Review Article

A review: Pesticide Toxicity in Avians

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Abstract

Use of pesticides in modern agriculture has increased tremendously. Pesticides affect humans, environment and wildlife including birds. Three main groups of chemical synthetic pesticides used are organochlorines, organophosphates and carbamates. Because of their persistent nature, organochlorines are no longer in use in several countries. But some of them like aldrin, dieldrin, lindane and endosulfan are still used in developing countries. They cause widespread population decline of raptorial birds like the peregrine falcon, the sparrow hawk and bald eagle. The well known effect of DDT in eggshell thinning of the peregrine falcon is caused by its highly persistent metabolite DDE [1,1, bis-4-chlorphenyl]-2,2 dichlorethylene]. Organophosphate and carbamate insecticides do not bioaccumulate in the food chains and are less persistent. They have replaced the more persistent organochlorines. This review elaborates the effect of synthetic chemical pesticides on birds.

Keywords: Acute and sub lethal effects, Birds, Organochlorines

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Introduction

Pesticides are the only group of chemicals that are purposely applied to the environment with the aim to suppress plant and animal pests and to protect agricultural and industrial products. However, the majorities of pesticides do not specifically target the pests exclusively but also affect non-target plants and animals. Repeated application leads to loss of biodiversity. Many pesticides are not easily degradable, they persist in soil, leach to groundwater and surface water and contaminate wide environment. Depending on their chemical properties they can enter the organism, bio accumulate in food chains and consequently influence human health. Overall, intensive pesticide application results in several negative effects in the environment that cannot be ignored [1]. In 1962, Rachel Carson, an American Scientist, pointed out sudden dying of birds caused by indiscriminate spraying of DDT. Pesticides enter the soil via spray drift during foliage treatment, wash-off from treated foliage, release from granulates or from treated seeds in soil. Some pesticides such as soil fumigants and nematicides are applied directly into soil to control pests and plant diseases present in soil [1]. Persistence of organochlorine pesticides in soil can vary from few hours to many years. Despite OC pesticides were banned or restricted in many countries, the residue is still being recovered in soils.

More recent studies also reported presence of pesticides in surface water and groundwater close to agriculture lands all over the world.

Status of pesticides in India

There are 234 pesticides registered in India. Out of these, 4 are WHO Class Ia pesticides, 15 are WHO Class Ib pesticides and 76 are WHO Class II pesticides, together constituting 40 of the registered pesticides in India. In terms of consumption too, the greatest volumes consumed are of these pesticides.

The following is a broad picture of the top pesticide-consuming states in India (total pesticides consumed, in metric tonnes of technical grade material, during 2005-2006 to 2009-2010, as per official data of the Directorate of Plant Protection, Quarantine and Storage, Govt. of India) (**Tables 1-2**).

Common routes of Exposure of Pesticides in Birds

Ingestion is probably the most common way that birds are exposed to pesticides. Birds can swallow the pesticides directly, such as when a bird mistakes a pesticide granule for a seed, or indirectly, by consuming contaminated prey. They may also ingest pesticide residues off feathers while preening, or they may drink or bathe in tainted water. Pesticides can also be absorbed through the skin, or inhaled when pesticides are applied aerially.

Table 1 Pesticide consuming states in India

S.No	State	Total pesticide consumed (in metric tonnes)
1	Uttar Pradesh	39948
2	Punjab	29235
3	Haryana	21908
4	Maharashtra	16480
5	Rajasthan	15239
6	Gujrat	13430
7	Tamil Nadu	12851
8	All India	2,10,600

Table 2 Most consumed pesticide in India during 2005-06 to 2009-10

S.No.	Pesticide (Technical grade)	Quantity consumed (in metric tonnes)
1	Sulphur (fungicide)	16424
2	Endosulfan (insecticide)	15537
3	Mancozeb (fungicide)	11067
4	Phorate (insecticide)	10763
5	Methyl parathion (Insecticide)	8408
6	Monocrotophos (Insecticide)	8209
7	Cypermethrin (Insecticide)	7309
8	Isoproturon (herbicide)	7163
9	Chlorpyrifos (Insecticide)	7163
10	Malathion (Insecticide)	7103
11	Carbendazin (fungicide)	6767
12	Butachlor (herbicide)	6750
13	Quinalphos (Insecticide)	6329
14	Copper oxychloride	6055
15	Dichlorvos (Insecticide)	5833

