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ANTIBIOTIC USE PRACTICES AND ENVIRONMENTAL RISK FACTORS ASSOCIATED WITH ANTIMICROBIAL RESISTANCE IN POULTRY FARMING SYSTEMS OF MUZAFFARGARH, PAKISTAN

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ABSTRACT

Antimicrobial resistance (AMR) has emerged as a major global public health challenge driven by the inappropriate use of antibiotics in both human and animal production systems, particularly in low- and middle-income countries. The present study aimed to evaluate the practices of using antibiotics in commercial poultry farms and environmental pathways involved in the spread of AMR in the District Muzaffargarh, Punjab, Pakistan. A structured and pre-validated questionnaire was used to conduct a cross sectional survey of 70 commercial poultry farms. Data were analysed descriptively, with Pearson's chi-square test, and by multivariable logistic regression, in IBM SPSS Statistics version 25.0. 97.1% of farms used antibiotic and therapeutic use was the main purpose of administration (49.0%), followed by use to prevent disease (31.4%), and use to promote growth (20.0%). Over half of respondents (57.1%) obtained antibiotics without veterinary prescription and 45.7% did not comply with recommended periods of withdrawal. The most commonly used antimicrobials were enrofloxacin (45.7%), doxycycline (38.6%) and amoxicillin (32.9%), while the use of colistin was also significant (21.4%). The findings of the environmental assessment were that 71.4% of farms did not have appropriate wastewater drainage systems, 65.7% disposed of untreated poultry waste in open areas and 59.1% reported dissemination of poultry waste from the farms to surrounding agricultural land and water bodies by flood. Multivariable logistic regression identified lack of formal education (AOR = 3.24; 95% CI: 1.28–8.17; P = 0.013), absence of professional poultry management training (AOR = 2.87; 95% CI: 1.16–7.09; P = 0.023), and farm location in flood-prone areas (AOR = 2.54; 95% CI: 1.03–6.28; P = 0.043) as independent predictors of non-prescription antibiotic use. The results have indicated a high prevalence of inappropriate use of antimicrobials and poor environmental management practices, which might speed up the spread of AMR. To reduce AMR risks in a One Health context, strengthening antimicrobial stewardship, farmer education, veterinary oversight, and environmentally sustainable waste management are crucial.

KEYWORDS: *Antimicrobial resistance; Poultry farming; Environmental contamination; Antibiotic use; Biosecurity*

INTRODUCTION

AMR has become one of the biggest health issues of worldwide importance, posing a threat to the efficacy of antibiotics and erasing decades of medical advancement (Tang et al., 2023). The alarming rate of the growth of the resistant pathogens has been greatly blamed on misuse and overuse of antibiotics in human medicine and animal farming. AMR is also estimated to result in up to 10 million deaths every year by 2050 unless effective control measures are taken (Salam et al., 2023, Adamie et al., 2024). The low- and middle-income countries (LMICs) are especially susceptible because of ineffective regulatory frameworks, lack of surveillance, and the easy access to the antibiotics without prescriptions. Poultry industry is a rapidly developing agricultural sector in the global world and it is an important sector in terms of food security and economic development (Nassar, 2026). Poultry production in Pakistan has been growing at a high rate to cater to the growing needs of low-cost animal protein. Nevertheless, this acceleration has been coupled with greater use of antibiotics to treat, prevent and promote growth of the diseases (Cook & Wright, 2022, Muteeb et al., 2023). Growth promoters involving the use of antibiotics, whilst limited in most of the developed world, are still prevalent in LMICs because of the economic pressures, ignorance and insufficient enforcement of regulations. Misuse of antibiotics in the rearing of poultry is also a major contributor to the emergence and transmission of antimicrobial resistance (Hedman et al., 2020). Bacterial resistance may be transmitted to humans in various ways such as eating infected meat, direct contact with animals and environmental exposure. Existence of antibiotic residues in poultry products makes the situation even worse as it promotes the development of resistance in human microbiota and decreases the efficacy of therapeutic drugs (Tian et al., 2021, Abreu et al., 2023).

