



Contents lists available at NCBI

The American Journal of Science and Medical Research

Journal homepage: <https://ajsmrjournal.com/>



Research Article

Impact of Agricultural Pesticides on the Biochemical Physiology of Freshwater Fish



Banoth Kalpana^{*1}, P. Subhashini², B. Santhoshi Kumari³

¹Department of Zoology, Pingle Government College for Women (Autonomous), Waddepally, Hanumakonda, Telangana State-506 370, India

*Corresponding author:

E-mail: banoth.k2013@gmail.com

<https://dx.doi.org/10.5281/zenodo.20475461>

Received: 21 April 2026

Revised 25 May 2026

Published on 31 May 2026

ISSN: 2377-6196© 2025 The Authors.

Published by AIRA

Keywords: Agricultural pesticides, Freshwater fish, Biochemical physiology, Aquatic pollution, Metabolic stress, Telangana

ABSTRACT

Agricultural pesticides are extensively used to enhance crop productivity; however, their indiscriminate application has resulted in contamination of freshwater ecosystems. The present study evaluates the impact of agricultural pesticides on the biochemical physiology of freshwater fish in selected water bodies of Karimnagar district, Telangana, India. Water and fish samples were collected from Lower Manair Dam and nearby irrigation tanks during different seasons between June 2023 and March 2024. Physicochemical parameters such as nitrate, phosphate, and dissolved oxygen were analysed along with biochemical parameters including carbohydrate content, protein levels, and enzyme activity in fish tissues. Results revealed elevated nutrient concentrations and reduced dissolved oxygen levels in contaminated sites, indicating agricultural runoff. Fish exposed to pesticide-contaminated environments exhibited behavioural abnormalities such as erratic swimming and reduced feeding activity. Significant reductions in carbohydrate and protein levels along with altered enzyme activity were observed, indicating metabolic stress. The findings clearly demonstrate that pesticide contamination adversely affects fish physiology and may lead to long-term ecological consequences. The study highlights the need for sustainable agricultural practices and continuous monitoring of freshwater ecosystems to protect aquatic biodiversity.

1. Introduction

Agricultural intensification has significantly increased the use of pesticides worldwide, particularly in developing countries like India where crop productivity is heavily dependent on chemical inputs. Pesticides such as organophosphates, carbamates, and neonicotinoids are widely used to control pests and improve agricultural yield. However, their excessive and indiscriminate application has resulted in serious environmental problems, especially contamination of freshwater ecosystems (Carvalho, 2017). These chemicals often reach nearby water bodies through surface runoff, leaching, irrigation return flows, and spray drift, thereby affecting aquatic organisms (Aktar et al., 2009). Freshwater ecosystems are highly productive systems that support a wide variety of aquatic organisms including fish, plankton, mollusks, and macroinvertebrates. Fish occupy an important position in aquatic food chains and are widely used as bioindicators of environmental pollution because of their sensitivity to chemical contaminants (Mason, 2002). Exposure to pesticides can disrupt

various physiological processes in fish, including respiration, metabolism, osmoregulation, and reproduction (Rand et al., 1995; Velisek et al., 2011). The environmental persistence and ecological risks of pesticides have also been widely reported (Saha & Zaman, 2013; Tilak et al., 2005).

Biochemical parameters such as carbohydrate metabolism, protein content, and enzyme activity are considered reliable indicators of physiological stress in fish exposed to toxic substances (Singh & Sharma, 2018). Pesticide exposure has been reported to cause depletion of energy reserves, inhibition of protein synthesis, and alterations in enzyme activity in fish tissues (Begum, 2004; Monteiro et al., 2006). These biochemical changes may ultimately affect growth, survival, and reproductive capacity of fish populations. Freshwater bodies in Telangana, particularly in Karimnagar district, are surrounded by intensive agricultural lands where pesticides are frequently used for crops such as paddy, cotton, and maize. These water bodies receive agricultural runoff during monsoon seasons, making them vulnerable to pesticide contamination. However,

limited studies have focused on the biochemical responses of fish to pesticide exposure in this region.

Therefore, the present study was undertaken to (i) assess pesticide-induced changes in water quality, (ii) evaluate biochemical alterations in freshwater fish, and (iii) understand the physiological stress responses in fish exposed to pesticide-contaminated environments in selected water bodies of Karimnagar district, Telangana.

