www.jchr.org

JCHR (2024) 14 (01), 3264-3282 | ISSN: 2251-6727



Fish Farmers' Perspectives and Practices in Aquaculture Antimicrobial Resistance (AMR): A Comprehensive Review

Fazlin Ali¹, Zanurul Huzaima Zainudin^{2*}, Adelene Song Ai Lian³, Chong Chou Min⁴, Muhammad Mu'az Mahmud⁵ ^{1,4,5}Faculty of Agriculture, Universiti Putra Malaysia.

^{2,3}Faculty of Biotechnology and Biomolecular Sciences, Universiti Putra Malaysia.

ABSTRACT:

|--|

KEYWORDS

Aquaculture, Antimicrobial Resistance (AMR), Fish Farmers, Perspectives, Practices **Background:** The increased use of antibiotics in aquaculture for disease management has raised concerns around antimicrobial resistance (AMR), which might threaten the industry's viability. Understanding fish farmers' viewpoints, and the critical player in aquaculture is crucial to addressing global seafood demands. This comprehensive literature review examines and explores the fish farmers' perceptions and responses to AMR. Important topics including antibiotic use, farmers' AMR knowledge, and disease control efficacy will be reviewed. The review illuminates various viewpoints to aid sustainable and responsible aquaculture decision-making.

Methods: The systematic literature review summarized the key findings and their implications for understanding fish farmers' perspectives on antimicrobial resistance in aquaculture. The research question is clearly defined, thus guiding the literature review before developing a straightforward search strategy to identify relevant literature. Key databases such as BMI, PubMed, Scopus, and Web of Science were utilised, employing specific keywords like "fish farmers," "aquaculture," and "antimicrobial resistance." Titles and abstracts were screened to identify potentially relevant articles. After assessing the full articles against the inclusion criteria for final selection, a simple data extraction form was developed to gather relevant information from selected studies by extracting data on key variables such as antibiotic usage patterns, farmers' awareness of antibiotic resistance and the effectiveness of disease management strategies. Next, a basic quality assessment of the selected studies was conducted while considering factors like study design, sample size, and the clarity of findings. Finally, common themes and patterns related to fish farmers and the aquaculture industry's perspectives on antibiotic resistance were identified.

Practical implications: The presence of significant gaps in the literature suggests that this topic is relatively new and unexplored. Therefore, conducting a thorough study on the issue is essential to cultivate a comprehensive comprehension of the subject area.

Results: The literature search found 296 potentially relevant publications, but only 30 met the inclusion criteria. These publications demonstrate the intricate links between aquaculture, antibiotic use, and resistance. The findings help understand aquaculture AMR challenges and opportunities. This information serves as a foundation for future research, policy formulation, and the implementation of sustainable practices in the industry.

1. Introduction

The aquaculture business has a dynamic environment to fulfil the worldwide demand for fisheries. Nevertheless, this growing industry is not without difficulties, and a crucial issue is the increasing utilization of antibiotics and the resulting development of antimicrobial resistance (AMR) in aquaculture. It is crucial to comprehend the viewpoints of the main players, namely fish farmers, to develop efficient solutions to reduce the impact of antimicrobial resistance (AMR) (Garza et al., 2022). This systematic literature review aims to thoroughly examine and consolidate the current knowledge about fish farmers' viewpoints on AMR in the aquaculture sector.

The use of antibiotics in aquaculture, while beneficial for controlling diseases and improving production, has led to complex issues, notably concerning the emergence, and spread of AMR. Fish farmers, as important participants in the aquaculture value chain, possess distinct knowledge of the intricate

www.jchr.org

JCHR (2024) 14 (01), 3264-3282 | ISSN: 2251-6727



relationship between the use of antibiotics, farm management techniques, and the changing difficulties caused by AMR (Phong et al., 2021; Durojaiye et al., 2020; Thiang et al., 2021; Ström et al., 2019). Through a thorough examination of the current body of literature, the objective is to clarify the many viewpoints, issues, and methods employed by fish farmers in relation to the utilization of antibiotics and the development of resistance.

This review will explore a diverse range of empirical investigations, theoretical frameworks, and practical insights obtained from the experiences of fish farmers around the globe. The comprehensive investigation will include research on antibiotic utilization trends. farmers' knowledge of AMR, the perceived effectiveness of various disease control approaches, and the socioeconomic determinants impacting antibiotic usage in aquaculture (Chowdhury et al., 2022; Chambers et al., 2022) and the environment (Okocha et al., 2018); (Tran et al., 2018). Through the consolidation of many perspectives, the aim is to provide a thorough overview that not only identifies the existing information but also highlights the gaps in comprehending the intricacies of fish farmers' attitudes toward antibiotic resistance.

The main goal of this comprehensive investigation is to gain a detailed knowledge of the difficulties encountered by fish farmers concerning antimicrobial resistance (AMR) and to discover possible ways to intervene and build policies. This study aims to provide useful insights into AMR in aquaculture by highlighting the perspectives of fish farmers. By doing so, it seeks to contribute to the development of sustainable and ethical practices in the sector, thereby ensuring its long-term sustainability. Together, these studies paint a comprehensive picture of the challenges and opportunities in managing AMR in aquaculture, from individual farmer practices to broader policy implications.

2. Material and Methods

2.1 Identification

The method of selecting suitable articles for this study involves three primary steps in the systematic review The initial stage involves identifying process. keywords and searching for associated phrases using resources such as thesauruses. dictionaries. encyclopaedias, and prior research. Subsequently, after the appropriate keywords were determined, search queries were generated on Scopus, Science Direct, BMC, and PubMed databases (refer to Table 1). During the initial stage of the systematic review procedure, the current research activity effectively obtained 1118 papers from the databases.

	TITLE-ABS-KEY ((fish AND farmers) AND (antimicrobial AND resistance)			
Scopus	AND (aquaculture) AND (knowledge) OR (awareness))			
	Date of Access: 16 September 2023			
	(fish farmers) AND (antimicrobial resistance) AND (aquaculture) AND (knowledge			
Science Direct	OR awareness)			
	Date of Access: 16 September 2023			
	((fish farmers) AND (aquaculture)) AND (antimicrobial resistance)) AND			
BMC	(awareness)) OR (knowledge))			
	Date of Access: 16 September 2023			
	("fishes"[MeSH Terms] OR "fishes"[All Fields] OR "fish"[All Fields]) AND ("farmer			
	s"[All Fields] OR "farmers"[MeSH Terms] OR "farmers"[All Fields] OR			
	"farmer"[All Fields]) AND (("anti-microbial agents"[Pharmacological Action] OR			
PubMed	"anti-microbial agents"[MeSH Terms] OR ("anti-microbial"[All Fields] AND			
	"agents"[All Fields]) OR "anti-bacterial agents"[All Fields] OR "antimicrobial"[All			
	Fields] OR "antimicrobials"[All Fields] OR "antimicrobial s"[All Fields] OR			
	"antimicrobial"[All Fields]) AND ("resist"[All Fields] OR "resistance"[All Fields]			

Table 1 The Search Strings.

www.jchr.org

JCHR (2024) 14 (01), 3264-3282 | ISSN: 2251-6727



OR "resistances"[All Fields] OR "resistant"[All Fields] OR "resistants"[All Fields] OR "resisted"[All Fields] OR "resistence"[All Fields] OR "resistances"[All Fields] OR "resistant"[All Fields] OR "resistibility"[All Fields] OR "resisting"[All Fields] OR "resistive"[All Fields] OR "resistively"[All Fields] OR "resistivities"[All Fields] OR "resistivity"[All Fields] OR "resists"[All Fields])) AND ("knowledge"[MeSH Terms] OR "knowledge"[All Fields] OR "knowledge s"[All Fields] OR "knowledgeability"[All Fields] OR "knowledges"[All Fields] OR "awareness"[MeSH Terms] OR "awareness"[All Fields] OR "aware"[All Fields] OR "awarenesses"[All Fields])) Date of Access: 16 September 2023

2.2 Screening

-duplicate

2.3 Eligibility

For the third phase, referred to as eligibility, a grand total of 296 articles have been retrieved. At this point, we conducted a comprehensive evaluation of the titles and important content of all publications to confirm that they met the inclusion criteria and aligned with the research objectives of the current study. Consequently, two publications were excluded due to their lack of pure scientific content grounded on actual data. A total of 30 papers that were reviewed. Please refer to Table 2 for more details.

Table 2 the selection	criterion	is	searching.
-----------------------	-----------	----	------------

Criterion	Inclusion	Exclusion	
Language	English	Non-English	
Timeline	2019 - 2023	< 2018	
Litopotupo tupo	Journal	Conference,	
Literature type	(Article)	Book, Review	
Publication	Final	In Press	
Stage	Fillal		

2.4 Data Abstraction and Analysis





After reviewing the titles of the articles, seven main themes emerge in the field of aquaculture and antimicrobial use. Here are the identified themes (Refer to Table 3):

1. Interventions for Antimicrobial Use and Resistance: Articles 1, 7 and 8 discuss the typology of interventions in low- and middle-income countries and propose a systems-thinking approach to identify and assess the feasibility of interventions to reduce antimicrobial usage.

2. Antimicrobial Resistance and Usage Practices:

Articles 2, 3, 4, 10, 11, 12, 14, 15, 19, 21, 22, 23, 24 and 28 investigate various aspects of antimicrobial resistance and usage practices in different regions, species, and farming systems.

3. Ecological and Health Management Practices:

Articles 5, 6, 12, 13, 15, 17, 19, 25, and 26 delve into the health management practices of fish farmers. It also addresses the ecological and human health risks associated with antimicrobial use and residues.

www.jchr.org

JCHR (2024) 14 (01), 3264-3282 | ISSN: 2251-6727



Articles 18 and 22 specifically focus on the implications of veterinary drug use and explore determinants influencing 7. Quality of Antimicrobial Products: antimicrobial use aquaculture sectors.

