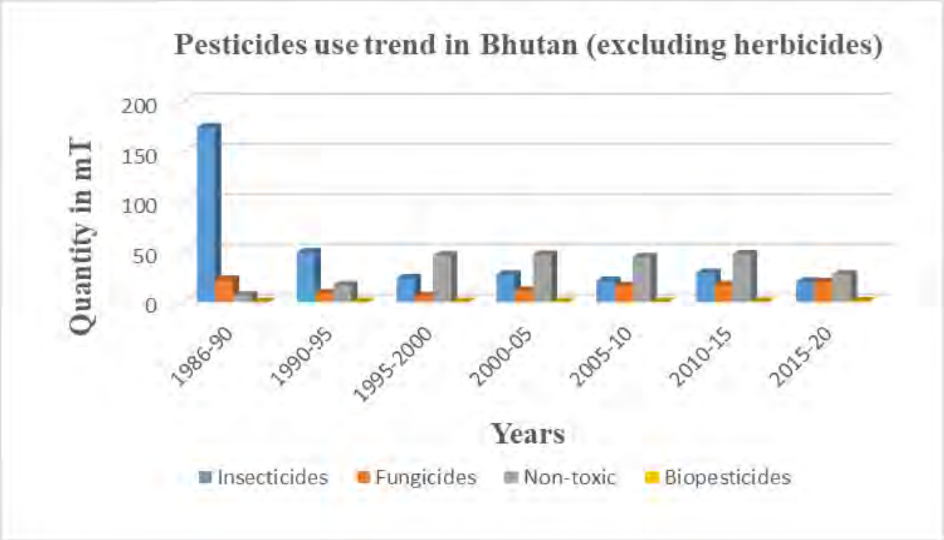



**Figure 1 B. Pesticides use trend in Bhutan**

*Source: NPPC year- wise pesticides sale record*

However, a matter of big concern is that the use of herbicides mainly butachlor has been on a steady rise in Bhutan. NPPC Annual Report (2015) observed a steady increase in the use of herbicides mostly butachlor from about 20 tons in 1986-87 to about 520 tons in 2014-15. Herbicide use in agriculture has further increased from about 993 tons in 2014-15 to about 1864 tons in 2018-20 as shown in Figure 1C mainly due to labour shortage in the farming communities. As reported by Ou, *et al.*, (2000), butachlor is widely used as pre-emergence herbicide by various countries which have carcinogenic properties.

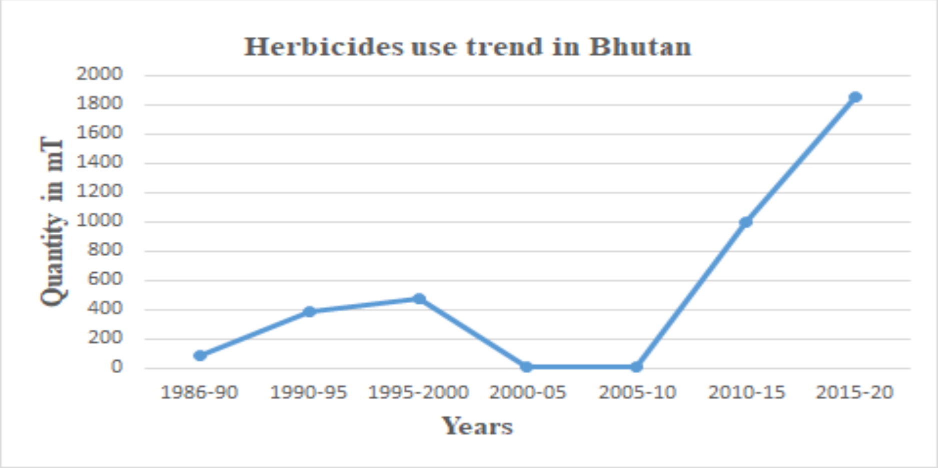



**Figure 1 C. Herbicides use trend in Bhutan**

*Source: NPPC year- wise pesticides sale record*

In Bhutan, butachlor is used as pre-emergence herbicide in rice while glyphosate is used as post emergence herbicide for dry land weeds for farming in Bhutan mainly because there are no alternative herbicides which are neither toxic to human health nor harmful to the environment. As the Government of Bhutan farming policy shifts to Organic Agriculture, the import and the use of chemical pesticides will slowly be phased out when we discover safe alternatives to these chemical pesticides. Use of non-toxic pesticides like linseed oil, protein hydrolysate, sandovit, tree spray oil and biopesticides is being promoted under the organic agriculture policy.

### *5.2. Current scenario on chemical fertilizers uses*

Bhutan started importing chemical fertilizers in the 1960s and its use has been an important component of agricultural development strategy as inputs to increase crops yield and production. The fertilizers import statistics indicate an increasing tendency mainly due to their increased availability with the improvement in road network and better distribution systems; efficient promotion of their use through district extension programmes; and their efficiency to provide substantial and cost-effective yield increases. Currently, no private companies are allowed to import chemical fertilizers and only National Seed Centre (NSC) is authorized to import and sell chemical fertilizers. In order to make accessibility to all the farmers, the Centre has trained a network of Agriculture Sales and Service Representatives (ASSRs) across the country who are authorized to sell imported fertilizers directly to the farmers/clients (Chhetri, 2019). The commonly used chemical fertilizers in Bhutan are presented in table 2.

**Table 2. Commonly used chemical fertilizers in Bhutan**

| Sl. No. | Commonly used fertilizers |
|---|---|
| 1 | Urea |
| 2 | Suphala |
| 3 | Single Super Phosphate |
| 4 | Muriate of Potash |
| 5 | Calcium Ammonium Nitrate |
| 6 | Triple Super Phosphate |
| 7 | Diammonium Phosphate |
| 8 | Bonemeal |
| 9 | Borax |

*Source: NSSC*

The rate of the chemical fertilizer is fixed by NSC and the fertilizers are sold at the same rate by all the ASSRs in the country. The import of chemical fertilizers increased from about 319 MT in the 1976-77 to 3,015 MT in 2018 (Figure 2). In 2015, the highest quantity of chemical fertilizer (3398.28 MT) was distributed in the country which corresponds to about 42.1 kg of fertilizer per hectare of cropped land which is minimal if compared to the quantity of fertilizers used by other South Asian countries. Farmers mostly use urea, suphala and single super phosphate as additional sources of plant nutrients.

In Bhutan, fertilizers are mostly applied in cash crops such as potatoes and apples which are exported outside the country. Within the four regions in the country, fertilizer distribution is highest in the west central region (30%) followed by western and eastern regions (27%) and then by east central (16%) (Chhetri, 2019). According to Dorji (2008), about 50% of the fertilizers are applied in potatoes, 25% in apples, 9% in paddy and 13% are applied in other crops like maize, wheat and buckwheat.

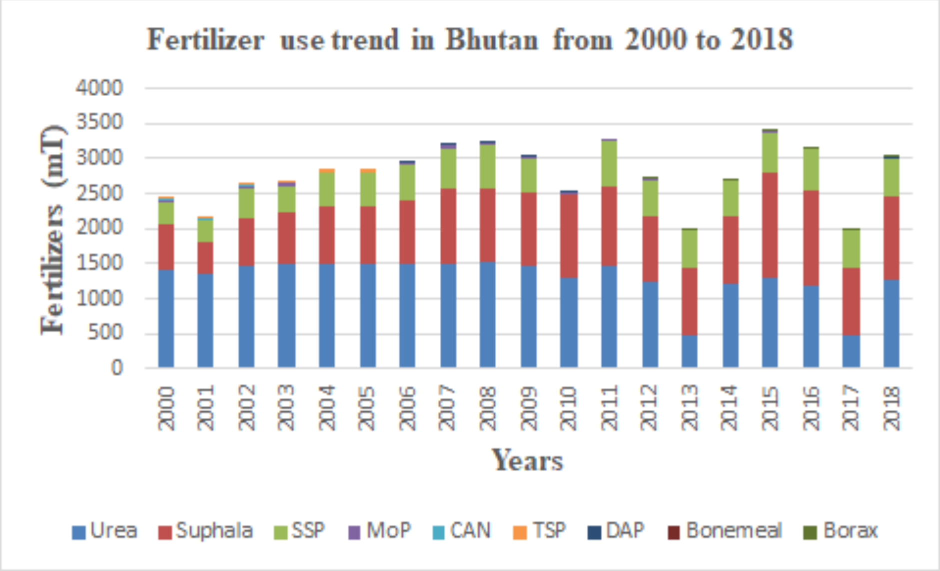



**Figure 2. Fertilizer use trend in Bhutan from 2000 to 2018**

*Source: NSSC District-wise fertilizers sale record 2000-2018*

## 6. Government Interventions on Rationalization of Agricultural Chemicals usage through

### Organic Agriculture

Bhutan has a strong developmental policy grounded firmly in the principles of the country's developmental philosophy emphasizing in achieving Gross National Happiness (GNH) against Gross National Product (GNP). Article 5 of Constitution of Kingdom of Bhutan spells "*Every Bhutanese is a trustee of the* *kingdom's natural resources and environment for the benefit of the present and future generations and it is the fundamental duty of every citizen to contribute to the protection of the natural environment, conservation of the rich biodiversity of Bhutan and prevention of all forms of ecological degradation including noise, visual and physical pollution through the adoption and support of environment friendly practices and policies."*. It also clearly mentions that at least 60% of the country's area should be under forest cover all the time. Grounded to this highest country's law, all developmental plans are guided and aligned with it. Under the national law, integration of sustainability and environmental conservation is the core national development objective in overall national development plans guided by the concept of balanced sustainable development measured by gross national happiness.

### *6.1. Current agriculture programs and approach focusing on minimizing agrochemical uses*

The current agriculture development approach is focused on six major food crops; rice, maize, vegetables, fruits and nuts, citrus and potato since they are vital commodities contributing to national food self-sufficiency, nutritional security, poverty alleviation and income generation. Beside commodity development, other thrust areas include; enterprise development, organic agriculture (minimizing agrochemicals), land development, farm mechanization, innovation and promotion of climate resilient technologies in present plan and priorities. The agriculture development is vision with; 'A self-reliant, productive, diverse, resilient and sustainable agriculture food system' and some specific key strategies related to organic agriculture (minimizing agrochemicals) development are:

- Sustainable agriculture is an important guiding factor for socio-economic development and growth with the policy of nation development without destroying the environment and ecosystem. Agro-chemical management and regulations are strongly illustrated for a sustainable developmental approach. For gearing towards sustainable agriculture, organic agriculture is promoted on a landscape approach without use of agrochemicals. Department of Agriculture is the sole authorized body for import and sale of chemical pesticides as per the Pesticide Rules and Regulations of Bhutan 2019. It is imperative to follow conspicuous decisions to limit overuse and prohibit use of hazardous chemicals which have negative impact on human health and environment in the long term. Generally, farmers practice integrated pest management for pests and disease management in which application of chemicals is a last resort;

- Sustainable soil fertility management and land development is critical since Bhutan is of sloppy and mountainous terrain. To minimize use of synthetic fertilizers, programs and activities are focused towards land development along with improvement of soil nutrient management for optimum crop productivity and soil health. Sloppy and narrow agricultural areas are terraced to facilitate farm mechanization and efficient utilization of available soil nutrients. Farm nutrient recycling is efficiently practiced through re-use of crop residues, animal manure, compost, green manure and other bio matters. Soil nutrient management technologies like intercropping with leguminous crops, crop rotation, large scale production of organic manure and mixed cropping are followed. Mineral fertilizers are applied only as supplement nutrients where accessible and affordable;
- With the priority on organic farming and rationalized usage of agrochemicals, climate smart farming and green technologies is felt as an adaptation measure for the current climate change challenges. As preventive and mitigation measures, micro irrigation technologies, organic farming, mixed farming with livestock, staggered crop cultivation and traditional crops varieties is an alternative approach for sustainable farming. In order to increase preparedness for unpredictable climate, agriculture agro-met services program is launched under the Department of Agriculture who will provide agro-meteorological advisory services and weather forecasting. With the weather forecasting and advisory services, the use of pesticides is reduced since early pests and diseases outbreak is detected;
- Enterprise development in the current agriculture approach is also focused on organic fertilizer production plants, vermicompost production and bio-pesticide production plants. With the policy of acceleration of farming towards organic agriculture, these programs will be an added advantage to Bhutanese farmers since they already follow more of an integrated pest management approach with minimal use of pesticides and chemical fertilizers;
- Agriculture input services will continue with the regulation on the sale of chemical fertilizers and pesticides, limiting to import and distribution by National Plant Protection Centre (NPPC) as practiced currently to ensure rational supply, quality product with safety measures both at human health and environment;
- Information and communication technology (ICT) agriculture is initiated at piloting scale and to be further disseminated to wider locations covering farming areas. The technology is aimed for agriculture research

and development in labour saving mechanisms, effective and efficient water management, forecasting pests and diseases outbreaks, early warning system for disaster prevention and enhanced agriculture system;

- A total of 5,560 acres (out of 261,567 acres) of agricultural land is brought under organic agriculture benefiting 2,680 households through capacity building, support to production inputs, product development and certification. As of now, ten products had been developed and certified in collaboration with the National Certification Body, Bhutan Agriculture and Food Regulatory Authority (BAFRA) and International Certification Body (IMO). A total of 24 farmer groups and cooperatives had been established to strengthen marketing of the produce. Three organic manure production plants had been established to supply bio-inputs for organic production (Department of Agriculture MoAF 2019).

### *6.2. Commodities identified for organic flagship program for reduction of agrochemicals*

For minimizing use of agrochemicals and effective execution of organic agriculture, the National Organic Flagship Program (NOFP) has been established since 12 FYP. Broadly, two categories of commodities are identified for flagship program: i) Export market for eight commodities namely; buckwheat, quinoa, ginger, cardamom, mushroom, turmeric, trout and lemon grass oil. ii) Domestic market for four commodities namely; asparagus, beans, cauliflower and chili. These products are produced organically without use of agrochemicals which will be further up-scaled and expanded to wider locations.

## 7. Farmers' Perception on Agrochemicals and its Impacts on Human Health and Environment

The National Plant Protection Centre Annual Report (2018-2019) reported that farmers are aware about the harmful effects of pesticides on human health and the environment. It was also reported that 50% farmers knew that the pesticides are moderate to highly harmful to human health and the environment (Figure 3). The most common effects of pesticides on human health described by respondents were vomiting, skin irritation, burning eye sensation and cancer. The common environmental hazards of pesticides known by respondents were the death of aquatic animals like fish, frogs, and toads. This information was based on the application of highly toxic pesticides which were used during subsidy period before 1992. With the lifting of subsidy and implementation of cash and carry system and restriction on import and use of toxic pesticides, such observations are not found.

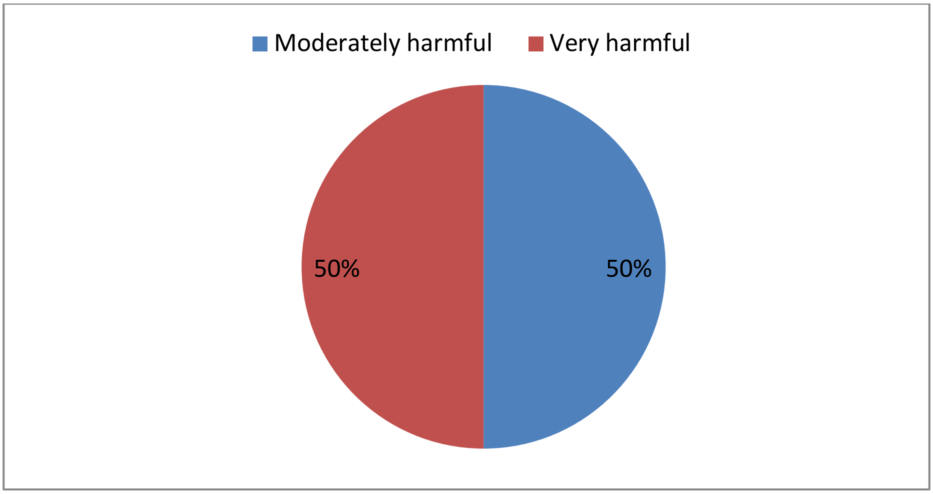
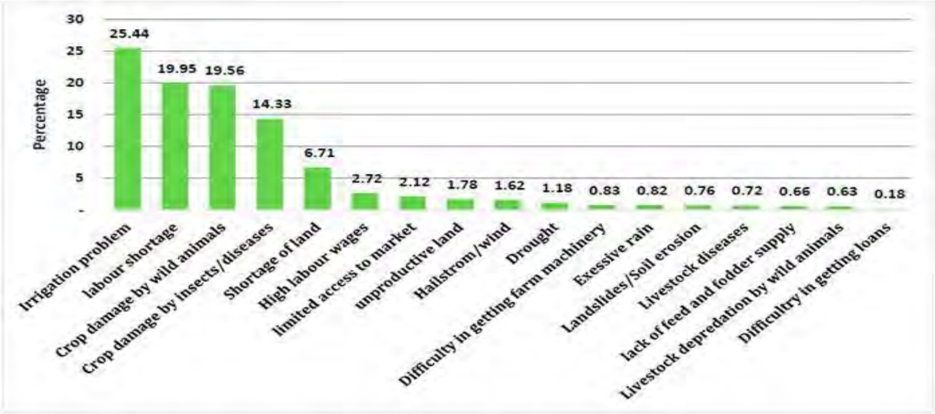



**Figure 3. Farmers' perception of harmful effects of pesticides on human health and environment**

*Source: NPPC Annual Report 2018-2019*

## 8. Challenges of Minimizing Adverse Impact of Agrochemicals

As per the Renewable Natural Resources Statistics Division (2019), various challenges are faced by the agriculture sector in Bhutan in terms of physical inputs, climate change, marketing facilities and others among which labour shortage, crop damage by insects/diseases and unproductive land are related to use of agrochemicals (Figure 4). The specific challenges related to use of agrochemicals in combating labour shortage, crop damage of insects/diseases and unproductive land are highlighted below:




*Source: RNR Census of Bhutan 2019*

**Figure 4. Challenges faced by agriculture in crop production**

- Farm labour shortage in rural areas is mainly due to rural-urban migration triggered by production challenges and competition from import of cheaper food materials has adversely impacted on the domestic food production. The youth and energetic population are mostly driven by urbanization and only age-old populations are left in farming business. Major labour input is required in paddy, maize and potato for weeds management. For this, they use Glyphosate for post emergence weeds in all crops and Butachlor for pre-emergence weeds especially in paddy;
- The increasing use of high yielding and hybrid varieties of seeds has high demand for soil nutrients since these varieties are highly responsive to nutrients. To gain maximum yield, use of synthetic fertilizers has remain a challenge. Organic soil manures are slow nutrient releasing and have diluted nutrients while synthetic fertilizers are concentrated and provide quick return. With such short-term benefits, many farmers are attracted towards use of synthetic fertilizers especially for commercial crops;
- The mountainous terrain and steep sloppy agriculture land have led to erosion of top soil and soil nutrients loss with decreasing crop yield. There is limited scale of land development program focusing on terracing of cultivated land and retention of soil fertility and reduce use of synthetic fertilizers;
- The increasing trend of intensive and commercialized farming with high yielding varieties has contributed in enhancing food self-sufficiency. Simultaneously, there is increasing incidence and outbreak of pests and diseases resulting in challenges in controlling through organic and mild pesticides;
- The conservation policy and organic framework of Bhutan aims at food self-sufficiency through sustainable and green socio-economic measures which is quite challenging;
- Farmers have limited knowledge on advantages of organic farming against conventional practices. With the limited exposure to outside world, they tend to go for usage of pesticides and synthetic fertilizers for immediate return;
- Farmers have limited knowledge on safe handling of pesticides, its impact in long term and residual effect on human health and environment;
- There is neither a dedicated agency nor any unit responsible to carry out studies on the effect of agricultural chemicals on human health and environment due to which there is limited information about it. All the

policies, strategies and guidelines are as per the observation on negative impacts of other countries;

- There are limited competent professional in agriculture to study the impacts of agrochemicals and recommend to minimize or avoid the adverse impacts;
- There is no facility for disposal of obsolete pesticides in Bhutan due to which the import is always rationalized and strictly controlled;
- There are limited alternatives for synthetic pesticides and fertilizers due to which the organic agriculture is a challenge.

## 9. Agriculture Development Opportunities

- Wide variation of agro-ecological conditions with altitude ranging from 150 masl to more than 4500 masl provides opportunities to grow a range of cereals and horticultural crops. It possesses diverse agro-biodiversity of crops varieties, flora and fauna. From such provision, there are advantages to develop crop varieties and associated production technologies for specific environmental locations.
- There are favorable conditions for organic agriculture which is currently practiced by farmers by default. There is a long history of traditional farming practices, low use of external inputs including agro-chemicals and diverse agro-ecological environment. These are major strengths for Bhutan to go for 100 % organic farming for which the country is pursuing to promote organic farming as high priority.
- There is a good opportunity to grow and market off-season crops particularly fruits and vegetables in the hills and mountains during hot summer seasons and export to the neighboring countries.

## 10. The Way Forward

In order to minimize the use of agrochemicals and reduce impact on human health and environment, measures are to be undertaken strongly and efficiently for long term benefits. Some of the important areas of actions to be undertaken and way forward from Bhutan perspectives are as highlighted as under:

- Explore technologies for an effective organic weedicide to be adopted as an alternative to synthetic weedicides for weeds control;
- Initiate and strengthen technologies to produce organic pesticides for pests and diseases control as an alternative to synthetic pesticides for safety of human health and environment;
- Establish laboratory facilities to study the pesticide residues in various food products to ensure health safety of humans;

- Invent/design agriculture machineries which are gender friendly and efficient to overcome the labour shortage especially for weeds control in order to reduce use of synthetic weedicides;
- Capacity building of farmers, extension, researchers and other relevant clients on importance and impact of agrochemicals on human health and environment. Importance of organic farming, safe handling of pesticides and integrated pest management are the areas for capacity building;
- Agriculture land development program to be strengthened focusing on land terracing for soil nutrient retention and reduce fertilizer application;
- Need to create separate agency to deal with the agrochemicals and to study its impact on human health and environment and also to assess minimum residue level on food;
- Establishment of disposal facilities for obsolete agrochemicals is necessary to avoid environmental pollution.

## 11. Strengthen Networking among SAARC Member Countries

Although there is existence of good networking system among SAARC member countries coordinated by SAARC Agriculture Centre (SAC), strengthening coordination and networking on the management of agrochemicals would be advantageous especially for Bhutan as a developing country. As Bhutan embarked on natural organic agriculture farming, sharing and learning on impact of agrochemicals on human health and environment is of utmost importance. This would create an opportunity for the researchers and professionals to upgrade their knowledge and embrace towards reduction of agrochemicals impacts and protect health and environment. Coordination of SAC on the following areas would be valuable for healthy agriculture farming:

- Maximize free exchange of new regional ideas among the research fraternity including the private entrepreneurs and NGOs for disseminating and transferring of proven technologies;
- Facilitate expertise exchange visits within the region for sharing technologies for enhancing crop production through safe measures;
- Full utilization of knowledge and skills of the researchers and scientists using both national and member countries facilities;
- Create an opportunity to institutionalize and initiate the best innovative technologies award to both the researchers and farmers;
- Institutionalize networking forum for SAARC member countries to share best practice of agrochemicals uses and proven technologies for safe and healthy agriculture without affecting human health and environment.

## 12. Conclusion

Bhutan being an agrarian country with 69% of its population engaged in agriculture with only 2.93% agricultural land available for food production. It is a great challenge to meet the goal of food self-sufficiency for the country with limited resources. The limitation on horizontal expansion of crop production is due to the limited land resource. Vertical increase on crop productivity is possible with application of agricultural chemicals to manage pests and disease and soil fertility. However, there are negative impacts of agricultural chemicals on human health and environment. In order to prevent such impact, Bhutan agriculture system is more on preventive approach by regulating the use of agriculture chemicals. The initial subsidy on pesticides and chemical fertilizers during the 1980s for about one decade was a learning period during which the government realized that the irrational and over use of agrochemicals led to negative impacts on human health and environment. With the lifting of subsidies, there was reduction on the import and application of agrochemicals which lead to the protection of the environment and human health. Policies, rules and regulation, strategies which are in place for environment conservation and organic agriculture regulate the use of agrochemicals thereby protecting human health and environment.

Having existing developmental policy and statutes may not be sufficient for Bhutan to be always safe from pollution and its effect on human health. Neither studies nor research were undertaken related to impacts of agrochemicals inputs in agriculture and there is no dedicated organization/agency responsible to undertake the studies. To combat such challenges, it is imperative for Bhutan to establish separate unit to deal with agrochemicals and its impact, disposal of obsolete chemicals and develop technologies for production of organic pesticides and weedicides.

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Chapter 4

# Impact of Agricultural Chemical Inputs on Human Health and Environment in India

**Arvind K Shukla**[1], **Anupama Singh**[2]
**Tirthankar Banerjee**[2] and **S K Chaudhary**[3]
[1]ICAR-Indian Institute of Soil Science, Bhopal-38
[2]ICAR-Indian Agricultural Research Institute, New Delhi-12
[3]Indian Council of Agricultural Research, KAB-II, New Delhi-12
*[1]arvind.shukla@icar.gov.in; [1]arvindshukla2k3@gmail.com*
*[2]head_chem@iari.res.in [2]anupamanil2000@gmail.com*

## 1. Introduction

Agriculture comprises livelihood source for around 50% human population of India. India with 29 states and 7 union territories is home to 2$^{nd}$ largest (1.3 billion) human population in the world. With 303 million tonnes food gain production (wheat & rice major ones), country has to produce more than 400 million tonnes of food grains by 2050, in order to feed an expected 1.65 billion people. Indian Council of Agricultural Research, one of the largest national agricultural systems in the world, consists of 104 National Institutes and 71 agricultural universities and has played the pioneer role in ushering Green Revolution, enabling country to increase food grain production by 5.6 times, horticultural crops by 10.5 times, fish by 16.8 times, milk by 10.4 times and eggs by 52.9 times during last seven decades. India, presently with worth $ 2.1 trillion economies, is major exporter of raw cotton, wheat, rice, fruits, vegetables, spices, meat and chemicals; largest producer of milk, pulses and jute, second largest producer of rice, wheat, sugarcane, groundnut, vegetables, fruit and cotton; leading in production of spices, fish, poultry, livestock and plantation crops. Agriculture accounts for 23% of GDP, employing 59% of the country's total workforce.

Balancing food security and environmental quality is one of the greatest challenges faced by humanity today. Fertilizer is the backbone of increased agricultural productivity for feeding the growing population of India. Fertilizer consumption in India has increased by about 13 times during 1970 to 2020, skewed to major share of fertilizer N leading to loss of reactive N (NR) increase by 5 times (FAI, 2019-20 and Bijay Singh, 2016). Excess use of two key nutrients (N and P), has led to alteration of the nitrogen (N) cycle, amplifying annual budget of reactive N (Nr) compounds from atmospheric dinitrogen (N2), resulting in reduced nitrogen use efficiency (NUE) of the Indian food system (30%) (Adhya *et al*, 2010). The fertilizer P use recovery is very low (15%) leading to deposition in soil and loss to water bodies through leaching of nutrients into groundwater and/or runoff of nutrients into surface waters. The related harmful effects due to excessive use of N&P include soil and atmospheric pollution, eutrophication (a reduction in dissolved oxygen in water bodies caused by an increase of mineral and organic nutrients) in rivers and lakes, threat to biodiversity and the health of native plant species and natural habitats, formation and release of nitrous oxide, a highly harmful greenhouse gas.

Another major constraint in ensuring sustainable agriculture, food and nutrition security of country is existing, emerging and invasive pest problems triggering huge production losses, estimated to Rs 90,000 crores annually, despite the use around 60,000 tonnes of pesticides every year. The use of pesticide is inevitable to control the pest and diseases to ensure sustainable agriculture and household food security of country. For protecting the pre and post-harvest losses due to insect, pest and disease, around 1,175 pesticide molecules both chemical and biological origins, are being used worldwide, about 293 molecules are registered for use in India. According to a report by Database Research and Markets, the Indian pesticides market was worth Rs 214 billion in 2019. Pesticides market is further projected to reach a value of Rs 316 billion by 2024, growing at a compound growth rate (CAGR) of 8.1 percent annually. Although pesticide use in India is much lower than many countries in the world. But, the long term and continuous application of synthetic pesticides in agriculture has caused accumulation of pesticidal residues in the environment leading to various chronic illnesses. Most of the pesticides compound are stable in nature and persist in soil and water sources for longer period due to elongated half-lives ranging from a few weeks to years, and they also enter the food chain leading to increased health risks. Pesticide contact may occur through various means, like inhalation of aerosols or droplets of pesticides smaller than 5 μm in diameter, dermal contact and consumption of directly contaminated food can lead to pesticide poisoning (Yadav *et al.,* 2015). Sometimes, pesticide reaches to the placenta that can cause structural and functional defects to the fetus. There is need to regulate and minimize the use of agrochemicals involved in food and horticultural production by incentivizing healthy and sustainable consumer choices, model crop management practices that reduce GHG emission, balanced nutrient consumption, adopting ecosystem-based approaches, green pesticide and strengthening policies so that little impact engraved on environment and animal/human health is negligible.

## 2. Scenario of Agrochemicals used in India

### *2.1. Fertilizer Consumption*

The fertilizer manufacturing Industry in India is second most important core sector after steel industry in terms of investment, developments, quantity and the types of fertilizers produced, the technologies used and the feedstock employed. After green revolution, the fertilizer consumption in India was accelerated with the introduction of fertilizer responsive high-yielding variety. The annual fertilizer consumption increased many folds, with current consumption of 28.97 million tonnes (2019-20) as against 2.26 million tonnes in1970-71 (Fig 1 casted by using fertilizer consumption and food grain production data from Fertilizer Statistics of India-2020 (FAI, 2019-20). However, fertilizer nutrients consumption varies significantly from state to state in India. While the North and South zones have a consumption of more than 100 kg $ha^{-1}$, in the East and West zones the consumption is lower than 80 kg $ha^{-1}$. Among the major states, the per-hectare consumption is more than 100 kg in West Bengal (122 kg), Haryana (167 kg), Punjab (184 kg), Uttar Pradesh and Uttaranchal (127 kg), Andhra Pradesh (138 kg) and Tamil Nadu (112 kg). In the remaining states, the consumption per hectare is lower than the all-India average. The overall NPK consumption in India has grown 11.84 times from 1970 to 2018-19. Fertilizer consumption has increased from 50.6 mt in FY2009 to 61.4 mt in FY2020 with compound annual growth rate of 2.0%. However, partial factor productivity (kg food grain produced per unit of fertilizer nutrient used) has declined from 28 kg $kg^{-1}$ to 10 kg $kg^{-1}$ during 1970 to 20109-20 (Fig 1). Total nutrient consumption (NPK) has gone up from 2.26 mt in 1970-71 to 28.97 mt in 2019-20, while food grain production has increased from 108.42 mt to 296.65 mt during the same

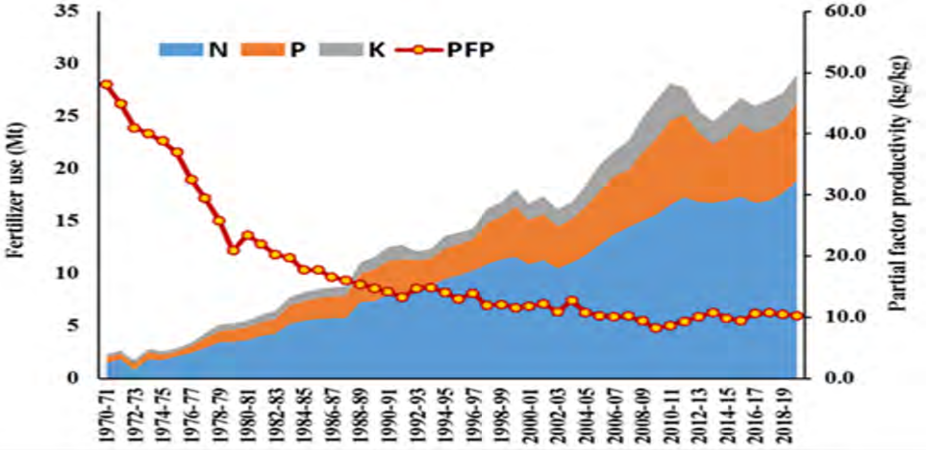



**Fig. 1. Fertilizer NPK used and partial factor productivity after green revolution FAI Statistics,2020)**

period. In terms of total fertilizer nutrient consumption (N+P+K) India ranks second in the world with 296.65 Mt, next only to China (52.5 Mt).

However, per hectare consumption of fertilizer in India is lower compared to many other countries, even the neighboring ones (Fig 2, FAOSTAT-2020). The current average fertilizer nutrients (NPK) use per hectare in SAARC countries was much higher (~174 kg $ha^{-1}$) than total nutrient consumption in India (~145 kg $ha^{-1}$) (FAI, 2019-20). Although the total fertilizer use is not high in India but fertilizer use pattern is highly skewed towards N consumption. Fertilizer-N consumption in India during 1970 to 2020 increased by about 13 times, whereas the crop N uptake increased by 4 times leading to loss of reactive N (NR) increase by 5 times. Besides Fertilizer-N application, N inputs are also added through biological N-fixation. As per conventional estimate N contribution through BNF in Indian agriculture varied from 5.20-5.76 Tg N making roughly 9.5%-10.6% of the global agricultural BNF with cereals contributing 32% and grain legumes amounting by 43%. Phosphorus consumption in India increased from 0.54 mt during 1970-71 to 1.21 mt during 1980-81, 3.22 mt in 1990-91, 4.80 mt in 2000-01, 7.28 mt in 2010-10 and 7.50 mt in 2019-20. This increase in P consumption has been recorded more than 14 time during 2010-11 as compared to 1970-71. Consumption of K was very meagre, i.e., 0.24 mt in 1970 which increased 11-fold by 2019-20 (2.64 mt).

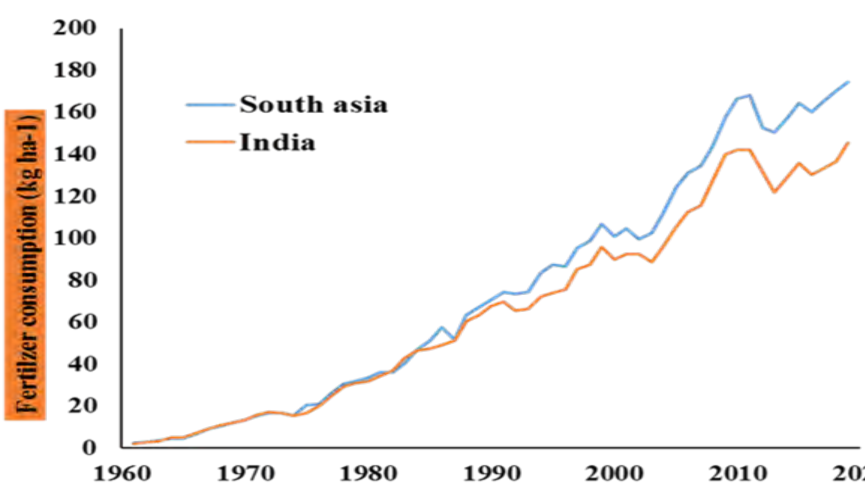



**Fig. 2. Comparative per hectare average fertilizer nutrients (NPK) consumption in India and South Asia**

***Source: Adopted world fertilizer trends and outlook to 2020, FAO***

### 2.2 Pesticides Consumption

India is the fourth largest producer of pesticides in the world. Domestic production has not only enabled India to become self-sufficient but also an important exporter of pesticides. However, use of pesticides in India is one of the lowest (< 0.5 kg/ha) in the world as compared to other agriculturally important countries like China (10.93 kg/ha), Japan (14.18 kg/ ha) and some Latin American countries (Fig. 3; FAOSTAT, 2019). The use of pesticide in India has always been less than 0.5 kg $ha^{-1}$ (Fig 4, FAOSTAT, 2019). Around half of the total used pesticides are applied in cotton, followed by rice (18%), fruit & vegetables (14%). Maharastra state consumes ~22% of pesticides followed by Uttar Pradesh (21%). India's imports of crop protection chemicals mainly the technical grade materials or active ingredients that go into making of end-use formulations stood at Rs 9,266.84 crores in 2018-19, most of it is coming from USA, EU, Japan, China and

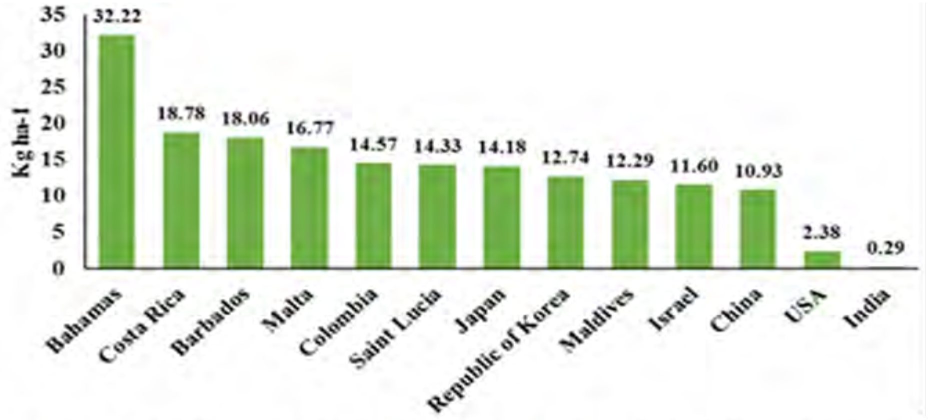



**Fig. 3. Comparative use of pesticides by different countries**

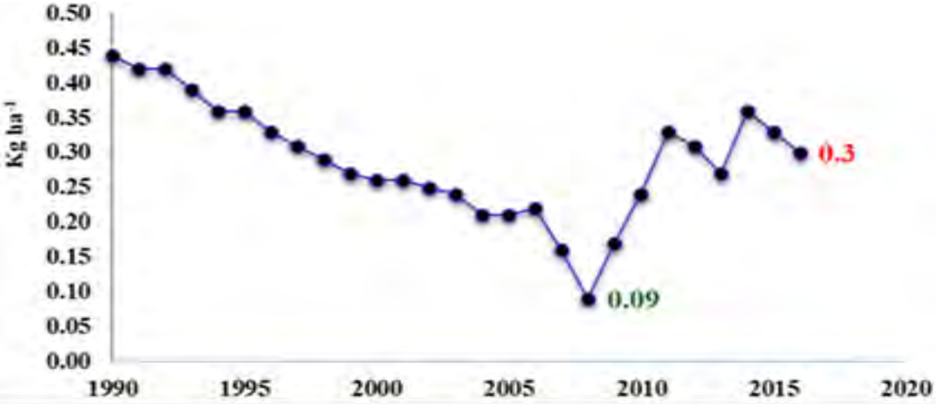



**Fig. 4. Trends of pesticide consumption in India**

Germany. Significantly, India, in 2018- 19, exported crop protection chemicals worth Rs 22,092 crores, a large part of it to Brazil (Rs 4314.74 crores) and the USA (Rs 4,238.63 crores). The pesticide industry had a business of about 43,000 crores during 2019-20. In view of the environment and food safety issues lately gaining prominence, concern for chemical residues in food and inadvertent soil, water and environmental pollution by pesticides is receiving greater attention. It is, therefore, important that farmers use right kind of pesticides in right way to increase their production while protecting environmental, human, and animal health.

## 3. Policy and Regulatory Farmeworks

The Government of India (GoI) has been regulating the sale, price, and quality of fertilizers under an essential commodity act, called Fertilizer Control Order (FCO) 1957, which was revised several times till 1985, called FCO 1985. No subsidy was paid on Fertilizers till 1977 except Potash for which subsidy was paid only for a year in 1977. Urea is the only controlled fertilizer, which is sold at the statutory notified uniform sale price. The Phosphatic and Potassic fertilizes are decontrolled and are sold at indicative maximum retail prices (MRPs). The most important factors which influence fertilizer use is prevailing fertilizer price policy and subsidy schemes implemented by GoI. Introduction of fertilizer price reforms by GoI had severe effect on fertilizer use and distorted the ratio of NPK fertilizer use accordingly. The five major milestone are, 1) Retention Price Scheme (RPS) (Marathe Committee) (cost plus pricing subject to some efficiency norms)-1977; 2) Economic Reforms and Joint Parliamentary Committee (JPC) during 1991-92; 3) Expenditure Reforms Commission (Geetha Krishnan)-2000; Nutrient Based Subsidy (NBS)-2010 and promotion of neem coated urea-2015. The cheaper price of fertilizer N and government subsidy has rendered higher proportion of N-fertilizer use by the farmers across the country. Abolition of retention price cum subsidy scheme in 1992 has distorted the NPK ratio to 9.2:3.2:1 as compared to 6.3:2.4:1 during 1977. Further, India announced the nutrient-based subsidy policy in 2010 to ensure application of fertilizers in a balanced approach, however, price decontrol on fertilizer P and K has led to an immediate rise in the prices of P and K fertilizers leading to a decrease in their use. The immediate effect of NBS was a sharp rise in fertilizer prices, particularly for phosphoric and potassic fertilizers, which increased on an average from 10,000 per metric tonne (mt) before the introduction of NBS to 25,000 per mt in 2013. The immediate outcome of this was a sharp decline in the use of phosphoric and potassic fertilizer mix, with increase in urea consumption.

