Chapter

Pesticides, Anthropogenic Activities, History and the Health of Our Environment: Lessons from Africa

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Abstract

This chapter describes the historical events related to pesticide use. The description of events focuses on human activities that necessitated the use of chemical agents for pest control to protect crops, and animals including humans in African countries. The description covers the common pests in Africa and the need for pest control using pesticides. History of pesticide use in Africa and the ban of organochlorines are covered. Controversies under discussion in Africa and the current trend of pesticide use in Africa are part of the chapter as well as pesticide import and supply. Hazard and risk of exposure of biological organisms including humans to pesticides due to anthropogenic activities in Africa and pros and cons of pesticide use in Africa are covered.

Keywords: anthropogenic activities, history of pesticides, humans, environment, health, Africa

1. Introduction

This chapter describes the historical events related to pesticide use and the pros and cons of pesticide use in Africa. Description for *pesticide* as any chemical used to prevent, destroy, or repel pests and also the description of *pest* as any species that interferes with human activities, properties, or health have been provided with examples. In Africa, rapid population growth, illiteracy, food insecurity, weak control systems, and poverty have accelerated the use and misuse of pesticides. Based on the latest, 2018, United Nations estimates the current population of Africa is now estimated at 1.3 billion, that is, 16.6% of the total global population. A large part of African population lives in tropical and subtropical climate with high temperatures [1] and moisture favorable for insects' population growth, as well as movement, agricultural and animal husbandry activities throughout the year [2]. Through these dynamics, humans modify the components of disease agents, including moisture to promote disease occurrence and spread. Hunger and malnutrition, as a result, are affecting many regions in Africa. In 2016, FAO estimated that 27.4% of the population in Africa is affected by severe food insecurity. Since food insecurity is on the rise, especially in sub-Saharan Africa, the need for increase of food productivity and use of pesticides are unavoidable. Over the past decades, the history of pesticides for agriculture, public health, and construction industry in Africa has gone

through milestones with several challenges. These challenges range from limited control in import, distribution, use, storage, and disposal of pesticides. As a result, the risk of exposure and health impact to humans and environment has become another challenge. This chapter not only describes the trend of pesticide use and the negative consequences experienced in the past and the current status but also predicts the future implications for environment and health. Controversies regarding the benefits of pesticide use and the disadvantages that are magnified by lack of knowledge, protection, and malpractice with pesticides are highlighted.

2. Anthropogenic activities

Human activities are a part of struggle for meeting basic needs of life. In order for humans to sustain life, they must discover better means for addressing the development challenges including those relating food security and safety for a peaceful and secure life. In order to sustain productivity, food security, and safety for survival and growth, humans have to control the environmental challenges due to anthropogenic activity including nuisance and threats.

Since before 2000 BC, humans have been utilizing pesticides to protect crops. In Mesopotamia, about 4500 years ago, they used elemental sulfur dusting as pesticide for their crops. In other places, they used poisonous plants for pest control [3]. Other methods of pest control included burning grasses not only to kill insects and to control plant diseases but also to inhibit the growth of unwanted weeds. The serious use of pesticides in the agriculture started in the nineteenth century and expanded in the twentieth century [4]. Pesticides were used to control various pests and disease carriers, such as mosquitoes, fleas, ticks, mice, and rats.

Use of pesticides to control pests of importance in public health and agriculture including animal husbandry and poultry has been necessary for improving health as well as quantity and quality of yield for feeding the growing population. As a result, these pesticides reach the untargeted organisms through direct contact, polluted water sources, air, soil, and the food chain due to weak control systems for importation, supply, use, and disposal. In general, human activities that involve application of pesticides pollute and destroy habitats, untargeted animals, and some plant species. Thus, as unwanted effect, exposure of pests to pesticides leads to pest resistance problem, loss of many untargeted species, and also biological magnification through food chain.

3. Pests in Africa

Despite the fact that poorly controlled human activities threaten different untargeted species, agriculture in Africa is threatened by pests, including insects. The insects can either be endemic or epidemic. The endemic insects in Africa include cereal stalk borers that destroy different kinds of cereal crops and crop-eating fall armyworms that destroy a wide variety of crops and also whiteflies that destroy root/tuber crops (e.g., cassava is one of main sources of carbohydrates). Bean flies, aphids, thrips, leafhoppers, whiteflies, and leaf beetles are also among common and endemic insects that destroy legume crops' source of protein and many more insects in Africa [5].

