Impacts of Various Insecticide Forms on Avian Health and Mortality: A Comprehensive Review

ABSTRACT

Different forms of insecticides, such as granular, liquid, and treated seeds, pose significant threats to birds. Granular insecticides, often used in agriculture, are highly concentrated and attractive to songbirds, shorebirds, and waterfowl. Liquid sprays, particularly those used for locust control, can affect bird species beyond agricultural areas due to wide-range applications. Treated seeds can poison birds depending on various factors like toxicity and seed availability. Birds are exposed to insecticides through ingestion, inhalation, and skin absorption, leading to severe health impacts, reproductive issues, and increased mortality. Despite the known dangers, many pesticide-related bird deaths go unreported, highlighting the need for comprehensive studies to understand and mitigate these effects.

Keywords: Agrochemicals; birds and agriculture; biodiversity; insecticides; pesticide exposure; chronic effect; environmental pollution.

1. INTRODUCTION

The effects of the pesticides are increasing nowadays due to its toxicity and moreover they cause impacts on various trophic levels and it mainly affects the birds and bio accumulates and causes serious effects. In recent years the manufacturing and consumption of agrochemicals (pesticides, insecticides, herbicides) worldwide have been increasing dramatically. Most pesticides damage non-target plants and animals in addition to the insect they are intended to kill. Most of the agrochemicals has high persistence ability which resist the degradation mainly persist in the soil and gets leached to groundwater and contaminate the soil and aquatic environment [1,2,3].

Due to the direct and secondary effects of pesticides, habitat change, intensified land use, and other reasons, the majority of bird species that inhabit agricultural landscapes are experiencing a decline. The use of pesticides, which is typically connected to contemporary agriculture, can endanger the survival of ecosystems by reducing biodiversity (flora and fauna) and contaminating natural resources, including groundwater, which affects both the environment and human health. According to a survey, herbicides kill between 0.25 and 8.9 birds per hectare of agricultural land annually. Due to the severe impact of pesticides approximately 67 million birds die each year [1].

The negative impact of the pesticides had been increasing mainly after the introduction of chemical pesticides which causes increase in the expenditure in agriculture and moreover increase in the pesticide drift by means of air and water [19-24]. The pesticides not only being toxic to the living organisms and continuous spraying of pesticides leads to increase in the pesticide resistance were developed in the microorganisms [14-18].

The majority of pesticides are synthetic substances meant to prevent, eradicate, repel, or lessen any type of insect. The Insecticides contribute a major part of agrochemicals used to kill insects Herbicides are used to kill weeds. The fungicides are mainly used to control fungal plant diseases. The Rodenticides are also the synthetic compounds used for the killing of rats, mice and other rodents [25-28].

Status of usage:

- India currently ranks twelfth in the world for pesticide use and is the country that produces the most pesticides in Asia. According to Sitaramaraju et al. (2004), Uttar Pradesh is the state that consumes the most pesticides, followed by Punjab, Haryana, and Maharashtra. For the main purpose of controlling diseases and pests, chemical pesticides are used.
- As a result of widespread education about the harmful effects of pesticide use, India's per hectare usage has been roughly 480 gms, compared to 4.5 kg in the United States and more than 15 kg in Japan and England.

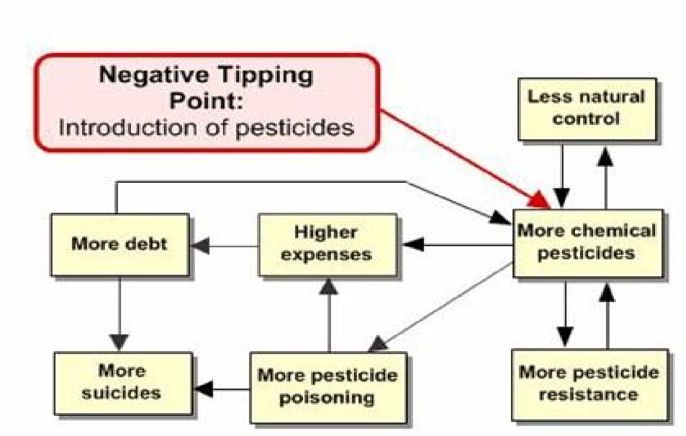

Fig. 1. Impact of pesticides

India's consumption pattern is more skewed towards pesticides due to its tropical climate (Indian Pesticides Industry, 2011). Thus, India's application pattern of agrochemicals differs from the global trend. In India, 76% of pesticides are insecticides, compared to 44% worldwide (Mathur, 1999). This results in a lighter treatment of fungicides and herbicides. When combined, they make up about 57% of all pesticides used in India. Although vegetables account for 9%, wheat and pulses for 4%, and other plantation crops for 7% (Ministry of Agriculture, 2009). According to state, Andhra Pradesh uses the most pesticides (23%) followed by Punjab and Maharashtra.

- In the consumption of agrochemicals in world scenario the insecticides usage was about 44% while the herbicides and fungicides usage are 30% and 21% respectively while other agrochemicals includes 5% of the use. In Indian scenario the utilization of the agrochemicals such as insecticides, herbicides and fungicides are 76%, 10%,13% respectively while other agrochemicals includes for about 1%.
- The pesticide consumption mainly started after the green revolution which leads to increase in high yield crop. The pesticide use had its peak in the years of 1988 - 1991 and it was about 75000 tonnes while it was greatly reduced to about 45000 tonnes in the years of 2012-2013 was about 45000 tonnes.