**Table 1. Fertilizer policy induced changes in ratio of NPK use in India**

| Fertilizer Scheme | Retention price cum subsidy scheme (RPS) on all fertilizer | Abolished RPS on P and K fertilizer only | GoI fixed MRP of all fertilizers | phased decontrol of fertilizer-N | NBS scheme and price decontrol on P and K fertilizers | Introductio n of Neem coated urea |
|---|---|---|---|---|---|---|
| Year | 1977 | 1992 | 1997 | 2003 | 2010 | 2015 |
| NPK ratio | 6.3:2.4:1 | 9.2:3.2:1 | 7.9:2.9:1 | 6.1:2.2:1 | 4.7:2.3:1 | 7.0:2.7:1 |

NBS-nutrient based subsidy, RPS- Retention price cum subsidy scheme

Although urea prices remained administered, the surge in demand for urea meant that not only was urea selling in the black market at twice the administered prices, there was also severe shortage of urea in the market. As result, NPK ratio distorted to 8.2:3.2:1 in 2012-13 as compared to 4.7:2.3:1 in 2010-11. Government proclamation on 100% use of neem coated urea has positive impact on fertilizer use efficiency and rate of fertilizer N use remain constant till 2018-19 with NPK ratio of 6.6:2.5:1 (FAI, 20). As against the ideal ratio of 4:2:1 (approximately 57% of N, 29% of P and 14% of K) the actual ratio has always been distorted due to some policy induced effect. For instance, price decontrol on P and K fertilizer and execution of NBS scheme has reduced the use of P and K fertilizer. As a result, NPK use has changed to 68.4, 23.0 and 8.6 % in 2013-14 and 65.1, 25.8 and 9.1% in 2019-20 as against 58.9, 28.6 and12.5% in 2010-11 (Fig 5). Inappropriate fertilizer use is certainly a matter of serious concern as it is not only detrimental to the soil health of the country but also causes severe environmental damage and fiscal health of the economy due to heavy exchequer on fertilizer subsidy. The biggest challenge is to change the fertilizer use pattern, which involves revamping and re-energizing the extension services but also changing the NBS suitably to remove the price distortion caused by it. Since fertilizer prices follow the trend in international petroleum prices, the only way

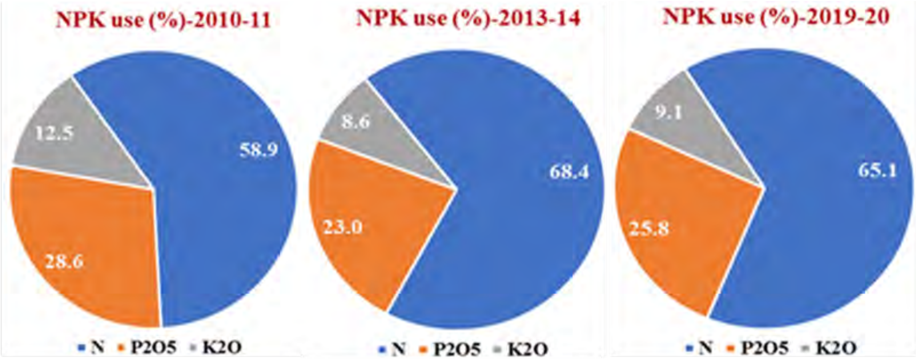



**Fig. 5. Relative changes in NPK use due to implementation of price decontrol and NBS**

*Source: Fig 5 casted by using fertilizer consumption data from Fertilizer Statistics of India-2020* to reduce the subsidy bill is to reduce the dependence on imports and increase domestic production. While rationalizing fertilizer subsidy across nutrients may be the short-term and immediate solution to the problem, the need of the hour is to have a policy framework that incentivizes domestic production of fertilizers.

In India, Insecticides Act was passed in 1968 to regulate the import, manufacture, sale, transport, distribution and use of insecticides with a view to prevent risks to human beings and animals and for other matters connected therewith. All the provisions of the Insecticides Act was brought into force with effect from 1st August, 1971. According to the rules framed under Insecticide Act 1968, there is compulsory registration of the pesticides at the central level and licence for their manufacture, formulation and sale are dealt with at the state level. The enforcement of the Insecticides Act in the country ensured availability of pesticides of very high quality to the farmers and general public for crop protection and public health respectively.

In order to ensure safe and judicious use of pesticides, Indian Council of Agricultural Research, Ministry of Agriculture and Farmers Welfare, Govt of India has developed web enabled and mobile friendly insecticide and fungicide calculators (IFCs) for major crops, to provide information on pesticides with label claims, quantity calculations based on recommended dosages, methods of application and application technology against target pests to aid in judicious selection, sale and use on target crops. Country farmers are aware regarding pesticide usage (42%), their adverse effects (70%) and pest management related capacity building programmes of the Government of India (76%). Country faces challenges like fast track registration of pesticide molecules, non-genuine / illegal pesticides, lack of legal control/deviation from the recommended pesticides and trade barriers. India is committed towards global harmonization of MRLs, strengthening of testing and certification procedures, capacity building and adoption of crop grouping concept for the welfare of farmers and consumers. In order to implement effective enforcement of the Insecticides Act, the two bodies *viz.* Central Insecticides Board and Registration Committee operate at the central level under ministry of agriculture and farmers welfare. Under FSS Act 2006, Food Safety and Standards Authority of India was established in 2008 with the objectives (i) to fix science based food standards (MRLs), (ii) to regulate manufacture, storage, distribution, sale and import of food articles (iii) to ensure availability of safe & wholesome food for human consumption. To achieve thiese objectives, MRL proforma as per JMPR format is submitted by applicant to CIBRC for all proposed crops for establishing MRLs by FSSAI. MRLs are fixed by the FSSAI as pre-requisite to registration of pesticides in stepwise manner as depicted in Fig. 6.

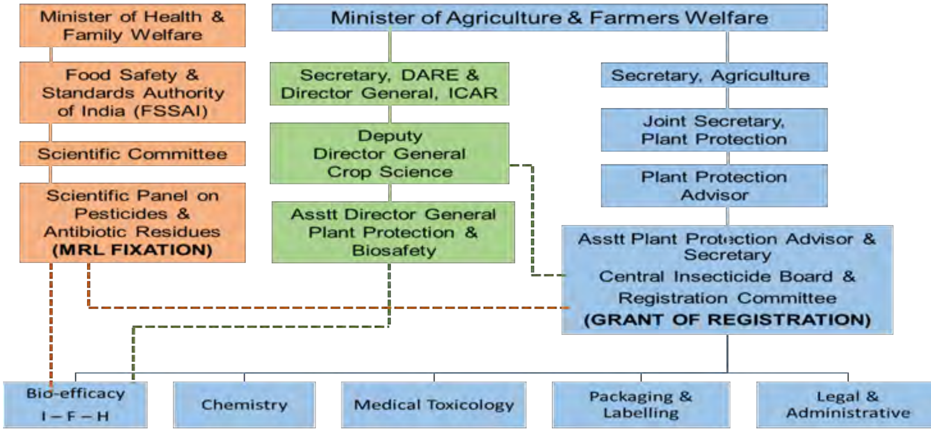



**Fig 6: Procedure of registration & MRLs fixation in India**

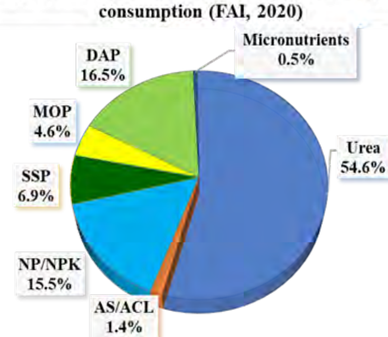
There are well defined guidelines under the Insecticides Act, 1968 and the Insecticide Rules, 1971 for obtaining the registration.

## 4. Agrochemicals Used in Agricultural Production Systems

### *4.1 Fertilizer*

Increase in food grain production could be possible by enhancing use of agrochemicals for production and protection of food and horticultural crops as there is no additional land available for cultivation in future. At present, large number of fertilizers products are used to grow crops in order to produce enough food to feed the burgeoning human population. Fertilizer products like Urea, ammonium sulphate/ ammonium chloride, Diammonium phosphate, single super phosphate, Muriate of potash, NP/NPK complex fertilizer, etc provide nutrients like nitrogen, phosphorus and potassium to crops, which allow crops to grow bigger, faster, and to produce more food. The growth in consumption of fertilizer product has been erratic since inception. In 2019-20, total nutrient consumption was 28.97 million tonnes. The consumption of N, $P_2O_5$ and $K_2O$ was 18.86, 7.46 and 26.4 million tonnes, respectively (FAI, 2020).

**Fig. 7. Share of various fertilizer products to total consumption (FAI, 2020)**




Supply of individual nutrients has also been skewed to Urea and DAP. Of the total fertilizer product supplied to Indian agriculture, the major share is owned by urea (54.6%) followed by DAP, NP/NPK, SSP and MOP was 16.5, 15.5, 6.9, 4.6 and 1.4%, respectively (Fig 7).

Share of micronutrient to total fertilizer product is very little (0.50%). For supply of nutrient N, fertilizer urea is still preferred by farmers of India as it contributed to 80% during 1990-91 and still its share to total N fertilizer supply is 82% during 2019-20 (Fig 8). DAP has been most preferred fertilizer to supply P nutrition to the crops. Share of NP/NPK complex fertilizer to P nutrition has increased from 22 to 30% from 1990-91 to 2019-20 while supply of P through single super

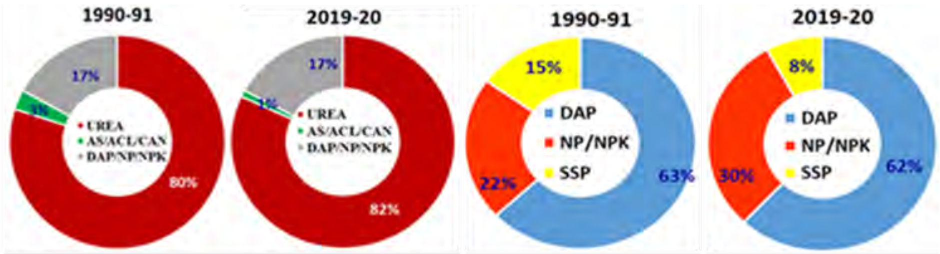



**Fig. 8. Share of N and P containing fertilizer products to total fertilizer consumption (FAI, 2020)**

phosphate has decreased from 15 to 8 percent during same period. While India uses many types of fertilizers, urea accounts for most of the consumption of N and DAP for most of that of $P_2O_5$. Urea accounts for 82 percent of the total consumption of straight N fertilizers. Other straight N fertilizers, such AS, CAN and ammonium chloride account for only 2 percent. Use of high analysis fertilizer like DAP, Urea and MOP, devoid of S and micronutrients content has led to multi-micronutrient deficiency in soils of India. The share of N through DAP and other complex fertilizers is about 17 percent. DAP accounts for 62-63 percent of total $P_2O_5$ consumption and share of other complex fertilizers has increased from 22 to 30% and share of Single superphosphate (SSP) decreased from 15 to 8% in 2019-20 as compared to 1990-91. Out of total fertilizer nutrients used in Indian agriculture, 67.1% goes to food crops followed by 9.6% to oilseed crops, 8.7% to cotton, 5.6% to sugarcane, 3.1% to vegetables and only 2.0% to fruit crops (FAI, 2020) (Fig 9). As per recent estimates of micronutrients consumption, the use of zinc sulphate fertilizer was the highest at 2,11,556 t followed by iron sulphate (28,867 t), boric acid/borax (21.204 t), manganese sulphate (11,343 t) and copper sulphate (2,938 t) during 2017-18 (FAI, 2016). Of the total Zn used, 70% goes to the field crops and remaining 30% finds use in vegetable and fruit crops, while the reverse is true for Mn, Fe and Cu. Of the total borax fertilizer used, about 60% goes to vegetable and fruit crops and the remaining 40% is consumed by food and oilseed crops (Shukla *et al*., 2020).

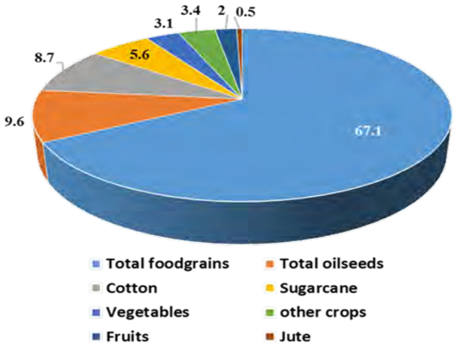



**Fig.9. Share of usage of fertilizer NPK by different crops (FAI, 2020)**

## 4.2 *Pesticides*

As far as the use of pesticide is concenred about 293 pesticides are currently registered under section 9(3) of the Insecticides Act, 1968 for use in the country. Forty six pesticides and 4 pesticides formulations are banned for manufacture, import and use in the country. Eighteen pesticides have been refused for registration and 9 pesticides have been restricted for use in the country. Among all pesticides currently used globally in agriculture, herbicides constitute the major proportion (44%) of the total pesticides followed by fungicides (27%) and insecticides (22%), whereas in India, the share of herbicides is only around 16 per cent of the total pesticides, which is quite low compared to insecticides (65%) and fungicides (15%) consumption (Fig. 10, Devi *et al.,* 2017). Further, it is interesting

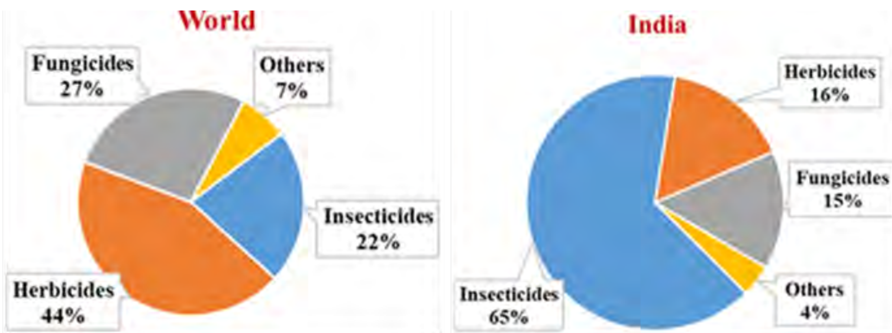



**Fig. 10 . Category wise consumption of pesticides in India vis-a-vis World**

to note that use of herbicides is increasing in the last one decade in India at a much faster pace (15-20% annually) (Fig. 10). In India, half of the total pesticides used are applied in cotton, followed by rice (18%) and fruit & vegetables (14%) (Fig.11, http://agricoop.nic.in). Maharastra state consumes highest proportion (~22%) of pesticides amounting to 13,243 MT (Technical grade) in 2020-21, followed by Uttar Pradesh (21%) (Fig. 12, http://ppqs.gov.in/).

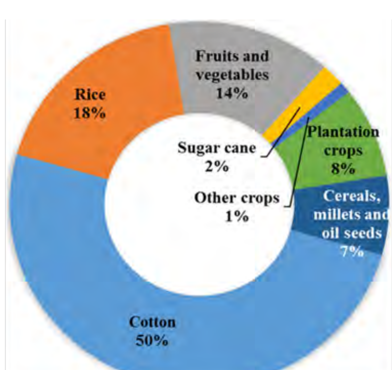



**Fig. 11 : Crop wise consumption of pesticides in India**

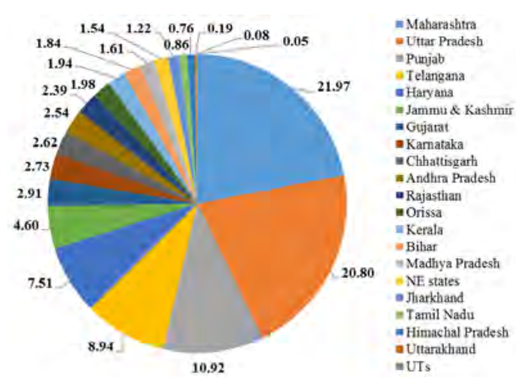



**Fig. 12. State-wise Consumption of pesticides in India**

# 5. Best Management Practices to Minimize Impact of Agricultural Chemicals

## *5.1 Best management practices for fertilizer*

In addition to weather, cultivars, spacing, crop rotation, tillage practices, fertilizer application method, rate, time and source have direct bearing on its utilization by the crop (Majumdar *et al*., 2014). Efficient nutrient management is highly challenging in environment due loss from soil-plant systems and its influence on crop proclivity as well as on environment. Enhancing recovery efficiency of applied N in crop plants continues to be a major challenge. In fact, fertilizer N recovery efficiency by the first crop is 30-50%. The rest of N either remains in the soil, the recovery of which in the following crops is very limited, or it is lost from the soil-plant system, causing serious disruptions in ecosystem functions (Ladha *et al.,* 2005). Large number of best management practices have been developed for optimum use of nutrients by enhancing NUE and reduce losses across the country. Some of the important BMPs are summarized as under: Balanced fertilization using fertilizer nutrients as per soil test and crop response function. The agronomic efficiency parameters measured in different cropping systems were higher under balanced NPK fertilization. Such improvement in NUE was attributed to increased indigenous nutrient supplying capacity of soil under balanced NPK fertilization (Yadav, 2001);

(2) Promote use of micronutrients application in adequate amount as per level of its deficiency in different soils. Application of micronutrients not only ensures improved nutrient use efficiency of major NPK but also increase the micronutrients load in edible plant parts to combat micronutrient malnutrition in the country;

(3) Integrated plant nutrient supply- involving conjoint use of different nutrient sources appeared a promising strategy for sustaining high yields, restoration of soil health, and improvement in fertilizer use efficiency as a whole including NUE (Dwivedi *et al.,* 2016). Important ingredients of IPNS -fertilizers, organic manures, green manures, crop residues (CR), industrial wastes and by-products, sewage-sludge, and bio fertilizers should be used in balanced and effective manner;

(4) In situ burning of crop residues by farmers in north-west India causes serious environmental implications besides loss of nutrients. Conservation agriculture has potential to save about 141 million tons of cereal residues are available for recycling in to the soil;

(5) Site specific and precision nutrient management refers to management strategies that encourage better utilization of applied nutrients, enhance NUE and minimize N losses. Use Leaf colour chart, chlorophyll meter for

synchronizing N application with crop N requirement and use of micronutrients kriged maps of 640 districts prepared by ICAR-All India Coordinated Research Project on micronutrients are important tools to execute SSNM and precision nutrient management at large scale in India. Use of critical LCC values for fertilizer N application optimizes the grain yield and NUE of rice and wheat crops. Considering AEN of 20 kg $kg^{-1}$ N and REN of 50% as optimum NUE for rice, critical LCC values were judged as: LCC ≤3 for Basmati, LCC ≤4 for inbred (Saket 4), and LCC ≤5 for Hybrid (PHB 71) rice (Shukla *et al.*, 2004). Fertilizer N-scheduling based on LCC proved superior to conventional practice, i.e., application of 120 kg N $ha^{-1}$ in three-splits (Bijay-Singh *et al.*, 2003; Shukla *et al.*, 2004). In certain cases, even a saving of fertilizer N (up to 30 kg N $ha^{-1}$) was recorded with the use of LCC;

(6). Inclusion of legume-based crop rotation in existing cropping pattern would help in restoring atmospheric N lost through denitrification or other processes;

(7) The nutrient use efficiency could be optimized by bringing in precision management following '4 R' principle, which implies right fertilizer source, right rate, right time, and right method of placement. The application of fertilizer as per 4R principle, enhances fertilizer nutrient recovery efficiencies (REN) in researcher-managed experiments for major grain crops range from 46% to 65%, compared to on-farm REN of 30-40%.

### *5.2 Best management practices for pesticide*

ICAR- National Research Centre for Integrated Pest Management, New Delhi has developed web and mobile enabled insecticide and fungicide calculators (IFCs) for 12 major crops *viz.*, Rice, Cotton, Pigeonpea, Groundnut, Tomato, Soybean, Chickpea, Chillies, Okra, Cabbage, Cauliflower and Brinjal available at: *http://www.ncipm.org.in/cropsapifc; http://www.ncipm.org.in/nicra2015/Software tools.aspx and http://www.ncipm.org.in/technologies.htm.*

IFCs provide information on pesticides with label claims, quantity calculations based on recommended dosages, methods of application and application technology against target insect pests and diseases to aid in judicious selection, sale and use on target crops.

**Rice**: **QR code for rice**

IFCs would be of immense use to pesticide dealers, crop specialists, plant protection personnel and State extension officials and have wider utility. Use of IFCs would enhance proper marketing and field use of insecticides and fungicides on scientific basis. (https://icar.org.in)

## 6. Impact of Agricultural Chemical Inputs

### *6.1 Heavy metal content*

Inadvertent use of chemical fertilizers in agriculture, resulting in a large number of environmental problems as fertilizers contain heavy metals and even some concentrations of radionuclides. Inorganic fertilizer like DAP, SSP, MOP, Urea, Zinc sulphate and even organic manure serve as potential source of heavy metals, like, Pb, Cr, Ni, Cd and Co. In India, the exponentially increased fertilizer consumption may affect the accumulation of heavy metals in soil and plant system, causing serious environmental problems and human health. The fertilizer, soil and plants samples collected from different locations of LTFE sites of India. The fertilizer samples contain heavy metals as impurities, which vary in different grades of fertilizer depending upon the raw material used for manufacturing. The heavy metal impurities are more in SSP, Dap and FYM as compared to Urea and MOP. Plants absorb the fertilizers through the soil, they can enter the food chain. The heavy metal content in fertilizer used in India are given in Table 2.

**Table.2. Average heavy metal content (mg kg$^{-1}$) in different fertilizers and FYM used in India (adopted from Adhikari *et al*, 2019)**

| Fertilizer/manures | Pb | Cr | Ni | Cd | Co |
|---|---|---|---|---|---|
| Single super phosphate | 10.84 ± 3.6 | 11.13 ± 6.6 | 9.75 ± 1.8 | 14.1 ± 5.7 | 4.06 ± 1.0 |
| Diammonium Phosphate | 8.16 ± 2.6 | 13.02 ± 1.9 | 14.76 ± 7.7 | 6.29 ± 2.9 | 8.16 ± 9.0 |
| Urea | 1.76 ± 1.8 | 2.81 ± 1.0 | 2.65 ±1.0 | 0.25 ± 0.2 | 0.16 ± 0.1 |
| Farmyard manure | 8.93 ± 1.5 | 10.10 ± 7.0 | 23.60 ± 7.9 | 0.75 ± 0.4 | 8.81 ± 3.8 |
| Muriate of Potash | 2.41 ± 2.6 | 6.09 ± 1.7 | 6.12 ± 4.9 | 0.22 ± 0.2 | 0.80 ± 0.4 |
| Zinc Sulphate | 7.13 ± 2.1 | 8.21 ± 3.1 | 9.76 ± 3.7 | 0.61 ± 0.1 | 2.56 ± 2.1 |

Organic fertilizers especially FYM contains heavy metals, which are bind or form complexes with the functional groups such as carboxylic and phenolic groups. When applied to the soils the heavy metals complex or chelate with it are released and absorb by the plants.

A large amount of agrochemicals applied to the agricultural soils as fertilizers and pesticides, thus increase the heavy metals particularly Pb, Cd, Co, Ni and Cr.

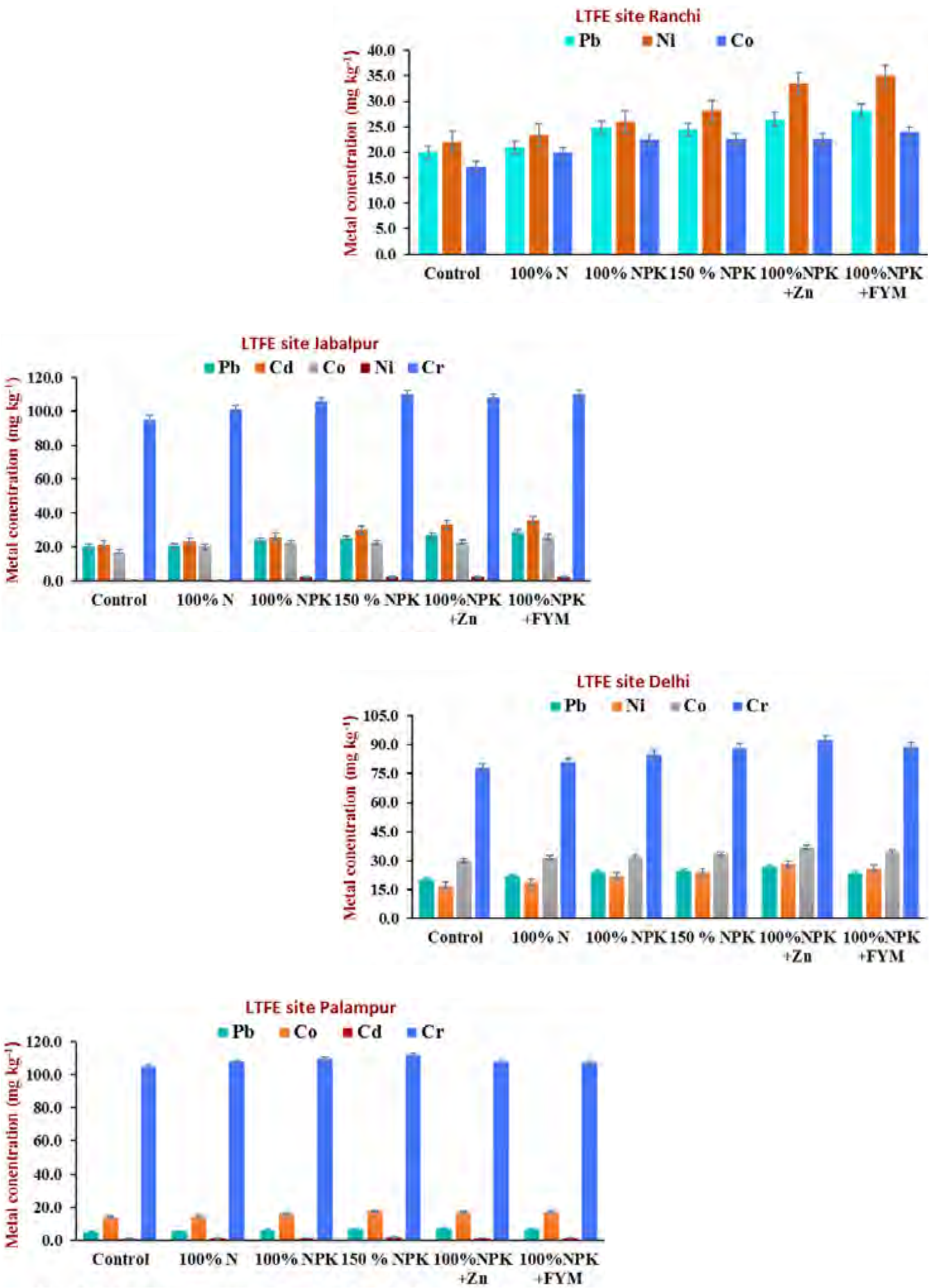



**Fig. 13. Total heavy metal concentration (mg kg-1) in top soils (0-15 cm) after 35 years of long-term fertilizer experiment at Jabalpur, Ranchi, Palampur and Delhi sites (adopted from Adhikari *et al*, 2019).**

Excess fertilization leads to water, soil and air pollution due to accumulation of inorganic pollutants in agro-ecosystem. Since fertilizer used for growing crops contain heavy metals as impurities, enhances the heavy metal contamination in soils. Although, there is no definite effect of treatments on trends of heavy metal accumulation/status in the soils. Accumulation of Cr and Cd was much higher than Pb, Ni and Co. Use of phosphatic fertilizer like, Diammonium phosphate (DAP) and single super phosphate (SSP) and organic manures are major culprit to increase metal content in soils. Phosphate rock used as raw material in manufacturing of phosphatic fertilizer contain lot of impurities in the form of heavy metals. At Ludhiana, Cr was recorded in the FYM-amended plot. Since FYM is an output of animal dung which is fed on fodder probably grown on soil contaminated with Cr, this could be the route of its entry into the soil. Currently, the content of heavy metals at all the centres is far below the safe limits reported in literature, however, this may be deleterious for crop growth in future. Accumulation of heavy metals recorded in rice, wheat and soybean at LTF experimental sites at a Barrackpore and Jabalpur exhibited higher in straw than grains (Fig.14 ABC). The increase in Cr and Ni was more in rice grain and Cd in rice straw. At barrackpore, increase in heavy metal was more in treatment receiving 150% recommended

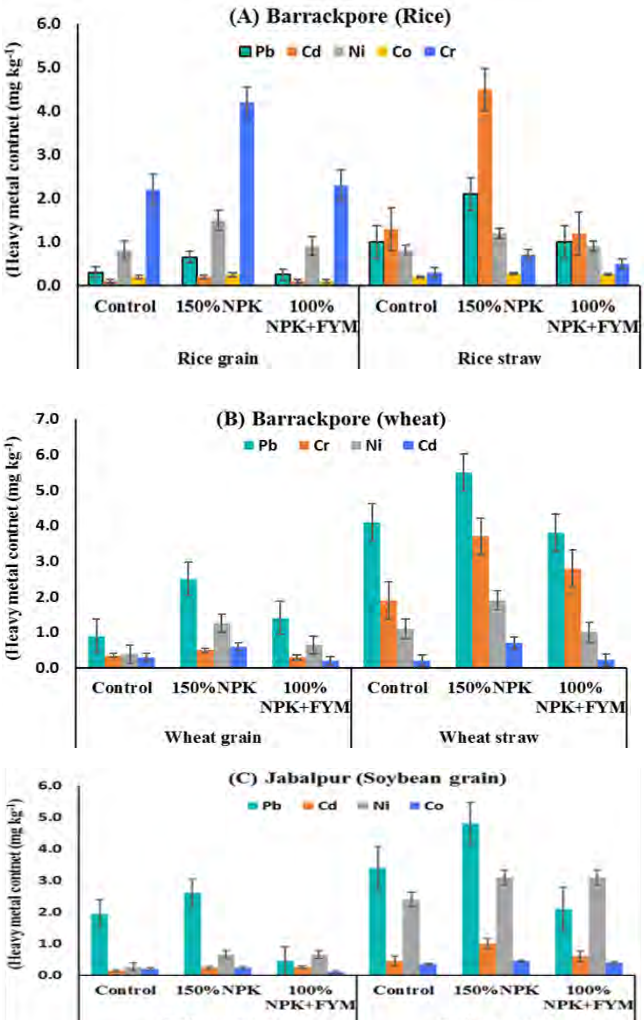



Fig. 14 ABC. Accumulation of heavy metals in rice, wheat and soybean at Barrackpore and Jabalpur site under LTF experiments after 35 years. (adopted from Adhikari et al, 2019)

dose of fertilizer than 100%NPK+FYM. This may be due adsorption of heavy metals in complex form in organic substances. In Soybean grown at Jabalpur showed higher accumulation of Pb and Ni as compared to other metals (Adhikari *et al.,* 2019). Studies conducted with long-term continuous application of fertilizer and manure in excessive amount may contribute the accumulation of heavy metals in the soils and plants (Singh *et al.*, 2020). The presence of high concentrations of metals may be of concern due to its ability to accumulate in soils and its bioaccumulation in plants and animals (Brigden *et al.*, 2002).

### 6.2 Nitrate Pollution

Excessive use of urea results into increased amount of nitrate in drinking water and rivers systems. The groundwater pollution due to nitrates is increasing in India. The water quality assessment studies carried out in 17 Indian states by NEERI showed that out of 4,696 water samples, 1,290 samples (27%) have nitrate exceeding the drinking water standard (Bulusu and Pande 1990). Analysis of ground water in agricultural district of Andhra Pradesh located in Vamsadhara river basin revealed that the nitrate concentrations ranged from traces to 450 mg $NO_3$/L in the groundwater. The nitrate concentrations were increased after fertilizer applications (Rao, 2006). Present consequences of nitrate pollution of freshwaters in India are a reflect legacies of excessive applications of fertilizers and manures in the past as well as current use. Thus, the nitrate N content in the groundwater in Punjab has been consistently increasing since 1975 when samples were analyzed for the first time (Bijay Singh *et al.,* 1995). Using data generated by reconnaissance of nitrate content in shallow ground waters, the Central Ground Water Board of India categorized Punjab region as the high-risk zone with respect to nitrate pollution of groundwater. Chhabra *et al.*, 2010 used a remote sensing and GIS approach based on data pertaining to fertilizer use, soil properties and rainfall at 1-km2 grid size, and N loss coefficients derived from published N dynamics studies to reveal that about 29% of the applied fertilizer N to rice is lost as nitrate in coarse textured soils of Punjab. The weighted average Nitrate-N loss via leaching in Punjab was estimated to be more than 50 kg $ha^{-1}$ $year^{-1}$

### 6.3 Pollution in water bodies

The amount of phosphate may increase in drinking water and rivers as a result of the transport of phosphorous fertilizer with the flow of surface. High level of Nitrogen fertilizer are used in soils for plants growth. It consists of carcinogenic substances such as nitrosamines, especially in plants such as lettuce and spinach leaves. Future research needs to be considered to improved water and fertilizer management in agroecosystems, which can reduce the contribution of fertilizers to nitrate pollution of water bodies but a host of factors determine the magnitude

(Sattar *et al.*, 2014). Study conducted on nutrient loads exported by rivers to coastal waters in Bay of Bengal Large Marine Ecosystem (BOB LME) in 2000 revealed that rivers exported 7.1 Tg N and 1.5 Tg P to the BOB LME. Three rivers (Ganges, Godavari, Irrawaddy) account for 75–80% of the total river export of N and P. It was simulated that river export of N may increase to 8.6 Tg by 2050 (Pedde *et al.*, 2017). The increased load in BOB LME leading to changes in nutrient stoichiometry (Tripathy *et al.*, 2005) and, as a consequence, harmful non-siliceous algae blooms (Garnier *et al.*, 2010). The rises in dissolved N and P loads are connected mainly with increased N and P losses from agriculture and sewage systems. The decreasing export of particulate N and P is associated with damming of rivers and increased human water consumption. There are large differences in nutrient export among rivers. Rivers draining into the western BOB LME generally export more N and P than eastern BOB LME rivers (Pedde *et al*, 2017).

Nitrate and Phosphate concentration in some inland waters in India vary significantly in water of ponds, lakes, and rivers in India (Vass *et al.*, 2015). Due to high levels of N and P fertilizers application in western Uttar Pradesh, and Mysuru district, Karnataka reported high concentration of N and P in lake and groundwater and channel waters (1.87 to 6.79 mg $L^{-1}$). Nitrate concentrations were high enough to damage the fish in Karnataka. Camargo *et al*, (2005) described that WHO safe limit of nitrate concentration (50 mg NO3-N L-1) is considered for drinking water by human. High concentration of nitrate than this limit can adversely affect freshwater invertebrates.

**Table 3. Nitrate and phosphate content in the Sutlej River at three different sites in Punjab**

| Location | Season | $NO_3$ ($mL^{-1}$) | $PO_4$ ($mL^{-1}$) |
|---|---|---|---|
| Ropar head works | Winter | 0.32 – 0.43 | 0.10 – 00.2 |
| | Summer | 0.40 – 0.62 | 0.22 – 0.27 |
| | Post Monsoon | 0.53 – 0.82 | 0.20 – 0.32 |
| Budha Nullah at Phillaour | Winter | 0.38 – 0.62 | 0.21 – 0.31 |
| | Summer | 0.80 – 1.05 | 0.33 – 0.50 |
| | Post Monsoon | 0.82 – 1.26 | 0.33 – 0.57 |
| Budha Nullah at Wallipur | Winter | 0.80 – 1.30 | 0.52 – 0.70 |
| | Summer | 1.10 – 1.35 | 0.67 – 0.98 |
| | Post Monsoon | 1-16 – 1.62 | 0.76 – 1.10 |

Phosphate concentration in river waters was much higher in northwestern rivers [Ravi (0.17–0.20), Sutlej (0.12–0.15), Beas (0.18–0.29)] as compared to that in the eastern [Brahmaputra (Tr-0.02), Damodar (Tr-0.35), Brahmani (Tr-0.03), and Mahanadi (Tr-0.001)], western [Narmada (Tr-0.10)], or southern India [Godavari

(0.06–0.18), Krishna (0.04–0.30) and Cauvery (0.02–0.94)]. Data presented in table 3 showed that higher concentration of nitrate and phosphate in water at three points in Sutlej River in Punjab was due to inflow of Buddha Nullah at Wallipur contains industrial effluents rich in nitrate and phosphate, a point near the industrial area of Ludhiana (Jindal and Sharma, 2011).

The phosphate concentrations increased over a period of 36 years (1960–1996), indicating increased pollution of the river water. The variation in phosphate concentration in river Ganges at Haridwar, Kanpur, Prayagraj, Varanasi and Patna clearly demonstrate the role of industrial effluents, which was the highest at Kanpur (0.07 – 0.21, 0.01 – 2.10 and Tr – 2.50 ppm during 1960, 1980 and 1996, respectively), while it was nil at Haridwar with no industry (Vass *et al.*, 2015).

Another study (Tiwari *et al.*, 2016) revealed that both nitrate and phosphate levels were the highest at Varanasi (Table 4). As per limit prescribed by (MPCA, 2007) total phosphorus levels above 100 ppb (0.1 mg $L^{-1}$) may cause eutrophication. Thus, as per available data on P concentration the inland waters in India may be highly eutrophic. Moreover, N: P ratio in most Indian inland waters was less than 10, may influence the possibility of developing phytoplankton 'Bloomers' leading to fish mortality.

**Table 4. Nitrate and phosphate concentration in Ganges River water at three locations**

| Location | Quality parameter | Summer | Monsoon season | Winter |
|---|---|---|---|---|
| Kanpur | Nitrate (mg $L^{-1}$) | 1.70 | 0.45 | 0.94 |
| | Phosphate(mg $L^{-1}$) | 1.58 | 0.66 | 0.82 |
| Allahabad | Nitrate (mg $L^{-1}$) | 1.5 | 1.4 | 0.23 |
| | Phosphate(mg $L^{-1}$) | 1.50 | 0.63 | 0.78 |
| Varanasi | Nitrate (mg $L^{-1}$) | 2.6 | 2.4 | 2.1 |
| | Phosphate(mg $L^{-1}$) | 1.42 | 1.11 | 1.37 |

### *6.4 Green House Gases*

Promotion of agrochemicals use intensified in modern agriculture and contribute immensely in achieving food and livelihood security of the country. But there are several negative impacts on environment and human health because of use of agrochemicals. India clearly illustrates a dual challenge for food and environment, consuming 17 Mt of N fertilizer annually (14% of the global total), which has increased approximately at 6% $year^{-1}$ since 1970. The cereals consume the highest proportion of fertilizer-N, but unfortunately more than 65% of applied N is being lost to the environment, rendering the poor N use efficiency in the system. Contribution from horticultural crops is less than the agricultural crops, however, the modern high intensity horticultural production system also causes outflow of substantial volume of NR into the environment. The nitrate concentrations are increasing in surface and groundwater in intensively cultivated states such as Haryana, Punjab, Uttar Pradesh, Maharashtra, Karnataka and Andhra Pradesh due to enhanced mobilization of N through cultivation, animal husbandry, and industrial and domestic discharges of wastewater. Further, overexploitation of groundwater causes harms to the aquatic and deterioration of the groundwater availability as well as quality, which in turn, influencing ecosystem and thereby animal and human health. Nitrous oxide, an important greenhouse gas has several negative impacts on human health and ecosystem services, contributes to fine particulate matter and regional haze concentration in the atmosphere. NOx and ammonia are important source of nitrous oxide emission, which influences the radiation budget of the atmosphere through $O_3$ formation and oxidation capacity of the atmosphere through -OH and nitrate release. N losses in rice field through $NH_3$ volatilization is higher in rice when the common practice of surface broadcasting N fertilizers was adopted, which entail reduction in the NUE (Ladha *et al.*, 2005).

Emissions of nitrogen oxides (NOx) from combustion sources are also increasing rapidly at 6.5% year$^{-1}$ currently. By comparison, population growth rate is lower (2% year$^{-1}$), while ammonia ($NH_3$) emission increase is even less (1%), pertaining to smaller changes in livestock numbers. At current rate, Indian NOx emissions will exceed $NH_3$ emissions by 2055. In addition to fertilizer N, the livestock

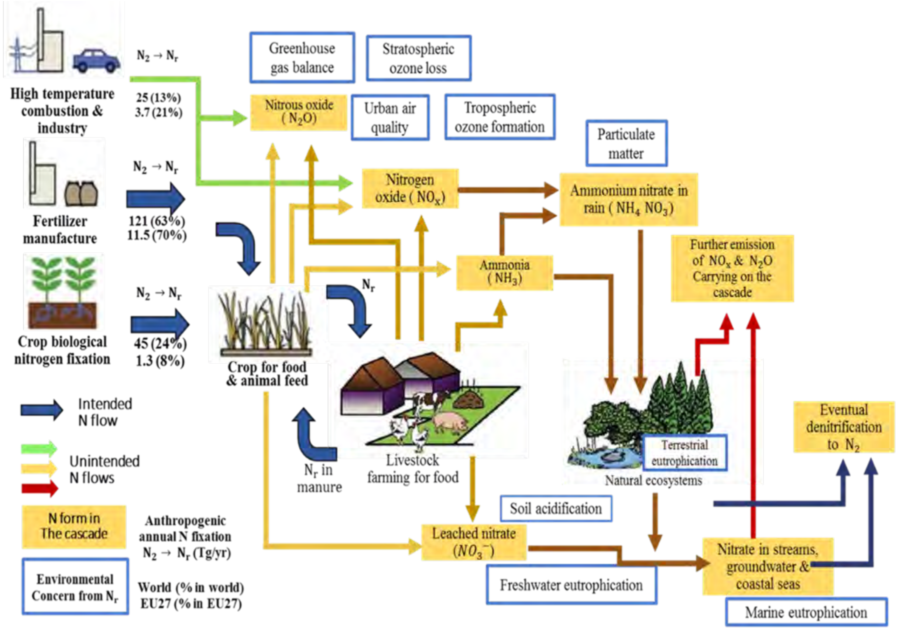



**Fig. 15. Global nitrogen cycle depicting reactive N losses, fixation of $N_2$ to Nr and the dissipation of energy as Nr is eventually denitrified back to $N_2$ (Adopted from Sutton el al, 2017)**

sector, particularly Cattle (56.1%) and buffaloes contributes the largest amount of NR in the form of ammonia. The scenario become quite alarming by the poultry industry, which has annual growth rate of 6% and may excrete NR to the tune of 1.089 million tons by 2030. India currently loses Nr worth US$10 billion year$^{-1}$ as fertilizer value, while costs of Nr to health, ecosystems, and climate are estimated at US$75 (38-151) billion year-1. Relative contribution to total GHG emission was increased due to fertilizer application from 8% in 1970 to 23 % in 2010 (Pathak *et al.,* 2014). GHG contribution from rice field decreased from 26 to 17% during same period due to promotion of direct seeded rice in contrast to puddled rice (Fig 16).

