

Ecotoxicology: A review on dimethoate and malathion induced toxicity in fishes

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Abstract

The study of toxic effects on ecosystem level is ecotoxicology. In this review ill effects of commonly used toxicants: dimethoate and malathion on fish are highlighted. These chemicals are organophosphate insecticide introduced in 1960 which contributed greatly to pest control and agricultural output. The main use of pesticides in India is for cotton crops (45%), followed by paddy & wheat. Liberal use of these chemicals played havoc with human and other life forms. From treated plants and soils these pesticides reach surface water through runoff, irrigation and rain, thus contaminate aquatic ecosystem. These chemicals get their entry in to food chain & found to be highly toxic to aquatic organisms mainly fish. The contaminated water causes various ill effects on fish health.

This article reviews some major induced toxicological aspects of dimethoate and malathion in fish including histopathological damages, haematological alterations, biochemical changes, fluctuations in Acetylcholinesterase activity and fish behaviour.

Keywords: Toxicity, dimethoate, malathion, histological effect, haematological effect, biochemical effect, fish behavior, acetylcholinesterase.

Introduction

Pesticides have been used widely in agriculture to protect the crops from weeds, diseases and insects pest, polluting a variety of aquatic environment. They have become a source of environmental concern due to their continual release (Shoaban *et al.*, 2021). Pesticides eventually find their way in to the aquatic ecosystem, where they induce toxic effects to many non-target organisms. Aquatic organisms are more likely to be affected by these toxicants in comparison to terrestrial ones since the transport of toxicant through water is faster and carried to greater distances. More than 90% of water and fish samples from all streams, contained one or several pesticides (Kole *et al.*, 2002) [22].

To study ecotoxicology of aquatic systems, fish have been widely and popularly acclaimed as the test species for evaluating the potency of toxicants to cause lethality on acute exposure or any other sub-lethal responses on chronic exposure, using selected behavioural (Agarwal, S. K., 1991) [1], biochemical (Haniffa & Selvan 1991; Jana & Bandyopadhyay, (1987), or physiological (Venkatasubbaiah *et al.*, (1991) [47], haematological (Baig *et al.*, 1984) [8] responses. Fishes may be exposed to toxicants in 3 primary ways.

- Direct absorption of toxicant through skin while swimming in contaminated waters.

- Direct uptake of toxicants through the gills during respiration.
- Orally, by drinking contaminated water or feeding on contaminated prey.

Pesticides induce toxic effects to non-target organism fish & other aquatic fauna as they serve ultimate sink for these pesticides. Hence pesticides pose a high risk to aquatic organisms because of their ability to bioaccumulation and disruption of food chain.

Abrupt mortality in fish may occur on acute exposure, while low dose and long term exposure may cause cellular & tissue damage, which generally end up impairing health issues of fish and making them more susceptible to additional stressors (Khatib *et al.*, 2022) [21].

Dimethoate and malathion are most popular, widely used, broad spectrum systemic organophosphate insecticides, preferred for cotton, cereals, fruits, vegetables, tea, coffee, tobacco crops (Aysal *et al.*, 2004) [7].

Hence some major toxic effects induced by dimethoate and malathion on fish are reviewed in present article.

Dimethoate and Malathion induced Toxicity in fish

Toxicity of any toxicant depends on exposure time, dose rate & its sensitivity to a particular species. Toxicity rating of any toxicant based on LC₅₀ values (concentration of pesticide that kills 50% of a test population). (Table – 1&2).

Table 1: Acute toxicity (LC₅₀) of Dimethoate to fish species.

S. No.	Test organism	Duration of exposure in hours	LC ₅₀ value	Reference
1	Heteropneustes fossilis	96	2.98 mg/l	Pandey <i>et al.</i> (2009) [29]
2	Labeo rohita	96	24.55 ug/l	Dey & Saha (2014) [13]
3	Catla catla	96	0.007 ppm	Singh & Kumar (2013) [42]
4	Clarias gariepinus	96	5.56 ug/l	Okogwu <i>et al.</i> (2022) [28]
5	Mugil cephalus	96	854.10 ug/l	Dake <i>et al.</i> (2021) [10]
6	Clarias gariepinus	96	29.05 mg/l	Oghale <i>et al.</i> (2021) [27]
7	Gambusia affinis	96	63.33mg/l	Alabssawy & Khalaf-Allah, 2019 [3]
8	Rasbora daniconius	96	9.136 ppm	Lokhande (2017) [24]

