Food and Agriculture Organization of the United Nations

भाकृअनुप ICAR

Surveillance data of the Indian Network for Fishery and Animal Antimicrobial Resistance (INFAAR) – An analytical report (2019–2022)

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Surveillance data of the Indian Network for Fishery and Animal Antimicrobial Resistance (INFAAR) –

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Preface

The Food and Agricultural Organization of the United Nations (FAO) underscores the importance and urgency of addressing the growing global threat of antimicrobial resistance (AMR) in all countries through a coordinated, multisectoral and One Health approach. Access to effective antimicrobials and their appropriate and prudent use has a role in productive and sustainable agriculture and aquaculture – and their misuse contributes to the rising rates of AMR which negatively impacts the advances made in medicine, public health, veterinary care, food and agriculture production systems, and food safety.

In India, the first National Action Plan on antimicrobial resistance was implemented from April 2017 to March 2022 and the response had been to set up a governance structure for surveillance. (Inter-sectoral Coordination with Health and Family Welfare Department).

In this respect, FAO and USAID collaborated to provide technical support to The Indian Council of Agricultural Research (ICAR), and helped establish a network of institutes - Indian Network for Fishery and Animal Antimicrobial Resistance (INFAAR), to undertake surveillance on antimicrobial resistance (AMR) in the aquaculture and veterinary sector. During 2019–2022, substantial data has been generated on AMR by this network.

FAO was also actively involved in training of members from the INFAAR network to facilitate collection of quality data through harmonizing SOPs, WHONET software and database management. By way of this report, I am pleased to announce that we have been able to generate nationally representative AMR surveillance data that can be used as baseline information upon which recommendations and subsequent trends can be monitored. The quality data and protocols generated can also support policy formulation.

I would like to take this opportunity to thank INFAAR scientists, senior officers of ICAR, the Department of Animal Husbandry and Dairying, as well as other experts for their hard work to produce this excellent report and hope that the findings will continue to inspire work to strengthen AMR surveillance in the livestock and fishery sectors.

Takayuki Hagiwara
FAO Representative in India

The National Action Plan on antimicrobial resistance (AMR) in India was implemented in April 2017. The plan warrants an evidence-based database on antimicrobial usage and dynamics of antimicrobial resistance emerging in the animal sector including fisheries. Surveillance encompasses systematic collection of long- term data on disease events, risk factors and other relevant parameters followed by analyzing the same with reference to temporal and spatial characteristics to arrive at a conclusion, so that necessary mitigation measures can be taken effectively.

The Indian Council of Agricultural research (ICAR), with support from FAO, started a network programme on AMR surveillance in food animals and aquaculture – known as Indian Network on Fisheries and Animal Antimicrobial Resistance (INFAAR) – in 2017. The long-term goal of the INFAAR programme aims to identify strategies to prevent and reduce the development and spread of AMR, for protection of animal/ human health and food safety in India.

This compilation includes information contributed by all INFAAR Coordinating and Collaborating Centers as per the standardized uniform SOPs and sampling frame on two pathogens; each in the livestock and poultry sector (*E. coli and S. aureus*) and in Fisheries (A*eromonas and Vibrio*). An exercise has been carried out to collate the surveillance data from INFAAR for evaluating the baseline data and get indications about the AMR trends in livestock, poultry, and fisheries. This is an attempt to further understand the impact of interventions required for mitigation of antimicrobial resistance.

I thank the expert committee and all the INFAAR members for their individual and group contributions. I appreciate the time, energy, and diligence as well as the diversity of experience and expertise brought by the group. When a diverse group of good people with good intent come together for a common purpose, the process and the outcome is richer, and the product more likely to be worthwhile.

The present trends would definitely inspire us to continue our efforts for strengthening AMR surveillance in the livestock, poultry, and fishery sectors.

J. K. Jena
Deputy Director General (Fisheries and Animal Science)
Indian Council of Agricultural Research (ICAR)

Executive summary

The Indian Council of Agricultural Research (ICAR) with technical support from the Food and Agriculture Organization of the United Nations (FAO) and USAID has established a network of laboratories (Indian Network for Fishery and Animal Antimicrobial Resistance - INFAAR) from the fisheries and livestock sectors to undertake surveillance of antimicrobial resistance (AMR) in the aquaculture and veterinary sector.

Freshwater fish samples were collected from farms located in 28 districts covering 7 states (Uttar Pradesh, Odisha, Himachal Pradesh, Jammu and Kashmir, West Bengal, Uttarakhand and Andhra Pradesh). A total of 4523 bacterial isolates comprising of 35 isolates of *Staphylococcus aureus*, 1390 Coagulase-negative *Staphylococcus* species (CONS), 1441 *E. coli* and 1657 isolates of *Aeromonas* sp were analysed. Shrimp samples were collected from farms located in 13 districts covering 5 states (Tamil Nadu, Kerala, Andhra Pradesh, Maharashtra and Gujarat). A total of 752 shrimp farms were sampled, and 1809 bacterial isolates comprising of 193 isolates of *S. aureus*, 444 CONS, 482 *E. coli*, 226 isolates of *Vibrio parahaemolyticus* and 464 *Vibrio* species were analysed. Cage cultured marine fish samples were collected from farms located in 5 districts covering 2 states (Karnataka and Kerala) and 205 cage cultured marine fish farms were sampled wherein 457 bacterial isolates comprising of 48 isolates of *S. aureus*, 61 CONS, 157 *E. coli*, 89 isolates of *V. parahaemolyticus* and 102 *Vibrio* species were analysed.

The *S. aureus* isolates from aquaculture were predominantly susceptible to chloramphenicol, co-trimoxazole, gentamicin, linezolid and tetracycline. However, 91.3 percent of the *S. aureus* isolates were resistant to penicillin, followed by erythromycin (36.1 percent) and cefoxitin (16.4 percent). Resistance to ciprofloxacin was high in freshwater fish isolates (54.8 percent) than shrimp (6.3 percent) and marine fish (18.8 percent).

The resistance in CONS to chloramphenicol, ciprofloxacin, gentamicin, linezolid and tetracycline was below 10 percent. Highest AMR was observed against penicillin (79.7 percent), followed by cefoxitin (33 percent), erythromycin (27.4 percent) and co-trimoxazole (13.8 percent). High AMR to penicillin in aquaculture isolates remains unexplained and requires further investigations.

The resistance in *E. coli* to amikacin, aztreonam, ceftazidime, ceftriaxone, chloramphenicol, co-trimoxazole, enrofloxacin and imipenem was below 10 percent. Resistance to tetracycline was observed in 11.5 percent of the isolates. High AMR was against cefpodoxime (66.9 percent), cefotaxime (54.1 percent), amikacin (29.9 percent) and tetracycline (24.2 percent) in marine fish isolates as compared to freshwater fish and shrimp isolates.

The AMR in *V. parahaemolyticus* to chloramphenicol, co-trimoxazole, gentamicin, meropenem and tetracycline was below 10 percent. Highest AMR was observed against ampicillin (56.1 percent) followed by cefotaxime (39.5 percent) and ciprofloxacin 29.6 percent). Similarly, <5 percent isolates of *Vibrio* species were resistant to chloramphenicol, co-trimoxazole, gentamicin, meropenem and tetracycline. Highest AMR was observed against ampicillin (53.3 percent) followed by cefotaxime (28.1 percent) and ciprofloxacin (19.8 percent). Resistance to cefepime was noted in 12.4 percent of the isolates. Higher AMR was observed in marine fish isolates as compared to shrimp isolates except against ampicillin.

Majority (`90 percent) of the *Aeromonas* isolates from freshwater were susceptible to amikacin, cefepime, chloramphenicol, imipenem and tetracycline. Highest AMR was observed against cefoxitin (42.7 percent) followed by cefotaxime (26.3 percent) and co-trimoxazole (20.6 percent).

In the livestock sector, antibiotic usage was higher among organized and contractual farming system where intensive production system is practised. Major food producing animals were included for surveillance – cattle, buffalo, goat, sheep, pig and poultry. Surveillance was carried out in 32 districts of the country and collected 5983 samples including milk samples from cows (1667), buffalo (808), goat (125), sheep (50) and rectal swabs from cows (397) and buffalo (134), goat (861), sheep (206), pig (477), poultry cloacal swabs (1120) and samples from other categories (138). Altogether, the network members isolated 2850 *E. coli,* 1617 *Staphylococcus* of which 2076 *E. coli* and 1244 *Staphylococcus* were characterized for their antimicrobial resistance profile.

Majority of the *S. aureus* isolates were sensitive to chloramphenicol, tetracycline, gentamicin and linezolid. Resistance to penicillin was ~ 72 percent. About 19 percent of these isolates were resistant to erythromycin and 17 percent to enrofloxacin. Based on detection of *mecA* and or *mecC* gene, 39 *S. aureus* were confirmed as methicillin resistant *Staph.aureus* (MRSA). From milk samples, only 35 *S. aureus* of bovine origin were confirmed as MRSA. The chance of milk borne MRSA infection from consumption of cow milk appears to be low.

Species wise analysis of the *Staphylococcus* isolates revealed that bovine *Staphylococcus* isolates were mostly resistant to penicillin (69 percent) followed by erythromycin (~23 percent) and enrofloxacin (~18 percent). Among the porcine isolates, higher resistance was observed to gentamicin (39 percent) and enrofloxacin (46 percent) which was much higher than that of the bovine isolates. However, linezolid resistance of porcine isolates was comparatively low (5.8 percent).

Among all the food animals, isolates of poultry origin (722) exhibited higher resistance rate to all the antibiotic tested by the network members. Resistance among avian isolates was much higher to ampicillin (58 percent), cefotaxime (52 percent), tetracycline (~ 50 percent), and nalidixic acid (47 percent). In addition, poultry isolates were also resistant to amoxyclav (36 percent), enrofloxacin (43 percent) and amikacin (32 percent). About 18 percent of the poultry isolates were imipenem-resistant. Resistance to chloramphenicol remains below 15 percent.

Porcine *E. coli* isolates were also frequently resistant to most of the antibiotics. Resistance was more frequent to ampicillin (~ 57 percent), cefotaxime (~ 53 percent), tetracycline (~ 48 percent), amoxiclav, amikacin (45 percent each) and nalidixic acid (41 percent). Although the chloramphenicol resistance remained quite low (~ 8 percent), about 33 percent of the porcine isolates exhibited resistance to imipenem.

