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REVIEW

A recent update on the antibiotic resistance pattern in *Aeromonas* from freshwater fishes and its impact on human health

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Abstract Antibiotic resistance has become a primary global health concern, affecting humans and animals. In the case of the fish population, *Aeromonas* is the most commonly found antibiotic-resistant pathogen and has emerged as a critical public health concern. *Aeromonas* species act as primary pathogens in fish and are widely present in fresh and brackish water environments. The majority of *Aeromonas* species exhibit resistance to a wide range of antibiotics. To prevent human infections, particularly those that affect fishermen, it is crucial to comprehend the incidence of *Aeromonas* and the patterns of antibiotic resistance. Hence, this study investigated antibiotic resistance patterns in the *Aeromonas* species isolated from freshwater fishes collected from various farm ponds. Instead of relying on antibiotics, treating infected fish with probiotics can reduce the risk of human fish-borne infections, enhance fish health, and antibiotic abuse can be decreased. A global effort is needed to reduce the overuse of antibiotics in aquaculture and encourage stakeholders to adopt preventive measures for disease control. This review article aims to provide an updated understanding of antibiotic resistance patterns in *Aeromonas* isolated from freshwater fish and assess their potential impact on human health. Additionally, by summarizing recent research findings, this study emphasizes the steps that must be followed to build management strategies and achieve successful control.

Keywords Antibiotics . Antibiotic resistant . Freshwater aquaculture . Freshwater fish

Introduction

Antibiotic resistant infections are posing a serious challenge to healthcare systems worldwide. In aquatic environments, including fish farms, *Aeromonas* have been identified as reservoirs for antibiotic resistant genes (Achee et al. 2019). The fish production status in various states of India shows that out of the total 141.64 Lakh tons of absolute fish production, inland fisheries added 10.437 million tons with top-level augmentation by Andhra Pradesh (36.1 Lakh Tonnes) (Ngasotter et al. 2020). Many other states, including India's freshwater fish basket, included Karnataka, Maharashtra, Odisha, Chhattisgarh, Jharkhand, and Gujarat (Mishra et al. 2017). Odisha, the other leading state, has contributed substantially to 6.6 Lakh Tonnes (Ngasotter et al. 2020). More than 95% of the total aquaculture production is contributed by freshwater aquaculture. The *Aeromonas* species have shown high resistance to 1st generation Cephalosporin (CEF), trimethoprim/sulfamethoxazole (SXT), ami-

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noglycosides (AN), tetracycline (TE), and streptomycin (STR) (Ayyappan and Gopalakrishnan 2006). The freshwater aquaculture yields three types of Indian Major Carps (IMC) i.e,, *Labeo rohita* (rohu)*, Catla catla* (catla) and *Cirrhinus mrigala* (mrigal), which includes three interesting species: *C. idella* (grass carp)*, Hypophthalmichthys molitrix* (silver carp), and *Cyprinus carpio* (normal carp). Indian Major Carps (IMC) or a combination of Indian and exotic carp can be used in polyculture (Katiha et al. 2005).

With the advancement and diversification in aquaculture systems and the need to meet the demand for higher fish production, culture practices are intensified, with possible transmission of diseases from fish to human. The most common are the parasitic and bacterial diseases (Sandeep et al. 2016). Various bacterial diseases commonly affect carp culture when we consider India, including *Streptococcal* septicemia, caused by *Streptococcus* species, and Motile *Aeromonas* Septicemia (MAS), caused by *Aeromonas hydrophila* and other *Aeromonas* species (Mohanty and Sahoo 2007). *Aeromonas* sp. is a microorganism found in the environment with global distribution causing disease in fishes, divided into two categories. The first group includes the psychrophilic non-motile *Aeromonas salmonicida*, which in temperate fishes causes furunculosis (Sharma et al. 2009), and the other group, such as *A. caviae, A. hydrophila,* and *A. sobria*, three species of mesophilic motile species (Praveen et al. 2014). Mesophilic motile *Aeromonas* can be found everywhere, as can endemic oceanic microorganisms that can be found, according to (Wei et al. 2015), in potable water, sewage, and freshwater that has been chlorinated or not (Abraham 2011; Janda and Abbott 2010). There mainly were four main types of *Aeromonas* infections reported:

i) fin decay-typically occurs by natural pressure,
ii) bacterial body ulcers-the fish's body noticed having open, shallow to profound sores
iii) bacterial gill sickness - significantly targeted in the gills
iv) systemic bacterial infection, harm happens to interior organs (Sandeep et al. 2016).

Motile *Aeromonas* septicemia is one more significant disease frequently muddled with red sickness in carp culture. As a result, this most prevalent bacterial disease is causing a considerable loss of production in freshwater fish farming. This infection has been related to a few individuals from the *Aeromonas* variety, including *A. hydrophila, A. veronica, A. caviae, A. sobria,* and *A. Schuberti* (Mohanty and Sahoo 2007).

Prevalence and identification of motile *Aeromonas* strains in freshwater fish

The gastrointestinal tract's resident and transitory microflora have been exposed to the motile *Aeromonas* strains of farm-cultivated freshwater fish like *L. rohita, C. catla*, and *C. Idella* (Hatha 2002).

