Biospectra : ISSN: 0973-7057, Vol. 18(2), September, 2023, pp. 35-40
An International Biannual Refereed Journal of Life Sciences

Animal Science

ISSN : 0973-7057

Effects of imidacloprid on biochemical and hematological parameters in *Cirrhinus mrigala*: An updated review

Wasim Raza[a], Nirmala Tripathi[b], Dipa Mahato[c] & Harishankar Mahto[d]*

[a]Department of Zoology, Sahibganj College, SKM University, Dumka, Jharkhand, India

[b]University Department of Zoology, SKM University, Dumka, Jharkhand, India

[c]Biology Division, State Forensic Laboratory, Ranchi, Jharkhand, India

[d]Department of Zoology, St. Paul's College, Ranchi University, Ranchi, Jharkhand, India

Received : 05rd May, 2023 ; Revised : 07th June, 2023

DOI:-https://doi.org/10.5281/zenodo.11909533

Abstract- The use of pesticides in agricultural practices has raised concerns about their impact on aquatic ecosystems, including the health of aquatic organisms such as fish. Imidacloprid, a widely utilized neonicotinoid insecticide, has garnered substantial attention due to its potential environmental implications. This review delves into the multifaceted effects of Imidacloprid on the biochemical and hematological parameters of *Cirrhinus mrigala*, a prominent freshwater fish species. The aquatic ecosystem's delicate balance is significantly impacted by the widespread use of this pesticide in agriculture. As such, understanding its effects on aquatic organisms, such as *Cirrhinus mrigala*, is paramount. We discuss the various routes through which Imidacloprid infiltrates aquatic ecosystems, highlighting its sources and its persistence in water bodies. Imidacloprid's presence in these environments exposes aquatic organisms to a spectrum of toxicological challenges. Subsequently scrutinize the specific effects on biochemical and hematological parameters. Biochemically, Imidacloprid exposure disrupts enzyme activity, notably acetylcholinesterase, and induces oxidative stress through lipid peroxidation and altered antioxidant enzyme levels. Imidacloprid also impacts metabolic parameters, such as glucose levels, and leads to histopathological changes in fish tissues. Hematologically, the insecticide results in deviations in hematocrit and hemoglobin levels, alterations in red and white blood cell counts, and changes in erythrocyte morphology. The review further probes into the broader ecological consequences of Imidacloprid contamination. This entails effects on fish populations, disruptions in food chains, and potential consequences for ecosystem health. In summary, this comprehensive review underscores the need for a deeper understanding of the effects of Imidacloprid on biochemical and hematological parameters in *Cirrhinus mrigala.* The intricate web of interactions between this pesticide and fish health, coupled with its broader ecological ramifications, highlights the importance of responsible pesticide management in safeguarding aquatic ecosystems and the organisms that inhabit them.

Key words: Imidacloprid, *Cirrhinus mrigala*, Hematological, Biochemical, Ecological

INTRODUCTION

Imidacloprid is a widely used insecticide known for its effectiveness in pest control.[1] It was first introduced in the 1990s and has since become one of the most commonly used insecticides globally. Imidacloprid belongs to a class of chemicals called neonicotinoids, which act on the nervous systems of insects by targeting their nicotinic acetylcholine receptors.[2] It is a synthetic chemical compound with a molecular structure that closely resembles nicotine. This similarity allows it to disrupt the nervous system of insects. Primarily it affects insects by

*Corresponding author :
Phone : 7250994887
E-mail : harry.keshaw@gmail.com

binding to nicotinic acetylcholine receptors in their nervous systems, leading to overstimulation, paralysis, and ultimately, death.[3] It has a relatively low toxicity to humans and vertebrates due to differences in receptor sensitivity.[4]

The pesticide is used to control a wide range of insect pests in agriculture, horticulture, and forestry. It is also utilized in pest management for ornamental plants, turf, and on pets to control fleas and ticks.[5,6] When applied to plants, it can be taken up by the plant's roots and distributed throughout the tissues, providing long-lasting protection against insects that feed on these plants. This pesticide is often used as a seed treatment, protecting the emerging seedlings from below-ground insect pests. This application method reduces the need for foliar sprays and minimizes environmental exposure.[7,8]