Epidemic insect attacks in Africa include locust outbreaks (e.g., Madagascar in 1997) that inflicted severe damage to crops and cattle pastures around the country. In this locust outbreak control, fipronil (insecticide) was donated by developed countries, later impact evaluation reported detrimental fipronil effects, ranging from genotoxicity and cytotoxicity, and impaired immune function, to reduced growth and reproductive success of vertebrates, often at concentrations below that which is associated with mortality [6].

Other pests include fungi, virus, and bacteria. There are substantial estimated losses caused by these pests per year. For example, in Tanzania, economic damage due to the other pests on crop productivity is estimated at 50% (Controller and Auditor General established that in 2015).

Human life in Africa is also threatened by vector-borne diseases. Such vectors (pests) transmitting diseases include female anopheles mosquito that transmits *Plasmodium falciparum* causing malaria. Culex and other mosquito species transmit *Wuchereria bancrofti* (mostly) causing elephantiasis leading to permanent disability. Fleas harbored by rats transmit *Yersinia pestis* causing plague and tsetse flies transmit *Trypanosoma brucei rhodesiense* and *Trypanosoma brucei gambiense* to cause sleeping sickness. Fresh water snails transmit schistosomes causing intestinal and urinary schistosomiasis [7–9]. All these cause a lot of socioeconomic losses due to diseases and deaths they cause to humans. Other pests like ticks cause health problems to animals.

4. Need for pest control

In order to achieve human and animal health and other social and economic targets, humans need to control pests, so that they can reduce nuisance to increase quantity and quality of crop harvest, the value of harvested crops for sale, and livestock. Not only pest control is necessary for decreasing human and animal diseases and deaths but also for decreasing nuisance, direct destructions of properties as well as promoting peace for social and economic activities to occur.

5. Pesticides used in Africa

Pesticides that are mostly used in Africa include insecticides (insects), fungicides (fungi), acaricide (ticks, mites), antibiotics (bacteria), molluscicide (snails),

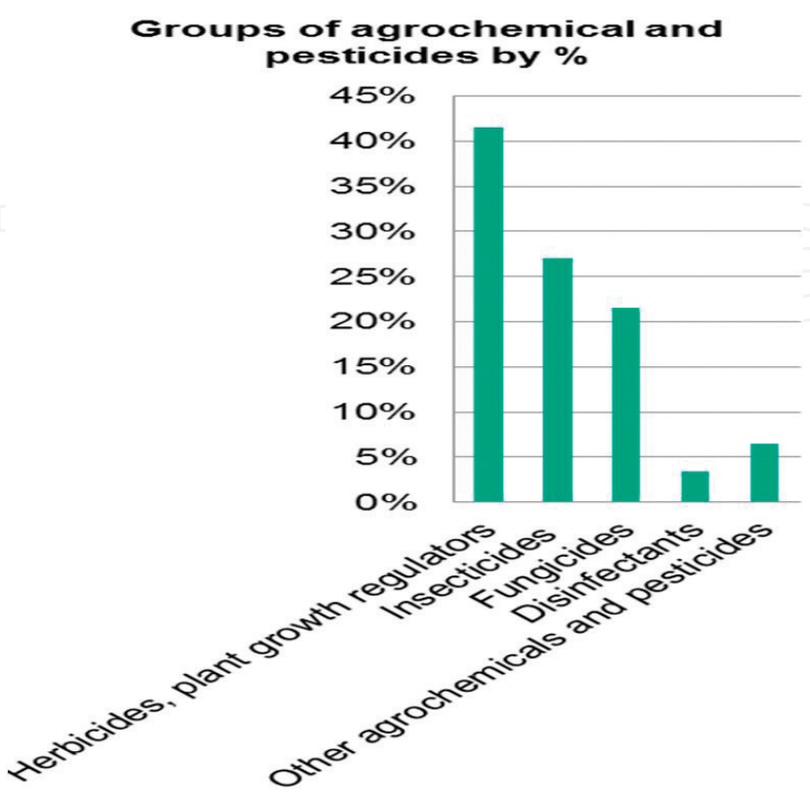

Figure 1.
Pesticides and other agrochemicals used in Africa.

nematicide (nematodes), ovicide (birds), repellents (vectors), rodenticides (rodents), and herbicides (weeds) (**Figure 1**).

