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Antibiotic Resistance Among Poultry Farms In South Asia: A Scoping Review

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Abstract

South Asia is a major hotspot of antimicrobial resistance (AMR) and the situation of increasing AMR is alarming. Livestock, particularly poultry sectors are supposed to have the highest burden of AMR in animal health sectors. We reviewed published works about AMR in poultry farms in South Asia from 2005–2020, identifying 37 relevant articles. Published articles showed the high prevalence of AMR among poultry farms in South Asian countries, India, Pakistan, Bangladesh, and Nepal. The pattern of resistance to antibiotics was found to vary with a higher degree of resistance to the most commonly used antibiotics such as ampicillin, tetracycline, streptomycin, and ciprofloxacin; and little or no resistance to less commonly used antibiotics such as amikacin and ceftriaxone. Antibiotics such as amikacin, ciprofloxacin, gentamicin, and ceftriaxone antibiotics were effective against E. coli; ampicillin, enrofloxacin, colistin, chloramphenicol in Salmonella sps; azithromycin, chloramphenicol, and gentamicin in Campylobacter sps; chloramphenicol and vancomycin in Staphylococcus sps. However, all these available scientific publications were based on point prevalence studies and lacked a comprehensive baseline, which makes it difficult to get a clear insight into AMR among poultry farms in South Asia. Thus, nationwide comprehensive studies on antimicrobial resistance among poultry farms in South Asian countries are necessary to get a clear picture of AMR in poultry farms in South Asian nations and to inform policies related to infection prevention and control measures.

Keywords: Antibiotics use; antimicrobial stewardship; poultry farms
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Introduction

The problem of antibiotic resistance (referred to as AMR hereafter as antibiotics resistance is used synonymously with antimicrobial resistance) is a growing concern globally and is a pressing public health issue (1). Non-compliance with prescriptions and irrational use of antibiotics have been major problems in the human health sector (2,3). The use of antibiotics as a growth promoter and unscrupulous use of these drugs for treatment have been major factors behind the increasing burden of AMR in the animal health sector (3). Though Europe and some other developed countries have limited their use as a growth promoter in animals, it is rampant in developing countries, including nations of South Asia (4). This led to the increasing use of antibiotics in the animal sector. The increased use of antibiotics is positively correlated with increased resistance (5–7). The amount of antibiotics used for animal production is estimated to have increased by 67% from 2010 to 2030 (8). With the increasing use of antibiotics, the burden of AMR has also been reported to increase correspondingly. The evidence of increasing antibiotics used, intensive production, and reports indicating the growing problem of AMR require robust and comprehensive evidence to inform timely policies and practices related to containment and control of AMR in South Asia. However, there is a lack of certainty about the current situation of the burden of AMR in the poultry sector in South Asian countries. Although the burden of AMR in developed countries is well understood, the burden of AMR in developing countries is not well documented. Due to a lack of information, it is difficult to set up initiatives/programs to monitor, regulate, control, and contain AMR in the poultry sector in South Asia.

South Asia is a major hotspot of AMR (9,10) and the situation of increasing AMR is alarming. The indiscriminate use of antibiotics in animal feed and associated AMR are considered to be a major driver of AMR in the human health sector (1). In the animal health sector, the poultry sector is notoriously known for its growing antimicrobial use and AMR. Farmers in South Asia are known to use antibiotics to compensate for poor sanitation and hygiene on farms which in turn favors the development of resistant microbes. The high burden of resistant microbes in the poultry sector, poor antimicrobial stewardship, poor sanitation and hygiene, and poor infection prevention and control measures, could increase the risk of bacterial resistance in humans, as humans live in close association with poultry farms in South Asia. Some point prevalence studies in countries such as Bangladesh (11–13), Pakistan(14,15), India (16–18), and Nepal (3,19–21) have revealed an alarming situation of AMR. These point prevalence studies in South Asian poultry farms are limited to poultry meat, carcass, or dressed poultry meat which restricts the availability of literature regarding the resistant microbes in live poultry birds and poultry farm environments. Thus, the situation of resistant microbes in poultry farms, their environments, as well as the extent to which these resistant microbes are responsible for increased AMR in poultry and humans remains unknown. Furthermore, a comprehensive analysis of the situation of AMR in South Asian poultry farms is lacking. This lack of comprehensive data on AMR in South Asian poultry farms could be due to insufficient national monitoring and surveillance programs.

To help address the current problem of AMR in South Asia, a robust infection prevention and control response is required, which involves robust and comprehensive data on the burden of AMR; this, in turn, requires a comprehensive review. A comprehensive review of data on AMR will help to identify and assess the risk factors behind resistant microbes in South Asia and will help to inform AMR control, create a containment plan and develop policies to protect animal health and human health. However, without a comprehensive review of existing information, it is difficult to build an evidence-based control and containment policy. This scoping review, thus, aims to investigate the situation of AMR in poultry farms in South Asia.