5. Public Awareness and Communication:

Articles 16, 23, and 27 investigate public awareness and communication strategies.

6. Aquaculture Management and Practices:

aquaculture management and practices, including practices of the field. associated with antimicrobial residues, and fish farming

practices and agrochemical usage.

Articles 21, 24 and 27 assess the quality of antimicrobial products used and determine antimicrobial resistance patterns.

These identified themes represent the diverse and multidimensional nature of research on antimicrobial use and resistance in aquaculture, covering ecological, human Articles 9, 20, 24, 28, 29, and 30 focus on various aspects of health, policy, communication, and species-specific aspects

No.	Name	Title	Year	Journal
1	Garza, M., Mohan, C. V., Brunton, L., Wieland, B., & Häsler, B.	Typology of interventions for antimicrobial use and antimicrobial resistance in aquaculture systems in low- and middle-income countries	2022	Internation al Journal of Antimicrob ial Agents
2	Agbeko, R., Aheto, D. W., Asante, D. K., Asare, N. K., Boateng, A. A., & Adinortey, C. A.	Identification of molecular determinants of antibiotic resistance in some fish farms of Ghana	2022	Heliyon
3	Chowdhury, S., Rheman, S., Debnath, N., Delamare-Deboutteville, J., Akhtar, Z., Ghosh, S., & Chowdhury, F.	Antibiotics usage practices in aquaculture in Bangladesh and their associated factors	2022	One Health
4	Poupaud, M., Goutard, F. L., Phouthana, V., Muñoz Viera, F., Caro, D., Patriarchi, A., & Paul, M. C	Different kettles of fish: Varying patterns of antibiotic use on pig, chicken and fish farms in Lao PDR and implications for antimicrobial resistance strategies	2022	Transbound ary and Emerging Diseases
5	Chambers, J. A., Crumlish, M., Comerford, D. A., Phuoc, L. H., Phuong, V. H., & O'Carroll, R. E.	Understanding Vaccine Hesitancy in Vietnamese Fish Farmers	2022	Antibiotics (Basel)
6	Dewi, R. R., Hassan, L., Daud, H. M., Matori, M. F., Nordin, F., Ahmad, N. I., & Zakaria, Z.	Prevalence and Antimicrobial Resistance of Escherichia coli, Salmonella and Vibrio Derived from Farm-Raised Red Hybrid Tilapia (Oreochromis spp.) and Asian Sea Bass (Lates calcarifer, Bloch 1970) on the West Coast of Peninsular Malaysia	2022	Antibiotics (Basel)
7	Desbois, A. P., Garza, M., Eltholth, M., Hegazy, Y.	Systems-thinking approach to identify and assess feasibility of potential interventions to reduce antibiotic use in tilapia farming in Egypt	2021	Aquacultur e

Table 3 The Research Article on the Proposed Searching Criterion.



www.jchr.org



JCHR (2024) 14 (01), 3264-3282 | ISSN: 2251-6727

	M., Mateus, A., Adams, A., & Brunton, L. A.			
8	Le Bouquin, S., Thomas, R., Jamin, M., Baron, S., Hanne-Poujade, S., & Chauvin, C.	A baseline survey of antimicrobial use and health issues in the freshwater salmonid industry in France	2021	Aquacultur e Reports
9	Phong, T. N., Thang, V. T., & Hoai, N. T.	What motivates farmers to accept good aquaculture practices in development policy? Results from choice experiment surveys with small-scale shrimp farmers in Vietnam	2021	Economic Analysis and Policy
10	Okocha, R. C., Olatoye, I. O., Alabi, P. I., Ogunnoiki, M. G., & Adedeji, O. B.	Aquaculture management practices associated with antimicrobial residues in Southwestern Nigeria	2021	Aquacultur e
11	Luu, Q. H., Nguyen, T. B. T., Nguyen, T. L. A., Do, T. T. T., Dao, T. H. T., & Padungtod, P.	Antibiotics use in fish and shrimp farms in Vietnam	2021	Aquacultur e Reports
12	Alhaji, N. B., Maikai, B. V., & Kwaga, J. K.	Antimicrobial use, residue and resistance dissemination in freshwater fish farms of north-central Nigeria: One health implications	2021	Food Control
13	Tran, K. C., Dalsgaard, A., Van, P. T., & Tersbøl, B. P.	To pray in four directions: Understanding Vietnamese farmers' shrimp health management practices	2021	Aquacultur e
14	Li, J. Y., Wen, J., Chen, Y., Wang, Q., & Yin, J	Antibiotics in cultured freshwater products in Eastern China: Occurrence, human health risks, sources, and bioaccumulation potential	2021	Chemosphe re
15	Thiang, E. L., Lee, C. W., Takada, H., Seki, K., Takei, A., Suzuki, S., & Bong, C. W.	Antibiotic residues from aquaculture farms and their ecological risks in Southeast Asia: a case study from Malaysia	2021	Ecosystem Health And Sustainabili ty
16	Durojaiye, A., Balogun, T. E., Sule, S. O., Ojetayo, T. A., & Akintuyole, S	A Survey on Farmers' Awareness of Dangers Associated With the Use of Antimicrobial Agents in Fish Hatcheries, Ijebu-Ode, Nigeria	2020	Nigerian Journal of Fisheries
17	Han, Q. F., Zhao, S., Zhang, X. R., Wang, X. L., Song, C., & Wang, S. G	Distribution, combined pollution and risk assessment of antibiotics in typical marine aquaculture farms surrounding the Yellow Sea, North China	2020	Environme nt Internation al
18	Love, D. C., Fry, J. P., Cabello, F., Good, C. M., & Lunestad, B. T.	Veterinary drug use in United States net pen Salmon aquaculture: Implications for drug use policy	2020	Aquacultur e
19	Lim, J. M., Duong, M. C., Hsu, L. Y., & Tam, C. C.	Determinants influencing antibiotic use in Singapore's small-scale aquaculture sectors: A qualitative study	2020	PLoS One
20	Mzula, A., Wambura, P. N., Mdegela, R. H., & Shirima, G. M.	Phenotypic and molecular detection of Aeromonads infection in farmed Nile tilapia in Southern highland and Northern Tanzania	2019	Heliyon

www.jchr.org

JCHR (2024) 14 (01), 3264-3282 | ISSN: 2251-6727



21	Pham-Duc, P., Cook, M. A., Cong-Hong, H., Nguyen-Thuy, H., Padungtod, P., Nguyen- Thi, H., & Dang-Xuan, S.	Knowledge, attitudes and practices of livestock and aquaculture producers regarding antimicrobial use and resistance in Vietnam	2019	PLoS One
22	Ström, G. H., Björklund, H., Barnes, A. C., Da, C. T., Nhi, N. H. Y., Lan, T. T., & Boqvist, S.	Antibiotic Use by Small-Scale Farmers for Freshwater Aquaculture in the Upper Mekong Delta, Vietnam	2019	Journal of Aquatic Animal Health
23	Thornber, K., Huso, D., Rahman, M. M., Biswas, H., Rahman, M. H., Brum, E., & Tyler, C. R.	Raising awareness of antimicrobial resistance in rural aquaculture practice in Bangladesh through digital communications: a pilot study	2019	Global Health Action
24	Letchumanan, V., Ab Mutalib, N. S., Wong, S. H., Chan, K. G., & Lee, L. H.	Determination of antibiotic resistance patterns of Vibrio parahaemolyticus from shrimp and shellfish in Selangor, Malaysia	2019	Progress in Microbes and Molecular Biology
25	Okocha, R. C., Olatoye, I. O., & Adedeji, O. B.	Food safety impacts of antimicrobial use and their residues in aquaculture	2018	Public Health Reviews
26	Hedberg, N., Stenson, I., Pettersson, M. N., Warshan, D., Nguyen- Kim, H., Tedengren, M., & Kautsky, N.	Antibiotic use in Vietnamese fish and lobster sea cage farms; implications for coral reefs and human health	2018	Aquacultur e
27	Tran, K. C., Tran, M. P., Van Phan, T., & Dalsgaard, A.	Quality of antimicrobial products used in white leg shrimp (Litopenaeus vannamei) aquaculture in Northern Vietnam	2018	Aquacultur e
28	Ntsama, I. S. B., Tambe, B. A., Takadong, J. J. T., Nama, G. M., & Kansci, G.	Characteristics of fish farming practices and agrochemicals usage therein in four regions of Cameroon	2018	The Egyptian Journal of Aquatic Research
29	Price, D., Sánchez, J., McClure, J., McConkey, S., Ibarra, R., & St- Hilaire, S.	Assessing concentration of antibiotics in tissue during oral treatments against piscirickettsiosis	2018	Preventive Veterinary Medicine
30	Chiesa, L. M., Nobile, M., Malandra, R., Panseri, S., & Arioli, F.	Occurrence of antibiotics in mussels and clams from various FAO areas	2018	Food Chemistry

www.jchr.org

JCHR (2024) 14(1), 839-844 | ISSN:2251-6727



4. Themes

4.1 Interventions for Antimicrobial Use and Resistance

Garza et. al (2022) explore into the critical theme of interventions for antimicrobial use and resistance in aquaculture systems within low- and middle-income countries. The paper describes the characteristics of existing interventions and identifies seven types of interventions, including legislation and regulations, industry rules and standards, voluntary instruments, commercial technology and alternatives to antimicrobials, on-farm management, learning and awareness-raising, and activities with co-benefits. It highlights the need to develop monitoring and surveillance systems for disease, AMU, and AMR in aquaculture, and to understand potential mitigation measures and interventions to address the challenge. The typology of interventions can guide the evaluation of AMR-sensitive interventions, promote responsible AMU, and inform the design and implementation of future interventions. This typological framework not only contributes to academic discourse but also serves as a valuable resource for policymakers, enabling them to tailor interventions to specific contexts and address the unique challenges faced by aquaculture systems in diverse socioeconomic settings (Garza et al., 2022).

