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Chapter 8
A systematic review on global environmental risks associated with pesticide application in agriculture

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Chapter contents

Abstract

Pesticides are used to avoid, remove, or regulate damaging pests. The extensive use of these chemicals has resulted in the contamination of soil, terrestrial and aquatic ecosystems and has been shown to have toxic effects on humans and nonhuman biota. Pesticides include a number of chemical families, with hundreds of active ingredients, thousands of different formulations and many known or suspected adverse health outcomes. Pesticides have been found to be as a common contaminant of soil, air, water, turf, and other vegetation. In addition to affecting insects or weeds, they are also known to be toxic to other organisms including fish, birds, insects, and non-target plants. The present book chapter deals with the global fates associated with pesticide application and their possible mitigation measures.

Keywords: Agrochemicals, Global pesticide risks, Health impacts, Persistence compounds

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Introduction

Pesticides are chemicals mainly used in agriculture to protect plants from pests, weeds or diseases, and in public health protection programs to protect humans from vector-borne diseases, such as malaria, dengue, and schistosomiasis. Insecticides, herbicides, fungicides, and rodenticides are the typical examples. The chemical structure of pesticides varies significantly (Baker and Wilkinson, 1990). These include organochlorine (aldrin and DDT), organophosphorus (diazinon and chlorpyrifos), benzoic acids (dicamba), carbamates (carbaryl and aldicarb), dipyridyl derivatives (diquat and paraquat), pyrethrinsand pyrethroids (cyfluthrin and cypermethrin), triazines (atrazine and simazine), glycine derivatives (glyphosate), di-thiocarbamates (maneb and ziram), and phenoxyacetic derivatives (2, 4-D). Agrochemicals (pesticides and fertilizers) have enabled to duplicate food production in order to feed the rapid growing human population (Tanabe *et al.,* 1990). In addition to the active ingredients, pesticides also contain chemicals known as 'inerts' such as solvents, surfactants, preservatives, which may have toxic actions distinct from the active ingredients. Some contaminants come from the production process. Dioxin, for example, is a contaminant of production of some phenoxyacetic acid herbicides, and is classified as a human carcinogen (Gilden *et al.,* 2009). Depending on the formulation type, the controlled pest and, the application timing, different techniques are used for application of pesticides. It can be applied to the crop or to the soil. Liquid sprays are commonly used in crops, usually using tunnel sprayers, boom sprayers, or aerial application. On the other hand, pesticides can be injected as a fumigant, applied as granules, or sprayed onto the soil surface. Once application of pesticides has been done, it can be taken up by the targeted organisms, degraded, or transported to the groundwater; followed by entry into the surface water bodies, or volatilize to atmosphere, or get to non-target organisms by ingestion (US EPA, 2006).

Global scenario of pesticide pollution

Among the countries that still use OCs, India has been one in all the foremost producers and shoppers in recent years. As a consequence, wild birds in India area unit exposed to nice amounts of OC pesticides (Tanabe *et al.,* 1998). Use of OCs in tropical countries might not solely lead to exposure of resident birds however conjointly of migratory birds after they visit tropical regions in winter. The Indian sub-continent may be a host to a mess of birds from western Asia, Europe and Arctic Russia in winter (Woodcock, 1980). The Global pesticide consumption was mentioned in the Figure 8.1. Many species of water bird, as well as walk birds like plovers, terns and sandpipers, migrate every winter to India covering long distances (Grewal, 1990). Whereas concentrations of OC pesticides in whole body homogenates of birds are reportable elsewhere (Tanabe *et al.,* 1998), concentrations of OCs in prey things and in eggs of Indian birds haven't been reportable. A number of studies associated with the decline within the populations of barmy in numerous elements of the planet to OC exposure were conjointly being conducted (Altenbach *et*

