



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

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Since the time of its synthesis and application, insecticides have prevented millions of deaths in humans, animals and avian lives. They have significantly contributed to the revolution in agriculture and human health by reducing agricultural pests and vector-borne illnesses. The chance of birds being exposed to insecticides is increased by a number of factors, including farming methods, insect and crop kinds, pesticide form, food, and habitat preferences. Granular insecticides, often used in agriculture, are highly concentrated and attractive to songbirds, shorebirds, and waterfowl.

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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. Despite the known dangers, many pesticide-related bird deaths go unreported, highlighting the need for comprehensive studies to understand and mitigate these effects. Insecticides have a variety of sub lethal effects on birds, such as deformed embryos, smaller broods, less vigilant parenting, weakened territorial defence, anorexia and weight loss, weakened immune response, lethargic behaviour, increased susceptibility to predators, disruption of the endocrine system, interference with thermoregulation, and inability to orient in the correct direction for migration. Therefore, exposure to pesticides lowers the likelihood of survival and successful reproduction, which eventually interferes with the growth of a robust bird population.

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 resists the degradation mainly persist in the soil and gets leached to groundwater and contaminate the soil and aquatic environment [1].

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.

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. 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. 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.

1.1 Status of Usage

A closer examination of pesticide use reveals that we are spraying crops more frequently and using more pesticides than ever before. The FAOSTAT database shows that the amount of pesticides used worldwide (measured in tonnes of active ingredient) grew by 58% between 1996 and 2023. Pesticides operate by harming the animals they are intended to kill. But not every species responds to pesticides in the same manner. They have an effect on non-target species as well. The most often used pesticides are pyrethroid, carbamate, and organophosphate. Presently, five million tonnes are used annually worldwide, with herbicides accounting for the majority (44%), followed by insecticides (27%), fungicides (22%), and other types including nematicides and rodenticides.

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 56%, while world share include for about 1% (Fig. 3).

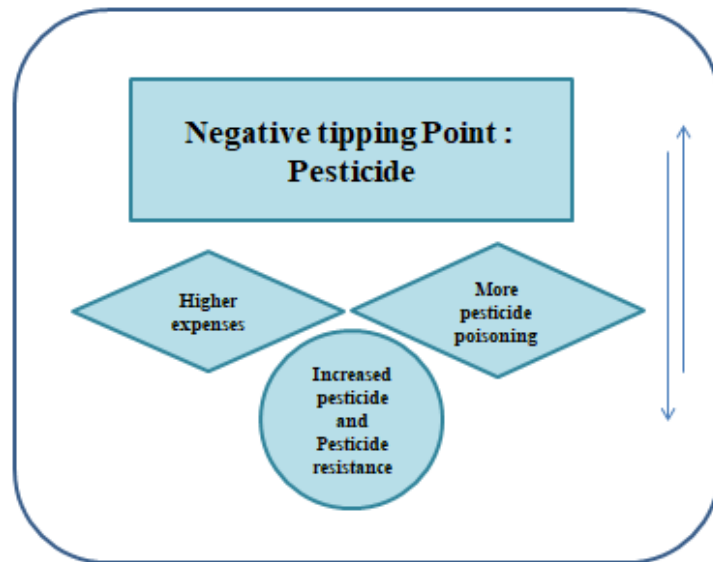


Fig. 1. Impact of pesticides

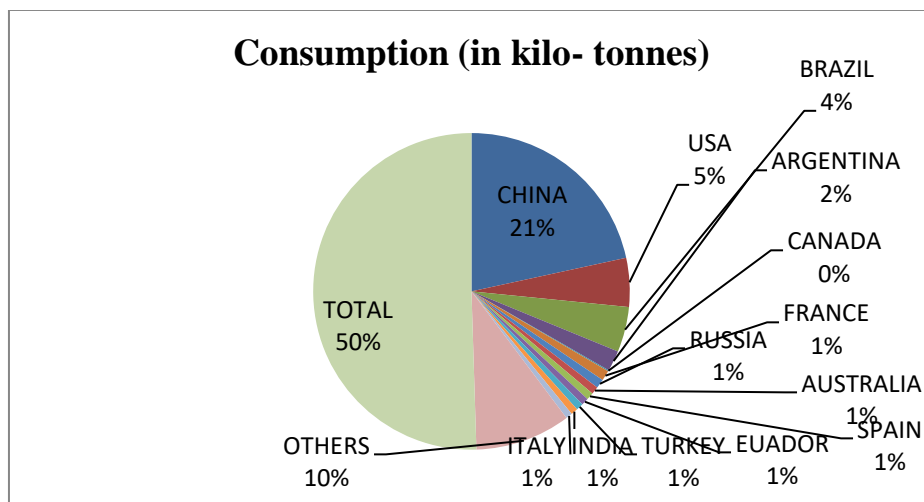


Fig. 2. Consumption pattern over the Globe (FAO, 2018)