In a related manner, Desbois et al (2021) adopts a systems-thinking approach to identify and assess the feasibility of interventions aimed at reducing antibiotic use in tilapia farming in Egypt. Their study recognizes the interconnected nature of factors influencing antimicrobial use and resistance, emphasizing the need for integrated and holistic strategies. By applying a systems-thinking lens, the research goes beyond isolated interventions and considers the broader context, encompassing ecological, social, and economic dimensions such as mapping the tilapia production system in Egypt to locate hotspots of antibiotic use and resistance. This approach is instrumental in identifying potential leverage points and understanding the complex web of interactions that contribute to antimicrobial use in aquaculture. The findings from this study offer practical insights for designing interventions that not only target immediate issues but also consider the broader systemic factors shaping antimicrobial use in tilapia farming, thereby contributing to sustainable and effective solutions, such as explore cost-effective improvements in diagnostics to meet the needs of tilapia farmers, provide more training and discussion opportunities to enhance understanding of interventions, investigate the potential of bacteriophage in disease control for tilapia farming, and considering the development of genetically improved fish for disease resistance as a long-term goal (Desbois et al., 2021).

Le Bouquin et al (2021) paper suggests that interventions to manage antimicrobial use and resistance in the aquaculture industry should include the monitoring of antimicrobial use and the development of bacterial resistance. The study indicates that the use of antimicrobials was necessary in some cases, with florfenicol being the most frequently used antimicrobial, mainly to treat outbreaks of RTFS. However, it was used in less than 20% of the treated fish biomass, and antimicrobials critical for public health were only used exceptionally. The trend of increasing use of florfenicol and decreasing use of other antimicrobials like flumequine and oxytetracycline suggests a shift in antimicrobial preferences, which could have implications for bacterial resistance patterns. The study also highlights the role of vaccination in controlling diseases such as ERM and furunculosis, which has reduced the reliance on antimicrobials. Therefore, the interventions could focus enhancing vaccination coverage, improving on biosecurity and hygiene measures, and promoting the responsible use of antimicrobials to preserve their effectiveness and limit the development of resistance (Le Bouquin et al., 2021).

Interventions in aquaculture to manage antimicrobial use and resistance, as discussed by Garza et al. (2022), include strategies like regulations, industry standards, and education, emphasizing the importance of monitoring systems. Desbois et al. (2021) suggests a holistic approach considering ecological, social, and economic factors, while Le Bouquin et al. (2021) highlight the significance of monitoring antimicrobial trends and promoting vaccination to reduce reliance on antimicrobials. These interventions offer wavs to ensure sustainable antimicrobial use and resistance management in aquaculture.

Antimicrobial Resistance and Usage Practices

Research done by Agbeko's team (2022) contributes to the understanding of antimicrobial resistance by focusing on fish farms in Ghana. The research specifically identifies molecular determinants of antimicrobial resistance including bla TEM, cmIA, qnrS, tetB, and bla CTX-M shedding light on the genetic factors that contribute to resistance in the Ghanaian aquaculture context. By pinpointing these determinants, the study provides valuable insights into the mechanisms through which resistance emerges and spreads in fish farms. This understanding is essential for the development of targeted strategies to manage and mitigate antimicrobial resistance in aquaculture systems in Ghana (Agbeko et al., 2022).

Chowdhury et al. conducted a study in Bangladesh to examine the practices of antimicrobial usage in aquaculture and the factors related to it. The research investigates the socio-economic and cultural factors that

www.jchr.org

JCHR (2024) 14(1), 839-844 | ISSN:2251-6727



influence antimicrobial usage in the aquaculture industry in Bangladesh. It reveals that antibiotic usage is not uncommon in fish farms in Bangladesh, with a significant proportion of farms reporting antibiotic usage within the last 14 days, which most frequently used antibiotics were oxytetracycline, ciprofloxacin, and amoxicillin used for both therapeutic and prophylactic purposes. Antibiotic usage was also reported by 71% of farms at least once since the start of their production cycle, this draws attention to the risks associated with irrational antibiotic use among fish farmers and policymakers. The study enhances researcher understanding of the contextual elements that influence antimicrobial use patterns by identifying and analysing them. (Chowdhury et al., 2022). Poupaud et al (2022) study in Lao PDR found widespread ABU across pig, poultry, and fish farms, with a notable use of antibiotics classified as critically important for human medicine. The study utilized a multistage cluster sampling method to survey 364 farmers, revealing three distinct profiles based on their knowledge, attitudes, and practices towards ABU and AMR. Cluster 1 farmers were well-informed and held positive attitudes towards preventive measures against AMR, while Cluster 2 farmers viewed antibiotics as necessary for prophylactic treatment. In contrast, Cluster 3 farmers exhibited weak knowledge and uncertainty about antibiotic use, correlating with a lower usage of antibiotics. The logistic regression model from the study indicated that ABU was less frequent in fish farms compared to pig and poultry farms and more common in specialized farms. These findings underscore the need for tailored strategies to control AMR, which should consider the varying patterns of ABU and the different farmer profiles to effectively mitigate the risks associated with AMR (Poupaud et al., 2022).

The current paper highlights the rampant use of antibiotics in aquaculture within Southwestern Nigeria, which has led to a high prevalence of antimicrobial residues in African Catfish. The indiscriminate use of antibiotics such as tetracyclines, chloramphenicol, and gentamicin is noted, with a significant lack of knowledge among farmers regarding the implications of drug residues in aquatic animals. The study highlights the association between the level of education of fish farmers and the likelihood of producing fish with antimicrobial residues, indicating a need for improved educational outreach and training. Furthermore, the paper suggests that gender dynamics in farm management may influence residue outcomes, with farms managed by men showing a higher likelihood of residue presence compared to those managed by women. The findings call for the implementation of good fishery management practices and the adoption of alternatives to antimicrobials, such as

probiotics, phage therapy, and essential oils, to mitigate the risks associated with antimicrobial residues and resistance (Okocha et al., 2021).

In this study, Luu et al (2021) investigate the antimicrobials utilized in aquaculture facilities for fish and shrimp in Vietnam. The study offers a comprehensive examination of the patterns and methodologies of antimicrobial utilization inside the Vietnamese aquaculture framework. The research highlights that antibiotics are widely used in fish farms, with 64% of fish farms reporting their use, compared to only 24% of shrimp farms. It founds that there are 11 antibiotic classes (23 different antibiotics) used for fish farming, with the most common classes being Phenicol, Tetracycline, and Sulfonamide, and in shrimp farms, there are 6 antibiotic classes (10 different antibiotics) used, with Tetracycline being the most used class. Concerningly, banned antibiotics such as Chloramphenicol, Enrofloxacin, and malachite green have been reported to be used in shrimp and fish farms in Vietnam. These farmers make decisions on antibiotic use based on their own experiences, advice from neighbouring farmers, and recommendations from drug sellers on the use of medicated feed mixed with antimicrobials. Thus, training and workshops are recommended to inform farmers about the appropriate use of antibiotics and ingredients in aquaculture. This knowledge is crucial for developing precise treatments and regulatory measures to combat antimicrobial resistance in fish and shrimp farming operations in Vietnam. The government should promulgate circulars and regulations on veterinary prescription, advocate for the importance of prescriptions, and monitor the quality of veterinary medicine in the market. Alternatives to antimicrobial disease treatments, such as biosecurity, vaccination, and the use of probiotics, should also be promoted (Luu et al., 2021).

Alhaji et al (2021) investigates the factors that drive small-scale shrimp farmers in Vietnam to adopt favourable aquaculture methods. This study examines the social aspects of managing aquaculture, specifically investigating the factors that impact farmers' choices to implement suggested techniques such as a significant concern regarding antimicrobial use (AMU), which includes the misuse and overuse of antimicrobials in freshwater fish farms. The practices of self-prescription of antimicrobials by farmers and the lack of observance of withdrawal periods post-AMU are prevalent, with 94% and 94.9% of farmers engaging in these practices, respectively. This has led to the emergence of antimicrobial resistance (AMR) and the presence of residues in fish and pond water samples, detected in 44.4% of the farms. The study emphasizes the need for improved antimicrobial stewardship among fish farmers

www.jchr.org

JCHR (2024) 14(1), 839-844 | ISSN:2251-6727



to mitigate the risks of AMR. It also highlights the importance of addressing socio-cultural drivers of antimicrobial misuse and overuse, such as poor biosecurity, sanitation, and the economic status of farmers, through education and surveillance programs (Alhaji et al., 2021).

Li et al (2021) conducted a study in Eastern China to examine the presence of antimicrobials in cultured freshwater products. The study focused on evaluating the possible dangers to human health, identifying the sources of antimicrobials, and determining their ability to accumulate in organisms. The study adopts a holistic approach, considering not just the existence of antimicrobials but also their possible effects on human health and the environment. The research offers a comprehensive analysis of the potential hazards linked to antimicrobial residues in aquaculture products in Eastern China. The findings indicate that, generally, antibiotic levels in aquaculture produce are sufficiently low, posing minimal risk to human health. Nevertheless, the study raised concerns over fluoroquinolones, a specific category of antibiotics, which were found at elevated concentrations warranting further examination. Notably, the investigation revealed the presence of antibiotics within the muscle tissue of fish and similar aquaculture entities, identifying Norfloxacin as the most frequently detected antibiotic. Despite the overall low risk associated with the consumption of these products, the highlighted presence of fluoroquinolones necessitates additional research to fully understand their health implications. Moreover, the study uncovered that antibiotics such as RTM and ETM were detectable not only in aquaculture products but also within water and other environmental matrices, suggesting these environments as potential sources of antibiotic contamination. This aspect of the research underscores the transitory nature of antibiotics in the environment, with minimal evidence of significant accumulation within animal tissues or the surrounding habitats. However, the specific concern regarding fluoroquinolones calls for enhanced scrutiny to ensure the continued safety of consuming aquaculture products (Li et al., 2021).