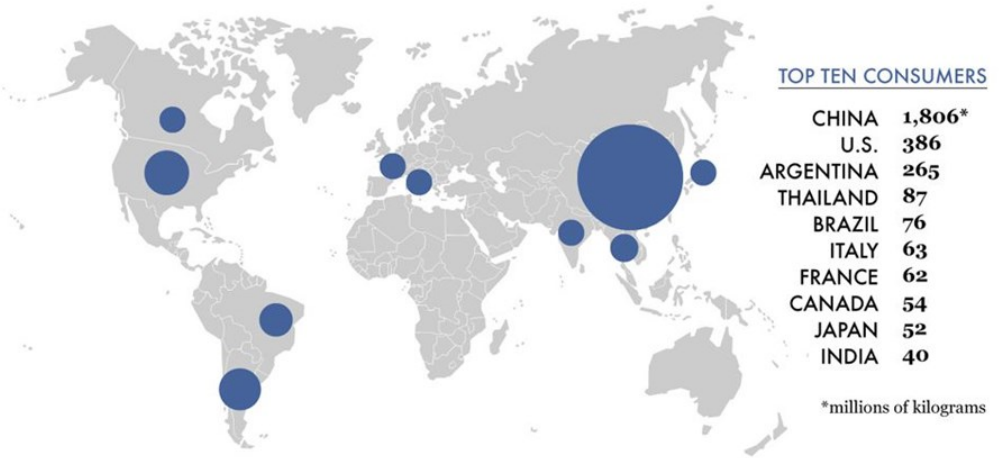

Figure 8.1. *Global pesticide consumption (Source: Pretty and Bharucha, 2015).*

al., 1979; Clark, 1976; Clark, 1983; Thies and McBee, 1994). The planet population of barmy was calculable to be 87 million throughout 1936 and it declined to close to 2000 in 1973 (Geluso *et al.*, 1976) it's recovered slightly to Associate in Nursing calculable variety of 700,000 in 1991 (Geluso *et al.*, 1976; Thies and McBee, 1994). High tissue concentrations of p, p'dichlorodiphenyldichloroethene (p, p'–DDE) are found in barmy in cavern in North American nation and in NM within the USA (Geluso *et al.*, 1976; Thies and McBee, 1994). Prevalence of stillbirths in very little brown barmy exposed to high concentrations of PCBs,p, p'–DDE, and/or oxychlordane was documented (Clark, 1976; Jefferies, 1972). These observations indicate that batscan accumulate high concentrations of OCs and will be plagued by their potential poisonous effects. The megabat or the new world megabat, short-nosed megabat and Indian pipistrel bat area unit resident species and area unit quite common in South India. Their surround is principally agricultural areas, rock caves, and abandoned homes in domesticated areas. Insects represent a crucial diet for several barmy, permitting the passage of OCs in their body (Mc Bee and Bickham, 1992). Many studies found OC pesticides and PCBs in livers and eggs of birds in developed countries (Bednarz *et al.*, 1990; Castillo *et al.*, 1994; Mora, 1996; Mora, 1997). Similarly, many studies reportable OCs in an exceedingly style of assemblage as well as humans and life from India (Senthilkumar *et al.*, 1999).

Risks of pesticides applications in agriculture

The ultimate fate of persistence and movement of the pesticide is defined by some of its properties, such as water solubility, half-life in soil and soil-sorption constant, the octanol/water partition coefficient and site conditions and management practices being used. Solubility of the