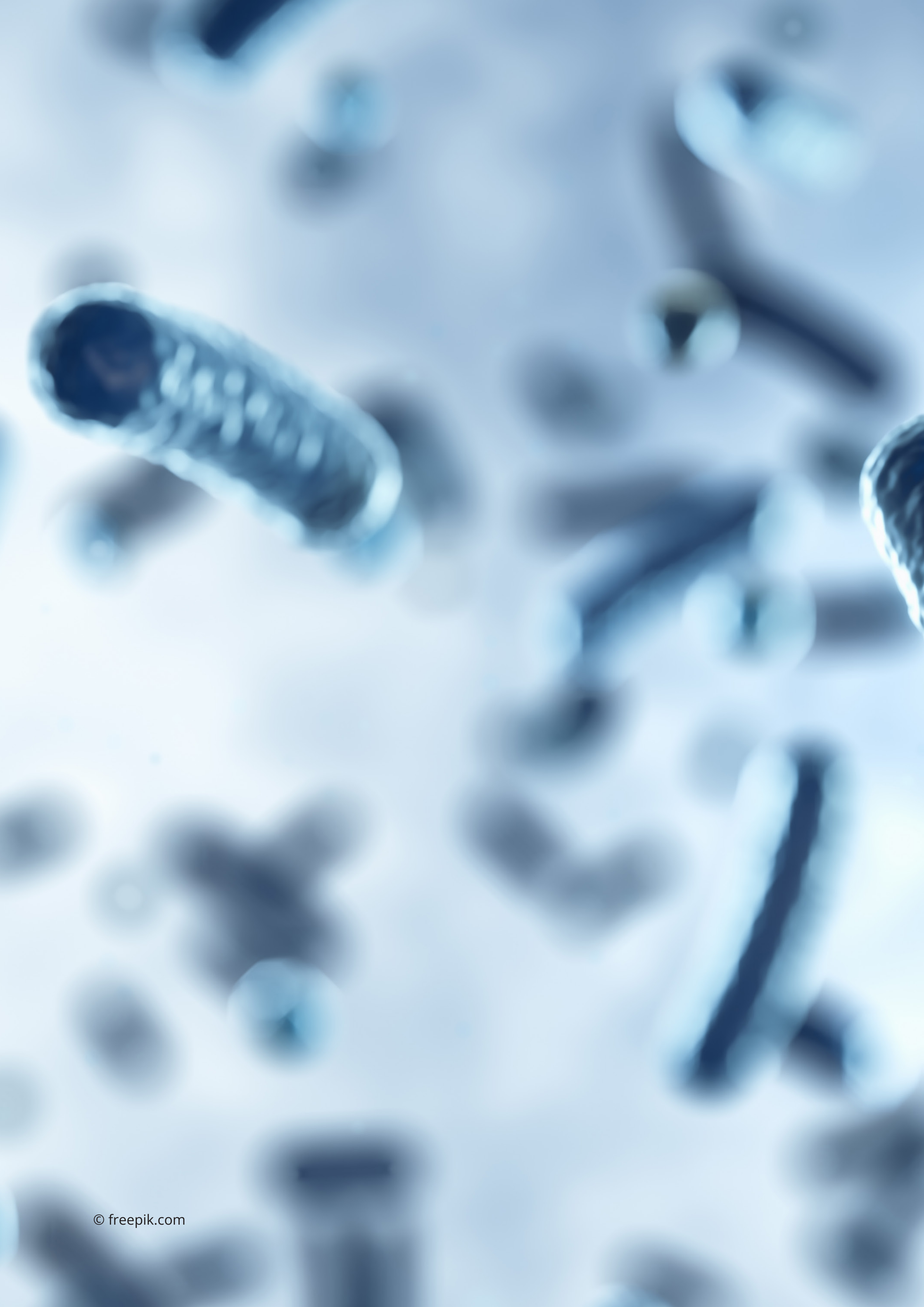
Given the statistically validated number, quality system in testing, and data management through a globally accepted software (WHONET); it is recommended that consolidated data from INFAAR may be used as national database to understand subsequent trends.

Background

Antimicrobial resistance (AMR) is now recognized as a major global public health problem which has been aggravated by the irrational use of antimicrobial agents in human and animal health as well as presence of these agents in the environment. AMR in animal pathogens make disease treatments ineffective, increases the severity of the disease, reduces productivity and leads to economic losses. In addition, more than half the quantity of antimicrobials used in animals/fish is excreted as waste contaminating soil, water and the environment. This also contributes to the emergence and spread of AMR through selection pressure on microorganisms in the environment. Besides, Antimicrobial Usage (AMU) can lead to presence of antimicrobial residues in edible animal/fish products which could become a public health risk.

Understanding the dynamics of AMR and its surveillance can only be done through quality laboratory services. Laboratory-based surveillance is an integral part of Objective 2 of the National Action Plan of India (2017-2021), which was developed in alignment with Global Action Plan for AMR.

Indian Council of Agricultural Research (ICAR), with technical assistance from FAO, has established a network of its institutions from the animal health and fishery sectors (INFAAR), to generate a nationally representative surveillance data on AMR.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Introduction

Networking of laboratories is important for generating reliable data for a defined geographical area (or entire country), in order to assist policy formulation and programme development. It also helps the partners in pooling their resources, skills as well as sharing from each other's experiences. Designation of different laboratories with specific tasks on behalf of the network amplifies the outcome and in case of need, ensures surge capacity too.

Accordingly, India, under the leadership of ICAR and with technical support from FAO and USAID has established a network of laboratories from the fisheries and livestock sectors to undertake surveillance of AMR. The network has been named as the Indian Network for Fishery and Animal Antimicrobial Resistance (INFAAR). Subsequent to the establishment of INFAAR in 2017, capacity building training programmes were organized for the members regarding Antimicrobial Sensitivity Testing and WHONET 5.6 for data management. Sampling frame and SOPs were framed for the Animal Sciences and Fisheries Sector for the pathogens-*E.coli, Staphylococcus aureus, Aeromonas* and Vibrio. For the last three years, data was generated for both these sectors and attempts have been made to analyse it for the development of baseline observations/recommendations.

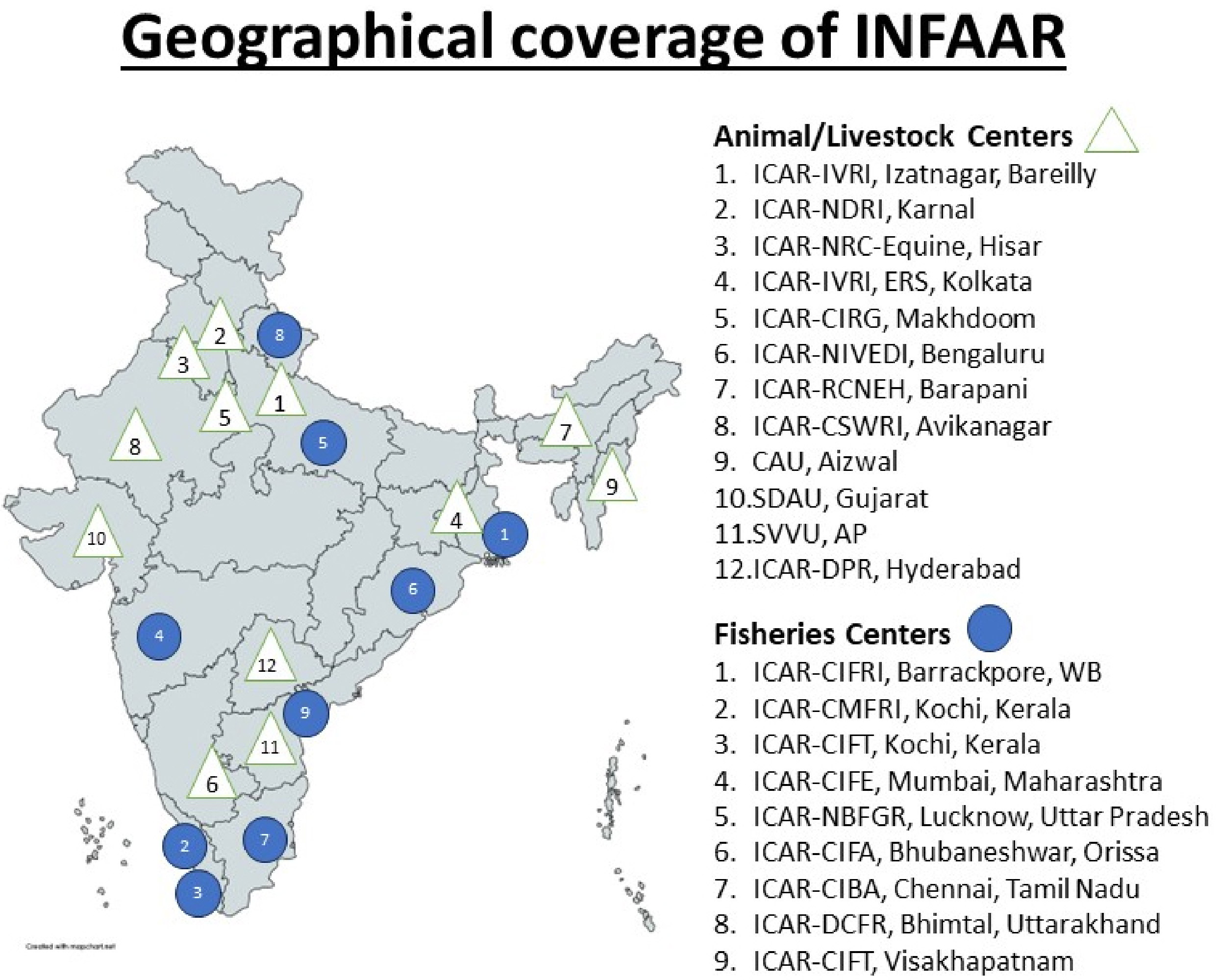


Figure 1: Geographical locations of members of INFAAR
Map conforms with UN Geospatial. 2011. Map of South Asia. New York, United States of America. https://www.un.org/geospatial/content/south-asia.

Characteristics of INFAAR

All member laboratories of INFAAR are following the uniform standard operating protocols for undertaking antimicrobial susceptibility testing (AST). All participating labs are sharing data on pre-agreed organisms and antimicrobial agents at a regular interval. Two coordinators have been designated (Lucknow-Fisheries/Aquaculture Sector and Kolkata-Animal Health Sector).

Training on uniform SOPs, WHONET software and database management, were done and repeat trainings were organized as and when required.

All the members of the network have been trained with support from FAO/USAID to facilitate generation of quality data. Active collaboration was envisaged and supported with leading laboratories in the health sector through the Indian Council of Medical Research (ICMR).

Currently, as per Figure 1, there are 20 laboratories comprising of 17 ICAR Research Institute Laboratories, 01 Central Agriculture University Laboratory, 01 State Agriculture University Laboratory, and 01 State Veterinary University. INFAAR is being further strengthened with more veterinary and fishery centres including regional diagnostic labs from various states. During 2019–2022, substantial data has been generated on AMR by this network.

Objectives and operations of INFAAR

INFAAR was established to:

(i) undertake surveillance of AMR in target microorganisms, isolated from healthy farmed animals and fish/shellfish to quantify its burden, and monitor the spatial and temporal trends of AMR in India, and

(ii) improve awareness and understanding of AMR among the farming community, veterinary and fish health professionals and policy-makers through effective communication, education and training to promote judicious use of antimicrobials in farmed food animals and fish.

INFAAR operations have been overseen and guided by the Advisory Board Committee constituted by the Government of India. The Advisory Board reviews the progress in terms of technical and operational activities bi- annually. In its eighth meeting, the INFAAR Advisory Board requested FAO to facilitate a meeting of selected experts to undertake analytical review of the data generated so far. Additionally, the objective was to determine whether this data can be used as a national baseline for AMR in the animal health sector.

Accordingly, a 2-day meeting of selected experts at New Delhi was convened on 1–2 Feb 2023 by FAO with the following objectives:

1. to review the AMR data generated by INFAAR;
2. to analyse the data and discuss its strategic application;
3. to identify its implications in context of AMR in the animal/fisheries sector;
4. to determine its suitability as national baseline data for AMR in animals (livestock, poultry and fisheries); and
5. to submit the report.