Aeromonas species from 179 samples of fish (gills) and chicken (raw meat) collected in the North Kolkata region were gram-negative short rods, oxidase negative, catalase negative, and faculatative anaerobic. Three *Aeromonas* species such as *A. hydrophila, A. sobria,* and *A. caviae*-were chosen from 179 samples and identified as chicken and fish, with 31 isolates accounting for (17.32 %) of the total. 24 (18.89 %) of the isolates were from fish, followed by 7 (13.46 %) from chicken, from which 29 (93.54%), 1 (3.22%), and 1 (3.22%) were identified as the three species mentioned (Praveen et al. 2014). The most prevalent *A.* species in Indian aquaculture include *A. veronii*, *A. caviae*, *A. hydrophila*, and *A. veronii biovar sobria*. Mesophilic *Aeromonas*, recently identified as the etiological representative of diarrheal disease, has become a significant warning to public health. (Hatha et al. 2005).

Effects of antibiotic resistant in *Aeromonas* from fish to human health

Aeromonas are zoonotic pathogens capable of causing human infections through consuming contaminated fish or exposure to contaminated water. This section discusses the potential routes of transmission and the associated risks to human health. *Aeromonas* are bacteria that can be detected anywhere in the environment, including in the aquatic habitat (Janda and Abbott 2010), where *A. salmonicida, A. caviae, A. hydrophila,* and *A. veronii biovar sobria* infect marine fish (Radu et al. 2003). *Aeromonas* species are also major human opportunistic disease-causing agents that can create three types of infections, including those caused by trauma in the intestines, blood, skin, and soft tissues (Janda and Abbott 2010; Real 1994). According to (Callister and Agger 1987; Gobat and Jemmi 1993), *Aeromonas* species have frequently been isolated from fish and other foods. According to (Tsai and Chen 1996), these bacteria may transmit disease and cause food spoilage. Infection can also result from contact with contaminated water or fish, according to (Janda and

Abbott 2010). *Aeromonas* pathogenicity is linked to the formation of extracellular hydrolytic compounds like lipases and proteases, which aid in bacterial attack and lay the groundwork for disease (Galindo 2006). Hemorrhage, cytotoxicity, enterotoxicity, and lethality are among the cytotoxic enterotoxin (Act) biological activities (Chopra et al. 1991). The worldwide expansion of intensive fish farming has led to an increase in the use of antibiotics to treat bacterial infections (Díaz-Cruz et al. 2003). Antimicrobials are typically added directly to the water or added to the feed in aquaculture to stop the spread of infectious fish diseases (Defoirdt et al. 2011) and, in some instances, to illegally encourage fish growth (Serrano 2005). Regulations governing the use of antibiotics in aquaculture vary widely and are rarely enforced in many of the world's major aquaculture-producing nations (Pruden et al. 2013). As a result of the widespread use of antibiotics in aquaculture, both food-borne and opportunistic human pathogens have developed antibiotic resistance (Marshall and Levy 2011). (Figure 1) According to (Figueira et al. 2011), *Aeromonas* species resistance to various antibiotic classes poses a significant threat to human health, as resistant bacteria can infect humans through food or direct contact. (Taylor NG et al. 2011; Levy SB and Marshall B 2004) claim that mobile genetic elements like plasmids, phages, and transposons can also transfer resistance genes (Janda and Abbott, 2010). *Aeromonas* can resist sulfamethoxazole, cephalosporins, penicillins (amoxicillin, ampicillin, ampicillin-sulbactam, ticarcillin, oxacillin, and penicillin), macrolides (clarithromycin), and cephalosporins. Four *Aeromonas* species are linked to the production of chromosomally encoded beta-lactamases, as stated by (Janda and Abbott 2010). First-generation cephalosporins and penicillins are ineffective against these species bla and tet genes, both of which are separately encoded in a variety of hereditary components, are additional significant obstruction determinants of resistance to antibiotics and beta-lactam antibiotics (Agersø et al. 2007; Wu et al. 2011) integrons, which are to blame for resistance to trimethoprim, chloramphenicol, aminoglycosides, tetracyclines, and aminoglycosides (Chang et al. 2007; Kadlec et al. 2011). Indeed, due to acquired antibiotic resistance among fish pathogens, the utilization of molecules whose class and structure are comparable to those used in mariculture or, in some instances, identical to those used in that industry could result in serious therapeutic issues for humans (Cabello 2006). The risk of transmitting this kind of resistance to humans from the aquaculture environment is undervalued (Cabello et al. 2013), so monitoring the efficacy of fish farming antibiotics is critical.

Resistance in aquatic ecosystems from the farmer's field

Over the past few decades, the aquaculture industry's rapid expansion has increased the treatment of infectious diseases with drugs. Fish ranch stores and sub-therapeutic levels of antibiotics in the water give ideal circumstances to the openness and determination of safe bacterial strains. To reduce their use in aquaculture, all stakeholders should be educated about the adverse effects of excessive antibiotic use on humans, fish, and aquatic ecosystems. They should also be inspired to use ecological disease prevention calculations (Dhanapala et al. 2021).

