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Review on Effect of the Type II Synthetic Pyrethroid Pesticides in Freshwater Fishes

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Abstract The use of pesticides is increasing day by day according to the demand of agriculture. Cypermethrin, deltamethrin and fenvalerate these three synthetic pyrethroid (type II), widely used in agricultural field. Therefore these insecticides contaminate nearby water body from agricultural runoff. Thus the aquatic organism including fishes is indirectly affected by the toxicity of these three pesticides. The LC_{50} value of toxicity is studied in various fresh water fish species. This review will show that these insecticides significantly affect the fish organ such as gill, liver, kidney, brain, muscle and also causes behavioral changes, biochemical changes, histopathlogical changes, hematological changes, alteration in DNA and RNA content, reproductive physiology. The information presented by this review may be useful for the assessment analysis of fresh water fishes and may help in the environmental Management.

Keywords Cypermethrin, Deltamethrin, Fenvalerate, Toxicity, Fresh water fishes.

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Introduction

In present days there is heavy increase of pesticides in agricultural field to prevent our food resource from the attack of pest and to accelerate the crop production according to food demand of our blasting human population (Aktar et al. 2009). Due to improper and injudicious use, insecticides leave their application site by different ways and drained to the nearby water body making the toxic aquatic environment. Pesticides also contaminate the water body from urban and industrial discharges. Thus the most pesticides are drained to the ponds, lakes and rivers (Werimo et al. 2009, Ngidlo 2013). These insecticides are highly toxic to the non target fishes as well as organism of fish food chain sometimes leading to the mortality (Lazartigues et al. 2013). These insecticides can damage the biochemical and physiological process of fish organ (Banaee et al. 2011). Cypermethrin, deltamethrin and fenvalerate are very efficient to control too many insect pests. These insecticides are relatively less harmful for birds and mammals but very harmful for aquatic organism including fresh water and marine fish species (Vani et al. 2011).

There are two types of synthetic pyrethroid i.e.

Table 1. Classification of the pyrethroid pesticides.

Type-1 pyrethroid	Type-II pyrethroid
Allethrin	Cypermethrin
Bifenthrin	Deltamethrin
Permethrin	Fenvelerate
Phenothrin	Cyfluthrin
Resmethrin	Cyhalothrin
Tefluthrin	Fenpropathrin
Teramethrin	Flucythrinate
	Fluvalinate
	Tralomethrin

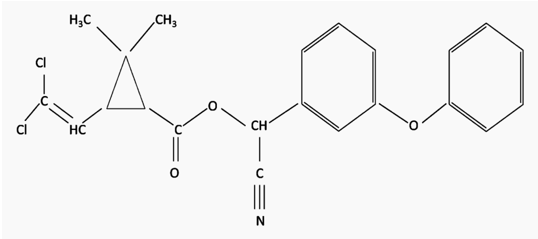

Fig. 1. Chemical structure of cypermethrin (Prusty et al. 2015).

type-1 (non-cyano) and type-II (α-cyano). Cypermethrin, deltamethrin and fenvalerate are the type-II pyrethroid. The classes of synthetic pyrethroid are given in the Table 1.

Cypermethrin

Cypermethrin is active compound of many insecticide viz. killer ammo, barricade, kafil super, polytrin, stockade. The chemical formula of cypermethrin is $C_{22}H_{19}Cl_2NO_3$ (Fig. 1).Cypermethrin is the most widely used synthetic insecticides though it is reported that cypermethrin is toxic to many fishes and aquatic invertebrates even at low concentration (Sarkar et al. 2005). Fishes are affected by cypermethrin which leads to changes in enzymatic alteration, fish behavior changes, hematological changes, biochemical changes, changes in oxygen consumption, alteration in enzyme activities, histopathological alteration, changes in reproductive physiology, changes in DNA and RNA content (Akinrotini et al. 2012, Ayoola and Ajani 2008, Balaji et al. 2013, Deka and Dutta 2012, Gracy 2012, Meenambal et al. 2012, Saha and Kaviraj 2013, Sarikaya 2009). Toxicity studies on the effects of cypermethrin on different fresh water fish species (Prusty et al. 2015, Shaluei et al. 2012) are given in the Table 2.

