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From Fish Farms to Global Threat: The Fight Against Antibiotic Resistance in Aquaculture

Qurratulain Qureshi[1]*, Tejpal Dahiya[1], Asif majeed mir[2]
[1]Department of Aquatic Animal Health, college of fishery science, Chaudhary Charan Singh Haryana Agricultural University, Hisar-125004 (Haryana), India
[2]Department of Veterinary Pharmacology and Toxicology, Nanaji Deshmukh Veterinary Science University, Jabalpur- 482004 (Madhya Pradesh), India
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Abstract

Aquaculture is one of the fastest-growing sectors in global food production, driven by the rising demand for fish and seafood. However, this rapid expansion has led to growing concerns about the contamination of fish with enteric pathogens and the associated public health risks. The excessive use of antibiotics in aquaculture for disease control has significantly contributed to the emergence of antimicrobial resistance (AMR). Antibiotic-resistant bacteria, originating from aquaculture-related pathogens, can transfer resistance genes to human pathogens, exacerbating the challenge of treating bacterial infections. This article reviews the transfer mechanisms of antibiotic resistance from aquaculture bacteria to human pathogens, the risks associated with such transmission, and the environmental implications. The article further explores case studies from different countries, with a particular focus on India, where high levels of resistance have been reported in aquaculture-related bacteria. Additionally, the environmental impact of AMR, especially in water sources contaminated by pharmaceutical waste and hospital effluents, is examined. The findings underscore the need for a multisectoral and coordinated approach to mitigate the spread of AMR, including stricter regulations on antibiotic usage, improved waste management in aquaculture, and enhanced monitoring of water ecosystems. This comprehensive approach is vital to safeguard both human and marine health from the increasing threat of antimicrobial resistance.

Keywords: Aquaculture, Antimicrobial Resistance, Disease, Antibiotics, Human Health

1. Introduction

Aquaculture is one of the fastest-growing sectors in global food production, driven by the increasing demand for fish and seafood. However, this rapid expansion has raised significant concerns regarding the contamination of fish with enteric pathogens, including harmful bacteria and viruses, which can pose serious public health risks. The widespread use of antibiotics in aquaculture, primarily for disease control, has contributed to the growing issue of antimicrobial resistance (AMR). Antibiotics, while effective at treating infections, are often used excessively in fish farming, leading to environmental contamination through the excretion of unmetabolized drugs into aquatic ecosystems. This has facilitated the development of antibiotic-resistant

bacteria, which not only threatens marine life but also poses a substantial risk to human health. Antibiotic resistance in bacteria from aquaculture has been linked to the transfer of resistance genes to human pathogens, further complicating the fight against bacterial infections. The spread of resistance genes, especially through water bodies, is a growing concern, as it can lead to the emergence of resistant pathogens that are difficult to treat with conventional antibiotics. This article explores the transfer of antibiotic resistance from aquaculture-related bacteria to human pathogens, the associated risks, and the environmental impact of this growing issue.

1.1 TRANSFER OF ANTIBIOTIC RESISTANCE FROM BACTERIA TO HUMAN

Antibiotic resistance in aquaculture poses a serious risk of transferring resistance to human pathogens. Quinolones, which target both Gram-positive and Gram-negative bacteria, can develop resistance when resistant genes, such as those in plasmids (e.g., qnrA, qnrB), are taken up by bacteria from the environment or other resistant strains. Tetracyclines, commonly used in both human and veterinary treatments, can transfer resistance from fish pathogens like *Vibrio anguillarum* to human bacteria, such as *E. coli*, through conjugation. Additionally, resistance to other antibiotics like β-lactams, macrolides, fosfomycin, and chloramphenicol has been observed in aquaculture-related bacteria from genera such as *Aeromonas*, *Yersinia*, and *Vibrio*. These resistance genes, often located on plasmids and integrons, can spread to human pathogens, posing a threat to both marine and human health by facilitating the transfer of resistance determinants in water and sediments.

1.2 RISK ASSOCIATED WITH AMR IN BACTERIA FROM CULTURED FISH

Exposure of commensals such as *Escherichia coli* to antibiotics increases the carriage levels of resistant organisms and if plasmid-mediated, resistance might be transmitted to a more virulent acquired organism (Szmolka & Nagy 2013). The spread of resistance factors from animal to human flora, including interbacterial species transmission, has been documented or it's highly suspected in *E. coli*, *Camphylobacter* spp., *Enterococcus* spp. Low level antibiotics use also may contribute to resistance, by selecting low-level resistance strains. Synthetic antibiotics (e.g. quinolones) can be more refractory to biodegradation.

