Effects of Pesticides on Environment

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Contents

Abstract Pesticides are used to kill the pests and insects which attack on crops and harm them. Different kinds of pesticides have been used for crop protection for centuries. Pesticides benefit the crops; however, they also impose a serious negative impact on the environment. Excessive use of pesticides may lead to the destruction of biodiversity. Many birds, aquatic organisms and animals are under the threat of

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harmful pesticides for their survival. Pesticides are a concern for sustainability of environment and global stability. This chapter intends to discuss about pesticides, their types, usefulness and the environmental concerns related to them. Pollution as a result to overuse of pesticides and the long term impact of pesticides on the environment are also discussed in the chapter. Moving towards the end, the chapter discusses the methods to eradicate the use of pesticides and finally it looks forward towards the future impacts of the pesticide use the future of the world after eradicating pesticides.

Keywords Pesticides • Environment • Chronic effects of pesticides • Environmental hazards • Pesticide registration

1 Introduction

A pesticide is a toxic chemical substance or a mixture of substances or biological agents that are intentionally released into the environment in order to avert, deter, control and/or kill and destroy populations of insects, weeds, rodents, fungi or other harmful pests. Pesticides work by attracting, seducing and then destroying or mitigating the pests. Pests can be broadly defined as "*the plants or animals that jeopardize our food*, *health and/or comfort*".

The use of pesticides has increased many folds over the past few decades. According to an estimate, about 5.2 billion pounds of pesticides are used worldwide per year. The use of pesticides for pest mitigation has become a common practice all around the world. Their use is not only restricted to agricultural fields, but they are also employed in homes in the form of sprays, poisons and powders for controlling cockroaches, mosquitoes, rats, fleas, ticks and other harmful bugs. Due to this reason, pesticides are frequently found in our food commodities in addition to their presence in the air (Pesticides n.d.). Pesticides can be natural compounds or they can be synthetically produced. They may belong to any one of the several pesticide classes. Major classes include organochlorines, carbamates, organophosphates, pyrethroids and neonicitinoids to which most of the current and widely used pesticides belong (Pesticides 101-A Primer n.d.). Pesticide formulations contain active ingredients along with inert substances, contaminants and occasionally impurities. Once released into the environment, pesticides break down into substances known as metabolites that are more toxic to active ingredients in some situations (What Is a Pesticide n.d.).

Pesticides promise the effective mitigation of harmful bugs, but unfortunately, the risks associated with their use have surpassed their beneficial effects. Non-selective pesticides kill non-target plants and animals along with the targeted ones. Moreover, with the passage of time, some pests also develop genetic resistance to pesticides. This chapter focuses on the use of pesticides since the ancient times,

merits of pesticide usage and most importantly, the harmful impact of pesticides on human health and the environment.

2 Pesticide Use: From Past to Present

The use of pesticides dates back to the times of Ancient Romans where people used to burn sulphur for killing pests and used salts, ashes and bitters for controlling weeds. A Roman naturalist urged the use of arsenic as an insecticide (History of pesticide use 1998).

In 1600s, a mixture of honey and arsenic was used for controlling ants. In late 1800s, farmers in the USA started using certain chemicals such as nicotine sulphate, calcium arsenate and sulphur for field related posts; however; their efforts were unfruitful because of the primitive methods of application (Delaplane 2000). In 1867, an impure form of copper, arsenic was used to control the outbreak of Colorado potato beetle in the USA (History of pesticide use 1998). The major breakthrough in pesticide development occurred in the period around and after World War-II, when several effective and inexpensive pesticides were synthesised and produced. This period is marked by the discovery of Aldrin, dichlorodiphenyltrichloroethane (DDT) in 1939, Dieldrin, β-Benzene Hexachloride (BHC), 2,4-Dichlorophenoxyacetic acid (2,4-D), Chlordane and Endrin (Jabbar and Mallick 1994; Delaplane 2000). A glimpse on the historical account about pesticide use is mentioned in Table 1.

