Antimicrobial Resistance in Aquaculture

Shrutika Khushal Masram[1], Jay Vijay Mute[1], Shilpkar Dipak Narwade[1] and Arambam Ashwini Devi[1]*

[1]College of Fishery Science, Nagpur, Maharashtra Animal and Fishery Sciences University, Seminary Hills, Nagpur-440006

Corresponding Author
Arambam Ashwini Devi
Email: arambamashwini@gmail.com

OPEN ACCESS

Keywords

Antimicrobial Resistance, Aquaculture, One Health, Resistant Gene Transfer.

How to cite this article:

Masram, S. K., Mute, J. V., Narwade, S. D. and Devi, A. A. 2025. Antimicrobial Resistance in Aquaculture. *Vigyan Varta* 6 (8): 156-160.

ABSTRACT

Antimicrobial resistance (AMR) represents an escalating global health challenge, with aquaculture emerging as a significant contributor due to its extensive and often unregulated use of antibiotics for disease control. This review investigates the emergence and transmission of AMR within aquaculture systems, where excessive antibiotic use selects for resistant bacterial strains capable of survival and replication. These bacteria disseminate resistance genes through horizontal gene transfer mechanisms, including transformation, transduction, and conjugation, facilitated by mobile genetic elements. The implications are far-reaching, including increased disease outbreaks in farmed fish, elevated production costs, trade barriers, and serious public health concerns via contaminated seafood and environmental pathways. Tackling AMR in aquaculture demands urgent interventions, including prudent antimicrobial use, improved aquaculture practices, development of alternative treatments, and coordinated One Health approaches that integrate human, animal, and environmental health strategies.

INTRODUCTION

Antimicrobial resistance (AMR) is a global health concern where microorganisms, including bacteria, viruses, fungi, and parasites, resist treatments that were once effective against them. AMR is a top ten threat to global public health, posing a risk of death, serious sickness, and disease spread. The aquaculture sector, the fastestgrowing food production industry, has been a significant contributor to AMR due to its rapid expansion and intensive farming practices. However, frequent disease outbreaks often accompany intensified production systems, leading to the widespread use of antimicrobials in unregulated or poorly monitored ways. This indiscriminate use promotes the survival and multiplication of resistant microbial strains, which can spread within aquaculture systems and surrounding environments via effluents, sediments, and farmed species. Aquatic ecosystems serve as dynamic reservoirs for resistance genes, with high microbial diversity and frequent gene exchange accelerating AMR spread. Over the past two decades, AMR research in aquaculture has evolved from identifying resistant strains to uncovering the genetic and ecological factors behind resistance.

Development of antibiotic-resistant bacteria in aquaculture

In aquaculture, antibiotics are commonly used to control disease-causing microbes and maintain the health of farmed aquatic species (Rakkannan & Priyadarshi, 2023). However, due to a lack of institutional knowledge and formal training, many farmers tend to misuse or overuse these medications, inadvertently contributing to the emergence of antimicrobial resistance in bacterial populations (Bbosa *et al*., 2014). Several practices exacerbate this issue. Overuse of antibiotics without confirmed infections increases microbial exposure and accelerates resistance (Hossain *et al*., 2022). Administering incorrect doses or failing to complete the full course of treatment allows bacteria to survive and adapt (Partridge *et al*., 2018). The absence of proper record-keeping leads to repeated and unmonitored usage, while relying on the same antibiotic repeatedly promotes the selection of resistant strains (Milijasevic *et al*., 2024). Poor water quality further facilitates the spread of resistant bacteria, especially when contaminated with antibiotic residues (Pepi & Focardi, 2021). Treating diseases without an accurate diagnosis often results in inappropriate medication use (Hossain *et al*., 2022). Mixing antibiotics into feed without expert guidance can cause uneven dosing and unnecessary exposure (Rakkannan & Priyadarshi, 2023). The use of human antibiotics in aquaculture is unsafe and contributes to cross-resistance between human and aquatic pathogens (Partridge *et al*., 2018). Employing antibiotics as growth promoters rather than for therapeutic purposes increases environmental contamination (Milijasevic *et al*., 2024). Administering expired or leftover medicines may be ineffective or harmful, and the misconception that higher doses ensure better recovery leads to dangerous overdosing (Pepi & Focardi, 2021). Improper disposal of medicated water or sediment introduces antibiotic residues into natural ecosystems, threatening biodiversity and public health (Tao *et al*., 2022). Addressing these challenges requires targeted education, professional oversight, and strict regulatory enforcement to ensure sustainable and responsible aquaculture practices. Antimicrobials eliminate susceptible pathogens but allow resistant bacteria to survive, multiply, and dominate aquaculture systems (Hossain *et al*., 2022). Their spread is accelerated by horizontal and vertical gene transfer, undermining treatment efficacy and complicating disease control (Milijasevic *et al*., 2024).