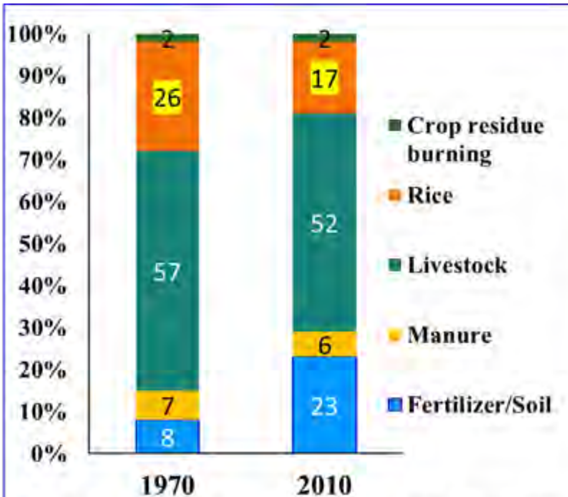


Fig. 16 . Relative contribution (%) of different sources of green house gases in Indian Agriculture in1970 and 2010 (Pathak et al, 2014)

The NR leakage tend to be higher in the major river basins of the country having extensive economic and agricultural activities and high population pressure. The vast portion of coastal areas along Indian coastline is experiencing ecological problem due to inflow of extensive inputs of NR from river system as well as other enhanced anthropogenic activities near seashore. Surface waters nitrogen assessment ($NO_2$ and $NO_3$ form) was carried out in Indian exclusive economic zones and the adjoining areas of seashore during the years 1998-2007 discovered that the annual concentrations of $NO_2$ in the Andaman Sea, Bay of Bengal and Arabian Sea ranged from 0 to 0.7, 0 to 0.6 and 0 to 0.4 (mM), respectively. Accordingly, the $NO_3$ concentration varied from 0 to 3.5, 0 to 3 and 0-2.5 (mM).

Even though BNF is environmentally benign source of N, this also leads to the production of NR,

albeit to a lesser extent. Moreover, the economic development, societal demands for increased energy, transport caused in massive transformations in structure and functions of nitrogen cycling during the last five decades has made the N cycling most perturbed biogeochemical cycle due to huge anthropological development. As a result, substantial increase in NR and its loss to aero-geo-biological system invokes disastrous consequences to the environment and ecological balance, like eutrophication, atmospheric N deposition, biodiversity loss, and negative effects on ecosystem services. The major challenge for India is to consider NR necessity as source of fertilizer-N, which has put huge burden to the country's exchequer in the form of subsidy as well as environmental burden associated with adverse climate and animal/human health impacts.

### *6.5 Soil Acidity*

Abundance amount of ammonia present in the atmosphere regulates the atmospheric acidity. It forms part of atmospheric aerosols, which get deposited to soil through rains and its oxidation releases acidic compounds and creates the soil acidity. Soil pH is an intrinsic property determined by the exchangeable cations on clay surface and takes long time to change. In addition to these atmospheric depositions, the excess use of inorganic fertilizer caused origin of NR. The major negative impact of NR depositions on soil quality is soil acidification. Long term fertilizer experiment conducted at Punjab Agricultural University (PAU), Ludhiana, India was conducted to assess the effects of inorganic fertilizers and farmyard manure (FYM) on soil quality revealed that soil acidity increased significantly in 100% NPK (pH 7.39) and 150%NPK (pH 7.25) treated plots as compared to non-treated control (7.90) after 36 years. Further, excessive application of N fertilizers may impair soil health through soil carbon degradation and adverse impacts on the structure and function of the soil biological community.

Data in fig 17 indicates that long-term application of N-fertilizer alone over the years caused reduction in soil pH at different experimental sites of India (Brar *et al*, 2015). The changes were more in Alfisols of Banglore Palampur and Ranchi. However, effect of fertilizer at Bhubaneshwar and Pattambi was little less, because at both the places rice-rice is grown under submerged conditions and soil pH normally stabilizes near neutrality under prolonged submergence. The effect of fertilizer application on soils other than Alfisols is not much visible.

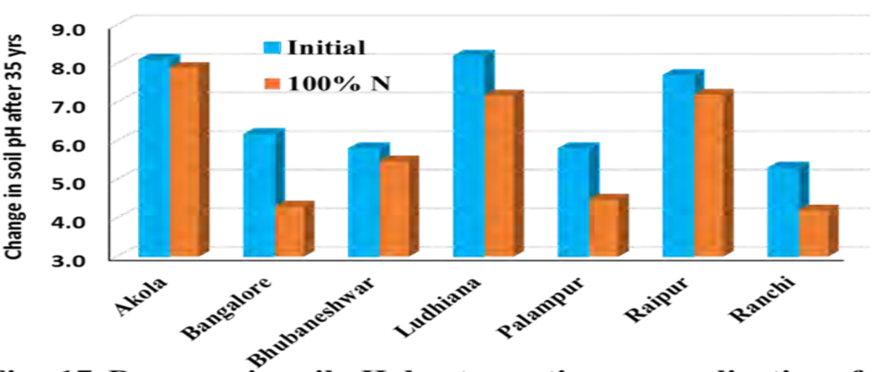



**Fig. 17. Decrease in soil pH due to continuous application of fertilizer N for 35 years(Brar et al, 2015).**

## *6.6 Damage to animal and human*

Another important aspect of excessive use of nutrients, especially nitrate and phosphate, on environment is a massive overgrowth of algae, known as an algae bloom, which harms the water quality and damages the aquatic life. Algal blooms reduce the ability of aquatic life to find food due to cloudiness of water and clog the gills of fish. Some algal blooms produce toxins that can cause illnesses or death of animals like turtles, seabirds, dolphins, fish and shellfish. People experience a wide range of health effects like stomach aches, rashes and more serious problems when comes in contact with algal toxins. Excessive use of agrochemicals also contributes in polluting the surrounding air. Long-term health effects from air pollution include heart disease, lung cancer, and respiratory diseases such as emphysema. Air pollution can also cause long-term damage to people's nerves, brain, kidneys, liver, and other organs.

## *6.7 Impacts of micronutrients deficiency*

Micronutrients play a key role in growth and development of plant, animal and human. Use of micronutrients has increased during last decade, which has significantly contributed in increasing food grain production of the country (Shukla *et al.*, 2012). The food and fodder produced on micronutrient deficient soils had poor trace element concentration and causing micronutrient malnutrition in animal and human. Even though the levels of trace elements like Cu, Zn, Mn, Fe, Mo, Se and Co in crops are sometimes sufficient for optimum yields but they are not adequate to meet the needs of livestock leading to wide spread deficiency. Widespread nutritional deficiencies of vitamin A, Fe, and Zn have been affecting human health disproportionately especially women and young children. Soil-related deficiencies of trace elements such as Se, Cu, Fe and Zn are also implicated as causal factors for anaemia. Toxic concentration of some trace elements in soils also adversely affected the animal and human health.

It has also been reported from a survey work in Vadodara district of Gujarat that dry fodder was tested low in Fe (61%), Zn (72%) and Cu (87%) and green fodders were low in Fe (17%), Zn (5%) and Cu (23%) although most of the soils are adequate in available Fe, Mn and Cu to support crop yields and need Zn fertilization to get good yields. In human, Zn deficiency was recognized as a health concern for the first time in 1961. Prasad *et al* (1961, 1963) described the first cases of human Zn deficiency syndromes: growth stunting, delayed sexual development and hypogonadism in young adults from Iran and Egypt. Besides, Zn deficiency leads to diarrhoea, respiratory malfunctions, weak immune system, impaired cognitive function, neuronal atrophy, behavioural problems, memory impairment, spatial learning, lesions on dermal tissue/keratin and parakeratosis. It is estimated that one third of the world population which lives in developing countries suffers from high prevalence of zinc deficiency. The vulnerable populations include infants, young children, and pregnant and lactating women because of their higher zinc requirements, as they are at critical stages of growth and physiological needs. In general, a strong correlation has been reported between soil Zn status and human Zn deficiency level (Shukla *et al.,* 2016). By and large, dietary Zn intake in the poor people of the country is far below the normal levels and is imbalanced consisting mainly of rice and wheat, low in Zn and high in phytate causing low Zn-bioavailability. For example, in the states of Assam, Bihar, Orissa, Tripura and West Bengal, the average consumption of Zn among various age groups was much lower than the recommended dietary allowance (RDA). Therefore, populations relying primarily on a plant-based diet, exclusively on cereals are susceptible to Zn deficiency. A large section (84%) of the families had deficient Zn intakes and more than 50% having moderate to severe deficiency level of Zn in their dietary intake. About 82% of pregnant women worldwide also have an inadequate zinc intake to meet the normative needs of pregnancy. In India, about 25% of the total population suffers from Zn deficiency. The prevalence of nutritional stunting due to Zn deficiency is about 47.9 % in children of < 5-year age while it is 33% in the world's population.

High incidence of Zn deficiency (43.8%) was confirmed among children belonging to low socio-economic groups in five major Indian states (Kapil and Jain, 2011) (Table 5).

**Table 5. Distribution of children below 5 years of age in India according to their serum Zn levels**

| State (no of sample) | Serum zinc levels | |
|---|---|---|
| | <55 μg/dL | <60 μg/dL |
| Orissa (n=345) | 34.5 | 43.2 |
| Uttar Pradesh (n=316) | 29.4 | 40.2 |
| Gujarat (n=353) | 25.8 | 34.0 |
| Karnataka (n=356) | 19.1 | 26.4 |
| Madhya Pradesh (n=285) | 14.7 | 22.8 |
| Total (n=1655) | 25.0 | 33.5 |

The highest Zn deficiency was in Orissa (51.3%), followed by Uttar Pradesh (48.1%), Gujarat (44.2%), Madhya Pradesh (38.9%), and Karnataka (36.2%). Another cross-sectional study (n=630) also confirmed low plasma Zn concentration and poor cognitive performance in 45% of the adolescent girls (10-16 years) from two secondary schools of Pune. Supplementation of Zn-rich recipes improved plasma Zn status, cognitive performance and taste acuity signifying the need to adopt dietary Zn intake for normal health (Kawade, 2012).

In a case study conducted in Mandala district of Madhya Pradesh, India revealed that analysis of Zn content in soil, grain, straw feed, animal and human blood serum established a strong correlation and interdependence among soil-plant-animal-human continuum (Figure 18). The results indicated a strong relationship of soil Zn with plant and human blood serum Zn. The coefficient of determination ($R^2$) was found between soil Zn content and grain Zn concentration ($R^2 = 0.36$), Zn concentration in human blood serum and grain Zn concentration ($R^2 = 0.48$). However, no relationship was recorded between straw Zn content and animal blood serum Zn concentration. When contribution of Zn through feed and Zn content in grazing grass was included with fodder Zn content, significant relationship emerged with animal blood serum Zn ($R^2 = 0.61$).

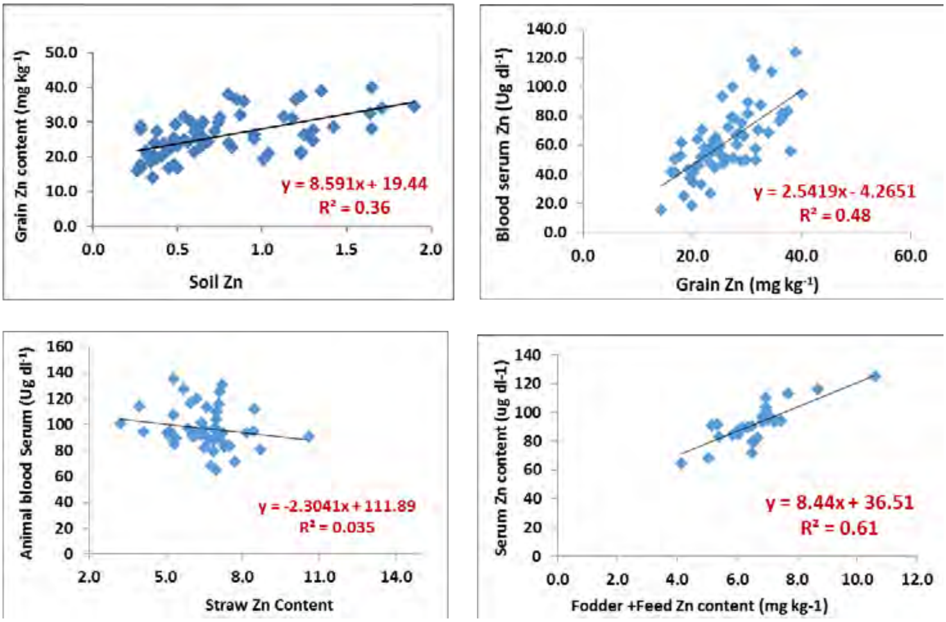



**Figure 18. Relationship between soil, plant, animal and human Zn**

## *6.8 Pesticide contamination level in Indian food commodities*

The Monitoring of Pesticide Residues in food commodities at National Level (MPRNL) scheme was initiated by the Department of Agriculture, Cooperation & Farmers Welfare, Ministry of Agriculture & Farmers Welfare as a central sector scheme during 2005-06. The participating laboratories in the scheme across the country represent Ministry of Agriculture & Farmer's Welfare, Ministry of Health and Family Welfare, Ministry of Environment and Forest, Ministry of Chemical and Fertilizer, Ministry of Commerce, Indian Council of Agriculture Research, Council of Scientific and Industrial Research and State Agricultural Universities. These laboratories collect food commodities and analyse the same for the possible presence of pesticide residues. The bird's eye view of the contamination status of food commodities domestically consumed in India is given in Fig. 20-21. The Year-wise comparison of total number of sample analysed and samples above FSSAI MRL during 2012-18 indicates that only 2.1 to 2.7% samples were found above MRL as prescribed under Food Safety Standard Authority of India (FSSAI), Ministry of Health and Family welfare. The data are comparable to the pesticide contamination level in fruits and vegetables in developed countries like USA, UK and EU where the samples detected above MRL ranging from 2.2 to 5% (Table 6).

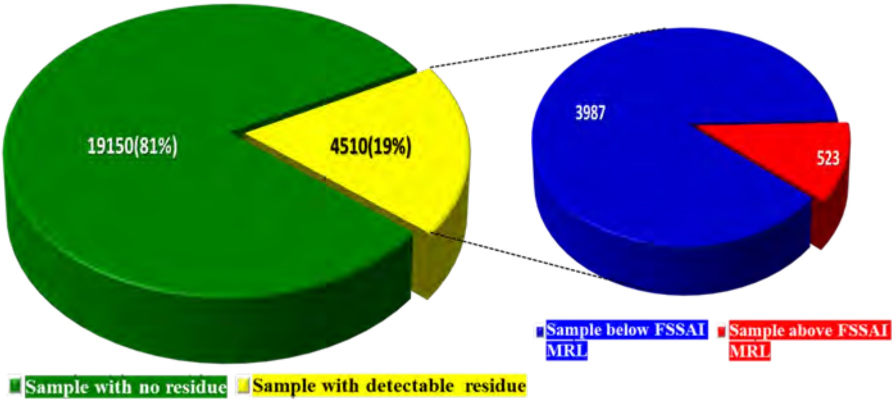



**Fig 19. Contamination status of food commodities domestically consumed in India (https://agricoop.nic.in)**

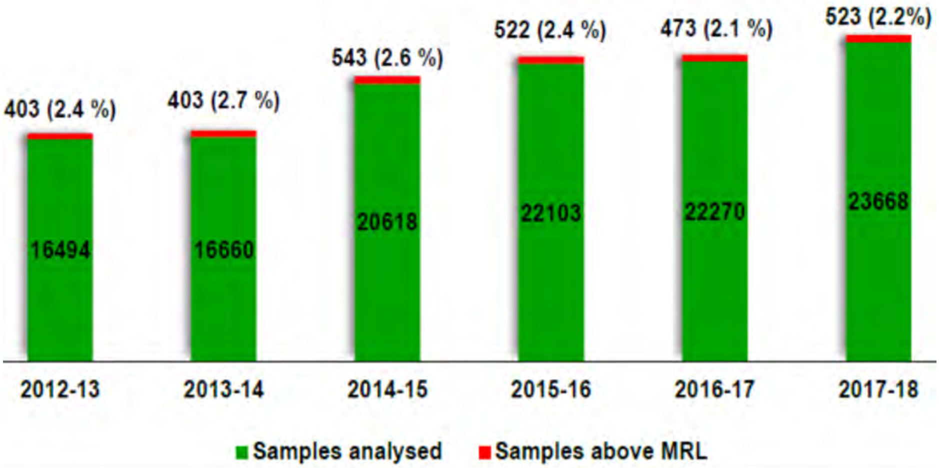



**Fig 20. Sample analyzed for Monitoring of Pesticides Residues at National Level (2012-18) (https://agricoop.nic.in)**

*Persistent pesticide contamination levels* - Discrete publications from India indicate that persistent organic pesticide residues are broadly distributed in soils and water. Yadav *et al.*, (2015) reviewed pesticides status in Indian soils and water and reported wide spread contamination.

**Table 6: Comparison of monitoring data of Fruits and Vegetables**

| Country | Year | Samples analysed | Samples with Detection | Above MRL |
|---|---|---|---|---|
| India | 2008-2015 | 60,432 | 9,388 (15.5%) | 1460 (2.4%) |
| USA | 2008-2013 | 6,142 | 2,742 (44.6%) | 137 (2.2%) |
| UK | 2008-2014 | 11,738 | 7,088 (60.4%) | 394 (3.4%) |
| EU | 2011-2013 | 54,208 | 20,255 (36.4%) | 2714 (5.0%) |

Predominantly Organochlorine pesticides like DDT, HCH and endosulfan have been reported in agricultural and forest soils, river water, sediment and ground waters. Concentrations as high as 1321.8 ng/g DDT, 9039.9 ng/g HCHs and 4569 ng/g endosulfan have been reported in forest soil. Contamination of these pesticides in water samples is too high (DDT- 6904, HCHs - 10014 and endosulfan - 8879 ng/L. Carbendazim (3.68-86.8 ppb, 100%), azoxystrobin (1.96-35.2 ppb, 20%), imidacloprid (1.47-31.5ppb, 86.66%), flusilazole0-.07 ppb, 6.66%), dimethomorph (1.84-63.7, 86.66%), thiamethoxam (1.09-24.8, 33.33%) , fenamidone (4.26-13.8,20%), pyraclostrobin (1.2-23.7,33.33%), clothianidin (1.47-7.92 , 33.33%) iprovalicarb (1.13-65.6, 26.66%), hexaconazole (2.6-4.89, 20%), kresoxim methyl (0-7.69, 6.66), triademefon (0-28.8, 6.66%), penconazole (0-2.48, 6.66%), spinosad A (0-2.15, 6.66%) are reported in grape soils of Nasik region (Patil et al., 2014).

## 7. Research Findings related to Agrochemicals Use

Carbon (C) stabilization in soil is critical to influence soil C sequestration and agricultural management on soil quality. The long-term experiment conducted at Jabalpur with soybean-wheat system while at Palampur and Ludhiana with maize-wheat cropping sequence, the grain yields was markedly improved with application of NPK and NPK+FYM. Long-term application of balanced fertilization and IPNS improved the crop yields as well as underground root biomass, and thereby soil C pools in different agro-ecosystems. The long-term fertilization experiment (LTFE) on arable land in India was established in 1972 in different agro-climatic regions of north and central India under sub-humid climatic conditions showed variable crop response enhanced on soil C status. IPNS and balanced fertilization lead to carbon stabilization at higher levels (Table 7). Application of NPK fertilizer had enhanced SOC stock by 20, 12 and 61% over the initial SOC stock at the Jabalpur, Palampur and Ludhiana sites, respectively, whereas the treatment receiving NPK+FYM increased SOC stock by 46, 30 and 107% over the initial value at the Jabalpur, Palampur and Ludhiana sites, respectively (Jha *et al.*, 2021).

**Table. 7. Changes in SOC under long-term cropping and manuring**

| Locations (Initial SOC stock) | Treatments | Steady state SOC stock (Mg $ha^{-1}$) | Years to reach steady state |
|---|---|---|---|
| Jabalpur (33.8) | No fertilizer | 29.0 | 55 |
| | NPK | 41.0 | 48 |
| | NPK+FYM | 60.0 | 108 |
| Palampur (40.5) | No fertilizer | 40.6 | 1 |
| | NPK | 49.0 | 40 |
| | NPK+FYM | 57.0 | 62 |
| Ludhiana (14.7) | No fertilizer | 15.9 | 44 |
| | NPK | 26.3 | 95 |
| | NPK+FYM | 37.6 | 116 |

LTF experiments across the country showed that continuous application of fertilizer P in balanced amount has resulted in buildup of available P levels in soils of India. This could be reutilized by readjusting the P doses in succeeding crops (Fig 21). The farmers have paid little attention to K use in agriculture due to the myth that 'Indian soils are rich in K'. Continuous absence K in fertilizer schedule or its application in inadequate quantities has led to net negative balance of K in Indian soil as evident from result of long-term experiments conducted across the country (Fig 22). Vertisols responsive to K application due to slower release of K from non-exchangeable pool and reduction in available K content.

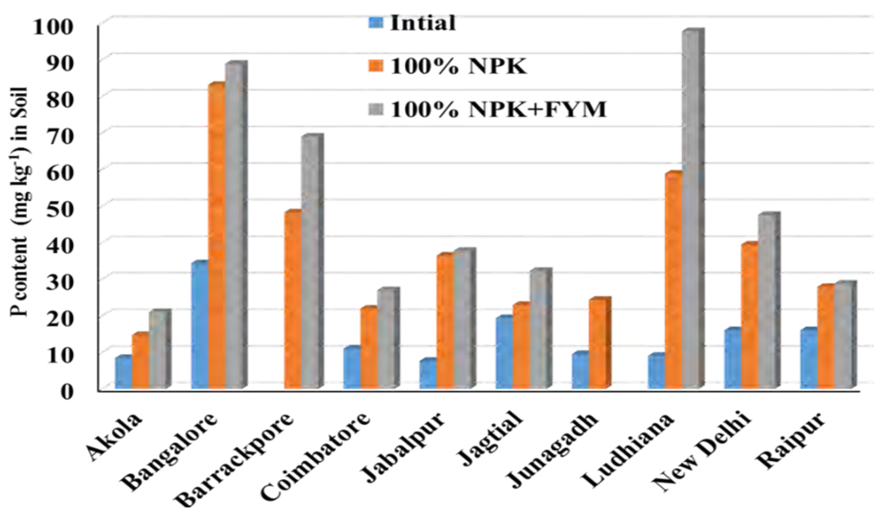



**Fig. 21. P build up in soils of various cropping system under long term fertilizer experimentation for 35 years (Singh et al, 2019)**

Application of K fertilizers for maintaining K fertility status of soil is very expensive as most of the potassic fertilizers production depends upon the imports of commercial grade K-bearing minerals. The low-grade K-bearing minerals available in India may serve as potential source of K by treating with potassium solubilizing microorganisms. in developing countries like India (Fig 22).

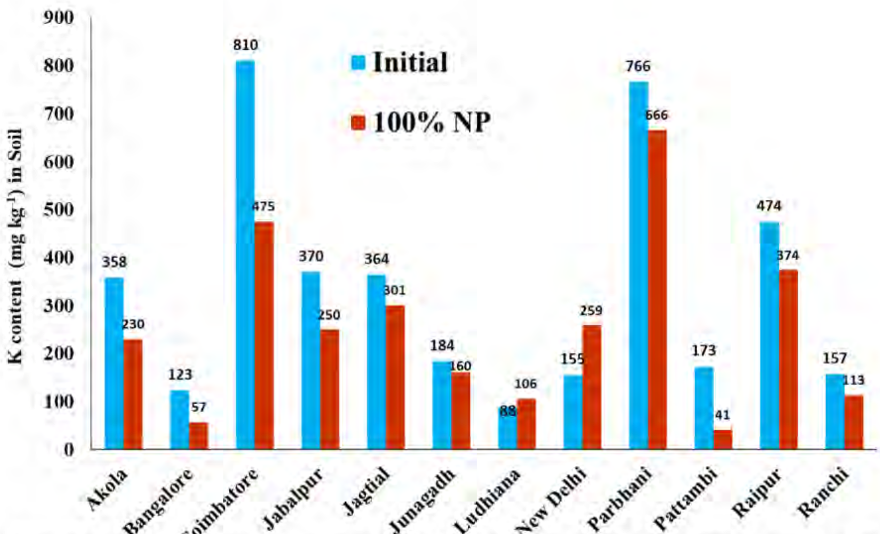



**Fig. 22. K mining from soils under different cropping system after 35 years of experimentation (Singh et al, 2019)**

Analysis of the trend of pesticide consumption in 29 states and Union Territories (UTs) of India has suggested a positive growth trend in 17 states/UTs. The positive growth has been observed highest in Jammu & Kashmir, Andaman & Nicobar Islands and Tripura. Uttar Pradesh, Maharashtra, Andhra Pradesh, Punjab and Haryana are the states that accounted for 70 per cent of total pesticide consumption (Fig 23). The use-intensity has been found highest in Jammu and Kashmir, followed by Punjab and Haryana. However, Punjab and Haryana have exhibited a declining trend in pesticide consumption. On the contrary, Meghalaya where the intensity of application is comparatively low, has registered an increasing trend in pesticide consumption. The majority areas in North-Eastern region in general apply low levels of pesticides and are in a

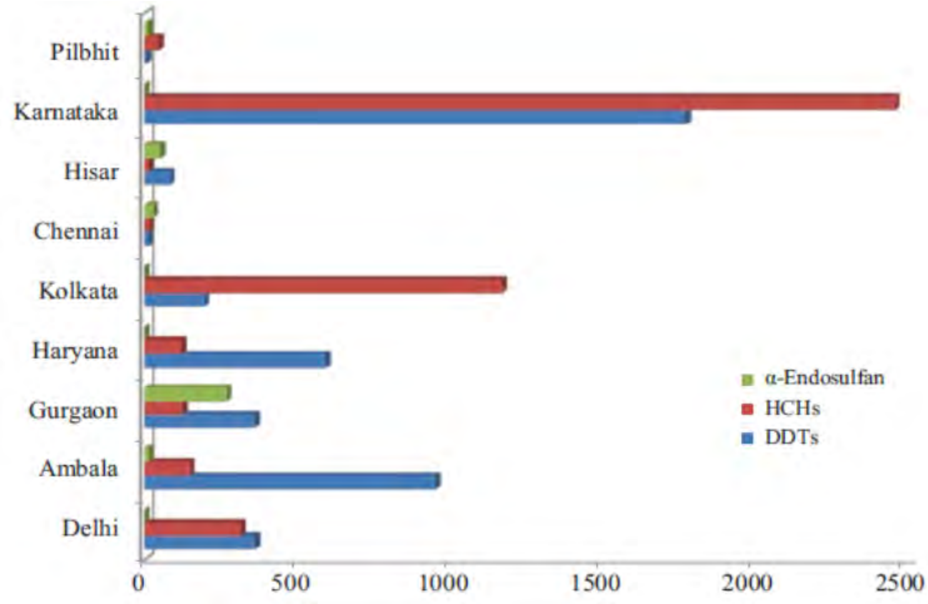



**Fig 23: Persistent organic pesticide residues (ng/l) in water from different regions of India**

*(Source: Kaushik et al., 2008, 2010, 2012, Sudar et al., 2010, Ghose et al., 2009, Begum et al., 2009, and Malik et al., 2009)*

declining mode of consumption, except the states like Sikkim, Meghalaya, Tripura, Manipur and Nagaland (positive growth rate). (Devi *et al.*, 2017). In a nationwide study in India on pesticide-use pattern by farmers (Shetty *et al.*, 2010), it was seen that only 20 per cent of the respondents obtained their information on plant protection aspect from the agricultural extension officer and the rest 80 per cent of the farmers used unreliable information. Nearly 40 per cent farmers get totally unreliable information from untrained persons. In another study, 47 per cent farmers said they obtained information from pesticide sellers in the market and 33 per cent from neighbours or relatives (Sadavy *et al.*, 2000).

## 8. Management Strategies to Minimize Impact of Agricultural Chemicals

Extensive review based on scientific on-station and on-farm studies revealed that adverse impact of fertilizer can be reduced by following efficient nutrient management strategies in various crops and cropping systems (Table 8).

**Table 8: Environmental problem associated with fertilizers and mitigation strategies**

| Environmental problems | Causative Mechanisms | Mitigation strategies |
|---|---|---|
| Ground water contamination | Nitrate leaching | Judicious use of fertilizers through LCC, increasing efficiency through novel, use nitrification inhibitors, Neem coated fertilizers |
| Eutrophication | Loss of nutrients, nitrate and phosphate through erosion and surface runoff | Reduce runoff, water harvesting, controlled irrigation, |
| Methaemo -globinemia | Consumption of high nitrates through drinking water and food | Reduce N leaching by adopting crop rotation with crops of different rooting zone. use balanced fertilization and NCOU. |
| Acid rain and ammonia redeposition | Nitric acid originating from reaction of N oxides with moisture in atmosphere, ammonia volatilization | Reduce ammonia volatilization loss, use the fertilizer formulations and inhibitors |
| Stratospheric ozone depletion | Nitrous oxide emission from depletion and global warming | Use nitrification and urease inhibitors and increase N use efficiency. Synchronize N use with crop demand. |

### *8.1 Promotion of Neem coated urea*

Controlled-release fertilizers have the potential to reduce losses of N from the system. Efficient fertilizer N management involving nitrification inhibitors and modified urea materials has been documented (Prasad, 2013). Thus, promotion of Neem cake/oil coated urea has dual benefit as fertilizer as well as pesticide. The key active ingredient in neem is azadirachtin- which exhibit agro-medicinal properties conferring insecticidal as well as immunomodulatory and anti-cancer properties. It acts as an antifeedant, repellent, and repugnant agent and induces sterility in insects by preventing oviposition and interrupting sperm production in males. As evident from research across the country that application of neem coated urea, NCU (200 kg neem cake $t^{-1}$ Urea) or neem oil coated urea, NOCU (0.5 kg neem oil $t^{-1}$ Urea) keeps nitrification inhibition properties and could enhance crop yield and N use efficiency as compared to untreated urea. However, about 30% comparisons did not exhibit increase in yield and efficiency. Yield increase using NOCU reported at farmers' field is generally lower than the researcher's plots due to poor crop management and plant protection measures. Farmers applying high and above optimal levels of Urea-N in different crops may not observe significant improvement in yield levels by applying NOCU. In India, more than 50% of the urea is consumed in rice and wheat crop. Replacement of urea with NCU or NOCU could enhance the grain yield by 5 to 6% in plots managed by researchers (Bijay Singh, 2018). The effect of nitrification inhibitors depends on concentration of triterpenoids in neem cake/oil, soil texture, pH and also on irrigated or rainfed condition. Nitrification inhibitors work better in acidic soils than in neutral or alkaline soils, in coarse textured soils than in fine textured soils, and in irrigated crops than in rainfed crops. Since, 30% share of total urea consumed in India is applied to crops grown under rainfed conditions.

Neem is used as a natural alternative to synthetic pesticides; however, little attempt has been made to study pesticidal properties associated with NCU or NOCU. Few studies associated with neem coated urea has been cited (Baboo, 2014). For example, neem oil is used an eco-friendly and economical agent to avert termite attack in field (Yash and Gupta, 2001). At one of the locations in the state of Uttar Pradesh, application of neem coated urea in rice fields by the farmers reduced the menace of blue bull (Boselaphus tragocamelus). At Panipat in Haryana, farmers observed no incidence of leaf folder and stem borer in the rice crop, and at Sangrur and Gurdaspur in the state of Punjab, farmers observed reduced incidence of white grub with the use of neem coated urea in the wheat crop. Site specific NOCU application using Leaf colour Chart would lead to higher or similar levels of crop production as observed with untreated urea but with lower fertilizer application rates (Shukla *et al.*, 2004). As farmers increasingly adopt SSNM principles for fertilizer management, demand for NOCU may contract from the present level of demand for urea.

### *8.2 Organic farming*

In recent years, traditional techniques, i.e., alternative to modern agriculture, including non-chemical alternatives are viewed as technology options that could help in decreasing or avoiding the need for undesirable chemical inputs and create environment friendly sustainable systems. Numerous models exist and have been advocated in this regard viz., Integrated Pest Management (IPM), Low External Input Sustainable Agriculture (LEISA) and Organic Agriculture (Tomer *et al.*, 2014).

Organic farming system in India is not new and is being followed from ancient time. It is primarily aimed at cultivating the land and raising crops in such a way, as to keep the soil alive and in good health by use of organic wastes (crop, animal and farm wastes, aquatic wastes) and other biological materials along with beneficial microbes (biofertilizers) to release nutrients to crops for increased sustainable production in an eco-friendly pollution free environment. India's rank is 8th in terms of World's Organic Agricultural land and 1st in terms of total number of producers as per 2020 data (FIBL & IFOAM Year Book, 2020). As on 31st March 2020, total area under organic certification process (registered under National Programme for Organic Production) is 3.67 million Hectare (2019-20). Country produced around 2.75 million MT (2019-20) of certified organic products which includes all varieties of food products namely Oil Seeds, Sugar cane, Cereals & Millets, Cotton, Pulses, Aromatic & Medicinal Plants, Tea, Coffee, Fruits, Spices, Dry Fruits, Vegetables, Processed foods etc.

## *8.3 Integrated Pest Management (IPM)*

National Research Centre for Integrated Pest management (NCIPM), a premier centre of Indian Council of Agriculture Research, has successfully elevated IPM paradigm from individual farm to area-wide pest management across the crops and regions through networks of partnerships and collaborations. NCIPM envisages larger role in making IPM practices more effective across the country through higher levels of integration of multidisciplinary technologies and stakeholders.

## *8.4 Use of Biopesticides*

In India, the concept of biocontrol of plant diseases has been in practice for a very long time. The neem tree (Azadirachta indica A. juss) and its derivatives, i.e. leaf extract, oil, and seed cake have been used as fertilizers and also for minimizing the risk of post-harvest loss in stored cereals (Isman 1997; Brahmachari 2004). However, in India, a major technological breakthrough in the field of biocontrol happened when chemical insecticides failed to control Helicoverpa armigera, Spodoptera litura, and other pests of cotton (Fig 24, https ://ppqs.gov.in/). India has increased use of biopesticides from 83 metric tons (MT) during 1994–1995 to 8847 MT in 2019-20. The lower adaptability and declining interest of farmers towards bio pesticides is a matter of concern.

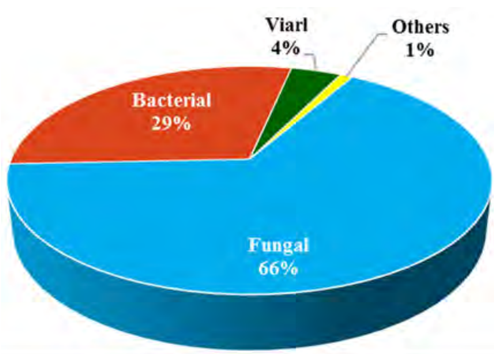


**Fig 24. Types of Biocides (%) used in India**

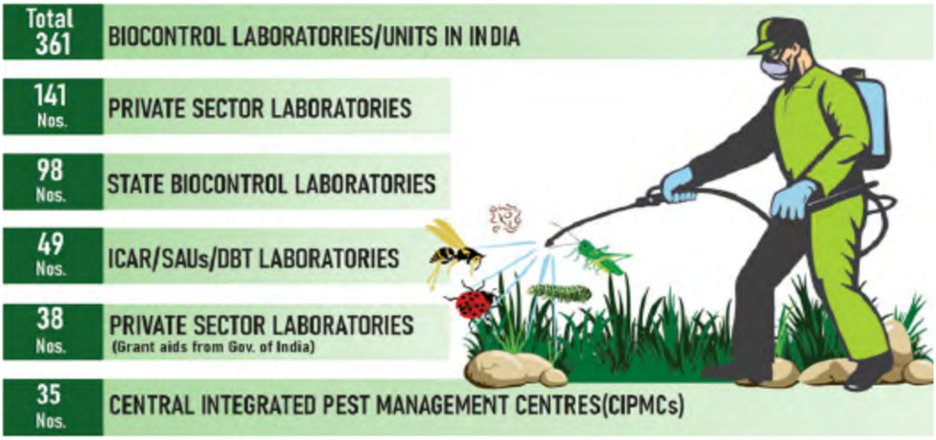



**Plate 1. Current structure of biocontrol laboratories and units working in India (source: Mishra et al. 2020)**

### *8.5 Awarness training on safe use of pesticides*

Promotion of good agricultural practices among the farmers is being emphasised to reduce incidences of acute pesticide toxicity. ICAR institutes, Krishi Vigyan Kendras, State Govt. Agriculture Departments and State Agricultural Universities regularly carry out awareness campaigns in vernacular languages for farm-workers regarding use of personal protection equipments, doses to be sprayed, recommended methods of pesticide application and hygienic practices to be adopted after spraying pesticides, adoption of IPM and comply with Preharvest Interval (PHI) for reducing dietary exposure of pesticide and overcoming the trade barriers.

### *8.6 Monitoring of pesticide residues at national level*

Already described above, the scheme funded by Govt of India has objectives: i) to identify crops and regions having preponderance of pesticide residues in order to focus extension efforts for Integrated Pest Management (IPM) and Good Agriculture Practices (GAP) ii) to test pesticide residues and other contaminants in food commodities and environmental samples like soil and water, iii) To strengthen infrastructure at Quarantine Stations to prevent entry of food and food commodities which have pesticide residues above Maximum Residue Limit (MRL) and iv) Testing / Certification of pesticide residue in export / import samples.

## 9. Farmers'Perception on Agrochemicals and its impacts

The pace of N and P consumption has exponentially increased as farmers believe that the fertilizer N and P use enhances crop productivity at faster pace by boosting crop growth. They ignore the awareness about balanced application of fertilizer because of availibilty of urea at cheaper rate under subsidized scheme. Hence, do not bother about (N: $P_2O_5$:$K_2O$) consumption ratio. This ratio is very wide in high productivity areas such as Punjab, Haryana, and Uttar Pradesh. The cost of cutomized fertilizer containing more than two nutrients.

Diagnostic surveys conducted in intensively cropped areas of Indo-Gangetic plains indicated that farmers' fertilizer practice was skewed toward N (because N is comparatively cheaper than P and

K), with optimal to suboptimal use of P and neglect of K, S, and micronutrients (Dwivedi *et al.,* 2001; Singh *et al.,* 2013). In intensively cultivated areas, the situation become more alarming due to unbalanced application of nutrient by the farmers. Farmers apply micronutrient, Zn to rice crop, that too at suboptimal rate. The indiscriminate use of N not only widens the fertilizer consumption ratio but also accentuates nonsustainability issues by way of promoting nutrient imbalances in soil-plant system, decreasing NUE, enhancing groundwater pollution through NO3 leaching, and escalating the cost of production.

As far as use of plant protection chemicals is concerned, a significant association observed between knowledge of the farmers and their practices related to pesticides ( Mohantey *et al.,* 2013). About 70% of farmers perceived that pesticide spraying affects a person's health. Only 40% were aware that it affects the environment. Two thirds of the farmers (62%) were aware that pesticide enters the body through nose and affects lungs and awareness on other modes of entry was less. Majority (76%) of them was aware of training programs conducted by government agriculture department on pest management. Between 40% and 70% of farmers donot use any protective equipments during pesticide spraying. Around 68% of farmers indiscriminately dispose off empty containers. Around 48% farmers buried the leftover pesticides.

## 10. Research-Extension-Farmer Linkages

Government of india has effective network of Scientist-extensionist-farmers interface though Krishi Vigyan Kendra (KVK) operated by Indian council of Agricultural Research and national agricultural research system (NARES). The basic aims of KVK is to assess location specific technology modules in agriculture and allied enterprises, through technology assessment, refinement and demonstrations. More than 700 KVKs have been functioning as Knowledge and Resource Centre of agricultural technology supporting initiatives of public, private and voluntary sector for improving the agricultural economy of the district and are linking the NARS with extension system and farmers. Each KVK has provision for providing advisory on use of agrochemicals (fertiliser nutrient mangment and plant protection measures) through soil scientist/agronomist and plant protection scientist accros the country.

The Government of India has started Soil Health Card Scheme in 2015 and is endorsed by the Department of Agriculture & Co-operation under the Agriculture and Farmers' Welfare Ministry with a view to enhance awareness about the balanced fertilizer application as per soil test requirement. A Soil Health Card is used to assess the current status of soil health and, when used over time, to determine changes in soil health that are affected by land management. A Soil Health Card displays soil health indicators and associated descriptive terms. Soil Health Card provides every farmer soil nutrient status of his land and advise him accordingly on the dosage of fertilizers and essential soil amendments that should be maintained for good soil health. The soil health card scheme properly examine the farmer's soil and accordingly give them a formatted report so that they can decide upon which types of crops to be cultivated for more income with balanced use of fertiliser and manures as per soil test report and crop demand.