Fungicides, captan and glyodin and organophosphate insecticide Malathion were introduced between 1950 and 1955 followed by the discovery of triazine herbicides in the years 1955–1960 (Jabbar and Mallick 1994). An experimental wartime herbicide named Agent Orange was developed by Monsanto in 1961–1971 and was used during the Vietnam War (History of pesticide use 1998). Moreover, in 1961, the use of pesticides also reached its peak. However, after 1962, there was a marked

Table 1 Historical account of pesticide use

Year	Events
1867	Paris Green (form of copper arsenite) was used to control Colorado potato beetle outbreak
1885	Introduction of a copper mixture by Professor Millardet to control mildew
1892	Potassium dinitro-2-cresylate was produced in Germany
1939	DDT discovered by Swiss chemist Paul Muller; organophosphate insecticides and phenoxyacetic herbicides were discovered
1950s	Fungicides captan and glyodin and insecticide malathion was discovered
1961–1971	Agent Orange was introduced
1972	DDT officially banned
2001	Stockholm Convention

decrease in the development of new pesticides as the public attention was drawn to the environmental hazards associated with indiscriminate pesticide use. In 1962, an American scientist Rachel Carson highlighted in her book, Silent Spring, that spraying DDT in the field causes sudden death of non-target organisms (Jabbar and Mallick 1994; Delaplane 2000) either by direct or indirect toxicity.

Silent Spring resulted in silence in the field of research on pesticide discovery and development. However, in the late 1960s, it opened a new arena in which "integrated pest management" (IPM) was introduced. IPM is a method in which biological predators or parasites are used for controlling the pests. Although the pest population can be reduced to significantly low levels, especially in pest outbreak situations, but unfortunately IPM was not a substitute for chemical pesticides (Delaplane 2000). In 1970–1980s, pyrethroids, sulfonylureas, synthetic fungicides triadimefron and metaxyl were introduced (History of pesticide use 1998). In 1972, DDT was completely banned in the USA followed by the placement of restriction on the use of Endosulfan, Dieldrin and Lindane. The list of banned pesticides has increased ever since. In 2001, 179 nations signed an international treaty known as Stockholm Convention that was intended to completely ban twelve Persistent Organic Pollutants (POP's) including DDT. Later in 2013, the European Union (EU) supported to banning the use of neonicotinoid pesticides (Jacobs n.d.).

It has been observed that the overuse of pesticides on aquatic ecosystems has led to a serious threat to species of fish including salmon. Pesticides are also seen to affect primary producers and macro-invertebrates (Macneale et al. 2010). In Pakistan, before 1980, Plant Protection Department of Government of Pakistan was responsible for the import and distribution of pesticides. Pesticide purchase was on pre-payment basis and there was also subsidy on it. However, in 1980, this responsibility was passed on to the private sector. Since that time, there has been a steady increase in pesticide import and consumption in Pakistan. Registration of a pesticide is renewed sporadically, which ensures the safety of used pesticides (Jabbar and Mallick 1994).

Currently, preference is given to biological control of pests. This is a bioeffector-method of controlling pests using biocontrolling agents including other living organisms. These biocontrolling agents are also known as bio-rational pesticides. An example of bio-rational pesticide is Insect growth regulators (IGRs) which are the hormones that regulate insect growth without affecting non-target organisms (Delaplane 2000).

3 Pesticide Registration and Safety

Registration of a pesticide is a complex, legal and administrative process that takes a considerable amount of time and resources and requires expertise and skills of registration authority as well as pesticide manufacturers. In this process, potential effects associated with the use of pesticide on human health and the environment are assessed (Monaco et al. 2002) in order to ensure the safety of active as well as inert ingredients used in the manufacturing of pesticide.