Using a sub-group of an independent, active sampling strategy can help determine the incidence and effects of particular pathogens, such as *Aeromonas* species., and provide interested parties with valuable in-

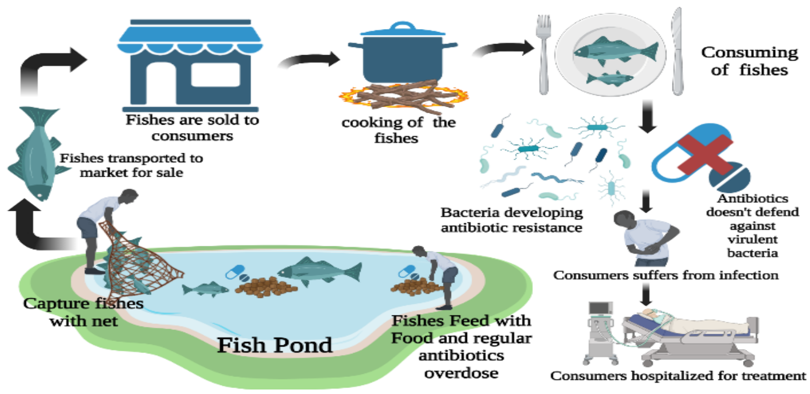

Fig. 1 The problem faced is due to antimicrobial resistance in fish

formation. Likewise, during these examining exercises, designs among networks of similar species possessing different topographical areas or during particular seasons might be dealt with unexpectedly, bringing about the meaning of hazard factors that would work with further developed species the executives. Additionally, there is developing concern concerning the limit of oceanic biological systems to gather land-based determinants of anti-microbial resistance and destructiveness as endpoints (Chen et al. 2018); using sophisticated testing methods to flag and prevent course focuses between the land-water interface is crucial to study and identify antibiotic resistant and destructiveness in typical sea-going environments (Grilo et al. 2020). Wildlife actively participates in the movement of genetic factors and microbiota in the natural habitats of *Aeromonas* species, making the microbiota of wild species particularly significant (Hu et al. 2017). additionally, they possess numerous harmful elements that participate in colonization and takeover, making them a reasonable source of danger in maritime environments (Harnisz and Korzeniewska 2018). Moreover, *Aeromonas* are valuable signs of antibiotic resistance in land and water proficient conditions because of their deeply grounded capacity to secure and decide the reasons for obstacles (Piotrowska and Popowska 2015).

Antimicrobial resistance and its possible side effects

The leftover antibiotics found in marketed fish and shellfish items are the after-effect of the unnecessary utilization of antibiotics in modern aquaculture (Grave et al. 1996; Grave et al. 1999; Sartakova et al. 2003; Angulo et al. 2004). Because of this issue, consumers of fish have taken antibiotics unnoticed, increasing their susceptibility to bacterial contamination and preferring bacteria that are safe for antibiotic use (Grave et al. 1996; Grave et al. 1999; Alderman and Hastings 1998; McDermott et al. 2002; Greenlees 2003; Cabello 2004; Salyers et al. 2004). Workers who sedate food in food plants, appropriate it to fish, and direct it to them can also cause sensitivities and poisonous issues for unprotected aquaculture workers. Additionally, sensitivities and harmfulness brought on by undetected food anti-infection use are challenging to analyze due to a lack of prior knowledge regarding antibiotics usage (Alderman and Hastings 1998; McDermott et al. 2002; Greenlees 2003; Cabello 2004). Many antibiotics can enter the skin, digestive system, and bronchial tracks (Grave et al. 1996; Lillehaug et al. 2003). The diversity of the microbiota in aquaculture may be altered by the persistent presence of large quantities of antibiotics in the water and silt, which may change the typical vegetation and microscopic fish in those specialties (Miranda and Zemelman 2001; Sartakova et al. 2003). According to experts, the increased nitrogen, carbon, and phosphorus inputs from fish feces and non-ingested food could cause eutrophication in the aquaculture environment (Sartakova et al. 2003). This significant use of antibiotics may disrupt the equilibrium of the environment at those levels because the microbiota of sea-going and dregs specialties complete essential trophic and metabolic capabilities. Algal sprouts and anoxic conditions, which could have an impact on fish and human health, could be accelerated by this (Sellner et al. 2003; Hernández et al. 2005).

Status of aquaculture's use of antibiotics

In aquaculture, antibiotics can be used as chemotherapeutic agents to treat infectious bacterial diseases if they do not cause harm to the host, whether natural or synthetic. Because of the viability of the fish's resistant framework in wiping out bacterial colonization and contamination (Sartakova et al. 2003; Barton and Iwama 1991; Naylor and Burke 2005), prophylactic antibiotics use has expanded. Fish get antibiotics as part of their diet, sometimes through an injection or a bath (Markestad and Grave 1997). As a result of the antibiotic laden fish feces and underutilized food, sediment reached the pen bottoms according to (Hektoen et al. 1995; Kerry et al. 1996; Coyne et al. 1997; Lützhøft et al. 1999; Guardabassi et al. 2000; Sørum and L'Abée-Lund 2002; Boxall et al. 2003), antibiotics diffuse into dregs, are filtered out of food and excrement, and can flow to distant areas (Hektoen et al. 1995; Kruse and Sørum 1994; Davison 1999; Miranda and Zemelman 2002; Miranda and Zemelman 2002; Burrus and Waldor 2003; Balaban et al. 2004; Beaber et al. 2004; Hastings et al. 2004; Kim et al. 2004). The microflora of the residue will be altered, and the excess antibiotics will attract microscopic organisms that are resistant to antibiotics, causing particular tension and remaining in the dregs (Kruse and Sørum 1994; Sandaa and Enger 1994; Rhodes et al. 2000; Rhodes et al. 2000). The determinants of antibiotic resistant that were chosen for this aquatic environment have the potential to spread to bacteria in the terrestrial environment, including pathogens that can cause disease in humans and animals through horizontal gene transfer (Sartakova et al. 2003; Sørum, 2005). This is also true in settings where aquaculture and agriculture are integrated, and standard practices include feeding fish manure and other agricultural residues (Petersen et al. 2002).