Thirty five Central Integrated Pest Management Centres (CIPMCs) are located in 29 States and one Union Territory. ICAR also has its own research body named ICAR –NCIPM as described above. India could achieve increase in crop yield from 6.72 – 40.14% in rice and 22.7 – 26.63% in cotton in IPM fields compared to non-IPM fields, with notable reduction in chemical pesticide sprays to the extent of 50-100% in rice and 29.96 to 50.5% in cotton. This led to increase in use of bio-pesticides/neem based pesticides from 123 MT during 1994-95 to > 8800 MT (Tech. Grade) during 2018-19 (DPPQS, 2020).

## 11. Research and Capacity Development

In order to optimize the fertilizer application, greater emphasis should be made on use of organics (enriched composts, crop diversification with legumes, Crop residue and waste recycling, industrial by-products) other than FYM. This will help in development/refinement of nutrient management customs for conservation agriculture (CA), rejuvenating agriculture (RA) and integrated farming system (IFS) with effective nutrient fluxes and flows. For promoting availability of quality manure and formulating cropping system-specific fertilizer prescriptions involving locally available organic sources through eestablishment of highly mechanized composting units in rural areas.

Identification of nutrients smart farmers (farmers adopting best fertilizer management practices or nutrient smart villages and introduction of incentivization scheme for smart farmer/village). This would help in capacity building of stakeholders and encouraging soil health rejuvenation campaigns involving field demonstrations on agricultural chemical management technologies and informal education/skill development to enhance farmers' awareness on nutrient recycling and safe use of pesticides.

To ensure reduction in adverse impacts of agrochemicals use and promote optimum use of pestcides and nutrients, the best management practices for rejuvenating agriculture should be linked with Govt initiatives e.g., National Mission on Sustainable Agriculture (NMSA), Doubling of Farmers Income (DFI), National Food Security Mission (NFSM), Pradhanmatri Krishi Vikas Yojna (PKVY), Soil Health Card scheme (SHC), Mission for Integrated Development of Horticulture (MIDH) etc.

Identification and disposal of basket of technologies, which encompasses the principles and practices that restore/ improve soil health, protect crop from insect pest and diseases and ensure sustained high productivity while minimizing environmental footprint. It is more realistic to promote practices for increasing SOC stock and thereby soil quality. The benefits accrued by small increases in SOC may not necessarily translating into increased crop yield but improve soil health and environment safety. Existing LTEs (AICRP-LTFE, DA, IFS) serves as repository of information, need to be modified to retain their relevance, and converge with present-day farming issues, like organic inputs, tillage, residue recycling and crop diversification.

Research and development needs of pesticides include implementation of sustainable medical management, epidemiological surveillance and monitoring of pesticide poisoning in hospitals and communities; development or strengthening of community programmes that minimize risks of intentional and unintentional pesticide poisoning; monitoring of currently registered pesticides in food and environmental components to assess the impact of agrochemicals on human and environmental health; establishment of more NABL accredited laboratories for estimation of pesticide residue status in food and environmental components; focus on sensor based rapid pesticide detection techniques.

Capacity Development efforts of stakeholders include awareness programmes for consumers, farmers and other stakeholders on safe waiting period (i.e. Preharvest Intervals), importance of MRL for export and domestic consumption of produce and adverse effects of pesticide contaminated food on human health. Promotion of good agricultural practices among the farmers to reduce incidences of acute pesticide toxicity; incentives to farmers who are following IPM approach; launch programs for 'empty container management' at farmer level.

## 12. Challenges of Agrochemicals Use

- To meet the additional foodgrains required by 2050, it is necessary to increase the use of fertilizer nutrients with similar magnitude if the NUE remains unchanged. Bringing urea under nutrient-based subsidy would eventually lead to its cost escalation, resulting in substantial increase in the cost of cultivation due to inefficient use of N and increased GHG emissions through indiscriminate fertilizer applications. Hence, there is a need to intensify research in this area using alternative management practices beneficial to both the group of indicators; i.e., use of organic fertilizers for biological soil quality as well as increase in crop yields.
- Notwithstanding established benefits of IPNS, its adoption at largescale could not become possible due to availability of subsidized fertilizers urea, time and labor needed for preparation of farmyard manure (FYM) and composts, and higher handling cost of organic manures.
- Use of fertilizer or organic manure alone led to decline in SOC and yield. In view of this and emphasis on soil health scheme of government of India, there is need for revival of interest in IPNS and its effective execution in mission mode for improving indigenous nutrient supplying capacity of soil, optimize nutrient input, enhance fertilizer use efficiency, and rejuvenating soil health.
- Crop rotation play an important role in rejuvenating soil fertility by utilizing the native nutrients at variable rate with different depth. However, farmers are reluctant to change cropping system due to lower yield of legumes and insecurity of MSP for new crops.
- It is not possible to sustain high productivity levels with fertilizers alone, but prevailing unbalanced and inadequate use of fertilizer continued due to availability of urea at subsidized rate and decontrol of other fertilizers.
- Crop response to K, S and micronutrients has been increased over time under intensive cropping, but their use is still inadeqaute to meet crop demand and sustain soil health. In general, mining of K from soil and its low use in crops leads to annual K balances highly negative in all cropping systems. Continued neglect of K input inclined to change the mineralogical make-up of soil, indicating deterioration in K supplying capacity of soils.
- Research on new pesticide molecules has mostly taken place outside India, mainly due to high cost involved in developing new molecules and relatively low priority accorded to pesticide research in India. The generic pesticides command about 80 per cent of the market share presently.
- Banning of pesticides: Recently 27 pesticides proposed for ban in India, constitute almost 25 per cent of total pesticide market in India. These are

used for pest control on 74 important food (mainly rice around 29%), fibre (mainly cotton around 19%) and horticultural crops. Some of these are also used against household pests, stored grain pests and in public health programs against vectors of human and animal diseases.

- Impact of non-genuine/illegal pesticides: Non-genuine/illegal pesticides constitute ~ INR 3,200 Cr (~ USD 525 Million) in 2013. It also unraveled that U.P, Jharkhand, M.P, erstwhile Andhra Pradesh, Haryana, Maharashtra, West Bengal, Karnataka and Tamil Nadu are the states which were highly affected with non-genuine/illegal products.
- Trade barrier: The presence of higher than permitted levels of pesticide residue have faced warnings, rejections, and alerts. For example in 2010, the denial of an Indian consignment of table grapes in the EU due to a higher than the permitted amount of chlormequat chloride received significant attraction of the media and the policymakers as the EU was India's largest export market for table grapes, accounting for about 60% of exports. The problem of the presence of excessive residues of pesticides usually arises at the field level and need to be addressed in terms of the use of correct pesticides or a correct application of pesticides.
- Frequent lowering of MRLs: Developed countries tend to lower the MRLs in the case of certain ingredients, sometimes more than 2-3 times a year, which creates barriers for exporters. This is because farm-level practices must comply with new requirements and it is not easy to frequently change farm practices. For example, the EU very often lowers the MRLs of chemicals, substantiated by the fact that the EU published MRL changes for several chemicals (such as carbetamide, cymoxanil and acrinathrin) between June 2015 and April 2016 in the case of basmati rice exported to the EU.
- Lowering of MRLs without any scientific justification: Occasionally, under the precautionary principle of the WTO Sanitary and Phyto sanitary (SPS) Agreement (Article 5.7), MRLs can be lowered without scientific justification, and this can go unchallenged in the WTO. In 2010, the EU reduced the chlormequat chloride MRL for table grapes to 0.05 mg $kg^{-1}$, which is consistent with the Codex guidelines. The EU again proposed to reduce the MRL for chlormequat chloride in table grapes from 0.05 $mgkg^{-1}$ to 0.01 $mgkg^{-1}$ in 2016. India argued in the WTO SPS Committee that roughly 24.5% of Indian table grapes exported to the EU could not meet the requirement and asked the EU to provide scientific justification for the reduction of the MRL. The EU decided to consider maintaining a temporary MRL of 0.05 $mgkg^{-1}$ as long as the European Food Safety Authority (EFSA) does not raise any concerns.

- Lack of harmonization of standards across countries: It has been disclosed that different countries allow different MRLs to enable exporters to export to the respective markets in order to meet a particular country's requirements for a commodity. A survey revealed that different countries have set different levels of tolerance for tricyclazole used by rice farmers in India [https://indofilcc.com]. A virtual ban on tricyclazole created issues for a majority of rice farmers and exporters in India. This is because two key basmati rice varieties, namely Pusa Basmati (PB) 1 and PB1401, which are the major varieties of rice exported to the EU, have been accepted with tricyclazole MRL at 0.03 mg per kg so far from India [http://economictimes.]. India exports INR 17 billion (USD 263.75 million) worth of basmati rice to the EU and as a result of this revision of tricyclazole MRL, the country is likely to lose its market share. Likewise, the EU has set stricter MRLs for aflatoxin in peanuts than the other countries such as the US.
- Lack of legal control/deviation from the recommended pesticides: It has been reported that residues of unapproved pesticides were found in 12.50 % of the 20,618 samples collected nationally in India as part of the central scheme 'Monitoring of Pesticide Residues'. The samples collected during 2014-15 were analyzed by 25 laboratories and non-approved pesticides like acephate, bifenthrin, acetamiprid, triazofos, metalaxyl, malathion, acetamiprid, carbosulfan, profenofos and hexaconazole, among others, were detected (https://economictimes). It indicates lack of legal control on non-recommended and non-judicious pesticide use, ignorance about safe waiting period (PHI) and variation of recommendations in plant protection practices.

## 13. A Way forward

The benefits of biofertilizers, particularly, Rhizobium, Azotobacter, Azospirillum, PSB could find lot of space in research journal, but inconsistent response to biofertilizers is often associated with their substandard quality and negligence during production, storage, transport, and usage. Efforts need to be made to ensure production of quality biofertilizer with long vitality and effectiveness at farmers' field. India has huge opportunity to seize the N challenge by collective effort of enhancing public and institutional awareness among the stakeholders' regarding threat perceptions of increased NR in the environment. India can achieve 20-30% reduction in the fertilizer use, particularly N and P by adopting best crop and fertilizer management practices in association of effective policy implementation (Abrol and Adhya, 2017). Established the advantage of balanced fertilization, IPNS, inclusion of legumes, precision N management, and CA in improving NUE may be harnessed through effective implementation of BMP.

Economic instruments may be used to create a level playing field for greener products and approaches; promotion of direct finance use to encourage sustainable agriculture; and strengthening standards and adopting corporate policies for sustainable supply chain management. Pesticide management should be strengthened by control of pesticide distribution and use as per legislation; prioritizing development of and access to low-risk pesticides; addressing the trade in substandard, illegal, and counterfeit pesticides; and supporting the adoption of extended product responsibility by pesticide manufacturers and traders.

Actions to strengthen fertilizer and nutrient management include: enacting national policies for quality fertilizer control; strengthening global policies on sustainable and safe fertilizer use; scaling up training of all relevant stakeholders in fertilizer and nutrient management; and ensuring accessibility of suitable and affordable fertilizers. Fertilizer product research needs to be intensified so as to come out with sustained N release materials to meet crop N demands and minimize N losses. Need to develop efficient farm machinery for site specific placement of fertilizer in root zone under diverse conditions for different crops. Efforts should be made to promote water soluble fertilizers (WSF) and their performance should be evaluated for improving NUE of locally manufactured or imported fertilizer.

The lessons learned so for in the area of improving NUE in cropping systems amply suggest that this issue cannot be addressed through conventional compartmentalized research. Scientists belonging to at least five disciplines, namely soil science, agronomy, crop improvement, microbiology, and crop physiology should join hands to deliver a tangible outcome. While developing strategies for enhancing NUE, a balance between NUE and crop productivity. should be maintained. For example, the NUE is often highest at the lower parts of the yield-response curve where fertilizer inputs are lowest, but effectiveness of fertilizers in increasing crop yields and optimizing farmer profitability should not be sacrificed for the sake of NUE alone.

Harmonization of MRLs are meant as a safety limit in International trade, however, it is one of the potential tools in form of non-tariff barrier. MRLs fixed many years ago still continue without revision. There is a need to review such old MRLs based on latest monitoring data on pesticides residues and availability of new data from time to time. Default MRLs comprise a major trade barrier. Harmonization as per international standards is need of the hour..

Strengthen testing and certification: Measures suggested are protocols for validation, testing and certification to be evolved at par with International standards and be implemented through the mechanism of accreditation, establishment of more laboratories as per the need and develop public-private partnership for this purpose, training and resource development for residue analysis, international validated testing procedures to be adopted by the laboratories (as an integral part of the accreditation process), residue data (as per GLP) to be implemented in line with international practice.

India is signatory of Mutual Acceptance of Data (MAD) to OECD for assessment of chemicals. GLP trials could be conducted in India by GLP accredited laboratories. Alternatively, residue data of other countries (with similar climate) could also be accepted. Extrapolation of residue data among different formulation types may be accepted, as is done in many developed countries. Monitoring of pesticide residues are required to be on the same commodities in all parts of the country. Such monitoring data could be used for re-evaluation of already established MRLs.

Emphasis on training and extension: There is a need to emphasize upon awareness campaigns among all stakeholders including farmers, pesticide manufacturers, regulators to adopt only approved usage of pesticides in a safe and judicious manner so as to minimize the level of pesticide residues (below MRLs) in commodities.

National MRLs : Adoption of Crop Grouping Approach is used in many parts of the world (EU, US EPA, Australia, Japan, etc.) to generate residue data on representative crop of crop group / sub group as per critical / worst GAP and residue data thus generated can be extrapolated to other member crops and Crop group MRLs are implemented. This obviates lot of monetary investments and also get rid of terrific, time consuming efforts of generating residue data on each and every crop. Residue data generated on the representative crops and MRLs thus fixed are applied to the whole crop group / sub group. The same principle, which was already been applied to existing molecules, may be extended to new molecules as well.

Crop grouping approach would also increase the scope and speed up approval process of products use on wide range of crops benefiting the farming community. An Expert Committee on Crop Grouping was formed by Registration Committee (RC) during 2013-15 who grouped various crops into several groups and sub-groups in harmonization with codex crop groups. Indian crop commodities were accommodated in the existing groups/ sub-groups. Recommendations of Expert Committee was adopted and agreed by RC for MRL fixation. RC nominated a sub-committee with ADG (PP&B) as its chairman to develop modalities for its implementation. Such a move will harmonize fixation of MRLs in several crops including minor crops.

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## Chapter 5

# Impact of Agricultural Chemical Inputs on Human Health and Environment in Maldives

**Mariyam Ajila**
Ministry of Fisheries, Marine Resources & Agriculture
Republic of Maldives
*mariyam.ajila@fishagri.gov.mv*

## 1. Introduction

In recent years, the demand for food has increased, due to the rapid growth of human population. Consequently, this puts increased pressure on the agricultural sector to address the growing food demands and to ensure food security. With the intensification of agriculture to improve productivity and crop protection, chemicals are one of the major approaches used to increase crop yields. Agrochemical products that are being heavily used in farming worldwide, consists of fertilizers, plant protection chemicals and plant growth regulators (Biswas, et al., 2014).

Maldives is no exception in this regard. In Maldives, agriculture contributes to 1.3% of GDP as of 2018 and this sector has been gaining attention in terms of growth and stability in production (Asian Development Bank, 2020). This is reflected in increased production and utilization of labor and land resources. Subsequently, the increased use of agrochemicals has been associated in the steady growth of the sector. These agrochemical products used in the Maldives are almost exclusively of foreign origin and that are imported to the country.

Consequently, the increased use of agrochemicals has demanded more focus to be put to solving the challenges these chemicals have on human health and the environment. The irresponsible use of agrochemicals has huge implications on our fragile environment and human health. Overuse, unauthorized application, and poor disposal of these products are some of the most critical issues relating to injudicious agrochemical use. In general, agrochemicals are known to pose neurotoxic, endocrine disruptive and carcinogenic effects on human health. However, in Maldives, monitoring and reporting mechanisms are not well established to identify the impacts of agrochemicals (Hameed, et al., 2015). Moreover, these chemicals have the potential to pollute the environment through land, water, or air.

## 2. Types of Agrochemicals used in different Agricultural Systems

Agricultural chemicals include various types of fertilizers, hormones, fungicides, insecticides, and soil treatments that improve the crop (Biswas, et al., 2014). These chemicals are mainly classified as fertilizers and pesticides. Fertilizer improves the quality of soil by enriching with essential nutrients, while pesticides assist in pest control and promote growth development of plants.

In the delicate ecosystems of Maldives, indigenous farming systems have evolved from traditional to conventional farming practices, which created the dependency on chemical fertilizers and pesticides. As the Maldivian islands are low-lying, the soils in the islands are infertile and very alkaline (Ministry of Environment and Energy , 2015). Therefore, to improve nutrient status and quality of soil, fertilizers are being used extensively by the farmers, which is evident from figure 1. The import of fertilizer has been increasing gradually and these fertilizers provide essential nutrients for the growth of plants. Fertilizers are broadly classified as organic and chemical.

Even though organic fertilizers are promoted in agriculture for its low harmful impacts, organic waste, poultry and meat industries are low in terms of catering organic fertilizer for the growing agricultural sector in Maldives. Therefore, import of organic fertilizers like manure and compost are done at a large scale which is evident from the graph shown in figure 1. The figure shows that in each year, the quantity of organic fertilizers imported to the Maldives are more compared to chemical fertilizers. Despite the fact that chemical fertilizers are imported at a small scale, Maldivian farmers give equal importance to use chemical fertilizers with organic fertilizers. This is mainly because chemical fertilizers are considered more cost effective, efficient, and readily available. Most fertilizers can typically provide one or more of the three primary nutrients; nitrogen, phosphorus, potassium; secondary nutrients; calcium, magnesium, sulfur; and other micronutrients such as, copper, iron, magnesium, zinc and boron.

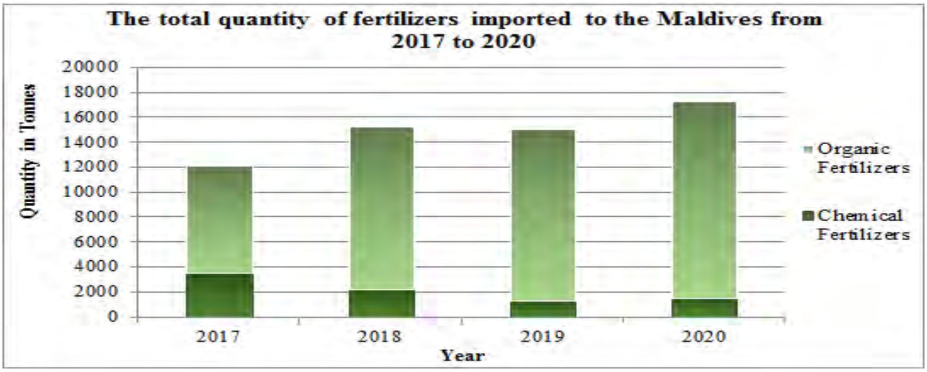


**Figure 1: The total amount of fertilizers imported to the Maldives from 2017 to 2020 with the composition of major types of fertilizers, Based on Maldives Customs Service - Import Statistics (Maldives Customs Services, n.d.)**

With intensification of the agriculture sector and shortage of land, different types of conventional hydroponic systems are adopted to grow certain fruits and leafy vegetables (Mohamed, 2018). These systems require hydroponic nutrient mixtures and most of these nutrient mixtures contain all three primary nutrients and few secondary nutrients. Even though these nutrient mixtures are advised to be used in hydroponics systems and as a foliar spray, Maldivian farmers frequently use these mixtures in soil cultivation (Mohamed, 2018).

Moreover, the progress of the sector shows, new agricultural systems shifting from subsistence to more commercialized approach. When the sector was solely to feed the family and to meet the daily nutrient needs, the use of agricultural pesticides was of no use. However, commercial agriculture is developing over the years, and is significant for larger islands (Asian Development Bank, 2005). These islands are either long term leased for agricultural use or inhabited islands with better soil profiles. With increased demand for new agricultural systems and increased import of various alien plant species in recent years, the prevalence of pests and diseases have increased. Therefore, to control these pests and diseases, pesticides are being used at a great extent.

Chemical pesticides from different classes, uses, mode of action, concentrations to different formulations are being used in the Maldives. The import data for these chemical pesticides are presented in figure 2. The data shows that insecticides represent the bulk of annual pesticide imports. Fungicides, herbicides and plant growth regulators are also imported in comparatively low quantities. This data also shows a negligible quantity of rodenticide and molluscicide being imported which also used for domestic pest management. Chemical pesticides gained popularity during the transitional stages from traditional to conventional farming. Also, at that time, it was believed that the use of chemical pesticides are effective and economically efficient as a pest management strategy. So, with the trust and recognition of farmers, it is difficult to change the perspective of farmers in shifting to organic pesticides.

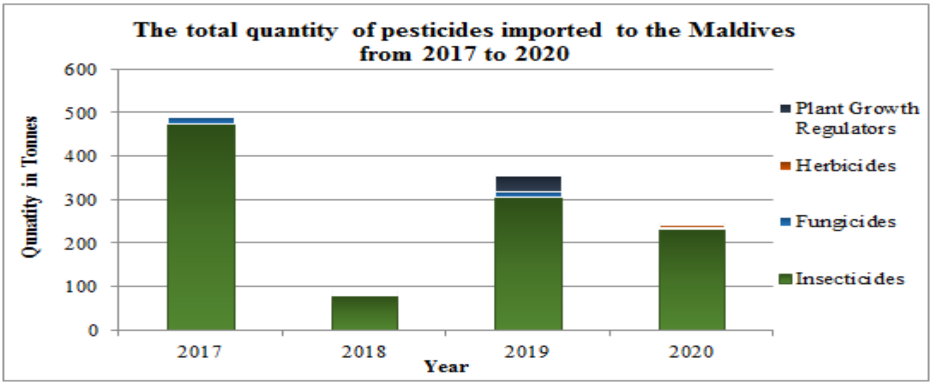


*Figure* **2: The total quantity of pesticides imported to the Maldives from 2017 to 2020, Based on Maldives Customs Service - Import Statistics (Maldives Customs Services, n.d.)**

According to the Maldives National Chemical Profile, the main type of pesticide imported to the Maldives, from 2010 to 2014 are insecticides (Hameed, et al., 2015). This was also the case with respect to the pesticide import trends presented in figure 2. In figure 2, the graph also shows that the import of pesticides decreased in 2018 and 2020. This is likely due to the lack institutional capacities in data collection and challenges posed by Covid-19 pandemic.

## 3. Importance of Agrochemicals

In the Maldivian agricultural system, soil fertility improvement and pest control are two major aspects that require heavy agriculture inputs. In this respect, chemical fertilizers help in achieving the result in a short period of time. Chemical fertilizer alternatives tend to be cheaper and more available to islanders compared to organic fertilizer products. Moreover, chemical fertilizers generally perform quicker in supplying essential pant nutrients with timely response, the demand and popularity for chemical fertilizers has increase among farmers.

Pesticides provide primary and secondary benefits to the agriculture and food system by preventing the plants from diseases which secures food availability for the population needs. Worldwide, approximately 40% of the agricultural products are lost due to diseases and pests (Mahmood, et al., 2015). In these cases, pesticides are known to be one of the extremely useful and beneficial agents for preventing crop losses and reducing human diseases. Pesticides can be classified as destroying, repelling and mitigating agents, which can have different modes of action for each pesticide. Further, if productivity is increased by using pesticides, the availability of food will meet the global food demand hence, decreasing the prices of food commodities. These chemicals can also prevent the pest contamination of agricultural goods which will ensure the safety and quality for the consumers.

## 4. Existing Regulatory Frameworks & Guidelines to support Optimum use of Agrochemical Inputs

In Maldives, the import and use of agricultural chemicals have increased over the years. Until very recently, there was no sector-wise regulation in the country to manage chemicals. All agrochemicals are managed by the Ministry of Defense under the 'Act number: 4/75; Substances Prohibited to be Brought into the Maldives' (Attorney General's Office, n.d.). The permits to import agricultural chemicals are given by the Ministry of Defense, in relation to the prior endorsement from the Ministry of Fisheries, Marine Resources and Agriculture, stating that the chemicals can be imported for agriculture use. Moreover, the Ministry of Defense has the mandate to inspect and register chemical warehouses. During inspection, fire safety, emergency procedures and storage measures are considered. Also, in 2019 the 'Regulation number: 2019/R-1057; Hazardous Chemical Regulation' under 'Act number: 4/75' by the Ministry of Defense was endorsed. This regulation aims to regulate the import, sale, usage, safe handling, storage and disposal of hazardous chemicals (Ministry of Defence, 2019).

The 'Act number: 21/2019: Agricultural Pesticide Control Act' and 'Regulation number: 2021/R-12; Agricultural Pesticide Control Regulation' was endorsed in 2019 and 2021 respectively (Ministry of Fisheries, Marine Resources and Agriculture, n.d.). The main aims of the mentioned agricultural pesticide control legislations are to regulate the agricultural pesticide use, manufacture, import, export, sale, and disposal. The underlying goal is to take actions regarding negative impacts of pesticides on human health and environment. Additionally, this legislation covers requirements in relation to storage, transport, sales outlets, manufacturing plant, storage containers and waste management procedures. Moreover, under this legislation, a list of 'Approved Pesticide Registry' has been published (Ministry of Fisheries, Marine Resources and Agriculture, 2020). This registry includes 188 pesticides with low WHO hazard class and 174 biopesticides. This was done to promote the use of biopesticides and to minimize the circulation of hazardous pesticide products within the country.

Other than the national legislations, Maldives became a party to the 'Rotterdam Convention on the Prior Informed Consent Procedure for certain hazardous Chemicals and Pesticides in international trade' on 15th January 2007 (Rotterdam Convention, 2010). The major objective of this convention is to promote shared responsibility and cooperative efforts among Parties in the international trade of certain hazardous chemicals in order to protect human health and the environment from potential harm (Rotterdam Convention, 2010). Furthermore, this convention aims to contribute to the environmentally sound use of those hazardous chemicals, by facilitating information exchange about their characteristics, by providing for a national decision-making process on their import and export and by disseminating these decisions to Parties (Rotterdam Convention, 2010). Under this convention Maldives has implemented the Prior Informed Consent (PIC) procedure. According to the PIC procedure implemented by Maldives, other than 'Thiram fungicide', the final decision was made as 'No consent to import' for all the other agricultural pesticides mentioned in Annex III of the convention (Rotterdam Convention, 2010). This decision of 'No consent to import' would prohibit the import of harmful pesticides into the Maldives and for other pesticides mentioned in Annex III of the convention, the designated national authority of the convention will receive an export notification prior to the import of hazardous chemicals and pesticides.

These international treaties and national legislations assist in better management of agrochemicals.

## 5. Status of Agrochemical Management

### *5.1 Storage*

All major agrochemical importers are required to register and declare a place of storage as part of the import procedure. The chemical warehouses are inspected and permitted by the Ministry of Defense under their Hazardous Chemical Regulation. The regulation states that the warehouse should be insured, and it should be according to the chemical storage warehouse guidelines (Ministry of Defence, 2019). If the warehouse meets the requirements, the Ministry of Defense issues a valid chemical storage warehouse permit for a one-year period. According to their Makudi Portal the total number of warehouses with valid permits is around 82 (Ministry of Defence, n.d.).

As chemical storage warehouse standards are general guidelines for all types of chemicals, detailed information regarding the chemical types is not available. Moreover, with the aim of chemical risk reduction, while inspecting, the Ministry of Defense ensures that the hazardous chemicals are stored separately in individual racks (Hameed, et al., 2015). Apart from the permitted warehouses, there are several other storage facilities with no permit or expired permit. These warehouses are not specifically for agricultural chemicals. Other than agrochemicals, chemicals are also imported for tourism, food industry, construction, and medical purposes. Hence, the specific producers required for agrochemical storage and that of warehouses will be enforced under the guidelines published by Pesticide Control Regulation 2021/R-12.

### *5.2 Application*

In developing countries like Maldives, there is an increasing concern about overuse and misuse of agrochemicals. In Maldives, currently there are no proper monitoring mechanisms established to understand the use of these chemicals by the farmers. Firstly, Maldives agricultural systems are dominated by foreigners who oversee day to day farming practices including nutrient and pest control applications (Mohamed, 2018). These farmers and foreigners lack technical knowledge of agrochemical applications. The farmers are not aware of proper diagnostic procedures associated with nutrient deficiencies and pest and disease identifications. Further, farmers do not use proper attire and follow handling procedures while applying agrochemicals. Therefore, this results in application of non-specific, intense use and unsafe handling of agrochemicals.

### *5.3 Transportation*

Agrochemical imports to the Maldives are done via maritime transportation channels. Chemical transportation within the Maldives is mainly done via sea and upon arrival to the domestic terminals, these products are transported by trucks to storage facilities (Hameed, et al., 2015). Agrochemicals are transported to islands in supply vessels and these chemicals are generally supplied with other goods. While transporting agrochemicals, safety measures and safety labels are not implemented by the vessel operators.

### *5.4 Waste disposal*

Waste is one of the most crucial life cycle stages of agrochemical. Even though solid waste management facilities are established in different regions in the Maldives, there is no designated area which meets the environmental criteria for disposing chemicals (Hameed, et al., 2015). According to the Hazardous Chemical Regulation, if a chemical is subjected for disposal, the owner must request the Ministry of Defense for disposal. Hazardous chemicals including agrochemical waste are diluted and drained into the ground or sea by the Ministry of Defense as they lack proper facilities for waste disposal (Hameed, et al., 2015).

At islands, waste segregation is not practiced, and all types of waste are discarded to dump sites, burnt or dumped into the ocean. Agrochemical wastes are no exception in this regard, the chemical wastes are mixed with other types of waste and discarded along with other waste. In order to tackle these issues, the best practices of agricultural pesticide waste management is discussed under the agricultural pesticide legislation. This also includes the procedures to follow while discarding pesticide concentrate, vacant containers, packaging materials, pesticide contaminated plant parts and water.

## 6. Hazards of Agrochemicals

The intensive use of chemical fertilizers and pesticides in agriculture to ensure food security is associated with many chronic health problems and unrecoverable environmental degradations. These implications are mainly resulted from the irresponsible use of agrochemicals. In Maldives, use of pesticides and fertilizers by the farmers exceed the technical guidance recommended by the manufacturer (Hameed, et al., 2015). Intense use of agrochemicals can leave chemical residues on harvested crops or these chemicals can leach into the groundwater system. Some of the major problems associated with agrochemicals include environmental pollution, reduced input efficiency, decreased food quality, resistance development, soil degradation, micronutrient deficiency, toxicity and less income from the production (Chandini, et al., 2019).

In addition, pest resistance has been observed in many major pests and diseases of most cultivated crops.

### 6.1 Environmental Hazards

When agrochemicals are applied or irresponsibly discarded, the pesticides have the potential to enter the environment by undergoing chemical transfer or chemical degradation (Tudi, et al., 2021). Agrochemical degradation can produce new chemicals in the process and chemicals can be transferred by adsorption, leaching, volatilization, spray drift and runoff.

#### 6.1.1 Water

In Maldives groundwater and freshwater are scarce resources due to the hydrology of the island nation (United Nations Development Programme, n.d.). As the soils of the Maldives are geologically young due to high porosity and extremely high infiltration rates (Selvam, 2007), the heavy use of agrochemicals can cause these chemicals to seep into water bodies easily. In addition, the unmanaged chemical waste can leach into the groundwater system and intime the chemicals can seep into the sea. Despite the fact that Maldives lacks adequate infrastructure to test the water parameters, the lagoons of most of the agricultural islands are covered with seagrass meadows, which can be related to the heavy use of fertilizers by the farmers. One of the major implications of the intensive use of fertilizer is water eutrophication (Impacts of chemical fertilizer) and it is important to know the likelihood of such impact to Maldivian water systems.

#### 6.1.2 Soil

The geologically young soil of the Maldives is very infertile, and the farmers have no choice rather than using fertilizers to improve the soil fertility. Soil is one of the major aspects, which contributes to ecosystem services and a home to different organisms. However, heavy use of fertilizers can lead to soil-acidification, loss of organic matter, loss of beneficial organisms, stunt the plant growth, alter the soil pH, increase pest and even can release greenhouse gases (Chandini, et al., 2019).

The process of degradation of pesticides within the soil causes the soil to adsorb pesticide residuals in the soil, which can accumulate and persist in the soil (Tudi, et al., 2021). Some of the pesticides such as DDT, endosulfan, endrin, heptachlor, and lindane are highly persistent within the soil, thus these chemicals are import prohibited to Maldives under Rotterdam Convention. Further, these chemicals are not mentioned under the 'Approved Pesticide Registry', which would ensure the use of environmentally safe pesticides.

### 6.1.3 Air

Agrochemicals have a role in polluting the air at the manufacturing stages and while application. As agrochemicals are not manufactured in the Maldives, the main point source of air pollution is from the residues of agrochemicals produced from agrochemical application or by volatilization from plants and soil. The most widely used pesticide application in Maldives is foliar spraying. However, all methods of spraying pesticides have the potential to be inefficient, as the pesticide residues are volatilized, dispersed, and transported in the process of application, which is then subjected to a process called environmental recycling between air and the terrestrial environment (Tudi, et al., 2021). This process can bring adverse impacts on the local and global environment.

High application rates of chemical fertilizers can generate greenhouse gases, which will deplete the ozone layer and expose the humans to harmful ultraviolet rays. During the manufacture of nitrogenous fertilizers greenhouse gases such as carbon dioxide, methane and nitrous oxide are produced (Chandini, et al., 2019). The volatilized or emitted ammonia from agricultural lands gets deposited in the atmosphere and after chemical transformations create acid rain, which can damage the vegetation, buildings, and the organisms (Chandini, et al., 2019). All these air pollutions from agrochemical emission are difficult to assess, but it is definite that these emissions contribute to global climate change.

### 6.1.4 Non-targeted organisms

The chemical fertilizers can have indirect effects on other organisms, while pesticides can negatively influence non-targeted organisms. Even in Maldives there were cases of beneficial organisms such as earwig (*Chelisoches morio*) disappearing from the islands, which is known to be a predator of hispid beetle (*Brontispa longissima*). Therefore, the negative impacts of agrochemicals can damage wildlife, birds, aquatic ecosystems, beneficial insects, and natural enemies of insect pests (Tudi, et al., 2021).

## 6.2 Human Health Hazards

Agrochemical users and consumers are subjected to agrochemical related health problems. Maldives lacks a proper mechanism to report accidental chemical poisoning in regional hospitals and health centers, therefore national data on accidental chemical poisoning in the country is underestimated (Hameed, et al., 2015). According to some farmers, if they come across accidents relating to agrochemicals, they tend to retain the cause of the incident from the health workers. Moreover, most of the farmers lack enough knowledge about health hazards associated with agrochemicals, which is one of the reasons why Maldives lacks a proper mechanism to collect accidental chemical poisoning.

Regardless of the unavailable national data relating to the agrochemical health hazards, some of the probable incidents and health impacts will be discussed here.

### *6.2.1 Acute illness*

Firstly, the farmers do not use personal protective equipment like face masks, gloves, goggles, cover roll and safety shoes. This could result in access of pesticides and other chemicals in the bloodstream through dermal exposure and inhalation (Sharma & Singhvi, 2017). Acute illness is considered, if any of the symptoms such as headache, skin rashes, dizziness, nausea, vomiting, impaired vision, and panic attacks, occur in a short time after contact with agrochemicals (Biswas, et al., 2014).

### *6.2.2 Chronic illness*

Besides the acute illness, agrochemicals can cause chronic illnesses if farmers are exposed over a long period. These substances are known to pose neurotoxic, endocrine disruptive and carcinogenic effects on humans (Hameed, et al., 2015). Various studies have found linkages between pesticides and cancer, however strong evidence is lacking in this regard. In Maldives cancer comprises 8.3% of all deaths (Hameed, et al., 2015), but there is no evidence to relate this with agrochemical users. Even though 'Approved Pesticide Registry' is limited to low toxic and hazardous pesticides, there are pesticides with carcinogenic potential, such as 'Diazinon', 'Malathion', 'Nitrobenzene' and 'Permethrin'. These chemicals have properties of depositing into the human body and overtime causing cancer.

## 7. Challenges & Recommendations

Agrochemicals are considered as quick, easy, and inexpensive solutions to improve the soil fertility and control agricultural pests. The farmers tend to depend on cheap agrochemical products, as the low toxic and eco-friendly agrochemicals are expensive and generally has a delayed response time. Moreover, the farmers lack proper information about identification of diseases, agrochemical application and hazards. Lack of technical and ecological knowledge resulted in strong reliance on ready-made products for solutions, poor application methods, excessive fertilizer use, and reduced innovation capacities (Mohamed, 2018). Therefore, correct knowledge is important to reduce irresponsible use of agrochemicals.

Furthermore, it is important to make farmers aware about Good Agricultural Practices. This is a standard which is optional for farmers in Maldives to comply. This standard aims to improve safety and quality of agricultural products, while at the same time protecting the environment and ensuring the health of farmers. Under these standard, farmers are obliged to record the use of agrochemicals and the standard ensures the food safety and workers safety in relation to the use of agrochemicals. The records would confirm the responsibility of farmers in utilizing agrochemicals in their farms.

The 'Act number: 4/75; Substances Prohibited to be Brought into the Maldives', is the main act which defines the rights and obligations of the Ministry of Defense to regulate the import of all chemical types (Hameed, et al., 2015). However, chemicals are managed by respective ministries with no defined obligations and rights under the act. Other than the 'Act number: 21/2019: Agricultural Pesticide Control Act' and 'Regulation number: 2021/R-12; Agricultural Pesticide Control Regulation', Maldives lack a legislative framework to manage agricultural fertilizers. Therefore, the need to formulate a comprehensive law regarding the import, use, export, sale, manufacture, discard, transport, storage and labeling of fertilizers is one of the key areas in terms of strengthening the legal framework.

Moreover, proper implementation of the existing acts and regulations is essential to utilize agrochemicals efficiently. In order to achieve this, technical experts need to be utilized efficiently, by redeveloping a nationwide management framework which would eliminate the duplication of works and develop an inter-agency level chemical information sharing mechanism.

Additionally, to understand the agrochemical utilization and impacts, research and monitoring should be done with respect to whether the farmers comply with the legal obligations, to understand the current gaps in management and to strengthen the agrochemical data management. Also, as several organizations are responsible for the management of different aspects of agrochemicals, a strong mechanism for data management and information sharing within the organizations should be established.

According to the National Food Safety Policy, agrochemical residue monitoring program is lacking and the existing laboratory lacks the capability for analyzing agrochemical residue in agricultural products. A lack of residue monitoring system and inspection and testing of food and food products will impact negatively on food quality and safety (Maldives Food and Drug Authority, 2017). To overcome this, the national laboratory should be updated with better food testing facilities with the capacity to analyze soil, water and food for agrochemical residues.

Moreover, agrochemical waste management is a major issue which needs immediate solution. Currently, agrochemical wastes are discarded with other types of waste, which can cause environmental degradation and negative health effects. In addition, under acts and regulations, the proper guidelines to discard and manage agrochemical wastes are not discussed. So, to tackle this, the responsible authority in implementing waste management regulations should facilitate a proper mechanism to discard the agrochemical wastes. As Maldives is a country with small islands, proper locations to store the agrochemical wastes, transporting these wastes to regional waste management facilities and proper discard of agrochemical waste should be incorporated within the waste management policies.

## 8. Conclusion

As the human population increases, the demand for food production has increased to achieve food security and sustain the livelihood of communities. The Maldives agricultural sector has been growing steadily over the years. With the aim of increasing productivity, meeting the food demand and to provide quality food, farmers depend heavily on agrochemicals. The major two categories of agrochemicals used by farmers are pesticides and fertilizers. The import and use of both pesticides and fertilizers have been increasing over the years.

The intense use of agrochemicals can cause health problems and environmental degradation. The irresponsible use and excessive application of agrochemicals can damage the soil, pollute the air, and contaminate the water reservoir. Futher, while applying agrochemicals, if safety measures were not taken, the residues can cause acute illnesses and long-term illnesses like cancer. Therefore, it is important to manage the agrochemical use.

Currently, legislative tools like, Substances Prohibited to be Brought into the Maldives Act and the Agricultural Pesticide Control Act are in effect to eliminate the challenges of managing chemicals. International conventions like Rotterdam convention are being implemented and this assists in controlling the import of hazardous chemicals. However, challenges such as, lack of agrochemical awareness, few legislative tools to regulate fertilizer, lack of technical support in agrochemical analysis and weak infrastructure to manage agrochemical waste, are the main gaps in working towards better management of agrochemicals. To combat these challenges, it is important to increase the awareness of farmers, strengthen the legal framework, increase technical expertise, enhance monitoring mechanisms, develop technical infrastructure for agrochemical analysis and establish a proper infrastructure to manage agrochemical wastes. This can create a safe environment for the farmer and safe food for the consumer.