Histopathological changes

Significant changes were studied in fish liver, gill, kidneys, brain, muscles. A necrosis of the primary gill lamellae and a major necrosis of the secondary gill lamellae were found in *Oreochromis mossambi-*

Table 2. Toxicity studied of cypermethrin on freshwater fishes (Prusty et al. 2015).

Scientific name	LC_{50} value	References
Clarias gariepinus	0.05, 0.10, 0.20 and 0.25 µg L	Akinrotimi et al. (2012)
Clarias gariepinus	0.063 mg/L (96 h)	Ayoola and Ajani (2008)
Cyprinus carpio	250 µg/L (96 h)	Meenambal et al. (2012)
Cirrhinus mrigala	150 µg/L (96 h)	Vasantharaja et al. (2014)
Colisa fasciatus	0.02 mg/L (96 h)	Singh et al. (2010)
Oreochromis niloticus	5.99 µg/L (96 h)	Sarikaya (2009)
Heteropneusts fossilis	0.67 µg/L (96 h)	Deka and Dutta (2012)
Heteropneustes fossilis	0.67-1.27 µg/L (72 h)	Saha and Kaviraj (2013)
Hypophthalmicthys molitrix	2.962 µg/L (24 h), 1.653 µg/L (48 h), 1.030 µg/L (72 h), 0.917 µg/L (96 h)	Shaluei et al. (2012)
Labeo rohita	0.323 µg/L (6 h), 0.278 µg/L (12 h), 0.240 µg/L (18 h), 0.205 µg/L (24 h)	Tiwari et al. (2012)
Labeo rohita	4.0 µg/L (96 h)	Marigoudar et al. (2009)

cas after exposure to cypermethrin (Karthigayani et al. 2014). Severe histopathological lesions in Nile tilapia, *Oreochromis niloticus* (Korkmaz et al. 2009), necrosis in the epithelial cells of kidney of *Clarias gariepinus* (Velmurugan et al. 2009), alteration in hepatocytes of *Heteropneustes fossilis* and neural degeneration were reported after exposure to cypermethrin (Joshi et al. 2007).

Biochemical changes

Cypermethrin exposure decreases the protein content of the fingerlings of *Labeo rohita* (Das and Mukherjee 2003). In *Oreochromis niloticus,* cholesterol levels decreased significantly with increase concentration of the pesticide while triglycerides level increased significantly with increase in concentration of the cypermethrin (Yaji et al. 2011). Changes in carbohydrate metabolism after exposure to cypermethrin were reported in *Tilapia mossambicas* (Jipsa et al. 2014). Cypermethrin induced alteration was noted in fish *Cirrhinus mrigala* (Vasantharaja 2014). Biochemical alteration also noted in *Catla catla* induced by cypermethrin (Kannan et al. 2014).

Hematological alteration

Cypermethrin exposure causes severe disfunction in hematopoietic system. Hematological alteration also noted due to time and density dependent exposure of cypermethrin in *Colisa fasciatus* (Singh et al. 2010), in *Labeo rohita* (Tiwari et al. 2012). Cypermethrin exposure increases WBC, MCV, MCH but decrease RBC in *Clarias gariepinus* (Ojutiku et al. 2013).

Inhibition of acetylcholinesterase activity

Cypermethrin decreases acetylcholinesterase activity depending on time and concentration in the tissues of *Labeo rohita* (Marigoudar 2009). A significant inhibition of acetylcholinesterase activity was noted with response to exposure to technical grade cypermethrin in *Channa punctatus* (Kumar et al. 2009).

Behavioral changes

Cypermethrin toxicity results hyperactivity and buoyancy loss in the fishes. It causes darting, disruption of normal movement, hyperactivity and bottom dwelling tendency in *Labeo rohita* (Marigoudar 2009).