Because of its systemic nature and relatively low environmental persistence, Imidacloprid is considered to be more environmentally friendly compared to some older pesticides. However, it's not without its ecological concerns, especially when it enters water bodies.[9,10] Over time, concerns about the impact of Imidacloprid, on non-target organisms, particularly pollinators like bees, have led to regulatory restrictions and bans in some regions. These actions reflect the need to balance the benefits of pest control with potential environmental risks. Due to concerns over Imidacloprid's environmental impact, there is a growing interest in developing and promoting alternative pest management strategies, such as integrated pest management (IPM) and the use of biological controls.[11] Imidacloprid's effectiveness in pest control and its systemic action have made it a valuable tool in agriculture and horticulture. However, its use is subject to ongoing scrutiny and regulation, reflecting the need to balance pest control needs with environmental protection and safety considerations.[12]

The study on effects of Imidacloprid on aquatic organisms is of paramount importance. Aquatic ecosystems are critical components of the environment.[13] They support diverse flora and fauna, including fish, amphibians, invertebrates, and aquatic plants. Disruption of these ecosystems can have far-reaching consequences, affecting biodiversity and ecological balance.[14] Imidacloprid can enter aquatic environments through runoff from agricultural fields or other sources. In aquatic food chains, pesticides like Imidacloprid can biomagnify, meaning that they become more concentrated as they move up the food chain. Predatory fish at the top of the chain can accumulate higher levels of the pesticide, potentially posing risks to both wildlife and humans that consume contaminated fish.[15,16] This pesticide is designed to target specific insect pests, but it can also affect non-target species, including aquatic organisms such as insects, crustaceans, and fish.[17] Understanding the potential harm to non-target species is crucial for safeguarding the overall health of aquatic ecosystems. Such Pesticides in water bodies can degrade water quality and may alter the chemical composition of water, affecting its suitability for aquatic life.[18-20] Moreover, they can lead to the growth of harmful algae (eutrophication) due to their impact on nutrient cycles.[21,22] This bioaccumulation can result in chronic exposure, leading to adverse effects on growth, reproduction, and overall health. As a key component of aquatic food chains, fish play a central role in transferring energy from lower trophic levels to higher ones. Imidacloprid's impact on fish can disrupt the food web, affecting populations of other species that rely on these fish as a food source.[23] Humans are part of the ecosystem too, and many communities rely on aquatic environments for sustenance and livelihoods. If Imidacloprid and other pesticides contaminate aquatic food sources, there can be direct and indirect health consequences for human populations.[16,24]

Cirrhinus mrigala, commonly known as the mrigala or mrigal carp, is a species of freshwater fish that is ecologically significant in many regions.[25] It plays a crucial role in the food web of aquatic ecosystems, often serving as both predator and prey. This fish is widely distributed in freshwater bodies across Asia, particularly in countries like India and Pakistan.[26,27] Its abundance and widespread distribution make it an accessible and representative model species. This fish species has economic significance in many regions. It is often harvested for human consumption and forms an integral part of local fisheries. *Cirrhinus mrigala*, are considered indicator species. These species are sensitive to environmental changes and can act as early warning signals for ecological disturbances.[28] Using this fish as a model species allows for meaningful comparisons with the responses of other aquatic organisms to Imidacloprid.

IMIDACLOPRID EXPOSURE IN AQUATIC ECOSYSTEMS

The most significant source of Imidacloprid contamination in water bodies is agricultural runoff, leaching, seed treatment, urban & residential use. Farmers often apply this pesticide to crops in the form of sprays or soil treatments to protect them from insect pests.[29,30] When it rains or irrigation occurs, the pesticide can be washed off fields and enter nearby streams, rivers, and groundwater. This runoff can carry Imidacloprid and its residues into larger water bodies and accumulated in water bodies as well as aquatic organisms too.[9]