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Chapter 6

# Impact of Agricultural Chemical Inputs on Human Health and Environment in Nepal

**Shree Krishna Neupane**
Ministry of Agriculture and Livestock Development, Nepal
*shree.neupane2000@gmail.com*

**Manoj Pokhrel**
Plant Quarantine and Pesticide Management Centre, Nepal
*manojpkrl@gmail.com*

## 1. Background

Nepal is a sovereign, landlocked Himalayan and federal republic country. The total area of the country is 147,516 sq.km. Its population is 2,95,48,345 with a growth rate of 1.85 percent. There is increasing trend of population and its concentration is increasing in urban areas. Agriculture employs is 80 percent of economically active labor force, and nearly 65 percent of the total population depends on it for livelihood. The contribution of agriculture to GDP is about 32% percent. Rapid growth of population demands significant increase of food production to offset human needs. The UN Sustainable Development Goal (SDG) 2 commits “End hunger, achieve food security and improved nutrition and promote sustainable agriculture”, whereas Target 2.3 states “by 2030 double the agricultural productivity and the incomes of small-scale food producers” and Target 2.4 “by 2030 ensure sustainable food production systems and implement resilient agricultural practices that progressively improve land and soil quality”. To meet the increasing demand of food, there need to be increased in the agriculture productivity. Among many factors (sowing time, fertilizers, irrigation, improved crop varieties, pests etc.) affecting crop productivity, the attack of pests can reduce crop yield significantly. This can be overcome using agrochemicals mainly with pesticides and fertilizers. After the green revolution, the usage of chemical fertilizer has significantly raised to increase crop production globally. Similarly, with the progress in science and technology, the usage

of chemical pesticides for the control of disease, pest, and weed had increased. The wide application of chemical fertilizer and pesticide in the crop is making them unsafe to consume, creating a threat to consumers and the producers. There has been bitter evidence of rejection of Nepalese products from the European Union. Further, it harms the soil, environment, and impedes the trading of agricultural products.

The environmental costs of intensification have received increasing attention over the last decade. The negative impacts of fertilizers, pesticides, and the huge amounts of water needed for irrigation, are well advertised. This has led to calls for 'sustainable intensification' (Evans, 2019). Sustainable Intensification (SI) is described as an agricultural process or system that maintains or improves valued outcomes while maintaining or improving environmental outcomes. It is a strategy for increasing productivity on existing agricultural land with positive environmental and social impacts.

The agricultural chemicals are those chemicals which are used in agriculture. Safety and healthy use of agricultural chemicals is one of the primary concerns of international organizations because some agrochemicals such as pesticides are extremely hazardous to the health of workers and the general public. The use of fertilizers and pesticides started with the growth of population and transfer of traditional farming to modern agriculture with the establishment of the Department of Agriculture Development (DOA) in the early 1960s. Pesticides are used for attracting, seducing and then destroying or mitigating the pests. Pesticides includes all of herbicides, insecticides, nematicide, piscicide, rodenticide, avicide, fungicide, bactericide, insect repellent, animal repellent and antimicrobial. There is discrepancy among published literatures and data as to the exact date of pesticides' first entry into Nepal. DDT was first introduced in 1956 in Nepal (WWF, 1995). The use of pesticides is increasing at the rate of 10-20% per year in Nepal with average use of 396 g/ha but in case of vegetables it is much higher, 1600g/ha in area with commercial vegetable production. There is a five-fold increase in pesticides import from 132 tons in 2007-08 to 635 tons in 2017-18. There are 3034 trade names and 169 pesticides registered in Nepal. The pesticide used daily in agriculture can cause significant human health hazard. Effect of pesticide on human may be acute or delayed depending upon how much the person is exposed to pesticides.

## 2. Policies and Regulatory Frameworks for Management of Agricultural Chemicals

The policies and plans of Nepal emphasized eco-friendly measures of agriculture production, IPM, IPNS and organic farming which directly or indirectly support the concept of agrochemicals risk reduction in food safety.

The preparation of pesticide policy and bio pesticide promotion directives is under way which encourages for the production, registration and use of bio-pesticides/botanical pesticides and bio-agent. The Government of Nepal is regularly organizing training and awareness program on safe use of pesticides to stakeholders and users of the pesticides. Agriculture Policy 2004 of Ministry of Agriculture and Livestock Development (MoALD) has emphasized on eco-friendly production system, organic farming and IPM practice for sustainable agriculture development and food safety. IPM trained people use less pesticide doses and prefer to go for alternative pesticides which are thought to be environmentally safe like green pesticides. Considering these issues, the Plant Quarantine and Pesticide Management Centre (PQPMC) has also emphasized for the registration of bio-pesticide/botanical pesticides and gradually reducing highly hazardous pesticides in Nepal. There is a regulatory infrastructure established for the management of agrochemicals in Nepal. It covers all handling and use aspects of agrochemicals.

- Environment Protection Act, 2076 (2019) and Environment Protection Rules, 2077 (2020)
    - Pesticides and fertilizers factory must go through IEE and EIA depending upon the scale of production;
    - The storage and management of date expired pesticides should need IEE;
    - The factory related to production formulation, blending, packaging/ canning and storage of chemical fertilizer, chemical pesticides, veterinary vaccine and organic manure production (2-10 ton/day) should need IEE;
    - The factory related to plant establishment of pesticide production and organic manure production (more than 10 ton/day) should need EIA.
- Plant Protection Act, 2064 and Rules, 2066.
- Pesticide Management Act 2076.
- Food Act 2023 (1966) and Food Rules 2027 (1970).
- Aquatic Life Protection Act, 1961 and Rules.
- National Fertilizer policy 2058.
- Distribution and management of subsidized fertilizer Nirdesika 2077.
- Climate change policy 2076.
- Seed Act, 2045 and Rules, 2054.
- Consumer Protection Act 2019.
- Soil and Water Conservation Act, 1982.
- Customs Act, 1962 and Customs Rules, 1962.
- Promotion of IPM program encouraged establishing bio/botanical pesticides factories and their uses at farmers' level are taking tempo for sustainable agriculture. Works towards establishment of central

pesticides laboratory, encouragement to private sector for formulation of user and environment friendly pesticides, awareness creation about the users & environmentally safe formulations are on-going activities.

## 3. International Treaties on Agricultural Chemicals

### *3.1 Basel Convention*

Nepal has already ratified the treaty on August 15, 1996 and was fully effective from January 13, 1997 to be the signatory country. The overarching objective of the Basel Convention is to protect human health and the environment against the adverse effects of hazardous wastes. Focal point (DNA) for this convention is assigned to Ministry of Forests and Environment MoFE), Nepal.

### *3.2 Rotterdam Convention*

Nepal has ratified the Rotterdam Convention on PIC in 2007 and became party to this convention. The main objective of the Convention is to promote shared responsibility and cooperative efforts among Parties in the international trade of certain hazardous chemicals in order to protect human health and the environment from potential harm and to contribute to their environmentally sound use Focal point (DNA) for this convention is assigned to MoALD, Nepal.

### *3.3 Stockholm Convention*

Nepal has committed to this convention by signing the treaty on 5 April, 2002 and ratified this convention in 2007 to become the party. Its objective is to protect human health and the environment from persistent organic pollutants or POPs. Focal point (DNA) for this convention is assigned to MoFE, Nepal.

## 4. Pesticides Use in Nepal

Most pesticides used in Nepal are imported from India, some from China and other countries on the basis of registration. In comparison to other countries in Asia Pacific Region, the use of chemical pesticides in Nepal is one of the lowest i.e., 0.396 a.i.kg/ha (PPD, 2015). The pesticides used in other countries such as India (500 gm/ha), Korea (6.6 kg/ha) and Japan (12 kg/ha). Pesticide use, however, is higher in fruits and vegetable production and areas having greater access to markets. The survey conducted by Department of Food Technology and Quality Control indicated that Nepalese people are at alarming threat of pesticides in their diets.

However, market-oriented production and agricultural intensification are leading farm workers to increase pesticide use at a rapid rate. Despite the long global history of the use of pesticides in agriculture, Nepal started to use them very late in around the 1950s. In 1952, DDT was the first chemical pesticide introduced in Nepal by the Ministry of Health. The impact of DDT for the control of vector of malaria was so remarkable that this situation encouraged the use of chemical pesticide in agriculture sector in 1956, when Ministry of Agriculture imported DDT for pest control purposes. The first pesticide production factory, Nepal Pesticide and Chemical Industries Private Ltd. (NEPCIL) was established in 1977 at Bahadurganj, Kapilvastu to produce/ formulate some of major pesticides as BHC, Methyl parathion and Zinc phosphide. In the field of pesticide quality analysis, there is shortage of skilled personnel and there is also the need to strengthen laboratories.

**Table 1: Ecological scenario of pesticides use**

| Ecological Belt | Total Pesticide applied (a.i. kg) | Percentage | Quantity (a.i. kg/ha) |
|---|---|---|---|
| High hill | 23.83 | 4 | 0.085 |
| Hill | 114.4 | 20 | 0.314 |
| Terai | 342.4 | 59 | 0.995 |
| Valley | 94.2 | 17 | 0.47 |
| Total | 574.9 | 100 | |

*Source: PPD, 2015*

**Table 2 : Trend of Pesticide Import & formulation from FY. 069/70- 074/75 (2012-2018)**

| Year | Pesticides | liquid | Liquid a.i. ( Kg) | Rupees NRs | solid | Solid a.i. (Kg) | Rupees NRs |
|---|---|---|---|---|---|---|---|
| 2069/70 (2012/13) | Insecticide | 255342.40 | 99607.42 | | 919691.30 | 39154.24 | |
| | Fungicide | 5575.00 | 319.60 | 2293299.00 | 223942.00 | 163571.20 | 124776954.00 |
| | Herbicide | 195757.00 | 97025.02 | 68188535.00 | 13271.00 | 3808.26 | 4141942.00 |
| 2070/71 (2013/14) | Insecticide | 329027.20 | 123799.24 | 209421481.00 | 809785.70 | 38526.76 | 95838239.00 |
| | Fungicide | 20171.00 | 7290.63 | 3617683.00 | 256788.50 | 184913.00 | 136987791.00 |
| | Herbicide | 159313.00 | 76355.65 | 78455035.00 | 33387.60 | 13771.34 | 13424874.00 |
| 2071/72 (2014/15) | Insecticide | 280642.00 | 117314.52 | 203733528.58 | 783428.54 | 38727.41 | 126325520.64 |
| | Fungicide | 11675.00 | 782.52 | 5347286.43 | 350860.90 | 250025.32 | 172290287.83 |
| | Herbicide | 247090.40 | 118391.43 | 111817479.77 | 38022.00 | 15465.95 | 13044839.16 |
| 2072/73 (2015/16) | Insecticide | 311222.00 | 140277.18 | 212324327.49 | 644243.25 | 40993.69 | 120301972.36 |
| | Fungicide | 10977.00 | 727.92 | 5509555.96 | 347631.00 | 246747.35 | 210670580.18 |
| | Herbicide | 241993.20 | 113598.03 | 107469019.34 | 51218.80 | 20634.34 | 23093494.59 |
| 2073/74 (2016/17) | Insecticide | 274245.84 | 122713.17 | 209848026.14 | 832360.46 | 46646.83 | 169360.00 |
| | Fungicide | 19122.50 | 1651.25 | 15013795.91 | 471203.45 | 346055.97 | 241991237.78 |
| | Herbicide | 158311.00 | 70357.13 | 79422178.63 | 53848.60 | 35088.31 | 18978585.32 |
| 2074/75 (2017/18) | Insecticide | 367277.90 | 157627.75 | 252715201.18 | 1133274.88 | 58264.16 | 179017559.31 |
| | Fungicide | 19542.00 | 1874.28 | 9182597.49 | 365871.80 | 265160.71 | 214388598.11 |
| | Herbicide | 286811.50 | 125382.40 | 129099923.62 | 57707.00 | 16760.30 | 33894165.56 |

*Source: PQPMC, 2019*

## 5. List of Banned and Registered Pesticides

Plant Quarantine and Pesticide Management Centre (PQPMC) implement Pesticide Act/ Regulation for pesticide management in the country. It performs the role of registration, management and regulation of pesticides to minimize haphazard use of pesticides and solve pesticide problems. At present 3035 pesticides by trade name and 169 pesticides by common name are registered in Nepal which are listed in the Table 4. After the realization of impacts of hazardous pesticides on human and environment, Nepal first banned twelve pesticides, mostly organochlorines in 2001 (2057 B.S). Later in year 2007, 2012, 2015, 2018 number of pesticides were banned. Recently in August, 2019 three pesticides were banned which can be used till 2021/8/4 and have yet to be notified in Nepal gazette. There are 24 pesticides banned in Nepal till date which are listed as in table 3.

**Table 3: List of Banned Pesticides in Nepal**

| S.N. | Name of pesticides | SN | Name of pesticides |
|---|---|---|---|
| 1. | Aldrin | 13 | Monocrotophos |
| 2. | BHC | 14 | Methyl Parathion |
| 3. | Chlordane | 15 | Endosulphan |
| 4. | Dialdrine | 16 | Phorate |
| 5. | DDT | 17 | Benomyl |
| 6. | Endrin | 18 | Carbofuran |
| 7. | Heptachlor | 19 | Trazophos |
| 8 | Lindane | 20 | Dichlorovos |
| 9 | Organo Murcary Compounds | 21 | Carboryl |
| 10 | Mirex | 22 | Carbosulphan |
| 11 | Phosphamidon | 23 | Dicofol |
| 12 | Toxaphane | 24 | Aluminium Phosphide |

*Source: NPPO, 2020*

**Table 4: Summary of Registered Pesticides (up to 2075/08/30 or December 15, 2018)**

| SN | Pesticides | Trade Name | Common Name |
|---|---|---|---|
| 1 | Insecticide | 1635 | 59 |
| 2 | Acaricide | 28 | 6 |
| 3 | Fungicide | 746 | 42 |
| 4 | Bactericide | 17 | 1 |
| 5 | Herbicide | 436 | 30 |
| 6 | Rodenticide | 38 | 2 |
| 7 | Molluscicide | 2 | 1 |
| 8 | Biopesticide | 113 | 14 |
| 9 | Nematicide | 1 | 1 |
| 10 | Herbal | 19 | 13 |
| | **Total** | **3035** | **169** |

*Source: PQPMC 2018*

## 6. Status of Fertilizer used in Nepal

Agriculture Perspective Plan (APP) has targeted to increase the use of chemical fertilizer up to 131kg per hectare. Nepal Government has started to give the price subsidy in chemical fertilizer since 1970. The import and distribution of chemical fertilizer is managed by Krisi Samagri Kampany Limited (KSCL) and Salt Trading Corporation Limited (STCL) by allocating the required subsidized and managerial budget through MoALD. On the basis of cultivable land and recommended dose, about 8 lakh tons of chemical fertilizer is needed in Nepal. There are mainly seven types of fertilizers being used in Nepal viz. Urea, Diammonium Phosphate (DAP), Muriate of Potash (MOP), Ammonium Sulphate (AS), Single Super Phosphate (SSP), Ammonium Phosphate Sulphate (APS) and NPK. The average consumption of fertilizer in Nepal is about 19.65kg/ha.

**Table 5: Supply trend of Subsidized Chemical fertilizer in Nepal**

| FY. | Total sell amount | | | | Total budget Rs |
|---|---|---|---|---|---|
| | Urea | DAP | Potash | Total | |
| 2070/71 | 146117.1 (62.74) | 81738.7 (35.10) | 5023.8 (2.16) | 232879.6 (100) | 5709800000.00 |
| 071/72 | 190224.52 (63.65) | 101902.85 (34.10) | 6731.40 (2.25) | 298858.77 (100) | 5615357378.69 |
| 072/73 | 164641.5 (63.62) | 87572.8 (33.84) | 6564.8 (2.54) | 258779.0 (100) | 5440306545.79 |
| 073/74 | 205424.85 (62.59) | 114801.55 (34.98) | 7990.50 (2.43) | 328216.90 (100) | 4809668171.79 |
| 074/075 | 235304.35 (67.47) | 105619.17 (30.29) | 7811.10 (2.24) | 348734.62 (100) | 4594386000.00 |

*Source: MoAD 2020*

## 7. Pesticides and Fertilizers Registration Mechanism

There is regulatory infrastructure established for the management of pesticides in Nepal. It covers all handling and use aspects of pesticides. The Pesticide Act has been enacted to promote the safe and effective use of pesticides in Nepal. The Act empower to establish a Pesticide Board, which is considered as a policy-making committee on matters relating to pesticides. Pesticides are registered and regulated under the Pesticide Act and Rules. The Act and Rules regulates the import, manufacture, sale, transport, distribution and use of pesticides with a view to prevent risk to human beings and environment. So, any person, institution, or body shall compulsorily register the pesticides in Plant Quarantine and Pesticide Management Centre (PQPMC) and register of fertilizers and micronutrients in Agri Input Management and Technology Section of MoALD by paying the prescribed fee and obtain a product registration certificate in order to import, export, produce use or distribute the pesticides and fertilizer.

## 8. Pesticide Poisoning and Statistics

Pesticide poisoning can be differentiated by intentional and unintentional exposure. Intentional exposure includes suicides and homicides. In some developing countries, such as Indonesia, Thailand, Malaysia, and Sri Lanka, suicides comprise the majority of reported poisonings. Unintentional exposure can be broken into occupational and non-occupational categories and defined by long-term and short-term exposure. Non-occupational exposure can occur through the accidental consumption of contaminated food. For example, vegetables or fruit may have high levels of pesticide residues. In the United States, it has been estimated that about 50 % of produce in supermarkets has detectable levels of residue. Finally, non-occupational exposures occur through inappropriate pesticide practices. This includes the treatment of head/body lice and bedbugs, inadequate storage and disposal (e.g. in unlocked/ unmarked containers and reuse of containers), and inappropriate house spraying. Children are particularly vulnerable and most often the victims.

In 1973, the World Health Organization (WHO) established a series of global pesticide poisoning estimates, reporting 500,000 poisoning cases annually. In 1986, WHO raised its estimate to one million cases of unintentional poisoning and 20,000 fatalities. A joint study by the WHO and United Nation Environmental Program (UNEP) in 1990, estimated three million hospitalized cases of which 220,000 resulted in fatalities. The break-down of cases included one million unintentional poisonings and two million suicides. The WHO extrapolated that for every 500 people who have pesticide poisoning symptoms, eleven are admitted to a hospital and one death occurs. In addition, an estimated 772,000 people sought medical treatment for chronic ailments due to long-term exposure. In recent years, Nepalese farmers have been using chemical pesticides in an increasing trend and as a result pesticide poisoning has increased at an alarming rate.

A hospital based retrospective study was carried out in March 2017 in BP Koirala Institute of Health Sciences, where 57 poisoned patients admitted, 24 (42.1%) were males whereas 33 (57.9%) were females varied from 14-68 years. 27 (47.36%) patients belong to 20-40 years. 17 (29.82%) patients were more than 40 years and 13 (22.8%) were below 20 years. The socioeconomic status of the country, frustration, increase trends of males working abroad, family conflict, and job problem, easy availability of the pesticides, drugs, and easy approachable placement of household chemicals / pesticides at home are the mainstay of cause of poisoning either intentional or accidental. Similar type of research was carried out on poisoning cases attending emergency department in Dhulikhel Hospital by Kathmandu University Teaching Hospital, where the Organophosphate pesticides poisoning (OP) was the most common. Oral route was the commonest route of poisoning accounting 98.1%. Sixty-six percentage (66.66%) of the cases had the poison stored in their home with 27.7% bought from the market once needed. Among the cases of acute poisoning 5.55% were fatal.

## 9. Perception of Farmers on Pesticide use

Farmers applied chemical and non-chemical pesticides (indigenous and botanicals) to reduce the pest infestation in Nepal. The knowledge, attitude and practices of farmers about the pesticides are differing. Study revealed that about thirteen percent farmers are familiar with "pesticides" along with other alternatives of pest management. They used the alternatives like indigenous methods and botanical to manage the pest in their field. However, around one percent of the farmers do not know about the pesticides. Almost all the farmers have belief that the use of pesticides and chemical fertilizer in the crops increase the crop production. Some farmers complain that without the use of the pesticides, the crops in their farm cannot grow well due to insects and diseases. Most farmers have known that the pesticides are harmful for human health and environment. But one study revealed that most farmers in terai districts like Sunsari, Bardiya, Kailali have low level of awareness about pesticide and 40-44% of the farmers of these districts treat "pesticide" as "medicine" which is necessary for production. Similarly, most of the farmers are aware that the use of high amount of pesticides increases the cost of production. The farmers buy pesticides from the following retailer: agrovet shop, local agro-shop, and farmers' cooperatives in consultation of JTA or local agro vet shopkeepers.

## 10. Impacts of Agrochemicals

Chemical pesticides are known to have deleterious effects on human health and the environment. During the past three decades, indiscriminate use of chemical pesticides in agriculture has created serious health and environmental problems in many developing countries. Pesticide pollution not only affects human health, but also other ecological assets, such as soil surface and ground water, micro and macro flora and fauna, etc. (Pimental, 2005). During the last five decades, use of agrochemicals especially through pesticides has created many problems in the Nepalese agriculture system. Pesticides, especially the organochlorine and organophosphate tend to persist in the environment, causing several types of damages including lowering of biodiversity, soil contamination, and water contamination. Once released into the environment, pesticides tend to build up in the fatty tissues of living organisms, causing serious harm to the health of species and a potential loss of bio-diversity. Excessive use of persisting pesticides in the fields also caused the surface and underground water contamination. It is also been identified that the pesticides and fertilizers are also responsible for ozone depletion and climate change. Chemical pesticides are responsible for resurgence of insect pests, pesticide resistant pests and crop failure, outbreaks of pests, destruction of parasitoids and predators. Pesticide pollution not only affects short-run health effects, but can also result in chronic diseases such as cancer. Pesticides also cause deaths of domestic animals, loss of natural pests, increase pesticide resistance, crop losses, bird and fishery losses, and surface and sub-surface water contamination. Therefore, the cost of pesticide pollution for the society is likely to be significantly higher than the cost estimated as we assumed.

## 11. Issues and Challenges

The use of agrochemicals mainly pesticides and fertilizers are a sensitive issue in the present context, especially in view of health hazard and environment pollution. Fertilizers and pesticides are discharged into the ecosystem by drifting, dripping or leaking into areas surrounding the target area. The deposited chemical is transformed by living systems, (Ghatak & Turner, 1978). It needs to be examined from different angles like quality, target group and regulation. Some of the important issues and challenges are as given below:

- Open boarder with neighboring countries invites chances of entry of unregistered products into the country;
- No well-equipped laboratory facilities for quality and residue analysis;
- Illiterate and ignorant target groups (farmer / user);
- Lack of skilled manpower and effective implementation of the Act and Regulations;
- Lack of awareness among farmers regarding safe use of pesticides (farmers have no idea of pesticide poisoning, first aid, waiting period and protective measure etc.);
- Monitoring and follow-up of pesticides resellers and dealers, particularly post-registration is not effective as much;
- Reclamation of degraded soil, air and water contaminations;
- Lack of comprehensiveness and quality data to better estimates of the effects of agrochemicals on human health and environment.

## 12. Institutions Responsible to Manage Agrochemicals

Department of Agriculture (DOA) initiated the use of chemical pesticides in agricultural sector to protect the crops from plants' disease and pest attack only after the second half of 1960s. Now, Plant Quarantine and Pesticides Management Centre, Department of Food Technology and Quality Control (DFTQC), Central Agriculture Laboratory under Ministry of Agriculture and Livestock (MoALD), Nepal Agriculture Research Council (NARC) ,National Academy of Science and Technology (NAST) and Department of Environment under Federal Government, Agriculture Knowledge Centre and Veterinary Expert Centre under Provincial Government, Local Governments and some I/NGOs are responsible for management of agrochemicals as well as to control and prevent agrochemicals hazards by implementing its safety measures. Not much laboratory facilities and expertise are available to address researchable problems in pesticides and other agrochemicals. Pesticide Association of Nepal (PAON) was established in 1997 as an association of Pesticide traders in Nepal. It integrates firms, companies & individuals involved in importation, distribution and marketing of pesticides.

Rapid Bioassay on Pesticides Residue (RBPR) Analysis Laboratory under Plant Quarantine and Pesticides Management Centre is operating since 2014 which analyze the chemical pesticides especially in fruits and vegetables. Central Agriculture Laboratory which analyzes the different diseases and insects especially in fruits and vegetables and also analyze soil characteristics. The laboratories under Department of Food Technology and Quality Control (DFTQC) are also analyzing the pesticides and other harmful chemicals in food items. Pesticides related incidents are reported by the Department of Health Service. This department keeps the records based on the hospital reports of such incidents. Pesticides Registration and Management Division is not accountable for keeping the records in place. Government of Nepal has some acts and regulations to regulate the use of pesticides directly related to human health. A food standardization committee is formed to carry out the functions as specified in the Food Act and this Regulation. The committee is to set the quality standard and limit of quantity of the food and advise Government of Nepal regarding the quality standard and quantity maintained and observed. Till 2008, Government of Nepal has set the mandatory pesticide residue limits as per Food Law and Regulation. The name of pesticides, food commodity, and their maximum residue limits (MRLs) are notified for public in Nepal Gazette.

## 13. Agricultural Chemicals Reduction Strategies

Due to sensitive issue of using agrochemicals, Nepal Government has emphasized on the reduction strategies of agrochemicals. Sustainable agriculture is an important strategy which encompasses a variety of approaches. Shrestha (2016) stated that planting climate resilient and high-yielding crop varieties, intercropping legumes in cereals, biodiversification, participatory breeding, conservation agriculture and Integrated Pest Management (IPM), are some examples of sustainable intensification. There are several approaches used to ensure sustainable agriculture in Nepal (Shrestha *et al.*, 2021).

### *13.1 Crop rotation*

Crop rotation is a method of growing various crops in a specific pattern on the same piece of land in order to preserve the productivity of the crop and fertility of the soil over the time. It helps to maximize resource efficiency in a sustainable manner and quality production with minimal environmental impact. Crop rotation disrupts the insect and pathogen reproduction and hence their life cycle. Plant nutrients are restored when certain plant species are included in crop rotation, requiring less chemical fertilizer.

### *13.2 Permaculture*

Permaculture focuses on the harmonious integration of people and landscape, providing the foods, feeds, fibres, shelter, energy and other material and non-material in a sustainable way. The practice of permaculture is one of the important aspects to reduce the use agrochemicals in Nepal which comprises of: (i) composting (ii) harvesting of rainwater (iii) practicing agroforestry (iv) practice of minimum tillage (vi) no chemical and synthetic fertilizers and pesticides application, cover (vii) cover crops and mulching etc.

### *13.3 Integrated Pest Management (IPM)*

Exposure to pesticides has been growing as a major public health challenge in developing countries. IPM is a method of pest control that uses a combination of biological, cultural, mechanical, physical, and chemical tools to reduce economic, health, and environmental risks (Romeh, 2018). The Government of Nepal has implemented the IPM program to minimize the use of pesticides in the country, however, farmers misuse and overuse pesticides in an agriculture sector. An adaptation process of IPM is found slow in Nepal. There is a need to develop the better mechanism to monitor the pesticide level in vegetables, fruits and cereals to reduce the health impact of pesticide among farmers and consumers. Government of Nepal has adopted the IPM Program as national plant protection strategy and it is implemented on crop-based Farmers Field School (FFS) approach.

## 13.4 Integrated Nutrient Management

Integrated nutrient management (INM) is the process of optimizing the benefits from all possible sources of organic, inorganic and biological components in an integrated manner to maintain soil fertility and plant nutrient supply for the optimal level of crop productivity. Soil fertility decline due to soil erosion and nutrients losses through runoff and leaching is a serious problem in the hills of Nepal. In Nepal, very little research has been conducted on integrated plant nutrient management practices, especially in hill agricultural systems. Chapagain and Gurung (2010) reported that maize yields under Improved and Farmers' management systems were found to be very similar to the research station yield, and were higher than the average productivity in the average farmers' field. Almost all farmers realized the technologies promoted were low-cost and complementary to their normal practices for enhancing overall system of productivity. They believed on the effectiveness of IPNS on major cereals (i.e., maize and the following crop, millet) and perceived it as a prime factor to improve food security and livelihoods.

## 13.5 Cover crops

Cover crops are essential to sustainable agricultural systems. Under zero tillage regimes, deep-rooted cover crops and biological agents (earthworms) can also help to alleviate compaction (Hobbs *et al.,* 2008). It is the thought of a sustainable investment in better soil quality and farm management. Nepal has been facing the problem of soil erosion in hilly area and increasing surface residue in plains area. Cover crops not only reduce the soil erosion but also maintain the soil fertility, suppress weed growth and improve the quality of soil and minimize the need for chemical fertilizer in the soil.

## 13.6 Agroforestry

Agroforestry is a land use management system that combines agricultural and forestry technologies to establish more complex, profitable, and long-term land use systems. In Nepal's hilly areas, the agroforestry method is widely used. It integrates fast growing, N-fixing woody species into small scale farming systems show great promise in enhancing by supplying and cycling of plant nutrients in soil-plant system. It also increases crop productivity and soil quality. Limited technical know-how of the farmers, farm labor shortage, limited market linkages, fragmentation of land and increasing number of dry days are the remarkable challenges of the agroforestry practices in Nepal. Agroforestry practices and species composition needs to improve for sustainable crop productivity and adoptability along with improvement in environmental condition in Nepal.

### 13.7 Natural pest predators

The predators, parasitoids, pathogens, and competitors are examples of natural enemies of insect pests, also known as biological control agents. Biological pest control has long been regarded as one of the most promising innovations for long-term agricultural sustainability: it reduces reliance on conventional pesticides, reduces negative environmental effects, and increases worker protection while preserving crop production's economic viability (Tracy, 2015). This approach is an economical, reliable and environmentally friendly pest management method; it uses living organisms to reduce pest populations. Natural predators are those that live in agricultural fields (environment) and are involved in hunting of pests such as aphids, pollen beetles and slugs. This approach takes the farm as an ecosystem rather than a production factor whereby effective control over pests is found by natural predation of other creatures such as birds, animals etc.

### 13.8 Conservation Agriculture (CA)

In Nepal, efforts to develop, refine and disseminate conservation based agricultural technologies started since the rice-wheat consortium in Terai since 1990s. It was developed in the 1970s in Brazil and Argentina (Project Drawdown 2021). CA is based on three key principles: minimizing soil disturbance, preserving soil cover, and crop rotation management (FAO 2014). Conservation agriculture is a set of practices which is gaining popularity and focuses on minimum soil disturbance that aims to increase production and promote profitability by reviving soil fertility status. Conservation agriculture is a system approach which is characterized by three interlinked principles namely minimum soil disturbance, permanent soil cover and crop rotation (FAO 2010). Improving productivity, conservation of scarce resources along with soil quality, protecting environment and improvement of livelihood are the key concerns. The task force consisting of all stakeholders need to be formed in order to formulate the conservation agriculture friendly agricultural policies. Short, medium and long-term strategies for research and development can be formulated and implemented in Nepal.

### 13.9 Organic farming

Increasing trend of using agrochemicals, higher production cost and deterioration of ecosystem have advocated the need to change the agriculture system towards safe and sustainable organic production. There should have a concrete set of strategies to the national organic standards, easy certification mechanisms, banning the hazardous pesticides import, reliable market and premium price of organic products, define the zones for organic production and intervention for implementation. Implementation of these strategies can lead to a pathway of food and nutritional security and sustainable agriculture. Due to geographical and climatic variation in Nepal, organic farming has a great potentiality. The Government of Nepal has promoted the organic agriculture first as a priority in the10th Five Year Plan and has been embedded in the national agricultural policy.

### *13.10 Good Agricultural Practices (GAP)*

After the green revolution, the use of chemical fertilizer and pesticides has significantly raised to increase crop production globally for the control of diseases, pest, and weeds. The wide application of chemical fertilizer and pesticide in crop production made them unsafe to consume, and threatened consumers as well as the producers. As a member of the World Trade Organization (WTO), Nepal has adopted the Agreement on the Application of Sanitary and Phyto-sanitary Measures and the Agreement on Technical Barriers to Trade. In response to international food safety and quality concerns, to promote sustainable development and increase the export of agricultural produce, Government of Nepal, Ministry of Agriculture and Livestock Development (MoAD) has prepared Nepal GAP Implementation Directives (NGAPID) is the first step towards food safety and trade facilitation in Nepal (MoAD, 2018).

Farmers seeking recognition or certification of Good Agriculture Practice (GAP) has to apply for it in the respective accreditation institute, which in case of Nepal is Department of Food Technology and Quality Control (DFTQC). Then farmers have to successively abide by the rules mentioned in the Nepal GAP Implementation Directive. Upon the successful accomplishment of the standards set by the certification body, the farmers are awarded a certification of GAP (MoAD, 2018).

## 14. Research and Development

Research and development on the use of bio-pesticides and eco-friendly measures are highly recommended to minimize the use of hazardous agrochemicals. For this, research laboratories must be strengthened in terms of both human resources and physical infrastructure. In 1990, Nepal Government accepted IPM as a part of plant protection program but due to the lack of trained manpower and budget, IPM program was not launched at the farm level till 1998. In 1997, Nepal adopted the Community IPM (CIPM) and first project of that was implemented in 1998 as Farmer's Field School (FFS) in rice (Westendorp and Biggs, 2002). As Nepal government started IPM-FFS other I/NGO also started programs in coordination with central and local government. Similarly, academic institutions also started teaching IPM-FFS for their graduate and undergraduate students. A group of farmers gets together in one of their own fields where real field problems are observed, recorded and analyzed from planting to harvest of the crop. Participants set up numbers of comparative studies and other supportive trials in the field. Participatory discussions, group decisions and agro-ecosystem analysis (AESA) are the fundamentals of IPM-FFS. The FFS was developed to help farmers adopt their IPM practices to diverse and dynamic ecological conditions (FAO, 2014). FFS is based on the concept of participatory extension approach (Hagmann *et al.*, 1999) and relies on discovery learning techniques (Miagostovich *et al.*, 1999) which is a different paradigm than that of the top-down model of technology development and transfer.

Recently, modified FFS also include soil fertility management, land, ground water management, conservation agriculture, land degradation, agroforestry, seed production, marketing, food security, nutrition, fishing, biodiversity, climate change and animal husbandry (Braun and Duveskog, 2008).

IPM supportive programs in Nepal:

- Plant clinic;
- Farmers Field School;
- Pesticide residue analysis;
- Regulatory controls.

Impacts of FFS Programs in Nepal:

- Changes in cultivation practices;
- Changes in pesticide use;
- Perception about pesticide effects;
- Changes in crop diversity;
- Changes in cultivation costs and farmer's income;
- Changes in the leadership capacity;
- Involvement in developmental activities.

## 15. The Way Forward

Traditional farming in Nepal is organic in nature and is therefore, ecologically sound and sustainable for human beings and other living organisms. Until the 1950s, Nepali farmers were unaware of agrochemicals. They were dependent upon their rich traditional wisdom to control pests. The following points should be considered for better management of agricultural chemicals in Nepal:

- Strengthening and implementation of pesticide management act and regulation;

- Government of Nepal has expressed its consent for organic agriculture and banning of highly hazardous and obsolete pesticides during various treaties and conventions. However, much need to be done in terms of enforcement of the legislations and regulations;
- Encourage and implement Good Agricultural Practice (GAP) to prevent adverse impacts of agrochemicals;
- Government should improve regulations in relation to collecting and recording data on import, formulation, quality and quantity of pesticides;
- National organizations need to prioritize promoting alternatives of pesticides;
- Advancing alternatives to pesticides, should be made easily available at farm level;
- Create mass awareness program for alternatives of agrochemicals like chemical pesticides and fertilizers;
- Equipped laboratories to enhance quality testing and residue analysis;
- Update standards for registration of products, screen out and deregister more toxic agrochemicals and banned;
- Better linkage and coordination among international/regional organizations and government agencies;
- Promotion and strengthen the concept of IPM Farmers' Field School (FFS) to effectively control insect pest and diseases which in turn helps to reduce the use of agrochemicals;
- Research and development on the use of biopesticides and eco-friendly measures are highly recommended to minimize the use of hazardous pesticides. For this, research laboratories must be strengthened in terms of both human resources and physical infrastructure;
- Central authority for chemical safety needs to be formed to work on chemical safety and risk management to cope with pesticide problems.

## 16. Conclusion

Agricultural chemicals are considered as a powerful weapon or magic bullets in the developing countries in order to enhance the agriculture productivity and considerably improve the major public health indices as well. However, it has been observed that agrochemicals are causing serious hazards especially by pesticides followed by fertilizers and others. Farmers have limited awareness about safe pesticide management and undesirable effects of pesticides. Promotion of alternative pest control measures such as application of bio-pesticides and integrated pesticide management (IPM) is of utmost importance. Use of bio pesticides, bioremediation of pesticide-contaminated soils/land, utilization of plant-associated microbes, and effect of transgenic crop cultivation are some of the successful alternatives to the use of hazardous agrochemicals. The impact of agrochemicals on the human immune system has also attracted attention from scholars. Certain agrochemicals may affect the human endocrine and immune systems and also affects the environment. Therefore, long-term environmental and health impacts of agrochemicals should be researched in depth in the future.

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Chapter 7

# Impact of Agricultural Chemical Inputs on Human Health and Environment in Pakistan

**Farrakh Mehboob**[1] and **Karam Ahad**[2]
Ecotoxicology Research Program
Institute of Plant & Environmental Protection
National Agricultural Research Centre, Islamabad
[1]*farrakhmehboob@gmail.com;* [2]*karam_ahad@yahoo.com*

## 1. Introduction

Pakistan has an area of 79.6 million hectares with a population of about 224.608 million and population density of about 282 per Km. Approximately 23.3 million hectares of land is under cultivation, almost 80 percent of which is irrigated (FAO 2021). Agriculture sector provides food and livelihoods to approximately 68% rural population of the country. The agriculture sector contributes 19.3% to Gross Domestic Product (GDP) and provides employment to 42.3% labour force (Pakistan Economic Survey, 2019-2020).

The farming land in Pakistan can be classified into three categories (1) Irrigated plains, dominated by the cultivation of wheat, rice, and cotton; (2) Rainfed plains (subtropics) is cultivated with wheat and pulses and (3) Nomadic systems consisting of rangeland for animal production (Byerlee and Husain, 1993; Afzal and Naqvi, 2004). There are two major cropping seasons i.e. Rabi (October to March) and Kharif (April to September) and three cropping systems i.e. (1) Cotton-Wheat (2) Rice-Wheat and (3) Mixed cropping.  Figure 1. reflects on the major cropping patterns in Pakistan

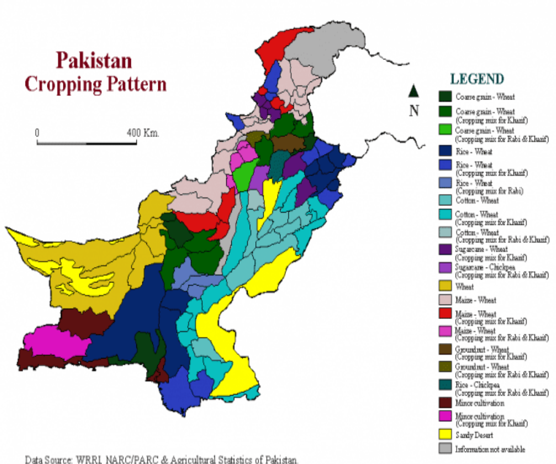


**Fig. 1: Cropping pattern in Pakistan** ***Source: WRRI, NARC/ PARC.***

## 2. Major Crops Area and Production

Wheat, rice, maize, cotton, and sugarcane are the important crops that are grown on 8,987, 2,813, 1,250, 2,685 and 1,040 thousand hectares of land with an average production of 25,533, 7,061, 5,711, 11,271, 66,880 thousand tons, respectively. They account for 21.73% in value addition of agriculture sector and 4.20% in GDP. The area and production data from 2014-19 (Figure 2 & 3) indicate a stagnancy in agriculture performance. Moreover, the contribution of this sector to overall GDP has gradually declined from almost 25% to 19.3% over a period of last few decades. While realizing the importance of agriculture and the issues being faced by this sector, the present government has introduced "Prime Minister Agriculture Emergency Programme" worth Rs 277 billion to revolutionize the agriculture and livestock sectors in Pakistan.

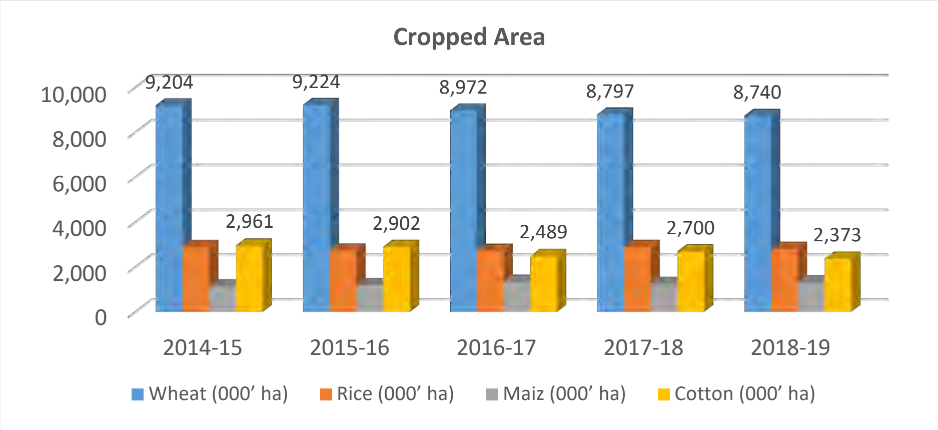


**Fig. 2: Area (000 hectares) under cultivation of major crops in Pakistan**

*Source: Pakistan Economic Survey 2019-2020*

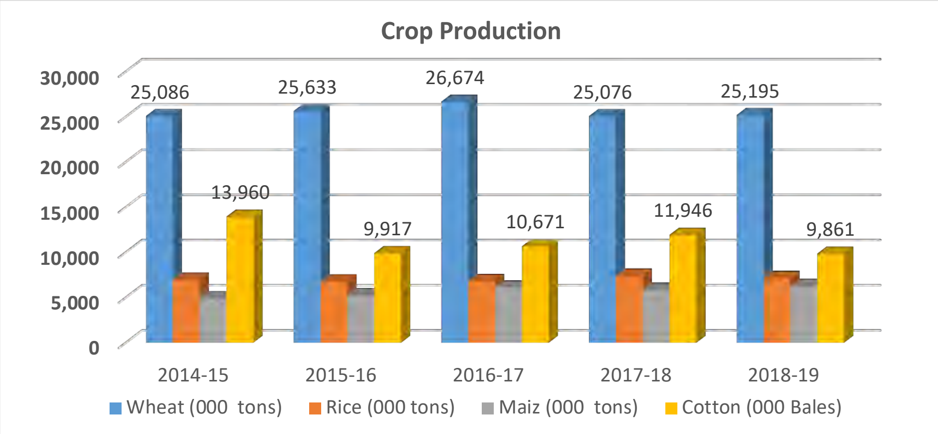


**Fig. 3: Production (000 tons) of major crops in Pakistan**

*Source: Pakistan Economic Survey 2019-2020*

In general, the average crops yield are 53%-82% lower as compared with developed countries (Kamal et al., 2012). This lower production can be increased by adopting modern practices including enhancing quality and quantity of inputs like fertilizers and pesticides.