Antimicrobial resistance systems and transactions escalate

Antibiotics are frequently incorporated into the feed that enters the water where the fish are kept in aquaculture. In this manner, resistance and exchange instruments are supported. Antibiotics can sometimes be added to the water directly. This philosophy achieves specific strain when applied to the revealed conditions, ordinarily water. In aquaculture, antibiotics can be used to affect numerous environmental bacteria. Following picking changes that increase their well-being in the new environment, different bacterial species could get through antagonistic conditions or regular modifications. Moreover, microbes use portable hereditary components like plasmids and transposons. Microorganisms can access many nomad qualities with these components, allowing them to spread across bacterial populations and move from one cell to the next. Antibiotic resistance can quickly spread to many different bacterial genera in several different ways. It's conceivable that the microorganism will gain qualities for chemicals similar to beta-lactamases and separate beta-lactams (penicillins). Phosphorylation, adenylation, and acetylation are additional synthetic reactions that inactivate antibiotics. Kumarasamy et al lately (Kumarasamy et al. 2010) utilized the significance of a single catalyst, the beta-lactamase NDM-1, as an illustration. Microorganism changes can alter the bacterial cell wall so that it no longer contains the antibiotics specialist's limiting site or multiple metabolic pathway characteristics that limit the antibiotics specialist's access to the intracellular objective site by downregulating protein characteristics. The widespread use of antibiotics in aquaculture for fish and livestock also affects the identification of pathogenic microorganisms resistant to various medications. The multidrug pathway is one of two methods by which microbes can become resistant to multiple drugs. A solitary cell might initially contain numerous medication opposition encoding qualities for these microorganisms. This accumulation typically takes place at resistance plasmids. Second, multidrug opposition may likewise result from an extended portrayal of the attributes that describe multidrug efflux siphons, which discharge different drugs.

It has recently been demonstrated that bacteria in the aquaculture environment and bacteria in the terrestrial environment, including pathogens that infect humans and animals, exchange antibiotic resistant genes (Rhodes et al. 2000; Rhodes et al. 2000; Sørum 1998; Schmidt et al. 2001). Human micro-organisms antibiotic resistant can be traced back to aquaculture. For example, strong epidemiological and subatomic evidence suggests that fish microorganisms like *Aeromonas* can spread antibiotic resistance genes to human microorganisms like *Escherichia coli* (Sørum and L'Abée-Lund 2002; Rhodes et al. 2000; Rhodes et al. 2000; L'Abée-Lund and Sørum 2001).

Disadvantages of antibiotic

It is common knowledge that numerous antibiotics are utilized in aquaculture to control bacterial infections as well as antibiotics and how they affect how fish react to pressure. Despite this, excessive use is associated with several secondary effects that affect the climate and the fish. Antibiotic-related environmental effects are primarily attributed to the aquaculture industry's excessive use of antibiotics and fish products and the presence of drug traces (Saglam and Yonar 2009). Unfortunately, very few studies have looked at how antibiotic use affects fish. Evidence shows some antibiotics can harm the kidneys (Hentschel et al. 2005). However, immunomodulation is the most striking optional impact (Rijkers et al. 1981; Grondel et al. 1985; Wishkovsky et al. 1987; Tafalla et al. 1999). The Bonventre gathering's review (Hentschel et al. 2005) looked at nephrotoxicity and found that the aminoglycoside antibiotic gentamicin causes acute renal failure in fish, like in rats and humans. The fish could not keep up with liquid homeostasis because of the gentamicin's time and portion subordinate pericardial effusion, as per their discoveries.

A potential means of reducing the overuse of antibiotic

Due to antibiotic-resistant bacteria and the transmission of antibiotic resistance determinants from the aquatic environment to the terrestrial environment, the use of antibiotics in aquaculture has been severely restricted in many nations (Angulo et al. 2004; Cabello 2004; Lillehaug et al. 2003; Markestad and Grave 1997; Goldburg and Naylor 2005). The practically complete end of anti-microbial prophylaxis here, more tight command over the remedy of remedial antibiotics, and the preclusion of antibiotics use in therapeutics that are still exceptionally valuable for treating human diseases are instances of limitations (Grave et al. 1996; Grave et al. 1999; Lillehaug et al. 2003; Markestad and Grave 1997). Without excessive antibiotic prophylaxis, it is financially possible to support a valuable aquaculture industry (Grave et al. 1996; Grave et al. 1999; Lillehaug et al. 2003; Markestad and Grave 1997). The utilization of antibodies and other clean measures have remained inseparable from this tight command over the utilization of anti-infection agents. As a result, developed nations' aquaculture industries have significantly reduced their use of antibiotics (Grave et al. 1996; Grave et al. 1999; Goldberg et al. 2001; Lillehaug et al. 2003; Markestad and Grave 1997). However, China and Chile, two nations with expanding aquaculture ventures (Cabello 2004), utilize numerous antibiotics, including quinolones, without restriction in aquaculture (Cabello 2004).

