International Journal of Ecotoxicology and Ecobiology
2024, Vol. 9, No. 2, pp. 88-93
https://doi.org/10.11648/j.ijee.20240902.12

Review Article

Agricultural Pesticide-Induced Physiological Stresses in Freshwater Fishes of Bangladesh

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Abstract

In Bangladesh, most croplands are situated in floodplains, enriched by numerous rivers and extensive freshwater wetlands. These areas also support productive open-water fisheries, crucial for supplying protein, generating income, creating jobs, and boosting the GDP. However, the widespread use of pesticides in these floodplains to protect crops and enhance food production leads to significant environmental issues. Agricultural pesticide residues enter water bodies through runoff, rainwater, drainage, seepage, and spray drift, contaminating natural water bodies and exerting continuous stress on aquatic life, including fish. Previous studies have detected pesticide residues in surface waters, sediments, and fish in Bangladesh, posing a major threat to wetland ecosystems. Research on freshwater fish species in Bangladesh has highlighted toxic effects on fish gonads, such as adhesion, inter-follicular space degeneration, ovigerous lamellae degeneration, necrosis, degenerated perinucleolar oocytes, cytoplasmic retraction in ovaries, and damage to sertoli cells. Additional observed effects include irregularly shaped seminiferous tubules, breakage of seminiferous tubules, and empty lumens in testes. Pesticides also inflict harm on other internal organs of fish, with gill effects like clubbing, reduction of gill filaments, telangiectasia of gill lamellae, hemorrhage, and damage to gill rakers. Kidney and liver damage include necrosis, cellular tissue degradation, acute cellular swelling, and irregular renal corpuscles, along with autolysis, vacuolation, and fatty changes in the liver. Developing embryos and larvae of freshwater fish are particularly vulnerable to the toxic effects of agro-pesticides. Studies reveal acute toxicity during early life stages, evidenced by deformities like edema, notochord deformity, caudal fin damage, yolk sac damage, posterior region damage, tissue fragmentation, black pigmentation on the yolk, body curvature, and lordosis in larvae. Exposed embryos exhibit deformities such as dark brown yolk sacs, notochord deformities, and broken eggshells. Mortality rates of fish embryos and larvae escalate with higher pesticide concentrations in water. Haemato-biochemical parameters serve as crucial indicators of pesticide exposure in fish studies, showing alterations in blood hemoglobin, glucose, RBC, WBC counts, and various erythrocytic abnormalities like twin cells, fusion, echinocyte formation, spindle-shaped, tear-drop, and elongated cells. Nuclear abnormalities include binucleated cells, nuclear buds, nuclear bridges, karyopyknosis, and notched nuclei. Research suggests that even at low concentrations, agro-pesticides disrupt physiological functions and life history traits of fish, adversely impacting the natural productivity and biodiversity of freshwater fish in Bangladesh.

Keywords

Agro-pesticide, Physiological Stress, Freshwater Fish, Deformity, Development

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Received: 23 May 2024; **Accepted:** 19 June 2024; **Published:** 29 July 2024

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1. Introduction

Bangladesh is a leading producer of inland fisheries globally, with a production of 1,646,819 tonnes during 2003–2004 [1]. During the same period, marine catch totaled 455,601 tonnes, and aquaculture contributed 914,752 tonnes, resulting in a total fish production of over 2.1 million tonnes for the year [2]. According to FAO (2005), Bangladesh was ranked as the sixth-largest aquaculture producing country, with an estimated production of 856,956 tonnes in 2003.

Aquaculture accounted for approximately 43.5 percent of the total fish production during 2003–2004, while inland open water fisheries contributed 34.8 percent [2]. Fisheries in Bangladesh boast a diverse range of species, including approximately 795 native species of fish and shrimp in both fresh and marine waters, alongside 12 introduced exotic species. Additionally, there are 10 species of pearl-bearing bivalves, 12 species of edible tortoise and turtle, 15 species of crab, and 3 species of lobster [1].

Among them, 54 species of fish in Bangladesh's inland waters are considered either to be endangered or to be critically endangered situation due to loosing suitability of aquatic habitat and breeding grounds [1]. Environmental pollutants enter aquatic ecosystems through various ways and adversely affect fish breeding grounds as well as the early life stage, by which fish are directly or indirectly impacted. More than 80% of the people depend on agriculture for their living in Bangladesh [2]. Owing to rapid population growth, food security needs, land scarcity, and agricultural intensification are quickly becoming issues of pressing importance to grow food under harsh conditions. Pesticide consumption increased more than 5 times (from 7,350 to 38,692) in the past decade from 1992 to 2018 [3]. These toxic chemicals enter into the aquatic ecosystem through drain, runoff and spray drift, which lead to the contamination of aquatic systems and affect aquatic organisms. This study aims to summarize the physiological stress induced by agro-pesticides in freshwater fishes in Bangladesh. It will particularly highlight the acute, chronic, and developmental toxic effects caused by agro-pesticide contamination.