Other than direct, environmental routes are also significant in the spread of AMR. Poultry rearing produces high volumes of wastes that have antibiotic residues and resistance microorganisms (Muhammad et al., 2020). This waste is usually not treated in most rural areas and is released into the farms, water bodies or uncovered areas. These practices enhance transmission of resistance genes in soil and water ecosystems, and generate environmental reservoirs of antimicrobial resistance (Sassi et al., 2025, Patra & Dubey, 2025). This is even being worsened in flood prone areas, where seasonal flooding may spread contaminated waste over a wide area, and this may pose a high risk of extensive environmental and human exposures. District Muzaffargarh, in the south of Punjab, Pakistan, is a special area to investigate the environmental aspects of AMR. The area is typified by the high rate of flooding caused by the closeness to the major rivers, large-scale agricultural production, and the fast-growing poultry farming complexes. All these factors contribute to the favorable conditions of the spread of antibiotic residues and resistant bacteria to the environment. These risks notwithstanding, regional-specific data on the practices of antibiotic use and AMR pathways in the environment is lacking in this region (WHO, 2024).

Past research in Pakistan has mainly addressed the antibiotic use practices and knowledge among poultry farmers, with most studies identifying problems related to the non-prescription use of antibiotics, ignorance, and non-observation of withdrawal periods. Nevertheless, little focus has been placed on the environmental issues that promote the spread of AMR, especially in ecologically susceptible areas. These environmental pathways are important to be understood in order to come up with comprehensive strategies to fight antimicrobial resistance. One Health approach as a method of considering the interrelation between human, animal, and environmental health has been more and more promoted as a tool to treat AMR. This strategy highlights the fact that combined interventions should be applied to focus on the practices of using antibiotics, enhance biosecurity, and reduce environmental contamination. With regards to poultry farming, this involves the promotion of responsible usage of antibiotics, better waste management systems and awareness and training of farmers. Thus, the current study aimed to evaluate the practices of usage of antibiotics and the environmental dissemination routes of antimicrobial resistance in poultry farming systems of District Muzaffargarh, Pakistan. A combination of behavioral and environmental aspects will help the study to offer a holistic view of AMR dynamics within a flood-prone environment. The results should also be helpful in evidence-based policymaking and the creation of specific interventions to mitigate the risk of AMR in a One Health framework.

MATERIALS AND METHODS

Study Design, Area, and Duration

The aim of the cross-sectional study was to assess the practice of using antibiotics and the environmental routes of transmission of antimicrobial resistance (AMR) in poultry farming systems of District Muzaffargarh, Punjab, Pakistan. The research was conducted during a three months period between January and March 2025. Muzaffargarh was specifically chosen because of its flood susceptible geography, high agricultural practices and growing poultry farming practices that together provide a high risk environment of the proliferation of antibiotic residues and resistant pathogens. The geographic location of the study area and the spatial distribution of the sampled villages are presented in Figure 1.