## 3. Trends of Fertilizers Demand, Production and Import

There are three major groups in fertilizer industries i.e. Fauji, Engro, and Fatima that accounts for 48%, 34% and 13% of the urea fertilizer production. Rest of the companies contribute merely 5% of the production. Major fertilizers companies in Pakistan are:

- Fauji Fertilizer Bin Qasim Limited.
- Fauji Fertilizer Company Limited.
- Engro Corporation Limited.
- Engro Fertilizers Limited.
- Fatima Fertilizer Company Limited.
- Arif Habib Corporation Limited.
- Dawood Hercules Corporation Limited.

There are three main types of fertilizer used in agriculture i.e. (1) Nitrogenous fertilizers (Urea and CAN), (2) Phosphorous fertilizer (DAP) and (3) Potassium fertilizers (NPK and NP). Urea manufactured locally fulfills 80% of the country's requirement while DAP is mostly imported except some is produced locally by Fauji Fertilizer Bin Qasim Limited (FFBL). Engro and Fauji Group are accounted for ~92% of the country's DAP offtake. The supply-demand situation of urea and DAP for Rabi and Kharif crops is shown in table 1. In aggregate Urea, DAP and others (CAN, NPK, NP, SSP collectively) accounts for 75% and 8-10% and 15-20% of the country's fertilizer production, respectively. On the offtake front, urea accounted for ~61% and DAP for 24% of the country's total fertilizer offtake in 2020.

**Table 1: Fertilizer (000 tons) supply and demand situation in Pakistan**

| *Description* | *Rabi* | | *Kharif* | | *FY2018-19* |
|---|---|---|---|---|---|
| | Urea | DAP | Urea | DAP | Total |
| Opening stock | 115 | 729 | 135 | 599 | 1578 |
| Imported supplies | 105 | 679 | 100 | 18 | 902 |
| Domestic Production | 2,923 | 354 | 3,217 | 360 | 6854 |
| Total Availability | 3,143 | 1,762 | 3,452 | 977 | 9334 |
| Off take/Demand | 3,033 | 1,164 | 2,942 | 865 | 8004 |
| Write on/off | 25 | 1 | 0 | 0 | 26 |
| Closing stock | 135 | 599 | 510 | 112 | 1356 |

*Source: Pakistan Economic Survey 2019-2020*

Fertilizer plays an important role in raising the productivity of crops. About 52 percent fertilizers are used in Rabi season while 48 percent in Kharif season when cotton, rice, maize and sugarcane are planted.

Domestic fertilizer production during 2020 increased by 5.8% due to additional supply of natural gas to the fertilizer sector. Almost 70-80% of the fertilizer's requirements are met by domestic fertilizer production. However, the supply of imported fertilizer decreased by 20.7 percent. Therefore, the total availability of fertilizer decreased by 0.28 percent. Total offtake of fertilizer nutrients witnessed decrease by 2.6 percent. Nitrogen offtake decreased by 2.4 percent, phosphate offtake decreased by 2.6 percent and potash offtake also decreased by 14.5 percent during FY2020 (July-March). The price of urea increased by 11.5 percent and DAP by 3.1 percent. During 2020, the Government has given different subsidies that include subsidy in the form of cheap natural gas used as feed for fertilizer production (Rs 865 per bag of urea as per fuel and feed price difference), LNG at subsidized rate for production of urea from Fatimafert and Agritech (Rs 976 per bag) and subsidy on imported urea (Rs 1,194 per bag) and Cash subsidy by Government of Punjab for phosphate and potash fertilizer (Rs 500 per bag of DAP). Fig. 4 indicates the overall fertilizer off take scenario from 2000-2001 till 2018-19.

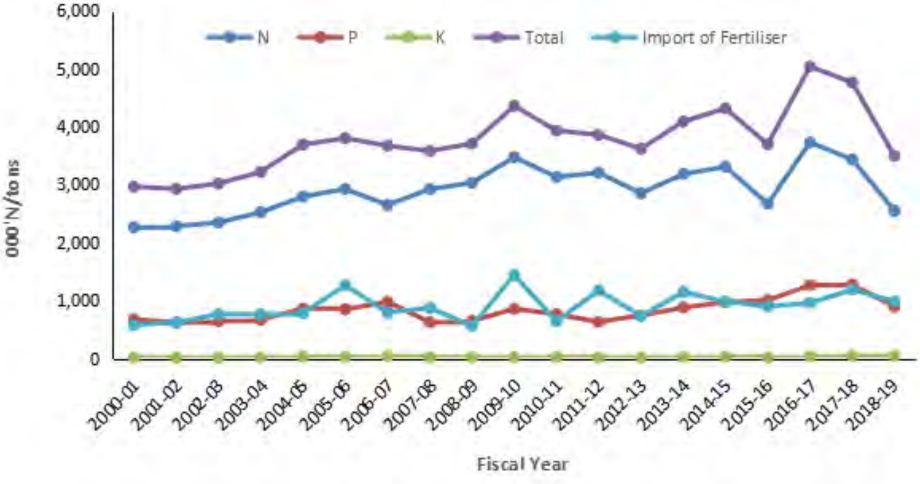


**Figure 4: Fertilizer Off take 2000 to 2018**

*Source: Agri. Statistics, 2000-18*

Around six and half fold increase in crop production in Pakistan was observed between 1961 and 2016 that can be attributed to adoption of improved varieties, increase land under irrigation and fertilizer inputs. Nitrogen fertilizer application rates have increased much faster than for P or K, as both P and K are considered expensive (Solaiman and Ahmed, 2006). Since the majority of agricultural soils in Pakistan are deficient in all three macro-nutrients, the addition of N has increased yields but the imbalance uses of fertilizer in terms of NP ratio as 4.15:1 against desirable 2:1 promoted yield gaps which triggers rural poverty whereby farmers due to low purchasing power, cannot afford the combination of nutrients that would allow them to increase their yields (Khan, 2019). To narrow down this NP ratio in 2015, the government decided to remedy the lag in Phosphorus fertilizer use by providing a subsidy of 190 million USD on P fertilizers (FAO, 2016) aimed at closing yield gaps through balance nutrients management.

## 4. Implications of Fertilizers

Most of Pakistani soils are deficient in major nutrients i.e., N, P and K. P & K fertilizers are used less because of high cost, however, application of N fertilizer has increased (Khan, 2019). Due to less usage, issue of pollution arising from leaching of fertilizers into groundwater are less as compared with pesticides. The N fertilizers may cause pollution of nitrates that in anoxic conditions is converted to nitrites. Nitrites are more toxic than nitrates. In the presence of nitrite, the ferrous ion ($Fe^{+2}$) of haemoglobin is oxidized to the ferric ion ($Fe^{+3}$) to form methaemoglobin (Gupta *et al.,* 1999). Methaemoglobin is the poor transporter of oxygen in the body and may cause oxygen deficiency (Sidhu *et al.,* 2011). In babies, such severe conditions may cause blue baby syndrome. Moreover, current research suggests that exposure to nitrate alter human thyroid gland function by competitively inhibiting thyroidal iodide uptake, leading to altered thyroid hormone concentrations and functions (WHO, 2016). The WHO and National Environmental Quality Standards value for nitrate is less than 50mg/l and for nitrite is less than 3 mg/l (WHO 2016; SRO 1062-1/2010). Most of the studies have shown that the concentration of nitrate/ nitrite found in groundwater from various regions of Pakistan are within the National Environmental Quality Standards for drinking water (Deeba *et al.,* 2019; Hameed *et al.,* 2020). However, certain fodder plants were found to accumulate high level of nitrates that also resulted in higher level of nitrites in the blood of the dairy animals that might threaten the health and productivity of dairy animals (Rashid *et al.,* 2019). However, only a few studies are available in this regard. There is dire need of use of sophisticated methods for determination of nitrate and nitrite in groundwater and various crops.

## 5. Pesticide Policy and Trend of Import & Consumption in Pakistan

In Pakistan, the climatic conditions favour insect pest infestation and diseases that causes ~50% losses of which 20% are due to insects, 15% due to weeds, 10% due to diseases and 5% due to rodents (Baloch and Haseeb, 1998). To minimize these losses, the use of synthetic pesticide was thought to be the only solution. Thus, pesticides were introduced in Pakistan in 1954 (Jabbar and Mallick, 1994) but ironically Pesticide Ordinance and Rules were adopted almost 17 years later in 1971 and 1973 respectively. There was a major shift in pesticide policy in 1980 that is the pesticides import, distribution and sale was transferred from public to private sector. This shift in policy resulted many fold increase in pesticide consumption. However, it also caused huge piles of obsolete pesticides (6306 tons) mostly including notorious Persistent Organic Pollutants (POPs).

In Pakistan, the pesticides business is managed by Ministry of National Food Security and Research (MNFS&R) under Pakistan Agricultural Pesticides Ordinance 1971 and Pakistan Agricultural Pesticides Rules 1973 through Department of Plant Protection (DPP). This Department is responsible to import, manufacture, formulate pesticides in Pakistan besides quarantine functions whereas, function to regulate inspection, testing, distribution, use, sale and storage has been shifted to the Provincial Agriculture Departments after 18$^{th}$ Constitutional Amendment in 2011. Table 2 shows the pesticide policy in chronological order.

**Table 2: Chronology of Pesticide Policy in Pakistan**

| | |
|---|---|
| 1952 | Agriculture Inquiry Committee recommended to establish Plant Protection Service in the country. |
| 1954 – 65 | Pesticides import for locust control. Pesticide distribution free of cost by public sector |
| 1966 – 74 | Subsidized price (upto 75%) |
| 1971 | Promulgation of Agricultural Pesticides Ordinance (APO) |
| 1973 | Framing of Agricultural Pesticide Rules |
| 1979 | Pesticide Ordinance amended. Shifting from public to private sector. |
| 1980 | Subsidy abolished and Trade Shifted to Private Sector |
| 1992 | Pesticide Ordinance amended. Introduction of Liberalized Import Policy. Introduction of generics. |
| 1994 | Duty and surcharge on herbicides reduced |
| 1995 | Sale tax exemption on pesticides |
| 1997 | Ban on the import of 21 hazardous pesticides. Enhanced punishment on pesticide adulteration. |
| 2000 - 01 | Pesticide Policy Analysis – Frame for Action |
| 2002 | Pesticide laws amended on pesticide adulteration |
| 2011 | 18th Constitutional Amendment-Agriculture is shifted to Provinces. |

The Department of Plant Protection (DPP) provides following services to its clients (importers, manufacturer, formulators, re-packers/ re-fillers of registered Pesticides).

- Certificate of Registration (Import Permit) for import of permitted pesticides under Form-1.
- Certificate of Registration (Import Permit) for import of notified pesticides under Form-16.
- Certificate of Registration (Import Permit) for import of New Chemistry Pesticides under Form-17.
- Certificate of Registration to Manufacturing / Formulation / Re-filling Plants for manufacturing/ Formulation / Re-filling Plants of permitted pesticides.
- Reference laboratory for pesticides testing and analytical standards.

Pakistan does not manufacture active ingredient (a.i.) of pesticide rather imports pesticides under different registration schemes (Form-1, Form-16 and Form-17). A total of 2,598 compounds have been registered from 1973 to 2019. Most of these compounds are deregistered and phased out now. There are about 26 compounds mainly Organochlorines Pesticides (OCPs) and organophosphates are banned in the country. Recent figures show that there are 272 registered importers who have 1,124 registered products (651 a.i.) under Form-1, while other 139 a.i. (Acaracides 5, Fumigants 3, Fungicides 13, Herbicides 40 and Insecticides 78) have been registered under Form-16.

The shift of agriculture sector from Federal to Provincial Governments under the 18th Constitutional Amendment in 2011 has created hurdle in retrieval of authenticated pesticide statistics, as all the pesticides are imported - Figure 5 shows the data of pesticide import since the year 2001.

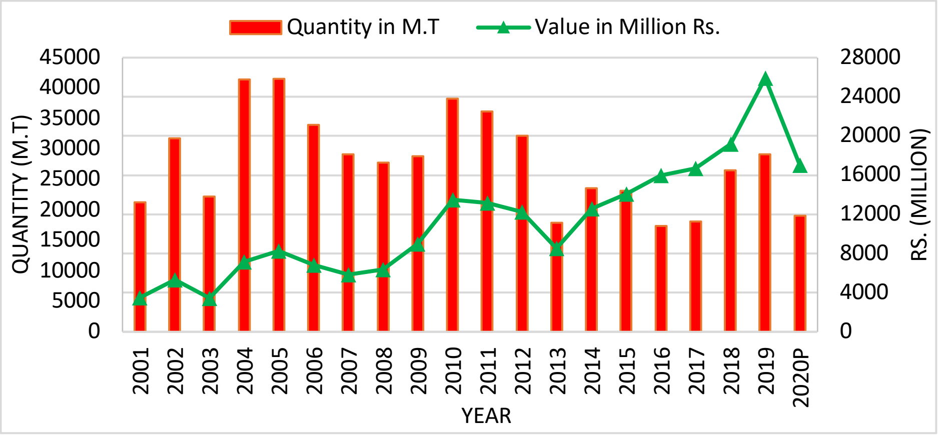


**Fig. 5. Pattern of pesticide import in Pakistan from 2001 to 2020 (first half)**

*Source: Pak Economic Survey, 2019-20*

Over the past few decades, the share of insecticides in the total pesticides' consumption has been decreased from 74% to 56%, while that of herbicides has increased from 14% to 29% and acaracides has been increased from 1% to 4%. The share of fungicides and fumigants remain constant at 9% and 2% respectively. Major chunk of the pesticides (65-70%) go to cotton crop followed by other crops that are mainly horticulture crops (30-35%).

Pesticides are toxic compounds that are purposely added into agro-ecosystems. They may be doing their indented job but certainly they create environmental issues, human health risks, trade concerns and pest resistance problems. Here we will focus on environmental and human health implications associated with pesticides usage in agriculture sector.

## 6. Environmental Implications

Pesticide being toxic compounds can have serious impact on the environment. According to a renowned entomologist David Pimentel, "only 0.1% of applied pesticides reach the target pests, leaving the bulk of the pesticides (99.9%) to impact the environment". Thus, pesticides result in severe environmental implications that include contamination of water bodies, and soil thus endangering the aquatic and terrestrial ecosystems. These pesticides then bio-accumulate in such ecosystem ultimately resulting in loss of biodiversity. This situation might get worse due to stockpiles of obsolete pesticides as in the case of Pakistan where huge stockpiles of pesticides are present.

### *6.1. Obsolete pesticides*

The pesticides were distributed free of cost or on subsidized rates for use in agriculture and health sectors till 1974. The transference of pesticide business from public to private sector in 1981 resulted in huge pile of pesticides that are stored in warehouses in shabby conditions. These pesticides also contain Persistent Organic Pollutants (POPs) that are hazardous due to their high lipophilicity, persistent nature, bioaccumulation and the capacity of transboundary movements that respect no boarder. They are now obsolete and banned under Stockholm Convention, 2001 which have also been ratified by Pakistan. Approximately, 6,306 tons of obsolete pesticides are present in the country (Fig. 6). Punjab province has the largest stockpiles of pesticides (3,805 tons) followed by Sindh (2,016 tons), Khyber Pakhtunkhwa (179 tons) and Balochistan (128 tons). Moreover, there are 178 tons of obsolete pesticides lying with Federal Department of Plant Protection (DPP). The contamination level in the water and soil samples collected from these hotspots (pesticide stores) ranged from 0.01 – 0.50$\mu gL^{-1}$ and 86 – 9157$mgkg^{-1}$ (Ahad *et al.,* 2010). However, these figures may not be generalized for agricultural soil and water bodies as the sampling was done from hotspots to evaluate the sites for remedial measures.

(a)

(b)

**Fig. 6: Stockpiles of obsolete pesticides at (a) Lodhran, Punjab and (b) Nara, Sindh.**

### *6.2. Pesticides residues in water*

The pesticide runoff and drift from agriculture land or direct contamination causes the pesticide residues in water reservoirs. A compilation of various studies regarding groundwater contamination in various region of Pakistan ranges from 0-100% depending upon the intensity of agriculture in various regions. Overall, 29% of the water samples were contaminated (Table 3). With exception to few cases, these contaminations are within the FAO/WHO safety limits. However, if the use is continued at the same level, it would not be long before our water supplies will be unfit for consumption and their accumulation in ground water over the time may lead to a serious disaster.

**Table 3: Compilation of various studies showing the groundwater contamination in various region of Pakistan.**

| *Location* | *Samples* | | *Pesticides detected* | *References* |
|---|---|---|---|---|
| | *Total* | *Contaminated* | | |
| Samundri | 10 | 7 (70%) | monocrotophos, cyhalothrin, endrin | Ali and Jabbar, 1992 |
| Karachi | 79 | 10 (13%) | DDT, DDE, ⊚-BHC, aldrin and dieldrin | Parveen and Masud, 1988 |
| Lahore | 03 | 02 (67%) | monocrotophos, cyhalothrin, cypermethrin | TARI, 1993 |
| Mardan | 12 | 12 (100%) | dichlorvos, mevinphos, dimethoate, methyl-parathion, fenitrothion, chropyrifos, endosulfan and profenphos | Ahad *et al.*, 2000 |
| Gadoon Amazai | 03 | 0 | Analyzed for diazinon methamidophos, benomyl & heptachlor. | Masud, *et al.*, 1991 |
| Total | 107 | 31 (29%) | | |

Surface water is more prone to pesticides contamination. In 2004, there was a massive death of fishes in Rawal Lake that caught the attention of media and local administration. A Study was conducted to assess pesticide residues in water samples from Rawal Lake collected before (June) and after (August) monsoon season. Pesticide residue levels were 35-86 times higher than EU standards for drinking water (0.1 ug/l for individual and 0.5 ug/l total pesticide residues). The results of the study showed the highest concentration of residues of alpha-cypermethrin followed by azinphos-methyl, fenitrothion and parathion-methyl. The results of the study also depicted a gradual decline in the concentrations of residues over time from June to August (Ahad *et al.*, 2004).

### 6.3. *Pesticides residues in food*

There is an ecological principle that the poison we put in the environment comes right back to us in our food. Results of multiple studies have been compiled regarding pesticides residues in different food matrices form various regions of Pakistan (Table 4). Over all 42% fruits and vegetables samples are contaminated and around 20% have pesticide residues higher than the CODEX Alimentarius MRLs.

**Table 4: Pesticide residues in various fruits and vegetables from various regions of Pakistan.**

| *Location* | *Samples* | | | *Reference* |
|---|---|---|---|---|
| | *Total* | *Contaminated* | *Exceeding CAC MRLs* | |
| Karachi | 141 | 09 (6%) | 02 (1%) | Masud & Farhat 1985 |
| Islamabad | 48 | 48 (100%) | 48 (100%) | NIH 1984 |
| Gadoon | 5 | 0 | 0 | Masud, et al. 1991 |
| Karachi | 250 | 93 (37%) | 45 (18%) | Masud & Hassan 1992 |
| NWFP | 154 | 54 (35%) | 22 (14%) | Masud & Hassan 1995 |
| Islamabad | 96 | 48 (50%) | 11 (11%) | Masud & Hasan 1995 |
| Quetta | 50 | 19 (38%) | 01 (2%) | Masud & Hasan 1995 |
| Islamabad | 13 | 05 (38%) | 0 | Tahir et al. 2001 |
| Islamabad | 117 | 95 (81%) | 48(41%) | Un-published |
| Total | 874 | 371 (42%) | 177 (20%) | |

Cotton is an important cash crop that is grown over 7% of the arable land but receives 65-70% of the pesticides marketed in the country. Thus, a study was designed to assess the pesticides residues in various commodities from cotton growing areas of Pakistan before and after the cotton season. The results of the study are presented in Table 5 showing a much higher number of samples above the MRLs in post-cotton season as compared to pre-cotton season.

**Table 5. Summary of pesticide residues in different matrices from Pakistan**

| Commodity | Pre-cotton season status (No. of samples) | | | Post-cotton season status (No. of samples) | | |
|---|---|---|---|---|---|---|
| | Analyzed (No.) | Contaminated (%) | Above MRL (%) | Analyzed (No.) | Contaminated (%) | Above MRL (%) |
| Water | 20 | 95 | 20 | 22 | 100 | 95 |
| Soil | 28 | 100 | -- | 23 | 100 | -- |
| Vegetables | 18 | 100 | 89 | 43 | 100 | 92 |
| Cottonseed cake/Fodder | 16 | 100 | 40 | 32 | 100 | 55 |
| Dairy milk | 17 | 29 | 6 | 30 | 73 | 23 |

In recent studies, the rice, peach, honey, brinjal and cauliflower were found to contain pesticide residues in 27-73% samples in which 20-36% samples were exceeding EU-MRLs except the peach where 70% of the samples were violating the EU-MRLs. The results are summarized in Table 6.

**Table 6: Status of pesticide residues in some commodities as determined by chromatography coupled to mass spectrometry.**

| *Commodity* | *% Samples contaminated* | *% Samples exceeding MRLs* | *Pesticides exceeding EU MRL* | *Reference* |
|---|---|---|---|---|
| Rice | 67 | 18 | atrazine, bifenthrin, carbaryl, carbofuran, triazophos, diazinon, dimethoate, hexaconazole | Tauseef, 2021 |
| Peach | 73 | 70 | azoxystrobin, bifenthrin, carbofuran, $\lambda$-cyhalothrin, $\alpha$-cypermethrin, dimethoate, endosulfan, fipronil, heptachlor, hexaconazole, iprodione, metalaxyl, pyraclostrobin, spiromesifin, tebuconazol | Samad *et al.*, 2019 |
| Honey | 27 | 15 | chlorpyriphos-methyl, dieldrin, lindane | Rafique, 2018 |
| Brinjal | 67 | 20 | chlorpyrifos | Unpublished |
| Cauliflower | 64 | 36 | chlorpyrifos | Unpublished |

### *6.4. Biomagnification of pesticides*

Since pesticides (specifically organochlorines) are fats soluble hence they tend to biomagnify in the food chain. A study of colonial water birds as bio indicators of POPs pollution was conducted at three different sites i.e. Haleji Lake (control site), Taunsa Barrage (agriculturally polluted) and Karachi Harbour (industrially polluted). POPs were analysed in sediments, prey and eggs to assess the bioaccumulation of these pollutants. Results of the study revealed a many fold increase in the concentration of POPs from sediments to eggs (Sanpera *et al.*, 2003). The highest contamination level of sum of POPs was around 8, 10 & 18 ng/g in sediments from Haleji Lake, Taunsa Lake and Karachi harbour that got concentrated into to 50, 220 & 500 ng/g while in the eggs of the birds it biomagnified to more than 2000, 5000 and 14000 ng/g approximately (Sanpera *et al.*, 2003). It shows that from sediments to eggs the cumulative concentration of these POPs gets around 250-750 times magnified. Due to the fact that POPs like DDT cause egg shell thinning such high concentrations of these compounds threatens the wildlife like water birds, thus, contributing towards the loss in biodiversity.

### *6.5. Impact on non-target organisms*

As mentioned earlier only 0.1% of the applied pesticides goes to the target pest and rest ends in the environment. Since all the pesticides are toxic by nature, hence they do affect all the non-target organisms. That's why Restricted Entry Intervals for each pesticide are prescribed. Phyto-toxicity of pesticides is a known fact and poisoning of cattle is also reported. But, the most affected non-target organisms reside inside soil and water when exposed to higher concentration of pesticides. Massive fish kill inside the Rawal Lake has been attributed to higher levels of pesticides like methyl parathion, fenitrothion, azinophos-methyl and alpha-cypermethrin (Ahad *et al.,* 2006). Similarly, microbial population inside the soil might not perform their intended functions when they are exposed to higher concentration of pesticides. Sometimes the intermediate products of pesticides are more toxic than the parent compound and may affect the microbial population in more severe manner. The effects are more devastating when the nitrogen fixing, phosphate solubilizing and growth promoting bacteria are exposed to higher concentrations of pesticides (Mubeen *et al.*, 2006), as they directly affect the soil fertility. Even if the pesticide concentration is less than the lethal concentration, it does affect the activity of the microbial enzymes like nitrogenases, nitrate reductase and phosphatase etc. Similarly, fungicide also inhibit the mycorrhizal associations thus affecting the soil fertility (Meena *et al.,* 2020). However, such studies are rare in Pakistani environment and this area requires further attention to work on in order to assess the implications of pesticides on non-target organisms.

### *6.6. Human health implications*

Pesticides are inherently toxic substances that might also interfere with the non-target organisms including humans. Symptoms of acute pesticides toxicity include headache, dizziness, nausea, tightness in chest, diarrhea, cramps, muscular weakness, rapid heartbeat, excessive salvation, blurred vision, and twitching movements. Chronic effects include carcinogenic, teratogenic, endocrine disrupting effects. Pesticides also affect the immune system in general and are also linked to other diseases like Alzheimer and Parkinson.

Multan (Punjab) and Khairpur (Sindh) are the major cotton growing areas where the farmers perform more pesticide application. By in-large cotton-pickers are females from poor background. They are exposed to pesticide residues mainly through dermal contact and inhalation. Female cotton-pickers are exposed to low doses for longer periods and spray-men are exposed to higher doses for shorter duration, respectively.

In 2010, a quantitative analysis of exposure of pesticides was done for 42 spray applicators and 46 cotton pickers by assessing symptoms experience by these study groups. The highest percentages of experienced symptoms were for muscular weakness (96%), headache (94%) and coughing (74%). A comprehensive biochemical analysis of for serum levels of (PChE) levels, luteinizing hormone (LH), follicle-stimulating hormone (FSH), testosterone, prolactin, thyroid-stimulating hormone (TSH), total triiodothyroxine (TT3), and free thyroxine (fT4) was determined. Acetyl cholinesterase levels of control and applicators/ cotton pickers were varying a lot showing the exposure/ toxicity of pesticides. FSH, LH, and testosterone levels were significantly higher in spray applicators ($P < 0.01$). Serum FSH and testosterone levels were significantly raised and serum fT4 was significantly reduced in cotton pickers ($P<0.01$). Serum prolactin was decreased significantly in both groups ($P<0.01$). The study concluded that the pesticide exposure is associated with thyroid and reproductive hormone levels disturbance (Khan *et al.*, 2011).

## 7. Strategies to Minimize Excessive Use of Fertilizers and Pesticides

As mentioned before, Pakistani soils are deficit in nutrients like N, P, K and hence, Government of Pakistan provides subsidy over the fertilizers to promote their usage as against the minimization of fertilizers. Studies have shown that the concentration of these nutrients in Pakistani groundwater are within the National Environmental Quality Standards for drinking water (Deeba *et al.*, 2019; Hameed *et al.*, 2020). WHO and National Environmental Quality Standards of Pakistan have established a standard value for nitrate less than 50mg/l and for nitrite less than 3 mg/l in drinking water (WHO 2016; SRO 1062-1/2010). These standard values for bottled drinking water are 10 mg/l for nitrate and 1 mg/l for nitrite (PS:4639-2004(R)).

However, pesticides are excessively applied and in order to control their usage the Government continues to regulate them by promulgating ordinance and rules. The Government of Pakistan has promulgated the first Pesticide ordinance in 1971 and framed agricultural pesticide rules in 1973. The ordinances have been amended in 1979, 1992 and 2002. The complete chronology of pesticide policy has been given in Table 2. Like fertilizers, PSQCA have also set maximum admissible concentrations for various pesticides and their solvents in bottled drinking water that are listed in Table 7.

**Table 7: Maximum admissible concentration of various pesticides in drinking water set by PSQCA**

| *Sl. No.* | *Pesticide Name* | *Maximum Admissible Concentration (mg/l)* | *Sl. No.* | *Pesticide Name* | *Maximum Admissible Concentration (mg/l)* |
|---|---|---|---|---|---|
| 1 | Alachlor | 0.002 | 12 | Ethylbenzene | 0.3 |
| 2 | Aldicarb | 0.003 | 13 | Heptachlor | 0.0004 |
| 3 | Aldrin/Dieldrin | 0.002 | 14 | Heptachlor & epoxide | 0.0002 |
| 4 | Arsenic | 0.01 | 15 | Hexachlorobenzene | 0.001 |
| 5 | Atrazine | 0.003 | 16 | Lindane | 0.0002 |
| 6 | Benzene | 0.001 | 17 | Methoxychlor | 0.04 |
| 7 | Carbofuran | 0.04 | 18 | Pentachlorophenol | 0.001 |
| 8 | Chlordane | 0.002 | 19 | Simazine | 0.004 |
| 9 | 1,2-dibromo-3 chloropropane | 0.001 | 20 | 2,4,5-TP | 0.01 |
| 10 | 2,4- Dichlorophenoxy acetic acid | 0.07 | 21 | Toluene | 1 |
| 11 | Diquat | 0.02 | 22 | Xylenes | 1 |

*Source: PSQCA PS:4639-2004(R)*

Pakistan Environmental Protection agency has set the limit of 0.15 mg/l in municipal wastewater (S.R.O. 549/I/2000). PSQCA have also set the limits of some pesticide residues in certain agricultural commodities. These pesticides include aldrin/dieldrin, azinophos methyl, binapacryl, bromophos, carbaryl, chlordane, 2,4-D, DDT, diaxinon, dichlorovos, dicofol, dimethoate, dioxathion, diphenyl, diphenylamine (PS2023-1988). But these standards are rather old and need to be revised. For this purpose, the upgradation of laboratories with state-of-the-art analysis facility were needed, hence the Government of Pakistan initiated a mega PSDP project entitled as "National Pesticide Residues Monitoring System in Pakistan".

### *7.1. National Pesticide Residues Monitoring System in Pakistan*

While realizing the importance of the pesticide residues monitoring, the Government of Pakistan has started a Public Sector Development Program (PSDP) project titled as "National Pesticide Residues Monitoring System in Pakistan". Wherein, 6 laboratories are being established each in every province while having a Center of Excellence at Islamabad. Moreover, a laboratory in Karachi is also being strengthened as it is the largest port city in the country. These laboratories have been equipped with the state-of-the-art equipment like mass spectrometers. The results of monitoring from this project indicating the status of pesticide residues in some selected commodities have been cited earlier (Table 6).

### *7.2. Integrated Pest Management*

While realizing the harmful impacts of pesticides, the Government of Pakistan took the initiative of National Integrated Pest Management Program (Nat IPM) in the year 2000. Nat IPM Programme is providing the technical support to all Federal, Provincial Institutions, NGO's and farmer organizations in the implementation of IPM through Farmer Field School (FFS) approach. Around 107 master trainers trained the 2,824 facilitators who in turn trained more than 0.15 million farmers through 6,985 farmer field schools. Through this program the use of pesticides was discouraged while promoting the environmentally friendly practices. These environmentally friendly practices include use of biological control agents, botanicals and organic farming.

Bio-control agents are environmentally friendly, self-propagating and very effective replacements of chemical pesticides. Use of parasitoid i.e. *Tichogramma chilonis* has resulted in effective control of boll worm population in cotton crop and vegetables (Masood *et al.,* 2011; Usman *et al.,* 2012). Similarly, use of predator i.e. *Chrysoperla carnea* resulted in effective control of white flies and bollworms in cotton and vegetables crops. *Chrysoperla carnea* is also voracious eaters of eggs and immature stages of multiple species of aphids, spider mites, thrips, whiteflies, leafhoppers, some beetle larvae, eggs and caterpillars of pest moths, and mealybugs (Sarwar and Salman 2016). Similarly, parasitoids *Aenasius* sp. have been used to control cotton mealy bug (Solangi 2011).

Extract of different indigenous plants like the neem (*Azadirachta indica*), harmal (*Peganum harmala*), sweetflag (*Acorus calamus*), turmeric (*Curcuma longa*), kuth (*Saussurea lappa*), Balchar (*Valeriana jatamansi*), korttumma (*Citrullus colosynthus*) and ner (*Skimmia laureola*) have been tested for controlling different pests of various crops. Out of these botanicles, neem (*Azadirachta indica*) has been extensively studied and found highly effective against various pests like cotton mealy bug, cotton spotted bollworm etc. Various commercial formulations of neem are available with trade name like Nimboli, Nimbokil and NimEra-X (Jilani & Rehman 2006).

## 8. Conclusion & Way Forward

The use of synthetic pesticides causes environmental issues and health risk apart from other issues like trade concerns. The most vulnerable groups of society like farmers including the cotton pickers, spray men and factory workers mostly do not observe protective and precautionary measures. This may cause serious health issues in these community groups. Farmers should be educated about good agricultural practices (GAP) and empowered them as they are the key players in this regard. For pesticide use reduction at farm and beyond farm levels, there is a need of adopting crop specific approaches and of the commitments of political and economic stakeholders as well as consumers. For pesticide use reduction, clear goals with time frame should be defined. Organic food production and environment friendly techniques and products like IPM should be promoted. Moreover, pesticide residues monitoring and their implications activities should be continuously carried out in order to assess the level of contamination and damage. Pesticides also have trans-boundary movements, trade concerns and pest resistance issues. Thus, collective approach is required at Regional Level (i.e. SAARC) like EU-RASFF for sharing real time information. Similarly, effort should be geared towards the harmonization of Regional MRLs.

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Chapter 8

# Impact of Agricultural Chemical Inputs on Human Health and Environment in Sri Lanka

**N. R. N. Silva**[1]
**P.W.Y. Lakshani**[2]
[1]Division of Soil and Plant Nutrition
[2]Central Analytical Laboratory
Horticultural Crop Research and Development Institute
Department of Agriculture, Sri Lanka
*[1]renukasilva@yahoo.com; [2]jayayoshil@yahoo.com*

## 1. Introduction

Sri Lanka, is an island in the Indian Ocean and located between latitudes 5°55′ and 9°51′ and longitudes 79°41′ and 81°53′ and has a maximum length of 432 km and a width of 224 km. The total area is 65,610 $km^2$ and consists of 24 agro-ecological zones. The agriculture sector plays a leading role in the economy of Sri Lanka, contributing to nearly 7.0 % of Gross National Product (GDP) in 2019. Domestic sector, which forms the dominant part of agriculture and accounts for 1.7 million farm families in a population of around 21 million. Out of total land area of 6.55 million hectares, 2 million ha are agricultural land, of which 650,000 ha are irrigated land. The total cultivated area, including home gardens and plantations is estimated at 2.86 million ha. Rice is a primary food crop of Sri Lanka and total land devoted for paddy is estimated to be about 708,000 hectares at present.

Global demand for food is growing continuously as a result of population growth and in Sri Lanka agriculture sector has undergone considerable transformation and improvements in response to green revolution. Productivity levels have been stagnant in recent years and raising concerns about food security and recent COVID-19 pandemic have also reiterated the importance of food security for a developing nation like Sri Lanka (Department of Agriculture, 2019). High yielding modern crop varieties are inherently more vulnerable to pests and diseases. Pesticides and fertilizers application play a vital role in modernization of agricultural practices. The spraying of pesticides can significantly reduce or offset the economic costs from plant diseases, insect pests, and weeds in agricultural production. Application of fertilizers can provide a variety of nutrients required for the growth of crops as well as to increase the yield of crops.

Since 1950s Sri Lanka started to use inorganic fertilizers such as urea, Triple Super Phosphate and Muriate of Potash etc. to enhance the crop yields. At present, use of inorganic fertilizer is widespread in agriculture. Urea is the most widely used fertilizer in Sri Lanka, followed by muriate of potash and triple super phosphate. Table 1 shows the amount of fertilizer consumption by crop sector.

**Table 1: Fertilizer consumption by crop sector**

| Crop | Urea | TSP | MOP | Others |
|---|---|---|---|---|
| | | Mt | | |
| Paddy | 224,814 | 56,054 | 65,210 | 325 |
| Tea | 90,138 | 370 | 42,275 | 79,244 |
| Rubber | 3,208 | 173 | 2,475 | 5,399 |
| Coconut | 16,664 | 3,602 | 23,145 | 13,516 |
| OFC | 32,422 | 9,549 | 7,611 | 3,757 |
| Vegetable | 10,464 | 10,297 | 12,528 | 32,614 |
| Potato | 1,396 | 5,176 | 5,318 | 9,881 |
| Fruit | 7,229 | 4,390 | 8,471 | 3,183 |
| Export Agric Crops | 5,558 | 670 | 3,434 | 7,588 |
| Others | 39,348 | 11,114 | 12,116 | 8944 |

*Source: Ag Stat, 2015*

Many countries have reported alarming residues of agricultural chemicals in soil, water, air, agricultural products, and even in human blood and adipose tissue (Alvarez, *et al.*, 2017). Farmers in developing countries are experiencing, either short-term or long-term, health effects from exposures to agricultural chemicals, including severe symptoms like headaches, skin rashes, eye irritations and some chronic effects like cancer, endocrine disruption, birth defects (Ridolfi, *et al.*,2014).

With the rising incidence of chronic kidney diseases in the agricultural areas of the Sri Lanka, the government is taking measures to control the indiscriminate usage of chemical fertilizer and agrochemicals by the farmers. Although, Sri Lanka has become self-sufficient in rice and some other crops, the adverse effects of chemical usage such as damage to bio-diversity and non-target organisms.

## 2. Agrochemicals Policy and Regulatory Frameworks

Sri Lanka has two separate Acts to manage and control agrochemicals use viz. Pesticides Act No. 33 of 1980 and Fertilizer act No. 69 of 1988.

### *2.1 Regulatory Frameworks*

#### *2.1.1 Pesticide Regulatory Framework*

The control of pesticides is quite challenging, since both risks posed by pesticides to public health and the environment due to over-uses and misuses.

Synthetic pesticides use in Sri Lanka since 1950 and no in-plant technical or formulations available in the country. Pesticides import, packing, labeling, storage, formulation, transport, sale and use are regulated by the Office of the Registrar of Pesticides (ROP), Kandy. ROP office functions under the Department of Agriculture and Registrar of Pesticides (ROP) is the legal authority empowered and entrusted on the functions related to the registration and regulation of pesticides in Sri Lanka under the Pesticides Act No. 33 of 1980, Amendment of the Act No. 06 of 1994 & the Act No. 31 of 2011. According to the Act, it is the duty of the Registrar of Pesticides to regulate pesticides imported to, and formulated/manufactured in Sri Lanka, and to assure their quality and safe use, and to assess and to declare Maximum Residue Limits (MRLs) in agricultural produce. Furthermore, Sri Lanka has ratified International Treaties such as Basel Convention ratified on 28. 08.1992, Stockholm Convention ratified on 22.12.2005, Rotterdam Convention ratified on 19.01.2006, and Chemical Weapon Convention on 2007 and accordingly the international guidelines and standards of FAO, WHO, OECD, CODEX, CIPAC are followed in pesticides evaluation.

The Pesticides Technical and Advisory Committee is the statutory body of the Control of Pesticides Act and assists the Registrar of pesticides on technical issues related to enforcement of the Act. This committee consists of experts and ex-officio members of relevant institutes. These members include the General of Agriculture (Chairman), Registrar of Pesticides (Secretary), Director General of Health Services, Director General Sri Lanka Standards Institute, Director General Central Environmental Authority, Commissioner of Labor (Occupational Health), Government Analyst, Director of Tea Research Institute, Director of Rubber Research Institute, Director of Coconut Research Institute, a representative of the Attorney General, and five expertise in related fields. Furthermore, there are two sub committees, Agrochemical Sub-committee and the industrial and house hold Sub-committee to safeguard human health and the environment against pesticides by evaluation of risks associated with the use of pesticides and bio efficacy in the field. In the registration process manufacturers have to submit their proposal in summary to the Agro-Pesticides Sub-committee, which consists of 18 eminent scientists from all disciplines concerned. The Sub-committee is involved in thorough evaluation of the proposals and recommend the proposal to conduct the bio efficacy trials at national crop research institutes under the supervision of subject discipline coordinators of Department of Agriculture. In the protocol of conducting bio efficacy trials, laboratory assay, field trial at research station and two seasonal multi-locational pilot scale trial have to be completed at farmer field.

All pesticides should be subjected to a comprehensive bio-efficacy testing procedure conducted by Department of Agriculture. The registration package consist with original reports on all related country of origin, chemical, physical, biological, toxicological and environmental data and reports are accepted from ISO 17025:2017 accredited and GLP laboratories. Pesticides cannot be imported to the country without license issued by Registrar of Pesticides and approval granted after evaluating the registration documents.