BIOCHEMICAL PARAMETERS

Imidacloprid leads to a significant reduction in AChE activity in Mrigala fish. Acetylcholinesterase is crucial for terminating nerve signals at cholinergic synapses by hydrolyzing the neurotransmitter acetylcholine.[31,32] Imidacloprid acts as an agonist at nicotinic acetylcholine receptors (nAChRs), which are present not only in insects but also in vertebrates, including fish.[17] Imidacloprid binds to nAChRs in the fish's nervous system, leading to excessive stimulation, which can ultimately result in the downregulation of AChE production or direct inhibition of AChE activity. The inhibition of AChE by Imidacloprid results in the accumulation of acetylcholine at nerve synapses, leading to continuous nerve stimulation, paralysis, and, ultimately, the death of the fish.[33]

Histopathological examination of fish tissues is a valuable tool for assessing the impact of environmental stressors, such as pesticide exposure, on the health and integrity of aquatic organisms like Mrigala. Imidacloprid has been shown to induce histopathological changes in the tissues of fish.[34,35] Previous studies observed histopathological changes in Mrigala fish affected by Imidacloprid exposure and their potential implications for the health of these aquatic organisms. Understanding these effects is essential for evaluating the environmental impact of Imidacloprid and for implementing measures to mitigate its potential harm to aquatic ecosystems.

HEMATOLOGICAL PARAMETERS

Imidacloprid exposure can lead to a decrease in the hematocrit, hemoglobin, Red Blood Cell (RBC) levels as well as also affects Hematological Indices; increase in Mean Corpuscular Volume (MCV) & either an increase or decrease Mean Corpuscular Hemoglobin (MCH) in fish.[36,37] Hematocrit is the proportion of blood volume occupied by red blood cells. Reduced hematocrit & hemoglobin & RBC levels can be indicative of anemia and oxygen deprivation. Further, excess exposure of the pesticide can also lead to alteration in WBC levels, which can impair the immunity of fish.[38]

MECHANISMS OF IMIDACLOPRID TOXICITY

The observed biochemical and hematological changes in Mrigala fish due to imidacloprid toxicity can be attributed to several interconnected mechanisms. Imidacloprid primarily affects the nervous system of both target pests and non-target organisms. However, these neurotoxic effects can have cascading physiological and biochemical impacts on fish.[17]

Imidacloprid's primary mode of action is its binding to nicotinic acetylcholine receptors (nAChRs) in the nervous system. This leads to prolonged stimulation of neurons, resulting in over excitation and paralysis in insects. The overstimulation of the nervous system triggers a stress response in fish. Stress hormones, such as cortisol, are released in response to the perceived threat. This stress response can impact various physiological processes.[39] Further, Acetylcholinesterase (AChE) is inhibited by imidacloprid, acetylcholine accumulates at nerve synapses, causing prolonged nerve stimulation.[4] This can result in impaired muscle control, altered respiration, and changes in responsiveness to stimuli.

ECOLOGICAL IMPLICATIONS

Imidacloprid is highly water-soluble and can enter aquatic systems through runoff from agricultural fields or other applications. It can directly harm aquatic invertebrates, such as insects and crustaceans that play crucial roles in aquatic food chains. This can disrupt the balance of the ecosystem.[17] The pesticide and its metabolites can contaminate surface waters. The persistence of these chemicals can lead to long-term exposure for aquatic organisms. Prolonged contamination can negatively affect water quality and aquatic life. It can also bioaccumulate in aquatic organisms, particularly in long-lived species like fish.[40] This bioaccumulation can lead to high concentrations of the pesticide in top predators, which can have cascading ecological effects.

Its contamination in water can impact the primary producers, such as algae and aquatic plants. Changes in the composition and abundance of these primary producers can influence oxygen levels in the water.[21] Altered primary producer communities and the decomposition of dead plant matter can lead to oxygen depletion in water bodies. This, in turn, can harm fish and other aquatic organisms that depend on oxygen-rich waters. The impacts of Imidacloprid on aquatic organisms can alter the community structure of aquatic ecosystems. The loss of certain species or the proliferation of others can disrupt the balance of the ecosystem and lead to biodiversity loss.[18,41]

The environmental impact of Imidacloprid on aquatic ecosystems extends well beyond its intended target pests. It can disrupt food webs, water quality, and ecosystem dynamics, leading to biodiversity loss and long-term ecological consequences.[42] Recognizing these impacts is critical for making informed decisions about the use of neonicotinoid insecticides and implementing strategies to mitigate their harm to aquatic ecosystems.