6. General history of pesticides

Initial history of pesticides is well documented in countries outside Africa. For example, the first generation of pesticides contained naturally occurring metal elements. These inorganic metals included lead, calcium, arsenic, and mercury. These pesticides were mainly discovered and used in European countries and the USA. Later, they were found to be less effective for insect control and they were highly toxic to plants and animals [10]. No data are available on the use of first generation of pesticides in Africa.

Data available for pesticide use in Africa are on second generation of pesticides (organochlorines). Second-generation (synthetic) pesticides were organochlorines such as dichlorodiphenyltrichloroethane (DDT). DDT was first synthesized in 1874 by the young Austrian chemist Othmar Zeidler (as a doctoral student), but in 1939, the DDT's insecticidal action was first discovered by the Swiss chemist Paul Hermann Müller [11]. These organochlorines replaced inorganic pesticides (first generation). Then, a third generation of pesticides included organophosphates, carbamates, pyrethroids, etc. These are the currently used pesticides in Africa and elsewhere, they were introduced between 1960s and 1980s [12, 13].

7. History of pesticide use in Africa

In Africa, data on pesticide use [14] are available from when (1939–1960s) the second-generation organochlorines were reported. In Tanzania, DDT was introduced during WWII for malaria and typhus and later, after WWII, it was available for public health and farm vector control. In 1945, DDT was introduced in Monrovia, Liberia, for indoor residual spraying (IRS) for controlling malaria vector [15]. After WWII, there was effective worldwide marketing and from 1950s and after that, there came introduction of lindane, dieldrin, chlordane, and endosulfan. DDT brought happiness to many countries because it was a broad-spectrum pesticide effective at killing pests and could be used by inexperienced people, improved crop yields, and needed no re-application—so, it was a cost-saving pesticide.

8. Advantages of DDT

During WW II, DDT was applied to control lice (typhus) that caused typhus fever [16], and to control mosquito that caused malaria [17]. Significant decline of malaria transmission and deaths after use of DDT was reported in different African countries from 1940s to 1950s on.

9. Negative effects of DDT

Later, research showed that DDT had a negative effect on the environment and biodiversity. Rachel Carson published the book, namely, Silent Spring in 1962 and the message from this book was an eye opener. She reported that DDT thinned bird egg shells, and, that, eggs were not able to support the weight of incubating birds, so not able to hatch. The reason was that the egg shells lacked enough calcium due

to DDT. In addition, DDT had estrogenic effect, thus affecting reproduction. DDT was affecting the nervous system and it also affected immunity leading to failure to resist against infections in animals. So, it was a threat to extinction of birds and other wild creatures [18]. A number of studies have revealed DDT residues in many kinds of samples in several African countries like Nigeria, Tunisia, Ethiopia, Burundi, South Africa, etc., in plants, animal feed, livestock and wild animals, birds including chicken, fish, and humans [19].

In the food chain, plants might have low DDT residues, and they are eaten by chicken, fish, and animals; the DDT concentration levels increase in the tissues, and high up in the chain to reach even innocent newborns via contaminated breast milk (i.e., highest DDT concentration level in the food chain).

As a result, examples of literature about negative effects of DDT in humans in Africa include those in breast milk. Organochlorine pesticides (OCPs) were reported to be present in human breast milk, thus causing health risk to nursing infants in northern Tanzania in 2017 by Müller et al. [20]; in South Africa in 2006 by Bouwman et al. [21]; and also reported in milk and serum of Ghanaian farmers [22]. Furthermore, long-term effects of DDT exposure not only affected semen, fertility, and sexual function of farm workers in South Africa [23], but also caused DDT genotoxicity to cultured lymphocytes in Tunisia [24] and reduced half-life of paracetamol in highly exposed mothers in Zimbabwe [25]. Paracetamol is useful for fever and different kinds of pains in humans, its half-life is 1–3 h (prescription is after minimum of 6 h). Say the half-life is reduced to 30 min due to DDT residues in the body, then, the interval of taking paracetamol must be less than 6 h. Thus, paracetamol toxicity to liver is increased due to increased frequency or it becomes a useless drug in places where DDT is applied.

