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REVIEW ARTICLE

Great Usefulness and Effectiveness of Pesticide in Agriculture

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ABSTRACT

Over the last 60 years, farmers achieved a significant progress in the production of foodstuff using pesticides. They have done this principally to prevent or reduce agricultural losses due to activity of pests which resulted in improved yield and greater availability of food, at a reasonable price and over all seasons. By the use of pesticides in agriculture, the productivity has increased dramatically in most countries. The primary benefits are known as consequences of the direct pesticides' effects such as protection of people, animal and crop health, and protection of recreational turf. The secondary benefits arise from primary and these are the less immediate, less intuitively obvious, or long-term consequences. Despite beneficial results of using pesticides in agriculture and public health sector, their use also invites deleterious environmental and public health effects. Pesticides hold a unique position among environmental contaminants due to their high biological activity and toxicity.

Key words: Diseases, organophosphate, pesticides, toxicity, vectors

INTRODUCTION

Pesticides

Pesticides are substances used by human beings to kill or deter organisms (pests) that threaten our health and well-being and the health and well-being of pets and livestock or cause damage to crops (Agrawal *et al.,* 2010). Antibiotics in the medical sense are excluded, but included are insecticides, herbicides, fungicides, acaricides, nematicides, molluscicides, and rodenticides, among others. Of these, insecticides (to control insects) and herbicides (for controlling unwanted vegetation) are used in large quantities and have the greatest impact on the environment. 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 worldwide. 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.) (Aktar *et al.,* 2009).

Pesticides can be natural compounds or they can be synthetically produced. They may belong to any one of the several pesticide classes. Major pesticides also belong to the classes of organochlorines, carbamates, organophosphates, pyrethroids, and neonicotinoids 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

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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 (Yadav *et al.,* 2015). 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. In general, a pesticide is a chemical (such as carbamate) or a biological agent (such as virus, bacterium, or fungus) that deters, incapacitates, kills, or otherwise discourages pests. Target pests can include insects, plant pathogens, weeds, molluscs, birds, mammals, fish, nematodes (roundworms), and microbes that destroy property, cause nuisance, or spread disease or are disease vectors. Along with these benefits, pesticides also have drawbacks, such as potential toxicity to humans and other species (Cocco *et al.,* 2013).

Many pesticides can be grouped into chemical families. Prominent insecticide families include organochlorines, organophosphates, and carbamates. Organochlorine hydrocarbons (e.g., dichlorodiphenyltrichloroethane [DDT]) could be separated into dichlorodiphenylethanes, cyclodiene compounds, and other related compounds (Yadav *et al.,* 2015). They operate by disrupting the sodium/potassium balance of the nerve fiber, forcing the nerve to transmit continuously. Their toxicities vary greatly, but they have been phased out because of their persistence and potential to bioaccumulate. Organophosphate and carbamates largely replaced organochlorines (Casabé *et al.,* 2007).

They are operated by inhibiting enzyme acetylcholineesterase and acetylcholine to transfer indefinitely nerve impulses and causing various symptoms like paralysis or weakness. Organophosphates are quite toxic to vertebrates and have in some cases been replaced by less toxic carbamates. Thiocarbamate and dithiocarbamates are subclasses of carbamates. Prominent families of herbicides include phenoxy and benzoic acid herbicides (e.g. 2,4-D), triazines (e.g., atrazine), ureas (e.g., diuron), and chloroacetanilide (e.g., alachlor). Phenoxy compounds tend to selectively kill broad-leaf weeds, rather than grasses. The phenoxy and benzoic acid herbicides function similar to plant growth hormones, and grow cells without normal cell division, crushing the plant's nutrient transport system. Triazines interfere with photosynthesis. Many commonly used pesticides are not included in these families, including glyphosate. The application of pest control agents is usually carried out by dispersing the chemical in a (often hydrocarbon based) solvent-surfactant system to give a homogeneous preparation. A virus lethality study performed in 1977 demonstrated that a particular pesticide did not increase the lethality of the virus; however, combinations which included some surfactants and the solvent clearly showed that pre-treatment with them markedly increased the viral lethality in the test mice (Singh, and Mandal, 2013).