pesticide defines their fate of being surface run off or their leaching to groundwater. Higher solubility reflects higher carrying and leaching. Second important factor is the partition coefficient as many pesticides do not leach as they get adsorbed on the soil particles which further depend on soil type and chemical nature of pesticide. Pesticides with high vapour pressure enter the atmosphere as a gas. Environmental conditions such as temperature and humidity influence the volatility of pesticide from soil, plants, or water surface. This can further result in surface water pollution. In environment, pesticides can be degraded by various mechanisms like photodecomposition and a variety of chemical and physical reactions or can be degraded by microorganisms. Pesticides with low degradation properties remain in the environment for long time and are known as persistent pesticide. Organochlorine pesticides (DDT, endosulfan, endrin, heptachlor, lindane) are persistent in environment, whereas organophosphates, chloroacetanilides, phenoxyacid derivatives, carbamates, are non-persistent. Non-persistent chemicals are known to have much shorter environmental half-lives and thus do not have a tendency to bioaccumulate. Other important factor is the texture of the soil as coarse textured sands have high infiltration capacities, and water tends to percolate through the soil and reach groundwater. On the other hand, fine textured soil like clay have low infiltration so water tends to run off, reaching streams and lakes. The most significant soil characteristic affecting pesticide fate is the organic matter content. Soils with higher organic matter content can adsorb pesticides more as it retains water with dissolved chemicals. Soil with higher load of microorganisms has more possibility to degrade the pesticide. Adsorption property of soil increases with decreasing pH for ionizable pesticides (e.g. 2, 4-D, 2, 4, 5-Tand atrazine) (Andreu and Pico', 2004). Site features like depth of ground water, topography and geological conditions. In the case of shallow groundwater, there is lesser adsorption by soil, so contamination is a major concern. Geological conditions also play an important role in defining the fate of pesticide. The presence of wells, or any highly permeable materials, such as gravel deposits, assists groundwater contamination. On the other hand, streams, ponds, and lakes increase the likelihood of contamination of surface water by rainfall or irrigation run off. In case of pesticides injected or incorporated into the soil, they are more prone to leaching into the groundwater, and those sprayed onto crops are more liable to volatilization and surface runoff, and finally entering into surface waters and the atmosphere.

Pesticides have been found to be as a common contaminant of soil, air, water, turf, and other vegetation. In addition to affecting insects or weeds, they are also known to be toxic to other organisms including fish, birds, insects, and non-target plants. Run off of pesticides from treated plants and soil results in contamination of surface water. More than 90 percent of samples from streams and major rivers were found to contain one, or more pesticides (Kole *et al.*, 2001; Bortleson and Davis, 1997). The USGS reported that concentrations of insecticides in urban streams commonly exceeded guidelines for protection of aquatic life (U.S. Geological Survey, 1999). The herbicides (2, 4-D, prometon and, diuron) and the insecticides (diazinon, and chlorpyrifos), which were commonly used by urban homeowners and school districts, were

detected in all surface and ground water (U.S. Geological Survey, 1998). Out of 20 river basins studied, 19 were found to contain trifluralin and 2, 4-D (Bevans *et al.,* 1998; Fenelon *et al.,* 1998; Levings *et al.,* 1998; Wall *et al.,* 1998). In most of cases, concentrations of insecticides in urban streams were commonly found to exceed as per the guidelines for protection of aquatic life (U.S. Geological Survey, 1999). Around 23 pesticides including 17 herbicides were detected in water bodies in the Puget Sound Basin. The most common pesticide detected in most of the streams was 2, 4-D. The weed-killers dichlobenil, triclopyr, diuron and glyphosate and insecticide diazinon, were also detected in Puget Sound basin streams (Bortleson and Davis, 1997). According to the USGS, more than 143 different pesticide belonging to all major chemical class and 21 transformation products have been detected in ground water. In India, 58% of drinking water samples from hand pumps and wells around Bhopal was found to be contaminated with organo chlorine pesticides exceeding the EPA standards (Kole *et al.,* 2001). Polar pesticides (carbamates, fungicides and some organophosphorus insecticide) move from soil by runoff and leaching, thereby posing a problem for the supply of drinking water to the population. Heavy use of soil with pesticides results in decline in the populations of beneficial soil microorganisms. Plants require microorganisms to transform atmospheric nitrogen into nitrates, usable form for plants.