Antibiotic resistance pattern of *Aeromonas* collected from the aquatic environment

The strains no longer responded to chloramphenicol, streptomycin, or tetracycline. The effectiveness of β-Lactam antibiotics against 20 distinct *A. hydrophila* strains was the subject of a study (Awan et al. 2009). The highest clavulanic acid activity and resistance to cephaloridine and ampicillin were observed when tested at sub-inhibitory concentrations (Awan et al. 2009). Concerning the lowest inhibitory concentrations of 22 antibiotics and 63 *Aeromonas* species *s*trains. The microdilution method was used for a single examination. They discovered that, in comparison to *A. caviae* or *A. sobria*, the majority of the strains in the class that were inhibited by more recent cephalosporins such as moxalactam, cefotaxime, and cefoperazone, aminoglycosides such as chloramphenicol, antibiotics such as nitrofurantoin, trimethoprim-sulfamethazole, and antibiotics for infections, were safer with *A. hydrophila* (Demarta et al. 2008*)*. The antibacterial resistance of the tropical fish *Aeromonas*, which was imported from Singapore, was evaluated in the study (Mukhopadhyay et al. 2008). From the different episodes of furunculosis created, 80 confines of *A. salmonicida* were detached, and Scottish wild salmon from 1988 to 1989, as well as these isolates, were viewed as safeguarded, which were introduced to the shortcoming to ß-lactam counter-specialist poison amoxicillin (Sharma et al. 2009). A collection of 234 isolates from *Aeromonas*, primarily *A. hydrophila*, was used to investigate the rising prevalence of antibiotic resistance in Taiwan. Using the agar dilution method, it was discovered that moxalactam, ceftazidine, cefepime, aztreonam, imipenem, amikacin, and fluoroquinolones were effective against more than 90% of the isolates. Cephalosporins, aminoglycosides, antibiotics, and trimethoprim-sulfamethoxazole, on the other hand, were more secure (Nagar et al. 2011). According to a report, *Aeromonas* isolates tolerated gentamicin, chloramphenicol, ciprofloxacin, and cotrimoxazole (Leitao and Silveira 1991). According to a study, individual and multiple antibiotic resistances were high in aeromonad bacterial susceptibility to five antibiotics over one year. This indicates the considerable effect of fish cultivation on various bacterial gatherings related to the aquaculture climate (Dallal et al. 2012). It is reported that chloramphenicol was extremely sensitive to *Aeromonas* species with antibiotic sensitivity patterns (Neyts et al. 2000). Every one of the 21 separates from cultivated carp (*Cyprinus carpio*) was impervious to ampicillin and penicillin and delicate to trimethoprim-sulphamides, oxolinic corrosive, flumequine, chloramphenicol, norfloxacin, lincomycin, and perfloxacin in a concentrate on the anti-microbial weakness of *A. hydrophila* and *A. sobria* (Guz and Kozinska 2004) interpreted in (Table 1).

After observing Table 1 According to a review of the Table above, Ampicillin was common antibiotic-resistant in two samples. *Cyprinus carpio* was used to isolate 21 *A. hydrophilic* and *A. sobria* isolates., a farm carp, and ought to be resistant to all *Aeromonas* strains Table 1. Tetracycline and trimethoprim/sulfamethoxazole resistance was found in *Aeromonas* species. and *A. hydrophila* samples from Taiwan. This effect of rare antibiotic resistance may result in bacteria that do not respond to antibiotics. This is very important because resistant adaptation, which should not be shown, allows bacteria to become stronger gradually. The standard sensitive antibiotic was Chloramphenicol among *Aeromonas* fundamentally *A. hy-*

Table 1 Comparative study bacterial isolates samples to their respective antibiotic resistance pattern of aquatic region