2. Environmental Monitoring of Agro-pesticide Study in Bangladesh

In Bangladesh, a large number of pesticides are used to protect crops in the agricultural sector. Sprayed pesticides enter destinations other than their target species, including non-target species, water, bottom sediments and aquatic food chain. With the aim of environmental monitoring, a study was conducted in Baitkamari (Table 1) and Pirijpur beel of north-west Bangladesh. From this research, the most commonly found pesticides that existed at high concentrations were chlorpyrifos, diazinon and quinalphos in surface water and sediment [4]. Suspended sediment adsorbs pesticides from running water in the Beel and deposits on the bed. This pesticide deposition in the bottom sediment can have a long-term effect on the bio-community through the food chain. In particular, benthic invertivore fish are in threat, as they consume bottom feed. Another study was conducted in Rangpur floodplain including Mulatol Beel, Nilkunja Beel, Chikli Beel and Ghaghot River to identify bioaccumulation of pesticide residue in fish. In this study, Endrin was detected from taki fish (*Channa punctatus*) with a residual concentration was 0.043ppm [5]. These carnivores are fish species found in mud and prefer stagnant water.

Table 1. *Residues of agro-pesticides found in surface water from environmental monitoring studies in Bangladesh. (dry season) [4].*

Pesticide	Concentration range
Acephate	n.d-0.6 ppb
Chlorpyrifos	n.d-5.2 ppb
Diazinon	n.d-6.9 ppb
Dimethoate	n.d-2.0 ppb
Ethion	n.d-0.9 ppb
Fenitrothion	n.d-3.1 ppb
Fenthion	n.d-2.9 ppb
Malathion	n.d-2.0 ppb
Methyl-parathion	n.d-2.4 ppb
Quinalphos	n.d-6.0 ppb

Table 2. *Residues of agro-pesticides found in surface water from environmental monitoring studies in Bangladesh. (wet season) [4].*

Pesticide	Concentration range
Acephate	n.d-1.0 ppb
Chlorpyrifos	n.d-3.1 ppb
Diazinon	n.d-9.0 ppb
Dimethoate	n.d-2.0 ppb
Ethion	n.d-0.8 ppb
Fenitrothion	n.d-1.0 ppb
Fenthion	n.d-2.0 ppb
Malathion	n.d-1.8 ppb
Methyl-parathion	n.d-2.0 ppb
Quinalphos	n.d-3.4 ppb

Table 3. *Residues of agro-pesticides found in sediment from environmental monitoring studies in Bangladesh. (dry season) [4].*

Pesticide	Concentration range
Acephate	n.d-1.7 ppb
Chlorpyrifos	n.d-39.0 ppb
Diazinon	n.d-15.0 ppb
Dimethoate	n.d-3.9 ppb
Ethion	n.d-2.4 ppb
Fenitrothion	n.d-5.8 ppb
Fenthion	n.d-7.8 ppb
Malathion	n.d-7.7 ppb
Methyl-parathion	n.d-4.7 ppb
Quinalphos	n.d-8.7 ppb

Table 4. *Residues of agro-pesticides found in sediment from environmental monitoring studies in Bangladesh. (wet season) [4].*

Pesticide	Concentration range
Acephate	n.d-10.3 ppb
Chlorpyrifos	n.d-45.0 ppb
Diazinon	n.d-51.0 ppb
Dimethoate	n.d-21.0 ppb
Ethion	n.d-5.4 ppb
Fenitrothion	n.d-7.2 ppb
Fenthion	n.d-21.4 ppb
Malathion	n.d-5.7 ppb
Methyl-parathion	n.d-2.8 ppb
Quinalphos	n.d-4.2 ppb

3. Impact of Agro-pesticides in Different Life Stages of Fish in Bangladesh

3.1. Early Life Stage (Embryo and Larvae)

In fish, life begins with the union of male and female gametes. Once the egg is fertilized by the sperm, a zygote is formed, initiating embryonic development which continues until hatching. After hatching, the larvae undergo organogenesis and develop into their adult forms, completing the larval stages. According to Marimuthu et al. [6], embryonic and larval fish are at their most sensitive stages and are highly vulnerable to environmental pollutants such as pesticides [6].

No studies have been found that identify malformations in embryos and larvae immediately after collection from contaminated aquatic areas. Most research has been conducted in the laboratory (in vivo) to identify toxic effects on early-stage fish [6-13]. Indigenous, ornamental, and exotic fish species in Bangladesh were used as model organisms to study the developmental toxicity of agro-pesticides. The findings of these studies indicate that pesticides are more toxic to fish during their early stages compared to their adult stages. Various malformations, LC50 values, and incubation periods were observed in embryos and larvae exposed to pesticides (Tables 5-7). A decreasing trend in hatching success was noted with higher pesticide exposure [14], and fries often died soon after hatching [15]. This could be due to the disruption of the hatching enzyme.