BACKGROUND

Since pesticides are by definition toxic to living organisms, there is a great public concern over the effect of these substances, not only on human beings but also on non-target organisms in the environment (Cocco *et al.,* 2013). People fear that they themselves may be poisoned by the indiscernible residues on the food that they eat or in the air that they breathe. They are also concerned that birds, fish, and other beneficial organisms may be adversely affected by pesticides. In the 1960s, this fear was articulately expressed by Rachel Carson in her best-selling book, Silent Spring, widely credited with giving impetus to the quest for the safer use of pesticides in particular and to the environmental movement in general. Since before 2000 BC, humans have utilized pesticides to protect their crops. The first known pesticide was elemental sulfur dusting used in ancient Sumer about 4,500 years ago in ancient Mesopotamia. The Rigveda, which is about 4,000 years old, mentions the use of poisonous plants for pest control. By the 15th century, toxic chemicals such as arsenic, mercury, and lead were being applied to crops to kill pests. In the 17th century, nicotine sulfate was extracted from tobacco leaves for use as an insecticide (WHO, 2009).

The 19th century saw the introduction of two more natural pesticides, pyrethrum, which is derived from chrysanthemums, and rotenone, which is derived from the roots of tropical vegetables. Until the 1950s, arsenic-based pesticides were dominant. Paul Müller discovered that DDT was a very effective insecticide. Organochlorines such as DDT were dominant, but they were replaced in the U.S. by organophosphates and carbamates by 1975. Since then, pyrethrin compounds have become the dominant insecticide. Herbicides became common in the 1960s, led by "triazine and other nitrogen-based compounds, carboxylic acids such as 2,4-dichlorophenoxyacetic acid, and glyphosate" (Casida and Durkin, 2013).

The first legislation providing federal authority for regulating pesticides was enacted in 1910; however, decades later during the 1940s, manufacturers began to produce large amounts of synthetic pesticides and their use became widespread. Some sources consider the 1940s and to have been the start of the "pesticide era (Damalas and Eleftherohorinos, 2011)." Although the U.S. Environmental Protection Agency was established in 1970 and amendments to the pesticide law in 1972, pesticide use has increased 50-fold since 1950 and 2.3 million tons (2.5 million short tons) of industrial pesticides are now used each year. Seventy-five percent of all pesticides in the world are used in developed countries, but use in developing countries is increasing. A study of USA Pesticide Use Trends through 1997 was published in 2003 by the National Science Foundation's Center for Integrated Pest Management. In the 1960s, it was discovered that DDT was preventing many fish-eating birds from reproducing, which was a serious threat to biodiversity. Rachel Carson wrote the best-selling book *Silent Spring* about biological magnification. The agricultural use of DDT is now banned under the Stockholm Convention on Persistent Organic Pollutants, but it is still used in some developing nations to prevent malaria and other tropical diseases by spraying on interior walls to kill or repel mosquitoes (Damalas and Eleftherohorinos, 2011).

Classification of pesticides

Pesticide is a common term that characterizes several classes of insecticides, herbicides, fungicides, rodenticides, wood preservatives, garden chemicals, and household disinfectants that are used to either to kill or protect from pests (Decourtye *et al.,* 2003). These pesticides differ in their physical, chemical, and identical properties from one class to other. Therefore it can be classified on the bases of their properties and can be studied in their respective groups. Synthetic pesticides are artificial chemicals and do not occur in nature. They are categorized into various classes depending on the needs. At present, there are three most popular methods of pesticide classification suggested by Drum. These three popular methods of pesticide classes are as follows:

(i) Classification based on the mode of entry
(ii) Classification based on pesticide function and the pest organism they kill
(iii) Classification based on the chemical composition of the pesticide.