Role of birds and agriculture: When it comes to recreational value, birds are more magnificent than other animals. Birds have always captivated people due to their innately gorgeous feathers, catchy songs, and creative behaviour (Shrestha 2000). Birds are valuable in many other ways as well. They are an accurate measure of pollution. They are quite important for pest control as well. Robert Van Den Our Nature (2003) 169 Bosch states "A pest is a species that, because of its great numbers, behaviour or feeding habit is able to inflict substantial harm on man or his valued resources." There are various types of pests. Key or important pests, insects are evergreens that, in the absence of adequate management measures, seriously and persistently harm an ecosystem's economy.

Various sources report the House crow (*Corvus splendens*) feeding on dead sewer rats, offal, carrion, kitchen leftovers and garbage, locusts, termites, fruit, grain, and eggs, or fledgling birds (Inskipp and Inskipp 1985,Ali 1989, Richard 1993, [5]. Fleming Sr. and Fleming Jr. made a substantial contribution to Nepalese ornithology (1952 to 1980). Subba (2001) has produced articles on garden birds in the setting of Biratnagar. The second-largest city in the nation, Biratnagar (Latitude N 26° 29', Longitude E 87° 16', altitude 72m), is the subject of the study effort covered in this paper. It covers an area of 760 square km.

The core region of Biratnagar is inhabited by agricultural land and human settlements on the eastern and western flanks. In Biratnagar's agricultural areas, which are located in the northeast (Kanchanbari), northwest (Air Port), southeast (Jatuwa), and southwest (Bakhary), birds were frequently observed. It was carried out once every week from September 2001 to August 2002. In order to investigate feeding habit and its function in pest control, binoculars, cameras, and field manuals (Fleming et al. 1984, Inskipp and Inskipp 1985, Ali and Ripley 1994, Shrestha 2000) were utilised.

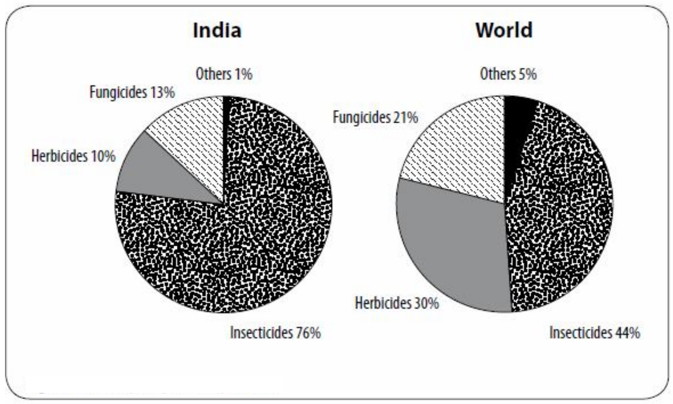

Fig. 2. Consumption pattern in India and world [4]

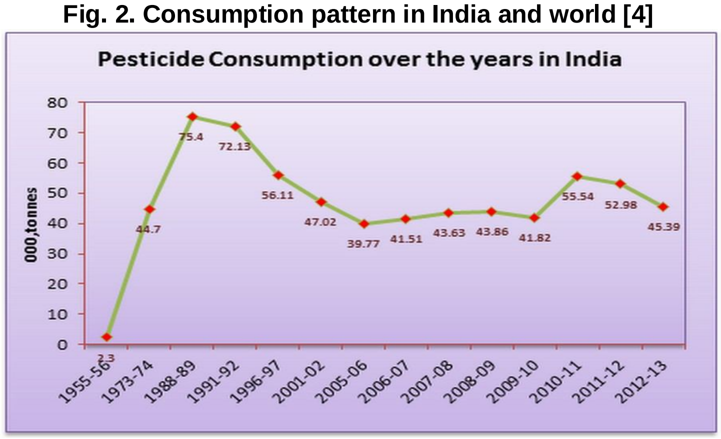

Fig. 3. Pesticide consumption over the years in India

Crow pheasants (*Centropus sinensis*) have been seen to consume huge amounts of the softer sections of garden snails (*Achatina fulica*) in the early morning and afternoon. Paddy- destructive crabs were observed being consumed by house crows (*Corvus splendens*). The following animals fed on grasshoppers: Indian tree pie (*Dendrocittavegabunda*), Crow pheasant (*Centropus sinensis*), Small green bee eater (*Meropsorientalis*), Blue-tailed bee eater (*Meropsphilippinus*), Common myna (*Acridotheristristris*), Bank myna (*Acridotherisginginianus*), House crow (*Corvus splendens*), and Red-vented bulbul (*Pycnonotuscafer*).

The Black Drone (*Dicrurusadsimilis*), the Jungle Babbler (*Turdoides striatus*), and the Magpie Robin (*Copsychussaularis*) were the main controllers of numerous kinds of moths and butterflies. The Indian treepie (*Dendrocittavagabunda*) consumed weevils. Aphid management by the large-pied wagtail (*Motacillamaderaspatensis*) was discovered. The three most damaging pests, housecrows (*Corvus splendens*), jungle crows (Corvus macrorhynchos), and owls, consumed rats and mice. Bird feeding behaviour is influenced by a variety of environmental factors, including habitat, location, time of year, water quality, competition (both intra- and interspecific), and food scarcity. You can view a list of farming birds in Table 1.