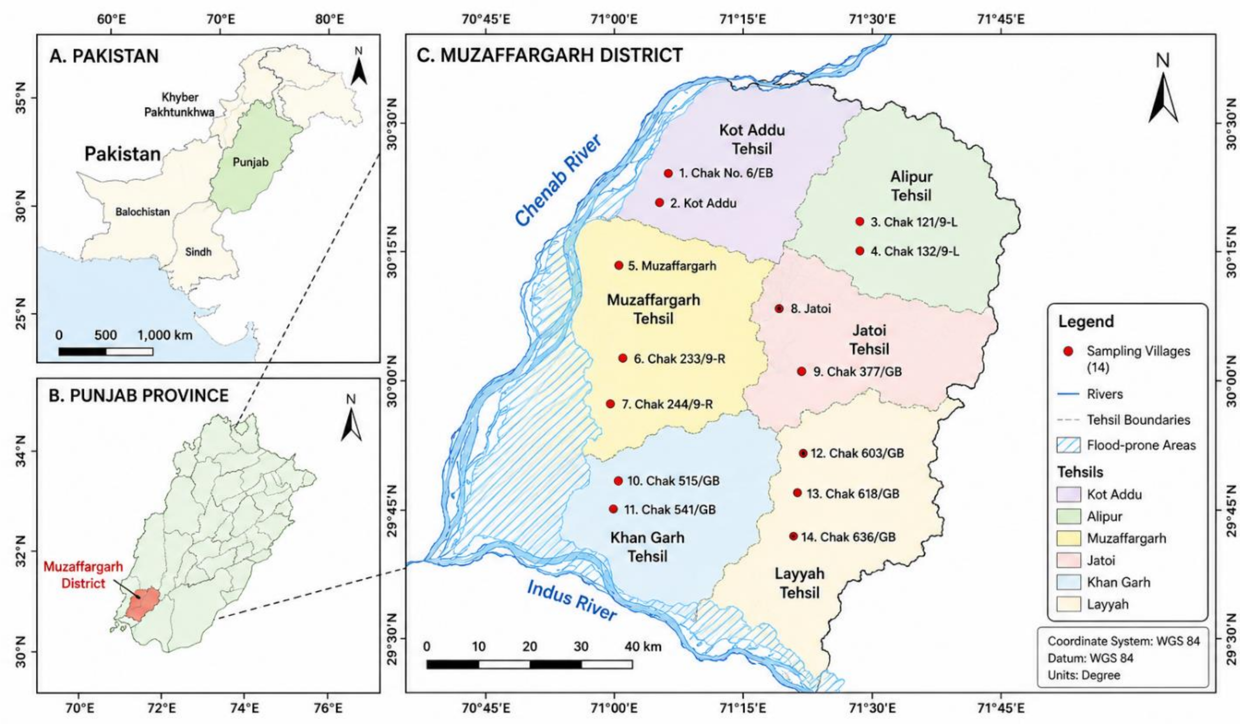

Figure 1. Study area and spatial distribution of surveyed poultry farms in District Muzaffargarh, Pakistan. (A) Location of Pakistan with Punjab Province highlighted. (B) Position of Muzaffargarh District within Punjab Province. (C) Detailed map of Muzaffargarh District showing tehsil boundaries, the Chenab and Indus rivers, flood-prone areas, and the locations of the 14 sampled villages included in the cross-sectional survey. The map provides the geographical framework for investigating antibiotic use practices and environmental pathways contributing to antimicrobial resistance in commercial poultry production systems.

Study Population and Sampling Strategy

The study population was the commercial poultry farmers in the flood and non-flood areas of the district who managed broiler farms. A multistage sampling method was used. First, 14 randomly chosen villages of Muzaffargarh were selected on different tehsils. Then, five poultry farms were chosen in each village, and the overall sample size was 70 farms (n = 70). The inclusion criteria were active poultry farmers with flocks in the study timeframe, and who were willing to give informed consent. The farmers that were not directly engaged in farm management or gave incomplete answers were excluded.

Data Collection Tool and Procedure

The structured and pre-tested questionnaire was used to gather data based on the previous research on antibiotic use and AMR in poultry farming systems. The questionnaire was put into context to incorporate environmental factors like exposure to floods, disposal of waste and possible routes of contamination. The questionnaire was divided into five parts: demographic and farm characteristics, antibiotic use practices, healthcare-seeking behavior, knowledge about antibiotic use and AMR, and environmental risk factors such as waste management and dissemination related to floods. The questionnaire was translated into Urdu and interviews were done in the local languages (Urdu and Saraiki) to make the questionnaire understandable. To determine reliability and validity, a pilot test was done on 10 farms not within the study area where necessary changes were made before the actual data was collected.

Study Variables

Patterns of antibiotic use (therapeutic, prophylactic, growth promotion), compliance to the withdrawal periods, and indicators of environmental dissemination (waste disposal, fertilizer use, spread by floods, and risk of water contamination) were the main dependent variables. Independent variables were demographic factors (education, experience), farm factors (size, location), professional training, and the access to veterinary services. Exposure to floods was added as one of the important environmental factors affecting AMR dissemination.

Statistical Analysis

The statistical analyses were conducted with the help of the IBM SPSS Statistics version 28.0. Categorical variables were summarized in terms of frequencies and percentages using descriptive statistics. Cross tabulation was done to examine the relationship between independent variables and antibiotic use patterns and environmental risk factors. Chi-square (χ^2) test was used to evaluate the relationships among the categorical variables like education level, training status, and AMR knowledge. The level of statistical significance was $p < 0.05$. To check the validity of data internal consistency checks were conducted.

RESULTS

Characteristics of respondents and poultry farms

In the present cross-sectional survey 70 commercial poultry farms were selected in District Muzaffargarh, Punjab, Pakistan. Table 1 shows that the majority of the respondents were in the age group 50 to 54, with a mean age of 50.3 years. Most participants in this study were males (91.4%, n = 64) and females (8.6%, n = 6). Almost half of the respondents (48.6%, n = 34) had less than 10 years of experience in poultry farming, while 34.3% (n = 24) and 17.1% (n = 12) had experience of 10–20 years and more than 20 years, respectively. In terms of level of education, secondary education was the most common level (37.1%), followed by primary education (25.7%), no education (20.0%) and higher education (17.1%). Formal poultry management training was received by 27.1% (n = 19) of the poultry farmers while 72.9% (n = 51) of the farmers had not participated in any formal poultry management training programme. The number of medium-sized farms, defined as those with 2,000–4,000 birds, made up half of the farms surveyed (50.0%), with 30.0% and 20.0% considered small and large-size operations, respectively. In addition, 62.9 % (44) of the farms were situated in flood prone regions near the banks of Chenab and Indus rivers, where there is high environmental exposure and may provide opportunities for the spread of antimicrobial contaminants (Table 1).