Categories of Pesticides

Insecticides: some naturally occurring compounds such as nicotine and pyrethrum, derived tobacco plant and chrysanthemium species, respectively, has insecticidal activities. This has been known for centuries. These have since been supplemented by inorganic compounds for insect control and sulfur- and copper-based compounds for fungus control. In the years between 1939 and 1953, tremendous advances were made in insect control as a result of the discovery of the insecticidal activity of a number of synthetic organic compounds, such as organochlorines like DDT, benzene hexachloride (already synthesized as chemicals in the previous century), dieldrin, and toxaphene; rganophosphates parathion and others; and carbamates such as carbaryl (Lorenz, 2009).

Pesticides for weed control called herbicides

The immediate post-war years also saw the discovery of the phenoxy herbicides, primarily 2,4-D. The selective action of this herbicide enabled farmers to control broad-leaved weeds among their cereal crops without damaging the crops (Heck *et al.,* 2010). Subsequently, a great variety of herbicides with a wide range of chemical structures and with many different characteristics, most of them with a relatively low toxicity to human beings, have been developed. However, public concern has been

raised since 1980s and early 1990s over he detection of their residues in soil and water. This is because of the potential health hazards caused by some of them (such as the impurity dioxin in 2,4,5-T, now withdrawn, and paraquat3), and their possible effect on rare plants (Casida and Durkin, 2013).

Pesticides for controlling fungus called fungicides

Fungicides are a third major group of agricultural pesticides, though the quantities used are smaller than the insecticides and herbicides. Some of them, such as sulfur and copper sulfate, have been in use for more than two centuries and are still on the market, but many new compounds have been developed. Their acute toxicity to human beings and wildlife is generally low, and as a result, there is less concern about their use than that of insecticides. However, discoveries about the reproductive toxicity and endocrine disruption in animals of commonly used fungicides have caused concern (WHO, 2009).

Ways of Appling Pesticides

Pesticide application refers to the practical way in which pesticides (including herbicides, fungicides, insecticides, or nematode are used as pest control agents. Some are used as *biological targets* (e.g. pest organism, crop or other plant Dawson et al., 2010. Public concern about the use of pesticides has highlighted the need to make this process as efficient as possible, in order to minimize their release into the environment and human exposure (including operators, bystanders and consumers of produce) (Eldridge, 2008). Pest management practices involve rational application of pesticides as the process is multidisciplinary, combining many aspects of biology and chemistry with: agronomy, engineering, meteorology, socio economics and public health, together with newer disciplines such biotechnology and information science (Forson and Storfer, 2006). Pesticides help keep homes free of termites, disease-carrying rodents and insects, and other unsanitary pests. Individuals use pesticides in the form of bug repellent to keep themselves and their families safe from bug bites that may carry diseases like the West Nile virus, Lyme disease, and malaria (Heck *et al.,* 2010).

Treatment of seeds

Seed treatments can achieve exceptionally high efficiencies, in terms of effective dose transfer to a crop (Heck *et al.,* 2010). Pesticides are applied to the seed prior to planting, in the form of a seed treatment, or coating, to protect against soil-borne risks to the plant; additionally, these coatings can provide supplemental chemicals and nutrients designed to encourage growth. A typical seed coating treatment include using a nutrient layer containing nitrogen, phosphorus, and potassium, a rhizobial layer containing symbiotic bacteria and other microorganisms, and a fungicide (or other chemical) layer to make the seed less vulnerable to pests attack (Helfrich *et al*., 2009).

