Pesticide: Use, abuse and awareness

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Abstract

Pesticides are the compounds used to prevent organisms harmful to man. Depending upon the types of pest controlled, toxic property and chemical composition, pesticides are classified variously. Despite the fact that pesticides were used from very ancient time, the chronological consideration regards the discovery of DDT (1939) as the era of chemical pesticides and its development in the subsequent years. Initially, pesticides had tremendous use to improve quality of life and survival rate of man by providing sufficient amount of food and security against life threatening diseases. Beside this, the overuse of chemical pesticides imparts harmful effects on environment, ecosystem and human health. These effects are intensified by the persistence of the pesticides in the environment and its mobility causing the toxicity to non-target species including man even in virgin area. Being aware of these damages, several measures have been taken that include the restricted use of most hazardous organochlorinated compounds along with the development and practice of eco-friendly approach of pest management for sustainable development.

Keywords: Pesticides, POP, Environment, IPM, Biopesticide

Introduction

Pesticides are the substances or mixture of substances that are used to prevent, destroy, repel or mitigate any organisms harmful to human beings or their belongings (Salau, 1993). Pesticide includes compounds like insecticides, fungicides, herbicides, rodenticides, molluscicides, nematicides etc. (Valavanidis and Vlachogianni, 2011). The invention of pesticides was a sort of blessing to the human civilization. The life of human beings before pesticides was miserable as they were suffering from malnutrition and disease with lesser expectancy of life. The use of indigenous pesticides for local application was practiced since long before. Homer referred the use of sulfur as fumigant around 100 B.C. The Chinese used arsenic to control garden pests by 900 C.E (Pujeri et al., 2010). The age of chemical pesticides started with the development of DDT (p,p-dichlorodiphenyl-trichloroethane), an organochlorine compound in 1939 and its successful application in agriculture (Valavanidis and Vlachogianni, 2011). This is followed by the development of other chemical pesticides with sufficient strength and effectiveness to destroy pests. Pesticides made life of average people better with adequate supply of foods, control of vector-borne diseases and safety of house-hold materials (Wasim et al., 2009). But as the story of golden eggs of the goose, instead of little, a lot more pesticides were applied to get higher yields. This thorough application of chemical pesticides particularly, in agricultural fields causes harm to the environment, hampers ecological balance and imparts adverse effects on public health. It causes extensive environmental pollution, freshwater contamination, wildlife loss and reduced...
biodiversity (Jeyaratnam, 1985; Igbedioh, 1991; Forget, 1993). The properties of pesticides like persistence, mobility, toxicity to non-target species etc also intensify these damages (Stockholm Convention, 2004). The threat was first noticed and announced by an American scientist cum writer, Rachel Carlson in 1962 in her famous book, Silent Spring by observing sudden dying of birds and egg shell thinning (Carson, 1962; Ratcliffe, 1969). This resulted in the ban of some pesticides, particularly organochlorine compounds and realization for the development of less-toxic eco-friendly pesticides and pest control practice. In this context, the present review deals with the origin and evolution of pesticides with its benefits and hazards and awareness taking a brief account of Indian scenario.

Classification

Pesticides can be classified on the basis of the type of pest control, toxic property and chemical composition (WHO classification of pesticides, 2004). On the basis of the type of pest control, pesticides are categorized as insecticides, fungicides, herbicides and others. Based on the nature of toxicity, pesticides are grouped as extremely hazardous, highly hazardous, moderately hazardous and slightly hazardous. Depending on the chemical composition, they are classified as organochlorine, organophosphate, carbamates, synthetic pyrethroid and biocides.

Characteristics

The hazardous pesticides might have the properties like persistence, transboundary transport, bioaccumulation and biomagnifications (Stockholm Convention, 2004). The pesticides are said to be persistence if these stay in the nature for long lime and thus degrade very slowly and have long half-life (e.g. DDT: 15 to 30 yrs, Toxaphene: up to 14 yrs, Mirex: about 12 yrs, Dieldrin: up to 7 yrs, Chlordenecone: up to 30 yrs etc.) (Stockholm Convention, 2004). Pesticides might be mobile i.e. carried from one source to other (Glottelt and Schomburg, 1989). For example, pesticides in the soil might remain adsorbed to the soil particles or dissolved in water. If the partition coefficient of the pesticides i.e. ratio of the pesticides bound to the soil to the pesticides dissolved in water is high, the pesticides pertain in the soil else are leached to ground water or run-off to surface water (Bicki and Peterson, 1988). Some pesticides are volatile or semi-volatile (Stockholm Convention, 2004) and contaminate the air, even carried to contaminate a virgin area. There is a report of detection of significant amount of persistent pesticides in the glacier and also in tissues of polar animals (Beyer et al., 2000). Thus, the transboundary transport of the pesticide is a global threat. Again, the lipophilic pesticides accumulate in the adipose tissues of animals (e.g. edible fishes) and propagate via food chain (e.g. fish-eating bird). The phenomenon is termed as bioaccumulation (Wania and Mackay, 1996; Vallack et al., 1998). As the smaller organisms are eaten by larger organisms, the concentration of pesticides is increasingly magnified in their tissues and other organs. Very high concentrations can be observed in top predators, including man. This is called, biomagnifications (Kelly et al., 2007).