Table 1. Demographic characteristics of respondents and poultry farm profiles in District Muzaffargarh, Punjab, Pakistan (N = 70).

Variable	Category	Frequency (n)	Percentage (%)
Gender	Male	64	91.4
	Female	6	8.6
Farming experience	<10 years	34	48.6
	10–20 years	24	34.3
	>20 years	12	17.1
Education level	No formal education	14	20.0
	Primary education	18	25.7
	Secondary education	26	37.1
	Higher education	12	17.1
Professional poultry management training	Yes	19	27.1
	No	51	72.9
Farm size	Small (<2,000 birds)	21	30.0
	Medium (2,000–4,000 birds)	35	50.0
	Large (>4,000 birds)	14	20.0
Flood-prone location	Yes	44	62.9
	No	26	37.1

Values are presented as frequency (n) and percentage (%).

Antibiotic use practices among commercial poultry farms

Poultry farms were almost all using antibiotics (97.1%, 68/70) in their normal production practices. Most antibiotics were used for therapeutic purposes (49.0%) followed by in growth promotion (20.0%) and in a prophylactic manner (31.4.) (Figure 2A). Monitoring of antibiotic use by vets was weak. The majority of respondents (57.1%, n = 40) reported that they had purchased antibiotics without a veterinarian's prescription, while 42.9% (n = 30) reported purchasing antibiotics with a veterinarian's prescription (Figure 2B). Routine antimicrobial use was widespread, 70.0% (n = 49) indicated that they used antibiotics in all production cycles. The duration of treatment ranged between farms, with the majority (58.6%) treating for 1–3 days, 28.6% for 4–7 days, and 12.8% for 7+ days. Compliance with the recommended withdrawal periods was still below the optimum (Figure 2C) with 45.7% (n = 32) reporting that poultry products were marketed prior to the recommended withdrawal period, while 54.3% (n = 38) noted that they did adhere to the recommended withdrawal period. Furthermore, almost half of respondents (47.1%) admitted to giving antibiotics for non-antimicrobial conditions.