9	Cyprinus Carpio	96	1.1 ppm	Qayoom <i>et al.</i> (2016) ^[33]
10	Oreochromis niloticus	96	25.00 mg/l	Hassanin & Asely (2015) ^[17]
11	Channa punctatus	96	19.10 µg/l	Ali <i>et al.</i> (2014) ^[5]

Table 2: Acute Toxicity (LC₅₀) of Malathion to fish specie

S. No.	Test organism	Duration of exposure in hours	LC ₅₀ value	Reference
1	Labeo rohita	96	15 mg/l	Thenmozhi <i>et al.</i> (2011) ^[45]
2	Carassius auratus	96	4.71 mg/l	Naserabad <i>et al.</i> (2015) ^[26]
3	Heteropneustes fossilis	96	0.98 mg/l	Deka & Mahanta (2012) ^[12]
4	Catla catla	96	0.047 ppm	Singh & Kumar (2000) ^[41]
5	Channa punctatus	96	6.65 ppm	Pandey <i>et al.</i> (2005) ^[30]
6	Clarias batrachus	96	0.25 ppm	Wasu <i>et al.</i> (2009) ^[48]
7	Cyprinus Carpio	96	15.24 ppm	Sharmin <i>et al.</i> (2015) ^[39]
8	Esomus danricus	96	17.9 µg/l	Das & Gupta (2013) ^[11]
9	Ophiocephalus punctatus	96	16 µl/l	Pugazhvendan <i>et al.</i> (2009) ^[32]
10	Oreochromis niloticus	96	1.06 ppm	Al. Ghanim (2012) ^[4]
11	Xiphophorus maculatus	96	12.05 ppm	Sadeghi & Imanpoor (2015) ^[34]

Histopathological Damages

Histopathological observations are proved to be very significant to find out deleterious effects of different pesticides as well as to monitor aquatic contamination. Organophosphorus pesticides considerably reduced the chance or recovery of different tissues with necrosis. (Aktar *et al.* 2009)^[2]. Histopathological changes exposed to dimethoate and malathion are traced in liver, gills, brain, kidneys. Changes documented in gills are extensive hyperplasia of epithelial cell, vacuolated spaces between the pillar system, proliferation of mucous cells at the tips of gill filaments & edema (Alabssawy & Khalal-Allah, 2019)^[3]. The increase in mucous deposition on the gills and damage caused to gill lamellae by the toxicant would reduce gases exchange. (Chandra & Sridhar, 2015)^[9]. Liver of mosquito fish *Gambusia affinis* exposed to dimethoate showed destroyed, congested blood vessels, fatty degeneration of hepatocytes and appearance of some necrotic areas. (Alabssawy and Khalaf-Allah, 2019)^[3], Singh & Kumar (2013)^[42] observed very prominent histopathological changes in brain of *Catla catla* exposed to dimethoate. They observed optic tectum is greatly affected. Vacuolation, necrosis and separation of nerve fibers are clearly seen in all layers of optic tectum. Chronic exposure to dimethoate causes encephalitis in stratum griseum centrale in the test fish.

Kidney of *Gambusia affinis* after 96 hours exposure to dimethoate showed degenerated renal tubules, severe congestion of blood vessels, fluid stagnation in the renal tubules, Oedema, necrosis of renal tubular cells. (Alabssawy & Khalaf-Allah, 2019)^[3]. These changes influence metabolic activities & elevates metabolic abnormalities in fish (Yokote, 1982)^[50]. Malathion also induced changes in histology of liver, ovary & kidney in *Heteropneustes fossilis* (Deka & Mehanta, 2012)^[12].

Haematological Alterations

Any alteration or infection in animal's body is reflected by haematological system the most important vital system, because blood is connective tissue (Pathak *et al.* 2013)^[31]. Several workers observed alterations in haematological parameters in fishes exposed to dimethoate and malathion. Farsani *et al.* (2016)^[14] observed significantly reduced RBCs and Hb level and increased WBC, MCV, MCH in rainbow trout exposed to malathion. Hamed, (2015)^[16] also

observed decreased RBC, Hb, HT & LPO and increased blood glucose, cortisol and WBC during short term malathion exposure of *O. niloticus*. Pathak *et al.* (2013)^[31] reported total erythrocyte count was decreased after exposure to malathion in *Catla catla*, *Cirrhinus mrigala* & *Labeo rohita*.

