NexAvens Scientific Library

OPEN ACCESS

NL Journal of Agriculture and Biotechnology

(ISSN: 3048-9679)

Volume 2 Issue 6 December 2025

Review Article

Assessment of Pesticides' Impact on Hematological Parameters in Aquatic Organisms

Mohammad Forouhar Vajargah[1*] | Ahmad Mohamadi Yalsuyi[2] |

1. PhD of Aquatic Ecology, Shahid Dr. Beheshti Sturgeon Restoration and Genetic Conservation Center, Iranian Fisheries Organization, Rasht, Guilan, Iran.
2. Head of the Aquaculture Development Group, Ardabil Provincial Fisheries Directorate, Iranian Fisheries Organization, Ardabil Province, Iran.

***Corresponding Author:** Mohammad Forouhar Vajargah, PhD of Aquatic Ecology, Shahid Dr. Beheshti Sturgeon Restoration and Genetic Conservation Center, Iranian Fisheries Organization, Rasht, Guilan, Iran.

doi: 10.71168/NAB.02.06.135

Received: October 25- 2025 **Accepted:** November 20- 2025 **Published Online:** November 30- 2025

Abstract: Apart from their ecological significance, aquatic organisms constitute a vital component of economic resources and the food chain. Exposure to agricultural pesticides in natural environments induces alterations in hematological parameters and tissues such as the intestine, kidney, liver, and gills, which in some cases may lead to mortality. Furthermore, human consumption of contaminated fish can result in poisoning and other health complications. Given the circulation of blood throughout the fish's body, hematological analysis is considered a common method for assessing the physiological status of these aquatic species. Additionally, in various studies, blood parameters have been employed as indicators for monitoring environmental pollution levels. Hematological factors such as hemoglobin, hematocrit, red and white blood cell counts, as well as indices like mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), and mean corpuscular hemoglobin concentration (MCHC), have been widely used to evaluate stress induced by environmental contaminants.

Keywords: Pesticide, Hematology, Ecological.

Introduction

Aquatic organisms, as key components of aquatic ecosystems, play a crucial role in maintaining ecological stability, biodiversity, food security, and the economy of human societies. Among them, certain species possess significant economic value and hold a prominent position in the aquaculture industry [1,2]. The rapid expansion of agricultural activities and the influx of chemical compounds into water resources pose a serious threat to the health of these organisms. Agricultural pesticides, heavy metals, and metallic nanoparticles are among the pollutants that enter aquatic habitats often considered the ultimate sink for contaminants via surface runoff, drainage water, and sediments, thereby affecting the vital physiological systems of aquatic species. Fish may be exposed to these compounds through various routes, including dermal absorption, contact with gills, or ingestion, depending on the physicochemical nature of the substances. For instance, compounds with a high affinity for binding to protein thiol groups, such as heavy metals, are more likely to be absorbed through the gastrointestinal tract (GIT) and transported to target tissues, potentially causing severe cellular and tissue dysfunction. These disruptions are often accompanied by physiological and immunological responses, many of which can be detected through hematological indicators [3,4].

Hematological parameters are widely utilized as sensitive and non-invasive tools for assessing the health status, stress levels, and immune responses in fish. Indicators such as hemoglobin (Hb), hematocrit (Ht), red blood cell count (RBC), white blood cell count (WBC), mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), and mean corpuscular hemoglobin concentration (MCHC) are among the variables that undergo alterations upon exposure to environmental pollutants. These changes may manifest as increases or decreases in absolute or relative values and are interpreted differently depending on the type of pollutant, its concentration, duration of exposure, fish species, and environmental conditions.

For instance, elevated hematocrit or hemoglobin levels may be interpreted as compensatory responses to reduced gas exchange capacity in the gills or increased metabolic demand under stress conditions. Conversely, reductions in these indices may indicate anemia due to hemolysis, impaired hematopoiesis, or direct toxic effects. Moreover, changes in the neutrophil-to-lymphocyte ratio, increased monocyte counts, or decreased white blood cells may reflect inflammatory responses, immunosuppression, or oxidative stress [5,6]. Experimental studies have confirmed these alterations. For example, in a study on common carp (Cyprinus carpio), exposure to iron nanoparticles led to significant increases in erythrocytic and leukocytic indices, whereas administration of the probiotic Lactobacillus mitigated the toxic effects of nano-iron and restored certain parameters to normal levels. These findings suggest that the interaction between emerging pollutants such as nanoparticles and biological modulators like probiotics can induce complex patterns of hematological responses in aquatic organisms [7].