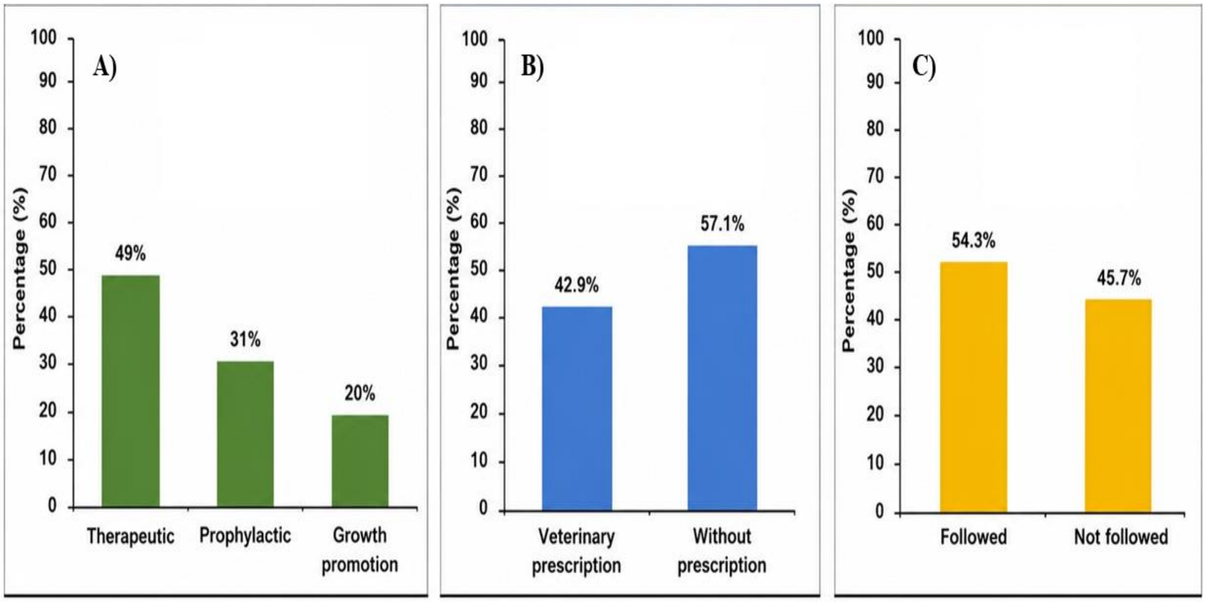

Figure 2. Use practices of antibiotics in commercial poultry farms in District Muzaffargarh, Punjab, Pakistan. **(A)** Therapeutic, prophylactic and growth promotion use of antibiotics. **(B)** Antibiotic supplies from different sources with and without veterinary prescription. **(C)** Compliance with the recommended period of withdrawal from antibiotics prior to poultry product marketing. Results indicate that antimicrobial usage is ubiquitous, antibiotics were often sold without prescription and withdrawal periods for antimicrobials were not always followed on the surveyed poultry farms.

Distribution of antimicrobial classes

Table 2 shows the distribution of classes of antimicrobials used in commercial poultry farms. The most common antibiotics (n = 32; 45.7%) were fluoroquinolones, mainly represented by enrofloxacin; tetracyclines (doxycycline; n = 27; 38.6%) and aminopenicillins (amoxicillin; n = 23; 32.9%). Macrolides (25.7%) were also used moderately. Remarkably, the use of colistin, a highest priority critically important antimicrobial used in human medicine, was noted by 21.4% (n = 15) of the farms. 18.6% (n = 13) of respondents received aminoglycoside (neomycin/gentamicin). In addition, 27.1% (n = 19) of the poultry farms were using more than one class of antibiotics at the same time in the same production cycle.

Table 2. Distribution of antimicrobial classes used in commercial poultry farms of District Muzaffargarh, Punjab, Pakistan (N = 70).

Antibiotic class	Antimicrobial agent	Frequency (n)	Percentage (%)
Fluoroquinolones	Enrofloxacin	32	45.7
Tetracyclines	Doxycycline	27	38.6
Aminopenicillins	Amoxicillin	23	32.9
Macrolides	Tylosin	18	25.7
Polymyxins	Colistin	15	21.4
Aminoglycosides	Neomycin/Gentamicin	13	18.6
Combination therapy	Multiple antibiotics	19	27.1

Values are presented as frequency (n) and percentage (%). Multiple responses were permitted; therefore, percentages do not total 100%.

Environmental risk factors associated with antimicrobial resistance dissemination

The conceptual environmental transmission pathways are shown in Figure 3 and the environmental management practices that could contribute to dissemination of resistance are outlined in Table 3. The majority of poultry farms (71.4%, n = 50) did not have wastewater drainage infrastructure and the poultry wastewater was directly discharged to the surrounding agricultural land, irrigation channels, or area. Likewise, 65.7% (n = 46) of respondents said they disposed untreated poultry litter in the open field or used untreated manure as a fertilizer on agricultural fields. Of the farms in areas subject to seasonal flooding, 59.1% (n = 41) reported that the seasonal flooding regularly carried poultry manure to other farm fields and surface water bodies. Furthermore, 48.6% (n = 34) felt that run-off from flooding caused local drinking water sources to be contaminated. Taken together, these observations illustrate several environmental pathways in which antimicrobial residues and resistant microorganisms can be found and spread outside of the production system.

Table 3. Environmental risk factors associated with antimicrobial resistance dissemination among commercial poultry farms in District Muzaffargarh, Punjab, Pakistan (N = 70).

Variable	Category	Frequency (n)	Percentage (%)
Wastewater drainage system	Present	20	28.6
	Absent	50	71.4
Poultry waste disposal	Managed disposal	24	34.3
	Open disposal	46	65.7
Untreated manure used as fertilizer	Yes	46	65.7
	No	24	34.3
Flood-mediated waste dissemination	Yes	41	59.1
	No	29	40.9
Perceived contamination of drinking water	Yes	34	48.6
	No	36	51.4

Values are presented as frequency (n) and percentage (%).

