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Effect of Chlorpyrifos toxicity on non target fresh water fishes: A Review

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Abstract: **Pest is a major problem for agriculture and economy. Pesticides are very effective for eradication of pest. Worldwide use of pesticide is an important tool for successful agricultural production. Organophosphate pesticides are now widely used pesticide to reduce the farm production loss. Chlorpyrifos is a widely used and successful organophosphate pesticide. Pesticides are very toxic chemicals. Though these pesticides are used in agricultural field but these pesticides contaminate the nearby water body. Thus like other agricultural runoff pesticides, chlorpyrifos also affect the non target organism such as fish. Chlorpyrifos is very toxic to fishes which are an important part of human food chain. This review will highlight the composition, use and toxic effect of chlorpyrifos on the physiology of fishes.**

Keywords: **pesticide, organophosphate, chlorpyrifos, effect of toxicity.**

I. INTRODUCTION

India mainly is an agriculture base country. India is the second largest populated country in the world. So, food supply to this huge population is the major target of agriculture. But pests are the major threat to the crop productivity causing agricultural loss. So use of pesticides is increasing day by day to boost up the agricultural production according to demand of rising population [1]. Pesticides play an important role in the agricultural progress with the protection of public health in the India like tropical country [2].Due to unscientific and indiscriminate use of pesticide the natural water bodies are getting contaminated by these pesticides [3]. Pesticides affect the aquatic ecosystem causing serious problem to aquatic biota particularly in fish [4] and moreover physiological and biochemical process of fish physiology may significantly affected by the herbicides, pesticides after entering into the fish body [5] [6]. As fish is the one of the major part of the food chain of aquatic ecosystem, they are widely used to evaluate pollutant of the water body [7]. In India, there are 234 kinds of used pesticide and among these pesticides 24 are widely used but 28 pesticides among them are banned due to their unwanted toxicity to non target organism [8]. Chlorpyrifos (CPF), a widely used broad spectrum organophosphate pesticide which mainly used to control the harmful foliar insects of agricultural crop and the subterranean termites [9]. In 1965, commercially it was first introduced to control the agricultural and indoor pests [9]. The half life of Chlorpyrifos is generally 30 days but it may extend to two months in less alkaline soil. It can also remain intact in indoor from one week to months [10]. Chlorpyrifos mainly acts on the nervous system of insects. The mode of action of chlorpyrifos is to inhibit the acetylcholinesterase activity which is very essential for breakdown of acetylcholine, a neurotransmitter of neuromuscular junction and chemical synapses [11]. The aim of the study of this review is to evaluate the toxic effect of chlorpyrifos on the non target fresh water fish species. Here it will show the impact on fish physiology such as behavioral changes, Effect on acetylcholinesterase activity, biochemical alteration, hematological changes, histopathological alteration, endocrine dysfunction, immunological changes, genotoxicity, developmental changes, oxidative stress etc. So this review may be an important attempt for documentation on the toxic effect of chlorpyrifos to help the future investigation with base line data.

II. PHYSIO-CHEMICAL PROPERTIES OF CHLOROPYRIFOS

Chlorpyrifos is an organophosphate sold under different brand name. It was first introduced by Dow chemical company in 1965 [11]. It is widely used to kill a number of pests like insects and worm by inhibiting the acetylcholinesterase activity [11]. According to Dow this organophosphate pesticide is registered for use in nearly 100 countries and its annual application approximately 8.5 million crop acres [12].

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Table 1: Physico-chemical properties of Chlorpyrifos [11]

Variable	Information
Chemical formula	$C_9H_{11}Cl_3NO_3PS$
IUPAC name	*O*,*O*-Diethyl *O*-3,5,6-trichloropyridin-2-pyridyl phosphorothioate
Molar mass	350.57 g·mol^{-1}
Appearance	Colorless crystals
Solubility in water	2 mg/L
Melting point	43 °C (109 °F; 316 K)
Boiling point	160 °C; 320 °F; 433 K
Odor	Marcaptan like

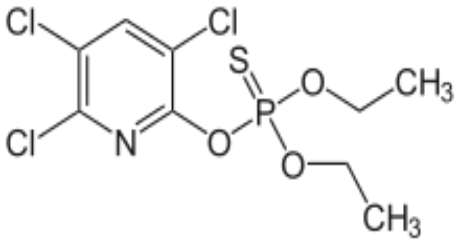

Figure: 1 Chemical structure of Chlorpyrifos. [11]

