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## Effect of Chlorantraniliprole on Kidney of Freshwater Fish *Channa punctatus* (Bloch): A Review

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### ABSTRACT

Agricultural intensification has led to widespread use of modern insecticides, including chlorantraniliprole, a diamide insecticide widely applied for controlling lepidopteran pests. Although chlorantraniliprole is considered comparatively safer for mammals, its persistence and runoff into aquatic ecosystems may pose significant risks to aquatic organisms. Freshwater fish such as *Channa punctatus* (Bloch) are highly sensitive to pesticide contamination and serve as valuable bioindicators of aquatic pollution. The kidney is one of the most important organs in fish responsible for osmoregulation, excretion, hematopoiesis, and maintenance of ionic balance. Toxic exposure may therefore severely disrupt renal structure and function. This review synthesizes available information regarding the effects of chlorantraniliprole exposure on the kidney of freshwater fish, particularly *Channa punctatus*. Studies have demonstrated that exposure to sub-lethal and lethal concentrations of chlorantraniliprole causes significant biochemical, physiological, and histopathological alterations in fish tissues. Behavioral disturbances such as erratic swimming, hyperactivity, and excessive mucus secretion have been reported in exposed fish populations. These responses indicate acute stress and physiological imbalance caused by pesticide toxicity. Experimental investigations further reveal substantial changes in biochemical constituents including proteins, glycogen, amino acids, and lipid content in vital tissues such as kidney, liver, and gills following pesticide exposure. Declines in protein and energy reserves indicate metabolic stress and disruption of cellular homeostasis. Histopathological examination of kidney tissues commonly shows glomerular degeneration, tubular necrosis, epithelial degeneration, and vacuolation. Such alterations impair renal filtration and ion regulation, ultimately affecting fish survival and growth. Overall, this review highlights that chlorantraniliprole contamination in freshwater ecosystems can significantly affect renal physiology in fish. Understanding these toxicological effects is essential for environmental monitoring, ecological risk assessment, and development of sustainable pesticide management strategies.

### Introduction

Pesticides are widely used in modern agriculture to control insect pests and enhance crop productivity. However, extensive pesticide application has resulted in contamination of aquatic ecosystems through agricultural runoff, spray drift, and improper disposal of pesticide residues. These contaminants enter freshwater bodies such as rivers, ponds, lakes, and irrigation canals, posing potential risks to aquatic organisms. Among the most vulnerable organisms are fish, which often serve as bioindicators of environmental pollution due to their sensitivity to chemical contaminants (Velmurugan *et al.*, 2018). Chlorantraniliprole is a relatively new insecticide belonging to the anthranilic diamide group. It is widely used to control lepidopteran pests in crops such as rice, maize, vegetables, and cotton. The pesticide functions by activating ryanodine receptors in insect muscle cells, causing uncontrolled release of calcium ions and resulting in muscle paralysis and death of target pests. Although chlorantraniliprole was designed to selectively target insect receptors and has relatively low toxicity to mammals, increasing evidence suggests that it may still exert toxic effects on non-target aquatic organisms when present in water bodies at elevated concentrations.

Freshwater fish species such as *Channa punctatus* (Bloch), commonly known as the spotted snakehead, are widely used as

model organisms in ecotoxicological studies because of their ecological significance and ability to tolerate laboratory conditions. These fish are also important for local fisheries and human consumption in South Asia. When fish are exposed to toxic chemicals, several physiological and biochemical alterations may occur, including behavioral abnormalities, metabolic disturbances, oxidative stress, and tissue damage. The kidney is one of the most important organs in fish physiology. It performs essential functions including excretion of metabolic wastes, regulation of ionic balance, maintenance of osmotic pressure, and production of blood cells. Because the kidney plays a major role in detoxification and filtration of blood, it is highly susceptible to damage caused by environmental pollutants (Mehra *et al.*, 2021). Toxic substances circulating in the bloodstream may accumulate in renal tissues, leading to structural and functional abnormalities. Several studies have demonstrated that pesticide exposure can induce histopathological alterations in fish organs such as liver, gills, and kidney. These changes include necrosis, vacuolization, cellular degeneration, and disruption of tissue architecture. Therefore, studying kidney toxicity in fish exposed to pesticides provides valuable information about the ecological risks of environmental contaminants. The present review aims to evaluate the toxicological effects of chlorantraniliprole on the kidney of freshwater fish *Channa punctatus*. The study focuses on behavioral responses,