Previous studies have demonstrated that common agricultural pesticides such as Diazinon, Azinphos-methyl, and Flonicamid can induce significant alterations in the hematological indices of fish. These compounds, through their effects on hepatic enzymes, cellular membranes, and immune pathways, may lead to reductions in hemoglobin levels, disruptions in white blood cell ratios, and changes in blood electrolyte concentrations. Such alterations not only pose a threat to fish health but also hold considerable importance from a food safety perspective, as human consumption of contaminated fish may result in secondary poisoning and other health risks [8,9,10,11,12].

The examination of immature cells such as erythroblasts, nuclear abnormalities, and morphological changes in blood cells, alongside classical hematological indices, can provide valuable insights into the genotoxic and cytotoxic effects of pollutants. Among these, previous studies have indicated that platelet counts, although less frequently emphasized can serve as meaningful indicators of hemostasis and nonspecific immunity, especially considering their alterations upon exposure to toxic compounds. These changes may offer significant information regarding pollutant concentration or identification [13].

Given the growing importance of biomonitoring in water resource management and ecosystem health assessment, a comprehensive and analytical investigation into the effects of agricultural pesticides on the hematological indices of aquatic organisms is an undeniable necessity. This article, through a review of experimental and analytical studies, aims to explore the role of blood parameters as sensitive biomarkers in identifying and elucidating the impacts of agricultural pollutants on aquatic health, and to propose a framework for their application in bio monitoring efforts [14,15].

Toxicological Impacts on Fish Hematology

The introduction of chemical pollutants into aquatic habitats particularly metal ions, pesticides, pharmaceuticals, and other compounds derived from human activities can lead to significant alterations in the hematological indices of aquatic organisms. These changes not only reflect physiological and immunological disturbances but can also serve as biological indicators for monitoring environmental pollution. However, accurate interpretation of such changes requires knowledge of reference hematological values for different fish species an endeavor complicated by the poikilothermic nature of fish and their high sensitivity to environmental conditions. Hematological parameters in fish can fluctuate considerably under the influence of factors such as temperature, salinity, dissolved oxygen, nutrition, age, size, and developmental stage. Therefore, establishing reference ranges for each species necessitates extensive and controlled studies [16].

Hematocrit Responses of Fish to Xenobiotics the hematocrit response of fish to xenobiotics (foreign compounds) varies depending on the type, concentration, duration of exposure, and biological characteristics of the species under investigation. These responses may manifest as adaptive mechanisms aimed at maintaining homeostasis, cellular damage, or a combination of both. For instance, elevated hematocrit and hemoglobin levels may indicate a compensatory effort to enhance oxygen transport capacity under stress conditions, whereas reductions in these indices may reflect anemia or impaired hematopoiesis. Environmental toxins and pollutants can activate oxidative stress pathways, induce cytotoxic effects, and stimulate inflammatory responses. These processes are often accompanied by changes in the neutrophil-to-lymphocyte ratio, increased monocyte counts, or decreased white blood cells, indicating either immune suppression or stimulation. It is noteworthy that the intensity and extent of these changes are highly species-specific and vary across different life stages; for example, larvae and juvenile fish are generally more vulnerable than adults [17,18].

Precise experimental design, control of environmental variables, and the use of validated reference values in the assessment of hematological changes in aquatic organisms are essential for obtaining reliable results. Such rigor enables the differentiation between genuine toxic effects and natural physiological fluctuations, thereby transforming hematological analysis into an effective tool for evaluating the health of aquatic organisms and their environment.

Alterations in Erythrocyte Parameters Induced by Chemical Compounds: Erythrocyte-Related Parameters in Aquatic Organisms. Erythrocyte-related parameters in aquatic organisms include hematocrit (Ht), hemoglobin concentration (Hb), red blood cell count (RBC), mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), and mean corpuscular hemoglobin concentration (MCHC). These indices serve as sensitive tools for evaluating physiological status, oxygen transport capacity, and compensatory responses to environmental stressors. Microscopic examination of blood smears provides complementary information regarding the status of the hematopoietic system. The assessment of the percentage of immature red blood cells (erythroblasts) can indicate bone marrow or hematopoietic tissue activity in response to damaging agents. Additionally, the observation of morphological and nuclear abnormalities in erythrocytes such as changes in shape, size, or nuclear structure is considered a valuable indicator of cytotoxic and genotoxic effects in toxicological studies [19].