Mechanisms of Resistance Gene Transfer

The spread of antibiotic resistance genes (ARGs) is largely driven by horizontal gene transfer (HGT), which allows bacteria to acquire genetic material from other organisms (Partridge *et al*., 2018). The three main mechanisms of HGT are transformation, transduction, and conjugation. In transformation, bacteria take up free DNA fragments, often containing resistance genes from their surroundings, especially in aquatic environments where biofilms and extracellular DNA are abundant (Hossain *et al*., 2022). Transduction occurs when bacteriophages, viruses that infect bacteria, accidentally package bacterial DNA with ARGs and transfer it to new host cells (Pepi & Focardi, 2021). Conjugation, the most efficient form of HGT, involves direct contact between bacteria to transfer plasmids carrying resistance genes (Partridge *et al*., 2018). This process is especially common in dense microbial communities like those in aquaculture, where low levels of antibiotics further promote gene exchange (Milijasevic *et al*., 2024). In addition to these mechanisms, other genetic elements enhance ARG spread. Integrons and transposons help capture and mobilise resistance genes within and between genomes (Partridge *et al*., 2018). Mobile genetic elements (MGEs) such as plasmids, integrative and conjugative elements (ICEs), and insertion sequences enable ARG transfer across diverse bacterial populations (Tao *et al*., 2022). When multiple resistance genes are present on a single MGE, the risk of multidrug resistance increases significantly (Pepi & Focardi, 2021).

Significance of Antimicrobial Resistance (AMR)

Antimicrobial resistance poses a significant challenge to animal health and the sustainability of aquaculture. It compromises the effectiveness of disease management strategies, leading to reduced treatment success and increased mortality among farmed aquatic species, which in turn results in considerable economic losses for producers (Milijasevic *et al*., 2024). Beyond the confines of aquaculture facilities, AMR presents a serious environmental and public health concern. Resistant bacteria and antimicrobial resistance genes (ARGs) can be released into surrounding ecosystems through aquaculture effluents, where they may persist and potentially transfer resistance traits to human pathogens (Pepi & Focardi, 2021). This creates a pathway for zoonotic transmission, as humans can be exposed to resistant bacteria through the consumption of contaminated seafood or contact with polluted environments, posing heightened risks to vulnerable populations (Tao *et al*., 2022). Furthermore, the presence of resistant microbes or prohibited antibiotics in aquaculture exports can trigger trade restrictions, product recalls, and reputational damage for exporting nations, thereby affecting global market access and economic stability (Hossain *et al*., 2022). Antimicrobial resistance (AMR) in aquaculture is a major concern with broad impacts. It leads to reduced productivity due to frequent disease outbreaks, higher mortality, and poor growth in farmed species, affecting both yields and animal welfare (Rakkannan & Priyadarshi, 2023). Farmers often turn to costly alternatives like advanced antimicrobials, vaccines, or probiotics, which strain small-scale producers financially (Milijasevic *et al*., 2024). AMR also threatens international trade, as residue or resistance gene detection in seafood can trigger export bans and economic losses (Pepi & Focardi, 2021). Public health is at risk through the transfer of resistant bacteria via contact, the environment, or contaminated seafood, potentially causing untreatable infections (Tao *et al*., 2022). Environmentally, resistant microbes disrupt ecosystems and aquatic biodiversity (Velazquez-Meza *et al*., 2022). These issues highlight the need for responsible antibiotic use, better farm practices, and strong regulation to sustain aquaculture and protect health (Hossain *et al*., 2022).

Strategies for Combating AMR in Aquaculture

1. **Responsible Antimicrobial Use -** Combating AMR in aquaculture requires strict regulation of critically important antimicrobials, especially those essential to human medicine (Milijasevic *et al*., 2024). Effective surveillance systems

must monitor antibiotic use and resistance trends. Adherence to withdrawal periods is vital to prevent residues in seafood. Long-term strategies should focus on reducing antibiotic dependence by adopting preventive measures such as improved husbandry, vaccination, and robust biosecurity practices (Rakkannan & Priyadarshi, 2023).

2. **Enhanced Aquaculture Management -** Good aquaculture practices play a key role in reducing AMR. Maintaining proper stocking densities, water quality, and nutrition helps lower disease risk (Pepi & Focardi, 2021). Vaccination reduces the need for antibiotics, while strong biosecurity, such as quarantining new stock and disinfecting equipment, prevents pathogen spread (Tao *et al*., 2022). Adding probiotics and prebiotics supports gut health and strengthens immunity in farmed species (Rakkannan & Priyadarshi, 2023).