10. Ban of organochlorines (OCs or OCPs)

The negative effects of OCs to the environment and humans outweighed their benefits, leading to ban of OC pesticides; reasons included resistance to degradation in nature and living organisms, its toxicity to biodiversity including humans but also pests developed resistance. So, it was banned in developed countries in 1970s (Europe and the USA).

10.1 Stockholm convention

A worldwide ban on production and use was formalized under the Stockholm Convention on Persistent Organic Pollutants (POPs) signed in 2001 and effected in May 2004. The ban included DDT and other 11 persistent organic pollutants (POPs), namely the dirty dozen. The dirty dozen are characterized by persistence due to slow degradation, they are lipophilic (i.e., high affinity for fatty tissue); so, they accumulate in fatty tissues of living organisms (bioaccumulation), and then there is an increase of concentration in food chain (biomagnification). Due to long (persistence) half-life, they can be transported far from the point of application via air [26]. DDT may be transported from tropical countries to polar regions via evaporation, then, condensed and in summer, again, they can evaporate (grasshopper effect).

11. Controversy under discussion

DDT is the most effective pesticide for malaria control. Following the ban of the dirty dozen, should DDT be banned for every activity? In 1990, African countries tried

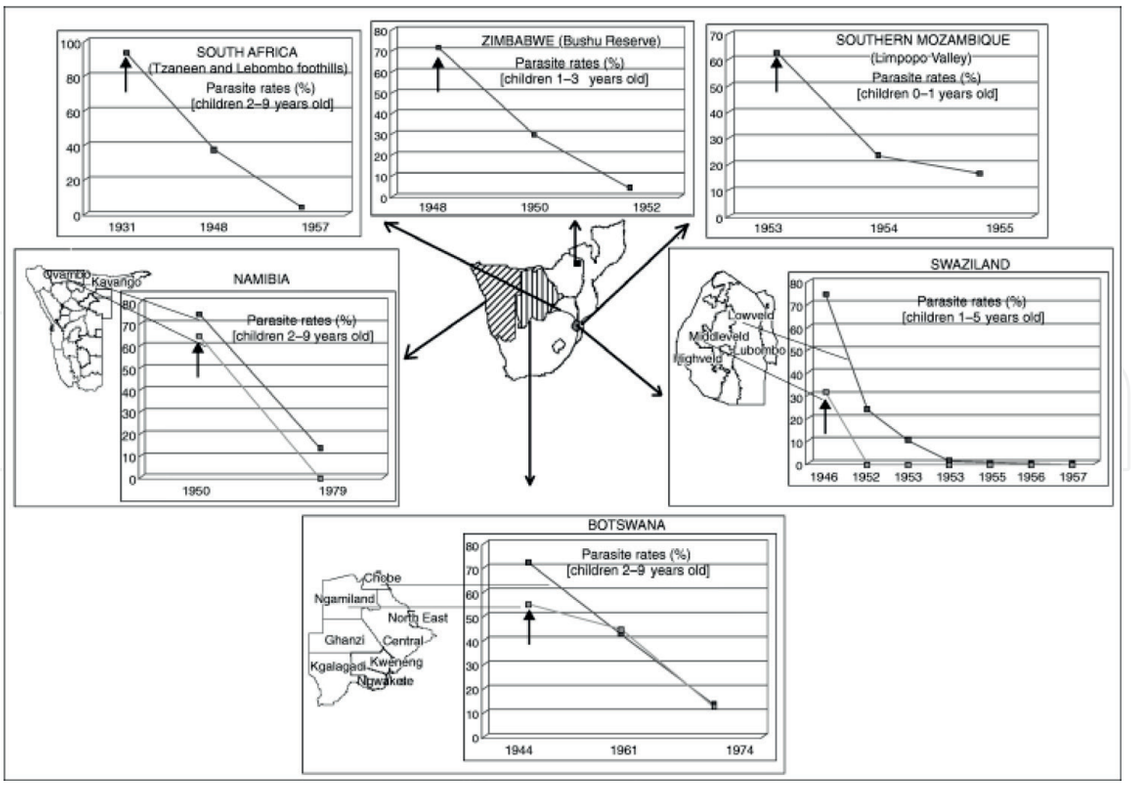

Figure 2.
Decline of malaria parasite rates in Africa after use of DDT.