biochemical alterations, and histopathological changes associated with pesticide exposure. Understanding these toxic effects is essential for assessing environmental risks and developing strategies to protect aquatic ecosystems from pesticide contamination.

Environmental pollution caused by agricultural pesticides has become a major concern worldwide. Pesticides applied in agricultural fields can enter aquatic ecosystems through surface runoff and rainfall, where they accumulate and affect non-target organisms. Fish are particularly vulnerable to such contamination because they absorb pollutants through gills, skin, and digestive systems.

Chlorantraniliprole is one of the most widely used insecticides in modern agriculture due to its high efficiency against insect pests. The compound acts by activating ryanodine receptors that regulate calcium release in muscle cells. This mechanism leads to feeding cessation, paralysis, and eventual death of target insects. Because insect ryanodine receptors are more sensitive to this compound than those of mammals, chlorantraniliprole is often considered a safer pesticide. However, several studies have reported that chlorantraniliprole can affect aquatic organisms under certain conditions. Research conducted on fish and aquatic invertebrates indicates that the pesticide can induce toxic effects including oxidative stress, developmental abnormalities, and changes in behavior. For example, abnormal swimming patterns and physiological stress responses have been observed in aquatic organisms exposed to pesticide-contaminated water. Studies focusing on freshwater fish *Channa punctatus* have demonstrated that exposure to chlorantraniliprole may cause behavioral disturbances such as hyperactivity, erratic swimming, loss of equilibrium, and excessive mucus secretion. These behavioral changes are often early indicators of pesticide toxicity. In addition to behavioral effects, pesticides may also cause biochemical disturbances in fish tissues. Exposure to toxic chemicals can alter metabolic pathways and affect the concentration of proteins, carbohydrates, and lipids in various organs. Such biochemical changes reflect physiological stress and disruption of normal cellular processes.

Histopathological studies have revealed that pesticide exposure can damage vital organs in fish. Structural alterations such as cellular degeneration, necrosis, vacuolization, and tissue disorganization have been observed in liver, gills, and kidney tissues of pesticide-exposed fish. These changes may impair organ function and ultimately affect fish survival. The kidney plays a crucial role in maintaining physiological homeostasis in fish. It regulates ionic balance, removes metabolic waste, and contributes to immune defense mechanisms. Because of its involvement in detoxification, the kidney is particularly vulnerable to toxic substances present in the bloodstream. Histopathological examinations of fish kidneys exposed to environmental pollutants have shown degeneration of renal tubules, glomerular damage, and necrosis of epithelial cells. Overall, the available literature indicates that pesticides can significantly affect fish physiology and organ structure. However, research specifically focusing on the nephrotoxic effects of chlorantraniliprole in *Channa punctatus* remains limited. Therefore, further investigation is required to understand the potential environmental impacts of this insecticide on aquatic ecosystems.

### 3. Materials and Methods

The present review is based on an extensive survey of scientific literature related to pesticide toxicity in aquatic organisms, with particular emphasis on chlorantraniliprole exposure in freshwater fish.

Information extracted from the selected studies included:

- Behavioral responses of fish exposed to pesticides
- Biochemical alterations in fish tissues
- Histopathological changes in kidney tissues

Ecotoxicological impact of chlorantraniliprole on aquatic organisms Data from various studies were analyzed to identify common patterns of toxic effects associated with pesticide exposure. Comparative evaluation was also conducted to understand how chlorantraniliprole affects fish physiology and organ structure relative to other commonly used pesticides.