During the normal hatching process of fish embryos, the chorion is digested by a proteolytic enzyme secreted from the embryo's hatching gland cells [16]. Pesticides may inhibit the structure and function of this enzyme, blocking the pore canals of the chorion and resulting in oxygen deprivation.

Table 5. *An overview of the acute toxicity of agro-pesticides on various life stages of different fish species in Bangladesh, focusing on malformations [17-19].*

Pesticides	Species	Malformations
Cypermethrin	*M. cavasius* (Gangetic Mystus)	Eggs: dark-brown yolk sac, broken egg shell, notochord abnormality and unhatched eggs. Larvae: broken notochord, yolk-sac edema, body arcuation, lordosis and irregular caudal region
Diazinon	*H. fossilis* (Stinging Catfish)	Eggs: degeneration of eggs Larvae: edema, deformed body structure, curved notochord, deformed mouth, jaw and caudal fin, damaged caudal fin
Chlorpyrifos	*T. fasciata* (Banded Gourami)	Eggs: unhatched eggs Larvae: Irregular head and eye shape, lordosis, body arcuation, caudal fin damage and notochordal abnormality

Pesticides	Species	Malformations
Sumithion	*H. fossilis* (Stinging Catfish)	Larvae: irregular head shape, lordosis, yolk sac edema, body arcuation, tissue ulceration

Table 6. *An overview of the acute toxicity of agro-pesticides on various life stages of different fish species in Bangladesh, with a focus on endpoints [17-19].*

Pesticides	Species	Endpoint	LC_{50} (μg/L)
Cypermethrin	*M. cavasius* (Gangetic Mystus)	Mortality (72h)	5.60 6.12
Diazinon	*H. fossilis* (Stinging Catfish)	Mortality (96h)	n.d
Chlorpyrifos	*T. fasciata* (Banded Gourami)	Mortality (48h)	11.8
Sumithion	*H. fossilis* (Stinging Catfish)	Mortality (120h)	n.d

Table 7. *An overview of the acute toxicity of agro-pesticides on various life stages of different fish species in Bangladesh, including the incubation period [17-19].*

Pesticides	Species	Life stage	Incubation period
Cypermethrin	*M. cavasius* (Gangetic Mystus)	Eggs Larvae (1-day old)	19-29h (increased)
Diazinon	*H. fossilis* (Stinging Catfish)	Eggs Larvae (1-day old)	n.d
Chlorpyrifos	*T. fasciata* (Banded Gourami)	Eggs Larvae (2-day old)	23-30h 30 min (increased)
Sumithion	*H. fossilis* (Stinging Catfish)	Larvae (1-day old)	n.d

3.2. Adult Fish

Both acute and chronic toxicity studies were conducted on adult and semi-adult freshwater fishes to assess the toxic effects of agro-pesticides. The studies identified the median lethal concentration (LC50), as well as histopathological and hematological alterations in fish exposed to pesticides. Histological observations revealed various changes in fish gonads (ovary and testis), gills, liver, and kidney, while blood analysis showed abnormalities in parameters such as hemoglobin, glucose, red blood cell count, white blood cell count, as well as cellular and nuclear erythrocytic abnormalities [17-19].

These studies involved different fish species, including banded gourami, stinging catfish, zebrafish, and tengra. Additionally, a study conducted on silver barb aimed to identify genetic damage and nuclear changes in peripheral erythrocytes at Bangladesh Agriculture University, Mymensingh [7, 19]. The results of this study indicated that exposure to pesticides led to erythrocytic cellular abnormalities (such as twin, fusion, echinocyte, spindle, tear drop, elongated shape, etc.), erythrocytic nuclear abnormalities (including binucleated cells, nuclear bud, nuclear bridge, karyopyknosis, notched nuclei, etc.), formation of micronuclei (MN), and DNA damage.

4. Conclusions

Studies conducted on various freshwater fish species in Bangladesh, exposed to a variety of pesticides, suggest that agro-pesticides can disrupt different physiological functions and life history characteristics of fish even at very low concentrations. This disruption negatively impacts the natural production and biodiversity of freshwater fish in Bangladesh. Additionally, the results of these studies could serve as a baseline for other researchers, as using indigenous fish species in Bangladesh as models can aid in assessing the acute, chronic, and developmental toxicity of pesticides.

Acknowledgments

We thank Al-Amin for his assistance with reviewing the works.

Author Contributions

Md. Mohibul Hasan: Conceptualization, Methodology, Supervision, Writing – original draft, Writing – review & editing

Shayla Sultana Mely: Conceptualization, Investigation, Methodology, Resources, Writing – original draft, Writing – review & editing

Funding

There was no financial support for this research work.

Conflicts of Interest

The authors declare no conflicts of interest.

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Biography

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Research Field

Md. Mohibul Hasan: Ecotoxicology, Fisheries, Environmental Pollution, Agricultural Pesticide, Microplastics

Shayla Sultana Mely: Ecotoxicology, Fisheries, Environmental Pollution, Agricultural Pesticide, Microplastics