Changes in reproductive physiology

Cypermethrin has an adverse effect on fish reproductive physiology. Exposure to this pesticide reduces the number of fertilized eggs fertilization chances in Atlantic Salman, *Salmo salar* (Richterova and Svobodova. 2012).

Alteration in protein content in fish

Marked decrease in the protein level and increase in free amino acid level was reported in *Tilapia mossambica* (Reddy and Yellamma 1991). Similar result was also found in *Cirrhinus mrigala* (Prashanth and David 2006). Many authors studied significant alteration in protein content and alteration in amino acid level in *Cirrhinus mrigala* (Veeraiah 2013), in *Clarias gariepinus* (Olalekan 2014).

Changes in DNA and RNA content

Sublethal concentration of cypermethrin shows significant decrease in the level of DNA, RNA and DNA/RNA ratio in *Channa striata* (Gracy 2012). A significant reduction in DNA and RNA content was noted in different organ of *Cyprinus carpio* due to cypermethrin exposure (Balaji et al. 2013). Cypermethrin exposure causes alteration in DNA content of various organ of *Cyprinus carpio*; maximum decrease noted in liver and minimum noted in muscle. Similar decrease in RNA content was noted in different organ. The decrease of DNA and RNA content is directly related with the days of exposure. (Neelima et al. 2015).

Changes in oxygen consumption

Cypermethrin contamination cause respiratory alteration in *Labeo rohita* (Marigoudar et al. 2009). Decline oxygen consumption was found in *Tilapia mossambicas* on sublethal concentration of cypermethrin (Logaswamy and Remia 2009). Altered oxygen consumption was also noted in *Tilapia mossambicas* (Jipsa et al. 2014). Cypermethrin is highly toxic and affect the respiration significantly in *Cyprinus carpio*

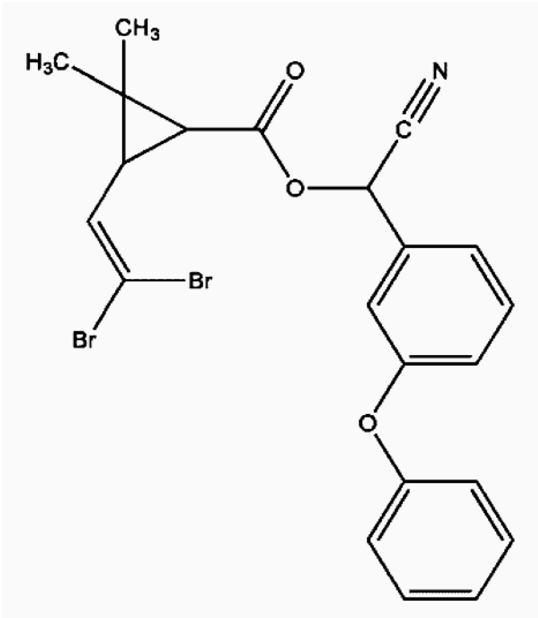

Fig. 2. Chemical structure of deltamethrin (Prusty et al. 2015).

in both lethal and sublethal concentration.

Deltamethrin

Deltamethrin is used world widely. It is a type II Pyrethroid . The chemical formula of deltamethrin is $C_{22}H_{19}Br_2NO_3$ (Fig. 2). It is one of the most effective pesticides among the synthetic Pyrethroids. Deltamethrin generally blocks the sodium ion channels of nerve. So it lengthens the depolarization phase. Large use of deltamethrin may affect the aquatic environment including aquatic organism. Fish species are very sensitive deltamethrin (De Assis et al. 2009, Amin and Hashem 2012). Fishes are affected by deltamethrin which leads to changes in enzymatic alteration, fish behavior changes, hematological changes, biochemical changes, changes in oxygen consumption, alteration in enzyme activities, histopathological alteration, changes in reproductive physiology, changes in DNA and RNA content (Atamanlp and Erdogan 2010, Jayaprakash and Shettu 2013, Karasu Benli et al. 2009, Khalili et al. 2012, Neeraja and Giridhar 2014, Rathnamma et al. 2009). Toxicity studies on the effects of deltamethrin on different fresh water fish species (Prusty et al. 2015) are given in the Table 3.