Bacterial isolates	Antibiotic resistant pattern		Reference
	Resistant R	Sensitive S	
A. hydrophila	Cephaloridine R Ampicillin R		Awan et al. (2009)
Aeromonas species	Cefotaxime R Chloramphenicol R Moxalactam R Cefoperazone R Aminoglycosides R Nitrofurantoin R Tetracycline R Trimethoprim/sulfamethoxazole R		Demarta et al. (2008)
80 farmed isolates of *A. salmonicida*	Amoxicillin/Amoxicillin R		Sharma et al. (2009)
Aeromonas, primarily *A. hydrophila* in Taiwan, a collection of 234 isolates	Tetracycline R Aminoglyco sides R Trimethoprim/sulfamethoxazole R	Cefepime S Imipenem S Amikacin S Ciprofloxacin S to *Aeromonas only* Chloramphenicol S to *Aeromonas only* Moxalactam S Ceftazidine S Aztreonam S Gentamicin S to *Aeromonas only* Cotrimoxazole Sulfonamide S to *Aeromonas only*	Nagar et al. (2011); Leitao and Silveira (1991)
A report of antibiogram studies revealed the presence of *Aeromonas* species.		Chloramphenicol S	Neyts et al. (2000)
21 *A. hydrophila* and *A. sobria* isolates from (*Cyprinus carpio)* farmed carp	Ampicillin R Penicillin R	Trimethoprim -sulfamethoxazole S Chloramphenicol S Oxolinic acid S Flumequine S Norfloxacin S Lincomycin S Perfloxacin S	Guz and Kozinska (2004)

drophila in Taiwan. An antibiogram report concentrates on 234 separates of *Aeromonas* species, including 21 segregates of *A. sobria* and *A. hydrophila* from cultivated carp *(Cyprinus carpio)*. Because of the susceptibility, bacteria can respond to antibiotics and deplete slowly. Explicitly analyzing from one example, *A. hydrophila* in Taiwan has Ciprofloxacin, Gentamicin, Cotrimoxazole Sulfonamide, and Chloramphenicol sensitive to *Aeromonas* just, which appears to be surprisingly Table 1.

Antibiotic resistant pattern of *Aeromonas* collected from local fish markets

Aeromonas.cavaie comprised 66% of the 132 *Aeromonas* collected from the fish market in Ankara, Turkey. *A. hydrophila* (22.6%) and *A. veronii biovar sobria* (11.6%) followed. All *Aeromonas* were resistant to ampicillin, cephalothin, and trimethoprim; chloramphenicol, however, was the least resistant (9.0%), and ciprofloxacin and ceftriaxone were susceptible to all of the above-mentioned strains (Yucel et al. 2005). Utilizing the plate dispersion technique, 51 *Aeromonas* isolates from 20 rainbow trouts (*Oncorhynchus mykiss*) were tried for aversion to different β-Lactam anti-infection gatherings (penicillin, cephalosporins, monobactams, and carbapenems). The investigation uncovered that ampicillin, carbenicillin, and ticarcillin had the most note-worthy paces of resistance (Saavedra et al. 2004). In a study, antibiotic resistance was looked at in several aquaculture species. Even though ciprofloxacin effective against all strains, amoxicillin, cephalexin, erythromycin, and ampicillin were all found to be resistant (Akinbowale et al. 2006). A system for treating fish with oxolinic acid and assessing quinolone antibiotic resistance was integrated into a prototype marine. In contrast, fish treated with this treatment developed resistance in their intestines, unlike bivalves or integrated aquatic system sediments, where resistance levels remained unchanged (Giraud E et al. 2006). According to an antibiotic sensitivity test report, *Aeromonas* was sensitive to ciprofloxacin, streptomycin, gentamicin, and amikacin (Alperi et al. 2008). A concentrate on anti-microbial responsiveness tests was done on 22 isolates of *Aeromonas i*n this study (Sharma et al. 2009). *Aeromonas* isolates were tolerant of gentamicin, ceftriaxone, and chloramphenicol. When the pattern of antibiotic resistance was examined, more than 90%, 80%, 70%, and 60% of the strains were resistant to ampicillin, cephalothin, tetracycline, and nalidixic acid, respectively (Awaad et al. 2011) interpreted in Table 2.

After observing Table 2 Four of the 132 *Aeromonas* taken from the fish market in Ankara, Turkey, were found to frequently be resistant to antibiotics, as shown in the Table above. These samples included 22 species of *Aeromonas* from 20 species of rainbow trout (*O. mykiss*) treated with antibiotics from various aquaculture species, hostile to a variety of aquaculture species microorganisms and a model marine system for fish raising facilitated oxolinic destructive treatment. Ciprofloxacin was found to be very sensitive in three models, and 132 *Aeromonas* were taken away from the fish market in Ankara, Turkey; 132 *Aeromonas* were thought to be immune to cephalothin and kept out of the fish market in Ankara, Turkey; Gentamicin was found to be common and sensitive in 22 *Aeromonas* isolates treated with oxolinic acid, and it was found to be present in two samples from a prototype marine integrated system used to raise fish. From the fish market in Ankara, Turkey, Chloramphenicoat-least Rin 132 *Aeromonas* were disconnected; Ampicillin was found to be resistant to more than 90%, Cephalothin above 80%, Tetracycline over 70%, and Nalidixic acid over 60% in 22 isolates of *Aeromonas*, which they found to be a strange observation Table 2.