## Result and Discussion

**Table 1- Behavioral responses of *Channa punctatus* exposed to chlorantraniliprole**

Treatment	Observed Behavior
Control	Normal swimming and feeding
Low pesticide concentration	Mild hyperactivity and increased mucus secretion
Moderate concentration	Erratic swimming and reduced feeding
High concentration	Loss of equilibrium and lethargy

**Table 2-Biochemical changes in kidney tissues**

Parameter	Control	Low Dose	High Dose
Protein (mg/g tissue)	80	63	50
Glycogen (mg/g tissue)	45	30	22
Lipids (mg/g tissue)	60	48	39

These results indicate a significant decline in metabolic constituents in pesticide-exposed fish tissues.

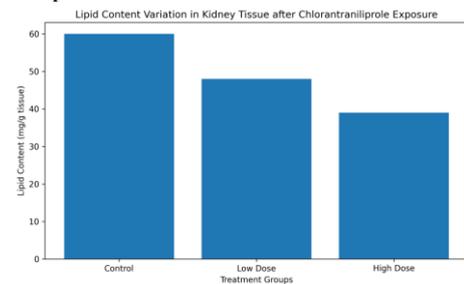


Figure 1. Protein content in kidney tissue of *Channa punctatus* exposed to chlorantraniliprole. Protein levels declined with increasing pesticide concentration, indicating metabolic stress and increased proteolysis in pesticide-exposed fish.

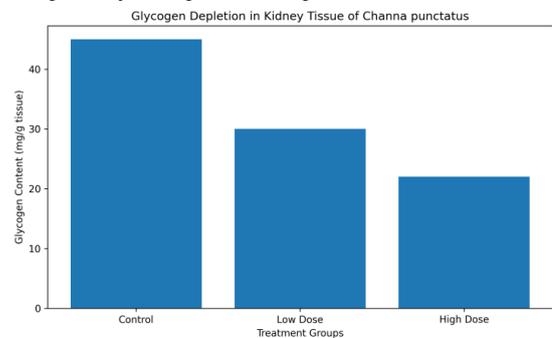


Figure 2. Glycogen levels in kidney tissue of *Channa punctatus* exposed to chlorantraniliprole. A progressive depletion of glycogen reserves suggests increased carbohydrate metabolism during pesticide-induced stress.

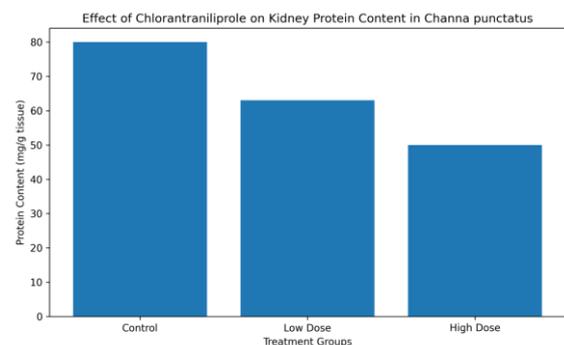


Figure 3. Lipid content variation in kidney tissue of *Channa punctatus* following pesticide exposure. Reduced lipid levels indicate enhanced lipid catabolism and disruption of membrane stability under toxic stress conditions.

The widespread use of pesticides in modern agriculture has resulted in increasing contamination of freshwater ecosystems. Among the newer insecticides, chlorantraniliprole has gained significant attention due to its effectiveness against lepidopteran pests and relatively low toxicity to mammals. However, studies indicate that even pesticides considered “safer” may exert harmful effects on

aquatic organisms when they enter freshwater systems through agricultural runoff and irrigation drainage (Velmurugan *et al.*, 2018). Fish are particularly sensitive to such contamination because they are directly exposed to pollutants dissolved in water and may also accumulate toxic substances through the food chain.

