



Pesticide Poisoning in Indian Peafowl *Pavo cristatus* from Tamil Nadu: A Continuing Threat to India's National Bird

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Abstract

Pesticide poisoning poses a continuing threat to wildlife, particularly avian species such as the Indian Peafowl *Pavo cristatus*, which holds ecological and cultural significance in India. Despite increasing reports of mass mortalities of the National bird across the country, confirmed and reported, cases of pesticide poisoning remain limited. In this study, eight mass mortality incidents involving death of 121 Indian Peafowls were investigated in Tamil Nadu between 2019 and 2021. Five separate tissue samples from each of 41 individuals were analysed for the presence of 45 pesticides using Liquid Chromatography–Tandem Mass Spectrometry (LC–MS/MS). In all cases, monocrotophos a highly toxic organophosphate pesticide was consistently detected in both tissue and bait samples at concentrations far exceeding known avian toxicity thresholds, indicating it as the cause of mortality. Concentration pattern was in the order; crop content (339.0 mg/Kg) > gut content (83.5 mg/Kg) > liver (1.59 mg/Kg) > kidney (1.00 mg/Kg) > muscle (0.45 mg/Kg). High concentration of monocrotophos were highest in crop and gut contents, suggesting oral ingestion through baited food grains recently. Additionally, flubendiamide, profenophos and carbendazim were also detected in one incident each, representing the first report of these pesticide residues in wild birds globally. These findings provide definitive toxicological evidence of pesticide-induced mortality in Indian Peafowls, reinforcing earlier suspicions from news and field reports. The study highlights the widespread possible misuse of the regulated pesticide and the urgent need for coordinated monitoring, stricter regulation, and community-level awareness to mitigate poisoning risks to non-target wildlife species in the country.

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Introduction

The Indian Peafowl *Pavo cristatus* (Henceforth, Peafowl), a species within the order Galliformes, is renowned for its vibrant plumage and cultural significance rooted in mythology. It was designated as the national bird of India in 1963 (Kushwaha and Kumar 2018), and its population is currently considered stable across its distribution range (Bird-Life International 2016). The peafowl is an omnivorous bird, and the largest among the pheasants. It is a common inhabitant of agricultural fields that exhibits a semi-feral state in areas of human habitation (Ramesh and McGowan 2009; Johnsgard 1986). However, its widespread presence has not always been celebrated, as its feeding behaviour has led to its classification as an avian pest in agricultural landscapes across the country. Studies suggest that peafowls frequently raid edible crops, resulting in significant economic losses; yet, the large-scale loss due to crop depredation by peafowl has not been quantified in India (Govind and Jayson 2018; Samson et al. 2025).

Considering their close association with agricultural landscapes, peafowls are particularly vulnerable to the harmful effects of pesticides commonly applied to crops (Nambirajan et al. 2018; Samson et al. 2025). Globally, the intensified use of synthetic insecticides has been identified as a significant threat to farmland-associated avian species. Galliform birds, including larger pheasants such as the Indian Peafowl, are susceptible to unintentional exposure to toxic agrochemicals through contaminated food sources in their environment (Crespo et al. 2018) as well as intentional poisoning. In addition to acute poisoning, studies demonstrated that pesticide exposure led to reduced embryo weight and increased embryo mortality in pheasants under experimental conditions (Fejes et al. 2003). Studies have also shown that differences in residual feed intake can influence growth performance, rumen microbial composition, and the metabolic status of animals, with low residual feed intake being associated with more active energy metabolism pathways and higher feed efficiency (Zhang et al. 2024). Similarly, pesticide exposure may affect the gut microbiome and overall health of farmland birds. Although numerous studies have reported pesticide residues and exposure in farmland birds from Western countries, such reports are scarce from India, despite its rich avian biodiversity and extensive agricultural landscapes.

In India, the Indian Peafowl faces numerous threats to its survival, including habitat conversion and illegal hunting for feathers, eggs, and wild meat (Chakkaravarthy 2002; Del Hoyo et al. 1994). Among these, chemical poisoning represents a particularly silent yet serious danger, as noted by several studies (Nambirajan et al. 2018; Borad and Parashar 2018; Govind and Jayson 2018; Kushwaha and Kumar

2018; Ramesh and McGowan 2009). Despite this, only a few investigations have confirmed pesticide poisoning in Indian Peafowls through pesticide residue analysis (Aulakh et al. 2005; Narang et al. 2006, 2016). However, there was no systematic scientific study on the mortality of Indian Peafowl including poisoning incidents in the country despite being the national bird of India. In our earlier research, we assessed organochlorine pesticide exposure and compiled reports of poisoning incidents involving Indian Peafowl across India; however, we were unable to confirm any specific cases of pesticide-induced mortality (Nambirajan et al. 2018). Therefore, building upon our previous work, the present study was undertaken to systematically document and confirm pesticide poisoning in Indian Peafowl, in response to reports of mass mortality incidents published in the media.

Since peafowl mortalities are reported more frequently in Tamil Nadu than in other states of India, and because obtaining permission to collect samples from the national bird is highly regulated, samples for the present study were received through the Tamil Nadu Forest Department. Furthermore, given the logistical challenges of conducting a nationwide study across India's vast landscape, Tamil Nadu was selected as a representative region to highlight the severity of the issue. The findings are expected to draw nationwide attention to retaliatory poisoning of Indian peafowls and contribute to broader conservation efforts.