1. Materials and Methods

2.1. Study Area

The present study was conducted in selected freshwater ecosystems of Karimnagar District, Telangana State, India, particularly in and around the Huzurabad region. The major study sites included Lower Manair Dam (LMD) and nearby irrigation tanks situated in agricultural landscapes. Lower Manair Dam is constructed across the Manair River, a tributary of the Godavari River, and serves as an important source for irrigation, fisheries, and domestic water supply. The surrounding areas are intensively cultivated with crops such as paddy (*Oryza sativa*), cotton (*Gossypium* spp.), and maize (*Zea mays*), which require substantial application of pesticides and fertilizers.

The selected irrigation tanks are directly influenced by agricultural runoff, especially during the monsoon season. The region experiences a semi-arid climate with an average annual rainfall of approximately 900-1000 mm, with most precipitation occurring between June and September. These study sites were selected because of their high vulnerability to pesticide contamination, making them ideal for evaluating the impact of agrochemicals on freshwater ecosystems (Carvalho, 2017; Aktar et al., 2009).

2.2 Sampling Design and Collection

Sampling was carried out during three distinct seasons- pre-monsoon (March- May), monsoon (June- September), and post-monsoon (October- February)- between June 2023 and March 2024 to capture seasonal variations in pesticide contamination. **Water Sampling:** Water samples were collected from multiple points at each site using pre-cleaned polyethylene bottles. Samples were collected from approximately 10- 20 cm below the water surface to avoid surface contaminants. The samples were stored at 4°C and transported to the laboratory for analysis within 24 hours.

Fish Sampling: Freshwater fish species such as *Channa punctatus* and *Oreochromis mossambicus* were collected using gill nets and cast nets with the help of local fishermen. These species were selected due to their wide distribution, ecological importance, and sensitivity to environmental pollutants. Immediately after collection, fish were washed with distilled water and transported in ice boxes to the laboratory for biochemical analysis (Rand et al., 1995).

2.3 Physicochemical Analysis of Water

Physicochemical parameters of water were analyzed following standard procedures recommended by APHA (2017) and Trivedi and Goel (1986). The parameters analyzed included temperature (measured using a digital thermometer), pH (measured using a calibrated pH meter), dissolved oxygen (DO) using Winkler's method, total dissolved solids (TDS) using the

gravimetric method, nitrate (NO_3^-) using the spectrophotometric method, and phosphate (PO_4^{3-}) using the molybdenum blue method. These parameters are widely used indicators of water quality and nutrient enrichment resulting from agricultural runoff (Mason, 2002; Carvalho, 2017).

2.4 Biochemical Analysis of Fish

Fish were dissected under sterile conditions, and tissues such as liver and muscle were collected for biochemical analysis.

Estimation of Carbohydrates: Carbohydrate content was estimated using the Anthrone method (Hedge & Hofreiter, 1962), which is widely used for determining total carbohydrate levels in biological samples.

Estimation of Proteins: Protein content was determined using the Lowry method (Lowry et al., 1951), which is a standard method for quantifying total protein concentration in tissues.

Enzyme Activity Analysis: Enzyme activity was measured to assess metabolic alterations and physiological stress in fish. Enzymes involved in metabolism and detoxification pathways were analyzed following standard protocols (Rand et al., 1995; Velisek et al., 2011; OECD, 1992).

Biochemical parameters are sensitive indicators of toxic stress and are widely used in aquatic toxicology studies (Begum, 2004; Monteiro et al., 2006).

2.5 Quality Control and Standardization

All instruments were calibrated prior to analysis, and standard solutions were used to ensure accuracy. Duplicate samples were analyzed to minimize experimental errors. Reagents used were of analytical grade.

Standard laboratory protocols were strictly followed to ensure reliability and reproducibility of results.

2.6 Statistical Analysis

The experimental data were expressed as mean \pm standard deviation (SD). Statistical comparisons between contaminated and control sites were performed using appropriate statistical tools.

Significance levels were determined using standard statistical methods, and results were interpreted at $p < 0.05$ level (Zar, 2010). Statistical analysis helps in validating the observed differences and ensuring scientific accuracy.