It might be due to damage in nervous system by insecticides and neural elements associated with both the blood vessels and the stroma affects haemopoiesis causing decrease in TEC (Yadav, 1993)^[49]. It may be also due to water loss from the plasma to the tissues or the haemopoietic organ might have been affected which may result decreased production of RBC (Sharma & Gupta 1982)^[37].

Biochemical Changes

As dimethoate and malathion are potent inhibitor of Acetylcholinesterase enzyme, which hydrolysis neurotransmitter acetylcholine at nerve synapse and plays a crucial role in neurotransmission (Kwong, 2002)^[23]. Significant reduction in AChE activity has been observed in *L. rohita* exposed to dimethoate and malathion (ManjuRani *et al.* 2017)^[25]. Singh and Kumar (2000)^[41] reported decreased AChE activity in brain of *Catla catla* exposed to malathion. Tembhe and Kumar (1994)^[44] reported decreased AChE activity in the gut of *Cyprinus carpio* exposed to sub-lethal dose of dimethoate. Satyadeven *et al.* (1993)^[35] reported decreased AChE activity in brain of *Cyprinus carpio* exposed to dimethoate. The liver, muscle & gill tissue showed decreased level of acid phosphatase (ACP) and Alkaline Phosphatase (ALP) activities during malathion exposure in *Labeo rohita* (Thenmozhi *et al.* 2011)^[45].

Behavioral Effect

To study the environmental pollutants' effect behavior acts as the link between physiological and ecological process. Thus it can be tool to monitor environmental contamination (Sindhe *et al.* 2007)^[40].

Dimethoate and malathion are neuroinhibitors of AChE enzyme which may cause paralysis in fishes exposed to these toxicants. Uner *et al.* (2006)^[46] reported abnormal behavioural changes such as loss of balance, erratic swimming, frequent surfacing and increased mucous secretion in *Danio rerio* exposed to dimethoate. Ansari & Ansari (2014)^[6] also reported surfacing, lack of equilibrium

due to sub-lethal exposure, and sudden quick & jerky movement at lower concentration of dimethoate in *Danio rerio*. Similar changes in fish behavior were observed by Fukuto (1990) ^[15] that reported sluggish, lethargic and abnormal swimming in *Heteropneustes fossilis* exposed to dimethoate. Khan *et al.* (2022) ^[20] reported opercular beat frequency was significantly ($P < 0.001$) decreased with increased exposure time of chlorpyrifos and dimethoate in *Cyprinus carpio*. Singh and Kumar (2013) also reported in *Catla catla* initial increase and gradual decrease in opercular beats exposed to dimethoate. Sharma *et al.* (2022) ^[38] & Okogwu *et al.* (2022) ^[28] also reported same behavior in *Cyprinus carpio* and *clarias gariebinus* on exposure to dimethoate.

Any behavioral change in fish, indicates deterioration of their habitat due to the effect of dimethoate (Sharma *et al.* 2022) ^[38]. Singh & Kumar (2013) ^[42] reported that change in behavior of fish such as decreased opercular movement helps the fish to improve resistance against toxic stress created by the presence of dimethoate by reducing the absorption of toxicant through gill and to increase the survival period of fish in toxic environment. Increased mucous secretion after dimethoate exposure is another adaptive feature in fish to counter the effect of pesticide on body surface and mucous membrane (Singh *et al.* 2009) ^[43]. Thus behavioural characteristics of the fish depict contamination in water body. Any change in normal behavior of fish indicates presence of toxicants in aquatic ecosystem (Jammu *et al.* 2023) ^[19].

Conclusion

It may be concluded that liberal use of pesticides is main cause of deterioration of aquatic ecosystems. Use of these agrochemicals should be replaced by Biopesticides and natural products. Further studies on the toxicity of organophosphates and other toxicants in the laboratory and field conditions are required to prevent aquatic ecosystems from toxic pollutants.

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