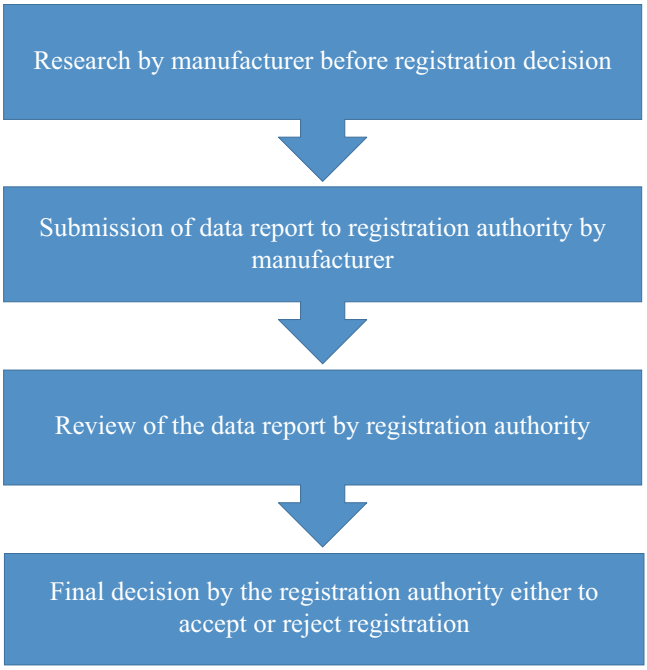

Fig. 1 Pesticide registration process

Registration is an important aspect of pesticide management that ensures that the pesticide product released in the market is authorised and is used only for the intended purpose. It also enables authorities to implement control over quality, price, packaging, labelling, safety as well as advertisement of pesticides to ascertain protection of users' interests (WHO 2010). In the registration process, registrant or the manufacture is required to conduct research and analyse different tests related to product chemistry before submitting the application or data report. These tests gauge the potential pesticide risks on humans, animals and non-target species as well as the fate of the pesticide once it is released in the environment (FAO 2002; WHO 2010). Registration process of pesticides is explained in Fig. 1.

Data report or application of registration include several aspects related to pesticide such as physical and chemical properties of active ingredient as well as formulated product, analytical methods, proposed environmental toxicity and human health hazards, recommended uses and labels, safety data, effectiveness for the intended use, container management, and disposal of waste products. Application is reviewed and analysed by the scientist in registration authority and after environmental, human and biodiversity risks assessment, the authority approves the pesticide as safe to be use or rejects it if it does not meet the standards as set by the regulatory and registration authorities. Furthermore, the registration authority ensures that each registered pesticide continues to meet the highest safety standards. Hence, previously registered pesticides are being reviewed to ensure that they meet

current scientific, safety and regulatory standards. This process is called re-registration (Damalas and Eleftherohorinos 2011).

4 Classification of Pesticides

Pesticides are known to be one of the extremely useful and beneficial agents for preventing losses of crops as well as diseases in humans. Based on the action, pesticides can be classified as destroying, repelling and mitigating agents. Insects and pests are getting immune to the commercial pesticides due to over usage. Recently pesticides have been developed which target multiple species (Speck-Planche et al. 2012). Nowadays, chemical pesticides and insecticides are becoming a dominant agent for eliminating pests. When these chemical pesticides are used in a combination of effective natural enemy than that result in enhanced integrated pest management and act as a comprehensive prophylactic and remedial treatment (Gentz et al. 2010).

On the level of population, the effects of pesticides depend on exposure and toxicity, as well as on different factors like life history, characteristics, timing of application, population structure and landscape structure (Schmolke et al. 2010). Nerve targets of insects which are known for development of neuroactive insecticides include acetylcholinesterase for organophosphates and methylcarbamates, nicotinic acetylcholine receptors for neonicotinoids, gamma-aminobutyric acid receptor channel for polychlorocyclohexanes and fiproles and voltage gated sodium channels for pyrethroids and dichlorodiphenyltrichloroethane (Casida and Durkin 2013). It is an observation that the use of neonicotinoid pesticides is increasing. These pesticides are associated with different types of toxicities (Van Djik 2010).

Worldwide pesticides are divided into different categories depending upon their target. Some of these categories include herbicides, insecticides, fungicides, rodenticides, molluscicides, nematicides and plant growth regulators. Non-regulated use of pesticides has led the environment into disastrous consequences. Serious concerns about human health and biodiversity are raising due to overuse of pesticides (Agrawal et al. 2010). Pesticides are considered to be more water soluble, heat stable and polar which makes it very difficult to reduce their lethal nature. Pesticides are not only toxic to people related to agriculture, but they also cause toxicity in industries and public health work places. Depending upon the target species, pesticides can cause toxicities in natural flora, natural fauna and aquatic life (Rashid et al. 2010).