Methods

Article selection:

We conducted a literature search to locate peer-reviewed research publications related to antimicrobial resistance in poultry farms in South Asian countries. PubMed, Scopus, Web of Science, and Google Scholar were used to search for peer-reviewed research articles published between 2005 and September 2020 (Figure 1), using terms such as Antimicrobial/Antibiotics/Prevalence/South Asia, with appropriate search MeSH heading (Detailed search strategy and terms used are mentioned in Appendix below: Appendix 1). For articles to be eligible for inclusion, they had to report the prevalence and antibiotic resistance in poultry farms in South Asian nations. Editorials, comments, letters, reviews, and correspondence articles were excluded. Papers on AMR that included literature other than poultry farms (poultry birds and/or their environment) such as retail chicken meat, and dressed poultry carcasses, were also excluded. Any articles that were not in the English language were not included.

Data extraction:

Data were extracted in data extraction form including author, title, year of publication, country, study, methods/designs, sample size, results, and reported microbial pathogen.

Results

Thirty-seven articles reporting AMR in poultry farms met inclusion criteria and were included in the review (Table 1). Twelve studies were conducted in India, ten studies in Pakistan, ten studies in Bangladesh, three studies in Nepal, and two studies in Sri Lanka, whereas no studies were reported from Maldives, Afghanistan, and Bhutan (**Table 1**). All the studies investigated more than one farm. All 37 research had used phenotypic antimicrobial susceptibility testing, whereas only 17 studies used the molecular genomic method to detect AMR genes (**Table 1**), which leads to antibiotic resistance. Thirty-four studies utilized the Kirby-Bauer disc diffusion method to perform an antibiotic sensitivity test (AST), while three studies used micro-dilution to assess the minimum inhibitory concentration test (MIC) in combination with the Kirby-Bauer disc diffusion method (**Table 1**). The commonly used antibiotics such as tetracycline, ciprofloxacin, enrofloxacin, amoxicillin, levofloxacin, and chloramphenicol were tested for sensitivity (**Table 1**). *E. coli, Salmonella sps, Staphylococcus aureus, Campylobacter, Klebsiella sps, Enterococci sps, and Enterobacter sps,* were studied in fourteen, fourteen, one, one, one, one, and one studies, respectively.

Eight studies reported AMR in broiler farms, four studies in layer farms, five studies in backyard chickens, and two studies in poultry litter (see Table 1). Two studies investigated the presence of AMR in both broiler and layer farms while four studies were conducted in the poultry farm environment. The majority of studies (19/37), on the other hand, did not specify the type of poultry farms on which their research was conducted. The most common antibiotic-resistant bacteria found in South Asian chicken farms were *E. coli, Salmonella sps,* and *Staphylococcus sps.* Eleven studies reported multidrug resistance (MDR) *E. coli* while seven studies reported MDR *Salmonella. E. coli* was reported in fifteen studies, and this *E. coli* was highly resistant to antibiotics such as tetracycline, amoxicillin, and ampicillin antibiotics. *Salmonella* was also identified in fourteen studies and these *Salmonella sps* were resistant to tetracycline, ampicillin, streptomycin, ciprofloxacin, and chloramphenicol (**Table 1**). Similarly, bacteria with extended-spectrum beta-lactamases *(ESBL)* were also identified. These ESBL bacteria were resistant to tetracycline, ampicillin, and sulphamethoxazole but were sensitive to gentamicin, tigecycline, chloramphenicol, nitrofurantoin, and ceftriaxone (Table 1). ESBL *E. coli* was identified in five of the studies while methicillin-resistant *Staphylococcus aureus* (MRSA) was studied in a single study. The ESBL *E. coli* isolates were susceptible to both tigecycline and chloramphenicol; however, MRSA was exclusively susceptible to chloramphenicol.

These results indicate that antimicrobial-resistant bacteria are prevalent among poultry farms in South Asian countries, mainly India, Pakistan, Bangladesh, and Nepal. Similarly, studies from Pakistan (7), Bangladesh (6), India (2), and Nepal (2) revealed the presence of multidrug-resistant (resistant to more than three or more classes of antibiotics) bacteria in those countries. The presence of resistant bacteria and associated antimicrobial resistance in Bhutan, Afghanistan, and the Maldives could not be studied as no data from these countries was available.