Chronology

Chronologically, organochlorine (OC) pesticides were reported to be the first synthetic chemical pesticides developed in 1940 (Valavanidis and Vlachogianni, 2011). Before innovation of OC pesticides, 30 pesticides like arsenic, sulfur dust, calcium arsenate, mercurial fungicides, dintro-ortho-creasil, pyrethrum, nicotine were used as insect repellents (Rattner, 2009). OC pesticides include
DDT, BHC (Lindane), Heptachlor, Aldrin, Dieldrin, Endrin etc. OC pesticides are persistant (half life 15-30 years), accumulate in living tissues and highly toxic (e.g. for endrin LD50 10-15 mg/kg) (Ahmed and Naqvi, 2011). The overuse of OC pesticides resulted in resistance in pests (Georghiou and Mellon, 1983). This led to the manufacture of organophosphate (OP) pesticides, compounds of phosphorus and sulphur in the year 1950. OP pesticides include malathion, parathion, methyl parathion, dimecron, diazinon, dimethoate, chlorpyriphos, DDVP or dichlorovos, TTEP etc. These are less persistant (half life 2-4 weeks) and toxicity more on mammals. Toxicity varies, for example, TEPP is the most toxic i.e. LD50 1 mg/kg while malathion is least toxic i.e. LD50 1500 mg/kg (Ahmed and Naqvi, 2011). Carbamates (CB) are contemporary to the organophosphates. They are the esters of carbonic acid. They are also less persistant and degrade in about 4 weeks. They include propoxur (baygon), carbaryl (sevin), Temik and Zectran. The use of synthetic pyrenoids started on about 1970 and mostly used chemical pesticides now a day. They are less persistant, degrade in 2-4 weeks, toxicity more on insects than on mammals. Synthetic pyrenoids is analogous to prethrine, the natural pesticide found in chrysanthemum flower. This natural product is far less persistant, less toxic than the synthetic ones and has immediate knockdown effect. OP, carbamate and synthetic pyrenoids work mainly by cholinesterase inhibition by interfering nerve impulse transmission (Ahmed and Naqvi, 2011). The use of biospesticides commences on about 1985. These are less persistent and less toxic. Integrated pest management is most ecfriendly method of pest control and recommended throughout the world (Patil and Katti, 2012).

Uses of pesticides: Pesticides are very much useful in controlling agricultural pests and improving quantity and quality of crop production (Wasim et al., 2009). The pesticides also regulate vector-borne diseases like malaria, encephalitis, dengue etc. and enrich the quality of human health. Pesticides again protect human belongings including different household goods, transports, sports complexes, buildings, wooden structures etc. (Wasim et al., 2009). Thus, pesticides give overall security for food and health and enhance the rate of survival and quality of life of human beings.

Abuses of Pesticides

‘If little is good, a lot more will be better’-pesticides if used legitimately is friend else is foe. The uncontrolled use of pesticides to get healthy crops in large amount, to control diseases and to protect house hold goods and stored foods has paid havoc to the ecosystem, environment and public health (Jeyaratnam, 1985; Igbedioh, 1991; Forget, 1993).

Effect on soil ecosystem

The pesticides, deposited to the soil by dropping from foliage or direct application is either remain adsorbed or leached to the ground water or run-off to the surface water. The contamination of the soil depends on the persistence of pesticides or its degraded products. For example, the metabolites of DDT, DDD and DDE are highly persistent and equally toxic (Ahmed and Naqvi, 2011). Again, the persistence of a pesticide depends on the soil structure, temperature, type of microorganisms found and other factors (Akhtar et al., 2004). For example, in temperate regions, DDT has a half-life of 10-15 years, while in tropical parts of the world, the half-life may be as short as 6 months. That’s why the use of DDT is still
permitted in India for only mosquito control, although it has been banned in some other countries (Banerjee and Sanyal, 2011). The extensive use of pesticides brings about changes in the physical and biotic structure of the soil by affecting (1) abundance and behavior of soil microorganisms, which are associated with maintenance of soil structure, transformation, mineralization, enhancement of soil fertility by nitrification and/or denitrification, regulation of plant nutrient uptake (Fox et al., 2007; Potera, 2007) (2) soil micro-fauna like micro-arthropods (like mites, spiders and ground beetles), mollusca (snails, slights), Annelida (earthworms) and protozoa (amoebae, paramaecium), which are very important in maintaining soil structure and nutrition, enabling decomposition of organic compounds to enhance soil aggregation, fertility and soil aeration (specially by earthworm) (Evans et al., 2010) (3) populations of predaceous and parasitic insects in soil particularly by using organochlorine insecticides in rice cultivation (Banerjee and Sanyal, 2011). Earthworms although can resist a large number of pesticides, a recent study reported a negative effect of some pesticides on their growth and reproduction (Sanchez, 2006; Yasmin and D’Souza, 2010).