Materials and Methods

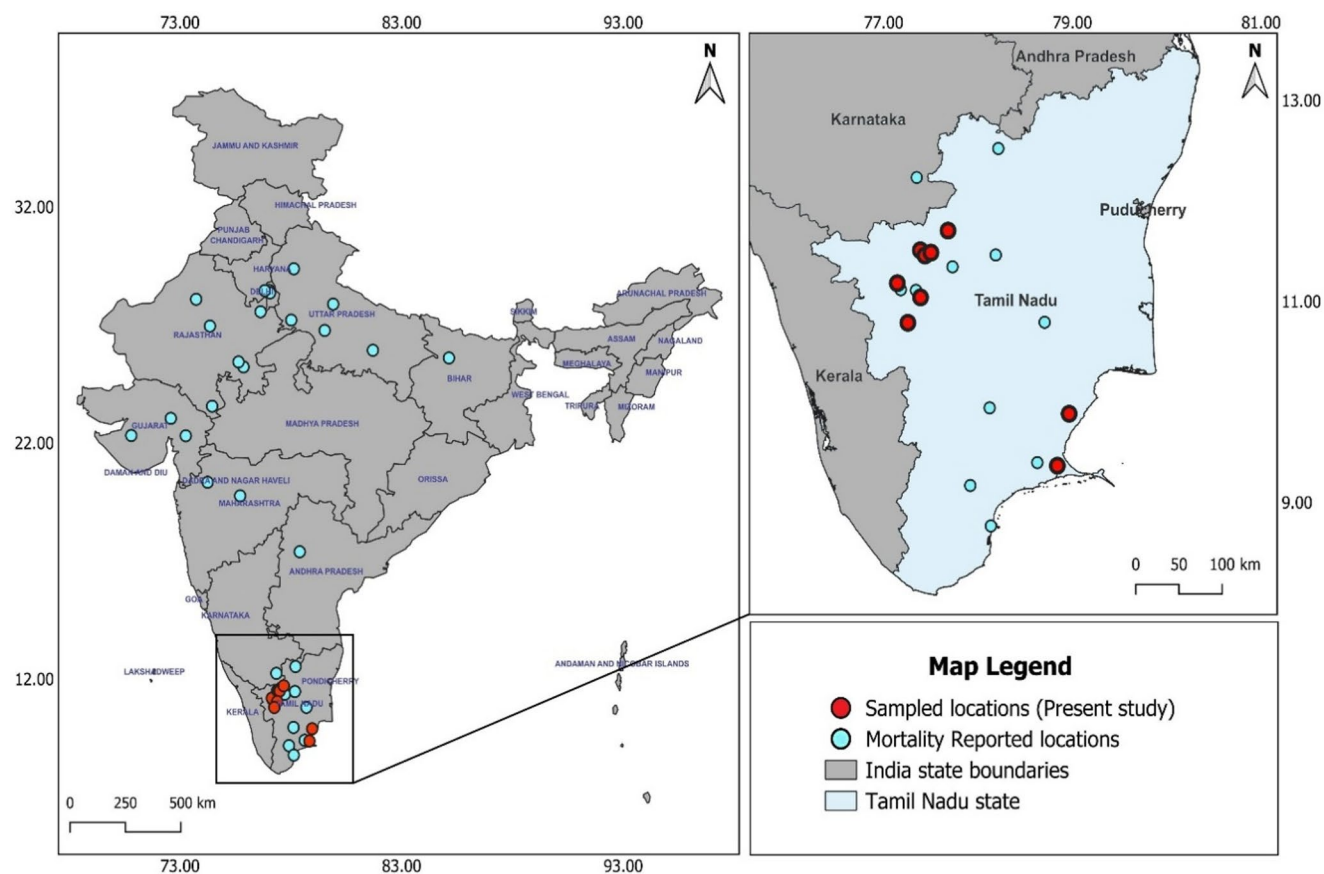
Sample Collection

A total of eight mass mortality incidents resulting in the deaths of 121 Indian Peafowls *Pavo cristatus* were investigated between 2019 and 2021 across Tamil Nadu, India (Table 1; Fig. 1). The carcasses were located and collected by officials of the Tamil Nadu Forest Department during field inspections or upon receiving public reports of mortality events. Post-mortem examinations were carried out either at the site or laboratory within 24 h of the discovery of the carcasses. Tissue samples, including kidney, liver, muscle, crop, and gut contents, were collected from the deceased birds for investigation. In incidents where poisoning was suspected, bait materials such as rice, maize and soil with grains, believed to have been intentionally placed to attract peafowls, were also collected to assess the likelihood of deliberate poisoning. All biological and bait samples were immediately deep-frozen and transported under cold chain conditions to the National Centre for Avian Ecotoxicology (NCAE), Sálim Ali Centre for Ornithology and Natural History (WII-SACON), Coimbatore, for toxicological

Table 1 Details of dead Indian peafowls collected and analysed for pesticides from Tamil Nadu between 2018 and 2021