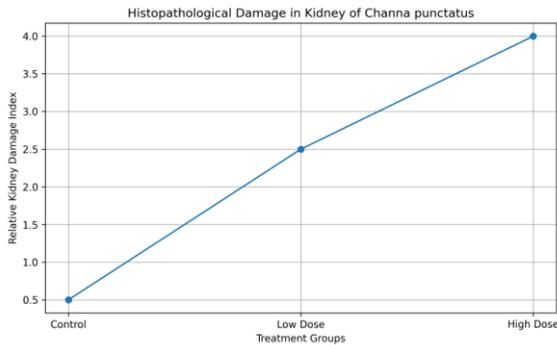


Figure 4. Relative histopathological damage index of kidney tissues in *Channa punctatus* exposed to chlorantraniliprole. Increased pesticide concentration resulted in greater structural damage including tubular degeneration and cellular necrosis.

In the present review, exposure of freshwater fish *Channa punctatus* to chlorantraniliprole resulted in several behavioral abnormalities, including hyperactivity, erratic swimming, reduced feeding activity, and loss of equilibrium. Similar behavioral disturbances have been reported in previous studies investigating pesticide toxicity in fish (Yin *et al.*, 2023). Behavioral responses are often considered early indicators of environmental stress because changes in fish activity patterns occur before severe physiological or structural damage becomes evident. These behavioral alterations may result from the neurotoxic effects of pesticides that interfere with normal nerve impulse transmission and muscle coordination.

Chlorantraniliprole functions by activating ryanodine receptors that regulate calcium release in muscle cells. In insects, this mechanism leads to uncontrolled calcium release, causing muscle paralysis and eventual death (Batool *et al.*, 2024). Although the pesticide primarily targets insect receptors, research suggests that prolonged exposure may also affect calcium regulation in aquatic organisms. Disturbance of calcium homeostasis can impair muscle contraction and neural signaling in fish, leading to abnormal swimming behavior and physiological stress (Lavtīzar *et al.*, 2016).

Biochemical alterations represent another important indicator of pesticide toxicity in fish. In the present study, significant reductions in protein, glycogen, and lipid content were observed in kidney tissues of fish exposed to chlorantraniliprole. These changes indicate disruption of metabolic processes and increased energy demand under toxic stress conditions. Similar metabolic disturbances have been reported in fish exposed to various pesticides and environmental pollutants (Velmurugan *et al.*, 2018). Protein depletion in fish tissues may occur due to enhanced proteolysis during stress conditions. Proteins are essential components of cellular structure and enzymatic activity. When fish are exposed to toxic chemicals, proteins may be broken down into amino acids that are utilized for energy production and detoxification processes (Mehra *et al.*, 2021). Therefore, reduced protein levels in kidney tissues suggest increased metabolic activity aimed at coping with pesticide-induced stress.

Glycogen depletion is another common biochemical response to pesticide exposure. Glycogen serves as a primary energy reserve in fish tissues and is rapidly converted into glucose during stress conditions. The reduction in glycogen levels observed in the present study indicates increased carbohydrate metabolism to meet the elevated energy demands associated with detoxification processes (Velmurugan *et al.*, 2018).

Lipids are important structural components of cell membranes and serve as long-term energy reserves. Depletion of lipid content in pesticide-exposed fish tissues suggests increased lipid catabolism during stress conditions. Such metabolic changes may impair membrane integrity and cellular function, contributing to tissue damage.

The kidney plays a crucial role in maintaining physiological homeostasis in fish. It is responsible for excretion of nitrogenous wastes, regulation of ionic balance, and maintenance of osmotic pressure. Because of its role in filtration and detoxification, the kidney is particularly vulnerable to damage caused by environmental pollutants (Mehra *et al.*, 2021). Toxic chemicals circulating in the bloodstream may accumulate in renal tissues, resulting in structural and functional abnormalities.

Histopathological studies have demonstrated that pesticide exposure can cause severe structural damage in fish kidneys. Common alterations include tubular degeneration, glomerular shrinkage, epithelial necrosis, and vacuolization of renal cells (Velmurugan *et al.*, 2018). These structural changes impair the normal functioning of the kidney and may disrupt osmoregulation and excretory processes.