**Effect on aquatic ecosystem**

Surface water is contaminated by run-off from agricultural fields, gardens, lawns, industrial sludge, domestic sewage, direct application etc. Ground water contamination occurs through leaching from the soil. Recent studies have reported that the surface and ground water closer to agricultural lands are more contaminated with pesticides (Cerejeira et al., 2003; Pujeri et al., 2010). Although the occurrence of pesticide in the water depends on the pattern of land and pesticide use, the compounds most frequently detected are herbicides (Atrazine, Simazine, Alachlor, Metolachlor and Trifluralin), insecticides (Diazinon, Parathion methyl) and organochlorine compounds (lindane, endosulfan, aldrin, and other organochlorine pesticides) due to their long persistence (FAO). Higher deposition of pesticides in water is lethal which causes the elimination of some floral and faunal species and change the community structure and community dominance which interferes with the population dynamics, species diversity, primary productivity, abiotic conditions (pH and dissolved oxygen) and survival of communities (Abrams, 1995; Kreutzweiser et al., 2002). There is a growing apprehension that pesticides at sub-lethal doses can alter a wide range of individual characters including changes in neurotransmitters, hormones, immune response, reproduction, physiology, morphology and behaviour (e.g.) swimming ability, predator detection etc. (Weis et al., 2001; Galloway and Handy, 2003; Walker, 2003). The study showed that relatively small concentration of malathion caused direct and also indirect effect on aquatic food web (FAO). Changes in plankton and periphyton abundance and composition consequently affected growing of frog tadpoles and reduced predation rates of amphibians (Relyea, 2003; Relyea and Hoverman, 2008). Moreover, the pesticides flow through food chain and biomagnify in higher consumer level. Pesticides in the body tissues of fishes, dolphins and turtles, far in excess of standards laid down for edible meat are indicative of contamination of water sources and bioaccumulation at higher consumer level of food chain (Kumari and Sinhar, 2001).

**Effect on birds, bees, butterflies**

The birds are badly affected indirectly or directly by pesticide application (Taylor et al., 2006). The reduction of herbs and insects by the unplanned application of
pesticides causes the reduction of food supply for farmland birds (Wasim et al., 2009). The fish eating birds acquire pesticides through food chain and bioaccumulate in their body parts. Moreover, DDT and its metabolite DDE cause eggshell thinning of birds (Lundholm, 1997; Decourtye and Devillers, 2010). There is report that the number of sarus crane and vulture in parts of India and bald eagle population in the United States has been reduced due to the effect of organochlorine pesticides (Muralidharan, 1993; Prakash, 1999; Liroff, 2000). It has been seen that the number of wild bees and butterflies decline after repeated application of pesticides (Longley and Sotherton, 1997; Thomson, 2003; Brittain et al., 2010).

**Effect on public health**

Human beings are exposed to the pesticides directly or indirectly (WHO, 1990). Human beings are exposed to pesticides during manufacturing, packaging, mixing, storing, spraying, disposing etc. or via consumption i.e. through food and drink or by accidental means (Ritter et al., 2007). These exposures cause various acute or chronic health hazards like skin disease, bronchial disorder, haematological disorder, cardiovascular disorder, immune suppression, hormonal disorder, neurological disorder, vision problem, skin disease, cancer, teratogenic effect, obesity, diabetes etc (Damstra, 2002; Lee et al., 2006; Dirinck et al., 2011; Ljunggren et al., 2014). The pesticide residues reach to the body of infants by plancental barrier and breast milk (Gupta et al., 1984; Brouwer et al., 1999; Butler et al., 2003).