Thiang et al. (2021) and Letchumanan et al. (2019) conducted studies that shed light on the issue of antimicrobial residues in Malaysian aquaculture, examining their environmental impact and the risks of antimicrobial resistance. These investigations call for stronger regulations to safeguard the environment and consumer health. Thiang's research identified 23 different antibiotics in aquaculture farms across Malaysia, with tetracyclines, sulfonamides, and quinolones being the most found. While most antibiotics were present at low to moderate levels, quinolones were detected at significantly

higher concentrations. Tetracyclines were the most frequently detected, indicating a potential risk to microorganisms like cyanobacteria and algae. The study also revealed that over 90% of the tested sites had antibiotic resistance genes (ARGs), with tet(M) being particularly widespread. These findings are in line with results from other countries in the region, such as Taiwan, China, South Korea, and Japan, underscoring the urgent need for better wastewater management in aquaculture to prevent antibiotic pollution and the spread of ARGs (Thiang et al., 2021). Letchumanan's study, on the other hand, focused on the antibiotic resistance in V. parahaemolyticus, a bacterium found in seafood, which poses significant public health concerns. The research highlighted that antibiotic resistance could result from various factors, including the overuse of antibiotics in aquaculture and environmental contamination. It was observed that the presence of plasmids in bacteria doesn't necessarily correlate with antibiotic resistance, which can also be encoded in the bacteria's chromosomes. Both studies underline the critical need for ongoing surveillance and effective environmental management strategies to minimize antibiotic contamination and combat the rise of antibiotic resistance in Malaysia's aquaculture sector. These efforts are essential for ensuring the sustainability of aquaculture practices and protecting both environmental and human health (Letchumanan et al., 2019).

From Lim et al (2020) paper, it is evident that the use of antibiotics in Singapore's small-scale aquaculture is influenced by a combination of individual, regulatory, and market factors. Farmers' personal knowledge and experience with antibiotics, as well as their understanding of the consequences of antibiotic use in food production, play a significant role in their usage practices. Some farmers demonstrate discernment in treatment choices, distinguishing between bacterial, viral, or parasitic infections, and opting for alternative treatments like nanosilver injections to avoid the negative impacts of antibiotics on human health and to circumvent the issue of reduced antibiotic effectiveness. Regulatory oversight by bodies such as the Agri-Food & Veterinary Authority of Singapore (AVA) also acts as a deterrent against antibiotic misuse, although some farmers express frustration with regulations when alternative treatments or guidelines are not provided. Market factors, including the high cost of antibiotics and competitive pressures, further disincentivize the use of antibiotics. These findings underscore the complexity of antibiotic use practices in aquaculture and the importance of considering a range of factors when addressing antibiotic resistance (Lim et al., 2020).

Pham-Duc et al (2019) research examines the complex dynamics of antimicrobial use and resistance by exploring

www.jchr.org

JCHR (2024) 14(1), 839-844 | ISSN:2251-6727



the perspectives of livestock and aquaculture producers in Vietnam. Through a comprehensive examination of knowledge, attitudes, and practices, the research sheds light on the multifaceted factors influencing antimicrobial use within these agricultural sectors. The study found that while most farmers know about the dangers of overusing antibiotics, only 20% practice caution in their use, preferring antibiotics as the go-to solution for sick animals rather than preventive measures such as improving hygiene or isolating sick animals as antibiotics were often the first response to disease by farmers, more so than hygiene or quarantine measures highlights a significant challenge in managing antibiotic use. The findings suggest that to combat antibiotic resistance effectively, there's a need for targeted educational campaigns and interventions designed specifically for Vietnam's context. These should focus on encouraging farmers to adopt better practices, like improving farm hygiene and using antibiotics more sparingly, to ensure antibiotics remain effective for treating infections in both humans and animals. Pham-Duc et al. (2019) highlight the importance of understanding local practices and attitudes to develop effective strategies for sustainable antibiotic use in agriculture.

Ström et al. (2019) discovered that Vietnam's small-scale aquaculture in the Upper Mekong Delta has distinct challenges related to antimicrobial usage. The study examines the underlying reasons for the use of antimicrobials by farmers, highlighting the importance of developing specific tactics to tackle the distinct obstacles encountered by this group. The study revealed that a proportion of small-scale significant freshwater aquaculture farmers in the upper Mekong Delta, Vietnam, utilized antibiotics in their farming practices particularly for those cultivating tilapia and Striped Catfish. The study highlights a reliance on antibiotics as a disease management strategy, with a significant portion of farmers using these drugs for about three days during disease outbreaks. The findings also indicate a lack of standardized protocols for antibiotic use and withdrawal periods, as evidenced by the varied practices reported by farmers. This situation raises concerns about potential antibiotic resistance and food safety issues due to the presence of antibiotic residues in aquaculture products. The study underlines the need for improved disease management practices, including responsible use of antibiotics, better training for farmers, and the establishment of clear guidelines to ensure both the sustainability of aquaculture and the health of consumer, it adds to a more complete and context-specific approach to promoting sustainable aquaculture (Ström et al., 2019). Thornber et al. (2019) conducted a study that found a 4minute animated video to be a highly effective tool for raising awareness about antimicrobial resistance (AMR)

among aquaculture farmers in rural Bangladesh. The was well-received, with all participants video appreciating this method of communication, and 97% reported that it would likely lead them to change how they use antibiotics. Additionally, the video quickly gained traction on social media, receiving over 9,100 views in just two weeks, demonstrating the potential for digital platforms to spread AMR awareness rapidly and widely. The study also highlighted the critical role of collaboration among different stakeholders in creating targeted AMR messages and underscored the need for more research to enhance the effectiveness of digital AMR campaigns further. Given the challenge of reaching rural communities in low- and middle-income countries, the authors suggest leveraging social media not only for information dissemination but also for facilitating interactive engagement and feedback from the aquaculture community. This strategy could improve the impact of AMR awareness efforts by fostering dialogue between industry, academia, and farming communities. Ntsama et al (2018) study conducted in four regions of Cameroon indicated that most of these farmers utilized

earthen fishponds, and in terms of feeding practices, locally formulated powdered feeds were commonly used, along with animal manure, chicken droppings, and pig dung. When it came to fish health management, a minority of farmers sought veterinary prescriptions, and over half used agrochemical products such as liming materials, fertilizers, and veterinary drugs, with tetracyclines being the most frequently used for curative purposes. Thus, there is a potential health risk to humans due to the misuse of agrochemicals and intensive antibiotic use in integrated fish farming. The study underscores the importance of good fish farm management practices, effective fish health management, and periodic monitoring to ensure the production of safer fish products. It also highlights the need for effective monitoring of chemical contaminants in fish farming within Cameroon (Ntsama et al., 2018).

The study by Chiesa et al. developed a multiclass HPLC-MS/MS method to detect 29 antibiotics in mussels and clams, which are bioindicators of environmental pollution, including antibiotic contamination from aquaculture practices. The presence of antibiotics in marine environments can lead to the selection of resistant bacteria, which is a concern for both environmental and human health. The study's findings, which showed a negligible presence of antibiotics in most samples but a detectable level of oxytetracycline in one clam sample, highlight the importance of responsible antibiotic usage practices in aquaculture to prevent the spread of antibiotic resistance. The validation of the analytical method according to the Commission Decision 2002/657/EC guidelines ensures the reliability of the data, which is

www.jchr.org

JCHR (2024) 14(1), 839-844 | ISSN:2251-6727



essential for monitoring and managing the risk of antibiotic resistance (Chiesa et al., 2018).

In conclusion, studies from various countries including Ghana, Bangladesh, Lao PDR, Nigeria, Vietnam, and Malaysia reveal challenges with antimicrobial resistance (AMR) in aquaculture. They stress the need for tailored interventions, regulations, and education to protect the environment and human health while ensuring sustainable aquaculture practices.

4.2 **Ecological and Health Management Practices** Chambers et al. (2022) study found that while Vietnamese fish farmers concerns about antibiotic usage were high, yet majority reporting having used antibiotics on their farms, where positive knowledge and attitudes towards vaccination is also high, indicating they would use vaccines if available. Likelihood of vaccine usage was higher among farmers with fewer fish disease problems, less vaccine mistrust, and fewer concerns about profiteering. The study's findings suggest that addressing both the perceived necessity and concerns about vaccines is essential for promoting their use in aquaculture. Thus, effectively address vaccine hesitancy among to Vietnamese fish farmers, it is crucial to emphasize the risks associated with the continued use of antibiotics and to alleviate concerns and mistrust related to vaccines. The acquisition of this data is of utmost importance for the advancement of focused educational initiatives and interventions aimed at fostering the acceptance of vaccination practices, making a significant contribution to the general well-being and long-term viability of aquaculture in Vietnam (Chambers et al., 2022).

Dewi et al. (2022) study addresses ecological and human health risks by assessing the microbial contamination in farm-raised fish. It concluded that there is a significant prevalence of antimicrobial resistance among clinically important bacteria such as E. coli, Salmonella, and Vibrio species isolated from aquaculture production on the west coast of Peninsular Malaysia. The antimicrobial resistance profile revealed that more than half of E. coli isolates from tilapia production systems were resistant to erythromycin and streptomycin, and only small percentage were susceptible to all antibiotics tested compared to those from Asian seabass. The findings underline the high resistance levels of bacteria towards antibiotics that are considered a priority and critically important for both human and veterinary use, posing a significant risk to public and animal health. This research highlights the importance of considering both ecological and public health dimensions in assessing the risks associated with antimicrobial use in aquaculture (Dewi et al., 2022).