5 Merits of Pesticide Use

Pesticides provide primary as well as secondary benefits. The former ones are obvious after direct usage of pesticides such as the killing of insects that feed on crops. Later are the result of the primary benefits and they are for longer periods.

Worldwide, 40 % of the agricultural produce is lost due to plant diseases, weeds and pests collectively. If there would have been no pesticides, crop losses would have been many folds greater. Moreover, these crop saving substances not only protect the crops from damage rendered by pests, but they also increase the yields of crops considerably (Benefits of Pesticides and Crop Protection Chemicals n.d.). In their study, Webster et al. (1999) indicated that there is a significant increase in crop production due to pesticide usage and stated that economic losses without pesticide use would be much more significant. According to an estimate, yield of bread grains has increased about 10–20 % due to herbicide usage and insect pollinators are responsible for the production of 70 % of the food (What are the benefits n.d.).

As discussed above, crop production would decline if crops are not protected by the disastrous effects of pests. Decline in food production would create food shortage that would ultimately result in increased prices of food commodities (Benefits of Pesticides and Crop Protection Chemicals n.d.). Therefore, pesticides indirectly play a role in keeping the food prices under control.

Many agricultural commodities are vulnerable to attack by aflatoxins and insect control is necessary to prevent the passage of these toxins from insect to plant. Aflatoxin is a carcinogen that can cause liver and other type of cancer in humans, lowers the body's natural immune response, and can impair growth and development in children. Crop protection chemicals are used to control insect mediated aflatoxin contamination (Benefits of Pesticides and Crop Protection Chemicals n.d.).

Pesticides also prevent disease outbreaks through the control of rodent and insect vectors hence they contribute to improved human health. Deaths of about seven million people all around the world have been prevented through insecticide mediated killing of disease vectors. The most significant example is of malaria control that was responsible for an average of 5000 deaths per day (Ross 2005). Many tick, rodent and insect-borne diseases such as encephalitis, yellow fever, bubonic plague, typhoid fever, typhus, Rocky Mountain spotted fever have been kept in control by the effective use of pesticides (Benefits of Pesticides and Crop Protection Chemicals n.d.; Cunningham n.d.).

Protection of farm and agricultural lands means protection of all forms of life. Pesticides protect forests and other wildlife habitats from invasive species of plants and non-native insects and other pests. Improved agricultural yields help the farmers to produce more food without expanding their agricultural land which consequently protects biodiversity (Benefits of Pesticides and Crop Protection Chemicals n.d.).

Insecticides also improve home sanitary conditions by keeping the population of bugs in control (Delaplane 2000). Moreover, pesticides also preserve the beauty of recreational spots by controlling weeds and also prevent structural damage associated with termite infestations (Benefits of Pesticides and Crop Protection Chemicals n.d.). Moreover, herbicides and insecticides are used to preserve the turf on grounds, pitches and golf course (Aktar et al. 2009).

6 Risks Associated with Pesticide Use

Risks associated with pesticide use have surpassed their beneficial effects. Pesticides have drastic effects on non-target species and affect animal and plant biodiversity, aquatic as well as terrestrial food webs and ecosystems. According to Majewski and Capel (1995), about 80–90 % of the applied pesticides can volatilize within a few days of application (Majewski and Capel 1995). It is quite common and likely to take place while using sprayers. The volatilized pesticides evaporate into the air and subsequently may cause harm to non-target organism. A very good example of this is the use of herbicides, which volatilise off the treated plants and the vapours are sufficient to cause severe damage to other plants (Straathoff 1986). Uncontrolled use of pesticides has resulted in reduction of several terrestrial and aquatic animal and plant species. They have also threatened the survival of some rare species such as the bald eagle, peregrine falcon and osprey (Helfrich et al. 2009). Additionally, air, water and soil bodies have also being contaminated with these chemicals to toxic levels.

Among all the categories of pesticides, insecticides are considered to be most toxic whereas fungicides and herbicides are second and third on the toxicity list. Pesticides enter the natural ecosystems by two different means depending upon their solubility. Water soluble pesticides get dissolve in water and enter ground water, streams, rivers and lakes hence causing harm to untargeted species. On the other hand, fat soluble pesticides enter the bodies of animals by a process known as "bioamplification" as shown in Fig. 2. They get absorbed in the fatty tissues of animals hence resulting in persistence of pesticide in food chains for extended periods of time (Warsi n.d.).