Caterpillars, large insects, lizards, small mice, and bird eggs and nestlings are among the foods that the Crow pheasant consumes, according to Ali (1990). The eating habits of house crows and crow pheasants were seen to have altered as a result of the severe environmental changes and food scarcity. The investigation also disclosed the method by which Garden snails are consumed by Crow pheasants. Additionally, the outcome supported the diets and feeding patterns of other birds such as the Cattle Egret, Small Green Bee Eater, Blue-tailed Bee Eater, Common Myna, Bank Myna, Indian Tree Pie, Red-vented bulbul, Pied myna, Magpie robin, Black drongo, Jungle babbler, Pied crested cuckoo, Gray-headed myna, King fisher, Flycatcher, Large pied wagtail, Owl, and Jungle Crow previously noted by previous researchers (Inskipp and Inskipp 1985, Ali 1990).

A wider range of activities, such as deforestation, erosion, channelling, flooding, draining, and other processes, as well as the eradication or spread of particular plant and animal species, are some of the ways that agriculture alters natural ecosystems (Steadman 1996). Agriculture has two key effects on biodiversity. The first method involves clearing pristine habitats for new plantings, which comes with challenges including pollution, disturbance, and habitat fragmentation for the surviving habitats. The intensification of current agricultural systems with the goal of raising crop yields per unit area is the second factor contributing to the reduction in biodiversity. During the past 30 years, this has increased overall commodity productivity more than new land planting (Donald and Evans 2006).

The behaviour, distribution, seasonal phenology, and demographic patterns of birds strongly correspond to the temporal and spatial scales of changes in agriculture. Features seen in the patchwork of agricultural ecosystems are reflected in foraging behaviour, nest-site selection, and breeding performance. Important life events like mating or migration are influenced by the annual farming calendar's pattern of events. The differences among their groups or populations are a reflection of regional, national, or local differences in land use or management. Their demographic drift from year to year means that their population patterns are in line with the progression of agricultural transformation.

Table 1: Bird species and their population in different land use systems in agro-ecosystem during the year 2012-2013

S.No	Species	CL	WL	Pl	FL
1.	Ashy drongo (*Dicrurus leucophaeus*)	0	11	0	0
2.	Ashy wood swallow (*Artamus fuscus*)	0	501	0	386
3.	Asian koel (*Eudynamys scolopaceus*)	18	42	29	55
4.	Asian palm swift (*Cypsiurus balasiensis*)	240	225	0	461
5.	Asian-paradise flycatcher (*Terpsiphone paradasi*)	0	0	0	20
6.	Barn owl (*Tyto alba*)	12	0	0	0
7.	Baya weaver (*Ploceus philippinus*)	126	0	0	0
8.	Black drongo (*Dicrurus macrocercus*)	56	63	27	137
9.	Black headed cuckoo shrike (*Coracina melanoptera*)	0	43	0	26
10.	Black headed ibis (*Threskiornis melanocephalus*)	0	27	0	0
11.	Black headed munia (*lonchura malacca*)	230	0	0	416
12.	Black hooded oriole (*Oriolus xanthornus*)	0	66	0	44
13.	Black kite (*Milvus migrans*)	0	0	2	7
14.	Blue-bearded Bee-eater (*Nyctyornis athertoni*)	0	103	0	0
15.	Blue-tailed bee-eater (*Merops philippinus*)	77	192	0	0
16.	Blyth's pipit (*Anthus campestris*)	24	0	0	111
17.	Brahminy kite (*Haliastur indus*)	22	35	18	61
18.	Bronze-winged jacana (*Metopidius indicus*)	0	62	0	0
19.	Cattle egret (*Bubulcus ibis*)	0	0	62	42
20.	Chestnut-headed bee-eater (*Merops leschenaulti*)	0	132	0	257
21.	Common hawk cuckoo (*Hierococcyx varius*)	0	0	4	23
22.	Common goldenback Woodpecker (*Dinopium javanense*)	0	0	48	44
23.	Common hoopoe (*Upupa epops*)	0	0	4	7
24.	Common kestrel (*Falco tinnunculus*)	7	0	54	44
25.	Common kingfisher (*Alcedo atthis*)	0	49	11	0
26.	Common iora (*Aegithina tiphia*)	0	0	57	94
27.	Common myna or Indian myna (*Acridotheres tristis*)	135	339	192	500
28.	Common sandpiper (*Actitis hypoleucos*)	0	65	0	0
29.	Common tailor bird (*Orthotomus sutorius*)	17	0	0	89
30.	Common tern (*Sterna hirundo*)	0	272	0	0
31.	Coppersmith barbet (*Megalaima haemacephala*)	0	75	0	144
32.	Cotton pygmy-goose (*Nettapus coromandeliamus*)	0	80	0	0
33.	Crimson backed sunbird (*Leptocoma minima*)	0	0	0	45
34.	Darter (*Anhinga melanogaster*)	0	74	0	0
35.	Drongo cuckoo (*Surniculus lugubris*)	0	0	0	8