Impact of pesticides on living beings

The reports of environmental impacts of pesticides and some human disease were reported in the Table 8.1 and 8.2. Despite importance of pesticides, they are known to adversely affect both humans and the environment. Many pesticides are known to be chemically persistent and remain there for years. This leads to their bioaccumulation and thus has toxic effects on environment. Impact of pesticides on the health of human is determined by the nature of the pesticide, the route and duration of exposure, and the health status of the individual. Skin contact, ingestion, or inhalation are the main routes of exposure to pesticides. In human or animal body, pesticides get metabolized, excreted, or stored. Health risks associated with pesticides include dermatological, carcinogenic, neurological, gastrointestinal, and other effects. General population gets exposed to pesticide residues either by occupational use or environmental contamination. The most effective route of the pesticide exposure to the pesticide applicator is via dermal exposure which might a result of a spill, splash or spray drift during loading, disposing, or cleaning of pesticides (Anderson and Meade, 2014; Salvatore *et al.,* 2008). The extent to which a pesticide gets absorbed through the skin is dependent on the physiochemical properties of pesticide, quantity and duration of the exposure, and temperature and humidity (Macfarlane *et al.,* 2013). Liquid formulations are more likely to get absorbed than than solid forms of pesticides. Some parts of the body are more susceptible to pesticide absorption than others parts (Dennis *et al.,* 2010). The most severe route of exposure is oral exposure which usually occurs by accident. The most frequent cases were when pesticides were transferred to an unlabeled bottle or food container (Gilden *et al.,* 2010). Consumption of pesticide will also happen in the cases where workers handling

Table 8.1. *Reports of environmental impacts of pesticides.*

Pesticide	Effect	Reference
Chlorpyrifos	Highly toxic to fish, caused fish kills in waterways near treated fields or buildings	US EPA (2000)
Trifluralin	Highly toxic to both cold and warm water fish	US EPA (1996)
Trifluralin	Vertebral deformities in fish	Koyama (1996)
Ronstar and Roundup	Acute toxic to fish	Folmar *et al.* (1979); Shafiei and Costa (1990)
Glyphosate or glyphosate-containing product	Erratic swimming and labored breathing behaviour in fishes which make them more to predators	Koyama (1996)
2,4-D herbicides	Physiological stress responses in salmon	McBride *et al.* (1981)
2,4-D herbicides	Reduction in food-gathering ability of rainbow trout	Little (1990)
Pesticide	Poisoning of dolphins	Tanabe *et al.* (1988)
Pesticides	Endangerment of fish, other marine or freshwater animals	Mohan (1989)
DDT	Adverse effects on reproductive and immune-logical functions in captive and wild aquatic mammals	Ross *et al.* (1995); Martineau *et al.* (1987); Kannan *et al.* (1993); Colborn and Smolen (1996)
2,4-D or2,4-D containing products	Toxic to shellfish and other aquatic species	Martineau *et al.* (1987)
Trifluralinis	Highly toxic to aquatic, estuarine and marine organisms	US EPA (1996)
Oxadiazon	Severely reduces algae growth	Ambrosi *et al.* (1978)
Atrazine and alachlor	Cell damage, blocked photosynthesis, and stunted growth of algae and diatoms	US Water News Online (2000)
Oxadiazon	Toxic to bees	Washington State Department of Transportation (1993)
2,4-D	Decline in spider and carabid beetle populations	Asteraki *et al.* (1992)
Brodifacoum	Highly toxic to birds	US EPA (2000)
Glyphosate	Decrease in bird population	MacKinnon *et al.* (1993)
Organochlorines pesticides (OCs)	Toxic to fish-eating water birds and marine mammals	Barron *et al.* (1995); Cooke (1979)
Triclopyr	Inhibition of soil bacteria that transform ammonia into nitrite Santos	Pell *et al.* (1998)
Glyphosate	Reduction in the growth and activity of free-living nitrogen-fixing bacteriain soil	Santos and Flores (1995)
2,4-D	Reduction in nitrogen fixation by the bacteria that live on the roots of bean plants	Arias and Fabra (1993); Fabra *et al.* (1997)
2,4-D	Reduction in the growth and activity of nitrogen-fixing blue-green algae	Singh and Singh (1989); Tözüm -Çalgan and Sivaci-Güner (1993)
2,4-D	Inhibits the transformation of ammonia into nitrates by soil bacteria	Frankenberger *et al.* (1991)
Oryzalin and trifluralin	Inhibition of the growth of certain species of mycorrhizal fungi	Kelley and South (1978)
Roundup	Toxic to mycorrhizal fungi	Chakravarty and Sidhu (1987); Estok *et al.* (1989)
Triclopyr	Toxic to mycorrhizal fungi	Chakravarty and Sidhu (1987)
Oxadiazon	Reduction in the number of mycorrhizal fungalspores	Moorman (1989)