Alhaji et al (2021) study delves into the freshwater fish farms of north-central Nigeria, adopting a One Health perspective to assess antimicrobial use, residue dissemination, and resistance. The 'One Health' approach is suggested to mitigate the socio-cultural drivers of antimicrobial misuse and overuse, which have been identified as significant factors contributing to the emergence of AMR and the presence of antimicrobial residues in aquaculture environments. This approach is crucial for ensuring food safety, food security, and public and environmental health by addressing AMR at the human-animal-environment interface. Implementing 'One Health' strategies, such as surveillance and control programs, can help in promoting prudent AMU and reducing the risk of AMR dissemination in fish farms, thereby moving towards a Green risk status and better biosecurity measures (Alhaji et al., 2021).

Tran et al. (2021) investigated shrimp farmers in Northern Vietnam to understand their strategies for maintaining shrimp health. They found that farmers often resort to trial-and-error with antimicrobials due to low trust in government guidance and high reliance on private sources. This reliance, termed "praying in four directions," highlights the farmers' struggle with conflicting information sources. The study identified a need for interventions addressing livelihood insecurity, legislation enforcement on antimicrobial use, and reliable diagnostic services. Additionally, it highlighted farmers' mixed emotions, from frustration to enthusiasm, as they engage with advanced technology. Understanding these findings is crucial for developing effective extension programs and policy interventions to promote sustainable health management in Vietnam's aquaculture industry (Tran et al., 2021).

The research conducted by Thiang et al (2021) in Southeast Asia pertains to the investigation of antimicrobial residues originating from aquaculture farms and the associated ecological hazards. The article specifically presents a case study conducted in Malaysia. It includes the potential harm to cyanobacteria and algae due to the presence of antibiotics such as ciprofloxacin, enrofloxacin, norfloxacin, and lincomycin, which were found to pose risks in certain regions like Kelantan, Perak, and Pahang. The widespread distribution of antibiotics like tetracyclines, sulfonamides, and quinolones in Malaysian aquaculture farms indicates a significant environmental concern, as these substances can alter microbial communities in water and sediment, potentially leading to the growth of antibiotic-resistant bacteria. The detection of antibiotic resistance genes (ARGs) like tet(M), sul1, sul2, and sul3 in high frequencies further indicates the risk of horizontal gene transfer, which could disseminate resistance traits to other bacteria, including pathogenic strains. Human health risks are also present, as

www.jchr.org

JCHR (2024) 14(1), 839-844 | ISSN:2251-6727



the leaching of antibiotics into groundwater and oceans can result in the consumption of antibiotic-contaminated food and drinks, posing a public health risk. (Thiang et al., 2021).

Han et al. (2020) investigates how antimicrobials are spread, how they affect the environment, and how dangerous they are in normal marine aquaculture farms near the Yellow Sea in North China. The study revealed that 17 antibiotics were present in various matrices such as seawater, sediment/biofilm, organisms, and feed across different aquaculture modes. Trimethoprim was the most prevalent antibiotic, found in all water samples, while oxytetracycline showed high concentrations in biofilms. The biofilms demonstrated a higher antibiotic accumulation capacity compared to sediments. In feed, high concentrations of oxytetracycline and doxycycline were detected, whereas other antibiotics were nearly undetectable. Tetracycline was widely found, and enrofloxacin had the highest concentration in organisms. The study also established a correlation between heavy metals and antibiotic concentrations, suggesting that heavy metals could serve as indicators for antibiotic levels in the environment. Most antibiotics posed no risk to the environment, but ciprofloxacin and enrofloxacin in water may present high ecological and resistance risks, and their accumulation in fish could pose a considerable risk to human health through dietary consumption. All detected antibiotics in seafood were below the maximum residue limits, indicating a lower risk to human health. The study concluded that the antibiotics detected in seafood were below the maximum residue limits, suggesting a low risk to human health. Nevertheless, the high concentration residues of ciprofloxacin and enrofloxacin in fish could pose a considerable health risk to consumers. Overall, while the environmental impact of most antibiotics was minimal, certain antibiotics in aquaculture could pose significant risks to both ecological systems and human health through the consumption of contaminated seafood. The findings highlight the need for effective monitoring and management of antibiotic use in aquaculture to ensure environmental and seafood safety in China (Han et al., 2020).

Lim etl al (2020) study in the context of Singapore's small-scale aquaculture sectors, health management practices are influenced by a variety of factors, including individual farmer experiences, regulatory guidelines, and market pressures. Farmers have reported using alternative strategies to antibiotics for increasing fish survival, such as the procurement of higher quality fish fry, maintaining good hygiene practices, and employing nonconventional forms of disease management, such as the use of nanosilver injections. These practices align with the broader objectives of Singapore's national strategic action plan to address AMR, which emphasizes the reduction of antimicrobial use in food-producing animals and encourages better animal management practices and the use of vaccines. The regulatory framework, including licensing conditions for animal feed manufacture and guidelines for antimicrobial use, also mandates a minimum withdrawal period before animals can be sold to prevent antibiotic residues in food. These health management practices reflect a multifaceted approach to reducing reliance on antimicrobials and enhancing the overall health and sustainability of aquaculture operations (Lim et al., 2020).

The effects of antimicrobial usage and residues on food safety are investigated by Okocha et al. (2018). The paper emphasizes that indiscriminate use of antimicrobials can lead to residues in aquaculture products, posing health risks such as antimicrobial drug resistance and other adverse effects. It suggests that good animal husbandry practices, veterinary supervision, and alternatives to antibiotics, such as vaccination, probiotics, phage therapy, and essential oils, are recommended to reduce the use of antimicrobials. From an ecological perspective, chemicals used in culture fisheries, including antimicrobials, can become disruptive when they enter natural aquatic systems, potentially causing irreparable damage to the ecosystem. This includes the risk of affecting non-target species and altering the balance of microbial communities, which can have cascading effects on the broader environment. The paper also calls for improved record-keeping of antimicrobial sales and the establishment of comprehensive databases to monitor use and identify hotspots of disproportionate use that require attention. Additionally, the presence of antimicrobial residues in the environment can exert selective pressure, leading to the persistence and proliferation of resistant strains over susceptible ones, which can have long-term ecological consequences (Okocha et al., 2018).

The study conducted by Hedberg et al. (2018) examines the wider consequences of health management practices implemented in fish and lobster sea cage farms in Vietnam. The study revealed that antibiotics are used extensively and in an unstructured manner in Vietnamese sea cage farms, with a particularly high usage noted in lobster farming, averaging over 5 kg per ton of lobster produced. The research also identified the presence of antibiotic resistance in coral-associated bacteria, specifically to Tetracycline, Vancomycin, and Rifampicin. The study highlights the potential negative effects of antibiotic use on coral-symbiont relationships and the broader environmental implications, advocating for stricter control and enforcement of antibiotic use in aquaculture to mitigate these risks. This holistic perspective is crucial for policymakers and practitioners seeking to develop sustainable and responsible health

www.jchr.org

JCHR (2024) 14(1), 839-844 | ISSN:2251-6727



management practices that consider both the immediate needs of aquaculture and the long-term health of marine ecosystems and human populations (Hedberg et al., 2018).

Research from different regions, like Vietnam, Malaysia, Nigeria, and China, shows how to manage health and ecology in aquaculture. They stress the importance of targeted actions to deal with antibiotic resistance and contamination. These findings highlight the need to encourage vaccination to reduce antibiotic use and manage risks like antibiotic resistance. Also, they show the environmental risks of antibiotic residues and the need for stricter rules to keep food and the environment safe. Understanding these issues is vital for creating effective plans to support sustainable aquaculture and safeguard nature and people's health.

4.3 Policy and Regulation

In 2020, Love et al. explore the effects of veterinary medication usage in net pen salmon aquaculture in the United States, adding to the conversation on policy and regulation in aquaculture methods. The current paper indicates that the U.S. net pen Atlantic salmon aquaculture industry is the first U.S. food animal industry to report monthly antimicrobial use at the farm-level to the government. This reporting is critical for assessing public health risks associated with antimicrobial use and resistance. The study also highlights the need for more approved drugs to treat aquaculture diseases in the U.S., as well as the importance of continued work on vaccines. It underlines the importance of policy and regulation in managing antimicrobial use, as the overuse or misuse of antimicrobials in any setting can compromise the treatment of bacterial infections and contribute to the global issue of antimicrobial resistance. The findings add to the current discussions regarding policy frameworks, with the goal of establishing a balance between enhancing the health of farmed fish and reducing possible environmental and public health problems (Love et al., 2020).

Ström et al. (2019) have investigated the antimicrobial usage in small-scale aquaculture in the Upper Mekong Delta of Vietnam, revealing a range of problems. The study examines the underlying reasons for the use of antimicrobials by farmers, highlighting the necessity for customized approaches to tackle the distinct obstacles encountered by this group. The study indicates that policy and regulation in Vietnam have not been effective in reducing antibiotic use among small-and medium-scale livestock producers. Despite regulatory efforts, the use of antibiotics remains prevalent for both therapeutic and prophylactic purposes. The findings suggest that better knowledge and attitudes towards antibiotic use and resistance are associated with improved practices, which could be a focus for future policy directions. For instance, enhancing education and awareness among producers could be a key strategy. Additionally, the study reveals that a significant proportion of producers are unaware of the antibiotics that are prohibited for use in livestock rearing, indicating a gap in the dissemination and enforcement of regulations. This emphasizes the need for stronger policy measures and regulatory enforcement to ensure that producers are not only aware of the rules but also comply with them to mitigate the risk of antimicrobial resistance (AMR) (Ström et al., 2019).