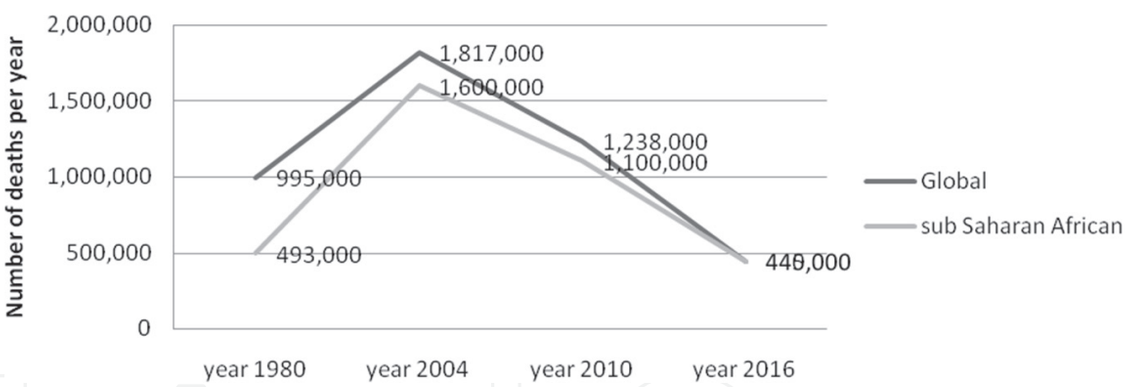

Figure 3.
Mortality due to malaria in Africa from 1980 to 2016 (90% contribution to global mortality). Figure based on data from UNICEF and WHO.

to substitute DDT with pyrethroids. The result was the rebound of malaria morbidity and mortality. So, the WHO allowed reintroduction of DDT in 2004. After 2004, mortality decreased. DDT use is reported to have led to decline of malaria morbidity and mortality in Africa. The challenge now for Africa is to rely on DDT use for malaria control despite the negative consequences, including the potential pest resistance.

Figure 2 has been adapted from European Journal TMIH by Musawenkosi et al., 2004. Historical review of malarial control in southern Africa with emphasis on the use of indoor residual house-spraying is given in **Figure 3**.

12. Trend of pesticide use in Africa

The organization currently known as African Union launched a program for self-sufficiency in agricultural food production in 1983. It was a 10-year program up to

1993. Example of Tanzania as one of the program implementers in Africa removed restrictions on imports of different pesticides including the banned pesticides; from there, was an observed rapid increase of pesticide imports. In addition to that, there was another increase of pesticide imports from 2000 to 2003 (about 5 times) [27].

13. Pesticide import and supply

On top of increased imports for self-reliance on food production through direct purchase, Africa also received donations from Europe (EU, UK), the USA, Asia (China and India), etc. [28]. Within the country, there are suppliers and distributors, that is registered companies and small-scale traders operating via local shops and also vendors.

14. Historical burden in African countries

As a result of donations and poorly planned imports, many countries in Africa have remained with obsolete pesticides accumulated over the past decades. These persistent organochlorine pesticides were stocked for use, but no longer useful, they required disposal because they have become a source of pollution to the environment and food chain and direct threat to human health.

15. Why did these stockpiles of pesticides end up in Africa?

Organochlorine pesticides were banned in developed countries in 1970s. At that time, many African countries received large donations of DDT and malathion for malaria control programs. Additional description was that the donations were for preparedness against locust outbreaks. This was an act of disposal and smart donation to solve environmental problems in donor countries. In addition, in 1991, during implementation of self-reliance program on food production, 1900 tons of banned pesticides manufactured in the USA were shipped to Africa. In some cases, there were even excessive donations without examining the actual need for these products in the recipient country. There were no prior arrangements for distribution and storage of these pesticides.

