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Role of Pesticides in Human Life in the Modern Age: A Review

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1. Introduction

Food production capacity is faced with an ever-growing number of challenges, including a world population expected to grow to nearly 10 billion by 2050 and a falling ratio of arable land to population. Based on evidences, in 1900 there were 1.6 billion people on the planet; in 1992 this had risen to 5.25 billion and by the year 2050 it will reach 10 billion. World population is increasing by 97 million per year. This explosive increase in world population is mostly in developing countries and this is where the need for food is greatest and starvation threatens human life; as, FAO¹ estimates that 500 million are already undernourished (Anon, 1990a).

Civilization has been combating weeds, insects, diseases and other pests throughout history and there are many examples of how these pests have had a major impact on humans. One of the worst examples is the Black Plaque of Europe in the fourteenth century when millions died from a bacterial disease spread by fleas from rats (Hock et al., 1991). Another example is the infamous Irish potato famine of the nineteenth century in which millions died and many more were forced to emigrate. A fungus also destroyed the entire German potato crop in the early twentieth century resulting in 700,000 deaths from starvation (Anon, 1992b).

Thus, food plays a vital and strategic role in growing global population. But, food production is encounter to different limits. For example, there is a limit to new areas to cultivate; therefore we must increase agricultural production from the areas available. However, the specialization of production units has led to the image that agriculture is a modern miracle of food production (Stoytcheva, 2011).

In our global society there is a place for people to grow and consume organic food, but if all our farmers decided against using farm chemicals, we would soon find ourselves in a grave situation. Without the use of farm chemicals, the production and quality of food would be severely jeopardized with estimates that food supplies would immediately fall to 30 to 40% due to the ravages of pests (Anon, 1990b; Anon, 1992a). While there are mountains of food in Europe and the US, this represents only 45 days food supply for the world. Only part of the problem is distribution and the ability to pay for purchases.

¹FAO

While the first recorded use of chemicals to control pests back to 2500 BC, it is really only in the last 50 years that chemical control has been widely used (Hock et al., 1991). Many of the earliest pesticides were either inorganic products or derived from plants (i.e. burning sulphur to control insects and mites). Other early insecticides included hellebore to control body lice, nicotine to control aphids, and pyrethrin to control a wide variety of insects. Some heavy metals like lead arsenate was first used in 1892 as an orchard spray while about the same time it was accidentally discovered that a mixture of lime and copper sulphate (Bordeaux mixture) controlled downy mildew, a serious fungal disease of grapes. It is still one of the most widely used fungicides (Hock et al., 1991).

Pesticides are an undeniable part of modern life, used to protect everything from flower gardens to agricultural crops from specific pests. Pesticides have contributed significantly to improving quality of life and safeguarding the environment. Although often taken for granted, without these important products, food production would decline, many fruits and vegetables would be in short supply and prices would rise. Some 20 to 40 percent of the world's potential crop production is already lost annually because of the effects of weeds, pests and diseases (according to the FAO reports) (WWW.CropLife America.mht). These crop losses would be doubled if existing pesticide uses were abandoned, significantly raising food prices. Even after harvest, crops are subject to attack by pests or diseases. Bugs, rodents or moulds can harm grains. In addition to increasing crop yields, crop protection products used in stored products can also prolong the viable life of products, prevent huge post-harvest losses from pests and diseases, and protect food safety for eating.

On the other hand, although pesticides are now commonplace, concerns still exist about their safety and proper use. Pesticides can be used safely and effectively. But if proper care is not taken, pesticides can harm the environment by contaminating soil, surface and ground water, and ultimately kill wildlife. Also, the modern human is constantly exposed to a variety of toxic chemicals primarily due to changes in life style. The food we eat, the water we drink, the air we breathe, and the environment we live in are contaminated with toxic xenobiotics. Humans are exposed to such chemicals while still in the womb of the mother (Lederman, 1996; Rathinam et al., 2004). Therefore, human life would be threatened not only directly by pesticides in environment, but indirectly by contaminated food chain.