2.7 Ethical Considerations

All experimental procedures involving fish were conducted following standard ethical guidelines for the use of animals in research. Care was taken to minimize stress and suffering during handling and sampling.

2. Results and Discussion

The results obtained in the present study clearly demonstrate that agricultural pesticide contamination has significant impacts on water quality and the biochemical physiology of freshwater fish. The results obtained from physicochemical and biochemical analyses are presented in accordance with the

objectives of the study. The findings are discussed under the following subheadings.

2.1 Physicochemical Characteristics of Water

The physicochemical analysis of water revealed considerable variations between contaminated (agricultural runoff-affected) and relatively less disturbed sites (Figure-1).

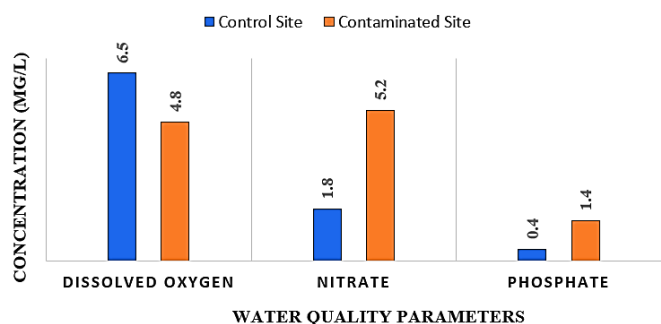


Figure-1. Comparison of water quality parameters between control and pesticide-contaminated sites

Nitrate concentrations in contaminated sites ranged between 3.5- 6.8 mg/L, whereas control sites showed lower values (1.2- 2.5 mg/L). Similarly, phosphate concentrations were significantly elevated (0.8- 1.9 mg/L) in contaminated sites. These elevated nutrient levels indicate the influx of agricultural fertilizers and pesticide residues into freshwater systems through runoff.

Dissolved oxygen (DO) levels were comparatively lower in contaminated sites (4.2- 5.5 mg/L) than in control sites (>6 mg/L), suggesting increased organic load and microbial activity. Reduced DO levels can adversely affect aquatic organisms, particularly fish, by impairing respiration.

These observations are consistent with earlier studies that reported nutrient enrichment and oxygen depletion in freshwater bodies receiving agricultural runoff (Carvalho, 2017; Aktar et al., 2009; Mason, 2002; Gurrapu et al., 2017). Increased nutrient loading can lead to eutrophication, which further deteriorates water quality and affects aquatic life.

2.2 Behavioral Responses in Fish

Fish collected from pesticide-contaminated sites exhibited abnormal behaviors such as erratic swimming, rapid opercular movement, frequent surfacing, loss of equilibrium, and reduced feeding activity. Such behavioral responses are early indicators of toxic stress and are often associated with neurotoxic effects of pesticides (Scott & Sloman, 2004; Rand et al., 1995; Velisek et al., 2011). Organophosphate and carbamate pesticides inhibit acetylcholinesterase activity, leading to disruption of normal nerve function (Rand et al., 1995; Velisek et al., 2011). Behavioral changes observed in the present study are in agreement with previous reports where pesticide exposure resulted in altered locomotion and feeding behavior in fish (Monteiro et al., 2006; Gujjeti et al., 2014). These changes may reduce the survival ability of fish in natural environments by affecting predator avoidance and food acquisition.

2.3 Alterations in Carbohydrate Metabolism

Carbohydrate analysis revealed a significant decline (approximately 20- 30% reduction) in fish tissues collected from

contaminated sites compared to control sites. Carbohydrates serve as the primary source of energy for metabolic activities (Figure-2). Under stress conditions, fish utilize carbohydrate reserves to meet increased energy demands required for detoxification and maintenance of physiological balance.

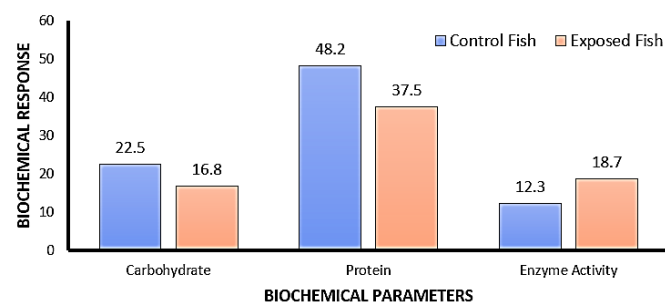


Figure-2. Comparative biochemical responses of freshwater fish from control and pesticide-contaminated sites.