Histopathological alteration

Deltamethrin contamination causes micronuclei formation and changes in the histopathology of liver and gill of *Oreochromis niloticus* (Kan et al. 2012). Changes in histopathology of gill and liver were also found in freshwater fishes. Deltamethrin induced toxocity changes histopathology of liver and gill (Staicu et al. 2007, Srivastava et al. 2010).

Biochemical changes

Deltamethrin toxicity causes decreased activities of glutathione reductase, catalase and glutathione peroxidase enzyne in *Carassius auratus* (Diana et al. 2007), decreased pyruvate level in the tissues of gill, liver and muscle in rainbow trout (Senturk et al. 2009). Deltamethrin exposures cause gradual decrease of the antioxidant enzyme activities in *Catla*

Table 3. Toxicity studied of deltamethrin on freshwater fishes (Prusty et al. 2015).

Scientific name	LC_{50} value	References
Catla catla	4.83 µg/L (96 h)	Vani et al. (2011)
Channa punctatus	0.75 mg/L (96 h)	Jayaprakash and Shettu (2013)
Clarias gariepinus	0.75 µg/L	Amin and Hashem (2012)
Heteropneustes fossilis	1.5 mg/L (96 h)	Srivastava et al. (2010)
Labeo rohita	1.00 mg/L (96 h)	Rathnamma et al. (2009)
Oncorhynchus mykiss	0.3 and 0.6 µg/L	Atamanlp and Erdogan (2010)
Oreochromis niloticus	1.17 µg/L (48 h),	Karasu Benli et al. (2009)
Oreochramis niloticus	1.70 µg/L (48 h),	Kan et al. (2012)
Xiphophorus helleri	2.87 µg/L (96 h)	Khalili et al. (2012)

catla fingerlings (Dinu et al. 2010).

Inhibition of acetylcholinesterase activity

Deltamethrin exposure causes inhibition of acetylcholinesterase activity in *Cyprinus carpio* (Balint et al. 1995).

Behavioral changes

Deltamethrin reduces swimming capacity in juvenile rainbow trout, *Oncorhynchus mykiss* (Goulding et al. 2013). Failure of darting movement, rapid gill movement, uncontrolled swimming, movements towards surface for air, laying down on the bottom were reported on *Cyprinus carpio.* Similar result was observed in silver catfish (Galeb et al. 2013).

Changes in reproductive physiology

Low level of deltamethrin may affect the carp population in aquatic environment. Deltamethrin causes inhibition of lipase activity which results the poor nutrition of reproductive physiology of guppies, *Poecilia reticulate* (Gunes and Yeril 2011).

Hematological alteration

Deltamethrin elevate RBC count i.e. suggesting accelerated erythropoiesis but decreases Hb, MCV, MCH and PCV in *Heteropneustes fossilis* (Kumar et al. 1999). Decreased RBC, Hb and PCV were studied in common carp but no changes in MCV, MCH, MCHC (Svobodova et al. 2003).

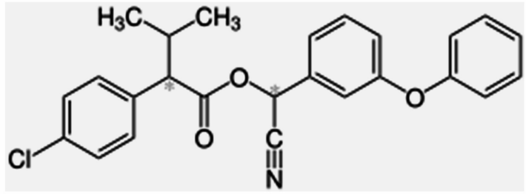

Fig. 3. Chemical structure of fenvalerate (Wikipedia).

Changes in protein content in fish

Deltamethrin causes alteration in protein content in fingerlings of *Catla catla* (Vani et al. 2011). It was noticed in *Labeo rohita* that exposure to deltamethrin causes sudden decrease in protein content after one day exposure but the level rises nearer to the normal limit within thirty days (Neeraja and Giridhar 2014, Kai-Yun et al. 2010).

Fenvalerate

Fenvalerate is another insecticide which belongs to synthetic pyrethroid. The chemical formula of Fenvalerate is $C_{25}H_{22}Cl_1NO_3$ (Fig. 3). Fenvalerate is very toxic to fish than other terrestrial animals such as mammals (WHO 1996). Fenvalerate enters into fish body mainly by gills and mouth and the residual

Table 4. Toxicity studied of envalerate on freshwater fishes (Prusty et al. 2015).