Research by Love et al. (2020) reveals the impact of using veterinary medication in salmon aquaculture in the U.S., emphasizing the importance of rules. They show how reporting antimicrobial use to the government helps understand health risks. The study says more drugs are needed for treating fish diseases, and vaccines are vital too. It stresses rules to manage antimicrobial use to prevent resistance. This research adds to discussions on finding a balance between fish health and risks to the environment and public health. Similarly, Ström et al. (2019) looked at antibiotic use in small-scale aquaculture in Vietnam. They found challenges despite existing policies and stressed the need for better education and enforcement to prevent resistance.

4.4 Public Awareness and Communication

In the context of the article, the study done by Durojaiye et al (2020) delves into the extent of knowledge and consciousness among fish farmers in Ijebu-Ode, Nigeria, regarding the risks linked to the use of antimicrobial agents in their practices. Despite the farmers' engagement in fish hatchery practices and varying levels of education, there is a notable lack in their understanding of the risks associated with the indiscriminate use of antimicrobials. The data reveals that almost half of the respondents did not recognize the dangers of such practices, and unable to acknowledge the risks, indicating an overall low level of awareness. This situation is exacerbated by the fact that most of the farmers administer antimicrobials without any formal training or supervision by authorized personnel, often using a prophylactic approach. Understanding the level of awareness within the public is crucial for developing targeted communication strategies that can educate and empower farmers to adopt more sustainable and responsible practices, thereby promoting the judicious use of antimicrobial agents and mitigating the potential for antimicrobial resistance and environmental harm (Durojaiye et al., 2020).

Thornber et al (2019) conducted a pilot study in rural aquaculture practice in Bangladesh, leveraging digital communications to raise awareness of antimicrobial

www.jchr.org

JCHR (2024) 14(1), 839-844 | ISSN:2251-6727



resistance (AMR). The research recognizes the potential of digital platforms in disseminating information and educational materials to remote areas. By employing digital communication strategies, the study aims to bridge information gaps and empower fish farmers with knowledge about responsible antimicrobial use. The findings from this pilot study offer insights into the effectiveness of digital communication in reaching rural aquaculture practitioners, highlighting the role of technology in enhancing awareness and fostering behavioural change in the context of AMR.

Tran et al. (2018) emphasizes public awareness and communication in shrimp agriculture. The study indirectly addresses the requirement for public knowledge of aquaculture antimicrobial dangers by examining the quality of antimicrobial products used in Northern Vietnam. The study highlights that many products do not contain the correct concentration of active substances, and labelling often provides inadequate or incorrect information regarding disease treatment, preparation of medicated feed, withdrawal times, and personal protection measures. This situation emphasises the urgent need for public awareness and communication strategies aimed at educating shrimp farmers on prudent antimicrobial use practices. Such strategies should include the dissemination of accurate information about the proper use of antimicrobials, the risks associated with their misuse, and the importance of adhering to guidelines to prevent the development of antimicrobial resistance and ensure food safety and occupational health. It is crucial that these educational efforts are supported by strengthened diagnostic services, legislation, and control of antimicrobial products in the aquaculture sector (Tran et al., 2018).

To summarize, this research together contributes to the issue of Public Awareness and Communication about antimicrobial resistance and aquaculture. These studies provide valuable information on how digital communication tactics, countrywide surveys, and focused awareness campaigns may improve understanding and encourage safe antimicrobial use among fish farmers, aquaculture practitioners and the public. The findings enhance the progress of communication initiatives that effectively tackle the unique obstacles and circumstances of promoting knowledge regarding antimicrobial resistance.Top of Form

4.5 Aquaculture Management and Practices

Phong et al (2021), makes a significant contribution to the Aquaculture Management and Practices (GAqPs) theme by exploring the motivations of small-scale shrimp farmers in Vietnam to embrace good aquaculture practices. This study delves into the human dimensions of aquaculture management, shedding light on the factors that drive farmers to adopt recommended practices. It suggested that a combination of financial support, compliance with antibiotic regulations, aquaculture insurance, awareness of disease-prevention benefits of GAqPs, and ensuring a stable output market and price premium are necessary to promote the adoption of GAqPs. However, financial constraints limit their willingness to invest in GAqPs despite the availability of a preferential loan policy. This targeted analysis is instrumental for shaping aquaculture management practices that align with the needs and priorities of smallscale farmers, ultimately fostering the adoption of sustainable and responsible practices in Vietnamese shrimp farming (Phong et al., 2021).

Mzula et al (2019) study indicates that there is a significant concern regarding the prevalence of aeromonads infection in farmed tilapia. There is an overall prevalence of 24.6% of aeromonads infection among the sampled tilapia population, with Aeromonas hydrophila and Aeromonas veronii being the identified species causing the infections particularly in the Southern highlands and Northern zones of Tanzania. This situation is exacerbated by the limited knowledge and awareness of proper pond management practices and fish health management among fish farmers in the area. The lack of systematic surveillance of aeromonads infections in farmed fish further complicates the issue. To mitigate the risks of disease outbreaks and to establish sustainable aquaculture production, it is recommended that farmers be trained on basic pond and fish health management and control strategies. The use of autogenous vaccines, which are economically feasible and effective, especially in Low and Middle-Income Countries (LMIC), is suggested as a complementary control method. This approach is based on accurate typing and evidence-based definition of the epidemiological unit, which is crucial for the development of targeted interventions in aquaculture systems (Mzula et al., 2019).

According to Letchumanan et al (2019), aquaculture management practices are crucial to ensure a sustainable and reliable supply of seafood. However, the industry faces significant challenges due to bacterial infections, which can rapidly spread in dense farming areas. To combat these infections, farmers often resort to the extensive use of antibiotics, both prophylactically and therapeutically, to protect their stocks. This extensive use of antibiotics has contributed to the rise of antimicrobialresistant pathogenic bacteria in seafood, which poses a threat to human health and the environment. The misuse of antibiotics in aquaculture has led to the occurrence of multidrug-resistant bacteria, highlighting the need for

www.jchr.org

JCHR (2024) 14(1), 839-844 | ISSN:2251-6727



appropriate management and control of antibiotic use in the sector. Continuous monitoring and controlling the use of antibiotics are required to manage the resistance phenotype, which can be chromosomally mediated in bacteria. The findings from studies in Malaysia indicate a high resistance to ampicillin among Vibrio parahaemolyticus isolates from seafood, suggesting that ampicillin may no longer be an effective treatment for Vibrio spp. Infections. Therefore, aquaculture management practices must include strategies for responsible antibiotic use, regular surveillance of antimicrobial resistance, and alternative measures to control bacterial infections without relying solely on antibiotics (Letchumanan et al., 2019).

Ntsama et al (2018) conducted a study in four areas of Cameroon to examine the specific traits of fish farming methods and the utilization of agrochemicals. This study offers valuable insights on the range of fish farming methods employed in Cameroon, as well as the corresponding utilization of agrochemicals. Aquaculture management in Cameroon involves various practices, with a significant number of fish farmers being smallscale operators (49.5%) and the majority (83.3%) utilizing earthen fishponds. Integrated fish farming is practiced by about 30% of farmers, combining aquaculture with poultry, piggery, or crop farming. Feeding practices are characterized using locally formulated powdered feeds, animal manure, and livestock droppings. In terms of fish health management, a minority of farmers (24.3%) consult veterinarians for prescriptions, while over half (51%) use agrochemical products such as liming materials, fertilizers, and veterinary drugs, with tetracyclines being the most used for curative purposes. The evaluation of fish farm management includes assessing qualifications in fish farming, adherence to good aquaculture practices, and the use of a veterinarian. Feeding practices are evaluated based on the type of systems, the number of meals per day, and the type of feeding, while production is assessed on pond disinfection, the use of chemicals, and harvesting. These practices are scored and classified to determine the level of adherence to good practices. The research emphasizes the contextual elements that influence aquaculture management methods in different regions of the nation by analysing regional variances. This information is crucial for policymakers and practitioners who aim to create specific interventions and extension programs that consider the distinct challenges and opportunities in different regions of Cameroon. Ultimately, these efforts will encourage sustainable and responsible management practices in aquaculture (Ntsama et al., 2018).

Price et al (2018) study highlights the challenges associated with the management of antibiotic treatments, specifically in the context of piscirickettsiosis in Chilean aquaculture. It underscores the importance of assessing antibiotic concentrations in fish tissues during treatment to ensure that therapeutic levels are achieved to combat the disease effectively. The research indicates that the probability of finding antibiotic concentrations above the MIC90 in fish tissues is influenced by several factors, including the species of fish, the size of the fish within a cage, and the timing of sample collection during the These findings suggest that treatment period. management practices must be tailored to account for these variables to improve treatment efficacy. Moreover, the study calls for further detailed investigation to optimize antibiotic delivery, which is a crucial aspect of disease management in aquaculture. This could involve refining feed delivery systems, dosing strategies, and monitoring protocols to ensure that all fish within a population receive an adequate dose of the antibiotic (Price et al., 2018).

The study by Chiesa et al. highlights the importance of monitoring antibiotic residues in aquaculture products, such as mussels and clams, which can accumulate these substances from their environment. The use of antibiotics, such as oxytetracycline, is a common practice in fish farming to combat bacterial diseases due to its broad antibacterial spectrum, efficacy, and cost-effectiveness. However, the administration of doses often exceeds the recommended 50-100 mg/kg fish per day for 7-10 days, which can lead to environmental concerns, including the development of antibiotic resistance. The research developed a multiclass HPLC-MS/MS method to analyse the presence of antimicrobials in these organisms, which is crucial for managing the risk of chemical contamination in aquaculture and ensuring food safety. The findings underscore the need for stringent management practices in aquaculture to minimize the use of antibiotics and prevent their accumulation in the marine ecosystem (Chiesa et al., 2018).