The depletion of carbohydrate reserves observed in the present study indicates increased metabolic stress caused by pesticide exposure. Similar findings have been reported in fish exposed to organophosphate pesticides, where glycogen depletion was observed due to increased energy utilization (Singh & Sharma, 2018; Monteiro et al., 2006; Kumar et al., 2010). This metabolic shift is considered an adaptive response to stress; however, prolonged depletion may lead to reduced growth and survival of fish.

2.4 Alterations in Protein Metabolism

Protein content in fish tissues showed a significant reduction in contaminated sites. Proteins are essential for structural integrity, enzyme function, and tissue repair. The observed decrease in protein levels may be attributed to increased protein degradation to meet energy demands and inhibition of protein synthesis due to toxic stress. Protein depletion is a common response in fish exposed to pesticides and has been reported in several studies (Begum, 2004; Velisek et al., 2011). Reduced protein levels can impair growth, reproduction, and immune function in fish, making them more susceptible to diseases and environmental stress.

3.5 Enzyme Activity and Physiological Stress

Significant alterations in enzyme activity were observed in fish exposed to pesticide-contaminated environments. Enzymes involved in metabolic and detoxification pathways showed increased activity, indicating activation of defense mechanisms. Enzyme modulation is a well-known response to toxic stress, as organisms attempt to detoxify harmful chemicals (Rand et al., 1995). Increased enzyme activity reflects the physiological effort to neutralize and eliminate toxic substances. Similar enzyme alterations have been reported in fish exposed to pesticides, indicating oxidative stress (Lushchak, 2011; Livingstone, 2001) and metabolic imbalance (Velisek et al., 2011; Monteiro et al., 2006). However, prolonged exposure may overwhelm these defense mechanisms, leading to cellular damage and impaired physiological functioning.

2.5 Integrated Impact on Fish Health and Population

The combined effects of altered water quality, behavioral abnormalities, and biochemical disturbances indicate significant physiological stress in fish populations inhabiting contaminated sites. Field observations revealed reduced fish

abundance, decreased size variation, and lower diversity in contaminated areas. These findings clearly indicate that chronic pesticide exposure can have long-term ecological consequences, including reduced fish populations and altered community structure. Such ecological impacts have been widely reported in pesticide-contaminated freshwater ecosystems (Aktar et al., 2009; Carvalho, 2017; Al-Masri et al., 2024).

2.6 Ecological and Environmental Implications

The results of the present study highlight the broader ecological implications of pesticide pollution. Freshwater fish play a crucial role in aquatic food webs, and their decline can affect higher trophic levels, including birds and mammals. Moreover, pesticide contamination poses risks to human health through bioaccumulation and biomagnification in aquatic food chains. The findings emphasize the need for sustainable pesticide management, adoption of integrated pest management (IPM) practices, and regular monitoring of freshwater ecosystems. These findings clearly demonstrate the significant impact of agricultural pesticide contamination on freshwater ecosystems.

3. Conclusion

The present study clearly demonstrates that agricultural pesticide contamination significantly affects the biochemical physiology of freshwater fish. Elevated nutrient levels and reduced dissolved oxygen indicate deterioration of water quality due to agricultural runoff. Fish exposed to contaminated environments exhibited behavioral abnormalities and metabolic disturbances, including reduced carbohydrate and protein levels and altered enzyme activity. These findings indicate severe physiological stress and potential ecological imbalance. Therefore, regulating pesticide usage, adopting eco-friendly agricultural practices, and implementing regular monitoring of freshwater ecosystems are essential for sustainable aquatic resource management.