36.	Great egret (*Casmerodius albus*)	0	259	611	75
37.	Great goldenback woodpecker (*Dinopium benghalense*)	0	0	18	18
38.	Green Bee-eater (*Merops orientalis*)	125	109	85	448
39.	Green sandpiper (*Tringa ochropus*)	0	8	0	0
40.	Grey francolin (*Francolinus pondicerianus*)	36	0	18	21
41.	Grey wagtail (*Motacilla cinerea*)	0	14	0	0
42.	House crow (*Corvus splendens*)	112	88	146	85
43.	House sparrow (*Passer domesticus*)	97	0	0	0
44.	Indian golden oriole (*Oriolus kundoo*)	0	0	0	62
45.	Indian cormorant (*Phalacrocorax fuscicollis*)	0	256	0	0
46.	Indian cuckoo (*Cuculus micropterus*)	0	64	44	27
47.	Indian grey hornbill (*Ocyceros birostris*)	0	0	0	18
48.	Indian jungle crow (*Corvus macrorhynchos*)	53	135	148	97
49.	Indian peafowl (*Pavo cristatus*)	10	0	73	77
50.	Indian pond heron (*Ardeola grayii*)	0	396	47	0
51.	Indian roller or Blue joy (*Coracias benghalensis*)	14	74	38	37
52.	Intermediate egret (*Mesophoyx intermedia*)	0	113	0	0
53.	Jungle babbler (*Turdoides striata*)	195	1043	122	660
54.	Jugle bush quail (*Perdicula asiatica*)	32	0	0	18
55.	Lesser whistling duck (*Dendrocygna javanica*)	0	177	0	0
56.	Little cormorant (*Phalacrocorax niger*)	0	288	0	0
57.	Little erget (*Egretta garzetta*)	0	1299	275	63
58.	Little grebe (*Tachybaptus ruficollis*)	0	110	0	0
59.	Little swift (*Apus affinis*)	277	224	0	683
60.	Orange minivet (*Pericrocotus flammeus*)	0	0	0	30
61.	Oriental magpie robin (*Copsychus saularis*)	15	0	0	24
62.	Paddy field pipit (*Anthus rufulus*)	39	0	0	39
63.	Pied bushchat (*Saxicola caprata*)	63	0	0	117
64.	Pied kingfisher (*Ceryle rudis*)	0	83	0	0
65.	Plain prinia (*Prinia inornata*)	48	0	0	63
66.	Purple heron (*Ardea purpurea*)	0	52	0	0
67.	Purple rumped sunbird (*Leptocoma zeylonica*)	0	0	0	56
68.	Purple sunbird (*Cinnyris asiaticus*)	0	0	0	6
69.	Purple swamphen (*Porphyrio porphyrio*)	0	67	0	0
70.	Red vented bulbul (*Pycnonotus cafer*)	85	352	0	201
71.	Red wattled lapwing (*Vanellus indicus*)	0	161	0	54
72.	Rock dove or Rock pigeon (*Columba livia*)	236	0	0	0
73.	Rose-ringed parakeet (*Psittacula krameri*)	301	0	140	481
74.	Rufous treepie (*Dendrocitta vagabunda*)	0	0	91	25
75.	Scaly breasted munia (*Lonchura punctulata*)	432	0	0	437
76.	Shikra (*Accipiter badius*)	15	0	17	18
77.	Southern coucal (*Centropus [sinensis] parroti*)	17	54	60	49
78.	Spotted dove (*Stigmatopelia chinensis*)	79	183	25	102
79.	Spotted owlet (*Athene brama*)	18	0	60	49
80.	Stork-billed kingfisher (*Pelargopsis capensis*)	0	73	0	0
81.	Striated heron (*Butorides striata*)	0	3	0	0
82.	Tickell's flower pecker (*Dicaeum erythrorhynchos*)	0	77	0	85
83.	White breasted water hen (*Amaurornis phoenicurus*)	0	4	0	0
84.	White browed bulbul (*Pycnonotus luteolus*)	0	87	0	2
85.	White cheeked barbet (*Megalaima viridis*)	0	0	0	90
86.	White rumped munia (*Lonchura striata*)	113	0	0	68
87.	White rumped spinetail (*Zoonavena sylvatica*)	0	12	0	0
88.	White-bellied drongo (*Dicrurus caerulescens*)	0	178	0	6
89.	White-browed wagtail (*Motacilla maderaspatensis*)	29	0	0	73
90.	White-throated kingfisher (*Halcyon smyrnensis*)	25	156	36	83
91.	Yellow footed green pigeon (*Treron phoenicopterus*)	0	0	0	4
92.	Yellow wagtail (*Motacilla flava*)	0	6	0	0
	Total	**3430**	**8661**	**2562**	**7572**

CL-Cropland, WL-wetland, Pl-Plantations, FL-Fallow land

These data are particularly important in showing the strong relationship between agricultural practices and ecological trends, especially when combined with equally valuable long-term land use monitoring (Ormerod & Watkinson, 2000). Changing farming practices or converting land can have a wide range of potential ecological repercussions. Some are directly caused by modifications in the structure or composition of the vegetation and the related faunal groups. Some are more delicately mediated, such as by changes in crop phenology. Furthermore, a vast range of indirect effects emerge, such as altered predator-prey dynamics or the chemical effects of agrochemicals on species composition. Other ecosystems, such as those downstream or in nearby bordering areas, are also impacted.

Increases in agricultural intensity have been connected to sharp drops in farmland bird populations in Europe, North America, Africa, and Asia (Donald & Evans 2006). Birds are frequently employed as indicators of agricultural environments. Ten specialist species were identified by Kati &Sekercioglu (2006) as being extremely characteristic and heavily dependent on the habitat types in which they occur, occurring virtually exclusively in those sites and infrequently in other habitat types. The ecological responsibilities of birds are sometimes lost along with unique ecosystems, like marshes or forests.