Chemical-Induced Alterations in Erythrocyte Parameters

Exposure to chemical compounds may lead to increases or decreases in the values of all or some erythrocyte parameters. These changes often reflect compensatory efforts by fish to maintain homeostasis under stressful conditions. For example, elevated hematocrit, hemoglobin, red blood cell count, or mean corpuscular volume (MCV) may occur in response to reduced gas exchange in the gills or heightened metabolic demand. Such conditions typically arise when toxic agents damage the gill epithelium or activate detoxification pathways within the body. Conversely, reductions in these indices may indicate anemia, hemolysis, or impaired hematopoiesis. Previous studies have shown that exposure to heavy metals such as cadmium or pesticides like glyphosate can significantly decrease Hb, RBC, and MCHC levels, suggesting disruptions in hemoglobin synthesis or damage to blood cells. Overall, precise evaluation of these parameters, alongside cellular and tissue-level indicators, provides an effective framework for biomonitoring and assessing the impacts of environmental pollutants in aquatic ecosystems [20].

Chemical-Induced Alterations in Leukocyte Parameters

White blood cells (leukocytes), as key components of the nonspecific immune system in fish, play a vital role in cellular defense against pathogens and environmental pollutants. Total white blood cell count (Total WBC) and differential leukocyte count (DLC) which includes the percentages of neutrophils, lymphocytes, monocytes, eosinophil's, and basophils are among the most commonly used indicators for assessing the immune status of fish in environmental and toxicological studies.

Leukocytosis is generally interpreted as an indication of immune activation in response to tissue damage or stimulation of the immune system by environmental pollutants. Under such conditions, increases in neutrophils (neutrophilia) or monocytes (monocytosis) are commonly observed, reflecting the onset of inflammatory responses. These reactions may occur following exposure to organophosphorus pesticides, heavy metals such as lead and cadmium, or reactive nanoparticles like nano-iron. Conversely, a decrease in white blood cell count (leukopenia) may signal immune suppression due to chronic stress or direct toxicity. This condition is often accompanied by lymphocyte reduction (lymphopenia) and an elevated neutrophil-to-lymphocyte ratio, which is recognized as an indicator of general stress and impaired leukopoiesis. Experimental studies have shown that compounds such as glyphosate and diazinon can significantly reduce WBC counts and disrupt differential leukocyte ratios.

Changes in monocytes and eosinophils may reflect chronic inflammatory responses or allergic stimulation. However, due to species diversity and physiological differences, interpreting these changes requires comparison with validated reference values and careful control of environmental variables. Ultimately, based on previous research findings, a thorough examination of leukocyte parameters alongside other hematological indices can provide an effective framework for biomonitoring, immune health assessment, and toxicological analysis of agricultural and industrial pollutants in aquatic ecosystems [21].

Chemical-Induced Alterations in Thrombocyte Counts

Thrombocytes, or blood platelets, are cells with dual roles in blood coagulation and nonspecific immunity. In fish, these cells differ structurally and functionally from those in mammals. Beyond their involvement in hemostasis and prevention of hemorrhage, thrombocytes actively participate in primary defense responses against tissue damage and environmental pollutants. Quantitative and qualitative changes in thrombocytes can serve as useful indicators for evaluating the ecological impacts of contaminants. However, direct measurement of thrombocyte counts in fish is less common due to the lack of standardized methods and high species variability, and only a limited number of studies have addressed this parameter. Typically, thrombocyte levels are estimated indirectly through blood smear analysis and by calculating their ratio to white or red blood cells. In certain species, thrombocytes exhibit morphological similarities to leukocytes and are sometimes included in differential white blood cell counts, which may lead to misinterpretation of results.

Studies have shown that exposure to environmental pollutants such as heavy metals (lead, cadmium) and pesticides (diazinon, chlorpyrifos) can lead to significant changes in thrombocyte counts. Depending on the type of compound, its concentration, duration of exposure, and fish species, these changes may manifest as increases (thrombocytosis) or decreases (thrombocytopenia). Thrombocytosis is typically interpreted as a compensatory response to tissue damage or immune system stimulation, whereas thrombocytopenia may indicate suppression of hemostasis or direct toxic effects on hematopoietic cells [22].

Given the dual role of thrombocytes in coagulation and immunity, precise analysis of their variations alongside other hematological indices can contribute to a better understanding of pollutant-induced damage mechanisms and inform the development of protective strategies in aquaculture. However, due to high natural variability, interspecies differences, and methodological limitations, interpretation of thrombocyte-related findings requires caution and the use of complementary data.