INFAAR AMR data

Currently, there is limited data available on AMR in the livestock and aquaculture sectors in India. Most of them are individual studies with limited geographical coverage, samples and questionable quality. Thus, it is important to quantify the burden of AMR in food-producing animals and aquaculture through structured surveillance with a pan-India coverage. Implementation of INFAAR is aimed to document AMR in different production systems, describe the spread of resistant bacterial strains and resistance genes, identify trends in resistance and generate hypotheses about sources and reservoirs of resistant bacteria through a structured national surveillance programme.

It is very important to ensure that the policy advice is based on reliable evidence which accurately represents the AMR situation. One Health AMR surveillance contributes information to understand the development, transmission and directional spread of AMR, and to estimate the burden of resistance in regional settings. It, therefore, provides important evidence for designing an AMR policy that addresses risk factors for AMR in different sectors.

Because only limited data existed, the INFAAR prioritised gathering local evidence and information, and so carried out studies on baseline resistance pattern, and a situational analysis.

INFAAR work on AMR surveillance (2019–2022)

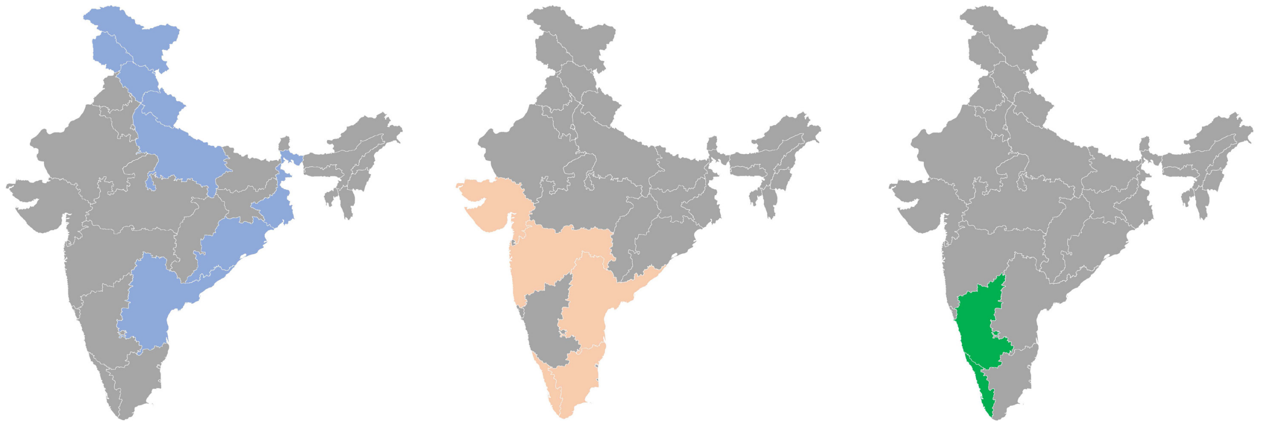
Fisheries Sector[1]

Aquaculture in India is carried out in three types of production systems, namely- Freshwater, Brackish-water and Marine (Figure 2). The freshwater production system comprises of three fish species, *Labeo rohita, Catla catla and Cirrhinus mrigala*, collectively termed as Indian major carps. These three fish species contribute towards >75 percent of total aquaculture production of India. Brackish-water aquaculture system contributes towards production of farmed shrimps mainly *Penaeus vannamei* intended mainly for exports, while marine aquaculture system is used for production of cage cultured marine fish mainly seabass, *Lates calcarifer*. For monitoring the AMR in the aquaculture sector, 3087 farms located in 42 districts covering 12 states of India were surveyed and samples from apparently healthy fish/shrimp were collected directly from farms for analysis.

AMR surveillance work in different aquaculture systems

Various culture-system, pathogen and antimicrobial combinations were used for antimicrobial susceptibility testing using CLSI breakpoints and WHONET software as has been shown in Table 1. Table 2 shows the number of samples collected for the fisheries sector.

[1] (In this study, Fisheries refers mainly to aquaculture)



MAJOR FRESH WATER FISH PRODUCING STATES IN INDIA

Andhra Pradesh, Jammu and Kashmir, Odisha, West Bengal, Uttar Pradesh, Uttrakhand, Himachal Pradesh

BRACKISH WATER FISH PRODUCING STATES IN INDIA

Tamil Nadu, Kerala, Andhra Pradesh, Maharashtra and Gujarat

MARINE FISH PRODUCING STATES IN INDIA

Kerala and Karnataka

Figure 2: Fish production in India

Map conforms with UN Geospatial. 2011. Map of South Asia. New York, United States of America. https://www.un.org/geospatial/content/south-asia.

Table 1: Organisms-antimicrobial combinations used by INFAAR-Fisheries

Common for freshwater, brackish water and Mariculture		Only for freshwater aquaculture	Only for Brackish-water and Mariculture
Staphylococcus species	*E. coli*	*Aeromonas* species	*Vibrio* species
Cefoxitin	Amikacin	Amikacin	Amoxi-Clav
Chloramphenicol	Amoxicillin-clavulanic acid	Cefepime	Ampicillin
Ciprofloxacin	Ampicillin	Cefotaxime	Cefepime
Co-trimoxazole	Aztreonam	Cefoxitin	Cefotaxime
Erythromycin	Cefotaxime	Ceftazidime	Cefoxitin
Gentamicin	Cefoxitin	Ceftriaxone	Ceftazidime
Linezolid	Cefpodoxime	Chloramphenicol	Chloramphenicol
Penicillin G	Ceftazidime	Ciprofloxacin	Ciprofloxacin
Tetracycline	Ceftriaxone	Co-trimoxazole	Co-trimoxazole
	Chloramphenicol	Imipenem	Gentamicin
	Co-trimoxazole	Tetracycline	Meropenem
	Enrofloxacin		Tetracycline
	Imipenem		
	Nalidixic acid		
	Tetracycline		

Table 2: Details of samples collected by INFAAR-Fisheries

Sample	NBFGR	CIFA	CIFRI	DCFR	CIFT-K	CIFT-V	CIFE	CIBA	CMFRI	Total
Fish/shrimp	437	377	317	229	126	149	236	241	205	2317
Water	0	469	0	165	22	20	0	66	28	770
Total	437	846	317	394	148	169	236	307	233	3087

Freshwater aquaculture: Freshwater fish samples were collected from farms located in 28 districts covering 7 states (Uttar Pradesh, Odisha, Himachal Pradesh, Jammu and Kashmir, West Bengal, Uttarakhand and Andhra Pradesh) of India wherein 1360 freshwater fish farms were sampled and the samples were processed for detection of AMR. In addition, pond water from 634 freshwater farms were also collected and processed. All samples were processed for isolation of *Staphylococcus* species, *E. coli* and *Aeromonas* species in accordance with approved SOP of the network. A total of 4523 bacterial isolates comprising of 35 isolates of *Staphylococcus aureus*, 1390 Coagulase negative *Staphylococcus* species (CONS), 1441 *E. coli* and 1657 isolates of *Aeromonas* sp were analysed.

Shrimp aquaculture: Shrimp samples were collected from farms located in 13 districts covering 5 states (Tamil Nadu, Kerala, Andhra Pradesh, Maharashtra and Gujarat) of India wherein a total of 752 shrimp farms were sampled and analysed for AMR during the reporting period. In-addition, pond water from 108 shrimp farms were also collected wherein 1809 bacterial isolates comprising of 193 isolates of *S. aureus*, 444 CONS, 482 *E. coli*, 226 isolates of *Vibrio parahaemolyticus* and 464 *Vibrio* species were analysed.

Table 3: Sectorwise number of bacterial isolates analysed

Aquaculture sectors	SAU	CONS	ECO	AER	VIP	VIB	Total
Freshwater fish	35	1390	1441	1657	0	0	4523
Shrimps	193	444	482	0	226	464	1809
Marine fish	48	61	157	0	89	102	457
Total	276	1895	2080	1657	315	566	6789

SAU-*Staphylococcus aureus*; Coagulase-negative *Staphylococcus* species (CONS); ECO-*E. coli*; AER-*Aeromonas* species; VIP- *V. parahaemolyticus;* VIB-*Vibrio* species

Mariculture: Cage cultured marine fish samples were collected from farms located in 5 districts covering 2 states (Karnataka and Kerala) wherein 205 cage cultured marine fish farms were sampled and subsequently analysed for AMR. In-addition, seawater from 28 cage cultured marine fish farms were also collected and analysed. All the samples were processed for isolation of *Staphylococcus* species, *E. coli* and *Vibrio* species. 457 bacterial isolates comprising of 48 isolates of *S. aureus*, 61 CONS, 157 *E. coli*, 89 isolates of *V. parahaemolyticus* and 102 *Vibrio* species were analysed.

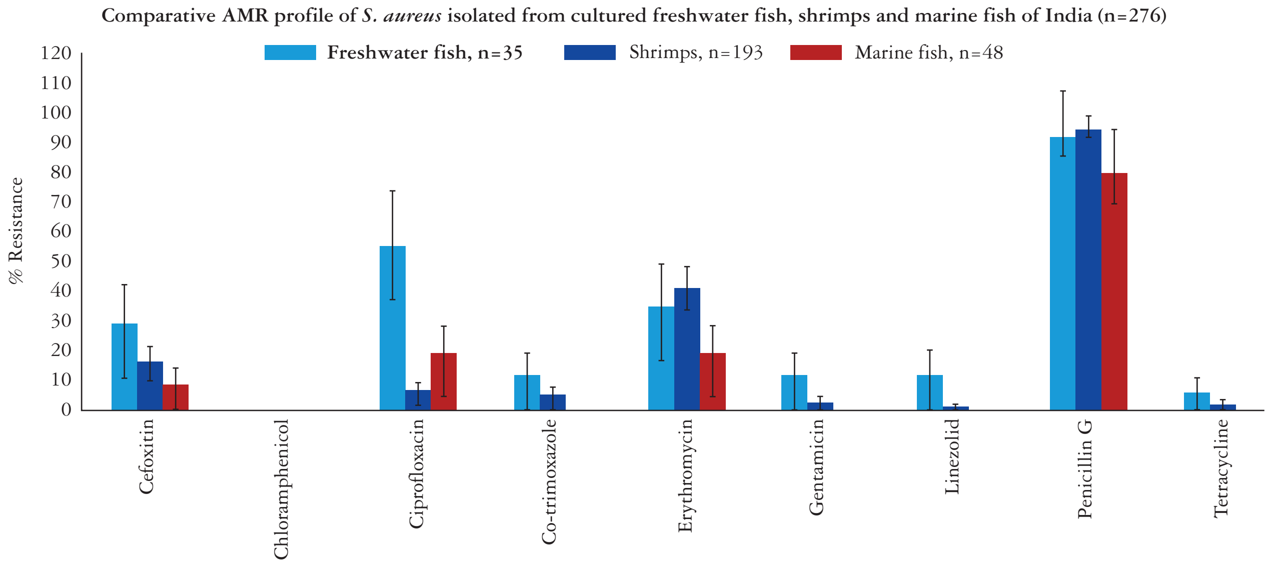
Status of AMR in *Staphylococcus aureus* of aquaculture origin: Majority of the *S. aureus* isolates were sensitive to chloramphenicol, gentamicin, tetracycline and linezolid (resistance below 10 percent). Very high AMR was observed against penicillin (91.3 percent). In addition, about 36.1 percent of the isolates were resistant to erythromycin and 16.4 percent to cefoxitin **(Figure 2)**. Notably, resistance to ciprofloxacin was comparatively higher[2] in freshwater fish isolates (54.8 percent) than shrimp (6.3 percent) and marine fish (18.8 percent).