S. No	Date of collection	Location of the incident	Reported deaths	Sex (nM & nF)	Individuals (bait sample) analysed	Pesticide detected (n)
1	July 2019	Karumathampatti, Coimbatore	5	(5F)	2	Monocrotophos (2)
2	Dec 2019	Ramanathapuram	30	—	5	Monocrotophos (5)
3	Feb 2020	TN Palayam range, Erode	3	(1 M & 2F)	3	Monocrotophos (3)
4	Feb 2020	TN Palayam range, Erode	14	(7 M & 7F)	7	Monocrotophos (7)
5	Mar 2020	Erode	6	(1 M & 5F)	6	Monocrotophos (6)
6	July 2021	Palladam, Tirupur	35	(10 M & 25F)	6 & (maize)	Monocrotophos (6)*
7	July 2021	Palladam, Tirupur	19	(7 M & 12F)	3 & (rice)	Monocrotophos (3)*
8	Dec 2021	Erode	9	(9F)	4 & (food grain)	Monocrotophos & Flubendiamide (4)*

(nM & nF) – Number of male & number of female; *Pooled samples

**Fig. 1** Map of India showing the locations of suspected peafowl poisoning (2018–2021) and peafowls collected dead for the toxicological investigation

examination, as chemical poisoning was suspected to be the primary cause of mortality.

Sample Processing and Analysis

Pesticide Analysed: In total, 45 pesticides (Table S1) currently in use were analysed from the collected samples. Monocrotophos, carbendazim, thiamethoxam, methomyl, imidacloprid, tricyclazole, acetamiprid, dimethoate,

thiacloprid, phosphamidon, metribuzin, propoxur, carbofuran, carbaryl (nac), atrazine, metalaxyl, carboxin, sulfosulfuron, propanil, fenobucarb, hexaconazole, alachlor, malathion, triazophos, quinalphos, fenthion, phenthoate, phorate, phosalone, pirimiphos-methyl, pretilachlor, indoxacarb, profenophos, benfuracarb, butachlor, pyriproxifen, temephos, pendimethalin, chlorpyrifos, ethion, propargite, carbosulfan, 2,4-D (2,4-PA), flubendiamide and fipronil. The types and chemical classes of the detected pesticides

are provided in the Supplementary Information and were referenced from the Pesticide Properties DataBase (PPDB 2020).

Chemicals and Reagents: Pesticide standards (certified reference materials) with purity higher than 97% were obtained from Sigma-Aldrich, GmbH, and Agilent Technologies, USA. Chromatography-grade acetonitrile and sodium chloride were purchased from Merck, India. Anhydrous magnesium sulphate was purchased from Himedia. Sample pre-treatment bulk sorbents, such as Primary Secondary Amine (PSA), C18 bulk sorbent, and Graphitized Carbon Block (GCB), were purchased from Agilent Technologies, USA. Ultrapure water was produced from a Elga water purifier in the laboratory.

Pesticide Extraction: Pesticide residues from tissue and bait samples were extracted using a multi-residue extraction method adapted by Nambirajan et al. (2018). The process began with the precise weighing of one gram of homogenized tissue, which was subsequently placed into a 50 mL centrifuge tube. To this sample, 10 mL of water was added. The mixture was thoroughly shaken to ensure homogeneity and then allowed to sit undisturbed for 30 min to facilitate the partitioning of pesticide residues. Following the incubation period, 10 mL of acetonitrile was introduced into the tube. The mixture was subjected to vigorous shaking for one minute to enhance the extraction efficiency of the analytes. Subsequently, four grams of anhydrous magnesium sulphate (MgSO_4) and one gram of sodium chloride were added to assist with the separation of the organic phase from the aqueous layer. The tube was shaken vigorously for an additional minute to ensure proper mixing, and then centrifuged at 2,000 g for ten minutes to achieve phase separation. After centrifugation, the organic layer (2 mL) was transferred into a separate 15 mL centrifuge tube that had been pre-added with 50 mg of Primary Secondary Amine (PSA), 50 mg of C18 bulk sorbent, and 250 mg of MgSO_4 . The contents of this tube were shaken well to facilitate further purification. The mixture was then subjected to centrifugation at 1,000 g for five minutes to obtain a clear supernatant. Finally, 1 mL of this supernatant was transferred into vials, preparing it for subsequent instrumental analysis to quantify the pesticide residues present in the tissue samples.

Instrument analysis (LC–MS): Instrumental method followed by Nambirajan et al. (2021) was followed to analyse the pesticides. Residues of pesticides were quantified using Shimadzu LCMS-8045 Liquid chromatography—Mass Spectrometer available at NCAE, Division of Ecotoxicology, WII-SACON. Instrument conditions were as follows: Shim-pack GISS C18 (3 μm , 2.1×150 mm) column (Shimadzu, Japan) was used for separation. Sample volume: 5 μL ; Mobile phase: a binary gradient elution profile, which consisted 0.1% acetic acid in water (solution A) and 100%

acetonitrile (solution B), as follows; starting conditions 65% A/35% B for 1.0 min, a 5-min linear gradient from 65% A/35% B to 10% A/90% B, followed by a 6-min column-wash step in 10% A/90% B, and a 6-min re-equilibration step with 10% A/90% B before the next injection. The flow rate was 0.3 mL/min, and the column temperature was 40 °C.