However, the chapter tries to discuss about necessity of pesticides use in modern agriculture for supplying human food. Actually, traditional chemical pesticides have environmental inconvenience and disadvantages for human health; thus, the problems along with the benefits of pesticides in improvement of quality of agricultural products and food production and storage are mentioned. According to world's food demands and health hazards caused by traditional pesticides, modern and new generation of pesticides and/or alternative methods to chemicals are modified to one of the most essential needs for modern agriculture in the present age. Some of the methods are titled in this chapter.

2. Traditional pesticides

2.1 What is a pesticide?

As FAO defined, pesticide is any substance or mixture of substances intended for preventing, destroying, repelling or mitigating any pest, including vectors of human or animal disease, unwanted species of plants or animals causing harm during or otherwise interfering with the production, processing, storage, transport or marketing of food, agricultural commodities, wood and wood products or animal feedstuffs, or substances

which may be administered to animals for the control of insects, arachnids or other pests in or on their bodies. The term includes substances intended for use as a plant growth regulator, defoliant, desiccant or agent for thinning fruit or preventing the premature fall of fruit, and substances applied to crops either before or after harvest to protect the commodity from deterioration during storage and transport. A pesticide may be a chemical substance, biological agent (such as a virus or bacterium), antimicrobial, disinfectant or device used against any pest. We use pesticides to cover a wide range of chemicals used to control insect pests, plant diseases, weeds, rats or other unwanted organisms. Currently, more than 800 pesticide active ingredients in a wide range of commercial products are registered for use in agriculture to meet food supply demands (Stoytcheva, 2011; Food and Agriculture Organization of the United Nations, 2002).

Pesticides can be classified by target organism, chemical structure, and physical state (Council on Scientific Affairs, American Medical Association, 1997). Pesticides can also be classed as inorganic, synthetic, or biologicals (biopesticides) which include microbial pesticides and biochemical pesticides. Plant-derived pesticides (botanicals), which have been developing quickly, include pyrethroids, rotenoids, nicotinoids, and a fourth group that includes strychnine and scilliroside (Kamrin, 1997). In addition, Pesticides can be classified based upon their biological mechanism function or application method. Basically, agricultural pesticides are divided into five categories, depending on the target pest (WWW.Humphath.com):

- i. insecticides,
- ii. herbicides,
- iii. fungicides,
- iv. rodenticides,
- v. and fumigants.

All pesticides are toxic to some plant or rodent species; at higher doses, they can also be toxic to farm animals, pets, and humans. In general, prominent insecticide families include organochlorines, organophosphates, and carbamates. Acute toxicity of insecticides for mammals ranges from low to high. Herbicides used to control weeds have low acute toxicity for mammals; and fungicides are characterized as moderately toxic (Shokrzadeh & Saeedi Saravi, 2009).

2.2 Advantages of using pesticides

A plentiful supply of fresh products is vital for a healthy population. Numerous scientific studies demonstrate the health benefits of regularly eating a variety of fresh fruit and vegetables; and consumers are increasingly aware of these benefits. Agricultural productivity is a key to ensuring that this demand can be met at an affordable price; and crop protection products help increase productivity and usable crop yields.

The crop protection industry's primary aim is to enable farmers to grow an abundant supply of food in a safe manner and prevent costs from increasing. Food production processes benefit from continual advancements in agricultural technologies and practices; in fact, a population now nearly twice as large has more food available per capita than 40 years ago. Tools such as herbicides, insecticides, and fungicides reduce crop losses both before and after harvest, and increase crop yields.

The major benefits of pesticides and their role in food production are listed below (WWW.CropLife America.mht):

- Increase food quality and quantity: Crop protection technologies allow producers to increase crop yields and efficiency of food production processes. Up to 40 percent of the world's potential crop production is already lost annually because of the effects of weeds, pests and diseases. These crop losses would be doubled if existing pesticide uses were abandoned. In addition, pesticides allow consumers to consume high-quality products that are free of insect blemishes and insect contamination. Crop protection chemicals that reduce, eliminate, and insect damage allow the consumers to purchase high-quality products free of insect fragments.
- Decrease price of food: Because the use of pesticides improves crop yields, crop protection technologies also impact the cost of food. Without crop protection chemicals, food production would decline, many fruits and vegetables would be in short supply and prices would rise. Helping to keep food prices in check for the consumer is another large benefit of pesticides.
- Human health protection: Pesticides are the most effective substances to eliminate insects that cause human diseases such as Malaria, Dengue fever, Lyme disease, and West Nile virus loom large. Also, human health is supported against insect and fungi-borne carcinogens, like aflatoxins, which is proceeding to hepatic and other cancers.
- Environmental protection: Other positive aspects of crop protection chemicals, in responsible and safe use, include household pest control, control of vegetation in industry and infrastructure, and recreation and protection of areas against environmental pests like noxious weeds, feral animals, etc, which cause land degradation.