Conclusion

Hematological analysis in aquatic organisms serves not merely as a diagnostic tool but as a platform for understanding the complex interactions between environmental pollutants and the biological responses of aquatic life. A review of previous studies reveals that blood parameters, both individually and in combination, exhibit multilayered response patterns to toxic compounds patterns that may involve physiological compensation, suppression of immune functions, or reorganization of hematopoietic and cellular defense pathways.

Simultaneous changes in erythrocytic, leukocytic, and thrombocytic blood parameters in response to pollutants such as metallic nanoparticles, pesticides, and heavy metals indicate that the homeostatic system of aquatic organisms is not only directly affected by environmental contaminants but also actively engages regulatory mechanisms to maintain internal balance. These compensatory efforts include enhancing oxygen transport capacity, targeted activation of immune cells, and regeneration of damaged tissues. However, under chronic exposure or at high concentrations, these mechanisms may become ineffective, leading to serious physiological damage. Therefore, the application of hematological indices in experimental studies should adopt an integrative and adaptive approach one that considers not only numerical values but also biological context, pollutant type, and potential routes of absorption and action. Such a perspective can contribute to the development of more precise biomonitoring systems, the formulation of protective strategies in aquaculture, and the assessment of ecological risks at the ecosystem level.

References

1. Sattari M, Bibak M, Forouhar Vajargah M. Evaluation of trace elements contaminations in muscles of Rutilus kutum (Pisces: Cyprinidae) from the Southern shores of the Caspian Sea. Environmental Health Engineering and Management Journal. 2020;7(2);89-96.

2. Montajami, S., Hajiahmadyan, M., Forouhar Vajargah, M., Hosseini Zarandeh, A.S., Shirood Mirzaie, F. and Hosseini, S.A., 2012. Effect of symbiotic (Biomin imbo) on growth performance and survival rate of Texas cichlid (Herichthys cyanoguttatus) larvae. Global Veterinaria, 9(3), pp.358-61.

3. Azar, H. and Vajargah, M.F., 2023. Investigating the effects of accumulation of lead and cadmium metals in fish and its impact on human health. J Aquac Mar Biol, 12(2), pp.209-213.

4. Forouhar Vajargah, M., Mohammadi Yalsuyi, A. and Hedayati, A., 2017. Acute toxicity of povidone-iodine (Betadine) in common carp (Cyprinus carpio L. 1758). Pollution, 3(4), pp.589-593.

5. Sattari, M., Namin, J.I., Bibak, M., Vajargah, M.F., Faggio, C. and Haddad, M.S., 2019. Trace and macro elements bioaccumulation in the muscle and liver tissues of Alburnus chalcoides from the south Caspian Sea and potential human health risk assessment. Journal of Energy, Environmental & Chemical Engineering, 4(1), p.13.

6. Yalsuyi, A.M., Vajargah, M.F., Hajimoradloo, A., Galangash, M.M., Prokić, M.D. and Faggio, C., 2021. Evaluation of behavioral changes and tissue damages in common carp (Cyprinus carpio) after exposure to the herbicide glyphosate. Veterinary Sciences, 8(10), p.218.

7. Sahraei Hassan, Hedayati Seyyed Aliakbar, Yarmohammadi Barbarestani Sarallah, Fakhrian Mohammad. Histological effects of feeding with different sources of zinc and iron (nano-particles and mineral form) in common carp (Cyprinus carpio). Journal of environmental science and technology. 2022;24(2 (117)):119-139.

8. Forouhar Vajargah, M., Ghafari Farsani, H., Gerami, M.H., Hedayati, S.A. and Nezhadheydari, H., 2017. Effects of the prebiotic in reducing histopathological changes and immune response of Cyprinus carpio after exposer to abamectin. Iranian Journal of Toxicology, 11(6), pp.21-26.

9. Vajargah, M.F., Hossaini, S.A., Niazie, E.H.N., Hedayati, A. and Vesaghi, M.J., 2013. Acute toxicity of two pesticides Diazinon and Deltamethrin on Tench (Tinca tinca) larvae and fingerling. International Journal of Aquatic Biology, 1(3), pp.138-142.