This was reported in Pesticides and agrochemical industry in sub-Saharan Africa, July 1994 (Contractual work prepared for division of food, agriculture and resource analysis-office of analysis, research and technical support bureau for Africa).

16. Is this a hazard to human health and environment?

Despite the cleanup program, there are still high levels of DDT and HCHs that were found in soil and water around. Although the visible remains of pesticides were removed, the soil is itself hazardous waste. For example, in Vikuge, in Tanzania, concentrations of DDT in grasses from nearby Vikuge were far above the acceptable limits for animal feed. Even at 6-km distance from Vikuge, DDT concentrations in grasses (animal feed) were still two times higher than the acceptable limits [29].

17. Africa stockpiles program funded by World Bank and non-bank sources

Other areas under the same cleanup program in 2013–2015 included Mali, Ethiopia, Morocco, Tunisia, and South Africa. Example of operations in Tanzania identified 14 sites of obsolete stockpiles. Three hundred tons of DDT of contaminated soils in Morogoro Region (one of the regions in Tanzania) were collected for destruction and 200 tons of DDT collected from the government-owned livestock farm at Vikuge [30].

Recent findings of pesticides (2016) in chicken eggs from Arusha, in Tanzania, by Polder et al. report that there are POPs including pesticides from free-ranging chicken eggs (free-ranging chicken are common in Africa for family use and for sale). They collect food from soil around the homes and come back during sunset. These findings from Arusha revealed extremely high levels of dieldrin in eggs from one specific urban farmer. This finding may reflect a possible source from an obsolete stockpile that was situated on that site before the town expanded.

18. Current pesticide use in Africa

Third generation of pesticides came in between 1960s and 1980s: these included organophosphates, carbamates, etc. These are the rapidly degraded pesticides, so they are less persistent in environment. They are acutely toxic to pests and more lethal in low dose compared to the banned organochlorines. The current global consumption of pesticides is at 2 million tons per year; of these, 25% (500,000 tons) is consumed in developing countries and 4% (80,000 tons) of global consumption is from Africa [31].

19. What is the problem of Africa with use of pesticides?

A survey report named Pesticides and Poverty [28] showed a number of problems noted in Africa; these include weak government organs for pesticide control systems, in particular, planning imports (imports may be in excess of requirements, so there is lack of efficiency). There are also weaknesses in supply and distribution (farmers accessed late and sometimes not according to needs). There is poor control (illegal entry of 2% pesticides, loop holes for misuse) and poor disposal plans of the remains. There is illegal trading (unwanted pesticides including WHO class I and unknown ingredients).

There are problems by users. These include not only improper practices (no personal protective equipment, contaminated water sources during pesticide applications) but also improper storage and disposal (throwing and burying containers in fields). In addition, users have low knowledge (on safe use and the associated health risks, also users cannot diagnose the plant disease and prescribe accurately), skills, and capacity. Some pesticide users have never attended formal education in school, these are the majority of that improperly use, store and dispose the pesticides.

20. Human exposure to pesticides in Africa

Common human exposure is through spraying (including mixing and loading), weeding, pruning, harvesting, etc., but also drift near the areas of pesticide applications, indoor spaying of mosquitoes, cockroaches, flies, ants, etc. Direct contact with contaminated materials (at farm/home) and ingestion (poor hygiene) are common exposure pathways.

21. What has been done with the problems?

African countries are taking some steps to address the described problems, these steps include the following: African member states have ratified the UN pesticide conventions and protocols as described by Flaubert Nana Sani (AU-IAPSC). Most African member states at the moment have Pesticide Evaluation Report & Safer Use Action Plans. At the moment, there are subregional regulatory bodies in Africa, these include: Central Africa Inter-State Pesticides Committee, the South East Africa Regulatory Committee on Harmonization, and another one for the west African member states. Among the activities that have been done by these member states at different levels include establishing harmonized pesticide registration, procedures, and evaluation criteria.

22. Pros and cons of pesticide use in Africa

22.1 Pros of pesticide use

Pesticides are important for economic development, food security (enough food, to avoid hunger), food production (able to conduct agricultural activities for food availability without pest disturbance), food safety (preventing biological harm to consumers), food quality (nutrients, appearance, texture, flavor, chemical, physical, microbial properties, etc.), vector disease control, improving human and animal health, decreasing morbidities and mortalities, insect nuisance control, and increased life quality. All these lead to peace.