However, in many instances, reductions in bird populations happen independently of habitat loss due to causes such as exploitation, invasive species, diseases, fragmentation, and others that remove birds and their benefits from ecosystems. Actually, factors other than habitat loss pose a threat to half of the threatened species. This is especially true for groups that are much more vulnerable than average, such as scavengers (100%), piscivores (80%), herbivores (78%), omnivores (76%), granivores (56%), frugivores (53%), and birds weighing 100 g (73%). 6-14% of all historical bird species are predicted to be extinct by 2100, whereas 7-25% are predicted to be functionally extinct and 13-52% to be functionally deficient (Sekercioğlu*et al.,* 2004).

Mode of poisoning:

First generation insecticides: When it comes to birds, the method of action usually manifests itself primarily in reproductive effects such eggshell thinning or acute mortality. Common examples of first- generation pesticides include dieldrin, aldrin, and DDT, or organ chlorines.

Second generation insecticides: Cholinesterase inhibition is the mode of action, causing neurological consequences that can be fatal or sub-lethal. Carbamates and organophosphates are two instances of second-generation insecticides. Barn owls (Tyto alba), American kestrels (Falco sparverius), Red- tailed hawks (Buteo jamaicensis), Great horned owls (Bubo virginianus), and Bald eagles (Haliaeetus leucocephalus) are the primary avian fauna affected by cholineesterse inhibition.

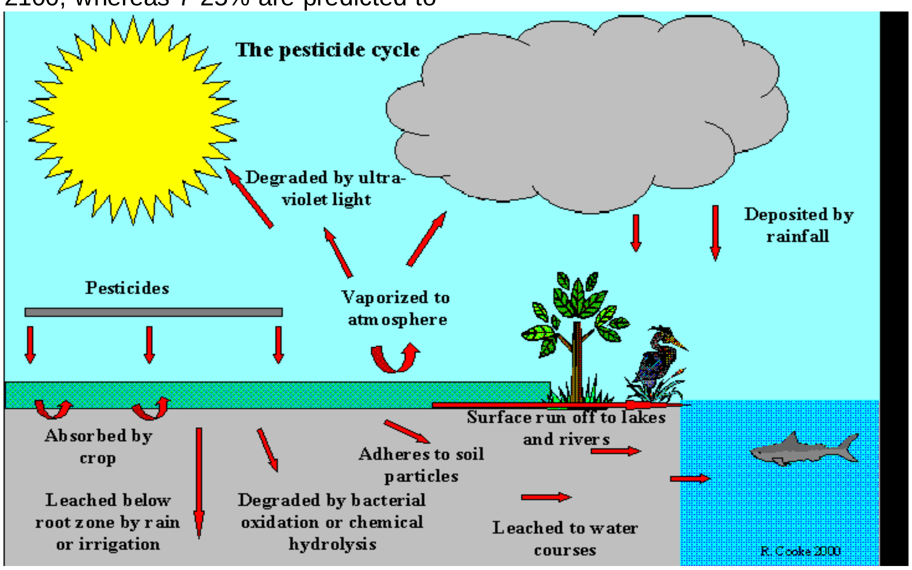

Fig. 4. Pesticide cycle

The pesticide cycle is mainly the biotransformation of the pesticides which tends to bio magnify and bio accumulate in biological systems and causes serious effects. After application of pesticides it gets absorbed by the crop and the remains are leached by the rain water or irrigation. Some fraction of pesticides are degraded by bacterial oxidation or chemical hydrolysis while some parts are leached from the soil through surface runoff and leaching and enters into the water bodies. The other route of pesticide transformation was the pesticides gets vaporised to atmosphere and they are degraded by UV light and then comes again to the soil and water bodies as rain and easily enter in to any biological system.

Types of pesticides that raise the chance of exposure:

The different forms of insecticide which pose threat to birds are as follows;

Granular forms: Granular pesticides are highly concentrated insecticides that are frequently used in agriculture to protect crops from certain pests and are frequently linked to songbird mortality.

Eg: Particularly attractive to songbirds, shorebirds and waterfowl [6]

Liquid forms: The toxicity and rate of application of agrochemicals in liquid form affect the mortality rate of birds. Several bird species experienced sub-lethal impacts from the liquid sprays. Due to their broad range of application, pesticides used for controlling locusts in agricultural regions via aerial spraying may have an impact on species other than those living in agricultural areas [6].

Treated Seeds: According to studies, certain seed treatments can occasionally poison birds in specific situations. The likelihood that treated seeds will poison depends on a number of factors, including the area seeded, the pesticide's toxicity, how much of it is applied to the seed, how densely the exposed seed is packed, the availability of alternate feeds, and the birds' capacity to avoid treated material on purpose. The percentage of birds who developed morality as a result of exposure to treated seed was probably between 0 and 5 percent (Hart *et al*., 1999).

Mode of exposure: The three main ways that avifauna are exposed to agrochemicals are by ingestion, inhalation, and skin absorption. pesticides consumed via eating polluted water, sprayed insects and vegetation, or pesticide-soaked granules or seeds. By consuming smaller creatures that have previously been exposed to pesticides, birds consume them. Dust that has been treated or chemical spray can both cause inhalation. Bathing in pesticide-contaminated water can cause skin absorption, as can standing in treated soil or vegetation and absorbing via the feet. Numerous bird species consume enough seeds to be potentially dangerous.

