

Antimicrobial Resistance in Aquaculture: An Emerging Threat

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SUMMARY

Antimicrobial resistance (AMR) in aquaculture is a rapidly growing global health threat. With aquaculture supplying 17% of animal protein worldwide, the sector's heavy reliance on antimicrobials over 10,000 tonnes annually, predominantly in Asia-Pacific has fueled the rise of resistant bacteria. These pathogens spread through water systems, horizontal gene transfer, and the food chain, bridging aquatic farms to human communities under the One Health framework. AMR already contributed to 4.7 million deaths in 2021, and aquaculture acts as a hidden accelerator of this crisis. Beyond human health, antimicrobial residues persist in sediments and water, disrupting aquatic ecosystems and enriching resistance genes in the environment. Mitigation demands a multi-pronged approach: replacing drugs with vaccines, probiotics, and improved biosecurity; strengthening surveillance and regulation; and enforcing the One Health approach that links human, animal, and environmental health. Without urgent, coordinated global action, aquaculture risks undermining the very food security it supports while amplifying the broader AMR emergency.

INTRODUCTION

Aquaculture the controlled cultivation of aquatic organisms such as fish, crustaceans, and molluscs has become one of the fastest-growing food production sectors globally. With the world population projected to exceed 9.7 billion by 2050, aquaculture is increasingly relied upon to meet rising demand for animal protein. Approximately 17% of all animal protein consumed worldwide comes from aquatic foods, and fish alone account for roughly 20% of per-capita animal protein intake for more than 3.3 billion people (FAO, 2022). However, this rapid expansion has come at a cost: the intensive use of antimicrobials to manage disease in crowded farming environments has catalysed the emergence and dissemination of antimicrobial resistance (AMR), posing a serious and growing threat to public health, food safety, and environmental integrity.

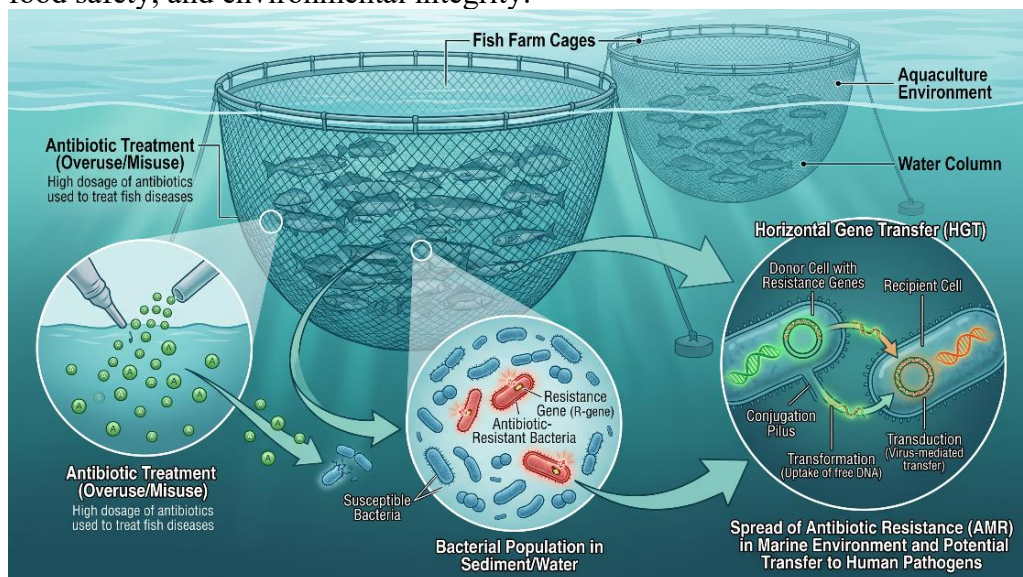


Figure 1: Illustration of antimicrobial resistance spreading through aquaculture environments

The Scale of Antimicrobial Use in Aquaculture

The scale of antimicrobial consumption in aquaculture is staggering. Researchers from the One Health Trust and collaborators estimate that 10,259 tonnes of antimicrobials were used globally in aquaculture in 2017. That figure is projected to increase by 33% to approximately 13,600 tonnes annually by 2030 (Schar et al., 2020). The Asia-Pacific region dominates this consumption, accounting for 93.8% of worldwide antimicrobial use in aquaculture, with China alone responsible for 57.9% of the global total. In many countries, antimicrobials are administered not only therapeutically to treat active infections but also prophylactically—as a preventive measure in crowded, stress-prone farming systems. This practice of routine, subtherapeutic dosing creates ideal conditions for the selection and amplification of resistant bacterial strains.

How Resistance Develops and Spreads

Antimicrobial resistance arises when bacteria evolve mechanisms to survive exposure to drugs that would normally kill them or inhibit their growth. In aquaculture settings, this process is accelerated by several factors. First, the high density of fish in farm enclosures facilitates rapid transmission of pathogens. Second, antibiotics released into water and sediment exert selective pressure on bacterial communities long after initial application. Third, the aquatic environment itself serves as a conduit: residual antibiotics, resistant bacteria, and antibiotic resistance genes (ARGs) can travel through water currents, sediments, and food chains, reaching ecosystems and human populations far beyond the farm site.