REGULATORY CONSIDERATIONS

In many countries, pesticides like Imidacloprid must undergo a rigorous registration and approval process before they can be used.[43] This process typically involves safety assessments, including assessments of their environmental impact on aquatic ecosystems and maximum Residue Limits (MRLs) for Imidacloprid in water and aquatic organisms.[44] These limits specify the maximum allowable concentrations of the pesticide in water bodies and aquatic organisms to minimize environmental contamination.

It's important to note that the regulatory landscape is dynamic, and measures may change based on new scientific findings and evolving environmental concerns. Therefore, it is essential for users, farmers, and regulatory agencies to stay informed about the latest guidelines and regulations related to Imidacloprid use in the context of aquatic ecosystems. Compliance with these measures is crucial to minimize the environmental impact of this pesticide and protect aquatic life.

MITIGATION AND FUTURE DIRECTIONS

Mitigating the effects of Imidacloprid contamination in water bodies is crucial to protect aquatic ecosystems and their inhabitants. Various strategies can be employed to reduce or prevent the adverse impacts of this neonicotinoid pesticide.[45] Integrated Pest Management (IPM) practices that focus on the minimal and targeted use of pesticides, including Imidacloprid. IPM emphasizes a holistic approach to pest control, which may involve biological control, cultural practices, and the careful selection of chemical treatments.[46] Reduce overall pesticide use, including Imidacloprid, through the adoption of alternative pest management techniques. This can include the use of pest-resistant crop varieties and crop rotation to decrease pest pressure. Explore the use of alternative pesticides with lower environmental impact. Some alternatives may have a narrower spectrum of activity and pose fewer risks to non-target organisms.[47]

CONCLUSION

The study on the effects of Imidacloprid on biochemical and hematological parameters in *Cirrhinus mrigala* has yielded several key findings that provide important insights into the potential impacts of this widely used neonicotinoid insecticide on aquatic organisms. Alterations in various biochemical parameters in *Cirrhinus mrigala* following exposure to Imidacloprid. Notably, there were changes in liver function markers such as increased levels of alanine aminotransferase (ALT) and aspartate aminotransferase (AST), indicating potential liver damage. This is particularly concerning as the liver is a vital organ for detoxification and metabolic processes in fish. Resulted in significant hematological changes in *Cirrhinus mrigala*. The reduction in red blood cell count (RBC) and hemoglobin (Hb) levels may have implications for the fish's oxygen-carrying capacity, which can ultimately affect their overall health and survival.

The effects of Imidacloprid on *Cirrhinus mrigala* demonstrates the profound consequences of pesticide contamination in aquatic environments. These findings emphasize the importance of sustainable agricultural practices, stringent pesticide regulations, and continued research to better understand and address the ecological and health implications of pesticide exposure in aquatic organisms. In summary, understanding the impact of pesticides on aquatic organisms is not just a matter of environmental concern; it is a multidisciplinary imperative that encompasses environmental, human health, economic, and regulatory considerations. A comprehensive understanding of these impacts is essential for preserving the health and integrity of aquatic ecosystems and, by extension, the well-being of our planet and its inhabitants.

REFERENCES

1. **Sheets L. P. 2010.** Imidacloprid: a neonicotinoid insecticide. Hayes' handbook of pesticide toxicology, *Elsevier*: 2055-2064.
2. **Klingelhofer, D., M. Braun, *et al.* 2022.** Neonicotinoids: A critical assessment of the global research landscape of the most extensively used insecticide. *Environmental Research* **213:** 113727.
3. **Anadon A., I. Ares *et al.* 2020.** Neurotoxicity of neonicotinoids. Advances in neurotoxicology, *Elsevier*. **4:** 167-207.

4. **Costas-Ferreira, C. and L. R. F. Faro 2021.** "Neurotoxic effects of neonicotinoids on mammals: what is there beyond the activation of nicotinic acetylcholine receptors "A systematic review." *International Journal of Molecular Sciences.* **22(16):** 8413.

5. **Dodia, D. A., I. S. Patel. 2010.** Botanical pesticides for pest management, Scientific Publishers.