Using various sprayers

One of the most common forms of pesticide application, especially in conventional agriculture, is the use of mechanical sprayers. Hydraulic sprayers consist of a tank, a pump, a lance (for single nozzles) or boom, and a nozzle (or multiple nozzles). Sprayers is used to carry a pesticide formulation, often containing a mixture of water and other liquid chemical. (It can also be used for application of liquid fertilizer) and released in droplets, which can be as large as rain-type drops or tiny almost-invisible particles (Gentz *et al.*, 2010). This conversion is accomplished by forcing the spray mixture through a spray nozzle under pressure. The size of droplets can be altered through the use of different nozzle sizes, or by altering the pressure under which it is forced, or a combination of both. Large droplets have the advantage of being less susceptible to spray drift, but require more water per unit of land covered. Due to static electricity, small droplets are able to maximize contact with a target organism, but very still wind conditions are required (Gentz *et al.,* 2010).

Spraying in accordance with germination status

Traditional agricultural crop pesticides can either be applied pre-emergent or post-emergent, a term referring to the germination status of the plant. Pre-emergent pesticide application, in conventional agriculture, attempts to reduce competitive pressure on newly germinated plants by removing

undesirable organisms and maximizing the amount of water, soil nutrients, and sunlight available for the crop. An example of pre-emergent pesticide application is atrazine application for corn. Similarly, glyphosate mixtures are often applied pre-emergent on agricultural fields to remove early-germinating weeds and prepare for subsequent crops. Pre-emergent application equipment often has large, wide tires designed to float on soft soil, minimizing both soil compaction and damage to planted (but not yet emerged) crops. A three-wheel application machine, such as the one pictured on the right, is designed so that tires do not follow the same path, minimizing the creation of ruts in the field and limiting subsoil damage.

Post-emergent pesticide application requires the use of specific chemicals chosen to minimize harm to the desirable target organism. An example is 2,4-dichlorophenoxyacetic acid, which will injure broadleaf weeds (dicots) but leave behind grasses (monocots) (Gentz *et al.,* 2010).

Such a chemical has been used extensively for example on wheat crops. A number of companies have also created genetically modified organisms that are resistant to various pesticides. Examples include glyphosate-resistant soybeans and Bt maize, which change the types of formulations involved in addressing post-emergent pesticide pressure. It is important to also note that, even given appropriate chemical choices, high ambient temperatures or other environmental influences, nontargeted desirable organismcan be damaged during application. As plants have already germinated, post-emergent pesticide application necessitates limited field contact to minimize losses due to crop and soil damage. Typical industrial application equipment will utilize very tall and narrow tires and combine this with a sprayer body which can be raised and lowered depending on crop height. These sprayer bodies usually carry the label "high-clearance" as they can be raised above growing crops, although usually not much more than 1 or 2 m high. In addition, these sprayers often have very wide booms to minimize the number of passes required over a field, again designed to limit crop damage and maximize efficiency. In industrial agriculture, spray booms 120 ft (40 m) wide are not uncommon, especially in prairie agriculture with large, flat fields. Related to this, aerial pesticide application is a method of top dressing a pesticide to an emerged crop, which eliminates physical contact with soil and crops (Eldridge, 2008).

Losses due to prevalence of weeds and insects on crop plants

Weeds and insects can directly damage crops and cause yield losses in many ways. Weeds compete with crops for nutrients, air, and space and may parasitize or contaminate crop seeds. Insects eat plant leaves and make them unattractive; insect larvae and caterpillars eat or make holes in the leaves or the stems of seedlings. Insects also reduce the ability of the plant roots to absorb water or nutrient when they eat parts of the roots. Sometimes, insects inject toxic substances when they feed on the plants or create holes through which disease-causing bacteria or fungi may enter the plant. The two main methods of controlling or reducing pest damage are chemical and non-chemical methods. Non-chemical methods include physical, cultural, biological, and mechanical methods. Chemical methods, which generally mean the use of pesticides, are discussed in this guide.

BASIC USEFULNESS AND UNIQUE EFFECTIVENESS OF PESTICIDES

The primary benefits are known as consequences of the direct pesticides' effects such as protection of people, animal and crop health, and protection of recreational turf. The secondary benefits arise from primary, and these are the less immediate, less intuitively obvious, or long-term consequences. Table 1 summarizes the effects, primary and secondary benefits, and their interactions. The interplay between negative effects and benefits is complex and not easy to follow always.