Electrospray Ionization (ESI) mode, a soft ionization technique, was used to ionize the pesticide molecules in mass spectroscopy. The interface, heating block, and dissolution line temperatures were 300 °C, 400 °C, and 250 °C, respectively. The pesticides were analysed in both positive and negative ionization modes using polarity switching within a single analytical run. Quantification was performed in multiple reaction monitoring (MRM) mode to achieve maximum sensitivity for target compound detection. Details of MRM transitions, ionization polarity, and collision energy are provided in Supplementary Table S2. A matrix-matched calibration curve was constructed for each compound at seven calibration levels using 1, 2.5, 5, 10, 25, 50, and 100 ng/mL of mixed pesticide standards. Tissue of an Indian Peafowl which died due to kite string injury without any of the target compounds was used for matrix match standard preparation and recovery study. The Peafowl tissue was confirmed for absence of all the target pesticides before use.

QA/QC: Analyses were done in batches of 10 samples plus three quality controls, namely solvent blank, matrix blank and mid-range standard. To verify the integrity of the analytical results, two distinct MRM transitions were closely monitored. Additionally, the ratio of their abundances (MRM2/MRM1) was maintained within a defined range, complemented by the alignment of retention times to ensure accuracy further. For each compound under investigation, a calibration curve was meticulously developed across seven different concentration levels (1 to 100 ng/mL). The acceptance criterion for linearity, established at $R^2 \geq 0.98$, was successfully achieved for all analytes included in the methodology, indicating a strong correlation between concentration and response. The lowest calibration level showing acceptable peak response and shape was considered as the limit of quantification (LOQ), corresponding to 10 ng/g for most pesticides and 25 ng/g for a few compounds in tissue samples. Limit of quantification (LOQ) and recovery (25 ng/g, $n=6$) of monocrotophos was 10 ng/g and 82.0% respectively. LOQ and recoveries from fortified samples of all other compounds are presented in supplementary table S2. Results were not corrected for per cent recovery. The resulting data were expressed in nanograms per gram (ng/g) based on wet weight, providing a clear representation of the compound concentrations.

Results and Discussion

Pesticide poisoning in Indian Peafowl appears to be widespread across India (Fig. 1). However, confirmed reports of avian pesticide poisoning remain limited, especially in developing countries like India, where constraints such as inadequate analytical infrastructure, high testing costs, and delayed response times hinder proper investigation (Vyas 1999; Ogada 2014; Nambirajan et al. 2018). Consequently, only a small fraction of suspected poisoning cases is conclusively confirmed. Eight mortality incidents, involved death of 121 peafowls across Tamil Nadu, India between 2019 and 2021 were investigated in the study (Table 1). Tissue

samples from 41 deceased peafowls and poisoned bait samples collected from these incidents were analysed for pesticides to identify potential sources of poisoning.

Monocrotophos was detected in all tissue and bait samples analysed (Table 2). Additionally, flubendiamide (12 – 3027 ng/g) was found in all six peafowl samples from an incident from Erode (Case No. 6). In another incident (Case No. 8), profenophos was detected in rice baits (228.6 and 272.8 ng/g) as well as in gut and gizzard contents (ranging from 19.7 to 1272.7 ng/g) of two peafowls. Carbendazim was also found in the gut and gizzard contents (80–538 ng/g) of the same individuals. Although the concentration of residues varied among individuals and tissue

Table 2 Concentration of monocrotophos (ng/g wet weight basis) recorded in the tissues of peafowls investigated in the study

Case No	Location of the incident	Peafowl Id	Concentration of monocrotophos in ng/g					Bait
			Gut content	Gizzard content	Liver	Kidney	Muscle	
1	Coimbatore	1	620.2	NA	28.2	10.7	BQL	
		2	16,094.4	NA	50.4	20.3	BQL	
2	Ramanathapuram	3	NA	NA	115.0	256.9	NA	
		4	NA	NA	73.4	341.0	NA	
		5	NA	NA	93.7	514.4	NA	
		6	NA	NA	384.4	983.3	NA	
		7	NA	NA	561.7	380.4	NA	
3	TN Palayam range, STR	8	14,636.8	4755.0	739.9	1171.9	NA	
		9	21,840.9	9556.5	2344.5	3240.9	NA	
		10	1925.5	5024.3	824.2	473.4	NA	
4	TN Palayam range, STR	11	7409.2	27,091.7	1258.6	718.0	254.2	
		12	5375.5	21,621.0	736.0	458.5	1186.8	
		13	3800.6	3139.6	203.3	171.6	10.1	
		14	7294.7	26,643.9	260.2	208.4	29.4	
		15	14,920.8	20,716.8	1881.1	NA	NA	
		16	13,514.9	15,996.1	NA	NA	135.2	
		17	2717.1	NA	1634.2	NA	169.2	
		Soil (poisoned baits)						197.5
5	Erode	18	25.8	510.5	16.4	NA	NA	
		19	103.3	3104.4	NA	NA	NA	
		20	176.8	160.3	14.5	NA	NA	
		21	31.4	933.9	13.2	NA	NA	
		22	29.2	24.2	1751.9	NA	NA	
		23	10.8	752.9	NA	NA	NA	
6	Tirupur	24–26*	NA	64,511.0	17,604.0	NA	NA	
		27–29*	790,196.0	6,319,983.0	410.0	2054.0	NA	
		Maize 1 (poisoned baits)						2,858,229.0
		Maize 2 (poisoned baits)						19,568,403.0
7	Tirupur	30–32*	711,114.0	NA	581.0	NA	NA	
		Rice (poisoned baits)						30,560,139.0
8	Erode, STR	33–34*	37,244.4	245,261.7	NA	995.8	NA	
		35	275,103.0	5884.0	NA	NA	186.8	
		36–38*	12,690.1	89,850.7	2294.3	376.4	956.0	
		39–41*	66,953.8	253,332.1	5960.7	4134.1	2171.6	
		Rice 1 (poisoned baits)						1,904,625.0
		Rice 2 (poisoned baits)						2,326,394.0