Antibiotic resistant pattern of *Aeromonas* collected from farmyard environment

Freshwater fish such as *Labeo rohita*, *Catla catla*, and *Ctenopharyngodon idella* are all of which are associated with the *Aeromonas* species, with a commonness of 33.5 % and 17.6 %, separately microfloand ra of farm-raised fish (Hatha 2002). Additionally, species-level characterization of these fish's intestines revealed that *Aeromonas sobria*, *Aeromonas caviae*, and *A. hydrophila* dominated (50–70%). The study looked at 8 *A. sobria,* 55 *A. hydrophila,* and 27 *A. caviae* strains. Around 2% of the *Aeromonas* species stayed unidentified. *A. hydrophila* was confined from south India and tracked down in business fish and prawn, with a commonness of 33.5 % and 17.6 %, separately, detailed by (Vivekanandhan et al. 2002). None of the *Aeromonas* strains tested in this study were resistant to streptomycin, and only 10% of the *Aeromonas* strains tested in this study were resistant to gentamicin, ciprofloxacin, and nalidixic acid. Additionally, resistance to chloramphenicol was low (b20%) (Vivekanandhan et al. 2002) found that the levels of protection against gentamicin and nalidixic acid were comparable. However, in this review, chloramphenicol resistance was

Table 2 Comparative study bacterial isolates samples to their respective antibiotic resistance pattern of marketing region

Bacterial strains	Antibiotic resistant Pattern		Reference
	Resistant R	Sensitive S	
In Ankara, Turkey, 132 *Aeromonas* were kept out of the fish market.	Ampicillin R Cephalothin R Trimethoprim R Chloramphenicoat-least R	Ciprofloxacin S Ceftriaxone S	Yucel et al. (2005)
On 20 rainbow trout (*O. mykiss*) isolates of 51 *Aeromonas* strains	Ampicillin R Carbenicillin R Ticarcillin R	Penicillin S Cephalosporins S Monolactam S Carbapenems S	Saavedra et al. (2005)
Antibiotics from different aquacultural species	Ampicillin R Amoxicillin R Cephalexin R Erythromycin R	Ciprofloxacin S	Akinbowale et al. (2006)
A model marine incorporated a framework for the treatment of oxolinic corrosive during fish raising	Quinolone R	Ciprofloxacin S Streptomycin S Amikacin S Gentamicin S	Alperi et al. (2008)
On 22 isolates of *Aeromonas*	AmpicillinMore than 90% R CephalothinMore than 80% R TetracyclineMore than 70% R Nalidixic acidMore than 60% R	Chloramphenicol S Gentamicin S Ceftrixone S	Awaad et al. (2011)

Table 3 Comparative study Bacterial isolates samples to their respective antibiotic resistance pattern of farmyard region

Bacterial Strains	AntibioticsResistance Pattern		Reference
	Resistant R	Sensitive S	
Different *Aeromonas* strains	Streptomycin R by none of the strains Gentamicin R by 10% of Strains Ciprofloxacin R by 10% of Strains Nalidixic acid R by 10% of Strains ChloramphenicolHigh level R among *Aeromonas* strains but less than 5% R among *A. hydrophila* strains		Vivekanandhan et al. (2002)
Aeromonas strains isolated from fish	Polymixin-B shows R by over 95 % of the *A. hydrophila* strains Streptomycin10% R		Vivekanandhan et al. (2002)

more common (Vivekanandhan et al. 2002), who discovered commercial fish *A. hydrophila* strains less than 5% chloramphenicol resistance. This is remarkable because the discovery of chloramphenicol residues in China and India's aquaculture products has caused some products supplied by China and India suppliers to be banned, particularly in countries that are members of the European Economic Community (EEC) (Vivekanandhan et al. 2002) discovered that streptomycin resistance was present in approximately 10% of fish-isolated *Aeromonas* strains. Polymyxin-B resistance was likewise tracked down in this concentrate by unexpected examples in comparison to those of (Vivekanandhan et al. 2002). Despite the fact that more than 95% of the *A. hydrophila* strains were discovered by 2002, polymyxin-B antibiotics were protected by less than half of the *A.hydrophila* strains excluded from this investigation, as interpreted in Table 3 .

According to the above Table 3 They discovered that Streptomycin was resistant in ten % of samples of fish-isolated *Aeromonas* strains and zero % of samples of various *Aeromonas* strains. 10% of strains were intolerant of gentamicin, 10% of ciprofloxacin, and 10% of naldixin acid, respectively, and 10% to chloramphenicol, Chloramphenicol was highly resistant in *Aeromonas* but less than 5% in *A. hydrophila* Polymixin-B was highly resistant in sample *Aeromonas* strains isolated from fish Table 3 .

Impact on public health

Aquaculture-related antibiotic-resistant microorganisms address a threat to general prosperity. Fish pathogens and other aquatic bacteria with resistance obtained have the potential to store resistance genes that can then spread to human pathogens or be dispersed further. Keep in mind that environmental microorganisms produce the majority of antibiotics used to treat infections consequently, the environment in which antibiotic resistant genes emerged must have also been artificial or nonclinical (Martínez 2008). With a superior comprehension of the biological job of antibiotics and antibiotic resistance in common habitats, antibiotic resistance may ultimately be anticipated and defeated.