Main types of pesticides are

Organochlorines

The OCs are divided into three groups, viz. the DDT related compounds, the cyclodiene insecticide (aldrin, dieldrin, endrin, heptachlor and endosulfan) and isomers of hexachlorocyclohexane (HCH). The acute toxicity of p, p'-DDT is attributed mainly to action on axonal voltage dependent Na+ channels. Normally, when Na+ current is generated during the passage of a nerve action potential, the signal is rapidly ended by the closure of the sodium channel. In DDT, poisoned nerves, the closure of the channel is delayed causing disruption of action potential regulation which can lead to repetitive discharges [2]. Apart from the action on Na+ channels, DDT or its metabolites also acts as indicators of Ca++ ATPases in the membrane of avian shell gland and reduces the transport of CaCO3 from blood into egg shell gland. This results in a dose dependent thickness reduction [3].

Cyclodienes primarily act as inhibitors of GABA receptor and reduce the flow of chloride ions which leads to neurological disorders like tonic convulsion and clenched claws in predatory birds [4]. Cyclodienes have more potential effect than DDT to land vertebrates. The LD50 of dieldrin is 67mg/kg in pigeon [5]. Residues of dieldrin, heptachlorepoxide and other OCs in the tissues of British sparrow hawk and kestrel from 1963 to 1990s were recorded. The cyclodiene endosulfan is highly toxic to birds [6]. It is transported over long distances through the air and has been found in the arctic region far from any source of use [7]. Endosulfan, a neurotoxic pesticide is moderately to highly toxic to bird species. Administration of endosulfan by the dietary route resulted in lethargy, weakness and diarrhea in Japanese quail [8].

Organophosphorus and Carbamate Pesticides

The insecticidal properties of organophosphorus (OP) and carbamate compounds were first discovered in the 1930s, and the compounds were developed for pesticide use in the 1940s. Organophosphorus and carbamate pesticides are generally short-lived in the environment and, generally, chemical breakdown is accelerated as temperatures or pH or both increase. OPs and CMs are most commonly used pesticides throughout the world because of their low bioacculmulation properties in comparision to OCs. Both these insecticides inhibit acetylcholinesterase (AChE) at the

postsynaptic membrane [9] in CNS and PNS of all vertebrates. Inhibition of AchE leads to accumulation of the neurotransmitter acetylcholine at the synaptic cleft in the sympathetic and parasympathetic nervous system and in neuromuscular junctions [10]. Birds appear to be more sensitive to acute exposure to anticholinesterase pesticides due to reduced level of anticholinestearse detoxifying enzymes [11]. Birds appear to be more sensitive than other vertebrates to the toxic effects of OP and carbamate pesticides.

Neonicotinoids

Neonicotinoids are the most widely used group of insecticides in the world, and their use has been steadily increasing in the United States as well as in India also. Neonicotinoids have been replacing OP and CM compounds, uses of which are increasingly being restricted due to concerns about pest resistance and effects on human and environmental health. They are systemic insecticides; the compounds are absorbed by a plant and are transported throughout its tissues by means of vascular system [12]. Six neonicotenoids- imidacloprid, thiamethoxam, clothianidin, dinotefuran, thiacloprid and acetamiprid are approved for use in crops. Compared to OP, they have reduced mammalian toxicity and can be used efficiently even at lower doses [13].

Effects of pesticides on birds

Effects on development

Effects of Organochlorines: The developing chicks showed malformed beaks and skeleton, fluid retention in their heart and problems in sex determination, after chronic sub lethal OC exposure [14]. Congenital abnormalities and defects of feather growth of young terns are reported after OC exposure along the East coast of USA [15].
Effects of Organophosphates and Carbamates: Delayed development has been observed in the birds infected with OPs and CMs.
Effects of Neonicotinoids: Reduced development [16].

