

Impact of Agricultural Runoff on Fish Health: A Growing Aquatic Crisis

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ABSTRACT

Aquatic habitats are seriously threatened by agricultural runoff, which has a negative impact on fish health. Water bodies are exposed to agrochemicals from fertilizers, pesticides, and herbicides, which alter their physiology, genetic makeup, and behavior. These pollutants create neurological problems that upset aquatic food webs, impede reproductive, genotoxicity, bioaccumulation, weakened immunity, and increased risk of disease. Monitoring is improved by the early detection of stress reactions made possible by advances in omics technologies like proteomics and metabolomics. In addition to ecological consequences, runoff causes economic harm, fisheries losses, and hazards to human health by contaminating food systems. For mitigation to guarantee ecosystem resilience, buffer zones, less chemical use, and wetland restoration are necessary.

INTRODUCTION

One of the main causes of non-point pollution in the globe is agricultural runoff. Through the use of fertilizers, pesticides, and herbicides, it is essential to

maintaining food production; nevertheless, the unintended result is that it negatively affects aquatic ecosystems, particularly fish health. The introduction of different agrochemicals

into freshwater and marine habitats is intensifying along with contemporary agriculture. This type of pollution poses a serious threat to fish population health, which is a crucial indicator of the integrity of aquatic ecosystems.

Understanding Agricultural Runoff

Agricultural runoff primarily includes water that flows over cultivated fields, carrying with it pesticides, fertilizers, animal waste, and soil particles into nearby rivers, lakes, and oceans. This runoff doesn't just dilute into the water it transforms the aquatic environment. Once in the water, pesticides can bioaccumulate in fish tissues, altering their physiology, behaviour, and reproductive success.

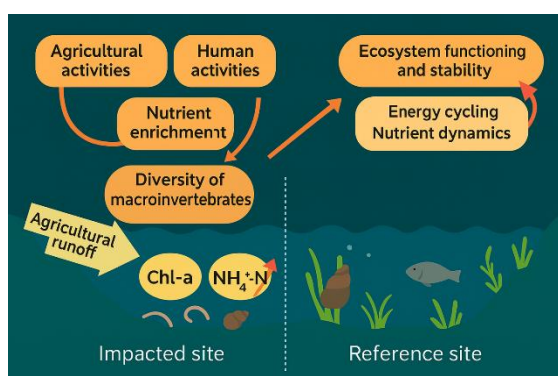


Fig. Impact of Agricultural Runoff on Fish Health

According to Amenyogbe et al. (2021), agrochemicals ranging from insecticides to herbicides often end up in aquatic systems where they harm not only target pests but also non-target organisms such as fish.

Effects on Fish Health:

1. Immune System and Disease Susceptibility

Fish that are exposed to pesticides have compromised immune systems. Research indicates decreased white blood cell numbers, compromised pathogen resistance, and heightened susceptibility to infections. Fish are more vulnerable to secondary bacterial or fungal infections as a result of the

immunological suppression, which frequently causes disease outbreaks in both farmed and wild populations.

2. Genotoxicity and Bioaccumulation

Repeated or long-term exposure to agrochemicals leads to genotoxic effects damaging the genetic material within fish cells. This results in chromosomal abnormalities, mutations, and developmental deformities. Pesticides such as organophosphates and carbamates have shown high bioaccumulation potential, leading to toxic residue buildup in vital fish organs like the liver, gills, and muscle tissues (Amenyogbe et al., 2021).

3. Reproductive Impairments

Several agrochemicals disrupt the endocrine system of fish, which governs reproduction and growth. Hormone mimicking chemicals cause irregularities in spawning, lower egg viability, delayed sexual maturity, and sex reversals. These disruptions lead to population declines over time and may even risk local extinctions in vulnerable species.

4. Behavioral and Neurological Effects

Fish exposed to certain insecticides and herbicides display erratic swimming, loss of balance, and heightened stress responses. Neurotoxic chemicals interfere with normal neurotransmission, leading to abnormal aggression, feeding behaviors, and escape responses all of which compromise survival in the wild.

Ecological Impacts Beyond Fish

In aquatic food webs, fish are frequently keystone species. In addition to affecting their predators, their dwindling population and health also upend entire ecosystems. Algal blooms brought on by fertilizer runoff, particularly nitrogen and phosphorus, produce

eutrophication, which lowers oxygen levels and creates dead zones where fish cannot live. This has already been noted in a number of places throughout the world, such as the Bay of Bengal and the Gulf of Mexico.

Modern Insights Using Omics Tools

Thanks to recent technological advancements, omics-based approaches like metabolomics, proteomics, and transcriptomics have been instrumental in identifying early stress responses in fish. These tools help detect biomarkers of pesticide exposure at a molecular level, even before physical symptoms appear. According to *Sidira et al. (2024)*, metabolomics and proteomics are now routinely used in fish health monitoring and seafood safety assessment, enabling better surveillance and quality control in aquaculture.

For instance, high-resolution mass spectrometry can trace the metabolic disruptions in fish liver exposed to pesticides, providing early warning signals of pollution. These methods are especially valuable in precision aquaculture and breeding for resilience against chemical stressors.

Economic and Food Safety Concerns

The contamination of fish by pesticide residues not only poses ecological threats but also economic and food safety concerns. Contaminated fish may carry traces of persistent organic pollutants (POPs), posing health risks to human consumers. Fish kills due to pesticide runoff lead to substantial economic losses in commercial and subsistence fisheries. Moreover, fisheries-dependent communities face long-term food insecurity and livelihood challenges.

Mitigation Strategies

Mitigating the effects of agricultural runoff on fish health requires an integrated approach:

- **Buffer zones:** Planting vegetation along waterways to filter runoff.
- **Controlled chemical use:** Promoting organic farming and biopesticides.
- **Wetland restoration:** Natural wetlands act as biofilters, absorbing excess nutrients and chemicals.
- **Policy and education:** Strengthening regulations on pesticide usage and educating farmers on sustainable practices.

In addition, omics-based environmental monitoring can help design early intervention strategies before full-scale ecological collapse occurs.

CONCLUSION

The health of fish and the vitality of aquatic ecosystems are inseparably linked to how we manage our agricultural practices. As scientific tools evolve, our understanding of the involved damage caused by agrochemicals becomes clearer and more alarming. From immune suppression to genetic toxicity, the impacts are profound and multi-layered. The future of sustainable aquaculture and fish conservation depends on a collective shift toward eco-friendly farming, science-driven policy, and proactive environmental stewardship.

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