The process of bioamplification can be described as follows:

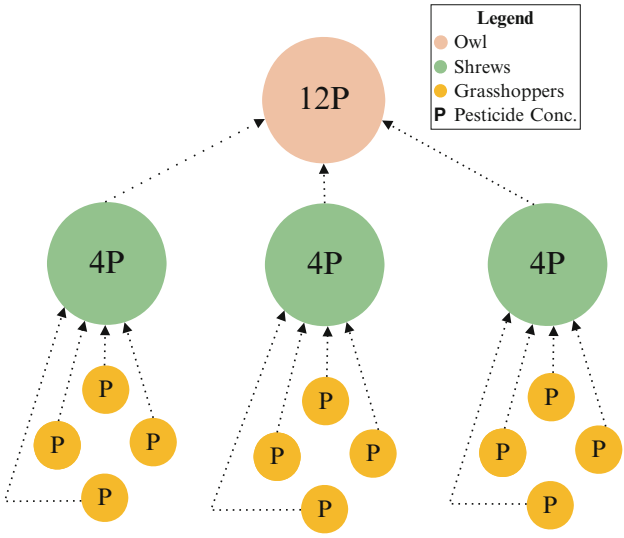

Fig. 2 Bioamplification of pesticide in the environment

1. Small concentration of pesticide enters the bodies of animal that are in low level in the food chain such as grasshopper (primary consumer).
2. Shrews (secondary consumer) eat many grasshoppers and therefore the concentration of pesticide will increase in their bodies.
3. When the high level predator such as owl eats shrews and other prey, the pesticide concentration eventually increases many folds in its body.

Therefore, the higher the trophic level, the greater will be the pesticide concentration which is known as bioamplification. This process disrupts the whole ecosystem as more species in higher trophic levels will die due to greater toxicity in their bodies. This will eventually increase the population of secondary consumers (shrews) and decrease the population of primary consumers (grasshoppers) (Warsi n.d.).

6.1 Threats to Biodiversity

The threats associated with the use of uncontrolled use of these toxins cannot be overlooked. It is the need of the hour to consider the pesticide impact on populations of aquatic and terrestrial plants, animals and birds. Accumulation of pesticides in the food chains is of greatest concern as it directly affects the predators and raptors. But, indirectly, pesticides can also reduce the quantity of weeds, shrubs and insects on which higher orders feed. Spraying of insecticides, herbicides and fungicide have also been linked to declines in the population of rare species of animals and birds. Additionally, their long term and frequent usage lead to bioaccumulation as discussed above (Pesticides reduce biodiversity 2010).

6.1.1 Threats to Aquatic Biodiversity

Pesticides enter the water via drift, by runoff, leaching through the soil or they may be applied directly into surface water in some cases such as for mosquitoes' control. Pesticide-contaminated water poses a great threat to aquatic form of life. It can affect aquatic plants, decrease dissolved oxygen in the water and can cause physiological and behavioural changes in fish populations. In several studies, lawn care pesticides have been found in surface waters and water bodies such as ponds, streams and lakes (How Pesticides Affect the Environment n.d.). Pesticides which are applied to land drift to aquatic ecosystems and there they are toxic to fishes and non-target organisms. These pesticides are not only toxic themselves but also interact with stressors which include harmful algal blooms. With the overuse of pesticides, a decline in populations of different fish species is observed (Scholz et al. 2012).

Aquatic animals are exposed to pesticides in three ways (Helfrich et al. 2009).

- *Dermally*: Direct absorption via skin
- *Breathing*: Uptake via gills during breathing
- *Orally*: Entry via drinking contaminated water

About 80 % of the dissolved oxygen is provided by the aquatic plants and it is necessary for the sustenance of aquatic life. Killing of aquatic plants by the herbicides results in drastically low O_2 levels and ultimately leads to suffocation of fish and reduced fish productivity (Helfrich et al. 2009). Generally, levels of pesticides are much higher in surface waters than groundwater probably because of surface runoff from farmland and contamination by spray drift (Anon 1993). However, pesticides reach underground through seepage of contaminated surface water, improper disposal and accidental spills and leakages (Pesticides in Groundwater 2014).