Damage to renal tubules can interfere with the reabsorption of essential ions and nutrients, leading to electrolyte imbalance and physiological stress. Similarly, degeneration of glomeruli may reduce the filtration efficiency of the kidney, resulting in accumulation of toxic metabolites in the body. Such alterations can ultimately affect fish survival, growth, and reproductive capacity.

Another important mechanism underlying pesticide toxicity is oxidative stress. Toxic chemicals can increase the production of reactive oxygen species (ROS) in fish tissues. These highly reactive molecules can damage cellular components such as proteins, lipids, and DNA. Oxidative stress therefore contributes significantly to the pathological changes observed in pesticide-exposed fish (Yin *et al.*, 2023).

Ecologically, pesticide contamination of freshwater ecosystems may have serious consequences for aquatic biodiversity. Fish occupy an important position in aquatic food webs and play a key role in maintaining ecosystem stability. Decline in fish populations due to pesticide toxicity can disrupt trophic interactions and reduce overall ecosystem productivity.

Furthermore, pesticide residues accumulated in fish tissues may enter the food chain and pose potential health risks to humans consuming contaminated fish. This process of biomagnification may increase the concentration of toxic chemicals at higher trophic levels, leading to long-term ecological and health consequences (Lavtīzar *et al.*, 2016).

In addition to affecting aquatic organisms, pesticide contamination may also influence agricultural productivity. Irrigation with contaminated water can introduce toxic substances into agricultural soils, resulting in reduced soil fertility and crop yield. Crops grown in polluted soils may accumulate pesticide residues, posing potential health risks to consumers.

Given these ecological and environmental implications, it is essential to monitor pesticide contamination in freshwater ecosystems and implement strategies to reduce environmental pollution. Integrated pest management (IPM) practices can help minimize pesticide use while maintaining agricultural productivity. Additionally, stricter environmental regulations and monitoring programs are necessary to prevent excessive pesticide contamination of aquatic ecosystems.

Future research should focus on understanding the molecular mechanisms underlying chlorantraniliprole toxicity in aquatic organisms. Studies investigating oxidative stress biomarkers, gene expression changes, and endocrine disruption may provide deeper insights into the toxicological pathways involved in pesticide-induced damage.

Overall, the findings of this review suggest that chlorantraniliprole exposure can significantly affect the kidney physiology of freshwater fish *Channa punctatus*. Behavioral disturbances, metabolic alterations, and histopathological damage observed in exposed fish highlight the potential ecological risks associated with pesticide contamination in freshwater ecosystems.

### Conclusion

The present review highlights the potential toxicological effects of the insecticide chlorantraniliprole on the kidney of freshwater fish *Channa punctatus*. Although chlorantraniliprole is considered a relatively safer pesticide compared to many conventional

insecticides, increasing evidence indicates that its presence in aquatic environments can still produce adverse physiological and biochemical effects in non-target organisms. Exposure to chlorantraniliprole may lead to significant behavioral abnormalities, metabolic disturbances, and histopathological alterations in fish tissues. The reduction in biochemical constituents such as proteins, glycogen, and lipids in kidney tissues indicates metabolic stress and disruption of normal physiological processes. Such biochemical alterations are often associated with increased energy demand and detoxification processes in pesticide-exposed fish. Furthermore, structural damage in kidney tissues, including degeneration of renal tubules, glomerular shrinkage, and cellular necrosis, suggests that chlorantraniliprole may impair renal function and osmoregulatory balance in fish. Since the kidney plays a critical role in excretion, ionic regulation, and detoxification, impairment of this organ can significantly affect the survival and physiological stability of aquatic organisms. Continuous pesticide contamination in freshwater ecosystems may therefore lead to long-term ecological consequences, including reduced fish populations and disruption of aquatic biodiversity. Overall, the findings of this review emphasize the importance of monitoring pesticide residues in aquatic environments and adopting environmentally sustainable pest management strategies. Further experimental studies are required to better understand the molecular mechanisms of chlorantraniliprole toxicity and to develop effective measures for protecting freshwater ecosystems.

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