Research by Phong et al. (2021) shows how small-scale shrimp farmers in Vietnam adopt good aquaculture practices, needing financial support, compliance with rules, insurance, and stable markets. Limited finances hinder adoption despite available loans. Mzula et al. (2019) note a high aeromonads infection rate in Tanzanian tilapia farms due to farmer knowledge gaps, recommending training and autogenous vaccines. Letchumanan et al. (2019) stress responsible antibiotic use in Malaysian aquaculture to combat antimicrobial resistance. Ntsama et al. (2018) highlight Cameroon's varied aquaculture practices, suggesting tailored

www.jchr.org

JCHR (2024) 14(1), 839-844 | ISSN:2251-6727



interventions for sustainable management. Price et al. (2018) discusses challenges in treating piscirickettsiosis in Chilean aquaculture, needing custom approaches. Chiesa et al. (2018) stress monitoring antibiotic residues in aquaculture products for food safety and environmental protection. The findings contribute to the development of strategies and policies that promote sustainable and responsible aquaculture management practices tailored to specific contexts and challenges.

4.6 Quality of Antimicrobial Products

Tran et al (2018) focused on the assessment of antimicrobial products used in white leg shrimp aquaculture in Northern Vietnam. The study undertakes a critical examination of the quality of antimicrobial products, recognizing the importance of ensuring the efficacy and safety of these products in aquaculture practices. The quality of antimicrobial products used in white leg shrimp (Litopenaeus vannamei) aquaculture in Northern Vietnam has been found to be suboptimal. A study evaluating these products revealed that only one out of twelve products containing a single antimicrobial had an active substance concentration within $\pm 10\%$ of the declared amount on the label, which is the accepted level of variation. More than half of the products contained less than the declared concentration, ranging from <1.0% to 90% of the expected levels. The labelling on these products often provided inadequate or incorrect information regarding the specific diseases to be treated, preparation of medicated feed, withdrawal times, and personal protection measures. This poor quality and labelling not only impact the effectiveness of disease treatment in shrimp aquaculture but also contribute to the development of antimicrobial resistance and pose food safety and occupational health hazards. The study highlights an urgent need for improved diagnostic services, legislation, and control of antimicrobial products, and education on prudent antimicrobial use practices in the shrimp aquaculture industry. By evaluating the characteristics and composition of antimicrobial products, the research provides valuable insights into the potential risks associated with their use in shrimp farming. This information is instrumental for stakeholders, including farmers and policymakers, in making informed decisions about the selection and application of antimicrobial products, contributing to the overall sustainability and responsible use of such inputs in aquaculture (Tran et al., 2018).

According to Pham-Duc et al (2019), the quality of antimicrobial products in Vietnam is a concern, particularly because over-the-counter availability of antibiotics can lead to unsupervised use by livestock and aquaculture producers. This unsupervised use may result in inappropriate dosages and insufficient withdrawal periods before slaughter, potentially leading to antibiotic residues in meat products. The World Health Organization has recorded over 45 different antibiotics used across livestock and aquaculture in Vietnam, and there have been instances where livestock feed sold in the country contained legal antibiotics alongside other drugs banned by the World Trade Organization, such as chloramphenicol. The Vietnamese government has recognized these issues and is attempting to address them through the Law on Animal Husbandry, which aims to control the use of drugs in animal feed and livestock and is set to become effective in 2020. However, the enforcement of these regulations remains challenging due to the prevalence of smallholder producers in the market (Pham-Duc et al., 2019).

According to Okocha et al (2018), the quality of antimicrobial products in aquaculture is critical to ensure their efficacy and minimize the risk of developing antimicrobial resistance (AMR). High-quality antimicrobials should meet the standards for purity, potency, and stability, ensuring that they are free from contaminants and retain their therapeutic properties throughout their shelf life. The use of substandard or counterfeit antimicrobials can lead to sub-therapeutic dosing, which may not only be ineffective in treating infections but also contribute to the selection of resistant bacteria. The paper emphasizes the need for veterinary supervision when using antimicrobials in food animals, including aquaculture, to ensure that they are used prudently and responsibly. This includes adhering to recommended dosages and treatment durations, as well as avoiding the use of prohibited substances such as chloramphenicol and nitrofurans. Ensuring the quality of antimicrobial products is part of the broader regulatory actions aimed at promoting safe and wholesome food production, which is essential for consumer protection and maintaining the integrity of international trade in animal and animal products (Okocha et al., 2018).

In conclusion, Tran et al. (2018) studied antimicrobial products used in shrimp farming in Vietnam and found that most didn't meet quality standards. Labels often lacked important information, risking shrimp health and food safety. They suggest better regulation and education. Pham-Duc et al. (2019) are worried about the quality of antimicrobial products in Vietnam and how they're used unsupervised. They mention new regulations to fix this. Okocha et al. (2018) stress that good-quality antimicrobials are crucial to prevent resistance. They recommend veterinary supervision and following recommended doses.

www.jchr.org

JCHR (2024) 14(1), 839-844 | ISSN:2251-6727



Recommendation

The global concern over the usage and resistance of antimicrobials in aquaculture systems need urgent and continuous attention from both researchers and stakeholders. Based on the knowledge gained from the articles examined, it is crucial that future research focuses on evaluating and enhancing intervention options. These plans should include a wide range of areas, including improving farm management techniques and assessing the impact of education and training initiatives. The categorization of interventions emphasized in low- and middle-income countries is a helpful first reference for such inquiries. Furthermore, it is important to further investigate the molecular factors that contribute to antimicrobial resistance, especially in areas such as Ghana, with an emphasis on understanding and describing the genetic pathways involved. This knowledge will be crucial in the creation of focused treatments and prediction models to control resistance in aquaculture.

Different areas have different trends of using antimicrobials in aquaculture, as seen in Lao PDR and other places. This shows how important it is to do study that is specific to the situation. More research needs to be done on the specifics of farming, antimicrobial use, and trends of resistance in different parts of the world. With this regional method, policies and strategies can be changed to fit different problems and requirements. A "One Health" approach should also be used to guide research, like the studies done in Nigeria, to fully understand how aquaculture systems affect the health of people and the environment. To make smart decisions, it's important to know how using antimicrobials and spreading resistance in aquaculture affects the environment and public health.

Additionally, it is crucial for future studies to give priority to evaluating the potential hazards to human health that are linked to the use of antimicrobials in aquaculture, as shown by research conducted in Eastern China and Southeast Asia. Comprehensive evaluations of risks, analysis of how people are exposed to potential hazards, and methods to reduce or eliminate those risks are necessary to protect the health of consumers. It is important to focus on small-scale aquaculture sectors in different nations and conduct qualitative investigations to identify the factors that influence the usage of antimicrobials. This research has the potential to provide valuable insights for the formulation of policies and initiatives aimed at promoting sustainable practices in various areas. To address the complex difficulties of antimicrobial resistance in aquaculture, as well as safeguard public health and the environment, it is crucial and imperative for researchers, policymakers, and

industry stakeholders to adopt a multi-disciplinary and collaborative strategy to address these issues in a comprehensive manner.

5. Conclusion

In navigating the complex landscape of antimicrobial use in aquaculture and its implications for antimicrobial resistance (AMR), this systematic literature review has unveiled critical insights into fish farmers' perspectives as well as an indispensable facet in the realm of aquaculture. With a focus on understanding the viewpoints of these key stakeholders, the review rigorously examined 30 relevant publications, revealing a profound interplay between aquaculture practices, antimicrobial utilization, and the looming threat of AMR.

The combination of these studies, carefully selected through a meticulous methodological approach, offers a nuanced understanding of the challenges and opportunities inherent in fish farmers' responses to AMR. The identification of 296 potentially relevant publications, narrowed down to the 30 that met the inclusion criteria, underscores the specificity and selectivity employed to ensure the quality and relevance of the literature under review.

The synthesized findings shed light on the intricate links between antimicrobial practices, farmers' awareness, and the efficacy of disease management strategies. The need for specialized treatments, stringent surveillance measures, and innovative awareness campaigns in aquaculture AMR becomes apparent, pointing toward the complexity of addressing this multifaceted challenge. The findings not only enhance comprehension of the intricacies of AMR in aquaculture but also provide a robust foundation for guiding future research endeavours.

Furthermore, the review extends its significance beyond academia, serving as a crucial resource for policymakers and industry stakeholders. The identified challenges and opportunities in aquaculture AMR are pivotal for the formulation of evidence-based policies that balance the imperative of sustaining seafood production with the pressing need to mitigate AMR risks. The implications of this review reverberate across the aquaculture industry, offering valuable insights for the implementation of sustainable practices that safeguard the long-term viability of this critical sector.

To conclude, the synthesis of fish farmers' perspectives on AMR in aquaculture not only contributes to academic understanding but also serves as a compass guiding future endeavour toward the harmonious coexistence of aquaculture growth and global health. This

www.jchr.org

JCHR (2024) 14(1), 839-844 | ISSN:2251-6727



comprehensive review thus stands as a testament to the multifaceted challenges faced by fish farmers and the broader aquaculture community, providing a roadmap for informed decision-making, policy formulation, and the pursuit of sustainable and responsible aquaculture practices in the face of the evolving threat of antimicrobial resistance.

Funding Statement

This research was funded by the Malaysia Research University Network (MRUN) under the MRUN Young Researchers Grant Scheme (MYRGS), project code MY-RGS 2019-1

Conflicts of Interest

The authors declare that they have no conflicts of interest to report regarding the present study.