Aquatic ecosystems are experiencing considerable damage due to drifting of pesticides into the lakes, ponds and rivers. Atrazine is toxic to some fish species and it also indirectly affects the immune system of some amphibians (Forson and Storfer 2006; Rohr et al. 2008). Amphibians are chiefly affected by pesticides contaminated surface waters, in addition to overexploitation and habitat loss (The Asian Amphibian Crisis 2009). Carbaryl has been found toxic for several amphibian species, whereas, herbicide glyphosate is known to cause high mortality of tadpoles and juvenile frogs (Relyea 2005). Small concentrations of malathion have been shown to change the abundance and composition of plankton and periphyton population that consequently affected the growth of frog tadpoles (Relyea and Hoverman 2008). Moreover, chlorpyrifos and endosulfan also cause serious damage to amphibians (Sparling and Feller 2009). Dr. Hayes discovered that 10 % of male frogs raised in atrazine-contaminated water developed into females. Male frogs that were genetically males phenotypically developed ovaries within their testes. They also developed the tendency to mate with other males and lay sustainable eggs (Environmental Impacts n.d.). The reproductive potential of aquatic life forms also reduces due to herbicide spraying near weedy fish nurseries which eventually reduces the amount of shelter that is required by young fish to hide from predators (Helfrich et al. 2009).

6.1.2 Threats to Terrestrial Biodiversity

Pesticide exposure can also cause sub-lethal effects on terrestrial plants in addition to killing non-target plants. Drifting or volatilization of phenoxy herbicides can injure nearby trees and shrubs (Dreistadt et al. 1994). Herbicide glyphosate increases susceptibility of plants to diseases (Brammall and Higgins 1988) and reduces seed quality (Locke et al. 1995). Even low doses of herbicides, sulfonylureas, sulphonamides and imidazolinones have a devastating impact on the productivity of non-target crops, natural plant communities and wildlife (Fletcher et al. 1993).

Pesticides have not even spared the terrestrial animal populations. Populations of beneficial insects such as bees and beetles can significantly decline by the use of broad-spectrum insecticides such as carbamates, organophosphates and pyrethroids. Insect population has also been found to be greater on organic farms compared to non-organic ones. Synergistic effects of pyrethroids and triazole or imidazole fungicides are harmful to honey bees (Pilling and Jepson 2006). Neonicotinoids insecticides such as clothianidin and imidacloprid are toxic to bees. Imidacloprid even at low doses negatively affects bee foraging behaviour (Yang et al. 2008) in addition to reducing learning capacity (Decourtye et al. 2003). The greatest havoc

wreaked by neonicotinoids was the sudden disappearing of honey bees at the very start of the twenty-first century. This was a major concern to the food industry as 1/3 of the food production depends on pollination by bees. Honey and wax obtained from commercial hives were reported to contain a mixture of pesticides of which neonicotinoids shared a significant portion. Since 2006, each year, honey bee populations have dropped by 29–36 % (Environmental Impacts n.d.).

Since pre-agricultural times, 20–25 % of the bird populations have declined. One of the major causes of this massive decline is the use of pesticides which was not known before 1962. Pesticide accumulation in the tissues of bird species leads to their death. Bald eagle populations in the USA declined primarily because of exposure to DDT and its metabolites (Liroff 2000). Fungicides can indirectly reduce birds and mammal populations by killing earthworms on which they feed. Granular forms of pesticides are disguised as food grains by birds. Organophosphate insecticides are highly toxic to birds and they are known to have poisoned raptors in the fields. Sublethal quantities of pesticides can affect the nervous system, causing behavioural changes (Pesticides reduce biodiversity 2010).

Pesticides can be applied as liquid sprays on the soil or crop plant, may be incorporated or injected into the soil or applied as granules or as a seed treatment. Once they have reached their target area, pesticides disappear via degradation, dispersion, volatilisation or leaching into surface water and groundwater; they may be taken up by plants or soil organisms or they may stay in the soil (Hayo and Werf 1996). The major concern of pesticide overuse is their leaching into the soil, which affects the microbes residing in it. Soil dwelling microbes help the plants in many different ways, such as nutrient uptake; breakdown of organic matter and increasing soil fertility. But indirectly they are also advantageous to humans as we heavily depend on plants. Unfortunately, pesticide overuse may have drastic consequences and a time may come when we would not have any more of these organisms and soil may degrade.