Discussion

The results indicate a high prevalence of antimicrobial-resistant bacteria including the MDR in poultry farms in South Asian countries especially India, Pakistan, and Bangladesh. This higher prevalence of resistant microbes could be due to poultry farming practices that rely heavily on antibiotics use as mentioned by Founou *et al.*, 2018 (22), Laxminarayan and Chaudhary (23) Brower *et al.*, 2018 (24) and Nandi *et al.*, 2013 (25). Other studies including modeling studies have shown similar conclusions including a gradual increase in antibiotics consumption and associated AMR in the animal health sector by 2030 (8). Although antibiotics have rarely been used, a high prevalence of resistant microbes in backyard free-range chicken has been reported in India (26–28) and Pakistan (29–31), which is possibly due to either sharing a common environment with broilers (which are treated with antibiotics) or environmental transmission through liquid manure of livestock and human excreta (26,27).
In addition, it has been reported that a higher resistance to antibiotics was reported in *E. coli* and *Salmonella sps.* (Table 1). This is higher than those reported by the European Union (EU) (32) and lower than reports from Africa (33). The good antibiotics (or antimicrobials) stewardship in EU countries has likely resulted in a low prevalence of AMR in the animal health sector (including poultry), which can be attributed to stringent regulations on antibiotics use as a growth promoter in animal feed as well as good infection prevention, and control measures which include nationwide monitoring and surveillance of antibiotics. Whereas in Asia and Africa, a lack of such measures could have contributed to a higher prevalence of MDR. In developed countries such as countries within European Union (34), and the USA (35), the use of antibiotics in animals has been regulated by laws, and the use of antibiotics as a growth promoter is banned (35,36); however, in countries from South Asia, there are no guidelines on the use of antibiotics on food-producing animals. Two countries in South Asia- Bangladesh (37) and Nepal (3) have banned the use of antibiotics in animal feeds whereas India has banned the use of human critical antibiotics in poultry farms (38). In addition, in a recent move, the use of colistin has been banned for use in animals in both Nepal and India (39). However, despite such bans and regulations, antibiotics are commonly used in poultry and other animals, which is attributed to the poor implementation of regulations leading to failure to achieve tangible results. High-risk antibiotics such as Chloramphenicol, Colistin, and Metronidazole that has been prohibited for use in European Union and other developed countries, are one of the most commonly used antibiotics in the poultry sector. Chloramphenicol is being used for the treatment of Salmonellosis, Metronidazole for diarrhea in combination with Sulphonamides, and Colistin for Colibacillosis and Salmonellosis even today in Nepal (Unpublished).
Antibiotics such as amikacin, ciprofloxacin, gentamicin, and ceftriaxone were found to be highly effective against *E. coli*; ampicillin, enrofloxacin, colistin, chloramphenicol in *Salmonella sps*; azithromycin, chloramphenicol, and gentamicin in *Campylobacter sps*; chloramphenicol and vancomycin in *Staphylococcus sps*. Resistance to amikacin and ceftriaxone was negligible for *E. coli* and *Salmonella sps,* and hence remains a drug of choice. The pattern of resistance to antibiotics differed with a higher resistance reported to most commonly used antibiotics such as ampicillin, tetracycline, streptomycin, and ciprofloxacin; and little/no resistance was reported to less commonly used antibiotics such as amikacin and ceftriaxone.
Twenty-two studies have reported a high prevalence of multidrug-resistant bacteria in poultry farms. This higher prevalence of resistance and MDR in poultry farms is not only of animal health concern but also a public health

concern as these resistant microbes could lead to the development of resistant microbes in the human health sector. For instance, *Salmonella enterica serovar enteritidis* (40) and *Salmonella enterica serovar typhimurium* (41), and *E. coli* (42) are zoonotic and are easily transmitted to humans. The presence of resistant strains of *Salmonella sps.* (43) and *E. coli* to third-generation cephalosporins, a reserved antibiotic to treat fulminating septicemia, portends an alarming situation for the future and insinuates for judicious use of antibiotics. Furthermore, the prevalence of resistance genes carried by plasmids such as the ESBL, aph(3")_Ib, and mcr-1, in poultry (26,44) highlights the high possibility of horizontal transfer of antibiotic resistance to among the poultry, poultry litter, surrounding environment, and humans. The resistant microbes from poultry farms may reach the environment, and humans via the food chain causing negative impacts on human health.

Studies reported so far are point prevalence studies and are scattered, having low sample size and limited geographical coverage, thus, comprehensive nationwide studies are needed to have a clear insight into the AMR burden in these pathogens. Scientific studies have shown that antibiotic resistance emerges with the excessive use of antibiotics in animals (45–47). A recent study in Vietnam, a Southeast Asian country, has shown that colistin resistance is linked to the rampant use of colistin in poultry and pigs (48). However, none of the studies in South Asia have investigated the increased use of antibiotics and the associated antibiotic resistance, although it has been clear that increased use of antibiotics leads to resistance. The lack of such comprehensive data means that we cannot use these studies to inform AMR policies to control and contain AMR.