[2] For the purpose of this report, the group decided to consider antimicrobial resistance as low is <10 percent, moderate 10-50 percent and high is >50 percent

- All the freshwater fish isolates were susceptible to chloramphenicol. Majority of the isolates were also susceptible to co-trimoxazole, gentamicin, linezolid and tetracycline. The resistance to these 4 antimicrobials ranged between 5.7 to 11.8 percent. Highest AMR was observed against penicillin (91.4 percent), followed by ciprofloxacin (54.8 percent), erythromycin (34.3 percent) and cefoxitin (28.6 percent);
- all the shrimp isolates were susceptible to chloramphenicol. Majority of the isolates were also susceptible to ciprofloxacin, co-trimoxazole, gentamicin, linezolid and tetracycline. The resistance to these 5 antimicrobials ranged between 0.6 to 6.3 percent. Highest AMR was observed against penicillin (94.3 percent), followed by erythromycin (40.8 percent) and cefoxitin (16.2 percent); and
- the marine fish isolates were susceptible to chloramphenicol, co-trimoxazole, gentamicin, linezolid and tetracycline (resistance below 10 percent). The AMR to ciprofloxacin and erythromycin was 18.8 percent each. Highest AMR was observed against penicillin (79.2 percent).

Status of AMR in Coagulase-negative *Staphylococcus* (CONS) of aquaculture origin: Majority of the CONS were susceptible to chloramphenicol, ciprofloxacin, gentamicin, linezolid and tetracycline, and the resistance was below 10 percent. Highest AMR was observed against penicillin (79.7 percent), followed by cefoxitin (33 percent), erythromycin (27.4 percent) and co-trimoxazole (13.8 percent) **(Figure 3)**. The AMR profile of CONS was almost similar in all the three culture systems. However, resistance to co-trimoxazole and linezolid was comparatively higher in freshwater fish isolates as compared to shrimp or marine isolates.

- Only 10 percent of the freshwater fish isolates were resistant to chloramphenicol, ciprofloxacin, gentamicin, tetracycline and linezolid. Resistance to co-trimoxazole was seen in 16.4 percent of the isolates. Highest AMR was observed against penicillin (76 percent), followed by cefoxitin (32 percent) and erythromycin (22.6 percent). Notably, cefoxitin and linezolid resistance was comparatively higher in the isolates from West Bengal;
- the shrimp isolates were susceptible to chloramphenicol (0.8 percent), whereas resistance to ciprofloxacin, co-trimoxazole, gentamicin, linezolid and tetracycline was below 10 percent. Highest AMR was observed against penicillin (91.5 percent) followed by cefoxitin (38.5 percent) and erythromycin (36.1 percent); and
- in marine fish isolates, no AMR was observed against gentamicin and linezolid. Resistance to chloramphenicol, ciprofloxacin, co-trimoxazole and tetracycline was below 5 percent. Highest AMR was observed against penicillin (78.7 percent) followed by erythromycin (27.9 percent) and cefoxitin (18 percent).



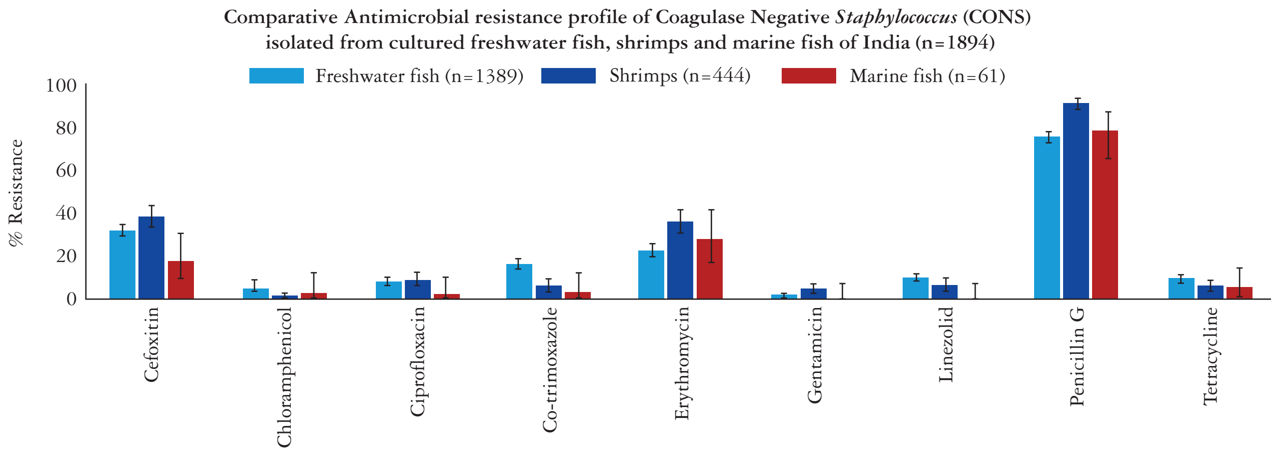


Figure 3: Resistance in *Staphylococcus aureus* and Coagulase negative Staphylococcus (CONS)

Majority of the *S. aureus* and CONS from aquaculture origin were susceptible to chloramphenicol, co-trimoxazole, gentamicin, linezolid and tetracycline. This could be perhaps due to less usage of chloramphenicol and gentamicin in the human and aquaculture sector. Low AMR to linezolid could be attributed to its non-usage in aquaculture. Co-trimoxazole and tetracycline are being used in aquaculture as therapeutic agents for treatment of bacterial infections in aquaculture. Low AMR to these agents could probably be due to judicious usage in aquaculture. Very high resistance to penicillin and erythromycin in aquaculture isolates remains unexplained and requires further investigations. There is limited published literature on unusually high AMR to penicillin in aquaculture, which warrants for detailed and further studies. There is also a possibility that the disk diffusion method employed for assessing penicillin resistance could be misleading (Ivanovic *et al.*, 2023).

Status of AMR in *E. coli* of aquaculture origin: Majority (~90 percent) of the *E. coli* were susceptible to amikacin, aztreonam, ceftazidime, ceftriaxone, chloramphenicol, co-trimoxazole, enrofloxacin, imipenem and tetracycline. Highest AMR was observed against ampicillin (29 percent) followed by cefotaxime (22.4 percent) and amoxycillin-clavulanic acid (20.5 percent) **(Figure** 4**)**. Comparatively higher AMR was observed against cefpodoxime (66.9 percent), cefotaxime (54.1 percent), amikacin (29.9 percent) and tetracycline (24.2 percent) in marine fish isolates as compared to freshwater fish and shrimp isolates.

- Predominantly, freshwater fish isolates were susceptible to amikacin, aztreonam, cefpodoxime, ceftazidime ceftriaxone, chloramphenicol, co-trimoxazole, enrofloxacin and imipenem (resistance below 10 percent). Highest AMR was observed against ampicillin (26.7 percent) followed by cefotaxime (19.7 percent) and amoxicillin-clavulanic acid (19.6 percent). Notably, resistance to amoxicillin-clavulanic acid was higher in isolates from West Bengal;
- in shrimp isolates, the resistance to 12 antimicrobials (amikacin, aztreonam, cefoxitin, cefpodoxime, ceftazidime ceftriaxone, chloramphenicol, co-trimoxazole, enrofloxacin, imipenem, nalidixic acid and tetracycline) was below 10 percent. Highest AMR was observed against ampicillin (39.2 percent) followed by amoxycillin-clavulanic acid (26.2 percent) and cefotaxime (19.6 percent). Resistance against amoxycillin-clavulanic acid, ampicillin, cefotaxime and imipenem were higher in isolates from Kerala as compared to Andhra Pradesh, Tamil Nadu, Gujarat and Maharashtra; and
- in marine fish isolates, only 10 percent of the isolates were resistant to aztreonam, cefoxitin, ceftazidime ceftriaxone, chloramphenicol, enrofloxacin and imipenem. Unusually high resistance was observed against cefpodoxime (66.9 percent), cefotaxime (54.1 percent) and amikacin (29.9 percent). Tetracycline resistance was observed in 24.2 percent of the isolates.

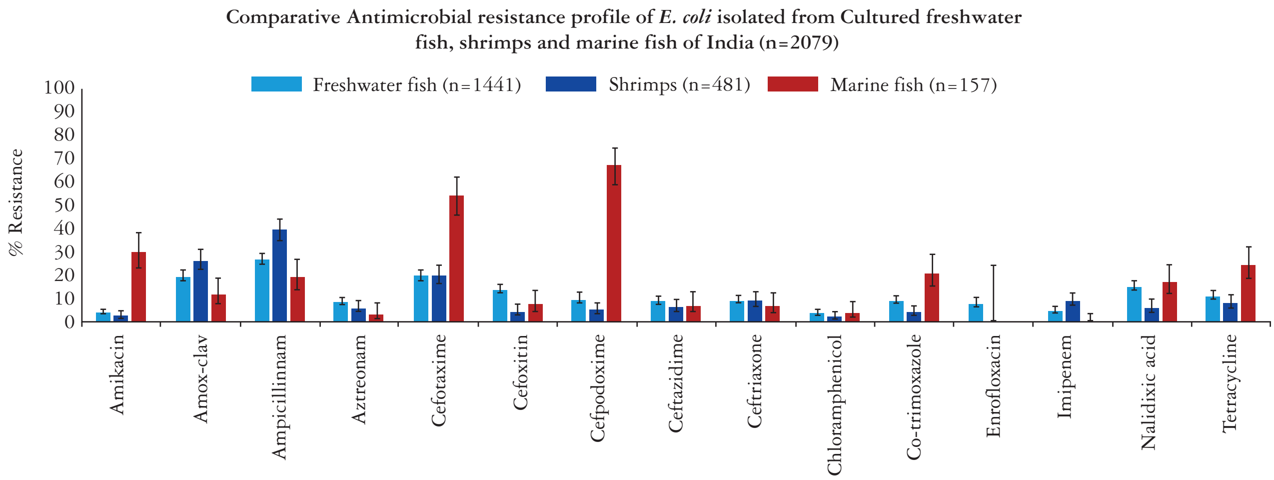


Figure 4: Resistance in *E. coli* of aquaculture origin.

E. coli of marine origin exhibited higher resistance to cefotaxime and cefpodoxime. This is quite similar to what is reported by different studies carried out in human (Paul *et al.*, 2020). Wide use of higher generation cephalosporins in clinical settings may lead to environmental dissemination of plasmid harbouring cefotaxime-resistant genes in the coastal environment and further colonization in marine fish. However, a conclusive inference requires further introspective analysis. Most of the aquaculture isolates were found sensitive to chloramphenicol, which is possibly due to low use of chloramphenicol in human and veterinary medicine.

Status of AMR in *Vibrio parahaemolyticus* of aquaculture origin: Majority of the *V. parahaemolyticus* isolates were sensitive to chloramphenicol, co-trimoxazole, gentamicin, meropenem and tetracycline (resistance below 10 percent). However, 56.1 percent of the isolates showed resistance to ampicillin, whereas 39.5 percent were resistant to cefotaxime, followed by ciprofloxacin (29.6 percent) **(Figure 5)**. Comparatively higher AMR was observed against cefepime, cefpodoxime, cefotaxime, cefoxitin, ceftazidime and ciprofloxacin in isolates from marine fish as compared to shrimp isolates.