Several soil microbes are involved in the fixation of atmospheric nitrogen to nitrates. Chlorothalonil and dinitrophenyl fungicides have been shown to disrupt nitrification and de-nitrification bacteria dependent processes (Lang and Cai 2009). The herbicide, triclopyr inhibits soil bacteria involved in the transformation of ammonia into nitrite (Pell et al. 1998). Glyphosate, a non-selective herbicide, reduces the growth and activity of nitrogen-fixing bacteria in soil (Santos and Flores 1995) whereas, 2,4-D inhibits the transformation of ammonia into nitrates carried out by the soil bacteria (Frankenberger et al. 1991).

Herbicides also cause considerable damage to fungal species in soil as pesticides trifluralin and oryzalin both are known to inhibit the growth of symbiotic mycorrhizal fungi (Kelley and South 1978) that help in nutrient uptake. Oxadiazon has been known to reduce the number of fungal spores (Moorman 1989) whereas triclopyr is toxic to certain species of mycorrhizal fungi (Chakravarty and Sidhu 1987).

Earthworms play a significant role in the soil ecosystem by acting as bioindicators of soil contamination and as models for soil toxicity testing. Earthworms also contribute to soil fertility. Pesticides have not spared earthworms from their toxic effects and the later is exposed to the former mainly via contaminated soil pore water. Schreck et al. (2008) reported that insecticides and/or fungicides produce

neurotoxic effects in earthworms and after a long term exposure they are physiologically damaged (Schreck et al. 2008). Glyphosate and chlorpyrifos have deleterious effects on earthworms at the cellular level causing DNA damage. Glyphosates affect feeding activity and viability of earthworms (Casabé et al. 2007). Goulson reviewed the harms of neonicotinoids on environment and animal life. He reported that as neonicotinoids have a tendency to accumulate in the soil, therefore, they can kill earthworms such as *Eisenia foetida* species (Goulson 2013).

7 Pesticide Impact on Human Health

Pesticides have improved the standard of human health by controlling vector-borne diseases, however, their long term and indiscriminate use has resulted in serious health effects. Human beings especially infants and children are highly vulnerable to deleterious effects of pesticides due to the non-specific nature and inadequate application of pesticides. As the pesticide use has increased over the past few decades, the likelihood of exposure to these chemicals has also increased considerably.

According to World Health Organization, each year, about 3,000,000 cases of pesticide poisoning and 220, 000 deaths are reported in developing countries (Lah 2011). About 2.2 million people, mainly belonging to developing countries are at increased risk of exposure to pesticides (Hicks 2013). Besides, some people are more susceptible to the toxic effects of pesticide than others, such as infants, young children, agricultural farm workers and pesticide applicators (Pesticides and Human Health n.d.).

Pesticides enter the human body through ingestion, inhalation or penetration via skin (Spear 1991). But the majority of people get affected via the intake of pesticide contaminated food. After crossing several barriers, they ultimately reach human tissues or storage compartments (Hayo and Werf 1996). Although human bodies have mechanisms for the excretion of toxins, however, in some cases, it retains them through absorption in the circulatory system (Jabbar and Mallick 1994). Toxic effects are produced when the concentration of pesticide in the body increases far more than its initial concentration in the environment (Hayo and Werf 1996).

The effects of pesticides on human health are highly variable. They may appear in days and are immediate in nature or they may take months or years to manifest and hence are called chronic or long-term effects. Acute and chronic effects of pesticide exposure on human health are discussed below.

7.1 Acute Effects of Pesticides

Immediate effects of pesticide exposure include headache, stinging of the eyes and skin, irritation of the nose and throat, skin itching, appearance of the rash and blisters on the skin, dizziness, diarrhoea, abdominal pain, nausea and vomiting, blurred

vision, blindness and very rarely death. Acute effects of pesticide exposure are not severe enough for someone to seek medical help (Pesticides and Human Health n.d.).