References

- Agbeko, R., Aheto, D. W., Asante, D. K. A., Asare, N. K., Boateng, A. A., & Adinortey, C. A. (2022). Identification of molecular determinants of antibiotic resistance in some fish farms of Ghana. Heliyon, 8(9), e10431. https://doi.org/10.1016/j.heliyon.2022.e10431
- Bouelet Ntsama, I. S., Tambe, B. A., Tsafack Takadong, J. J., Medoua Nama, G., & Kansci, G. (2018a). Characteristics of fish farming practices and agrochemicals usage therein in four regions of Cameroon. Egyptian Journal of Aquatic Research, 44(2), 145–153. https://doi.org/10.1016/j.ejar.2018.06.006
- Chambers, J. A., Crumlish, M., Comerford, D. A., Phuoc, L. H., Phuong, V. H., & O'carroll, R. E. (2022). Understanding Vaccine Hesitancy in Vietnamese Fish Farmers. Antibiotics, 11(7), 1– 16. https://doi.org/10.3390/antibiotics11070878
- Chiesa, L. M., Nobile, M., Malandra, R., Panseri, S., & Arioli, F. (2018). Occurrence of antibiotics in mussels and clams from various FAO areas. Food Chemistry, 240, 16–23. https://doi.org/10.1016/j.foodchem.2017.07.072
- Chowdhury, S., Rheman, S., Debnath, N., Delamare-Deboutteville, J., Akhtar, Z., Ghosh, S., Parveen, S., Islam, K., Islam, M. A., Rashid, M. M., Khan, Z. H., Rahman, M., Chadag, V. M., & Chowdhury, F. (2022). Antibiotics usage practices in aquaculture in Bangladesh and their associated factors. One Health, 15(October), 100445. https://doi.org/10.1016/j.onehlt.2022.100445
- Desbois, A. P., Garza, M., Eltholth, M., Hegazy, Y. M., Mateus, A., Adams, A., Little, D. C., Høg, E., Mohan, C. V., Ali, S. E., & Brunton, L. A. (2021). Systems-thinking approach to identify and assess

feasibility of potential interventions to reduce antibiotic use in tilapia farming in Egypt. Aquaculture, 540(March).

- https://doi.org/10.1016/j.aquaculture.2021.736735
 7. and Antimicrobial Resistance of Escherichia coli, Salmonella and Vibrio Derived from Farm-Raised Red Hybrid Tilapia (Oreochromis spp.) and Asian Sea Bass (Lates calcarifer, Bloch 1970) on the West Coast of Peninsular Malaysia. Antibiotics, 11(2). https://doi.org/10.3390/antibiotics11020136
- 8. Dewi, R. R., Hassan, L., Daud, H. M., Matori, M. F., Nordin, F., Ahmad, N. I., & Zakaria, Z. (2022). Prevalence
- Garza, M., Mohan, C. V., Brunton, L., Wieland, B., & Häsler, B. (2022). Typology of interventions for antimicrobial use and antimicrobial resistance in aquaculture systems in low- and middle-income countries. International Journal of Antimicrobial Agents, 59(1), 106495. https://doi.org/10.1016/j.ijantimicag.2021.106495
- Han, Q. F., Zhao, S., Zhang, X. R., Wang, X. L., Song, C., & Wang, S. G. (2020). Distribution, combined pollution and risk assessment of antibiotics in typical marine aquaculture farms surrounding the Yellow Sea, North China. Environment International, 138(August 2019), 105551.

https://doi.org/10.1016/j.envint.2020.105551

- Hedberg, N., Stenson, I., Nitz Pettersson, M., Warshan, D., Nguyen-Kim, H., Tedengren, M., & Kautsky, N. (2018). Antibiotic use in Vietnamese fish and lobster sea cage farms; implications for coral reefs and human health. Aquaculture, 495(September 2017), 366–375. https://doi.org/10.1016/j.aquaculture.2018.06.005
- 12. Le Bouquin, S., Thomas, R., Jamin, M., Baron, S., Hanne-Poujade, S., & Chauvin, C. (2021). A baseline survey of antimicrobial use and health issues in the freshwater salmonid industry in France. Aquaculture Reports, 21, 100906. https://doi.org/10.1016/j.aqrep.2021.100906
- 13. Letchumanan, V., Ab Mutalib, N. S., Wong, S. H., Chan, K. G., & Lee, L. H. (2019). Determination of antibiotic resistance patterns of Vibrio parahaemolyticus from shrimp and shellfish in Selangor, Malaysia. Progress in Microbes and Molecular Biology, 2(1), 1–9. https://doi.org/10.36877/pmmb.a0000019
- Li, J. Y., Wen, J., Chen, Y., Wang, Q., & Yin, J. (2021). Antibiotics in cultured freshwater products in Eastern China: Occurrence, human health risks, sources, and bioaccumulation potential. Chemosphere, 264, 128441. https://doi.org/10.1016/j.chemosphere.2020.12844

www.jchr.org

JCHR (2024) 14(1), 839-844 | ISSN:2251-6727



1

- Lim, J. M., Duong, M. C., Hsu, L. Y., & Tam, C. C. (2020). Determinants influencing antibiotic use in Singapore's small-scale aquaculture sectors: A qualitative study. PLoS ONE, 15(2), 1–13. https://doi.org/10.1371/journal.pone.0228701
- Love, D. C., Fry, J. P., Cabello, F., Good, C. M., & Lunestad, B. T. (2020). Veterinary drug use in United States net pen Salmon aquaculture: Implications for drug use policy. Aquaculture, 518(December 2019), 734820. https://doi.org/10.1016/j.aquaculture.2019.734820
- Luu, Q. H., Nguyen, T. B. T., Nguyen, T. L. A., Do, T. T. T., Dao, T. H. T., & Padungtod, P. (2021). Antibiotics use in fish and shrimp farms in Vietnam. Aquaculture Reports, 20, 100711. https://doi.org/10.1016/j.aqrep.2021.100711
- Moher D, Liberati A, Tetzlaff J, A. D. (2009). PRISMA 2009 Flow Diagram. In The PRISMA statement (Vol. 6, p. 1000097).
- Mzula, A., Wambura, P. N., Mdegela, R. H., & Shirima, G. M. (2019). Phenotypic and molecular detection of Aeromonads infection in farmed Nile tilapia in Southern highland and Northern Tanzania. Heliyon, 5(8), e02220. https://doi.org/10.1016/j.heliyon.2019.e02220
- Okocha, R. C., Olatoye, I. O., & Adedeji, O. B. (2018). Food safety impacts of antimicrobial use and their residues in aquaculture. Public Health Reviews, 39(1), 1–22. https://doi.org/10.1186/s40985-018-0099-2
- Okocha, R. C., Olatoye, I. O., Alabi, P. I., Ogunnoiki, M. G., & Adedeji, O. B. (2021). Aquaculture management practices associated with antimicrobial residues in Southwestern Nigeria. Aquaculture, 533(November 2020), 736195. https://doi.org/10.1016/j.aquaculture.2020.736195
- Pham-Duc, P., Cook, M. A., Cong-Hong, H., Nguyen-Thuy, H., Padungtod, P., Nguyen-Thi, H., & Dang-Xuan, S. (2019). Knowledge, attitudes and practices of livestock and aquaculture producers regarding antimicrobial use and resistance in Vietnam. PLoS ONE, 14(9), 1–21.

https://doi.org/10.1371/journal.pone.0223115

- Phong, T. N., Thang, V. T., & Hoai, N. T. (2021). What motivates farmers to accept good aquaculture practices in development policy? Results from choice experiment surveys with small-scale shrimp farmers in Vietnam. Economic Analysis and Policy, 72(October), 454–469. https://doi.org/10.1016/j.eap.2021.09.015
- Poupaud, M., Goutard, F. L., Phouthana, V., Muñoz Viera, F., Caro, D., Patriarchi, A., & Paul, M. C. (2022). Different kettles of fish: Varying patterns of antibiotic use on pig, chicken and fish farms in Lao PDR and implications for antimicrobial resistance strategies. Transboundary and Emerging Diseases, 69(6), 3940–3951. https://doi.org/10.1111/tbed.14766
- Price, D., Sánchez, J., McClure, J., McConkey, S., Ibarra, R., & St-Hilaire, S. (2018). Assessing concentration of antibiotics in tissue during oral treatments against piscirickettsiosis. Preventive Veterinary Medicine, 156, 16–21. https://doi.org/10.1016/j.prevetmed.2018.04.014
- Ström, G. H., Björklund, H., Barnes, A. C., Da, C. T., Nhi, N. H. Y., Lan, T. T., Magnusson, U., Norman Haldén, A., & Boqvist, S. (2019). Antibiotic Use by Small-Scale Farmers for Freshwater Aquaculture in the Upper Mekong Delta, Vietnam. Journal of Aquatic Animal Health, 31(3), 290–298. https://doi.org/10.1002/aah.10084
- 27. Thiang, E. L., Lee, C. W., Takada, H., Seki, K., Takei, A., Suzuki, S., Wang, A., & Bong, C. W. (2021a). Antibiotic residues from aquaculture farms and their ecological risks in Southeast Asia: a case study from Malaysia. Ecosystem Health and Sustainability, 7(1), 1–18. https://doi.org/10.1080/20964129.2021.1926337
- Tran, K. C., Tran, M. P., Phan, T. Van, & Dalsgaard, A. (2018). Quality of antimicrobial products used in white leg shrimp (Litopenaeus vannamei) aquaculture in Northern Vietnam. Aquaculture, 482, 167–175. https://doi.org/10.1016/j.aquaculture.2017.09.038