Competing interests:

The authors declare that they have no competing interests

References

- Aktar, M. W., Sengupta, D., & Chowdhury, A. (2009). Impact of pesticides use in agriculture: Their benefits and hazards. *Interdisciplinary Toxicology*, 2(1), 1- 12.
- Begum, G. (2004). Carbofuran insecticide induced biochemical alterations in liver and muscle tissues of the fish *Clarias batrachus* (Linn) and recovery response. *Aquatic Toxicology*, 66(1), 83-92.
- Carvalho, F. P. (2017). Pesticides, environment, and food safety. *Food and Energy Security*, 6(2), 48- 60.
- Hedge, J. E., & Hofreiter, B. T. (1962). Carbohydrate chemistry (Anthrone method). In R. L. Whistler & J. N. BeMiller (Eds.), *Methods in carbohydrate chemistry* (Vol. 1, pp. 17- 22). Academic Press.
- Kumar, A., Sharma, B., & Pandey, R. S. (2010). Biochemical responses in fish exposed to pesticides. *Pesticide Biochemistry and Physiology*, 98(3), 319- 324.
- Livingstone, D. R. (2001). Contaminant-stimulated reactive oxygen species production and oxidative damage in aquatic organisms. *Marine Pollution Bulletin*, 42(8), 656-666.
- Lowry, O. H., Rosebrough, N. J., Farr, A. L., & Randall, R. J. (1951). Protein measurement with the Folin phenol reagent. *Journal of Biological Chemistry*, 193(1), 265- 275.
- Lushchak, V. I. (2011). Environmentally induced oxidative stress in aquatic animals. *Aquatic Toxicology*, 101(1), 13-30.
- Mason, C. F. (2002). *Biology of freshwater pollution* (4th ed.). Pearson Education.
- Monteiro, D. A., de Almeida, J. A., Rantin, F. T., & Kalinin, A. L. (2006). Oxidative stress biomarkers in the freshwater fish *Prochilodus lineatus* exposed to organophosphate insecticide. *Comparative Biochemistry and Physiology Part C*, 143(2), 141- 149.
- OECD. (1992). *Guidelines for testing of chemicals: Fish toxicity tests*. OECD Publishing.
- Rand, G. M., Wells, P. G., & McCarty, L. S. (1995). *Fundamentals of aquatic toxicology*. CRC Press.
- Saha, S., & Zaman, M. R. (2013). Evaluation of possible environmental impacts of pesticides. *Environment and Ecology Research*, 1(2), 97- 102.
- Scott, G. R., & Sloman, K. A. (2004). Effects of environmental pollutants on fish behavior. *Aquatic Toxicology*, 68(4), 369- 392.
- Singh, S., & Sharma, B. (2018). Toxicological effects of pesticides on fish. *Environmental Toxicology and Pharmacology*, 62, 84- 92.
- Tilak, K. S., Veeraiyah, K., & Yacobu, K. (2005). Toxicity studies of pesticides on fish. *Journal of Environmental Biology*, 26(2), 191- 198.
- Trivedi, R. K., & Goel, P. K. (1986). *Chemical and biological methods for water pollution studies*. Environmental Publications.
- Velisek, J., Stara, A., & Svobodova, Z. (2011). Effects of pesticides on fish health. *Veterinarni Medicina*, 56(7), 343-350.
- Zar, J. H. (2010). *Biostatistical analysis* (5th ed.). Pearson Education.
- Al-Masri, A. A., Ameen, F., Davella, R., & Mamidala, E. (2024). Antidiabetic effect of flavonoid from *Rumex vesicarius* on alloxan induced diabetes in male albino Wistar rats and its validation through in silico molecular docking and dynamic simulation studies. *Biotechnology and Genetic Engineering Reviews*, 40(4), 4479-4494.
- Gujjeti, R. P., Namthabadi, S., & Mamidala, E. (2014). HIV-1 reverse transcriptase inhibitory activity of *Aerva lanata* plant extracts. *BMC Infectious Diseases*, 14(Suppl 3), P12.
- Gurrapu, S., & Mamidala, E. (2017). In Vitro HIV-1 reverse transcriptase inhibition of andrographolide isolated from *Andrographis paniculata*. *European Journal of Biomedical*, 4(12), 516-522.

From National Conference on Advances in Life Sciences: Present & Future (NCALS-2026) | 24-25 March 2026 | Organized by: Department of Zoology, Kakatiya University, Warangal-506 009, Telangana State, India