Scientific name	LC_{50} Value	References
Clarias batrachus	1.35 µg/L (96 days)	Datta and Kaviraj (2011)
Heteropneustes fossilis	0.65 µg/l (96 days)	Datta and Kaviraj (2011)
Channa punctatus punctatus	1.0 µg/L (96 days)	Datta and Kaviraj (2011)
Labeo rohita	5.36 µg/L (96 h)	Prusty et al. (2011)
Cyprinus carpio	2.171 mg/L (S) and 1.775 mg/L (C) (96 h)	Satyavardhan (2013)
Puntius sephore	1.789 mg/L (S) and 1.415 mg/L (C) (96 h)	Satyavardhan (2013)
Ctenopharyngodom idella	2.627 mg/L (S) and 2.121 mg/L (C) (96 h)	Satyavardhan (2013)
Channa punctatus	128.1 mg/L (S) and 110,7 mg/L (C) (96 h)	Satyavardhan (2013)
Anabas testudineus	472.5 mg/L (S) and 376.0 mg/L (C) (96 h)	Satyavardhan (2013)
Cyprinus carpio	3.059 (96 h)	Raja et al. (2010)
Clarias gariepinus	5.83-4.76 µg/L (24 h) and 74.24-2.94 µg/L (96 h)	
Channa punciatus	2.13 µg/L (96 h)	Singh et al. (2007)

concentration causes toxicity (Tilak et al. 2001). It was also noted that larvae of fishes as affected by fenvalerate. Toxicity studies on the effects of fenvalerate on different fresh water fish species (Prusty et al. 2015) are given in the Table 4 (Datta and Kaviraj 2011, Raja et al. 2010, Satyavardhan 2013, Singh et al. 2007).

Histopathological changes

Severe histopathological alteration in major organ tissues such as gill, liver and kidney of three Indian major carps *C. catla, L. rohita* and *C. mrigala* was noted by Susan et al. (2012) by the ten days exposure to the sublethal concentration of fenvalerate.

Biochemical changes

Sufficient inhibition of growth and also in survival of *L. rohita* fingerlings was observed due to short term exposure of sublethal concentration of fenvalerate (Prusty et al. 2011). Fenvalerate also inhibits aerobic as well as anaerobic metabolism in *Labeo rohita* (Suneetha 2012).

Inhibition of acetylcholinesterase activity

Fenvalerate inhibit the activity of acetyl cholinesterase *L. rohita* (Prusty et al. 2011).

Behavioral changes

Fenvalerate affect many freshwater fishes. The signs of fenvalerate toxicity are the loss of swimming capacity, increased gill mucous secretion, loss of buoyancy, hyperactivity. It was observed that acute toxicity of fenvalerate affect the fingrlings of Indian major carps (Anita et al. 2012).

Changes in endocrine and reproductive physiology

Fenvalerate causes disruption of endocrine chemicals (Gopi et al. 2012). Fenvalerate exposure reduces fecundity, hatching and growth of eggs of Australian crimpson spotted rainbow fish (Barry et al. 1995).

Hematological changes

Fenvalerate exposure causes significant changes in blood properties and serum biochemical parameters of *L. rohita* fingerlings (Prusty et al. 2011).

Conclusion

Fish is also a very good food source for human being. So it is very important to take necessary precaution for protection of fish population and also for human population while applying the pesticides. This review shows that long term exposure of fish to the type II synthetic pyrethroid pesticide causes alterations in biochemical, hematological, histopathological, behavioral and reproductive physiology. This continuous health hazard of fish causes loss in fish population. From a pesticides standpoint such pesticides should be avoided or should be used to minimum for protecting aquatic life. Furthermore these pesticides are often used in different combinations to protect crops. So there is an apparent risk factor of joint toxicity in aquatic environment. Future research should include not only the direct effect of a single compound but also indirect effects in presence of other chemicals to protect the environment.

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