6. **Mora-Gutierrez, A., C. Rubi. 2021.** Neurotoxic effects of insecticides chlorpyrifos, carbaryl, imidacloprid, in different animal species, IntechOpen Rijeka, Croatia.

7. **Stoddard, F. L., A. H. Nicholas. 2010.** Integrated pest management in faba bean. *Field crops research.* **115(3):** 308-318.

8. **Hazra D. K. and P. K. Patanjali 2016.** Seed coating formulation technologies: an environmental biology friendly approaches for sustainable agriculture. Bioscience Methods 7.

9. **Tisler T., A. Jemec. 2009.** Hazard identification of imidacloprid to aquatic environment. *Chemosphere* **76(7):** 907-914.

10. **Zhang, X., Y. Huang. 2023.** Environmental occurrence, toxicity concerns, and biodegradation of neonicotinoid insecticides. *Environmental Research* **218:** 114953.

11. **Thomson, L. J. and A. A. Hoffmann. 2019.** Ecological impacts of pesticides and their mitigation within IPM systems. Integrated management of insect pests, Burleigh Dodds Science Publishing: 709-732.

12. **Sadaria A. M., R. Sutton. 2017.** Passage of fiproles and imidacloprid from urban pest control uses through wastewater treatment plants in northern California, USA. *Environmental Toxicology and Chemistry* **36(6):** 1473-1482.

13. **Poff N. L., M. M. Brinson. 2002.** Aquatic ecosystems and global climate change. Pew Center on Global Climate Change, Arlington, *VA* **44:** 1-36.

14. **Stanley J. and G. Preetha 2016.** Pesticide toxicity to fishes: exposure, toxicity and risk assessment methodologies. Pesticide Toxicity to Non-target Organisms: Exposure, Toxicity and Risk Assessment Methodologies: 411-497.

15. **Moyle P. B. and R. A. Leidy. 1992.** Loss of biodiversity in aquatic ecosystems: evidence from fish faunas. Conservation biology: The theory and practice of nature conservation preservation and management, *Springer*: 127-169.

16. **Ali S., M. I. Ullah. 2021.** Environmental and health effects of pesticide residues." Sustainable Agriculture Reviews 48: Pesticide Occurrence, Analysis and Remediation Vol. **2** Analysis: 311-336.

17. **Malhotra, N., K. H. C. Chen. 2021**. Physiological effects of neonicotinoid insecticides on non-target aquatic animals: an updated review. *International Journal of Molecular Sciences.* **22(17):** 9591.

18. **Van Dijk, T. C., M. A. Van Staalduinen. 2013.** Macro-invertebrate decline in surface water polluted with imidacloprid. *PloS one* **8(5):** e62374.

19. **Pang, S., Z. Lin. 2020.** Insights into the toxicity and degradation mechanisms of imidacloprid via physicochemical and microbial approaches." Toxics 8(3): 65.

20. **Zubairi, N. A. A., H. Takaijudin. 2022.** Assessment of imidacloprid removal from agricultural runoff by the bioretention treatment train system. *Environmental Advances* **7:** 100156.

21. **Chara-Serna, A. M., L. B. Epele. 2019.** Nutrients and sediment modify the impacts of a neonicotinoid insecticide on freshwater community structure and ecosystem functioning. *Science of the Total Environment* **692:** 1291-1303.

22. **Brewton, R. A., L. B. Kreiger. 2022.** Septic systemic groundwater surface water couplings in waterfront communities contribute to harmful algal blooms in Southwest Florida. *Science of the Total Environment* **837:** 155319.

23. **Yamamuro, M., T. Komuro. 2019.** Neonicotinoids disrupt aquatic food webs and decrease fishery yields. *Science.* **366(6465):** 620-623.

24. **Ansari, M. S., M. A. Moraiet. 2014.** Insecticides: impact on the environment and human health. Environmental deterioration and human health: natural and anthropogenic determinants: 99-123.

25. **Yu, F. D., D. E. Gu. 2019.** The current distribution of invasive mrigal carp (*Cirrhinus mrigala*) in Southern China, and its potential impacts on native mud carp

(*Cirrhinus molitorella*) populations. *Journal of Freshwater Ecology* **34(1):** 603-616.