Table 8.2. *Some examples of human disease reported.*

Pesticides	Effect	Reference
Imazethapyr and imazaquin	Bladder cancer	Koutros *et al.* (2015)
Pesticide	Bladder cancer	Amr *et al.* (2015)
Imazethapyr	Bladder cancer and colon cancer	Koutros *et al.* (2009)
Herbicide	Meningioma	Samanic *et al.* (2008)
Pesticides	Brain tumors and gliomas	Provost *et al.* (2007)
Chlorpyrifos (CPF)	Induction in redox imbalance	Ventura *et al.* (2015)
Organochlorine pesticides	Breast cancer	Arrebola *et al.* (2015)
Pesticide spray drift	Breast cancer	El-Zaemey *et al.* (2013)
Acetochlor herbicide	Lung cancer	Lerro *et al.* (2015)
Pesticide	Lung cancer	Luqman *et al.* (2014)
Pesticide	Exacerbation of asthma by irritation, inflammation, immunosuppression, or endocrine disruption	Hernández *et al.* (2011); Amaral (2014)
Pendimethalin and aldicarb	Asthma	Henneberger *et al.* (2014)
Pesticides	Damage in the bronchial mucosa	Hernández *et al.* (2011)
Pesticides	Atopic asthma	Hoppin *et al.* (2008)
Organochlorines	Associated with higher risk of developing type 2 diabetes	Sylvie Azandjeme *et al.* (2013); Jaacks and Staimez (2015)
Organochlorine	Increase in incidence risk of type 2 diabetes	Tang *et al.* (2014); Everett *et al.* (2007); Turyk *et al.* (2009)
Pesticide	PD	Moisan *et al.* (2015)
Pesticides	PD mortality	Brouwer *et al.* (2015)
Pesticide	PD at a younger age	Ratner *et al.* (2014)
Frequent use of pesticide	Increased risk of PD by 47%	Narayan *et al.* (2013)
Pesticide	Acute lymphoblastic leukemia	Bailey *et al.* (2015)
Pesticides	Acute leukemia	Maryam *et al.* (2015)
Pesticides	Children had lymphoma and leukemia when their mother was exposed during the prenatal period	Vinson *et al.* (2011)
Insecticides and herbicide	Children had leukemia when their mother were exposed to pesticides during pregnancy	Turner *et al.* (2011)
Pesticides	Prenatal exposure to OP resulted in lower IQ, poorer working memory and perceptual reasoning of children	Bouchard *et al.* (2011); Engel *et al.* (2011); Rauh *et al.* (2011)
Organophosphorous pesticides	Adverse effects on male reproductive system	Mehrpour *et al.* (2014); Michalakis *et al.* (2014)
Organophosphates pesticide	Induction of long-term neurobehavioral deficits and depression	Baker *et al.* (1990)
Organophosphate	Reduction in psychomotor speed, executive function, visuospatialability, and work and visual memory.	Ross *et al.* (2013)
Pesticides	High risk of Parkinson disease	Dardiotis *et al.* (2013) Barnhill *et al.* (2014)
Pesticides	hearing loss	Mehrpour *et al.* (2014)
Pesticides	Diabetes and obesity	Thayer *et al.* (2012)
Pesticides	non-malignant respiratory disease	Hoppin *et al.* (2014)
Pyretroids at high levels	endocrine disruptors	Fortin *et al.* (2008)
Atrazine, a triazine herbicide	endocrine-disrupting effects on amphibians	Gupta *et al.* (2012)