Impact of Pesticide exposure on bird:

Pesticide exposure severely impacts birds' habitats, mating rituals, territorial defense, and overall health. It causes labored breathing, convulsions, and feather fluffing, increasing risks of predation, accidents, and food scarcity. Reproductive abilities are reduced, with failures in mating, territory defense, and nurturing young. Documented pesticide-related bird deaths are few due to limited scientists, funding, and diagnostic challenges. Many deaths go unnoticed as birds may hide, decay, or be scavenged. Sick birds evade capture, complicating

analysis. Singing bird counts, often used to estimate populations, may not accurately reflect sublethal effects, necessitating more detailed research to document nonlethal impacts.

Reproduction:

- The inability to locate a mate, carry out mating rituals, protect territory, and alter patterns of attention to their young all contribute to a reduction in reproductive capacities. Experiments done on red-legged partridges fed with imidacloprid and thiram treated seeds showed adverse reproductive effects at recommended doses after a 10 day exposure. (Scientific advisory Committee 2014)

In England showed delayed chick development and impaired blood cholinesterase activity in tree sparrows in intensively sprayed (organophosphates) area. (Bennett *et al*., 1991). By ingesting food that had high pesticide residues, predators are also indirectly impacted by pesticides. For instance, DDT. flies that reside just beneath cattle's skin. It has been demonstrated that feeding cow dung to calves can poison the magpies, which consume cattle hair as part of their diet. Frogs cultivated in the pesticide-containing water 27 There could be comparable issues with other organophosphates(Caroline Cox., 1991).

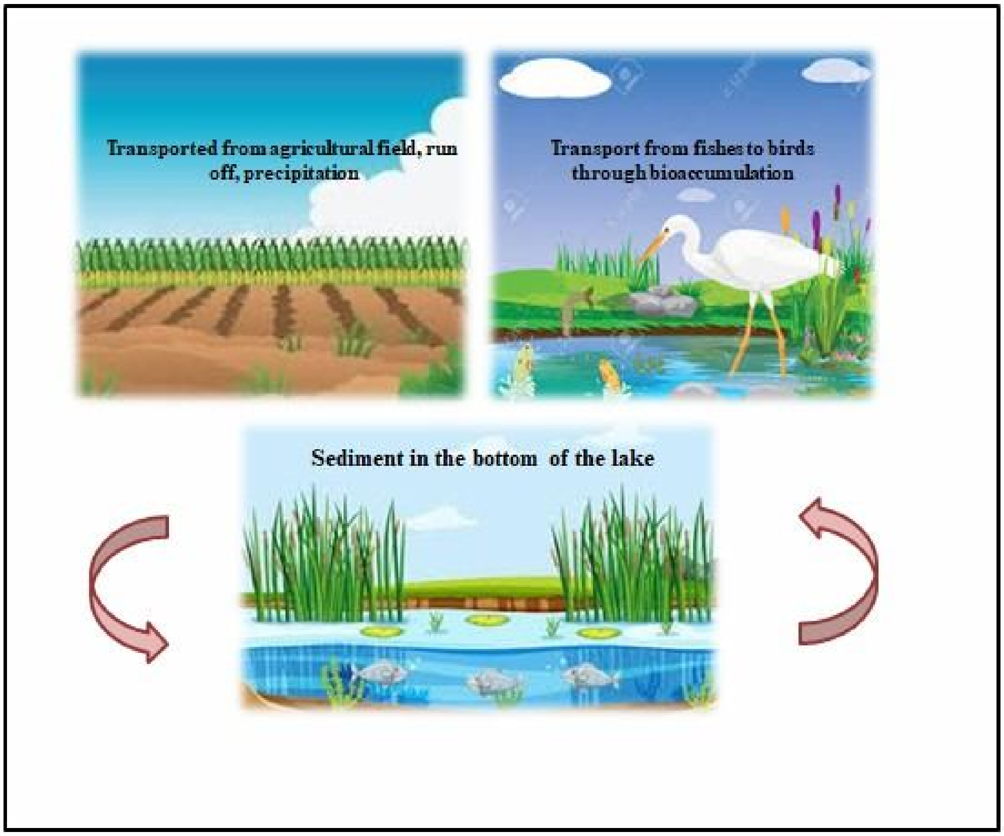

Fig. 5. Organochlorines in the food chain

Organo chlorines compounds used as agrochemicals which gets leached and enters in the water bodies and gets contaminated in the water at lower levels which thereby biotransform to the phytoplankton-zooplankton-small fishes-Large fishes-predatory birds and they bioaccumulate at all the trophic levels of the food chain which leads to increase in the concentration of the contaminants called as biomagnification. In each sucessive trophic level the concentration of the OC compounds increases and causes the toxicity.

Organo chlorines: The cessation of DDT's registered usage did not eliminate the organochlorine threat to birds. While the use of some organochlorine pesticides, such the miticide dicofol, which also thins bird eggshells, is still permitted in the US, the use of others, like chlordane, was banned or restricted far later than DDT. Furthermore, a lot of other nations continue to use DDT and its related substances. Birds that migrate abroad may return to the United States with residues stored in their tissues. For instance, the Virginia Wildlife Center's examination of great horned owls for the presence of organochlorine residues revealed high concentrations of the DDT metabolite DDE and lower concentrations of methoxychlor8 (an further organochlorine insecticide that is still authorised for use in the United States) and dicofol.

Organo phosphorus: Organophosphorus (OP) and carbamate compounds were originally shown to have insecticidal effects in the 1930s, and in the 1940s, these compounds were developed for use as pesticides. Since the United States outlawed the use of environmentally harmful organochlorine pesticides like dieldrin and DDT in the 1970s, their use has increased. Pesticides containing organophosphorus and carbamate often have a short environmental half-life—lasting only a few days to months as opposed to years—and their chemical degradation normally quickens with rising temperatures, pH levels, or other environmental factors [29-34].