NA: tissues not available for analysis. * Pooled samples (3 peafowls)

BQL: below quantification limit (10 ng/g)

types, it is noteworthy that monocrotophos was consistently present in all cases with high concentration, strongly suggesting its central role in the mortality events. However, the potential synergistic effects of other detected pesticides cannot be completely ruled out in contributing to the deaths of the birds.

Monocrotophos was detected in poisoned bait samples, including rice, maize, and soil, collected from all the investigated incidents. The concentration ranged from 1,904 mg/kg to 30,560 mg/kg in food grains, with a significantly lower level (0.2 mg/kg) found in a soil sample without visible grains. The mean concentration of monocrotophos in biological samples followed the pattern: Crop contents (339.0 mg/kg) > Gut contents (83.5 mg/kg) > Liver (1.59 mg/kg) > Kidney (1.00 mg/kg) > Muscle (0.45 mg/kg). This distribution among the organs of the peafowls is consistent with previous findings on organochlorine pesticide accumulation in Indian Peafowl (Nambirajan et al. 2018) and White-rumped Vultures (Nambirajan et al. 2024). Similar to this finding, in many avian mortality incidents, the most "stable" residues are found in the crop or gizzard contents rather than the tissues, as the pesticide may not have been fully absorbed before death or not bioaccumulated (Goldstein et al. 1999; Pain et al. 2004; Narang et al. 2016).

The levels of monocrotophos recorded in this study are higher than previously reported incidents in India. For instance, Narang et al. (2016) documented monocrotophos at 9.22 mg/kg and chlorpyrifos at 0.127 mg/kg in the gizzard contents of dead peafowls from Haryana. Similarly, Pain et al. (2004) reported monocrotophos levels ranging from 0.2 to 0.74 mg/kg in the alimentary tracts of Sarus Cranes *Grus antigone* that died due to monocrotophos poisoning in India. The landmark study by Goldstein et al. (1999) investigated a catastrophic mass mortality event in Argentina where between 5,000 and 20,000 Swainson's hawks *Buteo swainsoni* died following exposure to monocrotophos. Forensic analysis of the carcasses revealed that while the pesticide was rapidly metabolized, detectable residues remained in the gastrointestinal tract, with mean concentrations of 0.20 ppm in the ingesta of the 45 hawks tested. These findings established that even low parts-per-million residues in the crop or gizzard are indicative of lethal acute poisoning in raptors, as the extreme toxicity of the compound often causes death before systemic absorption is complete. Consequently, the monocrotophos levels recorded in our current study are higher than those reported in this Swainson's hawks case in Argentina.

Monocrotophos is a systemic and contact organophosphate insecticide and is considered among the most toxic pesticides to avian species (Hudson et al. 1984; Goldstein et al. 1999). Its acute oral LD₅₀ for birds typically ranges from 0.9 to 6.7 mg/kg, placing it in WHO Toxicity Class

I, extremely hazardous (Hudson et al. 1984; WHO 1993; Singh et al. 2021). The concentrations of monocrotophos residues recorded in the incidents investigated in the present study were higher than those reported in previous poisoning cases involving Indian peafowls and Sarus Cranes in India, as well as hawks in Argentina. Similarly, the levels detected in the crop and gut contents of peafowls in the present study exceeded the reported LD₅₀ values for birds. Therefore, it can be concluded that the peafowls examined in this study died as a result of monocrotophos poisoning.

The LD₅₀ value of monocrotophos for the highly sensitive Golden Eagle *Aquila chrysaetos* is 0.188 mg/kg. The extreme sensitivity of this species is a major reason why monocrotophos has been banned or severely restricted in many countries, particularly following mass mortality events involving raptors and migratory birds, such as the Swainson's Hawk incidents in Argentina (Hudson et al. 1984; Goldstein et al. 1999). Despite its recognized dangers, monocrotophos continues to be used in many developing countries, including India. Although it has been banned in the United States, United Kingdom, and the European Union, India still reports significant usage. The average annual consumption of monocrotophos in India between 2016–17 and 2020–21 was 364 metric tonnes (DPPQS 2024). While its application on vegetables is officially banned, enforcement remains inconsistent. Monocrotophos became infamous after a tragic 2013 incident in Bihar, India, where 23 school-children died after consuming a mid-day meal contaminated with the pesticide (New York Times 2013). Additionally, it continues to be a common agent in pesticide-related suicides in India (WHO 2009), further emphasizing the urgency for stricter regulations and public awareness.