2.3 Disadvantages of using pesticides

Food is the basic necessity of life and food contaminated with toxic pesticides is associated with severe effects on the human health. Hence it is pertinent to explore strategies that address this situation of food safety especially for the developing countries where pesticide contamination is widespread due to indiscriminate usage and a major part of population lives below poverty line.

The four main groups of pesticides such as the organochlorine, organophosphate, carbamate, and pyrethroid insecticides (Smith & Gangolli, 2002; Ahmed et al., 2000) are of particular concern because of their toxicity and persistence in the environment; however several of the banned pesticides are still used on a large scale in developing countries and continue to pose severe health and environmental problems. Pesticide use raises a number of environmental concerns, and human and animal health hazards. Over 98% of sprayed insecticides and 95% of herbicides reach a destination other than their target species, including non-target species, air, water and soil (Miller, 2004). Pesticides are one of the causes of water pollution, and some pesticides are persistent organic pollutants and contribute to soil contamination. As a result, we are closely exposed to pesticides in the food and water we consume and in the air we breathe. Unfortunately these chemicals are non biodegradable, persistent and get accumulated in the environment and thus into the human food chain. Despite regulatory measures, these compounds continue to be detected in measurable amounts in the ecosystem including marine life (Smith & Gangolli, 2002).

In addition, pesticide use reduces biodiversity, reduces nitrogen fixation (Rockets, 2007), contributes to pollinator decline (Hackenberg, 2007; Haefeker, 2000; Wells, 2007; Zeissloff, 2001), destroys habitat (especially for birds) (Palmer et al., 2007), and threatens endangered

species (Miller, 2004). It also happens that some of the pest adapt to the pesticide and don't die. What is called pesticide resistance, to eliminate the offspring of this pest, will be needed a new pesticide or an increase the dose of pesticide. This will cause a worsening of the ambient pollution problem.

There is a growing concern that environmental chemicals, both natural and manmade, can cause:

- Pesticide resistance in some pests;
- Water, soil and air contamination that transfers the chemical residues along a food chain;
- Reduction of biodiversity and nitrogen fixation;
- Destruction of marine and birds' life and/or genetically defects in their next generations;
- Changes in the natural biological balances, by means of reduction of beneficial and non-target organisms and insects, including predators and parasites of pests, and honeybees.

On the other hand, the human population is exposed to these chemicals primarily through the consumption of pesticide contaminated farm products, leading to long term health hazards.

Pesticides may induce oxidative stress leading to the generation of free radicals and alteration in antioxidant or oxygen free radical scavenging enzymes such as superoxide dismutase, catalase, glutathione peroxidase, glutathione reductase and glutathione transferase (Ahmed et al., 2000).

Pesticide toxicity can result from ingestion, inhalation or dermal absorption. Also, many evidences show that pesticides are persistent in fish tissues, adipose tissue and other organs including brain cells, nervous system and endocrine glands, and even breast milk, etc (Shokrzadeh et al., 2009). Thus, continued exposure to these chemicals for a long period may result in various diseases listed below:

- Neurological, psychological and behavioural dysfunctions, including Symptoms of mild cognitive dysfunction (leading to problems in identifying words, colours or numbers and inability to speak fluently), Parkinson's disease (PD) (Uversky et al., 2002; Xavier et al., 2004);
- Hormonal imbalances, leading to infertility, breast pain, menstrual disturbances, adrenal gland exhaustions and early menopause (Xavier et al., 2004);
- Immune system dysfunction, leading to immune suppression that cause potentially serious health risks in populations highly exposed to infectious and parasitic diseases, and subject to malnutrition (Xavier et al., 2004);
- Reproductive system defects, including birth defects (Petrelli & Mantovani, 2002);
- Cancers, including brain cancers (i.e. neuroblastoma), soft tissue sarcomas (i.e. Ewig's sarcoma), and colorectal and testes carcinomas (Xavier et al., 2004);
- Genotoxicity, including DNA damage in peripheral lymphocytes (Undeger & Basaran, 2002);
- Blood disorders, including leukaemia and non-Hodgkin's lymphoma (Zahm & Ward, 1998; Zahm et al., 1997);
- and abnormalities in liver and kidneys, ...

Between specific age ranges, infants and children are at great risk from the effects of pesticides. Several studies suggest that children may be particularly sensitive to the

carcinogenic effect of pesticides. There is a potential to prevent at least some childhood cancer by reducing or eliminating pesticide exposure (Zahm & Ward, 1998).

3. Modern alternatives to traditional pesticides

Until about four decades ago, crop yields in agricultural systems depended on internal resources, recycling of organic matter, built-in biological control mechanisms and rainfall patterns. Pesticides started a revolution in agriculture and quality improvement methods. The state of the art in pesticides continues to evolve and progress as time passes. But, in these years pesticides were very toxic and left residues in the environment for a long time. On the other hand, loss of yields due to pests in many crops (reaching about 20-30% in most crops), despite the substantial increase in the use of pesticides (about 500 million kg of active ingredient worldwide) is a symptom of the environmental crisis affecting agriculture.

However, farm products must obviously be free from pesticide contamination, which is possible primarily through organic farming. In addition, global social awareness of proper and minimal need based use of these chemicals, to some extent may reduce health related problems (Altieri, 1995).

Therefore, many countries established adequate regulatory safeguards over the manufacture, sale and use of the pesticides. For this reason, complex and costly studies were conducted to indicate whether the material is safe to use and effective against the intended pest. Despite the applications, some human disasters like which occurred in Bhopal and China, and long term side effects on human and animal life style and environmental contamination amplify the approach to find and produce modern pesticides with lower problems and/or to perform alternative applications to traditional pesticides.

IPM², the use of multiple approaches to control pests, is becoming widespread and has been used with success in countries such as Indonesia, China, Bangladesh, the U.S., Australia, and Mexico (Miller, 2004). IPM attempts to recognize the more widespread impacts of an action on an ecosystem, so that natural balances are not upset (Daly et al., 1998). New pesticides are being developed, including biological and botanical derivatives and alternatives that are thought to reduce health and environmental risks. In addition, applicators are being encouraged to consider alternative controls and adopt methods that reduce the use of chemical pesticides.

Pesticides can be created that are targeted to a specific pest's life cycle, which can be environmentally friendlier. For example, potato cyst nematodes emerge from their protective cysts in response to a chemical excreted by potatoes; they feed on the potatoes and damage the crop.[81] A similar chemical can be applied to fields early, before the potatoes are planted, causing the nematodes to emerge early and starve in the absence of potatoes (WWW. Wikipedia.com).

The major alternatives to traditional chemical pesticides are listed below:

- i. Natural pesticides,
- ii. Biological pest control,
- iii. Plant genetic engineering,
- iv. Interfering with insect breeding,
- v. Application of composted yard waste,

² Integrated pest management

- vi. Cultivation practices,
- vii. Release of organisms that fight the pests,
- viii. Interfering with insects' reproduction,
- ix. Soil steaming, etc.

In the last 10 years, one line of research has been in the area of natural pesticides. This typically means that certain botanical plant oils have been processed, combined, or concentrated into pesticides. These plant oils have a unique action that targets a key neurotransmitter receptor called octopamine which is found in all invertebrates (i.e. insects), but not in mammals.

Alternatives to pesticides are available and include methods of cultivation, use of biological pest controls (such as pheromones and microbial pesticides), plant genetic engineering, and methods of interfering with insect breeding (Miller, 2004). Application of composted yard waste has also been used as a way of controlling pests (McSorley & Gallaher, 1996). These methods are becoming increasingly popular and often are safer than traditional chemical pesticides. In addition, EPA is registering reduced-risk conventional pesticides in increasing numbers.