Over the last 60 years, farmers achieved a significant progress in the production of foodstuff using pesticides. They have done this principally to prevent or reduce agricultural losses due to activity of pests, which resulted in improved yield and greater availability of food, at a reasonable price and over all seasons. By the use of pesticides in agriculture, the productivity has increased dramatically in most countries. For example, wheat yields in the United Kingdom, corn yields in the USA, and total yields in the Russia and other countries, were enhanced

Table 1: Primary and secondary benefits of pesticides

Primary benefits	Secondary benefits
1. Controlling pests and plant disease vectors	**Community benefits**
Improved crop/livestock quality	Nutrition and health improved
Reduced fuel use for weeding	Food safety/security
Reduced soil disturbance	Life expectancy increased
Invasive species controlled	Reduced maintenance costs
2. Controlling disease vectors and nuisances organisms	**National benefits**
Human lives saved	National agricultural economy
Human disturbance reduced	Increased export revenues
Animal suffering reduced	Reduced soil erosion/moisture loss
Increased livestock quality	
3. Prevent or control of organisms that harm other human activities and structures	**Global benefits**
Tree/bush/leaf hazards prevented	Less pressure on uncropped land
Recreational turf protected	Fewer pest introductions elsewhere
Wooden structures protected	International tourism revenue

enormously.

It is believed that, consuming diets, containing fresh fruits and vegetables, far outweigh potential risks, from eating very low residues of pesticides in crops. Improved nutrition and reduced drudgery both improve the quality of life and longevity. Improved medical care and drug treatments along with hygiene have played a significant role in extending lives, but the value of nutritious, safe, and affordable food should not be underestimated as a health promoter that increases life expectancy.

The benefits of broad pesticides use include, control of wide range of human and livestock disease vectors, which reduce the number of infected individuals, and deaths by the prevention of disease spread, internationally. Killing of vectors is the most effective method to struggle them. According to the World Health Organization without access to chemical control methods, such as use of pesticides, life will be dangerous for a large proportion of mankind.

Pesticides play an important role in the destruction of various organisms which have a negative impact on human activities, infrastructure, and the materials of everyday life. In many specific sectors of human activity, pesticides are used to control unwanted organisms, such as prevention of accelerated corrosion of metal constructions, maintain the turf on sport pitches, cricket grounds and golf courses, helping to facilitate a hugely popular pastime that provides fresh air and exercise for millions of people around the world in domestic and ornamental gardening etc.

Health Effect of Pesticides

Despite beneficial results of using pesticides in agriculture and public health sector, their use also invites deleterious environmental and public health effects. Pesticides hold a unique position among environmental contaminants due to their high biological activity and toxicity. Most pesticides do not distinguish between pests and other similar incidental lifeform (Eldridge, 2008). They are potentially harmful to humans, animals, other living organisms, and the environment if used incorrectly. It is estimated that about 5000–20,000 people died and about 500,000–1 million people get poisoned every year by pesticides. At least half of the intoxicated and 75% of those who die due to pesticide are agricultural workers. The rest is being poisoned due to eating of contaminated food (Helfrich *et al.,* 2009).

Potential effects on human health

Pesticides may enter the human body through inhalation of polluted air, dust, and vapor that contain pesticides; through oral exposure by consuming contaminated food and water; and through dermal exposure by direct contact with pesticides. Pesticides are also beneficial in many aspects of life prevention of metal corrosion, maintaining grasses on sport pitches, cricket grounds and golf courses. It also help to promote photosynthetic fresh air for millions of people around the world who are interested in raising vegetables and ornamental gardens. When pesticides are sprayed onto food crops, especially fruits and vegetables, they cause food poisoning. When excess are washed into soils and groundwater they end up in drinking water. Pesticide spray can also pollute the air. Toxicity of chemicals, length and magnitude of exposure determines the degree of harmful impact on human health. Toxicity of chemicals depends on the nature of toxicant, routes of exposure (oral, dermal, and inhalation), dose, and organism (Helfrich *et al.,* 2009).