Three other pesticides, profenophos, flubendiamide and carbendazim were detected, but were probably not primarily responsible for the deaths. profenophos, an organophosphate insecticide, is classified as moderately hazardous (WHO Class II) according to the World Health Organization (WHO 2009). In the present study, profenophos was detected in rice baits (228.6 and 272.8 ng/g) as well as in gut and crop contents (ranging from 19.7 to 1272.7 ng/g) of two peafowls among the four from an incident (case No: 6). The recorded levels were comparatively lower than the reported LD₅₀ values to birds 5.5–10 mg/kg (Hill and Camardese 1986; Mineau et al. 2001). Hence, profenophos may not kill the peafowls. Flubendiamide, a modern insecticide belonging to the diamide class, exhibits low acute toxicity in birds. Studies have reported LD₅₀ values exceeding 2,000 mg/kg in Northern Bobwhite Quail and Mallard Ducks, with no adverse effects observed in dietary studies at concentrations up to 4,500 mg/kg feed (EPA 2010). As mentioned earlier, flubendiamide was found in all six peafowl samples from an incident in Erode district (Case No. 6). However, the

Table 3 Details of suspected poisoning incidents of Peafowls reported between 2017 and 2021

S. No	Location	State	Casualty (approximate)	Incident dated	Source, reported date
1	Juna Ghayila village, Rajkot	Gujarat	10	04-02-2018	The times of India, 05/02/2018
2	Gurugram district,	Haryana	5	09-05-2018	The times of India, 10/05/2018
3	Bhondsi, Gurugram district	Haryana	1	20-05-2018	The times of India, 21/05/2018
4	Banswara, Jaipur	Rajasthan	23	21-05-2018	The times of India, 22/5/2018
5	Madurai	Tamil Nadu	47	04-08-2018	The times of India, 05/08/2018
6	Ahmedabad	Gujarat	15	14-01-2018	The times of India, 06/08/2018
7	Golconda fort, Hyderabad	Telangana	11	28-08-2018	The times of India, 29/08/2018
8	Farrukhnagar, Gurugram District	Haryana	4	01-08-2018	The times of India, 31/08/2018
9	Erode District	Tamil Nadu	5	04-09-2019	The times of India, 05/09/2018
10	Kutch district, Rajkot	Gujarat	30	05-10-2018	The times of India, 05/10/2018
11	Patna Zoo	Patna	6	21-12-2018	The times of India, 25/12/2018
12	Rasipuram, Nammakkal	Tamil Nadu	15	16-02-2019	The times of India, 18/02/2019
13	Chandwad taluk, Nashik district	Maharashtra	7	01-05-2019	The times of India, 11/05/2019
14	Karumathampatti, Coimbatore	Tamil Nadu	5	05-06-2019	Simplicity online, 06/06/2019
15	Bijnor district,	Uttar Pradesh	4	18-11-2019	The times of India, 19/11/2019
16	Alwar	Rajasthan	9	20-11-2019	India TV Online, 21/11/2019
17	Seruna village	Jaipur	23	24-12-2019	The times of India, 25/12/2019
18	Mudnal village	Ramanathapuram	12	31-12-2019	The Hindu, 31/12/2019
19	Kota	Rajasthan	7	08-02-2020	The times of India, 09/02/2020
20	Nagaur district, Mithdiya village	Rajasthan	29	17-02-2020	The times of India, 19/02/2020
21	Kovilpatti, Thoothukudi district	Tamil Nadu	28	16-09-2020	The news minute, 17/09/2020
22	Karjan taluka, Vadodara	Gujarat	3	10-01-2021	The Times of India, 11/01/2021
23	Loni Village	Maharashtra	5	22-01-2021	The Hindu, 28/01/2021
24	Pratapgarh district	Uttar Pradesh	16	02-06-2021	India TV Online, 03/06/2021
25	Auraiya	Uttar Pradesh	11	06-06-2021	The news Track, 07/06/2021
26	Tiruppur	Tamil Nadu	54	17-08-2021	The Hindu, 18/07/2021
27	Thoothukudi	Tamil Nadu	5	26-08-2021	India today, 26/08/2021
28	Lalau village, Agra	Uttar Pradesh	8	11-11-2021	The times of India, 11/11/2021
29	Bundi District	Rajasthan	13	14-01-2021	The News Track, 14/12/2021
30	Shahjahanpur District	Uttar Pradesh	3	18-12-2021	The Times of India, 20/12/2021
31	Trichy District	Tamil Nadu	6	25-08-2021	The times of India, 27/12/2021
32	Vadambacheri panchayat	Tamil Nadu	33	19-11-2023	The Hindu, October 20, 2023
33	Krishnagiri	Tamil Nadu	2	18-03-2025	The Hindu, 18/03/2025

recorded flubendiamide concentrations (0.02 to 3.03 mg/Kg) are well below the reported No Observed Adverse Effect Level.

Similarly, carbendazim, a systemic fungicide from the benzimidazole group, is widely applied to control fungal infections in fruits, vegetables, cereals, and other crops, and has low acute toxicity to birds (LD₅₀: 2000 mg/Kg; EPA 2005; Kumar et al. 2016). In the present study, carbendazim was detected in gut and gizzard contents (0.08–0.54 mg/kg) of two peafowls from a single mortality incident (Case No. 8), with concentrations well below the reported avian LD₅₀ values. It is noteworthy that both profenophos and carbendazim were detected in these birds, suggesting potential exposure to a combination of pesticides. There are no reported residue concentrations of these pesticides, profenophos, flubendiamide and carbendazim in birds' tissue elsewhere. This is the first study documenting these residues in wild birds' tissues. Hence, could not draw any comparison

with previous studies. Considering the detected levels of pesticides in this study, alongside their toxicity, monocrotophos is the most probable cause of death in the investigated peafowls. However, the possibility of synergistic effects among these pesticides cannot be completely ruled out.