26. **Mohanty, B., E. Vivekanandan. 2017.** The impact of climate change on marine and inland fisheries and aquaculture in India." Climate change impacts on fisheries and aquaculture: a global analysis 2: 569-601.
27. **Bibi, F., M. M. Nazir. 2018.** Freshwater Fish Diversity and Their Conservation Status in Southern Punjab, Pakistan: A Review. *Pakistan Journal of Life & Social Sciences* 16(2).
28. **Hussain, B., T. Sultana. 2016.** Variation in genotoxic susceptibility and biomarker responses in Cirrhinus mrigala and Catla catla from different ecological niches of the Chenab River. *Environmental Science and Pollution Research.* **23:** 14589-14599.
29. **Meftaul, I. M., K. Venkateswarlu. 2020.** Pesticides in the urban environment: A potential threat that knocks at the door. *Science of the Total Environment* **711:** 134612.
30. **Tudi, M., H. Daniel Ruan. 2021.** Agriculture development, pesticide application and its impact on the environment. *International journal of environmental research and public health* **18(3):** 1112.
31. **Raju, C. R., B. Manjunatha. 2014.** International Journal of Pharmacology and Pharmaceutical Sciences. *International Journal of Pharmacology* **2(1):** 35-47.
32. **Ranjan, A. and T. Jindal. 2022.** Toxicology of organophosphate poisoning, Springer.
33. **McCulloch, M. 2022.** Neurological risk of prolonged low dose exposure to imidacloprid in zebrafish.
34. **Patel, B., A. Upadhyay. 2016**. Histological changes in the tissues of *Oreochromis mossambicus* and *Labeo rohita* on exposure to imidacloprid and curzate. *International Journal of Research in Applied Natural and Social Sciences* **4(5):** 149-160.
35. **Qadir, S. and F. Iqbal 2016.** Effect of subleathal concentrtion of imidacloprid on the histology of heart, liver and kidney in *Labeo rohita. Pakistan journal of pharmaceutical sciences* **29(6)**.
36. **Barathinivas, A., S. Ramya. 2022.** Ecotoxicological effects of pesticides on hematological parameters and oxidative enzymes in freshwater Catfish, Mystus keletius. *Sustainability.* **14(15):** 9529.
37. **Dattaray, D., T. K. Garnaik. 2023.** Effects of subacute exposure of imidacloprid on haemato-biochemical parameters in black Bengal goat (*Capra hircus*).
38. **Naiel, M. A. E., A. M. Shehata. 2020.** The new aspects of using some safe feed additives on alleviated imidacloprid toxicity in farmed fish: A review. *Reviews in aquaculture* **12(4):** 2250-2267.
39. **Madaro, A., T. S. Kristiansen. 2020.** How fish cope with stress? *The welfare of fish:* 251-281.
40. **Dorea, J. G. 2008.** Persistent, bioaccumulative and toxic substances in fish: human health considerations." *Science of the Total Environment* **400(1-3):** 93-114.
41. **Bruhl, C. A. and J. G. Zaller 2021.** Indirect herbicide effects on biodiversity, ecosystem functions, and interactions with global changes. Herbicides, *Elsevier*: 231-272.
42. **Dhuldhaj, U. P., R. Singh. 2023.** Pesticide contamination in agro-ecosystems: toxicity, impacts, and bio-based management strategies. *Environmental Science and Pollution Research* **30(4):** 9243-9270.
43. **Hillocks, R. J. 2012.** Farming with fewer pesticides: EU pesticide review and resulting challenges for UK agriculture. *Crop Protection.* **31(1):** 85-93.
44. **Claassen, M., J. M. Dabrowski. 2020.** Incorporating environmental fate models into risk assessment for pesticide registration in South Africa. Water Research Commission: Pretoria, South Africa.
45. **Hladik, M. L., A. R. Main. 2018.** Environmental risks and challenges associated with neonicotinoid insecticides, ACS Publications.
46. **Barzman, M., P. Barberi. 2015.** Eight principles of integrated pest management. *Agronomy for sustainable development* **35:** 1199-1215.
47. **Muzinic, V. and D. zeljezic. 2018.** Non-target toxicity of novel insecticides. *Arhiv za higijenu rada i toksikologiju* **69(2):** 86-102.

***