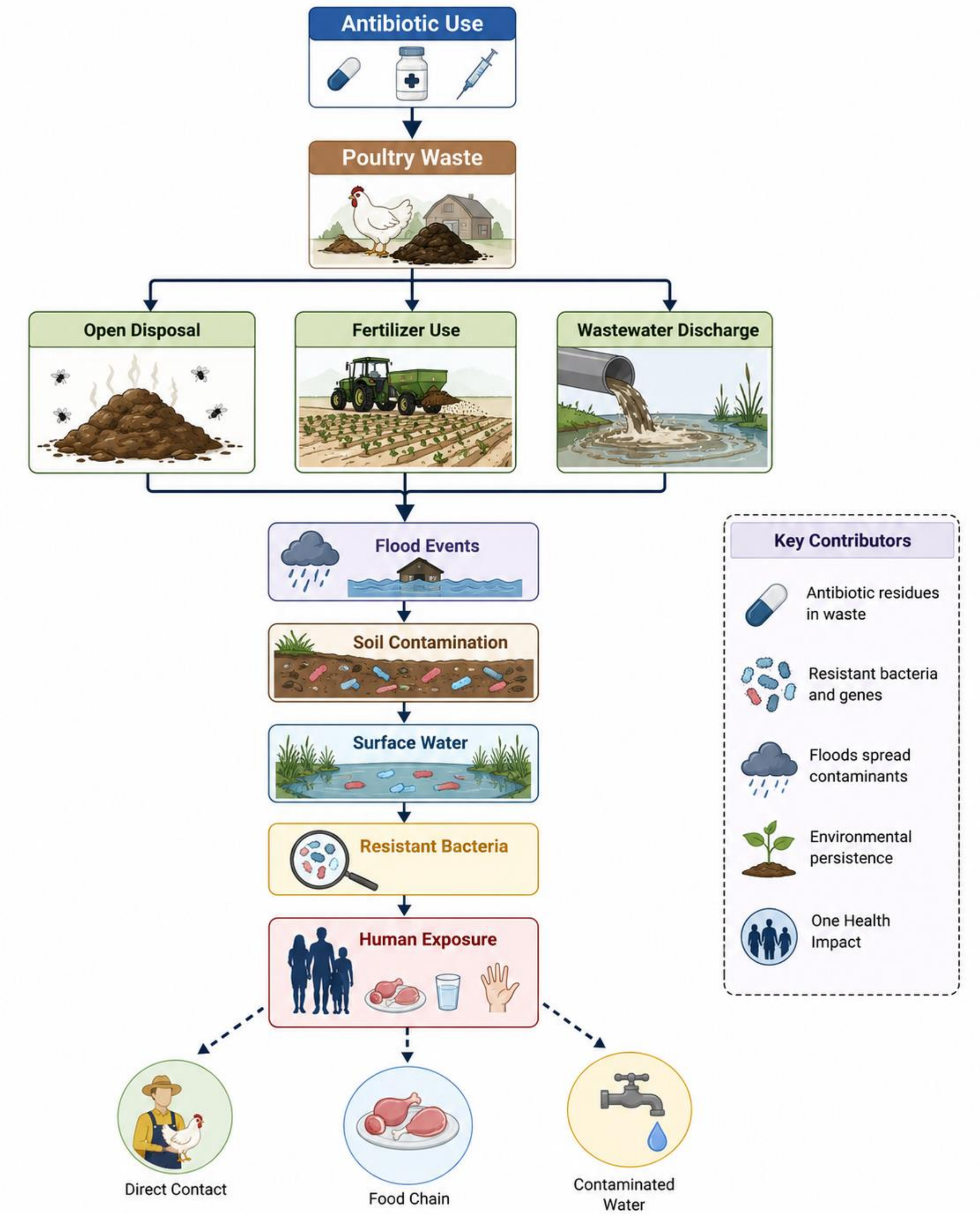

Figure 3. Conceptual illustration of the environmental pathways contributing to antimicrobial resistance (AMR) dissemination in commercial poultry production systems in District Muzaffargarh, Punjab, Pakistan.

Factors associated with non-prescription antibiotic use

The results of the univariable analysis reported in Table 4. Non-prescription antibiotic use was significantly related to the level of education of the farmers (χ^2 = 9.84, P = 0.020), absence of professional training in poultry management (χ^2 = 7.15, P = 0.008) and farm location (the flood prone areas, χ^2 = 5.27, P = 0.022). The size of the farm (P = 0.181) and the experience of the farmers (P = 0.097) were not found to be significantly related to the result.