- Majority of the shrimp isolates were sensitive cefepime, ceftazidime chloramphenicol, co-trimoxazole, gentamicin, meropenem and tetracycline (resistance below 10 percent). Highest AMR was observed against ampicillin (56.4 percent) followed by cefotaxime (34.6 percent), ciprofloxacin (26.2 percent) and amoxycillin-clavulanic acid (22.2 percent). Resistance against amikacin, amoxycillin-clavulanic and ciprofloxacin was higher in isolates from a few districts of Andhra Pradesh and Tamil Nadu as compared to Gujarat and Maharashtra; and
- the marine fish isolates were predominantly susceptible to amoxycillin-clavulanic acid, chloramphenicol, co-trimoxazole, gentamicin, meropenem and tetracycline ((resistance below 10 percent). Highest AMR was observed against ampicillin (56.1 percent) followed by cefotaxime (50.6 percent), ciprofloxacin (32.8 percent) and cefoxitin (38.2 percent).

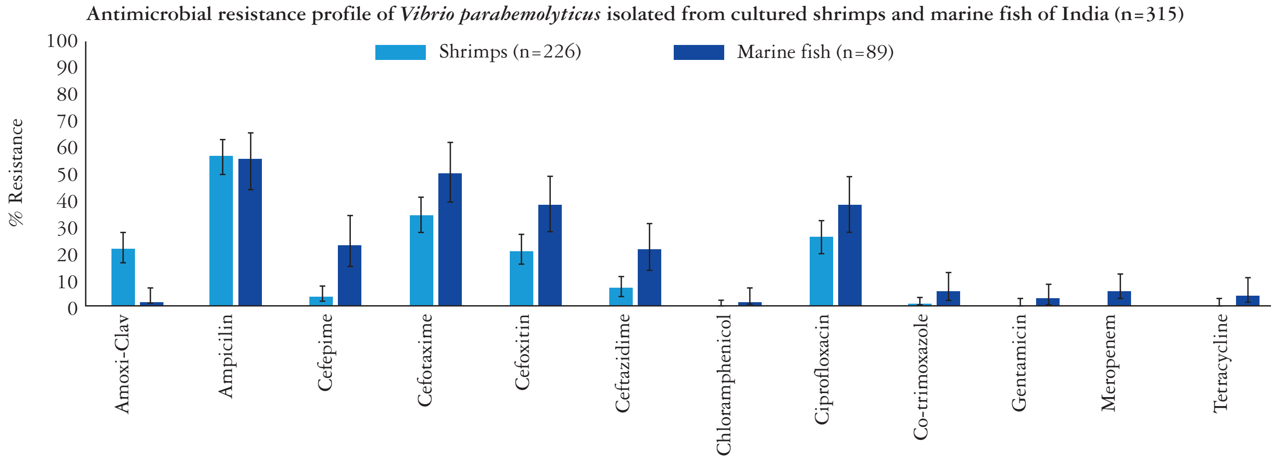


Figure 5: Resistance in *V. parahaemolyticus* of aquaculture origin.

Status of AMR in *Vibrio* species of aquaculture origin: Most of the *Vibrio* species were susceptible to chloramphenicol, co-trimoxazole, gentamicin, meropenem and tetracycline ((resistance below 10 percent). Resistance to ampicillin was observed in 53.3 percent of the isolates followed by cefotaxime (28.1 percent) and ciprofloxacin (19.8 percent) **(Figure 6)**. Resistance to cefepime was noted in 12.4 percent of the isolates. Higher AMR was observed in marine fish isolates as compared to shrimp isolates except against ampicillin.

- Majority of the shrimp isolates were susceptible to cefepime, ceftazidime chloramphenicol, co-trimoxazole, gentamicin, meropenem and tetracycline ((resistance below 10 percent). Highest AMR was observed against ampicillin (59.5 percent) followed by cefotaxime (21.1 percent), amoxycillin-clavulanic acid (17.2 percent) and ciprofloxacin (15.5 percent). Resistance against amoxycillin-clavulanic acid, cefotaxime, cefoxitin and ciprofloxacin was higher in isolates from Kerala as compared to Andhra Pradesh, Tamil Nadu, Gujarat and Maharashtra; and

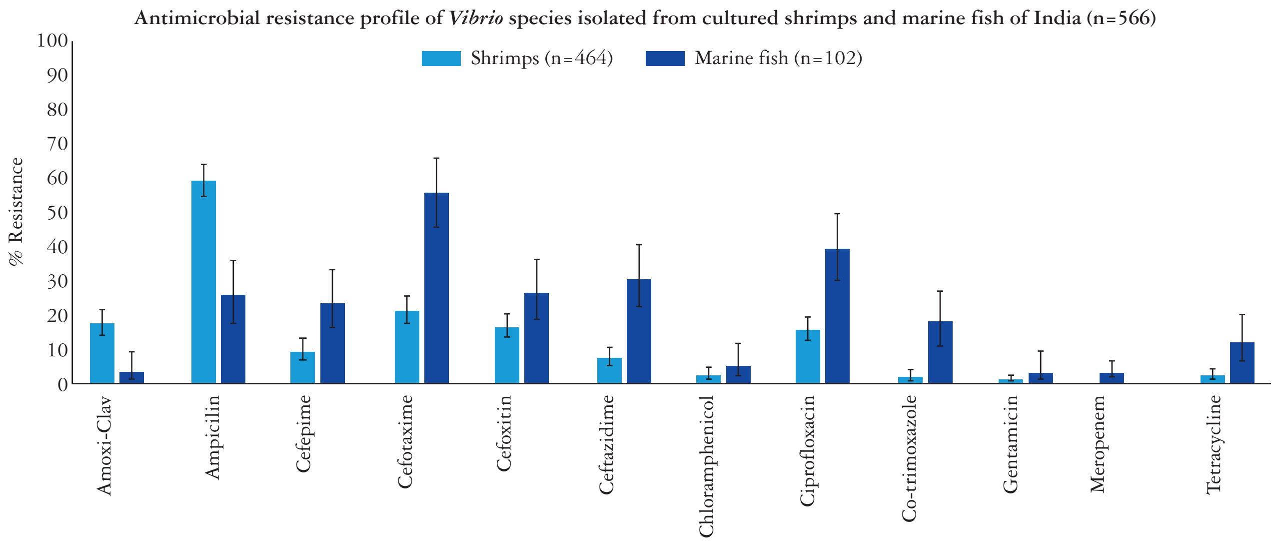


Figure 6: Resistance in *Vibrio* species of aquaculture origin

- most of the marine fish isolates were susceptible to amoxycillin-clavulanic acid, chloramphenicol, and gentamicin (resistance below 10 percent). Highest AMR was observed against cefotaxime (55.9 percent), followed by ciprofloxacin (30.4 percent) and Ceftazidime (30 percent).

Overall, majority of the *Vibrio* isolates from shrimps were found to be sensitive to chloramphenicol, co-trimoxazole, gentamicin, meropenem and tetracycline. This is in contrast to previous reports. A high prevalence of resistance to sulphonamide and tetracycline in bacteria has been reported in shrimp aquaculture (Gao *et al.*, 2012). A recent review also indicates that the resistance to ampicillin, amoxycillin, penicillin, tetracyclines, gentamicin, streptomycin and trimethoprim have been observed in the *Vibrio* species isolated from aquaculture system (Vaiyapuri *et al.*, 2021). In our study, shrimp isolates showed higher resistance to ampicillin, which is in accordance to the previous studies. Further, marine fish isolates showed higher resistance to many antimicrobials despite limited usage of only a few antimicrobials in mariculture. This could probably be due to cross contamination of antimicrobials used either in human healthcare or animal healthcare, eventually reaching the marine environment.

AMR in *Aeromonas* species of aquaculture origin: Majority of the *Aeromonas* species were susceptible to amikacin, cefepime, chloramphenicol, imipenem and tetracycline (resistance below 10 percent). Highest AMR was observed against cefoxitin (42.7 percent) followed by cefotaxime (26.3 percent) and co-trimoxazole (20.6 percent) **(Figure 7)**. Resistance against amoxycillin-clavulanic acid, cefepime and ciprofloxacin was higher in the isolates from West Bengal as compared to Odisha and Andhra Pradesh, Uttarakhand, Himachal Pradesh, Jammu and Kashmir and Uttar Pradesh.

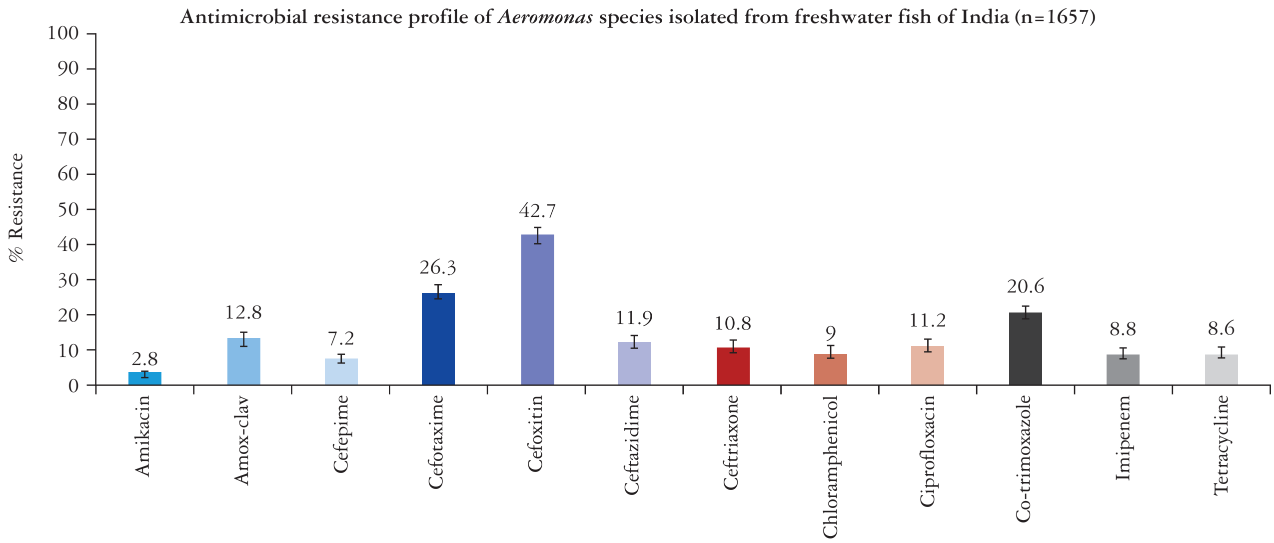


Figure 7: Resistance in Aeromonas species

Majority of *Aeromonas* species of freshwater aquaculture were susceptible to amikacin, cefepime, chloramphenicol, imipenem and tetracycline. Except for tetracyclines, the usage of the rest of the antimicrobials in freshwater aquaculture is not practiced for treatment of bacterial diseases of fish. Large number of isolates were found to be resistant to cefoxitin in our study. This finding is not surprising, as high resistance to first- and to a lesser degree second-generation cephalosporins has been detected in motile aeromonad isolates across the world. Resistance to amoxycillin-clavulanic acid, cefepime and ciprofloxacin was higher in isolates from West Bengal probably because the freshwater fish samples were collected from open water bodies, which may have contamination of antimicrobials.

Salient AMR trends during 2019–2022 in the fisheries sector

Figure 8 shows the preliminary trends of AMR in *E. coli* isolates of aquaculture origin.