10. Vajargah, M.F., Hossaini, S.A. and Hedayati, A., 2013. Acute toxicity test of two pesticides diazinon and deltamethrin on spirlin (Alburnoides bipunctatus) larvae and fingerling. Journal of Toxicology and Environmental Health Sciences, 5(6), pp.106-110.

11. Chorehi, M.M., Ghaffari, H., Hossaini, S.A., Niazie, E.H.N., Vajargah, M.F. and Hedayati, A., 2013. Acute toxicity of Diazinon to the Caspian vimba, Vimba vimba persa (Cypriniformes: Cyprinidae). International Journal of Aquatic Biology, 1(6), pp.254-257.

12. Vajargah, M.F., Hedayati, A., Yalsuyi, A.M., Abarghoei, S., Gerami, M.H. and Farsani, H.G., 2014. Acute toxicity of Butachlor to Caspian Kutum (Rutilus frisii Kutum Kamensky, 1991). Journal of Environmental Treatment Techniques, 2(4), pp.155-157.

13. Vajargah, M.F. and Hedayati, A., 2014. Acute toxicity of trichlorofon on four viviparous fish: Poecilia latipinna, Poecilia reticulata, Gambusia holbrooki and Xiphophorus helleri (Cyprinodontiformes: Poeciliidae). Journal of Coastal Life Medicine, 2(7), pp.511-514.

14. Mohamadi Yalsuyi, A., Forouhar Vajargah, M., Hajimoradloo, A., Mohammadi Galangash, M., Prokić, M.D. and Faggio, C., 2022. Can Betadine (10% povidone-iodine solution) act on the survival rate and gill tissue structure of Oranda goldfish (Carassius auratus)?. Veterinary Research Communications, 46(2), pp.389-396.

15. Vajargah, M.F. and Hedayati, A., 2017. Acute toxicity of butachlor to Rutilus rutilus caspicus and Sander lucioperca in vivo condition. Transylvanian Review of Systematical and Ecological Research, 19(3), p.85.

16. Forouhar Vajargah, M., Imanpoor, M.R., Shabani, A., Hedayati, A. and Faggio, C., 2019. Effect of long-term exposure of silver nanoparticles on growth indices, hematological and biochemical parameters and gonad histology of male goldfish (Carassius auratus gibelio). Microscopy research and technique, 82(7), pp.1224-1230.

17. Azadikhah, D., Varcheh, M., Yalsuyi, A.M., Forouhar Vajargah, M., Mansouri Chorehi, M. and Faggio, C., 2023. Hematological and histopathological changes of juvenile grass carp (Ctenopharyngodon idella) exposed to lethal and sublethal concentrations of roundup (glyphosate 41% SL). Aquaculture Research, 2023(1), p.4351307.

18. Vajargah, M.F., Namin, J.I., Mohsenpour, R., Yalsuyi, A.M., Prokić, M.D. and Faggio, C., 2021. Histological effects of sublethal concentrations of insecticide Lindane on intestinal tissue of grass carp (Ctenopharyngodon idella). Veterinary Research Communications, 45(4), pp.373-380.

19. Vajargah, M.F., Mohsenpour, R., Yalsuyi, A.M., Galangash, M.M. and Faggio, C., 2021. Evaluation of histopathological effect of roach (Rutilus rutilus caspicus) in exposure to sub-lethal concentrations of Abamectin. Water, Air, & Soil Pollution, 232(5), p.188.

20. Vajargah, M.F., Farsani, H.G., Naserabad, S.S. and Hedayati, A., 2019. Histopathological lesions in liver and gill of Capoeta capoeta gracilis in exposed to butachlor. Exp Anim Biol, 7, pp.69-81.

21. Hedayati, A., Forouhar Vajargah, M., Darabitabar, F. and Mohammadi Yalsuei, A., 2016. Performance evaluation of safety and protection Isomaltooligosaccharide prebiotics in reducing histopathological common carp (Cyprinus carpio) of different concentrations Pretilachlor. Zanko Journal of Medical Sciences, 16(51), pp.61-72.

22. Sattari, M., Bibak, M. and Vajargah, M.F., 2021. Trace and macro element contaminations in tissues of Vimba persa and Alosa braschnikowi from the South Caspian Sea and potential human health risk assessment. Avicenna Journal of Environmental Health Engineering, 8(2), pp.84-96.

Citation: Mohammad Forouhar Vajargah., et al. "Assessment of Pesticides' Impact on Hematological Parameters in Aquatic Organisms". NL Journal of Agriculture and Biotechnology 2.6 (2025): 24-28.