In our previous study, we compiled and documented 35 incidents of Indian Peafowl mortality involving the deaths of approximately 550 individuals reported across India between January 2011 and March 2017 (Nambirajan et al. 2018). In continuation of that work, we collected additional reports from various online news sources covering the period from 2018 to 2021. A total of 33 incidents from 10 different Indian states were compiled (Table 3), accounting for the deaths of approximately 455 Indian Peafowls. Among these, Tamil Nadu recorded the highest number of incidents, with 10 separate reports of suspected poisoning. This trend aligns with our earlier findings, where 18 suspected poisoning incidents out of 35 were reported from

Tamil Nadu alone, indicating a persistent pattern of reported peafowl mortality due to toxic exposure in the state.

Tamil Nadu ranks eighth in pesticide usage in India (DPPQS 2024). Although the population status of the Indian peafowl appears to be relatively stable across mainland India, state-wise population estimates are not available. Consequently, comparative assessments among states relating peafowl population status to pesticide consumption could not be undertaken. The higher incidence of reported pesticide poisoning in Indian peafowls in Tamil Nadu, compared to other states, may be attributed to greater public awareness and more effective reporting mechanisms. The apparent disparity in reported mortality incidents may also result from limited documentation efforts and reduced reporting from remote or inaccessible regions in other states, in contrast to Tamil Nadu.

Poison-laced baits are often deployed to control or eliminate Indian Peafowls, but they also pose a significant risk to other granivorous bird species. When the concentration of toxic compounds is high enough to be lethal to large-bodied birds such as pheasants, it can also be fatal to smaller, non-target species that consume the bait. This indiscriminate method results in bycatch poisoning, where unintended avian species are affected alongside the intended target, thereby contributing to broader avian mortality and biodiversity loss. Despite these risks, no case studies to date have specifically investigated this aspect of human–peafowl conflict. In some cases, peafowl become a non-targeted victim when they eat bait kept for rodents and pigs.

In general, published or documented information of wildlife mortality incidents represent only a small fraction of actual occurrences (Vyas 1999; Ogada 2014; Nambirajan et al. 2018). In the landscapes studied, not only Indian peafowls but also other small and common bird species are likely to be exposed to these pesticides. However, due to their status as the national bird and their relatively large body size, peafowl mortalities are more readily detected, reported, and brought to public attention. In contrast, mortalities of other common bird species often go unnoticed and remain underreported. It is noteworthy that most of the cases investigated in the present study involved human–peafowl conflict, with intentional poisoning of peafowls carried out to prevent crop raiding. In all such cases, the Tamil Nadu State Forest Department initiated legal action against the individuals involved. Based on the cases received by our laboratory and a review of compiled newspaper reports, incidents of peafowl poisoning in the state have declined in recent years. This trend represents a positive outcome for the conservation of the species. Similar stringent enforcement measures should be extended to protect other wild bird species to ensure broader avian conservation.

Conclusion

Chemical poisoning has emerged as a covert yet significant threat to the survival of birds including Indian Peafowl in the country. This study provides conclusive toxicological evidence of pesticide poisoning as a major cause of Indian Peafowl mortalities in Tamil Nadu, India. The consistent detection of monocrotophos in all examined cases underscores its continued misuse despite being banned on certain crops and known for its extreme toxicity to birds. The additional detection of profenophos, flubendiamide, and carben-dazim indicates exposure to multiple pesticide classes, with the potential for cumulative or synergistic effects. To our knowledge, this study represents the first global report of these pesticides in wild birds. The findings align with earlier documented incidents and news reports, highlighting a recurring and under addressed threat to avian biodiversity in India. Given the ecological importance of birds including Indian Peafowl and its role as a bio-indicator, there is an urgent need for national-wide monitoring, enforcement of pesticide regulations, and promotion of safer pest management alternatives. Furthermore, raising public awareness and educating farming communities about the consequences of illegal or improper pesticide use are essential steps toward reducing non-target wildlife fatalities and conserving India's avian heritage.

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Data Availability The data generated during the current study are available from the corresponding author on request.

Declarations

Conflict of interest The authors declare that they have no conflict of interest.

Ethical Approval Not applicable.