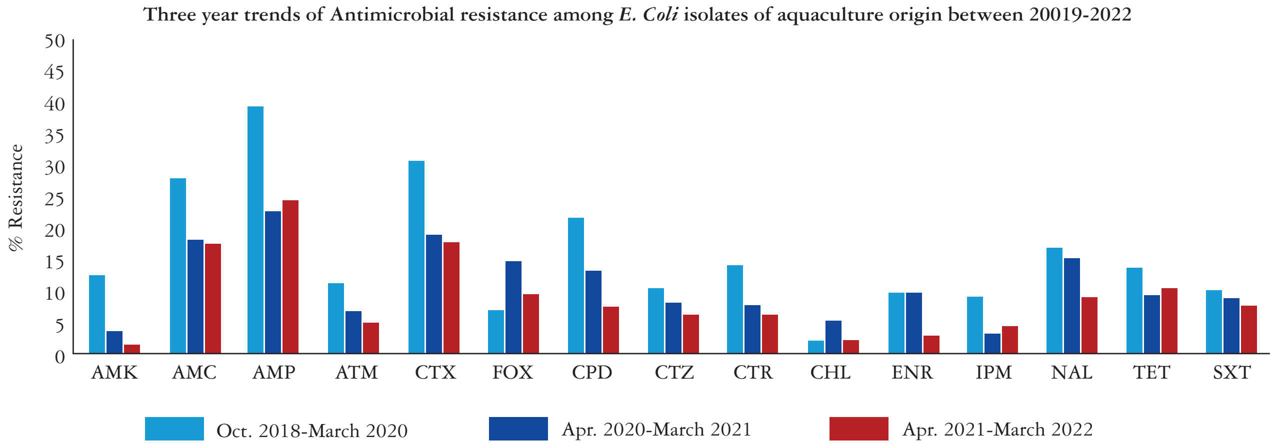


Figure 8: Salient trends in AMR in *E. coli* of aquaculture origin

The preliminary trends of AMR in *E. coli* isolates of aquaculture origin are mostly stable except for few β-lactam antimicrobials such as cefotaxime, ampicillin, *etc*., where a downward trend was observed. However, it would be pertinent to consider the available data as a baseline data. This baseline data could be used to depict the AMR trends in future.

Multi-drug resistance in pathogens from fisheries

Multidrug resistance (MDR) was analysed in *E. coli* isolates of aquaculture origin. Nearly 25 percent of the isolates were susceptible to 15 antimicrobials which is indicative of them being wild strains. Among the non-susceptible isolates, 39 percent of the isolates were MDR. The frequency of antimicrobial resistant phenotypes including MDR are given in Figure 9.

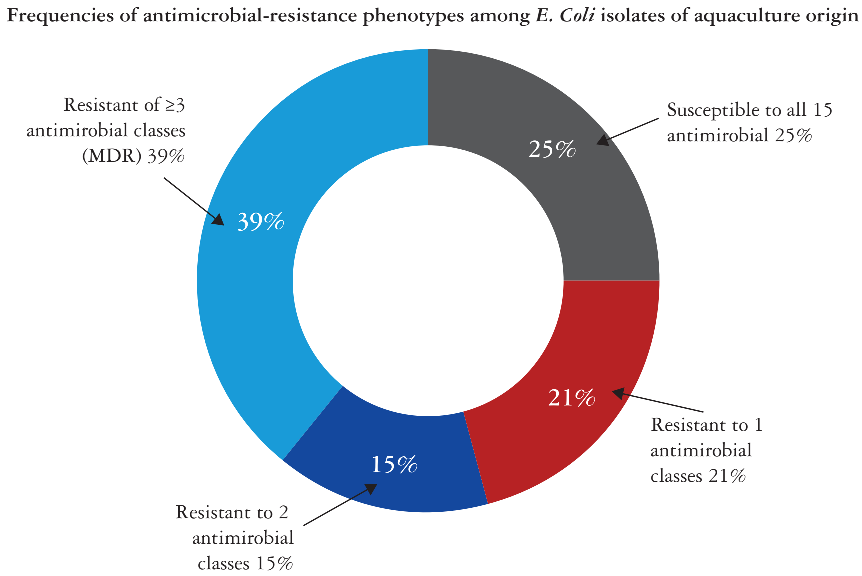


Figure 9: MDR in *E. coli* isolates from aquaculture (Source: MDPI)

General conclusions

Very low level of AMR against tetracyclines, sulphonamides, quinolones and phenicols was recorded in bacteria of aquaculture origin. These antimicrobials are generally used in aquaculture as therapeutic agents.

- the AMR against β-lactams and cephalosporins group of antibiotics was found to be higher. These antimicrobials are not used in aquaculture;
- variation in AMR profile was observed across different geographical regions and aquaculture systems;
- majority of the *S. aureus* and CONS were susceptible to chloramphenicol, co-trimoxazole, gentamicin, linezolid and tetracycline. Unusually high resistance to penicillin was noticed;
- freshwater fish and shrimp isolates of *E. coli* were generally susceptible to amikacin, aztreonam, cefoxitin, cefpodoxime, ceftazidime ceftriaxone, chloramphenicol, co-trimoxazole, enrofloxacin, imipenem, nalidixic acid and tetracycline. Marine fish isolates showed higher resistance to cefpodoxime and cefotaxime;
- *Vibrio* isolates of shrimp and marine fish origin were predominantly susceptible to chloramphenicol, co-trimoxazole, gentamicin, meropenem and tetracycline. Marine fish isolates showed higher frequency of resistance to ampicillin, cefotaxime and ciprofloxacin than shrimp isolates;
- *Aeromonas* isolates of freshwater fish origin were mostly susceptible to amikacin, cefepime, chloramphenicol, imipenem and tetracycline. Limited number of isolates exhibited resistance to cefoxitin, cefotaxime and co-trimoxazole;
- the three-year surveillance data can be considered as a baseline information on AMR in aquaculture and could be used to depict the AMR trends in future; and
- research efforts to understand the transmission dynamics of AMR in aquaculture and formulate strategies to reduce the concerns of AMR in aquaculture along with AMR surveillance is needed.

AMR in the livestock and poultry sector

AMR surveillance in the livestock sector was conducted by 11 animal science laboratories including eight ICAR institutes and three Universities (Figure 1).

Major food producing animals were included for surveillance – cattle, buffalo, goat, sheep, pig and poultry. The Animals Science institutes carried out the surveillance in 32 districts of the country and collected 5983 samples including milk samples from cows (1667), buffaloes (808), goat (125), sheep (50) and rectal swabs from cows (397) and buffaloes (134), goat (861), sheep (206), pigs (477), poultry cloacal swabs (1120) and samples from other categories (138).

Altogether, the network members isolated 2850 *E. coli,* 1617 *Staphylococcus* of which 2076 *E. coli* and 1244 *Staphylococcus* were characterized for their antimicrobial resistance profile. Same antibiotic panel was used for *S. aureus* and *E.coli* as with the isolates from the fisheries panels (Table 1).

Semi-intensive farming system shares the majority of food animal rearing in India under the control of poor and marginal farmers and anecdotal experience showed that use of antibiotics is very limited in these sectors. However, antibiotic usage may be higher among organized and contractual farming system where intensive production system is practised.

The samples collected and pathogens isolated have been summarized in Table 4 and Table 5.

Table 4: Details of samples collected from livestock and poultry (2019–2022)

Institutes	Sample types												
	Cow milk	Buffalo milk	Cow rectal	Buffalo rectal	Goat milk	Sheep milk	Goat rectal	Sheep rectal	Pig rectal	Pig nasal	Poultry cloacal	others	Total
NIVEDI	181	99	0	0	0	0	101	0	55	0	89	0	525
IVRI-Izatnagar	92	127	73	77	8	0	90	0	0	0	76	0	543
IVRI-Kolkata	395	0	21	0	18	0	70	0	16	7	299	0	826
SDDU	331	104					164	45			174		818
CIRG	37	30	44	36	94	15	124	30	19		59		488
SVVU		80			5	35					55		175
CSWRI	139	143					91	109	4		59		545
CAU	120		120				104		72		88		504
ICAR-NEH	100		102				95		144	136	133		710
NDRI	217	188	34	14									453
NRC Equine VTCC	55	37	3	7			22	22	24		88	138	396
Total	1667	808	397	134	125	50	861	206	334	143	1120	138	5983

Table 5: Details of the pathogens isolated from livestock and poultry (2019–2022)

Institutes	Pathogens	Isolates (no)
NIVEDI	*E. coli*	295
	Staphylococcus	254
IVRI-Izatnagar	*E. coli*	92
	Staphylococcus	395
IVRI-Kolkata	*E. coli*	92
	Staphylococcus	395
SDDU	*E. coli*	265
	Staphylococcus	163
CIRG	*E. coli*	301
	Staphylococcus	180
SVVU	*E. coli*	83
	Staphylococcus	39
CSWRI	*E. coli*	162
	Staphylococcus	197
CAU	*E. coli*	384
	Staphylococcus	77
ICAR-NEH	*E. coli*	239
	Staphylococcus	252
NDRI	*E. coli*	77
	Staphylococcus	97
NRC Equine VTCC	*E. coli*	353
	Staphylococcus	49

Resistance profile of *Staphylococcus aureus* of livestock origin (Figure 10). A total of 511 *Staphylococcus aureus* were confirmed. Out of which 452 *S. aureus* isolates were subjected to antibiogram. It was found that majority of the *S. aureus* isolates were sensitive to chloramphenicol, tetracycline, gentamicin and linezolid. However, they were frequently resistant to penicillin (~75 percent). In addition, about 16 percent of these isolates were resistant to erythromycin and 15 percent to enrofloxacin also.

Methicillin-resistant *S. aureus* is a drug-resistant variant of *Staphylococcus* which are responsible for causing recalcitrant infections and significant mortality among hospitalized patients (Gandra *et al.*, 2019). These pathogens carry *mec* gene which encodes modified penicillin binding protein making the bacterium resistant to β-lactam compounds. Based on detection of *mecA* and or *mecC* gene, 41 *S. aureus* were confirmed as MRSA. The resistance profile of the MRSA isolates was quite similar except their higher resistance to enrofloxacin, co-trimoxazole, gentamicin (~28 percent each), and tetracycline (26 percent). Although INFAAR screened about 2543 bovine milk samples including 1721 cow milk and 855 buffalo milk, only 35 *S. aureus* of bovine *S. aureus* origin were confirmed as MRSA.