7.2 Chronic Effects of Pesticides

Chronic effects of pesticides are often lethal and may not appear even for years. These are long term effects that cause damage to multiple body organs. Pesticide exposure for prolonged periods of time results in following consequences:

- Pesticide exposure can cause a range of neurological health effects such as loss of coordination and memory, reduced visual ability and reduced motor signalling (Lah 2011).
- Long-term pesticide exposure damages the immune system (Culliney et al. 1992) and can cause hypersensitivity, asthma and allergies.
- Pesticide residues have been found in the bloodstream of cancer patients compared to normal individuals. Pesticides have been associated with leukaemia, brain cancer, lymphoma, cancer of the breast, prostate, ovaries, and testes (Pesticides and Human Health n.d.).
- The presence of pesticides in the body for a longer time also affects reproductive capabilities by altering the levels of male and female reproductive hormones. Consequently, it results in stillbirth, birth defects, spontaneous abortion and infertility (Pesticides and Human Health n.d.).
- Lon-term exposure to pesticide also damages liver, lungs, kidneys and may cause blood diseases.

Ingestion of organochlorines causes hypersensitivity to light, sound, and touch, dizziness, tremors, seizures, vomiting, nausea, confusion and nervousness (Lah 2011). Exposure to organophosphates and carbamates causes, symptoms similar to those of increased neurotransmitter-acetylcholine. These pesticides interfere with the normal nerve signal transduction and exposure to them causes headaches, dizziness, confusion, nausea and vomiting, muscle and chest pain. Difficulty breathing, convulsions, coma and death may occur in severe cases (Pesticides and Human Health n.d.)

Pyrethroids can cause an allergic skin response, aggressiveness, hyper-excitation, reproductive or developmental effects in addition to causing tremors and seizures (Lah 2011). It is observed that there is a relationship between pesticides and Parkinson's disease and Alzheimer's disease (Casida and Durkin 2013).

8 Conclusion and Future Prospects

Pesticides have proved to be a boon for the farmers as well as people all around the world by increasing agricultural yield and by providing innumerable benefits to society indirectly. But the issue of hazards posed by pesticides to human health and the environment has raised concerns about the safety of pesticides. Although we

cannot completely eliminate the hazards associated with pesticide use, but we can circumvent them in one way or the other. Exposure to pesticides and hence the harmful consequences and undesirable effects of this exposure can be minimised by several means such as alternative cropping methods or by using well-maintained spraying equipments. Production of better, safe and environment friendly pesticide formulations could reduce the harmful effects associated with the pesticide usage. If the pesticides are used in appropriate quantities and used only when required or necessary, then pesticide risks can be minimised. Similarly, if a less toxic formulation or low dose of a toxic formulation is used, the havoc can be curbed. As Paracelsus also once said "*The right dose differentiates a poison from a remedy*".

There are organochlorines, which are used as pesticides. These pesticides are least biodegradable and their use is banned in many countries. Besides this fact, organochlorines are highly used in many places. This results in serious health hazards. Water pollution is on the rise due to these pesticides, even at low concentration, these pesticides have serious threat to the environment (Agrawal et al. 2010). The majority of farmers are unaware of the potential toxicities of pesticides. They have no information about types of pesticides, their level of poisoning, hazards and safety measures to be taken before use of those pesticides. Due to this reason, toxic and environmentally persistent chemicals are used to kill pests which can also lead to intentional, incidental or occupational exposure. These compounds have long term effects on human health. Awareness should be arranged for these farmers to reduce the uses of toxic pesticides (Sharma et al. 2012).

In future chemical pesticides can be used in combination with natural treatments and remedies which result in more sustainable elimination of pests and insects. This combination not only promises environmental sustainability, but also has diverse applications in controlling of urban pests and invasive species (Gentz et al. 2010). Pesticides have also posed a serious threat on biological integrity of marine and aquatic ecosystems. It is the need of time to integrate the studies of different disciplines including toxicology, environmental chemistry, population biology, community ecology, conservation biology and landscape ecology to understand direct and indirect effects of pesticides on the environment (Macneale et al. 2010).

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