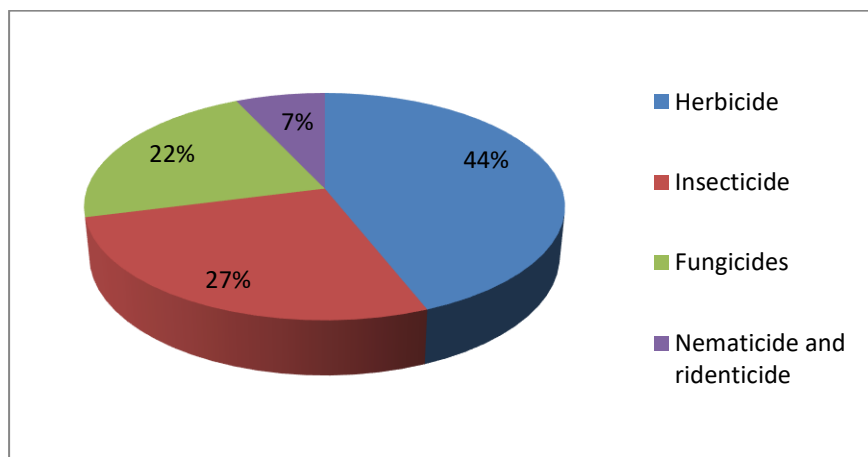


Fig. 3. Consumption pattern in India (FAO, 2018)

2. ROLE OF BIRDS AND AGRICULTURE

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. Fleming Sr. and Fleming Jr. made a substantial contribution to Nepalese ornithology. 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. In order to investigate feeding habit and its function in pest control, binoculars, cameras, and field manuals were utilized [2].

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 (*Dendrocitta vagabunda*), Crow pheasant (*Centropus sinensis*), Small green bee eater (*Merops orientalis*), Blue-tailed bee eater (*Merops philippinus*), Common myna (*Acridotheris tristis*), Bank myna (*Acridotheris ginginianus*), House crow (*Corvus splendens*), and Red-vented bulbul (*Pycnonotus cafer*). The Black Drone (*Dicrurus adsimilis*), the Jungle Babbler (*Turdoides striatus*), and the Magpie Robin (*Copsychus saularis*) were the main controllers of numerous kinds of moths and butterflies. The Indian treepie (*Dendrocitta vagabunda*) consumed weevils. Aphid management by the large-pied wagtail (*Motacilla maderaspatensis*) 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 [3].

Caterpillars, large insects, lizards, small mice, and bird eggs and nestlings are among the foods

that the Crow pheasant consumes. 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 [4]. 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 [5]. 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 [6]. 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 [7].

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 [8].

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. 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 [9].

Increases in agricultural intensity have been connected to sharp drops in farmland bird populations in Europe, North America, Africa, and Asia [10]. Birds are frequently employed as indicators of agricultural environments. Ten specialist species were identified by [11] 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 [12].

3. MODE OF POISONING

3.1 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 [13].

3.2 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 cholinesterase inhibition [13].