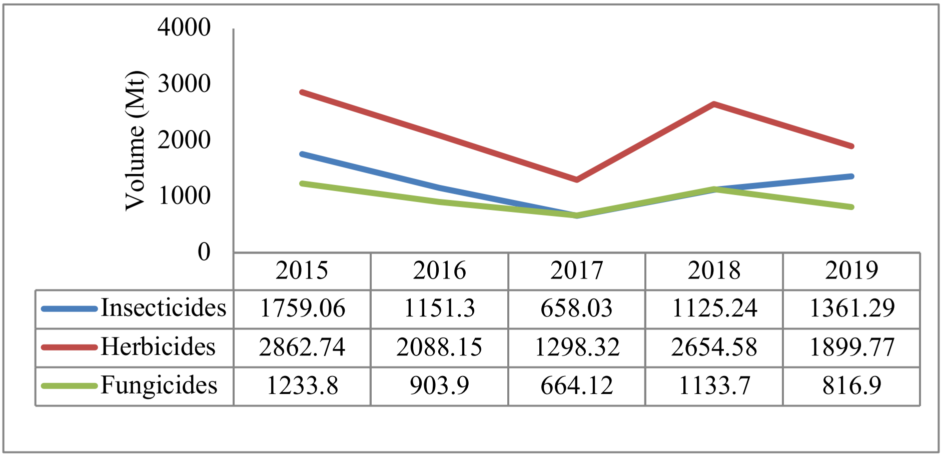
Stringent regulations are provided by the Control of Pesticides (Amendment) Act No. 06 of 1994 for licensing of traders, appointment of authorized officers to seize pesticides outlets by conducting inspections. Applicants for dealership are required to complete the 200-hour certificate programme conducted by the Office of the Registrar of Pesticides to avoid unscrupulous trade practices.

Quality assurance plays a vital role in controlling the pesticide and Department of Agriculture has equipped with ISO 17025:2017 accredited Central laboratory for the quality assurance of pesticides to strengthen the compliance monitoring programme. The laboratory has launched several research programme for assessment of the pesticides residue and heavy metal in food stuff and environment. Furthermore, Registrar of Pesticides issue maximum residue levels for sixty pesticides published by the extraordinary gazette no 2023/34 issued on 14.06.2017.

The glyphosate and CKDu and Glyphosate are restricted herbicide in Sri Lanka under the authority given by the Cabinet Memorandum No.18/0925/801/007 dated 08.05.2018. However, upon request of tea and rubber plantations industries Glyphosate 36% SL formulations have been authorized by the *Gazette Extraordinary* No. 2091/13 of 02.10.2018 under the Control of Pesticides Act No.33 of 1980 for a period 36 months for effective control of weeds in the plantations.

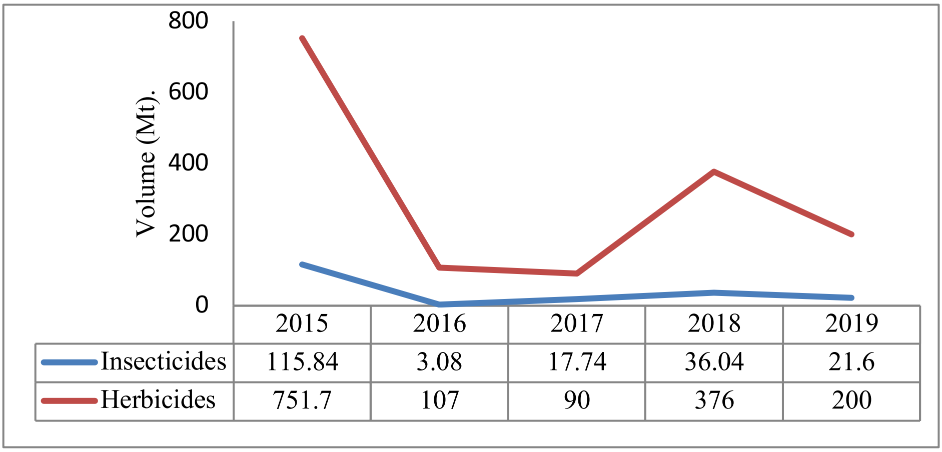
### *2.1.2 Pesticide importation details*

In 2019, 221.6 tons of technical material and 4077.67 tons of pesticide formulations were imported to Sri Lanka and abrupt decline of importation has observed due to stringent control over high volume pesticides such as Chlorpyrifos, Carbaryl, Carbofuran and Propanil. Further reduction is imminent due to banning of Glyphosate, which accounts for approximately 25% reduction in weedicide formulations and 18% reduction of all pesticide formulations in the country (Figure 1, Figure 2).




| | 2015 | 2016 | 2017 | 2018 | 2019 |
|---|---|---|---|---|---|
| Insecticides | 1759.06 | 1151.3 | 658.03 | 1125.24 | 1361.29 |
| Herbicides | 2862.74 | 2088.15 | 1298.32 | 2654.58 | 1899.77 |
| Fungicides | 1233.8 | 903.9 | 664.12 | 1133.7 | 816.9 |

**Figure: 01 Pesticide Technical imported**




| | 2015 | 2016 | 2017 | 2018 | 2019 |
|---|---|---|---|---|---|
| Insecticides | 115.84 | 3.08 | 17.74 | 36.04 | 21.6 |
| Herbicides | 751.7 | 107 | 90 | 376 | 200 |

**Figure:02 Pesticide formulation imported**

### *2.2.1 Fertilizer Regulatory Framework*

Presently, fertilizers used in Sri Lanka are N, P, K formulations with trace elements, micronutrients, mixtures of hydroponics and fertilizer mixtures for fertigation other than the straight fertilizer of urea, TSP and MOP. However, Department of Agriculture has recommended only N, P and K straight fertilizers as the inorganic fertilizers.

Fertilizer Act No. 69 of 1988 is regulating the importation, manufacture and distribution of fertilizer and to provide for matters connected therewith. This Act concerns the importation, manufacture, formulation and distribution of fertilizer in Sri Lanka. The National Fertilizer Secretariat (NFS) of the Ministry of Agriculture is the main regulatory body of importation, distribution, blending and storage of the fertilizer in the country. The importation, manufacture or formulation of fertilizer requires a license issued by the Director of the National Fertilizer Secretariat. A fertilizer advisory committee is established to advise the director. The Director shall have the power to inspect any place where fertilizers may be manufactured, formulated, stored or distributed and seize any adulterated fertilizers.

As the National Fertilizer Secretariat (NFS) is the main regulatory body of importation, distribution, blending and storage of the fertilizer in the country. NFS implements the standard procedure to follow the import of the fertilizers to the country. According to standard procedure adopted, first quality certificate from accredited laboratory has to be submitted to the NSF before the loading of the fertilizers to the country. Then random samples drawn by the NSF and are sent for the testing to verify the details of the quality report. Further, Sri Lanka Standards Institution (SLSI) established the standards for the composition and trace elements in straight fertilizers. Table 2 shows that presently implemented standard for trace elements in TSP fertilizer by Sri Lanka Standard Institution (SLSI).

**Table 2: Standards of trace elements in imported TSP fertilizer**

| Element | TSP Fertilizer mg/kg |
|---|---|
| Pb | 30.0 |
| As | 25.0 |
| Cd | 3.0 |
| Hg | 1.0 |
| Cr | 50.0 |

### *2.2.2 Trace Elements in Fertilizers*

Except N fertilizers, the basic raw material of both P and K fertilizers are obtained after mining and further treatments. However, among the fertilizers imported to Sri Lanka triple super phosphate contains appreciable amount of many trace elements as which is manufactured from rock phosphate in the ground. The quantity of trace elements or heavy metals in TSP varies with the deposit of rock phosphate used to manufacturing the TSP fertilizers.

The trace element contents of the fertilizers especially in TSP vary according to the source of fertilizers. Many literatures reported that all sources of the TSP in the world contaminated with trace elements of Pb, Cd, As, Cr etc. Dissanayaka *et al.,* (2009), reported that several TSP fertilizer samples use in the country contained appreciable amount of potentially toxic trace elements (Table 3). However, TSP and MOP samples collected from market in different areas in the country analyzed for As and Cd and results were below the acceptable limit (Table 4).

**Table 3: Reported values of Potentially Toxic Trace Elements in TSP in Sri Lanka**

| Location | Contents (mg/kg) | | | | | |
|---|---|---|---|---|---|---|
| | Al | Cr | Ni | Cd | Pb | U |
| Anuradhapura | | | | | | |
| Medawachchiya | 9405 | 43.6 | 27.1 | 4.0 | 79.2 | 76 |
| Medirigiriya | 8563 | 59.5 | 22.3 | 46.1 | 41.1 | 5.8 |
| Girandurukotte (1) | 9016 | 65.9 | 24.2 | 39.8 | 58.2 | 64.1 |
| Kandy | 10113 | 62.1 | 27.3 | 4.3 | 80.2 | 166 |
| Girandurukotte (2) | 5177 | 19.2 | 10.3 | 2.3 | 67.2 | 364 |

*Source: Dissanayaka and Chandarjith (2009*

**Table 4: Trace metal contents in Fertilizers in the market**

| Location | Contents (mg/kg) | | | |
|---|---|---|---|---|
| | TSP | | MOP | |
| | As | Cd | As | Cd |
| Batticallao | 5.05 | 3.9 | 0.43 | 0.75 |
| Trincomalee | 0.849 | - | 0.89 | 0.116 |
| Kanthale | 1.76 | 1.49 | 0.85 | 0.40 |
| Gampaha | 1.95 | 0.1 | 0.321 | 0.008 |

*DOA unpublished data (2017)*

### 2.2.3 Trace Metal Contents in Organic Fertilizers

Although, organic fertilizer has been considered as an environmentally friendly input, it is also contained appreciable amount of trace metals of Fe, Cu, Mn, Zn, Pb, Cd, Cr as in Table 5 showing trace metal contents in different types of organic manures collected from the different places of the country (Unpublished data, 2012). Nicholson *et al.,* (1999) reported that trace metal contents in farm yard manure collected from England and Whales which are almost similar to trace metal contents in organic manure in Sri Lanka.

**Table 5: Trace metal contents in organic manure**

| Source | Metals (mg/kg | | | | |
|---|---|---|---|---|---|
| | Cd | Pb | Fe | Mn | Cr |
| Cow dung | 0.46 | 1.39 | 4451 | 396 | 0.19 |
| Poultry dung | 0.14 | 0.43 | 2236 | 394 | 0.20 |
| Goat dung | 0.29 | 0.34 | 6849 | 354 | 0.51 |
| Swine dung | 0.50 | 0.28 | 2109 | 351 | 0.13 |

*Unpublished data DOA, 2012*

### *2.2.4 Fertilizer Importation Details*

Relatively large amount of urea, TSP and MOP fertilizers are imported annually compared to other fertilizers. The fertilizers and the amounts imported to Sri Lanka in 2018 are given in Table 6. Figure 3 and 4 showed that fertilizer imported to country from 2011 and fertilizer consumption in the country from year 2000 respectively. Excessive applications of inorganic fertilizers are common practice in agriculture in Sri Lanka.

**Table 6: Fertilizers imported in 2018**

| Fertilizer | Quantity Mt |
|---|---|
| Urea | 317,915 |
| MOP | 131,691 |
| TSP | 57,699 |
| Sulphate of Ammonia | 68,665 |
| Kiesarite | 13,331 |
| Potassium Sulphate | 1453 |
| DAP | 3466 |
| Zinc Sulphate | 869 |

*Source: AgStat 2019*

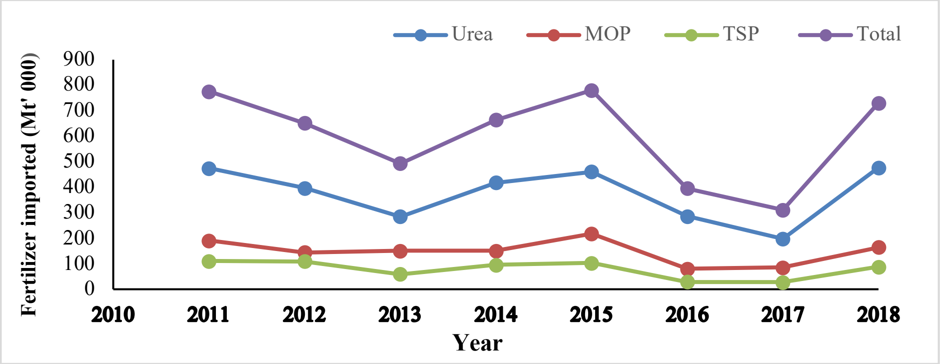



**Figure: 3 Fertilizers imported from 2011**

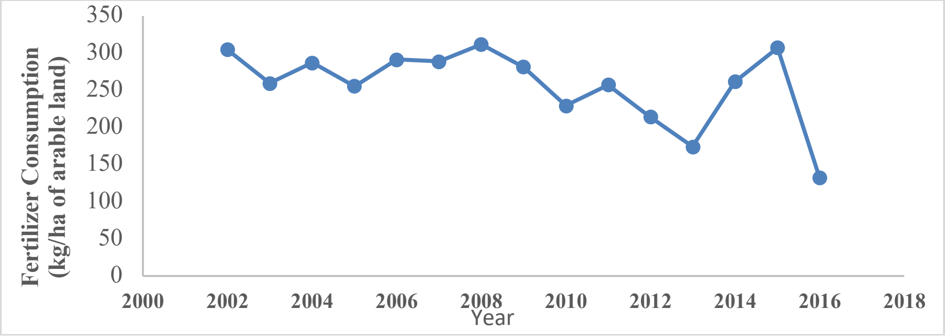



**Figure4. Fertilizer consumption in the country**

*Source: https//www.indexmundi.com*

## 3. Different Types of Agrochemicals Used in Agriculture

### *3.1 Types of Pesticides used in agriculture*

Registered pesticide published by the extraordinary gazette no 1994/71 issued on 24.11.2016 presence with 126 active substances including 47 insecticide, 32 herbicides and 47 fungicides representing nearly 440 agricultural pesticides are commercially use. Sri Lanka moving towards further reduction of highly hazardous pesticide formulations in agriculture and pesticide classifications is done according to the WHO hazard class classifications and highly encourage of class III pesticides with blue label and class IV pesticide with green label. WHO class 1 pesticides are not accepted for registration. Organochlorine pesticides including persistent organic pollutants are banned in the country under the gazette No .1190/24 in 2001. Currently Ia and Ib pesticides are not available in Sri Lanka.

**Table 7: WHO recommended classification of pesticide by hazard**

| WHO class | LD $_{50}$for rat (mg/kg) body weight | |
|---|---|---|
| | Dermal | Oral |
| I a- Extremely hazardous | < 5 | < 50 |
| 1 b-Highly hazardous | 5–50 | 50–200 |
| 11 moderately hazardous | 50–2000 | 200–2000 |
| 11 slightly harzardous | Over 2000 | |
| U- unlikely | 5000 or higher | |

*Source: WHO, (2019)*

Accordingly, 36 of active ingredients are banned as these pesticides are considered to be high acute toxicity and pesticides with accumulations in the environments. Consumption of methyl bromide in the country is maintained in compliance with the Montreal protocol. According to the provisions of Act no 06 of 1994, there are two types of agricultural pesticides; general pesticides and restricted pesticides. General pesticides can be sold only in authorized pesticide outlets, while highly hazardous products use or distribution require trained applicators under strict supervision and not available at retail market categorized as "Restricted Pesticide".

### *3.2 Types of fertilizers used in agriculture*

Due to N, P and K straight fertilizers has been recommended as the inorganic fertilizers relatively large amount of urea, TSP and MOP fertilizers are imported to the country annually compared to other fertilizers (AgStat, 2016). Small quantity of other fertilizers such as sulphate of ammonia, kisserite, commercial epsom salt, zinc sulphate, di ammonium phosphate, and single super phosphate are imported which are used for nurseries of tea and other plantation crops. DOA has recommended zinc sulphate only for rice while micronutrient containing fertilizers has not been recommended for any other food crops. However, there are more than hundreds of types of micronutrients containing fertilizers and other new fertilizer that are available in the market.

New fertilizers used in Sri Lanka are NPK formulations with trace elements, micronutrient mixtures, and fertilizer mixtures for hydroponics, fertigation mixtures and fertilizer with growth promoting substances and micronutrient containing liquid fertilizers. Most of these fertilizers are comparatively high value fertilizers imported in small quantities. They are either organic fertilizers or inorganic fertilizers. Although, DOA has not recommended liquid fertilizers or any other special fertilizers, some farmers are using them for crops such as vegetables, onion, potatoes, fruits and floricultural crops, etc. However, most of them are not essential for the farming, but farmers in the country use them due to influence by fertilizer companies.

## 4. Best Practices for Optimum Use of Agrochemicals

### *4.1 Best practices for optimum use of pesticides*

Various methods have been practiced throughout the past few decades in order to avoid misuse of pesticides, and avoid its threat to human health and environment through integrated pest management, organic farming and Good Agricultural Practices (GAP).

#### *4.1.1 Good Agricultural Practices (GAP)*

The Sri Lankan government has introduced an adaptation plan for GAP called "Sri Lanka Good Agriculture Practices/SL-GAP" which was launched in 2016 with the active assistance of the Department of Agriculture (DOA) for optimum use of agrochemicals. Currently, 1232 of Gap certificates were issued (Table 8).

**Table 8: Details of the GAP Certificates issued**

| Province | Admission certificates | Total GAP certificate 2016-2020 |
|---|---|---|
| Central | 200 | 194 |
| Southern | 175 | 184 |
| Western | 38 | 155 |
| Uwa | 51 | 128 |
| North Central | 181 | 99 |
| Eastern | 204 | 124 |
| Wayamba | 128 | 101 |
| Sabaragamuwa | 247 | 135 |
| North | 295 | 112 |
| **Total** | **1519** | **1232** |

### *4.1.2 Integrated Pest Management (IPM)*

Integrated Pest Management (IPM) in a global perspective involves the adoption of a combination of various pest control techniques in a compatible manner to maintain the pest populations below an economic threshold level with minimum reliance on low-toxic pesticides as an ultimate option. Farmers achieve this through destruction of crop residues, follow crop rotation, developing mass raring principals by protection of natural enemies, soil treatment, proper chemical fertilizer management, non-chemical weed management, non-chemical pest management, using traps and baits and mixed cropping.

### *4.1.3 Pesticide Recommendation Book*

Selection of pesticides, timing, frequency and dosage of application are some of the most frequent indiscriminate uses carried out by farmers and ultimately resulted poor yield, high input cost and low-quality produce with high residues. Therefore, Department of Agriculture has published a Pesticide Recommendations book since 1977. Pesticide recommendation is a result of extensive research evaluating bio-efficacy of new pesticide formulations imported for testing under local conditions in the country. Pesticide recommendations have been categorized according to crops/pest combinations for easy reference. In addition, the mode of action of pesticides are given for the farmers to select the best options to minimize resistance development in pests, pathogens and weeds to pesticides by selecting deferent pesticide with a deferent mode of action and the new recommendation is freely available

### *Best practices for optimum use of fertilizer*

Department of Agriculture formulated blanket recommendations for all food crops based on crop response in different agro-ecological zones. Fertilizer recommendation for rice was established for both different ecological zones and irrigation type such as major and minor irrigation and rainfed. DOA also advises to use of organic fertilizers with recommended inorganic fertilizers. In 1993, the Department of Agriculture introduced a programme to provide farmers with soil test-based fertilizer recommendations and it prevents the excessive application of inorganic fertilizers and minimize many soils related problems such as low pH, salinity development and maintain the organic matter content in soil.

In 2013, the Department of Agriculture has commenced a programme to test new fertilizer products that are being imported into the country. According to the protocol of testing new fertilizers, the suppliers should provide duly filled application through DGA to the fertilizer testing committee with reports from an accredited laboratory for the contents of the products (Nutrient, heavy metals and other hazardous materials).

Further, government of Sri Lanka stipulated national policies for the agriculture sector to promote the sustainable agricultural development with efficient and effective utilization of resources, promotion of good agricultural practices for nutrient management such as integrated plant nutrition management for sustainable agricultural development, promotion of production and utilization of organic and bio fertilizers, giving subsidy for organic fertilizers and taking other appropriate actions to prevent misuse and excessive use of fertilizers. The government also provides soil and plant testing facilities for their rational use through site specific fertilizer application and testing facilities to ensure the quality of fertilizer and compost.

### *4.2.1 Integrated Plant Nutrient Management System (IPNS)*

Due to continuous cultivation, heavy doses and misuse of fertilizers decline the soil fertility and crop yield. Therefore, it is important to maintain the soil fertility in long term. The integrated plant nutrient management advocates the balanced use of organic and inorganic fertilizer for sustainable crop production. In this regard, it is important to assess and consider the contribution of nutrients from different sources such as soil, water, organic manure and rain when applying chemical fertilizers.

## 5. Impact of Agrochemicals on the Environment and Human Health.

### *5.1 Impacts of Pesticides in Sri Lanka*

A healthy society is a major national priority. Therefore, it is proposed that necessary strengthening of institutional activities should be paramount important in order to tackle the issues in the rampant of health and environmental problems in the country. Available literature also confirm that, pesticides have been severely overused and misused in the agricultural sector of Sri Lanka over the past several years (Padmajani *et al.,* 2014). It has been reported that, majority of the local farmer communities have been using stronger concentrations of pesticides with increased frequency of applications and mixing of different pesticides together to combat existing pest resistance (Padmajani *et al.,* 2014). The same source confirms, data over 20 years show that, 59% of the farmers in Matale, Kandy, Badulla and Nuwara-Eliya Districts had used more than recommended amounts of pesticides in their vegetable cultivations (Padmajani *et al*., 2014). At the meantime, it has found that, farmers in Sri Lanka have a tendency to ignore given technical recommendations and depend on their own experience which may lead to misuse of pesticides (Padmajani *et al.,* 2014). Accordingly, there is a high tendency for foodstuffs of both plant-based and animal-based to be contaminated through food chains and food webs, with hazardous chemicals and to violate the given recommendations on food safety.

### *5.1.1 Pesticide residue analysis data*

Furthermore, to the above research, from 2016-2018and 2020, Registrar of Pesticides has analyzed 959 total number of vegetables and fruits samples containing export consignments, market samples and import samples of for pesticide residues. From the total number of 586 of ready to export samples only 44 samples contaminated with pesticide/pesticides and from that only 26 numbers of pesticides exceed the EU MRL's. Percentage of the ready to export sample exceeding MRL's in 2016, 2017, 2018 as 16.56%, 7.29% and 1.39 % respectively, while none of the samples exceeding the MRLs during the year 2020. Out of the 76 of imported samples 32 samples were contaminated with pesticides in 2018. Furthermore to that out of the 62 no. of rice samples analyzed in 2020 only 7 samples contaminated with pesticides and no samples were exceeding the EUMRL's. From the data to 2016-2018, reported with the decline of contaminated residue on the samples leads that controlling of the alarming situation of food safety. (figure 5, figure 6)

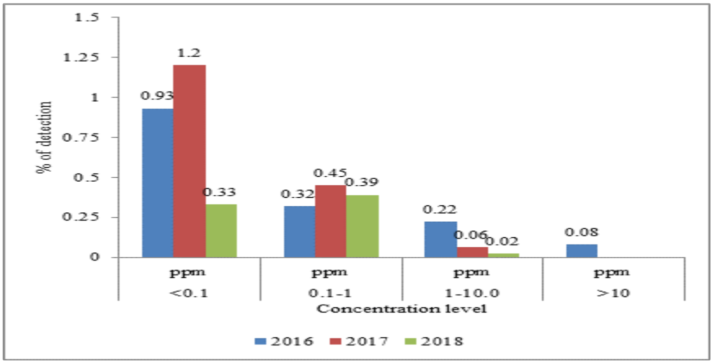



**Figure: 05 Pesticide residue details in year 2016, 2017, 2018**

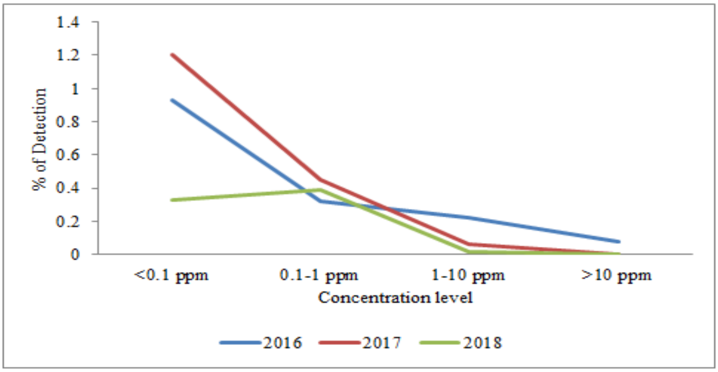



**Figure: 06 Decline of pesticide residue details in 2016-2018**

### *5.2 Impacts of fertilizers use in Sri Lanka*

Long term application and indiscriminate use of chemical fertilizers pronounced effect on the soil physical, chemical and biological properties which changes in soil organic carbon, nitrogen content and moisture, lowering the pH, salinization and decrease the living organisms in soil. Excess use of fertilizers also causes the accumulation of plant nutrients in soil especially P and K accumulation in soil which causes the nutrient imbalances in soil. This led to decline in soil fertility, crop productivity, nutrient value of the crop and lowering the quality of the agricultural produces. Over use of NPK fertilizers reduce the quantity of crops grown on soil over the years as well. Further, crops grown on over fertilized soil are more prone to attacks by insects and disease. Farmers apply high doses of fertilizers to increase crop production but this led to high pesticide residues in agricultural produces.

#### *5.2.1 Surface water contamination*

Excess use of fertilizers especially N and P fertilizers led to eutrophication in surface water because of the removal of excess nutrients from the root zone by run-off to water bodies. It may be toxic to aquatic life thereby, increasing the growth of algae in the water bodies and decreasing the levels of oxygen.

**Figure 7: Eutrophication in surface water in Nuwara Eliya**

### *Contamination of agricultural produces and ground water with Nitrate*

Agricultural produces and ground water sources that are used for the purpose of drinking contaminate with nitrate due to heavy use of N fertilizers. Nitrate poses dangerous threats to fetal development, infant health in terms of brain and immune system development, gastric cancer, goiter, birth defects, heart disease (Feigin & Halevy, 1989).

High nitrate concentrations in ground water due to excessive use of fertilizer and sewage contamination have been reported from Jaffna, Batticaloa and Kalpitiya aquifers (Kuruppuarachchi, 1995). Nitrate contents in ground water sources in sandy soils and intensive vegetable growing areas in Sri Lanka is shown in figure 8 (Kumudini *et al*, 2020). The excessive accumulation of nitrate or nitrite in plant parts consumed by humans or animals is likely to cause the same detrimental effects associated with nitrate contamination of water sources (Bhattacharyya *et al*., 2016). Table 9 showed that nitrate contents in vegetables increases with the increasing of N fertilizers while Table 10 showed nitrate contents in vegetables collected from market and organic farms.

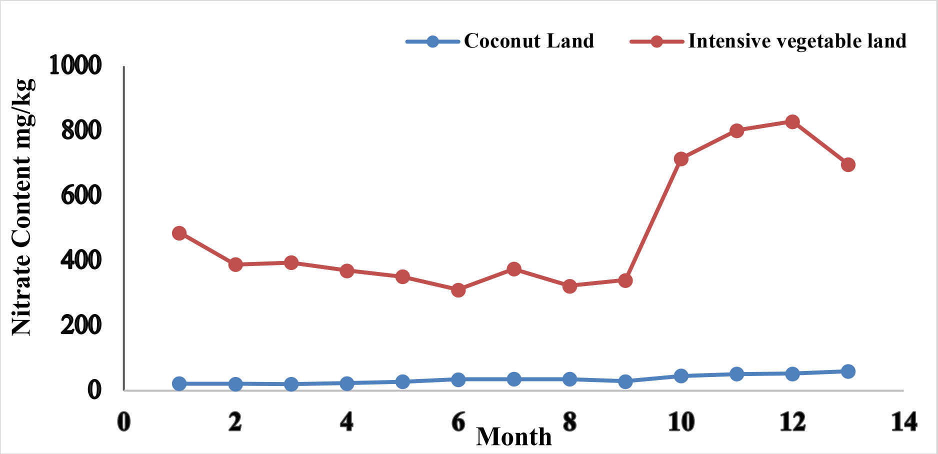



**Figure 8. Nitrate content in ground water and vegetable growing area**

*Source: Kumudni et al, 2020*

**Table 9: Nitrate content in leafy vegetables**

| Treatments | Nitrate Contents (mg/kg)- FW basis | |
|---|---|---|
| | Mukunuwenna | Kangkung |
| No N Fertilizer | 99.2 | 49.6 |
| 50% N from DOA Rec. | 314.1 | 499.2 |
| DOA Rec. N | 535.7 | 158.7 |
| 150% N r from DOA Rec | 476.2 | 162.0 |
| 200% N from DOA Rec | 790.3 | 548.9 |

*Source: DOA unpublished data*

**Table 10: Nitrate contents in vegetables**

| Vegetable | Mean Nitrate content mg/kg | |
|---|---|---|
| | Market | Organic farms |
| Green beans | 1929.76 | 517.31 |
| Tomato | 1125.72 | 271.15 |
| Brinjal | 1352.82 | 653.99 |
| Leeks | 905.043 | 468.21 |
| Carrot | 806.42 | 355.82 |
| Cabbage | 880.58 | 407.41 |
| Mukunuwenna | 1575.83 | 893.29 |
| Green Chillies | 1492.55 | 741.04 |

*Source: DOA unpublished data*

## 6. Research Findings related to Agrochemical Use.

Sri Lanka being a developing nation in the South Asian region is undoubtedly exposure to many challenges in terms of achieving the expected levels of food security resulting in the use of high quantity of agrochemicals. Indiscriminative usage of hazardous pesticides effects the health and well-being of the general public. Therefore, following research were conducted by the Department of Agriculture to assure the degree of safety of the food stuffs and water:

### *6.1 Pesticide residues in vegetables*

In 2016, 90 samples of vegetables including tomato, capsicum and cabbage were collected during the period of March to December 2016 from 3 districts. Out of 90 samples tested, 30 samples were contaminated with pesticides and the results of the study reveal that tebucanazole has higher possibility of contamination in all districts. (Lakshani *et al*., 2017).

### *6.2 Pesticide residue analysis in locally grown and imported crops*

In 2018, 111 samples of imported and locally grown potato, orange, onion, chilies, apples and grapes were analyzed for pesticide residues. 36 samples were found contaminated with pesticide and highest contamination of locally grown onion with 1.01 mg/kg fipronil and 4.6 ppm of tebucanazole presence on imported onion samples (Lakshani *et al*., 2019).

### *6.3 Pesticide residue analysis in export market*

In 2017, a total of 340 samples of fresh fruits and vegetables were analyzed for the presence of pesticide residues, out of them 65% of samples exceeded the EU MRL's and number of pesticides from identified samples were 24 and 50% of them are unauthorized to the European union. Contamination of leafy vegetables was relatively higher and most detected pesticide residues are profenaphos and tebuconazole (Magamage *et al.,* 2018)

Simultaneously, Registrar of Pesticide launched a research programme to analyze the pesticide residues in leafy vegetables. 30 samples of leafy vegetables are collected from 3 districts and profenaphos and tebucanazole were detected with exceeding MRL's. (Lakshani *et al.,* 2018).

### *Toxic trace elements in rice*

In year 2016, 68 samples of branded, local, traditional and imported rice were analyzed for As, cd, Pb, Hg and Se. The range of mean concentrations of different metals observed in different rice verities were 0.0106-0.1303 mg/kg, pb 0.150-0.211 mg/kg, cd 0.0033-0.0480 mg/kg, hg 0.0056-0.0355 mg/kg and Se < 0.2-0.4706 mg/kg. Except mean concentration of Se in imported rice and Pb in traditional rice, none of the other mean concentrations of heavy metals exceeded the permissible level recommended by FAO/WHO joint CODEX Alimentarius. Out of total samples analyzed, 98% of samples were found not exceeding the tolerable daily intake (TDI) with respect to heavy metals namely As, Cd, Se and Hg, while with regard to pb, 88 % of total samples were also under safe limits. The finding reveals that rice available in Kandy district is quite safe for consumption (Magamage *et al*., 2017).

### *6.5 Toxic trace elements in water*

Pesticides applied on agricultural lands reach groundwater by leaching, and move to offsite water bodies by direct runoff, erosion and spray drift. Therefore, an assessment of the mobility of pesticides in water resources is important to safeguard such resources. In this context, the mobility potential of 32 pesticides on surface water and groundwater was assessed by widely used pesticide risk indicators, such as Attenuation Factor (AF) index and the Pesticide Impact Rating Index (PIRI) with some modifications. Expected pesticide residue levels in both surface and groundwater were predicted to remain below the USEPA health advisory levels, except for carbofuran, indicating that pesticide pollution is unlikely to exceed the available health guidelines in the Mahaweli river basin in Sri Lanka. (Piyal *et al.,* 2016)

There are 103 rivers in the country starting from the central highlands. The Mahaweli River is a 335 km long river, ranking as the longest river in Sri Lanka. In 2018, water samples were collected from the 15 locations and analyzed for potentially toxic trace elements using inductively coupled plasma mass spectrometry. The results were compared against the drinking water standard WHO. Hg and Tl were not recorded while lower reaches of river Mahaweli from Peradeniya was comparatively more contaminated than the upper limits.

Butmanampitiya, serunuwara, Ralkuli ferry and Upparu Ferry was highly contaminated with B, Cu, As and Se. (Magamage *et al.*, 2016).

### *6.6 Toxic trace elements in agricultural soil and vegetables*

Excessive application of fertilizers and other agrochemicals may lead to contamination of agricultural soils, food crops and water resources. Major pathways of the human exposed to the trace elements are ingestion of contaminated soils, consumption of contaminated food crops and water sources. Trace metal of Cu, Zn, Cd, Pb, Cr and As contents in soil collected from intensive vegetable growing areas in Sri Lanka were within the acceptable limit shown in table 11 (Silva *et al*, 2020).

**Table 11: Toxic trace metal contents in vegetable growing soils**

| Location | Cu | Zn | Cd | Pb | Cr | As |
|---|---|---|---|---|---|---|
| Kandy | 48.1 | 60.0 | 0.47 | 6.6 | 56.7 | 21.7 |
| Matale | 62.4 | 56.4 | 0.58 | 43.5 | 45.0 | 29.2 |
| Nuwara Eliya | 38.6 | 83.2 | 0.39 | 31.0 | 72.5 | 18.7 |
| Maximum Allowable limits (EU and USEPA) | 50-140 | 150-300 | 1-3 | 50-300 | *300 | *50 |

*EU: European Union set standards for sewage sludge amended soils (McGrath and McCormack, 1999), *USEPA (McGrath et al., 1999).*

Silva *et al.*, (2016 & 2018) reported that potentially toxic trace metal concentration in vegetables collected from markets in Kandy district and root and tuber crops collected from intensive vegetable growing areas of upcountry wet zone and upcountry intermediate zone of Sri Lanka. were within the acceptable limit stipulated by WHO/FAO Joint Codex Alementarius, 2001 (Table 12 and 13).

**Table 12: Toxic trace metal contamination in vegetables collected from markets in Kandy district (FW basis)**

| Vegetable | Cu | Zn | Pb | Cd | Cr | As |
|---|---|---|---|---|---|---|
| | mg/kg | | | | | |
| Bean | 0.9 | 4 | 0.13 | 0.03 | 0.34 | 0.003 |
| Beet | 0.89 | 4.7 | 0.2 | 0.03 | 0.21 | 0.001 |
| Cabbage | 0.32 | 2.0 | 0.11 | 0.01 | 0.88 | 0.001 |
| Carrot | 0.66 | 4.9 | 0.13 | 0.04 | 0.97 | 0.003 |
| Leek | 0.96 | 3.8 | 0.16 | 0.02 | 0.43 | 0.001 |
| Potato | 0.94 | 4.6 | 0.41 | 0.02 | 0.51 | 0.005 |
| Brinjal | 1.2 | 2.1 | 0.05 | 0.02 | 0.75 | 0.001 |
| Bitter Gourd | 0.14 | 1.5 | 0.01 | 0.02 | 0.43 | 0.001 |
| Capsicum | 0.96 | 0.77 | 0.15 | 0.001 | 0.14 | 0.003 |
| *MPL (WHO/FAO Joint Codex Alementarius, 2001) | 40 | 60 | 0.3 | 0.2 | 2.3 | 1.0 |

*(Source: Silva et al, 2016)*

**Table 13: Toxic trace elements contents in root and tuber crops (mg/kg) –FW Basis collected from intensive vegetable growing areas in upcountry wet and upcountry intermediate zones**

| Element | Cu | Zn | Pb | Cd | Cr | As |
|---|---|---|---|---|---|---|
| Beet | 8.8 | 10.5 | 0.25 | 0.06 | 1.1 | 0.012 |
| Carrot | 10.9 | 12.3 | 0.33 | 0.07 | 1.35 | 0.025 |
| Potato | 2.0 | 7.8 | 0.24 | 0.07 | 1.6 | 0.015 |

*Source: Silva et al., (2018)*

## 7. Technologies and Strategies to Monitor and Control the Impacts of Agrochemicals

Sri Lanka has taken initiative to minimize the potential effects of agrochemicals on human health and the environment as described below:

### *7.1 Expansion of the analytical capacity of the laboratory*

Department of agriculture developed well equipped central soil and fertilizer testing laboratory and it was also accredited (ISO/IEC 17025:2017) from 2019 to monitor the quality of soil, water plant and fertilizers. In addition, DOA has 32 soil testing laboratories, 12 in Research Institution of DOA and other 20 laboratories in 20 districts under Provincial Department of Agriculture (PDOA). Further, research programme of monitoring of contamination of soil, water and food crops with hazardous material due to heavy use of fertilizer were conducted.

Simultaneously, Department of Agriculture has launched a Central Analytical laboratory attached to the Horticultural Crop Research and Development Institute and it is equipped with modern sophisticated technique as HPLC, GC, GC/MS, LC/MS/MS, Karl Fisher, UV spectroscopy and FTIR. This is the only ISO 17025:2017 accredited laboratory for pesticide formulation analysis in Sri Lanka. Laboratory is also accredited for pesticide residue analysis and heavy metal analysis and the Department has been conducting the several research programmes for random checking of the pesticide residues and heavy metal available on the food stuff. Registrar of pesticide office has already test the quality of the pesticide through this laboratory and issuing the repacking certificate after the confirmation of its quality. Currently, Central Analytical Laboratory has capacity for quality assurance of the 30 pesticide active Ingredients. During the year 2019 and 2020, random quality assessments of imported consignments of Fipronil (0.3% GR) from M/s Asiatic Agricultural Industries (Pte.) Ltd found to have significantly sub-standard in terms of presence of carbofuran impurity in 6 production batches and all were re-shipped. In 2020, 256 samples were analyzed from outsourced laboratories in support of compliance monitoring & issued 238 market clearance certificates on pesticide formulations covering 24 active ingredients. Meanwhile, 825 Quality Certificates were checked against FAO specifications. In addition, 251 heavy metal impurity reports were assessed. Among compliance verification for legal actions, 34 confiscated samples of Glyphosate were analyzed & reported in support on legal proceedings. (Annual report of Registrar of Pesticides Office, 2020). All pesticide industries importing 30 Mt annually have to submit the heavy metal reports for each and every formulations/technical from an accredited laboratory once a year and results are evaluated (Table 14).

**Table 14: Quality assurance of pesticides in 2017, 2018, 2019 and 2020**

| Parameter | Year | | | |
|---|---|---|---|---|
| | **2017** | **2018** | **2019** | **2020** |
| Issue of import approvals | 721 | 778 | 806 | 929 |
| Evaluation of quality certificates | 369 | 706 | 842 | 825 |
| Issue of packing clearance as per the quality analysis of samples on consignment basis | 123 | 261 | 157 | 238 |
| Evaluating Heavy metal report | 43 | 46 | 55 | 251 |

### *7.2 Update of soil fertility map*

DOA also conducted research on development and update of soil fertility map for Sri Lanka to guide fertilizer application, updating new fertilizer recommendations and developing best crop management packages for different food crops and farming systems in different agro-ecological zones and integrated use of organic and inorganic fertilizer, promotion of soil test-based fertilizer recommendations. Recently, government of Sri Lanka distributed soil field test kits among the extension staff in all agrarian service centers in the country to test the soil and provide soil health card for every farmer. In addition, application of slow-release fertilizers, application of N and K fertilizer with more splits and timely application are promoted to increase the fertilizer use efficiency and productivity of the crop and indirectly safe guard the environment.

### *7.3 Assessment of toxicologically-relevant impurities.*

Office of the Registrar of pesticide has launched a programme for the assessment of the toxicologically relevant impurities of long-term health risk. Ethylene thiourea (ETU), an impurity in one of the most extensively used class of fungicides is a potential carcinogen and required standard procedures for manufacturing it. But these impurities are not reported due to lack of analysis. Therefore, assessment of the toxicologically relevant impurities has started from 2021 (Table 15).