Toxicity can be either acute or chronic. Acute toxicity is the ability of a substance to cause harmful effects which develop rapidly following absorption, *i.e*., a few hours or a day. Chronic toxicity is the ability of a substance to cause adverse health effects resulting from long-term exposure to a substance. Toxicity of insecticides is commonly expressed

in terms of lethal dose 50% (LD50) or lethal concentration 50% (LC50). LD50 is the single exposure dose of the poison per unit weight of the organism required to kill 50% of the test population, where the population is genetically homogeneous. It is expressed in milligram per kilogram body weight. LC50 is the concentration of the chemical in the external medium (usually air or water surrounding experimental animals), which causes 50% mortality of the test population, where the population is genetically homogeneous. It is expressed in parts per million (ppm) (Helfrich *et al.,* 2009).

Acute harmful effect

The harmful effects that occur from a single exposure by any route of entry are termed "acute effects." The four routes of exposure are dermal (skin), inhalation (lungs), oral (mouth), and the eyes. Acute toxicity is determined by examining the dermal toxicity, inhalation toxicity, and oral toxicity of test animals. In addition, eye and skin irritation are also examined. Acute illness generally appears a short time after contact or exposure to the pesticide. Acute illness in human can arise through pesticides in agricultural fields. Intention or unintentional poisoning occur due to exposure during application. Several symptoms such as headaches, body aches, skin rashes, poor concentration, nausea, dizziness, impaired vision, cramps, panic attacks, and in severe cases, coma and death could occur due to pesticide poisoning. About 3 million cases of acute poisoning due to pesticides are reported worldwide every year. Out of these 3 million pesticide poisoning cases, 2 million are suicide attempts and the rest of these are occupational or accidental poisoning cases (Lorenz, 2009).

Toxic chronic effect

Any harmful effects that occur from small doses repeated over a period of time are termed "chronic effects." Suspected chronic effects from exposure to certain pesticides include birth defects, toxicity to a fetus, and production of benign or malignant tumors, genetic changes, blood disorders, nerve disorders, endocrine disruption, and reproduction effects. The chronic toxicity of a pesticide is more difficult than acute toxicity to determine through laboratory analysis. Continued and repeated exposure to sublethal quantities of pesticides for a long period of time (may be several years to decades) causes chronic illness in humans (Yadav *et al.,* 2015)

Pesticide effects 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 the World Health Organization, each year, about 3,000,000 cases of pesticide poisoning and 220,000 deaths are reported in developing countries. About 2.2 million people, mainly belonging to developing countries, are at increased risk of exposure to pesticides (Yadav *et al.,* 2015). 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. However, 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. Although human bodies have mechanisms for the excretion of toxins, in some cases, it retains them through absorption in the circulatory system. Toxic effects are produced when the concentration of pesticide in the body increases far more than its initial concentration in the environment (Yadav *et al.,* 2015)

Effect on environment

Extensive application and subsequent disposal of pesticides by farmers, institutions, and the general public offer numerous possible sources of pesticides in the environment. It is almost impossible to limit the area of effect of pesticides (Lorenz, 2009). Even when it is applied in a very small area, it spreads in the air, is absorbed in the soil, dissolves in the water, and eventually reaches a much bigger area. Pesticides once released into the environment may have many different

fates. When pesticides are sprayed in agricultural crop, it may find their way through the air and eventually end up in other segments of the environment, such as in soil or water. Pesticides that are applied directly to the soil may be washed off and reaches to nearby surface water bodies through surface runoff or may percolate through the soil to lower soil layers and groundwater. The effects of pesticides on environmental system may range from minor deviation on the normal functioning of the ecosystem to the loss of species diversity (Forson and Storfer, 2006).