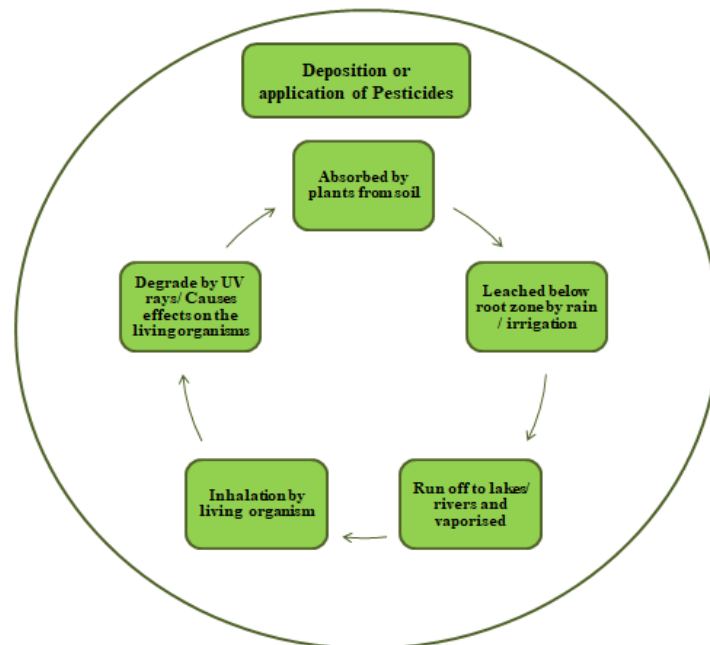


Fig. 4. Pesticide cycle

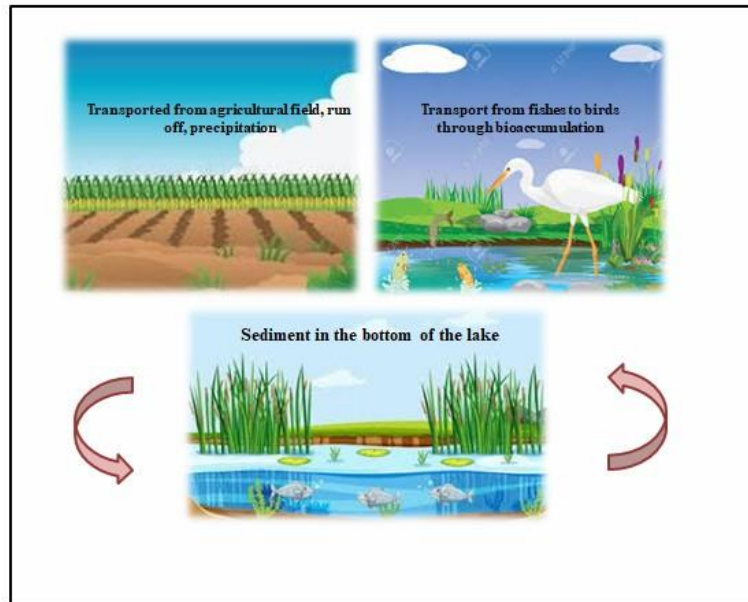


Fig. 5. Organochlorines in the food chain

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 is 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.

3.3 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 [14]. 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 [14].

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 [14].

3.4 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 mortality as a result of exposure to treated seed was probably between 0 and 5 percent [15].

4. 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 sprays can both cause inhalation. Bathing in pesticide-contaminated water can cause skin absorption, as can stand in treated soil or vegetation and absorbing via the feet. Numerous bird species consume enough seeds to be potentially dangerous [16].

Because of the natural food limitations in the autumn and winter, own seeds play a major role in the diets of many rural birds. Birds may consume these seeds and experience hazardous effects because they are frequently treated with insecticides. Information about wild bird exposure risk and the variables influencing it should be integrated with data on treated seed toxicity for the purpose of risk assessment. We examined the contents of the birds' stomachs to determine how red-legged partridges in a central Spanish agricultural area were exposed to seeds treated with pesticides. We quantified the partridges' diet's contribution from sowed seeds and examined its relationship to pesticide exposure. Additionally, we assessed how the composition of the landscape affected partridges' consumption of pesticides and sowed seeds. Partridges ingested half (50.7%) of the fresh biomass during peak sowing period, with winter grain seeds accounting for 42.3% of the biomass devoured. Thirty-three percent of the birds had residues from one pesticide and seven fungicides (active substances). Consumption of cereal-sown seeds has been associated with the presence of pesticides in the digestive tract [17].

4.1 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 [18].

The ecology greatly depends on wild birds. Pollution of the environment can be detected by a decline in the bird population. When pesticides like DDT are used repeatedly in the soil,

earthworms absorb them and then birds eat them. This can lead to a significant decline in the number of birds in the area. Birds like the bald eagle and sparrow drastically decline when organochlorine insecticides are used over extended periods of time. A deposit of contaminants in the body revealed the amount of organochlorines in seabird eggs, making them a good indicator of environmental contamination [19].