Table 4. Univariable analysis of factors associated with non-prescription antibiotic use among commercial poultry farms in District Muzaffargarh, Punjab, Pakistan (N = 70).

Variable	Category	Non-prescription use n (%)	Prescription use n (%)	χ^2	P-value
Education level	No formal education	12 (85.7)	2 (14.3)	9.84	**0.020**
	Primary education	12 (66.7)	6 (33.3)		
	Secondary education	12 (46.2)	14 (53.8)		
	Higher education	4 (33.3)	8 (66.7)		
Professional training	Yes	6 (31.6)	13 (68.4)	7.15	**0.008**
	No	34 (66.7)	17 (33.3)		
Farm size	Small	15 (71.4)	6 (28.6)	3.42	0.181
	Medium	19 (54.3)	16 (45.7)		
	Large	6 (42.9)	8 (57.1)		
Flood-prone location	Yes	30 (68.2)	14 (31.8)	5.27	**0.022**
	No	10 (38.5)	16 (61.5)		
Farming experience	<10 years	24 (70.6)	10 (29.4)	4.66	0.097
	10–20 years	11 (45.8)	13 (54.2)		
	>20 years	5 (41.7)	7 (58.3)		

Values are presented as frequency (n) and percentage (%). Pearson's χ^2 test was used. Significant associations (P < 0.05) are shown in bold.

Multivariable logistic regression analysis

The variables with P < 0.20 in the univariable analysis were included in a multivariable logistic regression model (Table 5). Following adjustment for potential confounding variables, the odds of antibiotic use without veterinary prescription were significantly higher for poultry farmers with no education than for those with higher education (AOR = 3.24; 95% CI: 1.28–8.17; P = 0.013). Similarly, respondents who didn't receive professional management training for poultry showed significantly higher odds of using non-prescription antibiotics (AOR = 2.87, 95% CI: 1.16–7.09, P = 0.023). Being in a poultry farm within the flood prone areas was also independently associated with non-prescription antibiotic use (AOR = 2.54, 95% CI: 1.03–6.28, P = 0.043). There were no significant predictors for farm size and farming experience in the final model.

Table 5. Multivariable logistic regression analysis of factors associated with non-prescription antibiotic use among commercial poultry farms in District Muzaffargarh, Punjab, Pakistan (N = 70).

Variable	Adjusted Odds Ratio (AOR)	95% Confidence Interval	P-value
No formal education	3.24	1.28–8.17	**0.013**
No professional poultry management training	2.87	1.16–7.09	**0.023**

Flood-prone farm location	2.54	1.03–6.28	**0.043**
Small farm size	1.62	0.69–3.83	0.271
Farming experience (<10 years)	1.94	0.82–4.63	0.131

Abbreviations: AOR, adjusted odds ratio; CI, confidence interval.

The overall results suggest that there is high usage of antimicrobials in commercial poultry farms in District Muzaffargarh, with alarming rates of self-medication, poor adherence to antimicrobial withdrawals, and continued use of the CIs, across the district. At the same time, improper wastewater treatment, open disposal of poultry manure, direct use of raw manure as fertilizer and seasonal flooding offer several environmental routes to spread antimicrobial-resistant bacteria and antibiotic residues. The analysis results also highlight education level, job training, and exposure to flooding as factors related to inappropriate antibiotic application among commercial poultry operators.

DISCUSSION

The current study gives essential information regarding the practice of antibiotic usage and the distribution pathways of antimicrobial resistance (AMR) to the environment in poultry farming systems of District Muzaffargarh, Pakistan. The results draw attention to the twin problem of irrational use of antibiotics and environmental contamination, especially in flood-prone areas, and the relevance of the One Health approach. The prevalence of antibiotic use (97.1%) in the present study is not an exception as the research in Pakistan and other low- and middle-income countries (LMICs) showed that antibiotic use in poultry farming is a common and unregulated practice (e Habiba et al., 2022, Habiba et al., 2023, Sajid et al., 2025). Despite a higher rate of therapeutic use (49%), ongoing use of antibiotics as prophylaxis (31%), growth promotion (20%), shows that the non-judicious use still persists. The same patterns have been observed in South Asia, where non-therapeutic use of antibiotics is being driven by economic factors and absence of regulation (Kumar et al., 2021, Singh et al., 2025). The observation that over fifty percent of the farmers (57.1) had obtained antibiotics without veterinary prescription highlights the lax regulatory system in place to regulate the sale of antibiotics. The trend is well-reported in LMICs where antibiotics are easily available in an informal environment (Lindfors, 2024, Mhone et al., 2025). The use of non-professional guidance and past experience are more likely to lead to the wrong choice of drugs, improper dosage, and incomplete treatment, which also leads to the appearance of drug-resistant strains of bacteria (Camilleri, 2024).