Our results suggest that there exists a variation in the prevalence of AMR in poultry farms varying based on the types of poultry farms, the nature of the biosecurity and hygiene controls, and farming practices. Research studies conducted on farms that have strong biosecurity measures and good husbandry practices in place had a lower prevalence (24.43%) of salmonellae infection, compared to traditional farms that had not implemented any biosecurity measures (38.07%) (49). The prevalence of AMR was found to be higher in broiler farms compared to layer farms (Table 1). This could be due to the antibiotics being used extensively to promote faster growth. Faster growth results in more health problems and farmers then use antibiotics to compensate for the poor hygiene and sanitation and to ward off diseases as mentioned by Laxminarayan and Chaudhary (23) and Hasan *et al.*, 2012 (50). Another reason for a lower prevalence of AMR in layers poultry could be due to the fact that antibiotics in layers farms are used more judiciously in consultation with qualified veterinarians. Whereas in case of broilers, the unqualified practitioners (quacks) guide the farmers on antibiotic use as mentioned by Habiba *et al.*, 2022 (51). Furthermore, a higher prevalence of AMR in broilers compared to layers could also be due to the rearing of broilers in a more intensive production system and more frequent antibiotics use which is a common tradition in South Asian nations (Unpublished). The resistant microbes in poultry could be released into the environment and reach humans. Previous research have highlighted the possible transfer of antibiotics and resistant microbes from farms to the environment owing to the poor biosecurity measures and wastewater drainage systems (51–53) and the practice of using poultry waste as a fertilizer for agricultural land (51,53,54). For example, a recent survey in Pakistan found that around 85% of the farmers surveyed did not have a wastewater drainage infrastructure and directly dump their poultry waste and antibiotics residue in the farm's surroundings (51). However, in our review, we did not find any such evidence for the possible role of poultry as antibiotics and resistant microbe contamination to the environment due to the absence of literature regarding this aspect. But, the contamination of the environment with antibiotics and resistant microbes is a distinct possibility in all South Asian countries, as there is a common practice of dumping poultry litter into nearby farm environments or using it as a fertilizer in agricultural lands as previously mentioned.

In South Asian countries, sub-therapeutic use of antibiotics as growth promoters has been prohibited by different regulations (3,4,12,55–58), but implementation of such regulations is very weak; thus, rendering these regulations ineffective. Furthermore, a shortage of skilled personnel in these countries makes efficient monitoring of irrational use of veterinary drugs in poultry farming difficult. The rampant use of antibiotics in South Asian countries such as India, Pakistan, and Bangladesh, has been further aggravated by the pressure to increase production to meet increasing demand in those countries; where farmers use antibiotics massively to increase the production. This unnecessary use of antibiotics results in the development of resistant microbes in poultry farms and these resistant microbes from poultry farms may contaminate the environment and be transmitted to humans via poultry products, emphasizing the importance of controlling AMR in the poultry sector as a means for controlling AMR in the humans.

A nationwide AMR surveillance system in the human health, animal health, and environmental health sectors is needed to help inform the national situation of AMR and to formulate plans and policies to help reduce the burden of AMR. Furthermore, a one-health approach is important for early monitoring and detection of AMR in zoonotic pathogens such as *Salmonellla enterica serovar typhimurium, Enterococcus sps,* and *Campylobacter sps,* as well as preventing the transmission of resistant bacteria to humans. A neglected but promising strategy to alleviate the problem of antimicrobial resistance would be to use alternatives to antimicrobials i.e., non-antibiotic therapy such as probiotics (59,60), organic acids (60), essential oils (60) and enzymes (60) either to prevent bacterial growth or to replace harmful bacteria with beneficial ones. Vaccines for poultry diseases, if available, will have a crucial role in reducing antibiotic resistance. Vaccination reduces antimicrobial resistance because it reduces the occurrence of infections and, as a result, the usage of antibiotics being used to treat such infections also decreases (61,62). A recent research that examined the effectiveness of vaccination to prevent colibacillosis in poultry birds challenged with avian pathogenic E. coli (APEC) found that vaccinated birds had significant protection against the APEC strains of *E. coli* (63). Thus, vaccines could be developed and used to prevent bacterial infections to the most common and economic diseases in poultry such as *E. coli, Salmonella sps, Staphylocccus sps, and Clostridium sps.*

This scoping review revealed a deficit of scientific studies on AMR in poultry farms in South Asia. The prevalence of AMR in South Asian poultry farms could theoretically be linked to the practice of using antibiotics to compensate for sanitation and hygiene, easy access to antibiotics, the practice of self-prescription by farmers and/or un-qualified veterinary technicians, and poor regulation and control by the government authorities as previously mentioned (3,4,64). However, there is a lack of comprehensive scientific research articles to prove this assumption. Once there are comprehensive data on AMR use and AMR burden, it will be possible to draw a better conclusion. Therefore, further comprehensive research data using a comprehensive and standard surveillance method in each South Asian country is necessary to have a clear insight into AMR in poultry farms in South Asia and to inform infection prevention and control programs, by real-time tracking of patterns of AMR in pathogens in poultry farms.

Conclusion

The examination of available scientific literature on antimicrobial resistance in South Asian poultry farms reveals a high prevalence of AMR in poultry farms in South Asia. In addition, our result also identifies a considerable variation in AMR with a higher degree of resistance reported to the most commonly used antibiotics and little or no resistance to less commonly used antibiotics. However, there is a lack of comprehensive data; so, firm conclusions could not be drawn. We suggest conducting comprehensive nationwide surveillance on the prevalence and incidence of AMR in poultry farms and creating baseline data on antimicrobial resistance. These comprehensive baseline data will help inform AMR policies in South Asian countries and help alleviate the problem of AMR in poultry farms in South Asia.