Aeromonas. hydrophila-actuated septicemia is one of the numerous ailments that can happen in aquaculture. The system is frequently treated with various antibiotics because this is a serious issue (Parker and Shaw 2011). According to the findings of this study, this made it easier for resistance to develop frequently. Various scientists found that *A. hydrophila* and different organisms traded antibiotic resistance conveying plasmids, demonstrating how far AMR qualities have spread (Stratev and Odeyemi 2016). *Aeromonas* strains are habitually utilized as a marker for estimating AMR in aquaculture due to their expanded ability to gain and move AMR qualities (Patil et al. 2016). Consequently, the study's discovery of highly antibiotic-resistant *Aeromonas* strains highlighted the danger of the rapid spread of AMR genes with mobile genetic elements. Studies claimed that extended-spectrum beta-lactamases (ESBL) increased in *Aeromonas* strains and that gene cassettes and mobile genetic elements containing AMR genes were transferred from fish to human pathogens (SØRUM 1998; Maravić et al. 2013). However,

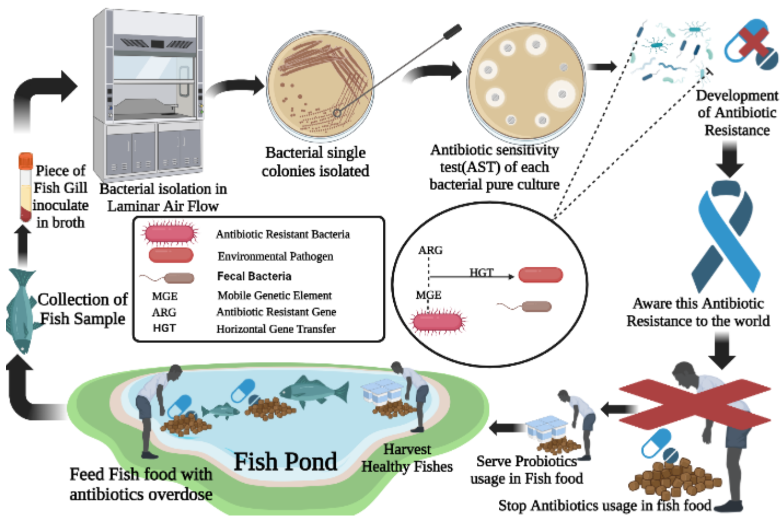

Fig. 2 The cure for the problem caused due to antimicrobial resistance

the pathogen antibiotic resistance found in this study is challenging due to the possibility of horizontal gene transfer. This study embodies the resulting information, which enables the aquaculture framework to carry out novel and successful treatments.

Possible control measures or way forward

According to (Kruse and Sørum 1994), antibiotic resistance in bacteria that infect humans results in a rise in the prevalence of infections, the severity of the infection, and the frequency with which treatments fail. Antibiotic residues pose a danger to human well-being and the threat posed by antibiotic-resistant bacteria, which pose allergies, toxicity, and other health risks. Shrimp flesh can accumulate some antibiotics, and the concentration gradually rises as more antibiotics are used. The antibiotic residue has an impact on trade prospects and poses a health risk. Thus, illness anticipation ought to overshadow infectious prevention in shrimp well-being on the board. Twenty antibiotics have been banned from being used in shrimp aquaculture by the Coastal Aquaculture Authority (CAA) in light of these considerations. antibiotics agents can be avoided or used less frequently to save money on farm management and preserve the integrity of the environment. Antibiotics have some advantages and disadvantages, but taking too many of them is a significant problem. We need to come up with other, less risky means of fighting fish diseases. There are some other options, such as probiotics, prebiotics, synbiotics, immunostimulants, bacterial therapy, vaccines, RNA interference, and Quorum sensing inhibition Figure 2.

Conclusion

Antibiotic resistance in *Aeromonas* from fish poses a considerable threat to human health. This review highlights the urgent need for comprehensive surveillance, research, and collaborative efforts to address this issue effectively. By adopting a One health approach and implementing strategic control measures, we can work towards safeguarding both animal and human health from the consequences of antibiotic resistance. *Aeromonas* showed an increase in resistance to cephalothin (CEF), trimethoprim/sulfamethoxazole (SXT), aminoglycosides (AN), tetracycline (TE), and streptomycin (STR) in this review. Customary observation and antibiotic resistance observation are required to determine the effect of antibiotic treatment in aquaculture with higher MAR indexes. These findings provide solid evidence of the presence of antibiotic resistance in contaminated fish-associated microorganisms and emphasize the significance of a single aquaculture well-being strategy.

List of abbreviations	
A. salmonicida	*Aeromonas salmonicida*
A. hydrophila	*Aeromonas hydrophila*
A. Caviae	*Aeromonas caviae*
A. Veronii	*Aeromonas veronii*
A. veronii biovar sobria	*Aeromonas veronii biovar sobria*
CEF	Cephalothin
SXT	Trimethoprim/sulfamethoxazole
AN	Aminoglycosides
TE	Tetracycline
STR	Streptomycin
MDR	Multi Drug Resistance
IMC	Indian Major Carps
L. rohita	*Labeo rohita*
C. catla	*Catla catla*
C. mrigala	*Cirrhinus mrigala*
C. idella	*Ctenopharyngodon idella*
H. molitrix	*Hypophthalmichthys molitrix*
C. carpio	*Cyprinus carpio*
MAS	Motile *Aeromonas* Septicemia
ESBL	Extended-spectrum beta-lactamases
MGE	Mobile Genetic Elements
EEC	European Economic Community
CAA	Coastal Aquaculture Authority
OH	One Health

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