Cause: The inhibition of cholinesterase (ChE) enzymes invertebrate or vertebrate nerve systems results in the toxicity of OP and carbamate pesticides. Throughout the neurological system, these enzymes are involved in the normal transmission of nerve impulses. Acute pesticide dosage decreases ChE activity, impairing normal nerve mpulses transmission. This may cause mortality, generally from respiratory failure, and paralyse the neurological system.

Thermoregulation: The pesticides induced reduction in body temperatures in birds are often associated with decrease in AchEacticity of more than 50% (Clement, 1991). It leads to enhanced mortality in birds is reported at sub lethal doses at thermo-neutral temperatures [7]. Interaction between low temperature and pesticides toxicity appears to be resilt of the impairment of thermoregulation causing inability of birds to withstand the cold [8,35-41].

Feeding: Exposure to pesticides has a direct impact on eating behaviour, affecting how prey is encountered, selected, caught, and handled. hunting skills may be hampered by side effects such spasms, dizziness, and loss of coordination. Acute low-level exposure can result in long- term alterations to food habits.When red-winged blackbirds (*Agelaius phoeniceus*) were exposed to parathion-contaminated prey, they developed a taste aversion to the species of prey, even in situations where the chemical was not present. This may lead to a decrease in food consumption and consequently in body composition, but it may also lessen the chance of food poisoning. (Doughwaite*et al.,* 1996).

Organophosphate and carbamate exposures affected the birds' capacity to distinguish between tainted and uncontaminated food. There was also a reduction in body weight, with an average weight loss of 14%, after sublethal exposure.A single dosage of dicrotophos was associated with this kind of weight loss (Grue *et al.,* 1984).Pesticide-induced lesions in the lateral hypothalamus result in ffod avoidance and a marked decrease in body weight in birds [49-51].

Chronic effects: The chicks were deformed, with deformed skletons and beaks, heart difficulties with fluid retention, and issues with determining sex. Following exposure to pesticides, tern chicks have been seen to develop feather growth problems and consequential abnormalities, which mostly affect the endocrine system (Bourne *et al.,* 1977). Because they consume large amounts of seed, birds are at a significant danger. Due to their weight loss, small birds are at risk. Herbst *et al.,* [9] reported that endosulfan, an endocrine disruptor, and lindane both alter blood hormone levels, which are crucial for metabolism and reproduction. Lower hormone levels were linked to lower egg production.

Effect on haematological and immune system: After birds were exposed to lindane, anaemia and a drop in haemoglobin concentration were observed [10].Grasman*et al.,*[11] discovered a correlation between high prenatal pesticide exposure and the suppression of T-cell mediated immunity in wild Caspian terns and herring gulls.

Starvation: The herbicides damage the habitat that the birds' prey uses, indirectly starve the birds or drive them out of treated regions.For instance, artificial pyrethroids can ruin bird food sources even though they generally have a minimal acute toxicity to birds. Particularly at risk are small insectivorous birds, waterfowl that feed on watery insects, and nestlings who eat insects [42-48].

The Indian subcontinenth as had a remarkablegeo-tectonic history,e specially during the period since the Cretaceous, when the proto-Indiancratonic mass rafted northwardfromGondwananAfricat o impactt he Eurasian plate (Mani, 1974a; Smith, Hurley & Briden, 1981). This collision produced the Himalayan uplift (Klootwijk, Conaghan & Powell, 1985) and definedt he boundarieso f the Indian regiontoday as an arc of mountainsthatrangesfromtheAndamanIslands (Ripley & Beehler, 1989) north-eastward along the India/Burmaborder,westward in the eastemmost Himalayas to Sikkim, north westward to Kashmir,and finally south westward to the Makran Coast of Pakistan.

The biomagnifications and the bioaccumulation was mentioned in the above figure as the waterhas lowest level of DDT concentration and it increases tremendously by successive trophic levels and shows a 10 million times increase in the fish eating birds (Caroline, 1991).

Pesticides have resulted in the decline in the abundance and diversity of invertebrates and plants. The effects of pesticides on the availability of chick food and thus nestling survival prospects (e.g.) Indirect effects are generally considered to be the greatest threat from pesticides to birds.