Contributors

Acharya KP conceived the idea of the manuscript and all the authors identified relevant data, wrote the first draft of the manuscript revised and approved for submission.

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Declaration of interests

no conflicts of interest to declare.

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Annex

1. Search strategy used:

Search strategy with MeSH headlines for Medline search

(Antibiotic resistance OR Drug resistance OR Antibiogram OR Resistance OR MDR OR Antimicrobial resistance OR Multiple drug resistance OR Resistance gene) AND (Escherichia coli OR E. coli OR Klebsiella OR Pasteurella OR Staphylococcus OR Streptococcus OR Salmonella OR Shigella OR Pseudomonas OR Proteus OR Enterobacter OR Enterobacteriaceae OR Yersinia OR Haemophilus paragallinarum OR Mycobacterium avium OR Campylobacter OR Mycoplasma OR Erysipelothrix OR Clostridium OR Bordetella avium OR Gram-Negative Bacteria OR Gram-Negative Bacterial Infection OR Gram positive Bacteria OR Gram-Positive Bacterial Infections OR Fluoroquinolones OR Quinolones OR Cephalosporins OR Penicillins OR Carbapenems OR Tetracyclines OR Macrolides OR Sulphonamides) AND (Chicken OR Duck OR Goose OR Quail OR Pigeon OR Turkey OR Guinea fowl OR Poultry OR Broiler OR Layer OR Poult OR Chick OR Squab) AND (farm OR shed OR litter OR environment) AND (Nepal OR India OR Bangladesh OR Bhutan OR Pakistan OR Sri Lanka OR Maldives OR Afghanistan).

Table 1: Antimicrobial resistance by countries in South Asia

1. Nepal

Organism Studied	Species	Type of Sample	Prevalence %	MDR %	Antibiotics and Resistance %	Genes Coding for Antimicrobial Resistance	Types of Tests Used	Studies
E. coli	Broiler	Liver	100 (50/50)	94	Amp (98), Cotrimox (90), Dox (62)		Kirby-Bauer disk diffusion method	Subedi *et al.*, 2018 (65)
E. coli	Broiler	Liver	100 (40/40)	100	Amox (75), Enro (37.4), Gent (0), Amik (0) Coli (50) Cephalex (77.5), Cipro (40)		Kirby-Bauer disk diffusion method	Khanal et al., 2017 (66)
	Layer	Liver	100 (40/40)	100	Amox (87.5), Coli (75), Cephalex (90), Cipro (70), Enro (70), Gent (17.5) Amik (0)		Kirby-Bauer disk diffusion method	
E. coli	Layer	Cloacal swab	36.41 (118/324)	N/A	Coli (22)	mcr-1, tet, sul, qnr, dfr,blaCTX-M	Disk diffusion method Micro-broth and agar dilution method to determine MIC Plasmid replicon typing for resistant gene	Joshi *et al.*, 2019 (44)

2. Srilanka

Organism Studied	Species	Type of sample	Prevalence %	MDR %	Antibiotics and Resistance %	Genes Coding for Antimicrobial Resistance	Types of Tests Used	Studies
MRSA	Chicks	Perianal/cloacal swab	9.3 (6/64)	N/A	Dox (61.5), Cipro (100), Genta (100), Chlor (4.2)		Kirby-Bauer disk diffusion method	Jayweera *et al.*, 2017 (67)
MSSA	Chicks	Perianal/cloacal swab	(21.8) 14/64	N/A	Dox (62.5), Cipro (60), Genta (44.3), Chlor (7.2)			
Not Specified	Litter	Litter	N/A	N/A	Enro, Tetra		Kirby-Bauer disk diffusion method	Lowe *et al.*, 2019 (68)

3. India

Organism Studied	Species	Type of Sample	Prevalence %	MDR %	ESBL	Antibiotics and Resistance %	Genes Coding for Antimicrobial Resistance	Types of Tests Used	Studies
Salmonella	Poultry farms (NS)		7.4 (71/956)	N/A	N/A	Amp (21.43), Amox (14.29) Genta (7.14), Cipro (19.95), Coli (16.67), Erythro (83.33), Tetra (78.57), Dox (100) Cefta (0)	tetA, blaTEM	Kirby-Bauer disk diffusion method PCR	Waghamare *et al.*, 2018 (69)
E. coli	Broiler	Cloacal swab	87 (235/270)	94	N/A	Cip, Cotri, Amp, Chlor, Tetra		Disk diffusion method	Brower *et al.*, 2017 (24)
	Layer	Cloacal swab	42 (110/260)	60	N/A				
E. coli	Broiler	Caecal sample	55 isolates from 39 samples	N/A	40 (22/55)	Tetra (98), Cip (73), Gent (38), Chlor (14), Cotrimox (47), Foso (5)	blaCTX-M-15	Kirby-Bauer disc diffusion method	Hussain *et al.*, 2017 (27)
	Free range chicken (Backyard poultry)	Caecal sample	46 isolates from 36 samples	N/A	30.43 (14/46)	Tetra (54), Cip (52), Gent (20), Chlor (0), Cotrimox (35), Foso (0)		Disk diffusion method PCR (whole -genome sequencing)	