5. 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. [20].
- The highest concentrations of PCBs, HCHs, and DDTs were found in the yolk of house crows followed by blue rock pigeons, turkey, sparrows, red jungle fowl, spotted doves, collard doves, and white wag-tails. In the yolk of a house crow, PCB and HCH concentrations were 1700 and 67,000 ng/g fat weight, respectively. The greatest DDT amounts were recorded by Sparrow (mean: 7900 ng/g fat weight, range: 6900-8700). The findings show that the accumulation of OCs in eggs was lower in granivorous or passerine birds than in omnivorous species such as house crows and sparrows. Even the OC concentrations in omnivorous birds' eggs were lower than those found in fish-eating or raptorial birds' eggs. The detrimental effects on reproductive function are the most well-documented among toxicity-related research works because of past records of eggshell thickness-induced reproductive failure susceptibility [21].
- In England showed delayed chick development and impaired blood cholinesterase activity in tree sparrows in intensively sprayed (organophosphates) area. 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. There could be comparable issues with other organophosphates [22].

- Muscle samples from 25 dead prey birds from the families Strigidae, Falconidae, and Accipitridae were used to test highly effective chromatographic techniques with tandem mass spectrometry for the detection and quantitation of 108 pesticides and metabolites, some of which are thought to be persistent organic pollutants. High quantities of pesticides that are forbidden for usage were found in the muscle samples that were examined [23].

Organochlorine compounds used as agrochemicals which get leached and enter in the water bodies and get 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 successive trophic level the concentration of the OC compounds increases and causes the toxicity [24].

Organochlorines: The cessation of DDT's registered usage did not eliminate the organochlorine threat to birds. While the use of some organochlorine pesticides, such as 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 methoxychlor (an further organochlorine insecticide that is still authorised for use in the United States) and dicofol [25].

Organophosphorus: 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 [26].

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 impulses transmission. This may cause mortality, generally from respiratory failure, and paralyse the neurological system [27].

Out of all the HCH isomers, 3-HCH was the most common isomer detected in birds and bats, indicating that it is more resistant to enzymatic degradation than the α - and γ -isomers. Notably, compared to other birds and bats, resident and migratory birds such as crimson-crested barbet, brain fever bird, koel, gull-billed tern, and whiskered tern exhibited comparatively larger proportions of α - and γ -isomers in flying fox, Indian pipistrelle bat, short-nosed fruit bat, and koel. This suggests that the birds and bats had recently been exposed to a technical HCH mixture that contained 70% α , 15% γ , 6% δ , and 9% 8-HCH, which is used in India [13].

Both carbamates and organophosphates are anti-cholinesterase substances. Acetylcholinesterase inhibition causes intoxication by building up acetylcholine at the synaptic junction, which then triggers the activation of cholinergic receptors, causing respiratory damage and finally leading to death. These pesticides can be inhaled by birds, come into contact with their skin, and are mostly ingested by them through infected seeds or insects [1]. Studies have shown that as agriculture has been more intensive and pesticide use has increased, the availability of invertebrates required to feed maize bunting chicks on farmlands has reduced [28].

Pesticide use over time disrupts the acetylcholinesterase enzyme, which causes alterations in bird posture. The other main impacts of these chemicals on birds are aberrant development, thinner eggshells, and changed tones in addition to these alterations in feeding behaviour. Most of

the time, the effects are not immediate; instead, the pesticides are absorbed by worms and fish, which then pass on to birds via the food chain. Pesticides throw local species into mass extinction, upsetting the delicate balance of the ecosystem. Since aves are one of the main things that increase soil fertility through their droppings, a significant decline in wetland bird populations also affects agricultural output. This analysis will contribute to raising awareness among the various [29].

Droppings from Eurasian skylarks (*Alauda arvensis*), a species that typically feeds on winter cereal crops, during their autumnal migration. The birds were housed in paper bags until their physical conditions were determined, each bird was marked, and then they were released. The excrement left in paper bags to check for the presence of eighty pesticides, including degradation products and rodenticides [30].

Anorexia, gastrointestinal distress, and even a breakdown in the bird's capacity to distinguish between tainted and uncontaminated food are among the effects on feeding behaviour. Exposure to pesticides causes people avoid food, increases male and female hostility. Decrease in birds singing and showy behaviour. The reduced ability to lay eggs as a result of aberrant incubation behaviour, which also lowers the success rate of hatching impacts on a woman's reproductive habits [31].

Thermoregulation: The pesticides induced reduction in body temperatures in birds are often associated with decrease in AchE activity of more than 50%. It leads to enhanced mortality in birds is reported at sub lethal doses at thermo-neutral temperatures. Interaction between low temperature and pesticides toxicity appears to be result of the impairment of thermoregulation causing inability of birds to withstand the cold [32].