1.3 ANTIBIOTIC RESISTANCE IN DIFFERENT BACTERIA REPORTED IN DIFFERENT COUNTRIES

Antibiotic resistance in aquaculture bacteria has been reported globally, with significant variations across countries. In India, the fourth-largest consumer of antimicrobials for animal use, studies have shown high levels of resistance, such as 77.5% of *A. hydrophila* isolates being resistant to amoxyclav (Alaali, 2020), and complete resistance to amoxyclav among motile aeromonads from ornamental fish culture in Kerala (Hossain & Heo, 2012). Similar findings were observed in *Aeromonas* species from fish in Kolkata, where 100% of isolates showed

resistance, highlighting the role of sewage in the spread of resistance (Karkman et al., 2018). In Vietnam, a 61.6% multi-resistance rate was noted in *E. coli* from raw food samples (Redwan et al., 2023), while *E. coli* from freshwater aquaculture in West Bengal showed 33- 87% multi-antibiotic resistance (MAR) (Bharathkumar & Abraham, 2008), and MAR was also identified in *E. coli* strains from retail fish in Spain (Al-Ghanayem et al., 2020). Studies in Europe and Australia have also reported widespread resistance in *Aeromonas* isolates, with 50% resistance to oxytetracycline and significant resistance to ciprofloxacin, trimethoprim, and other antibiotics (Cížek, 2010; Akinbowale, 2006). These findings underscore the global extent of antibiotic resistance in aquaculture and the risks it poses to both animal and human health.

1.4 ANTIMICROBIAL RESISTANCE & THE ENVIRONMENT

Antimicrobial-resistant bacteria and their resistance genes have been increasingly reported from various water sources across India, largely due to the release of pharmaceutical waste and hospital effluents into nearby water bodies without proper treatment. A study by Taneja & Sharma (2015) showed that the rate of *E. coli* resistant to third-generation cephalosporins was 25%, 70%, and 95% in water samples with varying levels of contamination: domestic water alone, domestic water with hospital effluent, and hospital effluent alone, respectively. Major rivers such as the Ganges and Yamuna, which span vast areas of northern India, receive multiple inlets containing varying concentrations of drug-resistant bacteria. In these rivers, 17.4% of Gram-negative bacteria were found to produce extended-spectrum beta-lactamases (ESBLs) (Ghorani-Azam et al., 2016), with resistance genes like *blaNDM-1* and *blaOXA48* detected (Bilik et al., 2021). In southern India, 100% of *E. coli* isolates from the Cauvery River in Karnataka were resistant to third-generation cephalosporins (Dhawde et al., 2018). Groundwater and surface water used for drinking and recreational purposes have also shown significant resistance rates: 17% in central India (Kaur et al., 2021), 7% in northern India (Kashmir) (Rather et al., 2013), 50% in eastern India (Sikkim) (Poonia et al., 2014), and 100% in Hyderabad, southern India (Lubbert et al., 2017). These studies, which sampled various water sources including rivers, ponds, lakes, springs, and tube wells, highlight the widespread contamination of water bodies with antimicrobial-resistant bacteria, posing a major public health risk.

2. CONCLUSION

The issue of antimicrobial resistance (AMR) in aquaculture is a critical and often overlooked environmental concern, especially in countries like India where antibiotic use in aquaculture is prevalent. The increasing contamination of water sources with antibiotic-resistant bacteria, primarily due to pharmaceutical waste and hospital effluents, poses significant risks to both human health and marine ecosystems. The transfer of resistance genes from aquaculture-

related pathogens to human bacteria can complicate the treatment of infections and lead to the emergence of multi-drug-resistant strains. To mitigate the growing threat of AMR, it is essential to adopt a multisectoral approach that includes stricter regulation of antibiotic use, improved waste management practices in aquaculture, and enhanced monitoring of water sources. Collaborative efforts from various stakeholders, including government bodies, healthcare providers, and the aquaculture industry, are crucial in tackling this global challenge and ensuring the protection of both public health and the environment.

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