Campylobacter jejuni		Cloacal swab	4 isolates	N/A	N/A	Tetra (199), Cip (100), Levo (100), Sulpha (100), Eryth (100), Chlor(100), Gent (100), Foso (25)	gyrA	Disk diffusion method MIC by agar dilution PCR 16sRNA	Kabir *et al.*, 2015 (70)
Campylobacter coli		Cloacal swab	16 isolates	N/A	N/A	Cip (100), Levo (93.75), Sulpha (100)			
Salmonella sps.	Broiler Feed Water	Cloacal swab Feed Water	Thirteen isolates *S. enteric ser. typhimurium* 69.23 (9/13)	N/A	N/A	Gent (84.61), Nor (76.92), Amp (61.53), Strep (61.53), Coli (0), Vanco (0)			Bordoloi et al., 2018 (41)
E. coli	Layer Litter Drinking water	Cloacal swab	75.5 (272/360)	N/A	N/A	Erythro (95.83), Chlor (87.52), Coli (78.26), Genta (65.23), Tetra (42.76), Cip (0), Levo (0), Cef (0)	Tested for blaTEM, blaSHV, blaCTX-M qnrA, but none of the isolates were positive	Disk diffusion method RAPD PCR	Samanta *et al.*, 2014 (71)
Bacillus sps. *Staphylococcus sps.* *Escherichia sps.* *Other sps.*	Litter	Litter	31 31 17 3	N/A	N/A	Amp (35), Cloxa (15), Chlor15, Amox (15), Cipro (15)		Disk diffusion method	Brovaragmoothy *et al.*, 2019 (72)
Non- typhodal salmonella	Poultry (NS)	Intestinal and faecal content	14.64 (58/396) *S. infantis* 43.1 (25/58)	N/A	N/A	Amp (32.8), Cipro (72.41), Gent (17.24), Coli (29.31), Amoxiclav (6.9),		Modified Kirby - Bauer disk diffusion	Sohan *et al.*, 2019 (73)
ESBL *E. coli* MBL *E. coli*	Poultry (NS)	Cloacal swab	N/A	41 (32/78) Virulence gene in 81 (26/32) of isolates of isolates)	N/A	Cefurox (91), Ceftri (72), Ampi (50)	CTX-M group 1, CTX-M group 4, TEM	Disk diffusion method PCR	Tewari *et al.*, 2019 (42)
Helicobacter pullorum	Broiler Free range chicken (Backyard chicken)		N/A	N/A	100 100	Nalidixic (100), Enro (100), Cotrimox (100), Cefo (100), Cipro (80), Clarithro (80) Tetra (0), Neo (0), Chlor (0), coli (0), Cephalo (100).	aph(3)-Ib, blaTEM	Disk diffusion method	Qumar *et al.*, 2017 (26)

Salmonella sps.	Layer Egg Feed Water		4.4 (8/180) 3.3 (6/180) 2.5 (3/120) 3.3 (4/120)	N/A	N/A	Cipro (88.5), Genta (84.6), Chlor (80.7), Amox (65.3), Ampi (0), Enro (0), Coli (0)		Disk diffusion method	Singh *et al.*, 2013 (74)
Staphylococcus sps. *Streptococcus sps.* *Micrococcus sps.* *E. coli* *Salmonella sps.* *Aeromonas sps.*	Poultry litter		29.1 25 20.8 12.5 8.3 5 4.1	120 isolates	N/A	Tetra (255), Erythro (56.6), Ampi (50), Tobra (54.1), Strepto (75), Rifampin (45.8), Chlor (3.33)		Disk diffusion method MIC Detection of plasmid DNA	Sridevi *et al.*, 2009 (75)
4. Bangladesh									
Organism Studied	Species	Type of Sample	Prevalence%	MDR%	ESBL	Antibiotics and Resistance%	Genes Coding for Antimicrobial Resistance	Types of Tests Used	Studies
E. coli	Chicken Ducks Geese	Cloacal sample	96.29	22.7 (15/66)	30 (27/90)	Tetra (46.15), Amp (28.84), Cipro (5.76) Chlor (7.69), Tige (0)	*bla*CTX-M-1, *bla*CTX-M-15 *bla*TEM-1	Disk diffusion method PCR	Hasan *et al.*, 2012 (50)
	Wild duck	Droppings	34.15			Tetra (7.14), Amp (28.57), Cipro (7.14) Chlor (0), Tigecycline (0)	*bla*CTX-M-15		
Enterobacter	Poultry (NS)	Cloacal swab	17 (18/106)	17 (18/106)	N/A	Ampi (94.4), Clinda (94.4), Erythro (94.4), Sulpha (72.2), Genta (5.6)	VanA SulI	Disk diffusion method Plasmid profile analysis by PCR	Nandi *et al.*, 2018 (25)
Salmonella sps.	Broiler Water sample Feed sample	Cloacal swab	46.09 (59/128) 18.74 (12/64) 17.18 (11/64)	80.91	N/A	Amox (42.73), Erythro (47.27), Tetra (80.00)		Disk diffusion method	Mridda *et al.*, 2020 (76)
Salmonella sps.	Broiler farms Litter Feed samples		48 (24/50) 25.71 (9/35) 0.13 (2/15)	100	N/A	Tetra (97.1), Chlor (94.1), Amp (82.9), Cef (0)	blaTEM-1, aadA1, floR Class 1 integron Int1	Disk diffusion method	Alam *et al.*, 2020 (77)