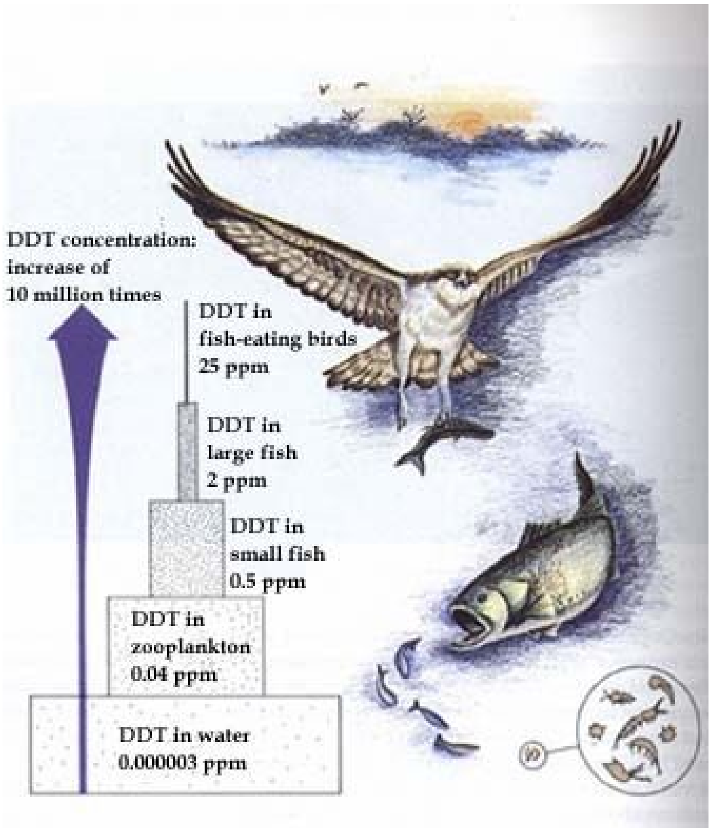

Fig. 6. Biomagnification of DDT concentration

Cholinesterase: Cholinesterase-inhibiting insecticides, which include organophosphates and carbamates, lead to impaired nest attentiveness and predator avoidance. On wading birds productivity in US showed that cholinesterase activity was low in some bird species nesting in an agricultural estuary compared to non-agricultural ones [52-55]. A review of evidence shows that cholinesterase inhibiting insecticides can affect a range of physiological and behavioural patterns, potentially affecting individuals' survival and productivity in the field [12].

Fig. 7. Bald eagle with clenched talon, a symptom of anti-cholinesterase pesticide exposure

Migratory bird: Throughout the winter months, a wide variety of birds from western Asia, Europe, and Arctic Russia visit the Indian subcontinent. Every winter, hundreds of species of waterfowl travel great distances to migrate to India, including wading birds like sandpipers, terns, and plovers (Grewal, 1990). There have been reports of OC pesticide concentrations in whole-body homogenates of birds (Tanabe *et al.,* 1998), but no reports of OC pesticide concentrations in prey items or Indian bird eggs.

IPM: Remedial M Integrated Pest Management, or IPM, is an effective technique to manage pests in your home and garden. By using IPM you can reduce the use of pesticides, have healthier plants, and enjoy your landscape.The seven steps the IPM includes introduction of Resistant varieties, Natural insect predators, Microbial pesticides, Controlling the population, Non toxic naturally occurring substances and Synthetic pesticides in small amounts.

Step 1. Prevention:

- Grow a range of species.
- Provide plants with the sunlight, water, and nutrients they require to grow healthy soil.
- Maintain tidy garden beds and walkways.
- Change up crop rotation measures [13]

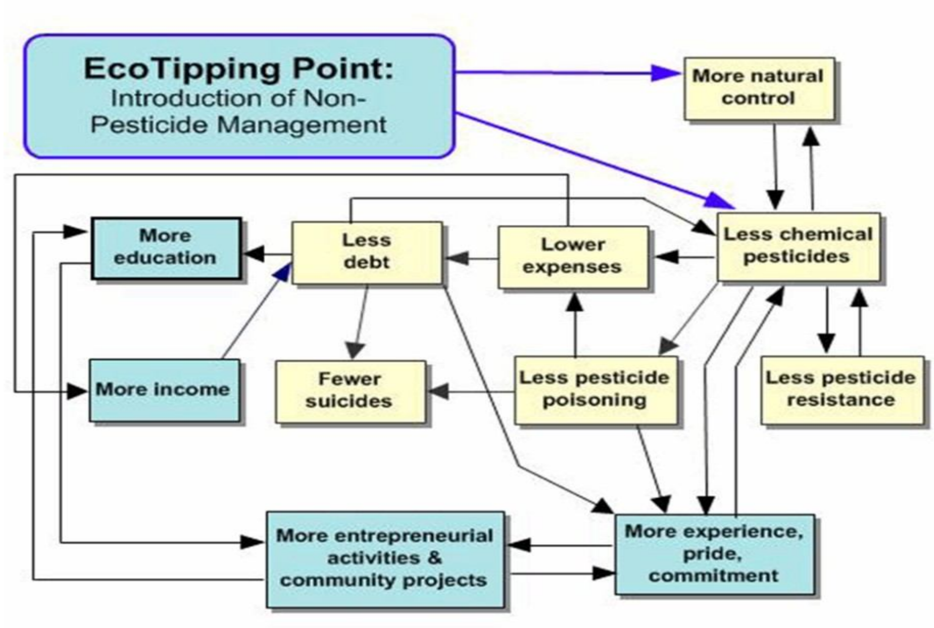

Fig. 8. Non-pesticide management positive tips

Step 2. Observation

- Keep a close eye on your plants.
- Maintain realism. Take just essential action.

Step 3. Taking Action

- Control measures

Step 4. Evaluation

2. CONCLUSION

By polluting food supplies, pesticides and their residues can have a direct or indirect negative impact on birds and their young. Pesticide exposure during the reproductive phases increases the likelihood of reproductive failure and has an impact on hatching success and fledging survival. These issues included malignancies, aberrant thyroid activity, behavioural abnormalities, feminisation of males and females, thinning of the eggshell, metabolic alterations, deformities and birth defects, immunological suppression, endocrine dysfunction, and reproductive dysfunction. Pesticide exposure, whether acute or chronic, raises mortality rates and has a negative impact on the avian population when it is sub lethal. Pesticide use is governed by international and national laws, which should be closely adhered to by users.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

Details of the AI usage are given below:

1. ChatGPT was used for editing this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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