3. **Innovative Therapeutic Alternatives -** New treatments can minimize reliance on antibiotics. Phage therapy offers targeted bacterial control, and immunostimulants enhance the natural defenses of aquatic species (Rakkannan & Priyadarshi, 2023). Plant-based antimicrobials provide sustainable treatment options (Hossain *et al*., 2022). Rapid diagnostics enable early disease detection and intervention, while selective breeding for disease-resistant strains promotes long-term aquaculture resilience (Milijasevic *et al*., 2024).

4. **FDA-Approved Antibiotics -** FAO studies highlight that in many low- and middle-income countries, the lack of uniform surveillance, inconsistent regulations, and weak antimicrobial stewardship increase the risk of resistant strains spreading through water systems, aquaculture products, and to humans (Pepi & Focardi, 2021). Using only antibiotics approved by authorities like the U.S. FDA is crucial to counter antimicrobial resistance. These drugs are rigorously assessed for safety, efficacy, and environmental impact. Their use prevents misuse of unregulated or poor-quality medicines, lowers the risk of residue in seafood, promotes responsible treatment, and ensures better monitoring and traceability—key for meeting trade standards and safeguarding public health (Partridge *et al*., 2018).

5. **One Health Approach -** Effectively tackling antimicrobial resistance requires a unified One Health approach that links animal, human, and environmental health (Velazquez-Meza *et al*., 2022). Educating stakeholders on responsible antibiotic use is key to reducing misuse and promoting sustainable practices (Milijasevic *et al*., 2024). Cross-sector collaboration and data sharing enhance understanding of resistance trends and support coordinated action (Tao *et al*., 2022). Developing unified policies through international cooperation ensures consistent standards and strengthens global efforts to manage AMR risks in aquaculture and beyond (Bbosa *et al*., 2014).

CONCLUSION

Antimicrobial resistance in aquaculture is a pressing issue with wide-reaching implications for animal health, environmental safety, public health, and global trade. Misuse and overreliance on antibiotics have accelerated the spread of resistant bacteria and resistance genes in aquatic systems. These resistant strains can persist, multiply, and transfer to humans through various pathways, making infections harder to treat. Addressing this complex challenge requires integrated efforts focused on responsible antibiotic use, improved aquaculture management, and a One

Health approach that unites human, animal, and environmental health sectors.

SUMMARY

This article explores the emergence and spread of antimicrobial resistance (AMR) in aquaculture, a rapidly growing food production sector. AMR arises primarily from the overuse and misuse of antibiotics, leading to the survival of resistant bacteria that spread through horizontal gene transfer mechanisms. These resistant strains pose serious threats to farm productivity, human health, environmental balance, and international trade. The paper discusses the biological basis of resistance, the factors driving its spread, and the consequences of untreatable infections in aquaculture systems. It concludes by recommending multi-faceted strategies including responsible drug use, alternative treatments, and coordinated global action through the One Health framework to mitigate the risks associated with AMR.

REFERENCES

Bbosa, G. S., Mwebaza, N., Odda, J., Kyegombe, D. B., & Ntale, M. (2014). Antibiotics/antibacterial drug use, their marketing and promotion during the post-antibiotic golden age and their role in emergence of bacterial resistance. *Health*, *6*(5), 410-425.

Hossain, A., Habibullah-Al-Mamun, M., Nagano, I., Masunaga, S., Kitazawa, D., & Matsuda, H. (2022). Antibiotics, antibiotic-resistant bacteria, and resistance genes in aquaculture: risks, current concern, and future thinking. *Environmental Science and Pollution Research*, *29*(8), 11054-11075.

Milijasevic, M., Veskovic-Moracanin, S., Milijasevic, J. B., Petrovic, J., & Nastasijevic, I. (2024). Antimicrobial Resistance in Aquaculture: Risk Mitigation within the One Health Context. *Foods*, *13*(15), 2448.

Partridge, S. R., Kwong, S. M., Firth, N., & Jensen, S. O. (2018). Mobile genetic elements associated with antimicrobial resistance. *Clinical microbiology reviews*, *31*(4), 10-1128.

Pepi, M., & Focardi, S. (2021). Antibiotic-resistant bacteria in aquaculture and climate change: A challenge for health in the Mediterranean area. *International journal of environmental research and public health*, *18*(11), 5723.

Rakkannan, G., & Priyadarshi, H. (2023). Selective Breeding for Disease Resistance in Aquaculture: Current Methods and Future Directions. *Biotica Research Today*, *5*(1), 45-47.

Tao, S., Chen, H., Li, N., Wang, T., & Liang, W. (2022). The spread of antibiotic resistance genes in vivo model. *Canadian Journal of Infectious Diseases and Medical Microbiology*, *2022*(1), 3348695.

Velazquez-Meza, M. E., Galarde-López, M., Carrillo-Quiróz, B., & Alpuche-Aranda, C. M. (2022). Antimicrobial resistance: one health approach. *Veterinary world*, *15*(3), 743.