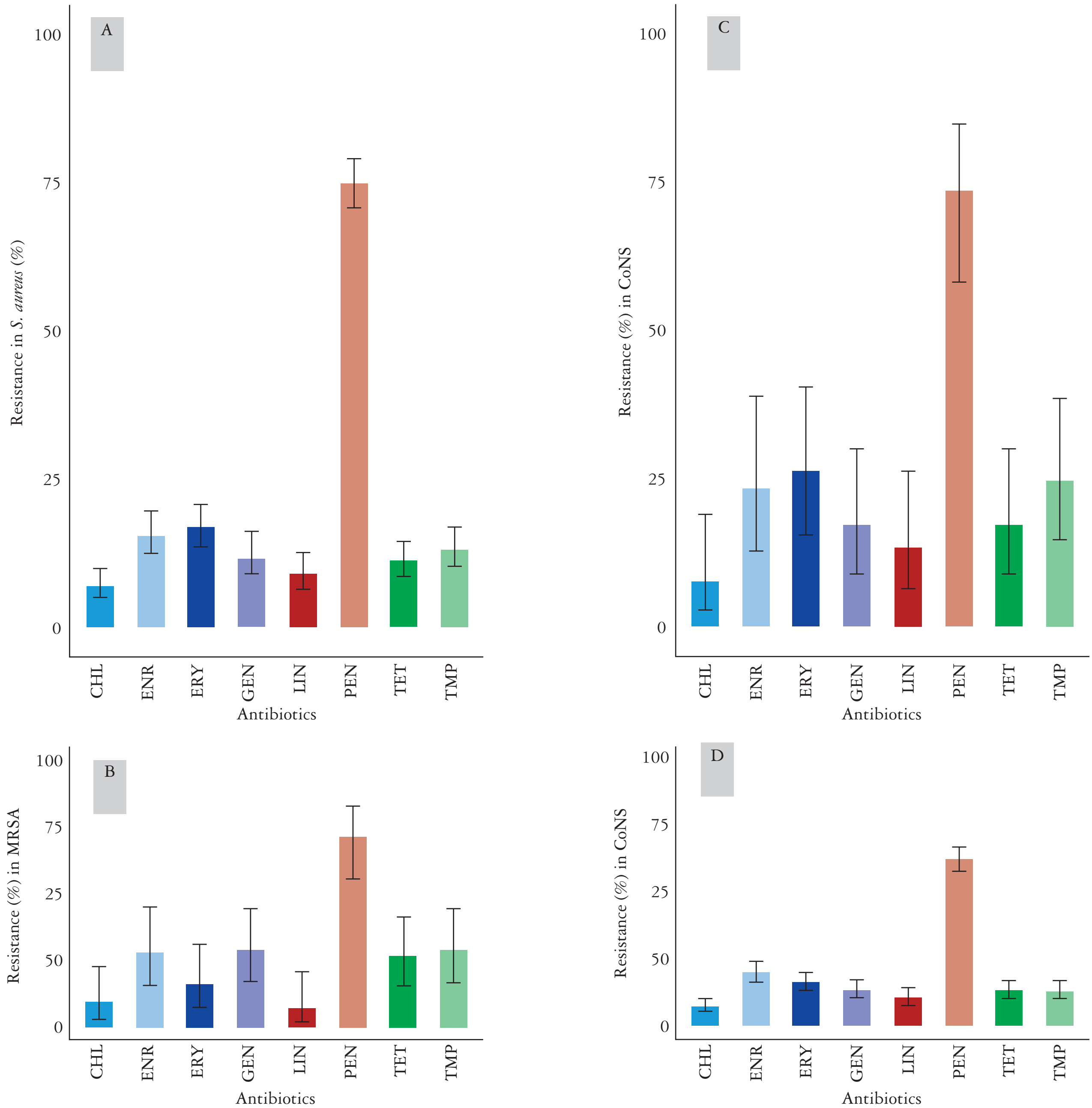


Figure 10: Antimicrobial-resistance profile of *Staphylococcus aureus* (A), methicillin-resistant *S. aureus* (B), Coagulase-negative *Staphylococcus* (C) and methicillin-resistant CoNS isolated from food animal and characterized under ICAR-INFAAR programme.

This is in contrast to the findings observed among hospitalized patients in the human sector in India. This may be due to the low antimicrobial usage in the bovine sector except in cases of refractory mastitis or due to low colonization of AMR pathogens in milk. Therefore, the chance of milk-borne MRSA infection from consumption of cow milk appears to be low. Of the 23 *S. aureus* of porcine and 29 *S. aureus* of caprine and ovine origin, respectively, one (4.3 percent) and three *S. aureus* (10.34 percent) were confirmed as MRSA. Although occurrence of MRSA appeared to be higher in the caprine or ovine sector, it may be due to limited sampling from these sectors.

Resistance profile of Coagulase-negative *Staphylococcus* (CoNS) in the livestock sector: In total, 792 CoNS isolates were subjected to AMR profiling. Similar to *S. aureus* isolates, majority of CoNS isolates of food animal origin were found sensitive to all the antibiotics used in the screening except to penicillin. About 62 percent of the CoNS isolates were found penicillin-resistant. In addition, erythromycin and enrofloxacin-resistance was found among 16 percent and 19.6 percent of CoNS isolates, respectively. In contrast to *S. aureus* isolates, 10 percent of the CoNS isolates were found linezolid resistant. In total, out of 53 methicillin-resistant CoNS isolates, 42 carried *mecA* and 11 carried *mec*C gene. About 73 percent of the MRCoNS isolates were penicillin-resistant and their resistance to enrofloxacin, and co-trimoxazole varied was 23 to 24 percent. About 13 percent of the MRCoNS isolates were found to be linezolid resistant.

Species wise analysis of the *Staphylococcus* isolates revealed that bovine *Staphylococcus* isolates were mostly resistant to penicillin (69 percent) followed by erythromycin (~ 23 percent) and enrofloxacin (~18 percent). Among the porcine isolates, Porcine *Staphylococcus* isolates' higher resistance was observed to gentamicin (39 percent) and enrofloxacin (46 percent) which was much higher than that of the bovine isolates. However, linezolid resistance of porcine isolates was comparatively lower (5.8 percent).

Results from the study carried out by the Animal Science Institutes under INFAAR indicated that although the *Staphylococcus* isolates of food animal origin were sensitive to most of the antibiotics screened, they were frequently resistant to penicillin. A recent study carried out in the USA also mirrored similar observations among porcine and bovine *Staphylococcus* isolates (Rao *et al.*, 2022). Of late, another group reported that penicillin resistance in bovine *S. aureus* isolates, was often dependent upon presence of functional *bla* operon and disk diffusion method which is generally recommended and employed for assessing penicillin resistance could be misleading (Ivanovic et al., 2023).

AMR in *E. coli* of livestock origin (Figure 11): In total 2076, confirmed *E. coli* isolates from different food animals were analyzed for AMR profile. Overall, the *E. coli* isolates of food-animal origin were found more frequently resistant to cefotaxime (46 percent) and ampicillin (41 percent), followed by amikacin (34 percent), tetracycline and nalidixic acid (32 percent each). However, isolates were least resistant to chloramphenicol (~ 9 percent). It is noteworthy that about 18 percent isolates were found to be resistant to imipenem.

Of the 2079 *E. coli* isolates, 545 *E coli* isolates were of bovine origin – cattle (420) and buffalo (125). Among the cattle isolates, the resistance was more frequently noticed to cefotaxime (42 percent), ampicillin (31 percent) and amikacin (33.7 percent). However, only 26 percent isolates were ceftriaxone-resistant. Bovine isolates were mostly sensitive to chloramphenicol (~ 94 percent) and imipenem (~90 percent). Similar trend was observed among the buffalo isolates, except for a little higher resistance to ampicillin (~40 percent). During 2019–2022, a total of 2475 bovine milk samples were collected and only 75 *E. coli* isolates of bovine milk origin were isolated and characterized. The resistance profiles of bovine rectal origin and bovine milk origin isolates were substantially different. It was found that resistant population was more frequent, when samples comprised of the rectal sources rather than the milk. About 60 percent of the *E coli* from buffalo rectal origin were cefotaxime resistant.

In contrast, only 29 percent of *E coli* from buffalo milk were found to be cefotaxime resistant. Similar difference was observed when *E coli* from cow milk (28 percent) and cow rectal (31 percent) were analysed for cefotaxime resistance.

The resistance frequency was much less in caprine isolates (434) except to cefotaxime (41 percent), amikacin (35 percent) and ampicillin (26 percent). The resistance rate of caprine *E. coli* isolates from goats was below 25 percent for all the antibiotics. Resistance of the goat isolates to commonly used antibiotics like tetracycline and cotrimoxazole was below 20 percent and only 6 percent of the isolates were chloramphenicol resistant. However, about 20 percent of the goat isolates were imipenem-resistant which is very difficult to explain.

In total, 222 ovine *E. coli* isolates were screened for resistance pattern. Similar to goat isolates, isolates of sheep origin exhibited lower rate of resistance to most of the antibiotics. About 37 percent of the ovine isolates were cefotaxime resistant and 25-27 percent of the isolates were amoxyclav, ampicillin and nalidixic acid -resistant. Like isolates of other food animals, the sheep isolates were least resistant to chloramphenicol (~5 percent). In contrast to the goat isolates, imipenem-resistance was much less among sheep isolates (~10 percent).

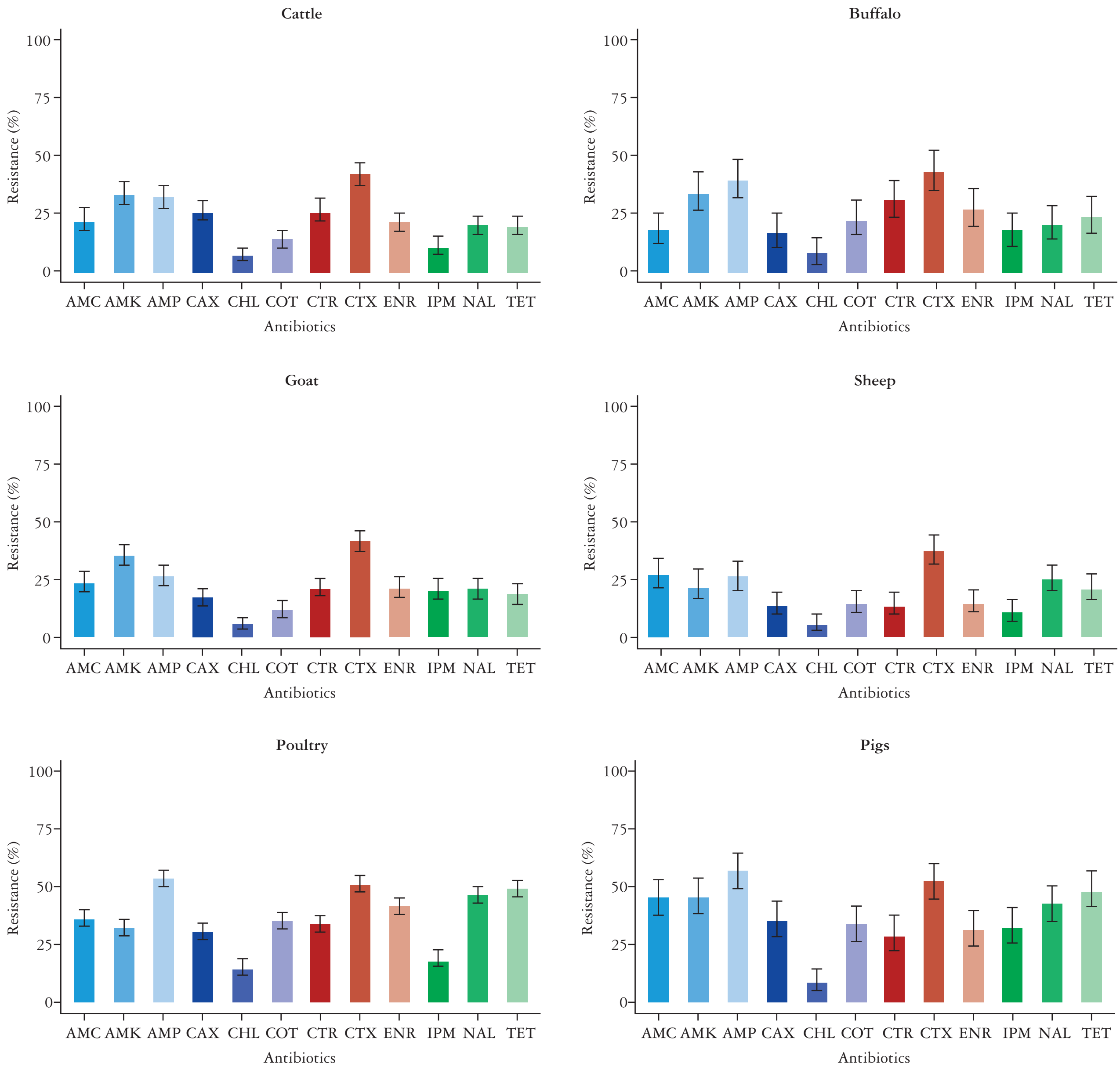


Figure 11: Resistance profile of the *E coli* isolated from different food animals

AMR in *E. coli* and Staphylococci of poultry origin

Among all the food animals, isolates of poultry origin (722) exhibited higher resistance rate to all the antibiotic tested by the network members. Resistance among avian isolates was much higher to ampicillin (53 percent), cefotaxime (51 percent), tetracycline (~ 50 percent), and nalidixic acid (47 percent). In addition, poultry isolates were also resistant to amoxyclav (36 percent), enrofloxacin (41 percent) and amikacin (32 percent). About 18 percent of the poultry isolates were imipenem-resistant. However, resistance to chloramphenicol remains below 15 percent (Figure 11).