Table 2: Toxicity studies on the effect of chlorpyrifos on various fish species

Scientific neme	LC50	Reference
Oreochromis niloticus	154.01 µg/L(96 h)	Rusyniak et.al (2004) [13]
Poecila reticulata	0.176 ppm/L	Sharbidre et.al (2014) [14]
Gambusia affinis	297mg/ L (96 h)	Kavithaa et.al (2015) [15]
Cyprinus carpio	580 µg/L (96h)	Xing et.al (2011) [16]
Heteropneustes fossilis	0.174m.M./L (96h)	Misha et.al (2016) [17]

III. COMMON NAME

Chlorpyrifos is used in different trade name such as Dursbaan, Larsban, Killer, Goldban and also in combination with other pesticides such as Horn, Hammer etc.

IV. EFFECT OF CHLORPYRIFOS (CPF) ON FISHES

Chlorpyrifos, an organophosphate pesticide is used to kill many agricultural pests but it can affect the non target fresh water fishes in different way.

1. Behavioural changes:

Toxic effect of CPF causes changes in behavior of fish such as in erratic swimming, swimming at the water surface, buoyancy, rapid gill movement, motionless activity, laying down on the bottom of surface etc. It was observed that CPF exposure causes continuous behavioural dysfunction in zebrafish [18]. CPF exposure to *Poecila reticulate* resulted aggressive behavior, erratic swimming, rapid operculum movement, stress etc. [14].

2. Effect on acetyl cholinesterase activity:

Acetyl cholinesterase activity is a specific biomarker of Chlorpyrifos like organophosphate [19]. Chlorpyrifos exposure causes reduction in acetylcholinesterase activity in *Channa punctatus*[20]. 96 hour exposure to sub lethal concentration of Chlorpyrifos inhibits the acetylcholinesterase activity resulting in behavioral changes in *Gambusia affinis* [15] and also exposure to higher concentration of Chlorpyrifos causes upto 66% acetylcholinesterase inhibition in *Poecila reticulates*

[14]. The acetylcholinesterase, play an important part in neurotransmission of both central nervous system and neuro-muscular junction. Chlorpyrifos causes a significant inhibition of resulting in behavioral changes in *Gambusia affinis.* A decrease was noted due to exposure to chlorpyrifos in the concentration of acetylcholinesterase in muscle in common carp [21], in milkfish [22]

3. Biochemical alteration:

Pesticide causes serious physiological changes. So, regular biochemical tests are very useful to determine the toxicity of insecticides. Chlorpyrifos exposure increases serum triglyceride, AST, LDH, CK with hyperglycemia in *Cyprinus carpio*[23]. Padmini and Rajaram's experiment on *Channa gachua* showed that chlorpyrifos exposure decreases the level of glycogen, protein and lipid in liver and kidney in comparison with control [24]. Exposure to a certain level of chlorpyrifos resulted a altered protein profile of liver tissue of *Carassius auratus* [25]. Khan and Sharma studied that sub lethal concentration of chlorpyrifos exposure showed increased activity of acid phosphatase and alkaline phosphatase in the tissues of kidney and liver [26]. Total protein, amino acid, ammonia contents was decreased in all the tissues of gill, liver, kidney and muscle but elevated alaine, protease, alkaline phosphatase was noted in the different tissues due to exposure to sub lethal concentration of chlorpyrifos by Reddy et.al [27]. It was reported that chlorpyrifos exposure inhibits the LDH activities in different tissues of fish by Tripathi and Shasmal [28]. Alteration in proteins was observed in *Labeo rohita* by the exposure of chlorpyrifos for 2 days [29] and maximum depletion of protein was observed in head. 96h exposure to lethal concentration of chlorpyrifos causes as elevation in lipid peroxidation level in *Gambusia affinis* [25].

4. Hematological changes:

It is observed that chlorpyrifos also affect the hematological parameter of non target aquatic organism including fishes. So, hematological parameters are very important for environmental monitoring and stress in toxicological research [30]. Chlorpyrifos exposure causes significant changes in erythrocyte sedimentation rate (ESR) in *Channa punctatus* [31]. Sub lethal concentration of chlorpyrifos can decrease the erythrocyte, leukocyte count, haemoglobin and haematocrit value of *Channa punctatus* [32].