**Table 15: Details of the toxicologically-relevant impurities**

| Pesticide | Toxicologically-relevant impurity |
|---|---|
| Carbosulfan | N - nitrosodibutylamine |
| | 5-chlorocarbofuran |
| Chlorothalonil | Hexachloro benzene(HCB) |
| | Decachlorobiphenyl(DCB) |
| Diuron | Tetrachloroazobenzene(TCAB) |
| Fipronil | N-Nitrosodimethylamine(NDMA) |
| Mancozeb | Ethylene Thio urea(ETU) |
| Profenaphos | 4-bromo-2-chlorophenol |
| Propineb | ProphyleneThio urea(PTU) |
| Propanil | Tetrachloroazobenzene(TCAB) |

### *7.4 Assessment of pesticides in maize*

Fall Armyworm (FAW) or *Spodoptera frugiperda* has been reported in all major maize growing areas in Sri Lanka by end of December 2019. Department of Agriculture recommended 8 insecticides and depending of the situation. DOA conducted a research programme to assess the pesticide residue after the pre-harvest interval. In 2019, two supervised field trials were carried out at Field Crop Research & Development Institute, Mahailluppallama (Dry Zone) and Agriculture Farm at Pasyala (Wet Zone) to determine residue status of 8 insecticides used on maize crop. The analytical results of five insecticides were received in 2020 and the data analysis revealed that the residues of insecticides spinetoram, spinosad, chlorantraniliprole and diazinon were detected above the maximum residue limits (MRL) days after keeping the recommended pre harvest intervals (Figure 9). In 2021, Central analytical laboratory has conducted a research to the assessment of the pre-harvest interval on tomato and pesticide and in 2021, Office of the Registrar of Pesticides will continue it for Bitter gourd and Brinjal.

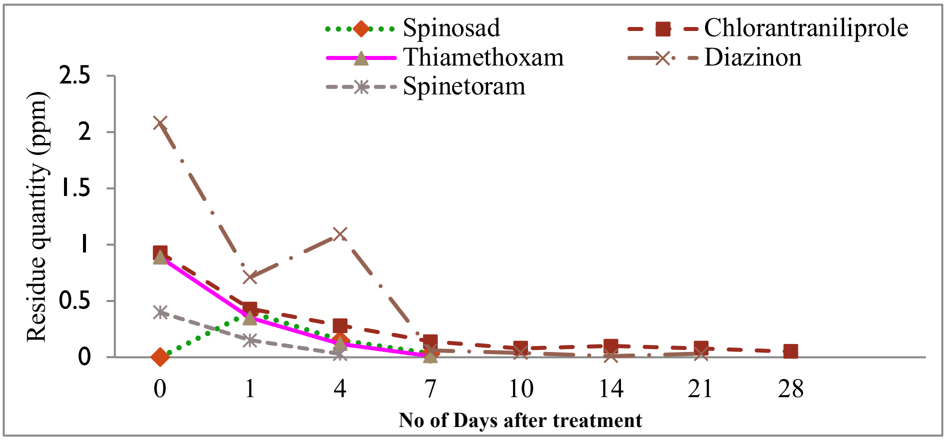



**Figure: 09 Residue level status of five insecticudes in maize after application of pesticides**

### *7.5 Incidences monitoring and occupational exposure study*

A survey among 228 farmers in Puttalam, Kurunegala and Anuradhapura districts was carried out to monitor pesticide use scenario and incidences with the objectives of assuring occupational safety and minimizing risks to human health. The project was funded by FAO/ Rotterdam Secretariat. Among the large amount of collected data were demographic & socio-economic facts, pest control scenario, pesticide and personal protective equipment use & knowledge, health issues faced during pesticide use etc. Under the normal use patterns in Sri Lanka, 85 different incidences were monitored, questioning the safety at occupational level. For minimizing the risks, safety kits were purchased to distribute among the surveyed farmers at awareness programmes.

### *7.6 Identification of toxicity status of insecticides on honey bee (Apiscerana)*

For registration, Sri Lanka rely on bee toxicity data generated for *Apismelifera* due to lack of data generated on *Apiscerana* species. Since the local endemic honey bee species is *Apiscerana,* it is important to assess the risk posed by pesticides on it. A project has been initiated at laboratory level to assess the risk of selected pesticides on local honey bee *Apiscerana* and validating test methodologies and identification of toxicity status of twenty selected commonly used insecticides on local honey bee (*Apis cerana*) to ensure pollinator safety.

### *7.7 Safe disposal of pesticides container*

Mismanagement of agrochemicals containers waste constitutes a major environmental problem, resulting in pollution of soil, air, and water resources compromising the agricultural products safety, protection of the environment, and public health. Department of Agriculture, established 5 empty container collection centers at Seetha aeliya, Palwehera, Makandura, Karadiyanaru, Angunakolapalassa, and ultimately empty containers are recycled as raw materials for furnishing products.

### *7.8 Incineration of outdated pesticides*

25 tons outdated pesticides since 1970 accumulated at Department of Agriculture and Obsolete stocks of chemicals stored at facility at Field Crop Research and Development Institute (FCRDI), Maha–illuppallama and confiscated glyphosate stocks those were stored at Puttalam, Matara, Kotte and Getambe totaling up to 30.6 tons were co-processed at M/s INSEE Eco Cycle.

### *7.9 Detection of Counterfeits pesticide*

Counterfeit and illegally sold pesticides are a rapidly growing problem in Sri Lanka, which affects the food production, health of farmers, consumers, and the environment. Counterfeits, which have packaging that is authentic in appearance but contain impure or incorrect chemicals or illegal imports, which are generic copies of legitimate products of pesticides. It is very important and compelling to eliminate trade of illegal pesticides. In 2019, legal actions against perpetrators of illegal trafficking & smuggling of Glyphosate were taken. A total of thirteen court cases were conducted against illegal Glyphosate.

### *7.10 Introduction of New Labeling System*

New labeling guideline was issued in order to implement the *Gazette Extraordinary* No. 2135/53 dated 07.08.2019 issued under the Consumer Affairs Authority Act No. 09 of 2003 on putting additional information, viz. Country of Origin/Country of Manufacture & Date of Re-packing. In addition, the Mode-of-Action code was given more prominent position on the front panel for easy comprehension by the farmer & the extensions for adoption.

## 8. Farmers' Perception on the Use of Agrochemicals

### *8.1 Inappropriate Use of Pesticides*

Despite the knowledge on risk of handling pesticides, farmers prefer to apply pesticides without protective measures. They feel the personnel protective measures are inconvenient to wear in the hot and humid climate. Investigations have shown that the incidences of overexposure are common in spraying situations and overdosing can take place not following the label instructions on safety. Application of pesticides to harvest fruits and vegetables and harvesting before completing the preharvest interval (PHI) also contribute to accumulation of pesticide residues. The over use of pesticides can result in high residue level in commodities and in the immediate environments such as soil, biota and aquatic system. (Marasinghe *et al.,* 2018)

According to the literature, 50% of farmers apply higher concentration of pesticides than recommended level to the fields. On the other hand, in 37% of the cases, the time between harvest and last spay is less than 7 days. Such vegetables have a higher possibility to carry harmful residues to humans and those chemicals do not degrade rapidly (Samarajeewa, 2007).

### *8.2 Indiscriminate use of fertilizers*

Excessive application of chemical fertilizers, soil amendments such as lime, dolomite etc., and organic manures, continuous cultivation without any fallow period are major constraints in the intensive vegetable growing areas in the country. Less or no application of organic matter to the soil is major problem among the farmers in low country. In addition, almost all farmers in the country use non-recommended fertilizers, do not follow the recommended technologies of fertilizer application. Therefore, nutrient supply capacity in soils decreased considerably and yields of crops and soil fertility decline.

## 9. Research–Extension-Farmer Linkages

### *9.1 Pesticides used in Agriculture*

Presently, farmers have been noted to use pesticides more than recommended dose and spray on not recommended crops. As an example, profenaphos has not recommended for leafy vegetables but farmers use it which resulted in exceeding MRL's of exported leafy vegetable consignments. Farmers do not follow the pre-harvest intervals and repeated application of pesticide resulted in accumulation of pesticide residues. Further, frequency of pesticide application exceeds the recommended times. In the long run, this can create pest resistance towards pesticides. Even though awareness programs on the handling, proper attire and safe practice associated with pesticide use is conducted via training and media campaigns, farmers do not follow the safe practices in most of the cases due to the high cost and they are not sufficiently protected during application. Proper storage of pesticides is also not done in a safe manner, empty bottles disposal is not proper and half-full pesticide bottles are often disposed at the sites or with municipal solid waste, leading to contamination of water ways. The major issue of pesticide application is not using the calibrated and standard nozzles. The recommended nozzle is hollow cone and most of the farmers use flat fan nozzle where outflow is doubled when compared, according to the DOA. The cost incurred for this is doubled creating a lot of environmental issues and toxins are directly sprayed in to the air contaminating the surrounding environments as well (Agriculture modernization project, 2016).

### *Fertilizer used in Agriculture*

Farmers use more than recommended level of fertilizers and non-recommended fertilizers. Lack of knowledge of farmers on technologies of correct fertilizer application and inadequate linkage and interaction among researchers, extension officers and farmers are major problem to dissemination of best practices. Therefore, government and other respective organizations should encourage the farmers by providing suitable facilities, conducting large scale demonstrations, training and awareness progrmmes. Further, those relevant organizations should develop suitable technologies on correct fertilizer application based on different agro-ecological zones, soil types and different cropping systems. In addition, soil test-based fertilizer recommendation should be popularized among the farmers and they should encourage to follow the soil test-based recommendation.

## 10. Challenges of Agrochemical Uses in Agricultural System

### *10.1 Lack of the monitoring system and interactions*

There are no any programmes to monitor the quality of the environmental samples and agricultural inputs in the market continuously. Due to the lack of knowledge on best practices among the farmers and their attitude of getting quick economic benefits, they do not follow any fertilizer recommendation or other recommended technologies. This is because of poor linkages and interactions among researchers, extension officers and farmers in the use of fertilizers and pesticides in agricultural system. No proper coordination among relevant stakeholders such as Department of Agriculture, National Fertilizer Secretariat, Agrarian Development Department and private companies.

### *10.2 Inadequate analytical facility*

There are no adequate analytical laboratory facilities to analyze the chemicals residues and impurities. There is no program currently in place in the country to conduct continuous monitoring of residues, due to lack of required laboratory facilities. Therefore, analytical capacity has to be developed based on the requirement. Currently, there are 6 laboratories accredited for pesticide residue analysis only. Residue analysis is quite expensive due to use of traceable grade standard and reagents. Laboratory facility for analysis of bio pesticide is less due to unavailability of standards.

### *10.3 Not following preharvest interval*

Establishment of the pre harvest intervals is important to calculate the MRL's and check whether preharvest interval does not exceed the MRL's. Regulatory authorities have the necessary mandates for establishment of Maximum Residue Limits (MRL) for crops with respect to pesticides registered in the country. It enables to determine the Pre-Harvest Intervals (PHI) for pesticides given in the label for the farmers to follow, thus maintaining residue in acceptable levels. Analyzed data revealed that the residues of insecticides spinetoram, spinosad, chlorantraniliprole and diazinon were detected above the maximum residue limits (MRL) days after keeping the recommended pre harvest intervals. Therefore, establishments of the preharvest intervals play a vital role in food safety and farmer should follow pre harvest intervals.

### *10.4 Poor research on toxic metabolites*

Public concern over pesticide residues in vegetables and fruits has been increasing during the past years. But no research has been carried out for detection of the metabolites. As some of those chemicals are potential carcinogens, presence of traces in the environment poses serious threat to human health

### *10.5 Inadequate facility for incineration*

Holcim Geocycle is the competent authority for incineration of hazard waste in Sri Lanka. But they do not have adequate facility to incinerate all the waste. Therefore, establishment of the incineration system may help to disposal off outdated pesticides, packaging and waste generated during the repacking

### *10.6 Not practicing IPM*

Pesticides dependent pest control practices are common in the country which results in unexpected massive destruction of pollinators of crop plants leading to poor crop yields. Further, use of pesticides develop pests' resistance to pesticides, encouraging further increases in the use of chemical pesticides leads to contamination of the soil and water bodies, Pesticide poisoning of farmers and decline of biodiversity in the environment. Therefore, considerable attention needed to be given for IPM practice in agriculture sector.

## 11. The Way Forward for Optimum Agrochemicals Use in Agricultural System

### *11.1 Optimum pesticides use to prevent adverse impacts*

Our target is to build "Centre for Pesticide Regulation and Safety (CPRS)" to ensure environmental, health, consumer safety and food security at par with the national & international standards. Following are the points for optimum agrochemicals uses in the agricultural system to prevent the adverse impacts:

Registrar of Pesticides has proposed to develop the infrastructure at office of the Registrar of Pesticides with Sri Lanka Customs for compliance monitoring programme by establishing a laboratory facility with fast detective equipment like Raman Spectroscopy and FTIR Technology. Further, establishment of the sample point at sea port will prevent the quantity of low-quality products entering to the country.

As the current pesticides regulation does not provide guidelines for the registration of bio pesticides until necessary amendments are made, Special Technical Advisory Committee was appointed in 2015 to prepare the guidelines for bio pesticide registration in Sri Lanka. Presently, guidelines are prepared for registration of locally produced botanicals, Entomopathogenic Fungi, Entomopathogenic bacteria, Antagonistic fungi, Antagonistic bacteria, and Baculoviruses. In these guidelines comprise of description, biological characteristics and chemistry, bio efficacy, toxicity, packaging, and labeling.

Currently, Department of Agriculture has launched several research programme to assess the fate of the pesticides and their metabolites, and establish the pre harvest intervals by supervised trials for selected pesticides. The analytical capacity is being facilitated by the Department of Agriculture. The Department has upgraded with ISO 17025:2017 accreditation for two laboratories including Pesticide residue analysis, pesticide formulation analysis, heavy metal analysis and fertilizer analysis. These laboratories are equipped with sophisticated instruments like LC/MS/MS, ICP-MS, ICP-OES, GC/MS, GC-FID-ECD, HPLC, FTIR, Karl Fisher, etc.

Increasing the analytical capacity and assessment of the banned pesticide residues in water bodies and river basin, and regular pesticide residue monitoring program for all Sri Lanka imported and local crops including the processed food should be done on a priority basis. Establishments of the proper surveillance system in health sector for chronic health effects due to exposure of pesticides is important. Central Analytical Laboratory for pesticides related research including toxicological analysis and chemical analysis are identified as important research areas to minimize the potential effects from agrochemicals.

Awareness programmes of stakeholders for management of pesticides and appointment of rapid deployment unit with legal officers to control counterfeits should also be done on a priority basis. Encourage to replace chemical pesticides by bio-pesticides and initiate research programme in collaboration with universities and sharing resources have to be implemented for the proper management of the health and to minimize effects on the environmental by agrochemicals.

Introducing the improved technologies of crop cultivation under poly tunnels, application of drip irrigation systems, optimum input applications, pest and disease control, postharvest management, quality packaging and improved transportation methods will play crucial role in optimum use of agrochemicals.

### *11.2 Optimum fertilizers use to prevent adverse impacts*

Declining of soil nutrients due to imbalance and indiscriminate use of fertilizers are major problem in soil fertility management, crop productivity and environmental safety. Therefore, it is important to introduce sound nutrient management programme like integrated plant nutrient management system in the country. Government of Sri Lanka promotes balance use of organic and inorganic fertilizers. Therefore, Ministry of Agriculture and Department of Agriculture developed a national policy for the promotion of Integrated Plant Nutrition System (IPNS) in Sri Lanka.

In addition, periodic monitoring of environmental contamination such as food crops, water and soil and quality of the fertilizers in the market are needed. Therefore, sufficient laboratory facilities should be developed. Government of Sri Lanka popularized soil test-based fertilizer recommendation among farmers and it has successfully made a difference. Hence, Ministry of Agriculture has planned to distribute soil test kits for all Agrarian Service Center of the country. Slow-release N fertilizers, use of plant test kits or leaf colour charts should be introduced for all crop sectors to manage the nitrogen fertilizer. Farmers should be encouraged to follow application of any fertilizer at an economic rate other than optimum rate and application of fertilizers from right source, rate, placement & time. It will then reduce the adverse effects on both the crop and the environment.

## 12. Government Restriction on Import of Agrochemical

With effect from 06.05.2021, Sri Lanka has been converted to the green agriculture by imposing the government's restriction on agrochemicals imports under the Imports and Exports (Control) Regulations No. 07 of 2021 (regulation), as published in the Sri Lanka Gazette No. 2226/48 of May 6, 2021. Green agriculture is a major national priority for healthy society and to protect the environment. Therefore, it is proposed to strengthened institutional capacity to tackle the issues of human health and environment in the country.

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Chapter 9

# Impact of Agricultural Chemical Inputs on Human Health and Environment in Afghanistan

**Fariba Amini**[1] and **Tamana Dawi**[2]
Ministry of Agriculture, Irrigation and Livestock
[1]*fariba.amin999@gamil.com; tmndawi@gmail.com*

## 1. Introduction

Agriculture is the basis for Afghan economy and a vital source of livelihood employing 62.2% of the national workforce out of 10.9 million people. Approximately about 80% of the population directly and indirectly are engaged in agriculture sector where some are involved in secondary or tertiary activities. This sector is considered a source of economy, wealth and capital for the Afghan future. Some of the former agricultural infrastructures have been restored, and considerably more remains to be done in this sector as new possibilities in the development of infrastructures and technologies are emerging. However, the agriculture producers, processors and traders are demanding for more support in market assessment and new market identification for their products. Agricultural practices in Afghanistan represent an evolving narrative – while some farmers continue to engage in subsistence farming, many are discovering that intensive farming is profitable, but only if Government invests in creating a range of services and enabling structures.

The seminal planning framework for development has been the Afghan National Development Strategy (ANDS-2008), within which, a National Agricultural Development Framework (NADF-2009) was developed. A series of 22 National Priority Programs (NPPs) were formulated following the Kabul Conference in 2010, of which the Ministry of Agriculture, Irrigation and Livestock (MAIL)'s priorities were reflected within two programs i.e. Agriculture and Rural Development (ARD) Cluster's NPP1 which dealt with water, irrigation and natural resources and ARD NPP2 program dealt with agriculture priorities in production, market development and food security covering 2012-2014 period. This also includes the formulation of various agricultural sub-sectoral policies and strategies such as policies for wheat, poultry and food and nutrition, women in agriculture, medicinal plants etc.

These policies emphasis and reflects the views of the Government and the Ministry's leadership in realigning the broader priorities of the MAIL into seven key areas with specific focus on creating an enabling environment for farmers, to produce agriculture surplus and increase commodities, to increase on and off-farm employment, and to generate income through increasing exports. The identified strategic priorities in the NPP will still continue to form the broader backdrop for agricultural development in order to underpin the capacity of MAIL to support and enable the achievement of targets under these priority areas. The seven key priorities for MAIL mostly cover the institutional and sectoral priorities in the following area:

- Improved service delivery;
- Food security;
- Increased productivity to enhance national revenue.

While, the specific redirection of priorities is in the following sectors and in the form of seven Strategic Priorities: (1) Irrigation; (2) Wheat and cereal production; (3) Horticulture value-chain; (4) Livestock Production; (5) Climate-sensitive Natural Resources Management; (6) Food and Nutrition Security and Resilience building; and (7) Institutional reform and capacity development. The above priorities will include many of the normative integrated activities such as Research and Extension, Integrated Pest Management; Input Delivery Systems; Quality Control; Quarantine; Farmer Organizations, Public & Private Partnerships; Data and Information; Policy and Legal Framework; and Governance and Coordination.

The total arable land area is 12% that includes irrigated area, rain-fed land, and temporary fallow land. At the same time, 3% of its area is covered by the forest, 46% covered by permanent pasture and 39% covered by villages, mountains and rivers. Agricultural crops are cultivated in rain-fed and irrigated areas; however, rain-fed wheat has an important role for the cereal production. Wheat is the major crop for the production of cereal in the country which constitutes 89% of consumption. Fruits, including watermelon and melon, apricot, pomegranate and grape are produced for consumption and export. Dried fruits especially apricot and almond play a significant role in exports

## 2. Major Crops

Wheat is a major crop grown every year on irrigated and rain fed land. Wheat production in 2019 was 4.89 million tons, rice 0.38 million tons, barley 0.12 million tons and maize 0.18 million tons. So, the total land under grain cultivation was 2.9 million hectares. Vegetables are mostly grown for market and home consumption. An estimated 5.12 % of the total irrigated land was planted with vegetables; the total area under potato cultivation was 57,000 hectares while its production was 921,000 tons with its yield of 16 tons per hectare. Potato and onion are major vegetables and particularly used as staple food in the country. The area under onion cultivation in 2019 was 18,343 hectares. Different varieties of fruit trees such are apple, pomegranates, apricots, mulberries, grapes and almonds were grown in almost 2.84% of the arable land (222,000 hectares). Grape's production was 1,112,000 tons. Almost all farming households in the rural area have some fruit trees for self-consumption. In addition, orchards are the major source of income for farmers in many areas of the country and the majority of large to medium sized orchards are exclusively for markets production.

## 3. Agrochemicals – Pesticides and Fertilizers

Agrochemical or agrichemical is defined as any chemical used in agriculture such as pesticide or fertilizer. However, in most the cases, agrochemical refers to pesticides which includes insecticides, herbicides, fungicides, nematicides, molluscicide, piscicide, avicide, rodenticide, bactericide, insect repellent, animal repellent and antimicrobials.

The Environmental Protection Agency (EPA) and the U.S. government defined pesticides as any substance or mixture of substances intended to use for preventing, mitigation, repelling or controlling any pest including vectors of human and animal diseases. While pesticides also include plant regulators, defoliants and desiccants. Pesticide's invention enabled the growers to produce more crops on less land with high productivity rate between 20 and 50 percentages (Croplife India, 2021). Pesticide safe usage allows the growers to maximize the valuable agricultural crops tools benefits such as quality seeds, fertilizers and water resources. Therefore, pesticides safe usage can lead to a sustainable production of high-quality food and fibers per unit area with less tillage, thus limiting deforestation, conserving natural resources and decreasing the soil erosion while controlling the invasion of pest species and weeds (Croplife India, 2021).

### *3.1 Effects of pesticides*

The effects of pesticides use in agriculture are:

- It causes environmental pollution and kills the beneficial insects and birds;
- Having high residue in the soil and plants and contamination of human and animal food and water;
- It causes insect pests resistant to pesticides and helps the non-native pests' species by killing the natural enemies;
- It could break the food chain or could stops it.

### *3.2 Type of pesticides*

- *Insecticides*: Insecticides are the chemical substances that are used against insect eggs and larvae such as ovicides and larvicides. Insecticides are widely used in agriculture, medicine, industry and by household consumer;

- *Rodenticides*: Are the pesticide that kill rodents such as mice and rats. It is usually formulated as baits with attractants which is providing a short-term control for rodent infestations;
- *Herbicides*: They are chemicals that used to employ and control the undesirable vegetations. It can be applied either before or after planting to maximize crop production and minimize the undesirable vegetation growth;
- *Miticides*: Used in the fight against animal and vegetable mites;
- *Algaecides:* Used against algae, such as blue seaweed;
- *Fungicides*: It is used to control the fungal pathogen on the crop or animal (such as powdery mildew on grapes and ring worm in animals);
- *Nematicides:* It is used to kill plant-parasitic nematodes. However, it can be used for the indoor pest control, termite, pet collars, school use, restaurant use, and hospital use;
- *Bactericides:* It is a chemical agent that is helping in preventing the formation of bacteria or kill bacteria.

### *3.3 Essential points on using pesticides*

- Right selection of pesticides and safe transportation of pesticides;
- Storing pesticides (It should be store in a separate dry and cool place away from food products).
- Safe mixing and using pesticides;
- How to use pesticides?
- Dispose of empty containers and pesticide residual;
- Safety points for the applicators, plant protection officers and farmers.

### *3.4 Pesticide safety tips*

The most effective way to reduce risks posed by pesticides is to use non-chemical control methods. Likewise, pesticide use should be the last option of pest control in the production area; in case of using the pesticides to control the growing pest following points should be considered widely:

- Read the label before buying and using the pesticides, so this will help us to understand the active ingredient and inert ingredients;
- Use pesticides only for the pests that are listed on the label. This will help to understand about the legal use of the product;
- Only use the dosage as indicated on the label;
- Use protective measures when handling pesticides as directed by the label, such as wearing impermeable gloves, long pants, and long-sleeve shirts.

Change clothes and wash your hands immediately after applying pesticides;
- Don't spray on windy or rainy days.

### 3.5 Methods of pesticide application

The successful application method depends on how we select and use the pesticide to eradicate the pests. The following factors are governing the right and safe pesticides application:

- The type of pest to deal with and the environment that the pest thrives in;
- Preferred method of delivery and the available equipment to use in delivering the pesticide;
- The considered control measures to reduce any potential risk to the environment, human and animal life.

### 3.6 Types of pesticide application

Different application methods work on different kinds of crop and pest; the most common methods of application are:

- Band application, where you apply the pesticide in between the rows of crops rather than over the entire area;
- Broadcast application which spreads the pesticide over the entire area;
- Direct-spray which takes the pesticide directly to the pest while reducing its exposure to surrounding crops;
- Foliar application for pests that usually attack leaves;
- Soil incorporation which puts the pesticide directly into the soil by using irrigation equipment;
- Tree injection which places the pesticide right underneath a tree's bark.

### 3.7 Authorized fertilizers in Afghanistan

The list of fertilizers below is permitted by the plant protection and quarantine department's technical board and the import of these fertilizers are not ban in the country. However, in case of fertilizers production in the country, it can be exported.

- Uriah fertilizer;
- Riah fertilizer with Sulfur cover;
- Macro grain urea fertilizer;
- Triplephosphite fertilizer (0-46-0);
- Benchmarks of zenny urea fertilizer;
- Dominium phosphorite fertilizer (0-46-18);
- Monoemonium fasphyte or emofus fertilizer (11-46-0);
- Nitrous fertilizer (0-23-23);

- Criteria of grained potassium chloride fertilizer;
- Fully dissolved in water (20-20-20) K-P-N Complex determinants;
- (14-28-14) Water disbandment (N-P-K) complex fertilizer;
- Criteria for n-p-k complex fertilizers (dissolved in water 14-35-14);
- Krap Max fertilizer;
- Biological fertilizer of Rhizobium;
- Biological fertilizer of Esotobacteria.

## 4. Impacts of Pesticides on Human Health

According to the recent researches on pesticide impact on human health, it is clear that pesticides can cause health issues in two distinct ways of acute and chronic. In acute pesticide exposure, it causes stinging eyes, rashes, blisters, blindness, nausea, dizziness, diarrhea and death. While, chronic effects are cancer, birth defects, reproductive harm, immunotoxicity, neurological and developmental toxicity, and disruption of endocrine system. The researches depicted that the vulnerability rate to pesticide impact differ from people to people for example, infants and young children are more susceptible compared to the adults. However, farm workers and pesticide applicators are also more vulnerable since they receive the great amount of the drift and exposures.

### *4.1 Toxicity of pesticides*

In human exposure situations, toxicity by pesticides may be divided into three main types, based on the exposure time to the pesticide and how rapidly the toxic symptoms develop (Damalas and Kourtroubes, 2016).

**Table 1: Types of toxicity based on the extent of exposure to a pesticide**

| Type | Definition |
|---|---|
| Acute toxicity | Occurring from a single incident of exposure (single short-term exposure). |
| Subchronic toxicity | Occurring from repeated incidents of exposure over several weeks or months (intermediate exposure, normally less than the lifetime of the exposed organism). |
| Chronic toxicity | Occurring from repeated incidents of exposure for many months or years (repeated long-term exposure, sometimes lasting for the entire life of the exposed organism). |

*Source: Damalas and Kourtroubes, 2016*

### *4.2 Classification of Toxicity by Route of Entry*

Pesticides can enter the human body via three common ways: through the skin (contact), the mouth (ingestion), and the lungs (inhalation):

#### *4.2.1. Through the skin*

Pesticide easily absorbs through the skin and it is a very common way for its entry. Dermal absorption may occur as a result of splashes and spills when handling (mixing, loading or disposing of) pesticides. Powders, dusts, and granular pesticides are not absorbed so easily through the skin and other body tissues as are the liquid formulations. On the other hand, liquid pesticides containing solvents (e.g., organic solvents) and oil-based pesticides usually are absorbed more quickly than dry pesticides (Damalas and Kourtroubes, 2016).

#### *4.2.2 Through mouth (Ingestion)*

Pesticides entering the body through the mouth (oral exposure or also called ingestion) may cause serious illness, severe injury, or sometimes even death. These products may be consumed accidentally or intentionally by individuals who intend on personal harm. Oral exposure can also occur when hands are not properly washed before eating or smoking. Frequent cases of accidental oral exposure, probably the most frequent, are those in which pesticides have been moved from their original labeled container to an unlabeled bottle or food container. There are many cases where people have been poisoned by drinking pesticides or water stored in pesticide-contaminated bottles (Damalas and Kourtroubes, 2016).

#### *4.2.3 Entry through Inhalation (Nose)*

Pesticides entering the body through inhalation can cause serious damage to the nose, the throat, and the lung tissues. The rapid absorption of pesticides through this specific route increases the risk of respiratory exposure. The greatest potential for poisoning via respiratory exposure is with vapors and extremely fine particles of the spray solution. Respirators and gas masks can provide protection from respiratory exposure. Eyes are particularly sensitive to absorption, and therefore any contact of pesticides with the eye presents an immediate threat of injury, blindness, or sometimes even death. Therefore, protective goggles should be used whenever there is a possibility of pesticides coming into contact with the eyes (Damalas and Kourtroubes, 2016).

### *4.3 Protective clothing (defensive)*

A person who uses one of the pesticides with regard to the weather conditions of the region and considering the properties and shape of pesticides should use clothes and protective equipment that are easy to wear and mastered, the use of such clothes is more than necessary. Protective gloves are one of the most important protective tools that are necessary to be in every pesticide warehouse and when packing and colonization of pesticides. Gloves should still be worn when there is a risk of cutaneous mollification of the body, long serita gloves should always be used. The gloves should be washed by soap or detergent and good water after being washed well. Boots that are used for chemicals spraying should be made of rubber. When spraying pesticides, hats and other protective gears for face should be worn. Different types of masks are used based on the nature of pesticides.

## 5. Use of Bio-pesticides in Afghanistan

Bio-pesticides are inherently less toxic than conventional pesticides. There is no evidence on widely use of bio-pesticides in agriculture sector in Afghanistan because of limited availability of bio-pesticides in the country. Farmers have no knowledge about bio-pesticides and their usage in agricultural fields. It is important to train farmers around the country on the use of bio-pesticides practice in agriculture. The Ministry of Agriculture, Irrigation and livestock of Afghanistan has got sole responsibility to import the required bio-pesticides for a short-term and for a long-term supply, bio-pesticides should be produced in Afghanistan. Bio-pesticides generally affect only the targeted pests and closely related organisms, in contrast to broad spectrum of conventional pesticides that affect non-targeted organisms, insects, birds and mammals. It is often effective in very small quantities and often decompose quickly, thereby resulting in lower exposures and largely avoiding the pollution problems. When it is used as a component of Integrated Pest Management (IPM) programs, bio pesticides can greatly decrease the use of conventional pesticides, while crop yields remain high. The government should create enabling environment for the farmers to use bio-pesticides and develop capacity of all stakeholders for effective use and to avoid adverse impacts from conventional pesticides use.

## 6. Bio-pesticides Use in Afghanistan

Bio-pesticides are used on a limited scale in Afghanistan as it is not widely available. The effects of limited bio-pesticides used in Afghanistan were found to be successful in crop protection. During the last 2-3 years the following bio-pesticides were imported by the government and used in some regions of Afghanistan:

- The bio-fungicide, Trichoderma, is used in two provinces to fight fungal diseases in vegetables. Ground application equipment is used to disperse this pesticide in a total of 20 hectares of farmland.
- Madix plus is used in 15 northern provinces to control codling moth in apple production. Ground application equipment is used to disperse this pesticide in a total of 200 hectares of farmland;
- Dipple 150 dust is used by Kabul University's Faculty of Agriculture to prevent cabbage worms and grape leaf folder in leafy vegetable

production. Powdering by hand techniques are used to disperse this pesticide in a total of 2 hectares of farmland.

## 7. Challenges and Way Forward

The following are the challenges faced by the agriculture sector with regards to agrochemicals uses in the country:

- No guidelines for farmers to use agrochemicals and to safeguard farmers from adverse health impacts;
- No long-term strategies, policies and management plans about usage of agrochemicals and their impact on human health and environment;
- Lack of capacity building plan for farmers;
- Inadequate public awareness about agrochemicals inputs and its impacts on human health and environment;
- Security issues for data collection and implementation of plans and programs in the villages.

Government is likely to continue imposing strict safety criteria on conventional pesticides, this will lead to increase in import of bio-pesticides to the country. Perhaps the biggest advances in bio-pesticide development will come through exploiting knowledge of the genomes of pests and their natural enemies. This information will give us new insights into the ecological interactions of pests and bio-pesticides and lead to new possibilities for improving bio-pesticide efficacy. Situation of Afghanistan is very suitable for product of bio-pesticides as Afghanistan is an agrarian country and the government is prioritizing human health and environment.

The adverse effects of these synthetic chemicals on human health and environment can only be reduced or eliminated by adopting new agricultural technological practices such as shifting from chemical intensive agriculture to the use of organic inputs such as manure, bio-fertilizers, bio-pesticides, slow-release fertilizer etc. Afghanistan should work on organic farming as organic resources are available in many Provinces of Afghanistan. Opting organic farming will create a healthy natural environment and ecosystem for the present as well as for future generation. Regulations, strategies, policies and long-term management plans for agriculture should incorporate measures to protect environment and human health from adverse impacts of agrochemical use in agriculture. Close collaboration and coordination between partners working in agriculture sector should be strengthened to produce safe food and at a same time protect human health and environment.

## 8. Conclusion

It is found that over-use of agrochemicals in farmland has already been a serious problem in Afghanistan. Chemical fertilizers play a great role in agricultural growth, however, indiscriminate application of these fertilizers adversely affect the quality of soil, water and air. Excessive use of agrochemicals results in ecological imbalance and gradually lead to environmental degradation. Non-target organisms have been affected by agrochemicals inputs resulting in loss of biodiversity. People are exposed to various kinds of complicated diseases and experienced health complication like cancer, heart disease, diabetes, kidney problem, eye sight issues, and skin diseases. Moreover, neurological, urinary and reproductive health are presently at risks due to agrochemicals impacts. To minimize these problems, policy-makers have to formulate laws and regulations to prevent adverse impacts of agrochemicals on the environment and human health. Implementation of legal frameworks have to be emphasized and field level agricultural administration has to be committed and accountable, so that they can control agrochemical use.

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# Report of the SAARC Regional Expert Consultation Meeting on "Impact of Agricultural Chemical Inputs on the Environment and Human Health in South Asia" *(virtual)* organized by the SAARC Agriculture Centre (SAC), Dhaka, Bangladesh

(21-22 April, 2021)

## Opening of the consultation meeting

The SAARC Agriculture Centre (SAC), Dhaka, Bangladesh organized the Virtual Regional Expert Consultation Meeting on 'Impact of Agricultural Chemical Inputs on the Environment and Human Health in South Asia' during 21-22 April, 2020. Mr. Kinzang Gyeltshen, Senior Program Specialist (NRM) was the Program Coordinator and led the SAARC regional expert consultation meeting. The meeting was attended by the National Focal Experts of 8 SAARC Member States; Director, Senior Program Specialists, Senior Technical Officer and Senior Program Officer of SAC. Welcome address was delivered by Mr. Kinzang Gyeltshen, Senior Program Specialist (NRM), SAC and special remarks of the meeting were delivered by Chief Guest, Mr. Md. Mesbahul Islam, Senior Secretary, Ministry of Agriculture, Government of the People's Republic of Bangladesh and Special Guest, Dr. S. M. Bokhtiar, Executive Chairman, Bangladesh Agriculture Research Council. The Director of SAARC Agriculture Centre, Dr. Md. Baktear Hossain chaired the inaugural session and delivered the closing remarks.

## Objectives

- ❖ Assess the impacts of agricultural chemicals inputs on the environment and human health;
- ❖ Share technologies and strategies to monitor and control the impacts of agrochemicals inputs;
- ❖ Identify issues and challenges to minimize impacts of agrochemicals inputs on the environment and human health.

## Paper Presented

A total of eight country papers on 'Impact of Agricultural Chemical Inputs on the Environment and Human Health in South Asia' were presented at the regional consultation meeting covering Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan and Sri Lanka.

## Recommendations

The following recommendations emerged during the virtual regional expert consultation meeting 21-22 April, 2020:

## Policy

- Develop/ strengthen national policies on research & development of agrochemicals and strengthen the regulatory mechanism for their rational use.
- Review agrochemical Acts/Regulations in SAARC member countries.
- Provide incentives to bio-pesticide and bio-fertilizer (bio-stimulant) manufacturers, promoters and users.
- Develop regional level protocol on transboundary movement of pesticides and bio-control agents.
- Develop a Rapid Alert System for food and feed at regional level by networking the national laboratories of Member Countries under the umbrella of SAARC Agriculture Centre.

## Strategy

- Strengthen research for developing IPM/IPNS technologies.
- Develop strategy for availability and easy access of bio-pesticides and bio-fertilizers to farmers.
- Develop collaborative bio-pesticides development and dissemination mission mode program.
- Develop strategy to promote micronutrients use to develop self-defense mechanism in plants against insect pests and diseases.
- Develop roadmap for one health program (soil-plant-animal/human continuum) with special emphasis on micronutrients and pesticides.

## Management

- Strengthen enforcement of agrochemicals rules and regulations to control their adverse impacts on the environment and human health.
- Promote Good Agricultural Practice (GAP) to ensure safe food and minimize adverse impacts.
- Carry out continuous research and development of new technologies to counter changing characteristics of insect pests.
- Conduct supervised trials to establish Pre-Harvest Intervals (PHIs) and ensure safe food.
- Establish/strengthen laboratories for pesticides/fertilizers testing and residues monitoring.

## Capacity development

- Conduct massive awareness program for stakeholders (farmers etc.) on judicious and safe use of agrochemicals.
- Conduct adequate number of trainings on agrochemicals and balanced fertilization at regional level under the umbrella of SAARC Agriculture Centre.
- Establish networking of scientists working in SAARC region for exchange of technical expertise on agrochemicals and their implications.
- Establish strong collaboration among SAARC member countries for sharing of plant protection and nutrient management technologies.
- Build strong linkages between researchers, academia, extension workers, industry and farmers for safe use and production of agrochemicals in SAARC region.
- Promote digital learning on judicial usage of agrochemicals and fertilizer.

# LIST OF PARTICIPANTS

## Country National Focal Experts

**AFGHANISTAN**

Ms. Tamana Dawi
Head of Protected Areas
Ministry of Agriculture, Irrigation and Livestock.
Email: *tmndawi@gmail.com*

Ms. Fariba Amini
Drainage Planning Specialist
Ministry of Agriculture, Irrigation and Livestock.
Email: *fariba.amin999@gmail.com*

**BANGLADESH**

Dr. Nirmal Kumar Dutta
Chief Scientific Officer (CC)
Bangladesh Agricultural Research Institute, Gazipur.
Email: *nkdutta83@yahoo.com*

Mr. Md. Aminur Islam
Additional Deputy Director (QC)
Department of Agriculture Extension
Email: *iaminsau@gmail.com*

**BHUTAN**

Ms. Pema Tshoki
Plant Protection Officer
National Plant Protection Center
DOA, MoAF
Email: *ptshoki@moaf.gov.bt*

Mr. Chinta Mani Dhimal
Senior Plant Protection Officer
National Plant Protection Center
DOA, MoAF
Email: *cmdhimal@moaf.gov.bt*

**INDIA**

Dr. Arvind Shukla
Project Coordinator (Actg) AICRP on
Micro and secondary Nutrients ICAR
Indian Institute of Soil Sciences, Bhopal
Email: *arvind.shukla@icar.gov.in; arvindshukla2k3@yahoo.co.in*

Dr. Anupama
Head (Actg)
Agricultural Chemical Division
ICAR-IARI, New Delhi
Email: *head_chem@iari.res.in; anupamanil2000@gmail.com*

**MALDIVES**

Mr. Mariyam Ajila
Project Officer
Ministry of Fisheries, Marine
Resources and Agriculture
Email: *mariyam.ajila@fishagri.gov.mv; arjiler@gmail.com*

**NEPAL**

Mr. Shrikrishna Neupane
Crop Production Officer
Ministry of Agriculture and Livestock Development
Email: *shree.neupane2000@gmail.com*

Mr. Manoj Pokhrel
Plant Protection Officer
Plant Quarantine and Pesticide Management Centre
Email: *manojpkrl@gmail.com*

**PAKISTAN**

Dr. Karam Ahad
Director/PSO, IPED, PSD
NARC
Email: *karam_ahad@yahoo.com*

Dr. Farrakh Mehboob
PSO/PI, PSD
NARC
Email: *farrakhmehboob@gmail.com*

**SRI LANKA**

Ms. N.R.N.Silva
Principal Agriculture Scientist
Horticulture Crop Research & Development Institute,
Gannoruwa
Email: *renukasilva@yahoo.com*

Ms. P.W.Y. Lakshani
Assistant Director of Agriculture
Horticulture Crop Research & Development Institute,
Gannoruwa
Email*: jayayoshil@yahoo.com*

**Participants from SAARC Agriculture Centre, Dhaka, Bangladesh**

Dr. Md. Baktear Hossain
Director

Mr. Kinzang Gyeltshen
Senior Program Specialist (Natural Resource Management)

Dr. Nasreen Sultana
Senior Program Specialist (Horticulture)

Dr. Sreekanth Attaluri
Senior Program Specialist (Crops)

Dr. Ashis Kumar Samata
Senior Program Specialist (Livestock)

Dr. Grinson George
Senior Program Specialist (Fisheries)

Dr. Younus Ali
Senior Technical Officer

Ms Fatema Nasrin Jahan
Senior Program Officer

## VIRTUAL REGIONAL EXPERT CONSULTATION MEETING PHOTO


**SAARC Agriculture Centre (SAC)**
BARC Complex, Farmgate, Dhaka-1215, Bangladesh
Phone: +880-2-55027712, Fax: +880-2-55027714
Email: director@sac.org.bd, website: www.sac.org.bd

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