pesticides or equipment for their application do not wash their hands prior to eating or smoking (US EPA, 2007). The other means of oral exposure to pesticides is through contaminated food. In 1996, apples, tomatoes, lettuce, strawberries and grapes were found to contain seven pesticides (acephate, chlopyriphos, chlopyriphos-methyl, methamidophos, iprodione, procymidone and chlorothalonil). Lettuce was found to be with the highest number of positive results, with residue levels exceeding the MRLs more frequently than in any of the other crops investigated.

Due to volatile property of the components of the pesticides, their potential for respiratory exposure is higher (Amaral, 2014). Inhalation of ample amounts of pesticides can cause serious effects to nose, throat, and lung tissues (Damalas and Eleftherohorinos, 2011). Application of concentrated pesticides in small droplets results in higher potential risks (Amaral, 2014). Pesticides should be applied at air temperatures below 30°C as higher temperature increase the vapour levels of pesticides (USEPA, 2007). In a study, elevated levels of DAPs were found in hair and urine samples of persons involved in spraying organophosphorus pesticides (OPPs) compared to control group (Koutroulakis *et al.,* 2014). Around 97.8% of 415 women's amniotic fluid (AF) was found to be were positive for at least one of the non-specific dialkyl-phosphate (DAPs) metabolites during the second gestational trimester (Koutroulakis *et al.,* 2014). Analysis of rabbit hair also showed higher levels for Cypermethrin (a synthetic pyrethroid used as an insecticide) metabolites (Koutroulakis *et al.,* 2014). Absorption of some pesticides by the eyes was reported causing serious illness (Gilden *et al.,* 2010). Eye protection (face shields or goggles) is recommended while measuring or mixing highly toxic pesticides.

Fish area unit sensitive to pyrethrin and pyrethroid merchandise, and contamination of lakes, streams, ponds, or any aquatic surround could be a concern. The US National Academy of Sciences expressed that the DDT matter DDE causes egg shell dilution which the eagle population within us declined primarily due to exposure to DDT and its metabolites (Liroff, 2000). Future Can we have a tendency to do better? The need for manufacturing a lot of food to feed the growing human population is probably going to extend (UN, 2015). To fulfil this goal, many choices area unit open. One choice could be to continue the trail of intensive use of agrochemicals, as well as pesticides, with subsidiary analysis to supply a lot of selective pesticides and improved application techniques. Alternative different choices are projected and embody the employment of genetically changed organisms for higher yield crops and crops proof against pests, organic farming, development of recent cultivars and convalescence of recent cultivars, enhanced use of bio-pesticides and secretion traps to manage pests, and alter of dietary habits of human populations. the present pathway of applying artificial crop protection chemicals has been walked through on a circular approach consisting of identification of a pesterer, development of a chemical, observation of collateral effects and rise of recent issues, development of recent chemicals, etc. we have a tendency to may take into account this as AN approach supported the trial and error technique. There has been results quickly achieved, certainly, however they continuously have go along with AN associated value.