Effects on reproduction

Effects of Organochlorines: Chronic low level OC exposure affects the reproductive success of birds and changes their mating behavior. The affected birds ignore territorial barriers, exhibit less attentiveness to young and decrease the extent of their home range [17]. When fed with DDE for longer duration, courtship behavior in ring doves [18] and nocturnal activity in white –throated sparrow [19] were disturbed.
Effects of Organophosphates and Carbamates: Alteration in the reproductive behavior and gonadal development in birds have been noticed due to ventromedial hypothalamic lesions. Delayed development and degeneration of spermatogenic cells has occurred when domestic and semi-domestic birds were exposed to OPs. Decreased level of cholinesterase activity in testes and brains of adult male is directl related to increased number of degenerated germ cells in the seminiferous tubules, after exposure to parathion [20]. When treated with two OP such as parathion and phosphamidon separately, the phosphamidon showed more potential effect and impaired gonadal functions even at very low sublethal doses in female spotted munia.
Effects of Neonicotinoids: Eggshell thinning reduced egg hatching rate and low weight in chicks; and in mammals, they include reduced reproduction, premature deliveries and deformities in fetuses [21].

Effects on feeding behaviour

Effect of Organochlorines: The birds infected with organochlorines show reduced feeding and weight loss [16].
Effects of Organophosphates and Carbamates: OP and CM intoxication are often associated with anorexia and symptoms of gastrointestinal stress. Long term exposure to OPs and CM affect the feeding behavior of breeding Red-winged Blackbirds [22]. Exposure to OPs and CMs interferes with the bird's ability to discriminate between contaminated and clean foods. Reduction in body weight was also recorded. Lesions in hypothalamus due to pesticide exposure lead to food avoidance and cause a sharp reduction in body weight.

Effects of Neonicotinoids: Birds show reduced feeding [16].

Effects on hematological and immune system

Effects of Organochlorines: Anemia and decreased hemoglobin concentration have been documented after birds were exposed to lindane [23]. Suppression of T-cell mediated immunity in the Wild Caspian terns and Herring gulls were found to be associated with high prenatal exposure to OC compounds [24].

Effects of Organophosphates and Carbamates: Exposure to high doses of OPs can cause direct damage to cells and organs of the immune system and decrease the immune function. Histopathological changes in immune tissues, cellular pathology, altered maturation, changes in lymphocytes and functional alteration to immunocompetent cells are documented after OP exposure [25]. Other effects include direct damage to proteins and DNA. OPs interfere with immune system response in animals through both anticholinergic and non-cholinergic pathways. Chloropyriphos and methidathion causes reduction in WBC, neutrophils and lymphocyte count.

Effects of Neonicotinoids: Exposure to high doses of neonicotinoids can cause direct damage to cells and organs of the immune system and decrease the immune function [16].

Effects on thermoregulation

Effects of Organochlorines: Organochlorines affects the thermoregulation in birds. It results in hypothermia [16].

Effects of Organophosphates: These two insecticides also affect the thermoregulation in birds. Acute sub lethal exposure to OP results in pronounced, short-lived hypothermia. OP and CM induced reductions in body temperature in birds are often associated with decrease in AchE activity of more than 50%. The interaction between low temperatures and pesticide toxicity appears to be the result of the impairment of thermoregulation, causing inability of birds to withstand the cold.

Effects of Neonicotinoids: Neonicotinoids results in hyperthermia in birds [16].

Conclusion

Pesticides are often considered a quick, easy, and inexpensive solution for controlling weeds and insect pests. Pesticide contamination poses significant risks to the environment and non-target organisms ranging from beneficial soil microorganisms, to insects, plants, fish, and birds. Chemical pesticides cause serious sub lethal effects during the reproductive stages of birds. Sub lethal exposure may contribute to other causes of mortality such as trauma. Exposure to pesticides during reproductive stages affects hatching success and fledging survival, as well as increases the chance of reproductive failure.

For controlling the use of pesticides, farmers must be educated for judicious use of pesticides, use of biopesticides and the pesticides derived from the natural products should be promoted.

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