Not only have controlled vector-related diseases (acute and chronic) including malaria morbidity and mortality been significantly reduced but also threat of elephantiasis and bilharziasis has gone down among many pest and vector-borne/related diseases. The same controlled picture is observed in animal health and zoonotic diseases.

22.2 Cons of pesticide use

Pesticides contaminate water, air, and soil, leading to damage of ecosystems (some organisms and habitats are destroyed and no longer exist in their natural habitat). Thus, pesticides diminish biodiversity (some biological species become extinct) and affect natural biological equilibrium. In affected systems of living organisms, some biological species are forced to live in new environment; thus, they adapt and may become pests. Some pests prevail in excess or less where not expected.

Other problems due to pesticides include pesticide resistance and costs to controlling resistance. Human and animal exposure to pesticides end into health problems and also it is reported that efficacy of the vaccine is reduced due to exposure to pesticides. Pesticides are threats to human health by directly causing diseases. Diseases due to pesticides can be divided into two kinds of manifestations: acute and chronic poisoning.

In acute poisoning (high dose), the body reacts to present with diarrhea, vomiting, coughing, difficult breathing, skin irritation, rashes, fasciculation, headache, dizziness, etc. When humans are exposed to low dose, chronic symptoms manifest including slow onset of symptoms. Pesticides are neurotoxicants, so they affect the central nervous system and manifest through loss of memory, orientation to time and space, etc., and on the peripheral nervous system, numbness of feet and hands manifest among other symptoms. Pesticides also have effects on reproductive system because they are endocrine disruptors (they affect reproduction, e.g., lead to abortions, etc.).

On immune system, they disturb body function, so resistance to infections is reduced. Cancers, for example, lymphomas, sarcoma, etc., are also reported to occur more in populations exposed to pesticides (cause effect not established). In addition, more than 40% of the health care professionals interviewed could not recognize pesticide poisoning cases; this reflects that the recognition for chronic manifestation of low-dose occupational exposure to pesticides may be worse [14].

Contamination of water threatens aquatic organisms, frogs, and fish, leading to extinction of aquatic biodiversity. Contamination of soil may lead to extinction of fertilizing organisms, whereas air pollution leads to population decline of pollinators (honey bees). The persistent organic pollutants are transported far away from the area of application and they end up in biomagnification that threatens human health.

In addition, environmental contamination causes lack of safe water supply for human consumption, which threatens human health. Contaminated water and grass lead to wildlife poisoning and extinction of wildlife including birds, leading to loss of small mammals, bird species, and insects.

Pesticides are expensive. Since pesticide use is a solution for temporary protection, it forces frequent use that in turn increases risk of exposures. As a result, pesticide resistance occurs. Pest resistance is a big challenge. When the pests do not die following pesticide application, the users increase the dose. At the same time, the natural enemies for pests are killed by pesticides during applications, leading to pest resurgence. Pests come back stronger than before because there is no natural enemy. To control pest resurgence, the users increase quantity and frequency for spraying. As a result, secondary pest outbreak occurs, in which, normal species become pests because natural enemy is destroyed. This kind of new pest is sprayed like target pest.

23. Conclusions and recommendations

Human struggle for survival has led to increased use of pesticides. Loopholes in controlling use and disposal of pesticides have threatened the human and environment health over decades. As a result, morbidities and mortalities and other negative consequences to untargeted biological organisms need serious considerations and adequate actions. Recommendations may not be limited to adjustment of the laws and regulations to be in harmony with international conventions and standards but also strengthening implementation and enforcement of the existing rules and regulations, registration and quality controls. Having infrastructure for handling sewage systems and proper disposal systems for pesticides and other chemicals and development of alternative for sustainable food production is important. Education and training on safe pesticide use, storage, disposition of pesticides and training in schools on environmental, occupational and dietary-related non-communicable diseases are necessary.

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Conflict of interest

It is declared that there is no conflict of interest between the author and any other part regarding the content of this chapter.

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