Cultivation practices include polyculture (growing multiple types of plants), crop rotation, planting crops in areas where the pests that damage them do not live, timing planting according to when pests will be least problematic, and use of trap crops that attract pests away from the real crop. In the U.S., farmers have had success controlling insects by spraying with hot water at a cost that is about the same as pesticide spraying (Miller, 2004).

Release of other organisms that fight the pest is another example of an alternative to pesticide use. These organisms can include natural predators or parasites of the pests. Biological pesticides based on entomopathogenic fungi, bacteria and viruses cause disease in the pest species can also be used (Miller, 2004).

Interfering with insects' reproduction can be accomplished by sterilizing males of the target species and releasing them, so that they mate with females but do not produce offspring (Miller, 2004). This technique was first used on the screwworm fly in 1958 and has since been used with the medfly, the tsetse fly, and the gypsy moth. However, this can be a costly, time consuming approach that only works on some types of insects (Miller, 2004).

Another alternative to pesticides is the thermal treatment of soil through steam. Soil steaming kills pest and increases soil health.

3.1 Effectiveness of alternatives to traditional pesticides

Some evidence shows that alternatives to pesticides can be equally effective as the use of chemicals. The experiences resulted from some countries used alternatives emphasize that reduction of pesticide use, application of composted yard waste with high carbon to nitrogen ratio to agricultural fields, etc were highly effective at increasing crop yield. As a result, today's pesticides and alternative methods are safer and more effective in controlling pests than ever before in our history.

3.2 Problems of modern pesticide systems

As agricultural modernization progressed, the ecology-farming linkage was often broken as ecological principles were ignored and/or overridden. In fact, several agricultural scientists have arrived at a general consensus that modern agriculture confronts an environmental crisis. A growing number of people have become concerned about the long-term

sustainability of existing food production systems. Evidence has accumulated showing that whereas the present capital- and technology-intensive farming systems have been extremely productive and competitive; they also bring a variety of economic, environmental and social problems. Evidence indicates, however, that excessive reliance on monoculture farming and agro-industrial inputs, such as capital-intensive technology, pesticides, and chemical fertilizers, has negatively impacted the environment and rural society. Most agriculturalists had assumed that the agroecosystem/natural ecosystem dichotomy need not lead to undesirable consequences, yet, unfortunately, a number of ecological diseases have been associated with the intensification of food production. They may be grouped into two categories:

- i. diseases of the ecotope, which include erosion, loss of soil fertility, depletion of nutrient reserves, salinization and alkalinization, pollution of water systems, loss of fertile croplands to urban development;
- ii. diseases of the biocoenosis, which include loss of crop, wild plant, and animal genetic resources, elimination of natural enemies, pest resurgence and genetic resistance to pesticides, chemical contamination, and destruction of natural control mechanisms.

4. Conclusion

Agricultural and veterinary chemicals are vital to our welfare and the protection of the health of our families and pets. Unless, and until, better, more efficient and more cost effective means of pest control are developed, farm chemicals will remain a major weapon in our constant battle against pests. Production would drop drastically, and food would be of poorer quality, more expensive and in short supply. Many pets and farm animals would suffer and die needlessly. World's economy and our standard of living would rapidly decline. In addition, to elevate the human life quality level and to protect public health against even mortal effects of chemicals, new generations of pesticides and alternatives to traditional chemical pesticides are applied to produce healthier and larger amount of various food.

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This book is a compilation of 29 chapters focused on: pesticides and food production, environmental effects of pesticides, and pesticides mobility, transport and fate. The first book section addresses the benefits of the pest control for crop protection and food supply increasing, and the associated risks of food contamination. The second book section is dedicated to the effects of pesticides on the non-target organisms and the environment such as: effects involving pollinators, effects on nutrient cycling in ecosystems, effects on soil erosion, structure and fertility, effects on water quality, and pesticides resistance development. The third book section furnishes numerous data contributing to the better understanding of the pesticides mobility, transport and fate. The addressed in this book issues should attract the public concern to support rational decisions to pesticides use.

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