Effects on non-target organism

Most insecticides once applied to kill pests; it may also adversely affect non-target organisms such as earthworm, natural predators, and pollinator. Pesticide applications can cause decline in earthworm populations. For example, carbamate insecticides are very toxic to earthworms and some organophosphates have been shown to reduce earthworm populations. Unfortunately, natural predator such as parasitoids and predators (essential for controlling pest population level) are most susceptible to insecticides and are severely affected. The destruction of these natural predators can exacerbate pest problems. Usually, if natural enemies are absent, additional insecticide sprays are required to control the target pest. In addition, pesticides can also affect predator behavior and their life history parameters including growth rate, development time, and other reproductive functions (Eldridge, 2008).

Effects on soil microflora

A major portion of the non-target pesticides from agriculture application and other sources may accumulate in soil. Further, the indiscriminate and repeated use of pesticides aggravates this soil accumulation. Soil properties and soil microflora gets affected due to pesticides which may undergo a variety of degradation, transport, and adsorption/ desorption processes. The degraded pesticides interact with the soil and with its indigenous microorganisms, thus altering its microbial diversity, biochemical reactions, and enzymatic activity. Any alteration in the microbial diversity and soil biomass eventually leads to the disturbance in soil ecosystem and loss of soil fertility (Forson and Storfer, 2006). Pesticide application may also inhibit or kill certain group of microorganisms and outnumber other groups by releasing them from the competition. They may also adversely affect the soils vital biochemical reactions including nitrogen fixation, nitrification, and ammonification by activating/deactivating specific soil microorganisms and/or enzymes. Pesticides have also been reported to influence mineralization of soil organic matter, which is a key soil property that determines the soil quality and productivity (Fishel *et al.,* 2013).

Effects on water and air ecosystem

Pesticide residues in water are a major concern as they pose a serious threat to biological communities including humans. There are different ways, by which pesticides can get into water. They include accidental spillage of pesticide, industrial effluent from pesticide factory, surface run off from sprayed field and transport from pesticide treated soils. It may also be by washing of spray equipment after spray operation,washing into ponds, lakes, streams and river water, aerial spray to control water inhabiting pests. Pesticides generally move from fields to various water reservoirs by runoff or in drainage induced by rain or irrigation. Similarly, the presence of pesticides in air can be caused by the number of factors including spray drift, volatilization from the treated surfaces, and aerial application of pesticides. Extent of drift depends on droplet size and wind speed. The rate of volatilization is dependent on time after pesticide treatment, the surface on which the pesticide settles the ambient temperature, humidity, and wind speed and the vapor pressure of the ingredients. The volatility or semivolatility nature of the pesticide compounds similarly constitutes an important risk of atmospheric pollution of large cities (Decourtye *et al.,* 2003).

Use of Pesticide

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. The later one 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 (Lorenz, 2009). 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, 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.) (Lorenz, 2009).

Danger associated with pesticide use

Danger associated with pesticide use has surpassed their beneficial effects. Pesticides have serious effects on non-target species. It also affect biodiversity of animal and plant species. Aquatic as well as terrestrial food webs and ecosystems are not sparred (Fishel *et al.,* 2013) about 80–90% of the applied pesticides can volatilize within a few days of application. It is quite common and likely to take place when using sprayers. The volatilized pesticides evaporate into the air and subsequently may cause harm to non-target organism. A very good example is the use of herbicides, which run off the treated plants and the liquid cause severe damage to other plants. Uncontrolled use of pesticides has resulted in the 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. In addition, air, water, and soil bodies have also being contaminated with these chemicals to toxic levels (Fishel *et al.,* 2013).

CONCLUSION

Pesticides have proved to be a boon for the farmers as well as people worldwide by increasing agricultural yield and by providing innumerable benefits to society indirectly. However, 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, 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 minimized by several means such as alternative cropping methods or using well-maintained spraying equipment. 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, pesticide risks can be minimized.

RECOMMENDATIONS

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.

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