Salmonella sps.	Layer	Blood	21.07	N/A	N/A	Amp (99, Amox (98), Tetra (93), Genta (46), Cipro (40),		Disk diffusion method	Mahmud *et al*., 2011 (78)
Salmonella sps.	NS poultry	Liver	23.11 (52/225)	N/A	N/A	Cipro (20), Nitro (0), Amox (50), Tetra (40), Erythro (100)		Disk diffusion method	Akter *et al*., 2007 (79)
E. coli	Chicken	Cloacal swab		N/A	N/A	Genta (60, Azm (80), Tetra (80), Met (100)		Kirby-Bauer disk diffusion	Zinnah e al 2007 (80)
	Duck			N/A	N/A	Azm (50), TE (70), Met (100)			
	Pigeon				N/A	Azm (50), TE (80), Met (100)			
E. coli	Broiler	Cloacal swab	61.67(37/60)	100	N/A	Amp (100), Tetra (100), Genta(43.24),, Coli (51.35)	blaTEM, tetA, Sul2	Kirby-Bauer disk diffusion method PCR	Sarker et al., 2019 (81)
E. coli	Broiler Layer	Heart and liver sample	39.43	36.65	N/A	Tetra (45.5), Ampi (25.7), Strep (20.8), Gent (2.0).		Disk diffusion method	Hasan *et al*., 2011 (49)
E. coli	Broiler	Clocal swab	100 (400/400)	100	N/A	Coli (73.5), Gent (49), Levo (17). Tetra (95.25; Amp (91.25), Strept (88.25), Erythro (84.75), Trimetho (65.5).	tetA, tetB, blaTEM, aadA1, ere(A), dfrA1	Disk diffusion method PCR	Azad *et al*., 2019 (82)
5. Pakistan									
Organism Studied	Species	Type of Sample	Prevalence%	MDR%	ESBL	Antibiotics and Resistance%	Genes Coding for Antimicrobial Resistance	Types of Tests Used	Studies
Salmonella sps.	Broiler	Heart, liver, kidney, breast tissue, and leg pieces	23.3 (35/150)	54.8		Amp (82.2), Tetra (80), Chlora (54.2), Cipro (42.8),		Kirby Bauer disk diffusion	Asif *et al*., 2017 (83)
E. coli	Free range poultry	Cloacal swab		N/A	13.7	Amp Amox, Chlor	blaCTX-M-15 blaCTX-M-55	Disk diffusion method PCR	Umair *et al*., 2019 (31)
Salmonella enterica *Salmonella typhimurium*	NS poultry	Heart, liver	28.4 9.2	100 100	N/A	Imipen (64.75), Azithro (77.2), Perflo (100), Levo (22.7), Cipro (27.2), Amp (54.55), Gent (40.9), Amp (40.9). Perflo (92.6), Levo (44.1), Cipro (51.4), Amp (66.1), Gent (64.7), Amp (55.8)	blaTEM-1 pare strB, aadA1, aadB, aadA, aphAI-IAB, aadA2, strA, aacC2	Disk diffusion method PCR	Wazid *et al*., 2019 (84)
Salmonella enteritidis *(zoonotic potential)*	Egg shell Droppings Egg interior		40 8.33 55	73.75 (83/113)	N/A	Erythro (100), Baci (100), Genta (78.57), Strep (92.85), Tetra (28.57),		Disk diffusion method	Akhtar *et al*., 2010 (40)
E. coli	Broiler	Heart, liver	89.20 (75/84)	100	5.3	Ampi (98.6), Tetra (97.3), Cipro (72)		Kirby-Bauer disk diffusion method PCR	Azam *et al*., 2019 (85)