Implications for physiology have an impact on thermoregulation. Make birds' body weight drastically decrease. OP causes transient hypothermia. It causes a drop in body temperature, making birds less able to tolerate the cold. Impact on the endocrine system and reproductive behaviour. Changes in gonadal development and reproductive behaviour. Delays in spermatogenic cell development and degeneration. Reduced number of degenerated germ cells in the seminiferous tubule is

directly correlated with reduced levels of cholinesterase activity in the brain and testis of male birds. Decreased functionality of the testicles. Changes in LH and testosterone output along with a reduction in progesterone levels. Impact on the hormone feedback system [33].

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 [34].

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 dicofol was associated with this kind of weight loss. Pesticide-induced lesions in the lateral hypothalamus result in food avoidance and a marked decrease in body weight in birds [35].

Chronic effects: The chicks were deformed, with deformed skeletons 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. Because they consume large amounts of seed, birds are at a significant danger. Due to their weight loss, small birds. 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 [36].

Effect on haematological and immune system: After birds were exposed to lindane, anaemia and a drop in haemoglobin concentration were observed a correlation between high prenatal pesticide exposure and

the suppression of T-cell mediated immunity in wild Caspian terns and herring gulls [37].

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 [38].

The biomagnifications and the bioaccumulation was mentioned in the above figure as the water has 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. The migratory birds that exhibited higher BMFs for PCBs were the common red shank, gull-billed tern, long-billed Mongolian plover, pintail snipe, sandwich tern, white-cheeked tern, common sandpiper, and white-winged tern. The fact that most tern species biomagnified PCBs at higher levels than

DDT and HCHs is concerning. This is consistent with a few studies that found higher PCB accumulation [39].

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 [40].

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. 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 [41].

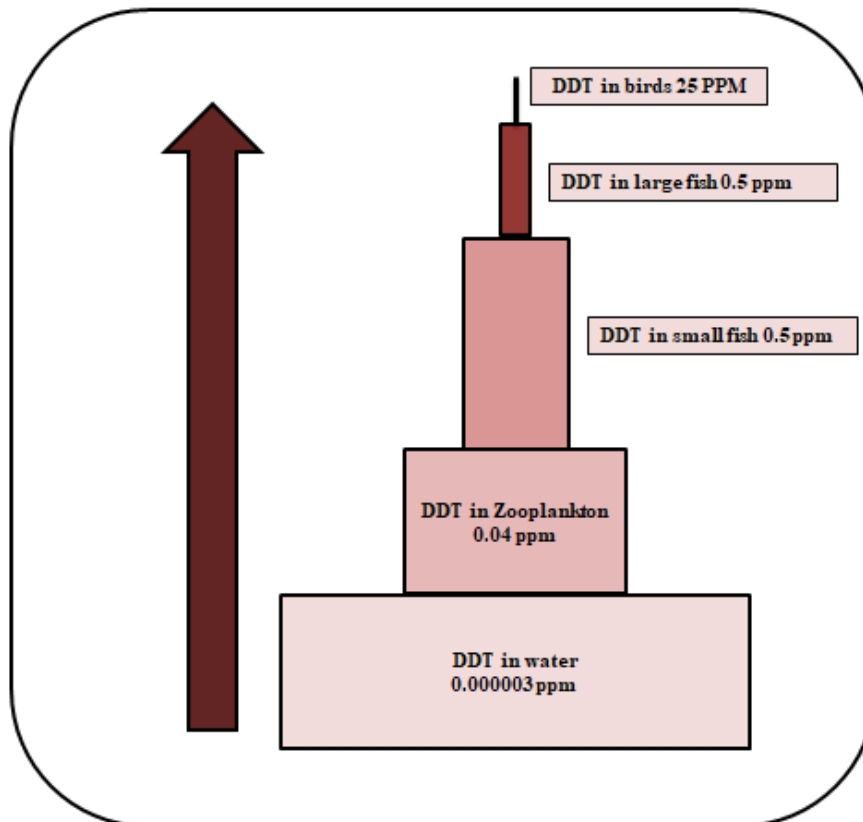


Fig. 6. Biomagnification of DDT concentration



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

Migratory birds: 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. There have been reports of OC pesticide concentrations in whole-body homogenates of birds [42], 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 [43].

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

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 [44]

5. 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 generative AI technologies such as Large Language Models, etc have been used during writing or editing of this manuscript. This explanation will include the name, version, model, and source of the generative AI technology and as well as all input prompts provided to the generative AI technology.

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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