Like the poultry sector, **porcine *E. coli*** isolates were also found to be frequently resistant to most of the antibiotics. Resistance was more frequent to ampicillin (~57 percent), cefotaxime (~52 percent), tetracycline (~48 percent), amoxyclav, amikacin (45 percent each) and nalidixic acid (41 percent). Although the chloramphenicol resistance remained quite low (~8 percent), about 33 percent of the porcine isolates exhibited resistance to imipenem. However, sampling from pig was quite low and restricted to only a limited geographical region.

Extended spectrum β-lactamase producing *E.* coli are known as the common offender to cause life-threatening infection in animals and human beings. Similarly, AmpC type β-lactamase producers are also responsible for such complications and both these pathogens are considered to be multi-drug resistant because of acquisition of transposons with multiple drug resistant genes. In this study, a total of 370 *E coli* isolates were confirmed as ESBL producers and 292 as AmpC type β -lactamase producers.

Multidrug resistance in pathogens of animal origin

Multidrug resistance is antimicrobial resistance shown by a bacterium to at least one antimicrobial drug belonging to three or more antimicrobial categories. This phenomenon is often investigated to understand the dynamics of AMR phenomenon in a particular setting and to help the clinicians determine the best therapeutic choice. Analysis of the *E coli* isolates of food animal origin having such multidrug resistance revealed, that highest co-resistance was evident against cefotaxime-enrofloxacin and tetracycline (12.6 percent) and about 15.8 percent of poultry isolates exhibited such simultaneous resistance.

Irrespective of the species of origin, *E. coli* isolates exhibited higher cefotaxime-resistance. This is quite similar to what is reported by different studies carried out in humans (Paul *et al.*, 2020). E coli (~12 percent), particularly those from the poultry were found to to be co-resistant to tetracycline and enrofloxacin (~15 percent). A recent study from Equador showed that about 98 percent of the cefotaxime-resistant *E coli* were multi-drug resistant (Vinueza-Burgos *et al.*, 2019). Wide use of higher generation cephalosporins in a few areas may lead to environmental dissemination of plasmid harbouring cefotaxime-resistant genes and further colonization to animals. However, a conclusive inference requires further introspective analysis. Although carbapenem is not used in animals, a small proportion of *E. coli* isolates were found imipenem-resistant. Loss of outer membrane porin or enhanced efflux pumps may also lead to carbapenem-resistance (Jacoby, 2009)

Most of the isolates were found sensitive to chloramphenicol, which is possibly due to low use of chloramphenicol in human and veterinary medicine.

Conclusions and recommendations

- INFAAR has generated reliable AMR data utilizing statistically validated sampling from the field, employing globally accepted standard operating procedures for antimicrobial susceptibility testing in laboratories, participating in external quality assessment scheme and managing AMR data by using

WHONET software with frequent periodic reviews by the INFAAR Advisory Board. Accordingly, this expert group strongly supports the reliability of the AMR data generated by INFAAR during past three years;

- the expert group recognises that despite the fact that the INFAAR AMR data is not Pan Indian and has not been collected from all geographical regions of India, it does provide actionable information for instituting and monitoring appropriate interventions to contain AMR in near future;
- both in the fisheries and the animal sectors, very low resistance was seen to some of the antibiotics which are not in great use. Most important example is that of chloramphenicol which is not in use even in human health. Accordingly, very low resistance was observed by INFAAR too;
- *Staphylococcus* showed extremely high resistance to penicillin in INFAAR studies. This resistance was observed across the country to the level of more than 60 percent. This is despite limited use of penicillin for decades. The reasons for persistence of resistance to penicillin remain unknown and require further in-depth studies;
- many bacteria under INFAAR have shown resistance to multiple antimicrobial agents. These MDR pathogens are indicative of long-term excessive and misuse of antibiotics;
- some antibiotics which are used extensively on the human side, *e.g.*, cefotaxime with virtually no use in the animal health sector showed significant resistance in the livestock sector. Whether it has happened *in situ* or there is a link between the human and animal sectors through contaminated environment requires further studies; and
- low resistance in milk samples despite extensive antibiotics use reinforces the importance of application of withdrawal period to provide safe milk to the people.

In summary, the group strongly recommends

1. Expansion of INFAAR to make it real pan India entity that generates nationally representative data on AMR in the animal sector; and
2. utilization of AMR surveillance data generated till date by INFAAR as the baseline data for AMR in India in the animal sector for further understanding of trends and impact of interventions.

References

1. **Rao S, Linke L, Magnuson R, Jauch L, Hyatt DR.** *Antimicrobial resistance and genetic diversity of Staphylococcus aureus collected from livestock, poultry and humans.* One Health. 2022 Jun 11;15:100407. doi: 10.1016/j.onehlt.2022.100407. PMID: 36277090; PMCID: PMC9582408.
2. **Ivanovic I, Boss R, Romanò A, Guédon E, Le-Loir Y, Luini M, Graber HU.** *Penicillin resistance in bovine Staphylococcus aureus: Genomic evaluation of the discrepancy between phenotypic and molecular test methods.* J Dairy Sci. 2023 Jan;106(1):462-475. doi: 10.3168/jds.2022-22158. Epub 2022 Nov 21. PMID: 36424317.
3. **Gandra S, Tseng KK, Arora A, Bhowmik B, Robinson ML, Panigrahi B, Laxminarayan R, Klein EY.** *The Mortality Burden of Multidrug-resistant Pathogens in India: A Retrospective, Observational Study.* Clin Infect Dis. 2019 Aug 1;69(4):563-570. doi: 10.1093/cid/ciy955.
4. **Paul D, Babenko D, Toleman MA.** *Human carriage of cefotaxime-resistant Escherichia coli in North-East India: an analysis of STs and associated resistance mechanisms.* J Antimicrob Chemother. 2020 Jan 1;75(1):72-76. doi: 10.1093/jac/dkz416. PMID: 31622465.
5. **Vinueza-Burgos C, Ortega-Paredes D, Narváez C, De Zutter L, Zurita J** (2019) *Characterization of cefotaxime resistant Escherichia coli isolated from broiler farms in Ecuador.* PLoS ONE 14(4): e0207567. https://doi.org/10.1371/journal.pone.0207567
6. **Jacoby GA. AmpC beta-lactamases. Clin Microbiol Rev.** 2009 Jan;22(1):161-82, Table of Contents. doi: 10.1128/CMR.00036-08

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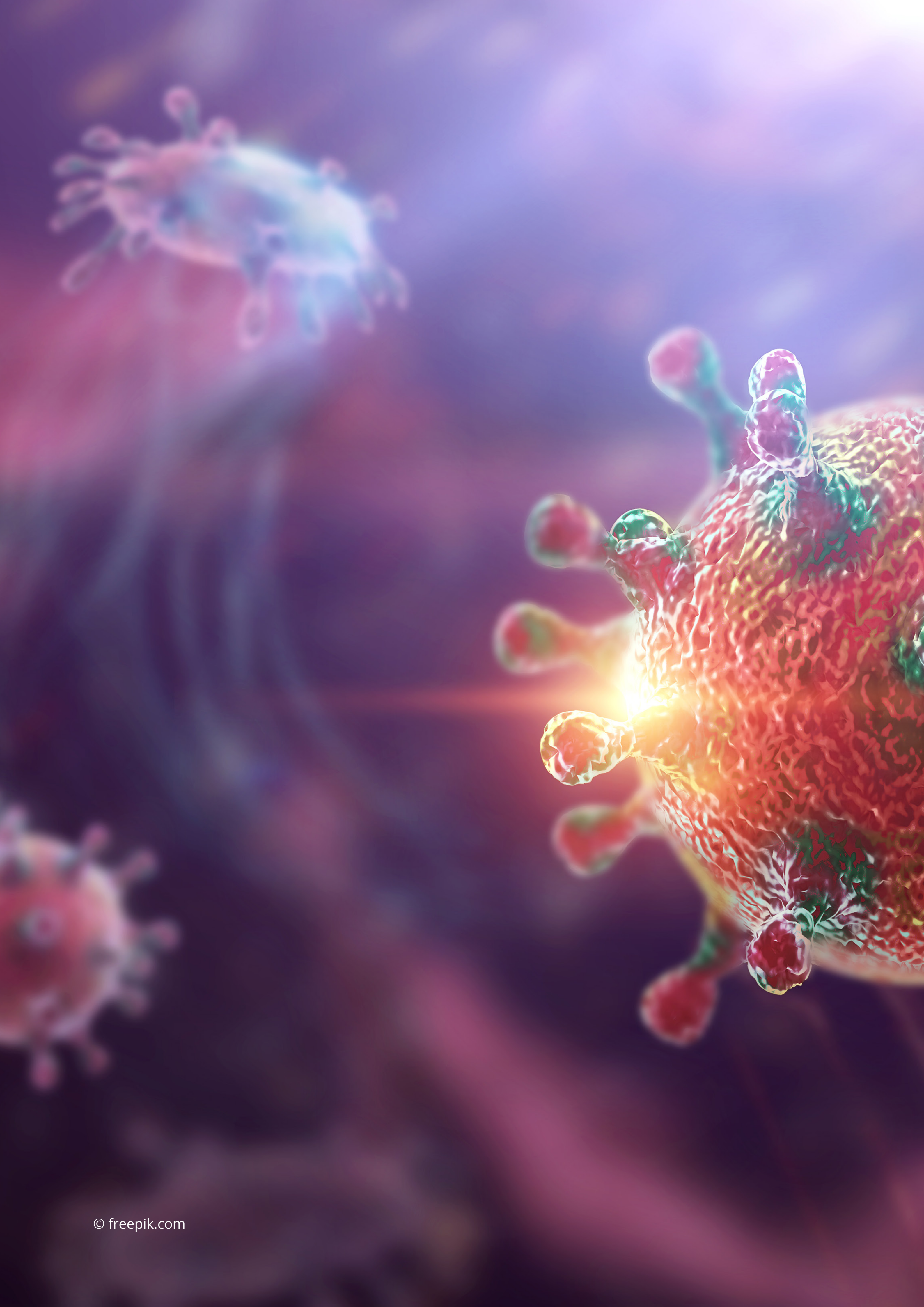
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