A growing concern for public health, aquaculture farms and antibiotic resistance

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India is in need of increasing its production on par with its major population change. It has already reached seven-fold increase in aquaculture production compared to the 1950 s. The average growth rate of aquaculture industry is 4.5% every year and India with its aquaculture and capture fisheries, contribute to 7% of world fish production. The rapidly expanding fisheries sector also faces a critical challenge in the form of antimicrobial resistance from fish farming operations. Disease is considered as one of the critical factors determining the success of aquaculture. The disease management with antibiotics knowingly or unknowingly by the farmers cause the treated water to runoff from the main system where it meets in sublethal level of various bacteria and become the root cause of antibiotic resistance. Pathetically the recognised aquaculture hotspots are the areas that share the resistant bacteria that pose significant threat to human and animal health.

How intense is the problem?

Antimicrobial resistance is the resistance of microbes to the available antibiotics, that has reached alarming proportions causing approximately 58000 neonatal deaths annually because the treatment antibiotic is becoming less usable (Lakshminarayanan and Chaudhury, 2016) _. The intensive forming activity are the main places where the antibiotics are used but the impact from intense farming run off can be less because of the availability if effluent treatment options. Where as in the semi-intensive set up when the antibiotics are used, the run off or the treated water is the cause of concern. The aquatic environment is interconnected with fish farming systems, food processing industries and human settlements. The gene pool of resistance can go to any point can reach another point within no time

The traditional farming systems and AMR

India s aquaculture mainly relies on traditional pond culture systems particularly in Andhra Pradesh, Kerala, Tamil Nadu and West Bengal**.** the traditional systems contain many ways that can facilitate AMR development. The traditional pond systems in west Bengal which uses household waste water for culturing fishes may increase the selective pressure because of the cleaning products also.

Integrated aquaculture systems

Here the fish is cultivated with other livestock and poultry where if the animals get sick the usage of antibiotics is common. When they get sick the farmer unknowingly introduced antibiotics to the aquaculture systems creating complex reservoirs for resistance genes.

Poor water management

When animal waste is used as a manure or pond input if they are not dried properly, they can cause other pathogenic and opportunistic flora to flourish in the system and the antibiotic resistance flora also mix with the normal aquatic flora. The animal faeces which accumulate in the system also serves as selective pressure for the bacteria to undergo transformation, sometime set high stocking densities also increase the stress levels of animals which can cause disease susceptibility and subsequent antibiotic usage.

Antibiotic Usage Patterns in Indian Aquaculture

The common antibiotics used in ornament al fishes and in aquaculture are oxytetracycline, chloramphenicol's and fluoroquinolones which are also used in human medicines. (Hemamalini *et al*, 2022). Faced with recurring disease outbreaks and significant economic losses, culturists frequently resort to various chemicals, disinfectants, and antibiotics without proper guidance or regulation. Unregulated access to the antibiotics is the main culprit in veterinary oversight countries like India. Most of the aquaculture systems are guided by quacks who don't have any professional education in the field of aquaculture and veterinary medicine. They propose the treatment plan which can sometime cure the animal but most of the time with high risk because of inappropriate usage patterns including incorrect dosages, treatment durations, and drug combinations (Preena *et al,* 2020).

Reasons for Resistance Gene Dissemination

The studies have indicated numerous resistance genes in aquaculture pond sediments across Asia, including India. The most frequently detected genes confer resistance to Beta lactams sulphonamide and tetracyclines (Kemp *et al,* 2021). These genetic elements can persist in sediments long after antibiotic use ceases, creating lasting environmental reservoirs.

The warm water conditions and selective pressure during stress conditions can increase horizontal gene transfer between bacterial species. This process allows resistance traits to spread rapidly through microbial communities, including to pathogenic bacteria that may later infect humans.

Biofilm Formation

The biofilm is the complex structure formed by bacteria to escape from the disinfectants and stay persistently in the system. Aquaculture systems harbour complex biofilm communities which are normally harmless if alone that protect resistant bacteria and pathogenic from environmental stresses and antimicrobial treatments, serving as persistent sources of resistance genes. These biofilms are the main reason behind year after year infection to the same bacteria endemic to the particular area (Karunasagar *et al*, 2020). But every year they will be resistant to some new set of antibiotics

Climate Change Amplification

The climate change which has increased the temperature level of water can increase some of the bacterial occurrence such as vibrios. These are the emerging zoonotic pathogens where their occurrence mainly temperature dependant. Warmer conditions accelerate bacterial metabolism and gene transfer rates, while climate-induced stress on aquaculture systems increases disease pressure and antibiotic dependency. Climate change also decreases the water availability force farmers to reuse water, concentrating antibiotic residues and resistant bacteria in aquaculture systems. Due to climate change some calamities like landslide and cloud burst happens and they naturally increase the emerging and remerging of pathogens.

Public Health Implications of AMR

The emergence of aquaculture as an AMR reservoir poses several direct threats to public health in India. Consumption of inadequately cooked fish harbouring resistant bacteria can lead to treatment-resistant infections. Raw fish preparations and cross-contamination during processing amplify these risks. Aquaculture workers face direct exposure to resistant bacteria through water contact and fish handling, potentially acquiring and spreading resistant infections to their communities. AMR genes from aquaculture systems can contaminate irrigation water, groundwater, and coastal areas, exposing broader populations to resistant pathogens. As resistance spreads, traditional antibiotics become ineffective for treating fish diseases, forcing farmers to use newer, more expensive drugs or accept higher mortality rates. (Goh et al, 2024)

How to address the challenge

Tackling AMR in Indian aquaculture requires coordinated efforts across multiple sectors:

1. Establishing comprehensive regulations governing antibiotic use in aquaculture, including prescription requirements, approved drug lists, and residue monitoring programs.
2. Promoting alternate medicines, probiotics, improved biosecurity, and water quality management as alternatives to antibiotic dependence. (Bhat and Altinok, 2023)
3. Developing targeted training programs to educate farmers about proper antimicrobial stewardship and sustainable aquaculture practices.
4. Implementing national surveillance systems to track AMR trends in aquaculture and establish early warning systems for emerging resistance threats. (Xiao et al, 2023)

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