**Awareness**

The risk of overuse of pesticides was first perceived by Rachel Carson, an American scientist. She wrote a book titled as, Silent Spring in 1962 discussing the adverse effect of the excessive use of the pesticides on environment (Carson, 1962; Ratcliffe, 1969). This led to the alertness at Governmental and non-Governmental levels to protect the environment from pesticides, particularly persistent organic pesticides (POPs). The outcome is the Stockholm Convention on POPs in 2004 which declared ban on production and use of 12 first generation POPs that includes aldrin, dieldrin, endrin, heptachlor, chlordane, mirex, toxaphene, polychlorinated biphenyls (PCB), DDT, dioxine, furan, hexachlorobenzene (HCB). DDT is allowed for production and use only to control disease (malaria) vector control and PCBs in transformers (Stockholm Convention, 2004). The subsequent conventions banned other POPs like α-hexachlorocyclohexane, β-hexachlorocyclohexane, Chlodecone, Lindane (γ-hexachlorocyclohexane), Hexabromobiphenyl, Pentachlorbenze etc. (Stockholm Convention, 2009), Endosulfane (Stockholm Convention, 2011), Hexabromocyclododecane (Stockholm Convention, 2013). Lindane is allowed to use for pharmaceutical cause to control the head lice and scabies. The awareness regarding overload and harmful effects of chemical pesticides on environment, ecosystem and public health led the scientific world to think on the alternative of chemical pesticides that would regulate pests without compromising the sustainability of the environment. This results in the development of biopesticides and introduction of integrated pest management (IPM).

**Biopesticides**

These pesticides are natural substances of biological origin used to control pest (Bhardwaj and Sharma, 2013). Biopesticides are of three types i.e. microbial, biochemical and plant pesticides (Gupta and Dikshit, 2010). Microbial pesticides include microorganisms like bacteria (e.g. *Bacillus thuringiensis*), virus (e.g. *Baculovirus*), fungus
(e.g. *Trichoderma*), protozoa (e.g. *Tricogramma*) etc. Biochemical pesticides are the naturally occurring chemical substances that control pests in non-toxic way, e.g. Neem, pheromones etc. Plant pesticides are produced from pesticide producing genes incorporated within the plant genome, for example, genetically modified (GM) plants by BT pesticidal genes (e.g. Bt cotton, Bt rice, Bt brinjal etc.) (Gupta and Dikshit, 2010). Biopesticides are less harmful to the environment. This is required in small amount and decomposes quickly, so these have less environmental load. These affect only one specific pest or in some cases, a few target organisms (Gupta and Dikshit, 2010). Biopesticides act as the important component of Integrated Pest Management (IPM).

**Integrated Pest Management (IPM)**

IPM is the simpler and ecologically safer measure of pest control to reduce environmental pollution and other problems caused by excessive and indiscriminate use of the pesticides (Patil and Katti, 2012). IPM aims at keeping the pest population below the level that would cause harm to the crops. UNCED (United Nations Conference on Environment and Development) at Rio De Janeiro in June 1992 identified IPM for sustainable agricultural and rural development. The main components of IPM include (EPA, USA; Mathur, 2001): seasonal pest surveillance, use of crop varieties resistant to pest, sound cultural practices, biological control of pest and use of biopesticides having less mammalian toxicity, limited use of chemical pesticides, targeted application of pesticides and education of farmers and environmental awareness.

**Pesticide usage in India**

India is the second largest producer of pesticides in Asia and ranks twelfth in the world for the use of pesticides (Mathur, 1999). The domestic demand of pesticides in India accounts for about 76% of the total pesticides against 44% globally. The pesticide usage pattern in India is different from that of the world. Among different types, the mostly used pesticide in India is insecticide (76%), while herbicides and fungicides are used in less heavily. On the other hand, global use of insecticides is only 44%, while that of herbicides and fungicides are used in higher amount (Mathur, 1999). Amongst the insecticides, organochlorinated and organophosphorous compounds are preferably used in India as evidenced by its presence in surface and ground water, fruits and vegetables and bovine milk (Bempah et al., 2005; Sankaramakrishnan et al., 2005; Srivastava et al., 2008). Inspite of the enormous usage of chemical pesticides, biopesticides are used in satisfactorily high amount in India. The record of biopesticide usage since 1994-95 to 2005-06 suggests that the biopesticide usage has been increased by 20 times (Gupta and Dikshit, 2010). The biopesticides successfully used in India are *Bacillus thuringiensis*, *Beauveria*, *Helicoverpa*, neem products, Trichogramma etc. (Gupta and Dikshit, 2010).

**Conclusion**

General people should be aware of the risk of overload of pesticide on environment. Before application of the pesticides, other alternative methods like selecting resistant varieties of crops, crop rotation, using appropriate fertilizers, adequate monitoring of the pest abundance, selection of pesticides with only specific toxicity to target species should be considered. Safe storage, careful preparation and application, appropriate disposal of unused pesticides and containers are important to prevent pesticide pollution. Only trained persons should be allowed to spray pesticides with appropriate precaution. People should give priority for non-toxic indigenous methods to control pests.
in house or garden. Conscious attitude of the general people along with the scientific and administrative strategy for wider use of eco-friendly approach of pest management can only reduce the burden of the environmental toxicity caused by the overuse of chemical pesticides.

References


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