5. Histopathological alteration:

It was proven by many researchers that chlorpyrifos significantly affect the fish body. So in bio monitoring process of the health of the fishes of aquatic ecosystem, histopathology test is a cost effective tool [33]. It was observed that chlorpyrifos exposure alters the structure of gills with epithelial hypertrophy, oedema, and the liver tissue with vacuolization, fatty infiltration and altered nuclei of *Cyprinus carpio* [34]. Similar altered histopathology of gill, liver and kidney was observed in common carp by pal et.al [35].Chlorpyrifos exposure causes alteration in liver with vacuolization and more sinusoid spaces of *Danio rerio* [36]. Devi and Mishra also studied that sub lethal concentration of chlorpyrifos changes the histopathology of gill tissue and liver tissue of *Channa punctatus* [37]. Constricted glomeruli with wide urinary space were noted in Nile Tilapia by the 21 days exposure to chlorpyrifos [38].

6. Endocrine dysfunction:

Chlorpyrifos causes alteration in the endocrine system like other physiological system of fish body. Khatun et.al reported that chlorpyrifos exposure significant decrease in serum T3, T4 and TSH of *Heteropneustes fossilis* causing impaired thyroid function [39]. Cortisol level in *Oreochromis niloticus* after exposure to chlorpyrifos was also found lower than the control [40]. 21 days exposure to chlorpyrifos of *Heteropneustes fossilis*, prolactin cells showed slight degranulation but after 28 days it exhibited degranulation [41].

7. Immunological changes:

Immune system is very important for defense against harmful pathogen. But insecticides can alter the immune system. Wang et.al reported that chlorpyrifos exposure can alter the mRNA levels of IL-1β and IFN- γ2b in immune organ of common carp [42]. Chlorpyrifos exposure decreases the IgM concentration of plasma of *Oreochromis niloticus* [43].

8. Genotoxicity:

The genotoxic properties of chlorpyrifos were contradictory in the past century. But now it is proven that most of the inscticides has genotoxic property with a potential of damage DNA, potential of neoplasia formation and also has bad

impact on vitality and progeny of aquatic animal. Chlorpyrifos exposure causes nuclear anomalies in blood cell of *Cirrhinus mrigala* and also alteration in cell morphology [44]. It is also observed in the micronuclei assay that abnormalities increased with the increase of chlorpyrifos in *Chanos chanos* [22]. Ali et.al studied that chlorpyrifos exposure causes micronuclei induction with DNA damage in *Channa punctatus* [45].

9. Developmental changes:

Many studies showed that pesticides exposure causes alteration in developmental biology of fishes. It was observed that sub lethal concentration of chlorpyrifos affects the development potential in *Danio rerio* [46]. Eddins et.al observed that chlorpyrifos exposure causes reduction in swimming capacity, response latency and impaired learning in zebra fish [47]. It was also observed that sub chronic dose of this pesticide (1µM) can affect post fertilization body morphology of Zebra fish [48].

10. Oxidative stress:

Oxidative stress is a tool of measurement of possible pesticide induced toxicity and this tool play an important role in toxicological research [49]. Antioxidant defense system is very essential for protection of biomolecule from adverse effect reactive oxygen species. Fish are capable to neutralize the effect of reactive oxygen species. If reactive oxygen species cannot be controlled by antioxidant defense system, it will target membrane lipid which undergo peroxidation [9]. In *Gambusia affinis*, an elevated peroxidation level was observed after 96 hour chlorpyrifos exposure [15].

V. CONCLUSION

It is observed in this present review that chlorpyrifos can affect the aquatic organism in several ways. This agricultural runoff pesticide directly affects the non-target fresh water fish. Different concentration of Chlorpyrifos can significantly damage the fish physiology and also reduce life span of fish fauna. Especially long term exposure can cause several and serious abnormalities. So, fish fauna are under direct threat of this highly toxic pesticide. Beside, fish is also a very useful experimental tool for monitoring the pollutant level and physicochemical properties of water body. So, biochemical, hematological and histopathological changes of fish can be used for evaluation of toxicological impact of chlorpyrifos.

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