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References

- Aulakh RS, Gill JPS, Bedi JS, Sharma JK, Joia BS (2005) Pesticide residues in human breast milk: Risk assessment for infants. *Environ Toxicol Pharmacol* 20(3):395–401
- BirdLife International (2016) *Pavo cristatus*. The IUCN Red List of Threatened Species 2016.
- Borad CK, Parashar BD (2018) Peafowl and humans: A study of conflicts in human–wildlife interaction. *Int J Ecol Environ Sci* 44(3):211–220
- Chakkaravarthy QA (2002) Peafowl: Ecological and cultural symbol of India. *Indian Birds* 1(4):83–85
- Crespo S, Fernandez C, Gosalvez J (2018) Impact of pesticides on bird diversity in agricultural landscapes. *Ecol Ind* 84:161–169
- Del Hoyo J, Elliott A, Sargatal J (1994) *Handbook of the birds of the world*, vol Vol. 2. Lynx Edicions
- DPPQS (2024) Pesticide consumption statistics in India. directorate of plant protection, quarantine and storage, ministry of agriculture and farmers welfare, government of India.
- EPA (2005) Carbendazim risk assessment. U.S. environmental protection agency
- EPA (2010). Flubendiamide factsheet. U.S. environmental protection agency
- Fejes S, Zsarnóczai S, Török A (2003) The effects of pesticides on embryo development of pheasants. *Pestic Biochem Physiol* 77(3):170–176
- Goldstein MI, Lacher TE, Woodbridge B, Bechard MJ, Canavelli SB, Zaccagnini ME, Cobb GP (1999) Monocrotophos-induced mass mortality of Swainson's Hawks in Argentina, 1995–96. *Ecotoxicology* 8(3):201–214
- Govind G, Jayson EA (2018) Crop depredation by peafowl in Kerala. *Indian J Ecol* 45(1):144–148
- Hill EF, Camardese MB (1986) Lethal dietary toxicity of environmental contaminants and pesticides to birds. *Arch Environ Contam Toxicol* 15(3):261–266
- Hudson RH, Tucker RK, Haegele MA (1984) *Handbook of Toxicity of Pesticides to Wildlife*. Fish and Wildlife Service, Resource Publication, U.S., p 153
- Johnsgard PA (1986) *The pheasants of the world: biology and natural history*. Oxford University Press
- Kumar A, Kumar R, Chauhan A (2016) Assessment of carbendazim toxicity in birds. *J Environ Biol* 37(3):377–382
- Kushwaha SPS, Kumar S (2018) National bird of India: a review of conservation issues. *Indian Forester* 144(2):107–114
- Mineau P, Baril A, Collins BT, Duffe J, Joerman G, Luttik R (2001) Pesticide acute toxicity reference values for birds. *Ecotoxicology* 10(1):1–10
- Nambirajan K, Muralidharan S, Ashimkumar AR, Jadhav S (2021) Nimesulide poisoning in white-rumped vulture *Gyps bengalensis* in Gujarat. *India Environ Sci Pollut Res* 28(41):57818–57824. <https://doi.org/10.1007/s11356-021-14702-y>
- Nambirajan K, Muralidharan S, Ashimkumar AR, Jadhav S (2024) Assessment of chlorinated pesticide exposure to white-rumped vulture *Gyps bengalensis* in India. *Environ Sci Pollut Res* 31(8), 12422–12430 <https://doi.org/10.1007/s11356-024-31997-9>
- Nambirajan K, Muralidharan S, Manonmani S, Kirubhanandhini V, Ganesan K (2018) Incidences of mortality of Indian Peafowl *Pavo cristatus* due to pesticide poisoning in India and accumulation pattern of chlorinated pesticides in tissues of the same species collected from Ahmedabad and Coimbatore. *Environ Sci Pollut Res* 25(16):15568–15576
- Narang D, Lather D, Kumar R (2016) Confirmation of pesticide poisoning in Indian peafowl. *Veterinary World* 9(4):392–395
- Narang D, Lather D, Kumar R, Singh P (2006) Pesticide poisoning in Indian peafowl in Haryana. *J Wildl Dis* 42(2):399–402
- Ogada DL (2014) The power of poison: Pesticide poisoning of Africa's wildlife. *Ann N Y Acad Sci* 1322(1):1–20
- Pain DJ, Gargi R, Cunningham AA, Jones A, Prakash V (2004) Mortality of globally threatened Sarus cranes *Grus antigone* from monocrotophos poisoning in India. *Sci Total Environ* 326(1–3):55–61
- PPDB (2020) Pesticide Properties Data Base. <https://sitem.herts.ac.uk/aeru/ppdb/en/atoz.htm>, Accessed on 12th March, 2020
- Ramesh K, McGowan PJK (2009) On the current status of Indian Peafowl *Pavo cristatus* in India. *J Bombay Nat Hist Soc* 106(1):57–63
- Samson A, Princy JL, Beulahbah J, Regupathikannan J, Edward PS, Bajpai H, Moinudheen N (2025) Ecology and conservation challenges of Indian Peafowl (*Pavo cristatus*) in Mudumalai tiger reserve, Tamil Nadu, Southern India. *Труды Мордовского государственного природного заповедника им. ПП Смидовича* 36:126–137
- Singh A, Sharma A, Mehra A (2021) Toxicity classification and regulation of pesticides in India. *Pestic Res J* 33(1):10–20
- Vyas NB (1999) Factors influencing pesticide-related bird mortality. *Environ Toxicol Chem* 18(4):715–721
- WHO (1993) *Classification of Pesticides by Hazard*. World Health Organization.
- WHO (2009) *Preventing Suicide: A Resource for General Physicians*. World Health Organization
- Zhang Y, Zhang X, Cao D, Yang J, Mao H, Sun L, Wang C (2024) Integrated multi-omics reveals the relationship between growth performance, rumen microbes and metabolic status of Hu sheep with different residual feed intakes. *Animal Nutrition* 18:284–295

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