Research has demonstrated that aquaculture environments function as reservoirs and amplification points for ARGs. Fish farms in both freshwater and marine settings have been found to harbour elevated concentrations of resistance genes—including those conferring resistance to critically important antibiotics for human medicine, such as fluoroquinolones, tetracyclines, and beta-lactams. Horizontal gene transfer among aquatic bacteria further accelerates the spread of these genes, enabling resistance to move across species and even across genera.

One Health Implications

The intersection of aquaculture-driven AMR with human health is best understood through a One Health lens, which recognises that the health of people, animals, and the environment are deeply interconnected. Resistant bacteria originating in fish farms can reach humans through multiple pathways: direct contact with contaminated water during farming or processing, consumption of seafood carrying resistant pathogens or resistance genes, and environmental contamination of drinking water sources. The World Health Organisation (WHO) has identified AMR as one of the top ten global public health threats, estimating that bacterial AMR was associated with more than 4.7 million deaths globally in 2021 (WHO, 2026).

Of particular concern is the use of antibiotics in aquaculture that are classified as critically important for human medicine. When resistance to these compounds emerges in aquatic environments, it can undermine the effectiveness of last-resort treatments for serious human infections. Colistin, for example—once considered a drug of last resort for multidrug-resistant Gram-negative infections—has been widely used in Asian aquaculture, and the emergence of mobilisable colistin resistance genes (*mcr*) in aquatic bacteria has raised alarm among public health authorities worldwide.

Environmental Consequences

The environmental footprint of antimicrobial use in aquaculture extends well beyond the immediate vicinity of fish farms. Antibiotics that are not metabolised by the farmed organisms are excreted into the surrounding water, where they persist in sediments for weeks or months. These residual compounds disrupt microbial community structure, reduce the abundance of beneficial bacteria, and exert chronic selective pressure favouring resistant organisms. Studies have shown that antibiotic concentrations in sediments beneath fish cages can exceed those in the overlying water by orders of magnitude, creating long-lasting hotspots of resistance.

Furthermore, the interconnectivity of aquatic systems means that resistance propagated in one location can be transported across wide geographical areas. Rivers, estuaries, and coastal currents carry resistant bacteria and ARGs downstream, potentially contaminating wild fish populations, shellfish beds, and recreational waters. This environmental dissemination complicates containment efforts and underscores the need for a coordinated, ecosystem-level approach to AMR management.

Strategies for Mitigation

Addressing AMR in aquaculture requires a multifaceted approach. Key strategies include the following:

1. **Strengthening surveillance systems:** Robust monitoring of antimicrobial use (AMU) and antimicrobial resistance (AMR) patterns is essential for evidence-based decision-making. Initiatives such as those led by WorldFish across South Asia—supported by the UK Fleming Fund and CGIAR—are building laboratory capacity and harmonising surveillance protocols to enable early detection of emerging resistance threats.
2. **Promoting antimicrobial stewardship:** Responsible use of antimicrobials must replace routine prophylactic dosing. This includes restricting antimicrobial use to cases confirmed by diagnosis, adhering to appropriate dosages and withdrawal periods, and phasing out the use of critically important antibiotics for human medicine in aquaculture.
3. **Improving biosecurity and husbandry practices:** Better farm management—including optimised stocking densities, improved water quality, adequate nutrition, and effective vaccination programs—can significantly

reduce disease incidence and, consequently, the need for antimicrobial treatment. Probiotics, phage therapy, and immunostimulants represent promising alternatives that are gaining traction.

4. **Developing and deploying vaccines:** Vaccination against common bacterial pathogens is one of the most effective strategies for reducing antibiotic dependence. Increased investment in aquaculture-specific vaccines, along with mechanisms to make them accessible and affordable in low- and middle-income countries, is urgently needed.
5. **Enacting and enforcing regulatory frameworks:** Many aquaculture-producing countries lack comprehensive regulations governing antimicrobial use. Where regulations exist, enforcement is often weak. Governments must establish clear legal frameworks, require veterinary oversight for antimicrobial prescriptions, and implement traceability systems to ensure compliance.

The Path Forward

The global aquaculture sector stands at a crossroads. Continued reliance on antimicrobials at current levels risks compromising not only the sustainability of aquatic food systems but also the efficacy of life-saving medicines for human health. The challenge is particularly acute in the Asia-Pacific region, where the majority of global aquaculture production and antimicrobial consumption are concentrated, and where smallholder farmers often lack access to alternatives such as vaccines and improved biosecurity technologies. However, momentum for change is building. International organisations, research institutions, and national governments are increasingly recognising the urgency of the AMR threat in aquaculture and are investing in surveillance, stewardship, and innovation. The adoption of the One Health approach integrating human, animal, and environmental health perspectives—provides a framework for coordinated action. As the theme of World AMR Awareness Week 2025 urged: “Act Now: Protect Our Present, Secure Our Future.” The time to act on antimicrobial resistance in aquaculture is not tomorrow—it is today.

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