The trend of antibiotic classes utilized in this study further depicts the possible risk of developing AMR. The use of fluoroquinolones (enrofloxacin) and tetracyclines is predominant in accordance with the results of the previous research in the poultry production systems (Shang et al., 2023, Fucik et al., 2024). Even though the colistin (21.4% of use) usage was less than reported previously, its use persists and is alarming, as colistin is a last-resort antibiotic in human medicine (WHO, 2019; EMA, 2021). Multidrug-resistant pathogens have been closely linked to the use of critically important antimicrobials in animal agriculture (Matheou et al., 2025). The lateral practice of antibiotic administration could also be found to be suboptimal in this study as most of the farmers were applying antibiotics in brief periods (1-3 days). Partially resistant bacteria are known to survive incomplete treatment regimens, increasing resistance development (Tarin-Pello et al, 2022). Moreover, non-observance of withdrawal periods in 45.7% of farmers is a serious risk to food safety as the risk of antibiotic residues entering the human food chain is possible (Njoga et al., 2021). The identification of pathways in the environment that cause the spread of AMR is among the greatest contributions of this study. Lack of adequate wastewater management systems in 71.4% and use of untreated poultry waste as fertilizer (65.7%) in most farms provide an environment that favors the proliferation of resistant bacteria in the soil and water systems. These results are aligned with earlier works that show the implication of farming activities in the transmission of AMR on the environment (Wu, 2024, Sangoremi et al., 2025). This is worsened by the fact that Muzaffargarh is a flood prone area. Seasonal flooding helps in the extensive spread of contaminated poultry waste into agricultural areas and water bodies as noted by 59.1% of farmers. Antibiotic residues and resistant bacteria spread by means of flooding is a significant and usually unaddressed route in the epidemiology of AMR. The role of water systems in the spread of resistance genes has been studied using similar environmental transmission mechanisms (Lin et al., 2021; Jian et al., 2021).

The fact that almost half of the respondents (48.6) report that drinking water sources are potentially contaminated is one of the indicators of the intersection of environmental and public health risks. Contaminated water is a reservoir and the transmission pathway of resistant pathogens, and it exposes humans to a higher risk of being exposed (Stec et al., 2022, Lanrewaju et al., 2022). This observation supports the need to incorporate the idea of environmental management in AMR control initiatives. The level of education and professional training represents the most important factors that determine the practices and awareness of antibiotics use. Past research has repeatedly shown that increase in education and access to training is related to better knowledge and responsible antibiotic use (Lim et al., 2020, Ashiru-Oredope et al., 2021, Wiese-Posselt et al., 2023). Though these patterns are not the main focus of this research, they indicate that interventions that focus on educating farmers may be of great help in abating antibiotic misuse.

The use of antibiotics in conditions that are not bacterial as indicated by this study is also an indication of the lack of knowledge and awareness. Such practices have been reported all over the world, especially in LMICs, where misunderstandings about the effectiveness of antibiotics are widespread (Sartelli et al., 2020, Al Meslamani et al., 2023). Here, awareness campaigns at the community level regarding animal and human use of antibiotics are necessary. In sum, the results of this study highlight the intricate interaction between practices related to the use of antibiotics and the environment in the development of antimicrobial resistance. The findings greatly confirm the need to implement a One Health approach which combines human, animal, and environmental health approaches. Enhancing regulatory systems, provision of better veterinary services, increased biosecurity measures, and reduction of environmental pollution are key in reducing the risks of AMR in poultry farming systems.

CONCLUSION

This study brings out the high prevalence of antibiotics and the importance of the environmental pathways in the spread of antimicrobial resistance in poultry farming systems of Muzaffargarh, Pakistan. Although the therapeutic use is the most common, a non-prescription practice and poor compliance with the withdrawal period are still the burning issues. Poor waste management and the effects of flooding further propagate resistant pathogens into the environment. These results highlight the necessity of combined measures, such as enhanced biosecurity, education of farmers, and the enforcement of regulations. The One Health approach is critical to reduce the risks of AMR and to provide sustainable poultry production in the endangered areas.

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