Contamination of agricultural products with pesticides

Today, food and setting contamination with nephrotoxic chemicals contact on public health over many human generations is taken into account unaffordable. Probably, agriculture and intensive food production might not dispense the employment of current agrochemicals within the next few years. Many measures might be introduced to raised mitigate their collateral effects within the meanwhile. For instance, introduction of exactitude application of agrochemicals (as well as exactitude irrigation) may scale back the number of chemicals (and water) applied over the fields. another easy measures might be additionally forthwith applied everyplace, such as: a) recovery and treatment of contaminated agriculture runoff with installation of ground stripes appropriate to wash up runoff and water drainage) reinforce education of farmers and also the public normally regarding chemical hazards; and c) thorough toxicity testing and correct registration of chemicals and formulations. These measures might facilitate to achieve some beyond regular time. Meanwhile, we should always look on the far side this time for property solutions. There's agreement that intense analysis on higher food production and production of food with higher quality is required. what is more, it's recognized that productive soil could be a finite resource (as water) and, so as to make sure continued production of food, the agriculture should go facet by facet with soil and ecosystems preservation, restoration, and science analysis on higher yield cultivars. Therefore, it's pressing to realize a generalized agreement on chemical application and adoption of fine agriculture practices, considerately to integrated pesterer Management (IPM) techniques. Consumers and also the public normally have rejected already the environmental and health prices of unsafe chemicals, and awareness of chemical residues in foods created the demand for clean foods. A lot of food and safer food is, therefore, required, however the human population and natural ecosystems might not survive longer to poor designing and poor agriculture practices.

Susceptibility of Genetically Modified Organisms (GMOs) towards pesticides

A scientific application of the precaution principle within the introduction and application of all chemicals, as well as pesticides, is required (EEA, 2013). This needs thorough risk assessment of chemicals toxicity to setting and humans. Rising different ways in food production, like development of GMO varieties and unharness national agriculture while not application of the precaution principle and satisfactory risk assessment, should be avoided. This issue deserves pressing international discussion. AN agreement ought to be reached supported science and on moral principles for making certain food security and food safety. Moreover, different ways for food production mustn't repeat the mistakes of chemical applications and should reach making certain food safety and food security. Current and future increase in food production should go together with production of food with higher quality and with less nephrotoxic contaminants.

Different ways to the intensive use of crop protection chemicals area unit open, like genetically built organisms, organic farming, amendment of dietary habits, and development of food technologies. Agro industries have to be compelled to any develop advanced practices to shield public health, which needs a lot of cautious use of agrochemicals through previous testing, careful risk assessment, and licensing, however additionally through education of farmers and users normally, measures for higher protection of ecosystems, and sensible practices for property development of agriculture, fisheries, and cultivation. Increased research for brand new developments in food production and food safety, likewise as for environmental protection, could be a necessary a part of this endeavour. What is more, worldwide agreement on sensible agriculture practices, as well as development of genetically changed organisms (GMOs) and unharness for international agriculture, could also be pressing to make sure the success of safe food production. Pesticides area unit agrochemicals employed in agricultural lands, public health programs, and concrete inexperienced areas so as to shield plants and humans from varied diseases. However, because of their celebrated ability to cause an oversized variety of negative health and environmental effects, their facet effects are often a vital environmental health risk issue. The pressing would like for a lot of property and ecological approach has created several innovative ideas, among them agriculture reforms and food production implementing property apply evolving to food sovereignty.

Conclusion

Although pesticides are developed to prevent, remove, or control harmful pests, concerns of the hazards of pesticides towards the environment and human health have been raised by many studies. There are indeed many inherent problems in conducting large-scale experiments to directly assess the causation of the human health problems associated with the use of pesticides. However, the statistical associations between exposure to certain pesticides and the incidence of some diseases are compelling and cannot be ignored. Moreover, some members of the population have an inherent genetic susceptibility to pesticide associated diseases and are thus likely to be more at risk than others. Evidence suggests that much of this exposure is presented as multiple mixtures of chemicals and that the toxic effect of such exposure is unknown, particularly over longer time scales. It is very important to develop the precision and accuracy in the quantitation of pesticides along with improved safety profiles to reduce possibly adverse effects on human health and the environment. Furthermore, there should be a focus on determining what types of chemicals or formula are the most appropriate tools for environmental and ecological management of pests. Hence, natural bio-control agents, such as beneficial bacteria, viruses, insects, and nematodes, should be used for agricultural purposes. Moreover, both the public and private sectors such as government agencies, NGOs, and manufacturers should put much greater effort into research, product development, product testing and registration, and implementation of pesticide use strategies, while advocating public education concerning pesticides.

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