Salmonella enteric ser infantis	NS poultry		43.82 (149/340)		N/A	Perflo (94.4), Chlor (83.3), Imipenem (77.7)	blaTEM-1, parE, strB, aadA1, aadB, aadA, aphAI-IAB, aadA2, strA, aacC2	Disk diffusion PCR	Wazid 2019 (84)
MDR E. coli	Commercial broiler Backyard poultry	Cloacal swab	70 (70/100) 56 (56/100)	64.2 53.5	N/A	Gent (28.5), Strepto (28.5), OTC (57.1), Amp (28.5), Chlor (21.4), Cef (21.4) Gen (0), Strepto (64.2), OTC (82.1), Amp (17.8), Chlor (8.9), Cef (8.9)	*bla*CTX-M, *bla*SHV	Disk diffusion method PCR	Akhtar *et al.*, 2016 (29)
E. coli	Backyard chicken Commercial broiler	Liver	60 (73/117) 103 isolates	41.10 66.99	N/A	Amp (80.82), Chlor(64.24), Dox (52.05), Amox (93.15), Cip (71.60), OTC (84.93), Ceftri 90), Genta (24.655) Amp (100), Chlor (53.59), Dox (73.78), Amox (93.20), Cipro (2.52), OTC (80.58), Ceftri (10.67), Genta (26.22)		Disk diffusion method	Kamboh *et al.*, 2018 (30)
Salmonella sps.	Backyard chicken Commercial broiler		12.61 (27/214) 37.85 (81/214)	44.44 69.32	N/A	Amp (77.77), Chlor (65.55), Dox (88.80), Amox (77.77), Cipro (44.44), OTC (100), Ceftri 0), Genta (22.22) Amp (92.59), Chlor (85.18), Dox (92.59), Amox (85.18), Cipro (81.48), OTC (96.29), Ceftri 7.4), Genta (51.85)			
Klebsiella sps.	Backyard chicken Commercial broiler		14.52 (17 /117) 14.01 (30/214)	41.28 63.33	N/A	Amp (23.52), Chlor(100), Dox (100), Amox (23.52), Cipro (100), OTC (100), Ceftri (0), Genta (23.52) Amp (50), Chlor (76.66), Dox (100), Amox (76.66), Cip (76.66), OTC (76.66), Ceftri 26.66), Genta (76.66)			
Salmonella gallinarum (SG) *Salmonella enteritidis* (SE)	NS poultry	Droppings, liver, intestine	44.66 (67/150)	SG (34/67) SE (21/67) Others (12/67)	N/A	Amp (100), Amox (94.1), Tetra (58.8), Cip (58.8), Ceftri (23.5) Amp (95.2), Amox (95.2), Tetra (61.9), Cip (76.2), Ceftri(33.3)		Kirby-Bauer disk diffusion with minor modification Serovar specific PCR	Yasmin *et al.*, 2019 (43)

						Amp (100), Amox (100), Tetra (58.3), Cipro (75), Ceftri (25)			
Enterococcus faecalis	Broiler poultry Poultry feed Air		53 isolates from 50 samples 20 isolates from 25 samples 1 isolate from 25 sample	98.6	N/A	Tetra (100), Gen (66), Amp (9.4), Erythro (9.4), Cipro (62.2), Ceftri (100), Vanco (0) Tetra (100), Gen (20), Amp (5), Erythro (80), Cipro (55), Ceftri (100), Vanco (0) Tetra (100), Gen (0), Amp (0), Erythro(0), Cipro (0), Ceftri (0), Vanco (0)	pbp4, tetL, tetM, ermB, cat, acc6-aph2, aaph(3)-III, gyrA, parC	Agar dilution as per CLSI Multiplex PCR	Hasan *et al.*, 2017 (86)
Salmonella enterica var. typhimurium *Salmonella enterica var. enteritidis*	34 isolates (18/250) 20 isolates	Cloacal swab	7.2		N/A	Amox (94.9), Linco (93.5), Amp (92), Tetra (84.1), Strepto (83.4), Gariflo (5.7), Ceftri (6.4) Amox (74.6), Linco (92.6), Amp (48.4), Tetra (NA), Strep (37.8), Gariflo (13.6) Ceftri (11.5)	blaTEM, blaSHV, tetA, tetB, aadB, *strA/strB*	Disk diffusion method PCR	Khan *et al.*, *2019* (87)

Footnotes:
NS: Non-specified; N/A: not available; Tetra: tetracycline; Gen: gentamicin; Amp: ampicillin; Erythro: erythromycin; Ceftri: ceftriaxone; Cipro: ciproflxacin; Vanco: vancomycin; Strepto: streptomycin; Gariflo: garifloxacin; Dox: doxycycline; Chlor: chloramphenicol; Amox: amoxicillin; OTC: oxytetracycline; Cef: cefexime; Perflo: perfloxacin; Levo: levofloxacin; Imipen: imipenem; Azithro: azithromycin; Met: metronidazole; Clinda: clindamycin; Sulpha: sulphonamide; Cotrimox: cotrimoxazole; Cefurox: cefuroxime; Nor: norfloxacin; Amik: amikacin; Linco: lincomycin; Trimetho: trimethoprim.

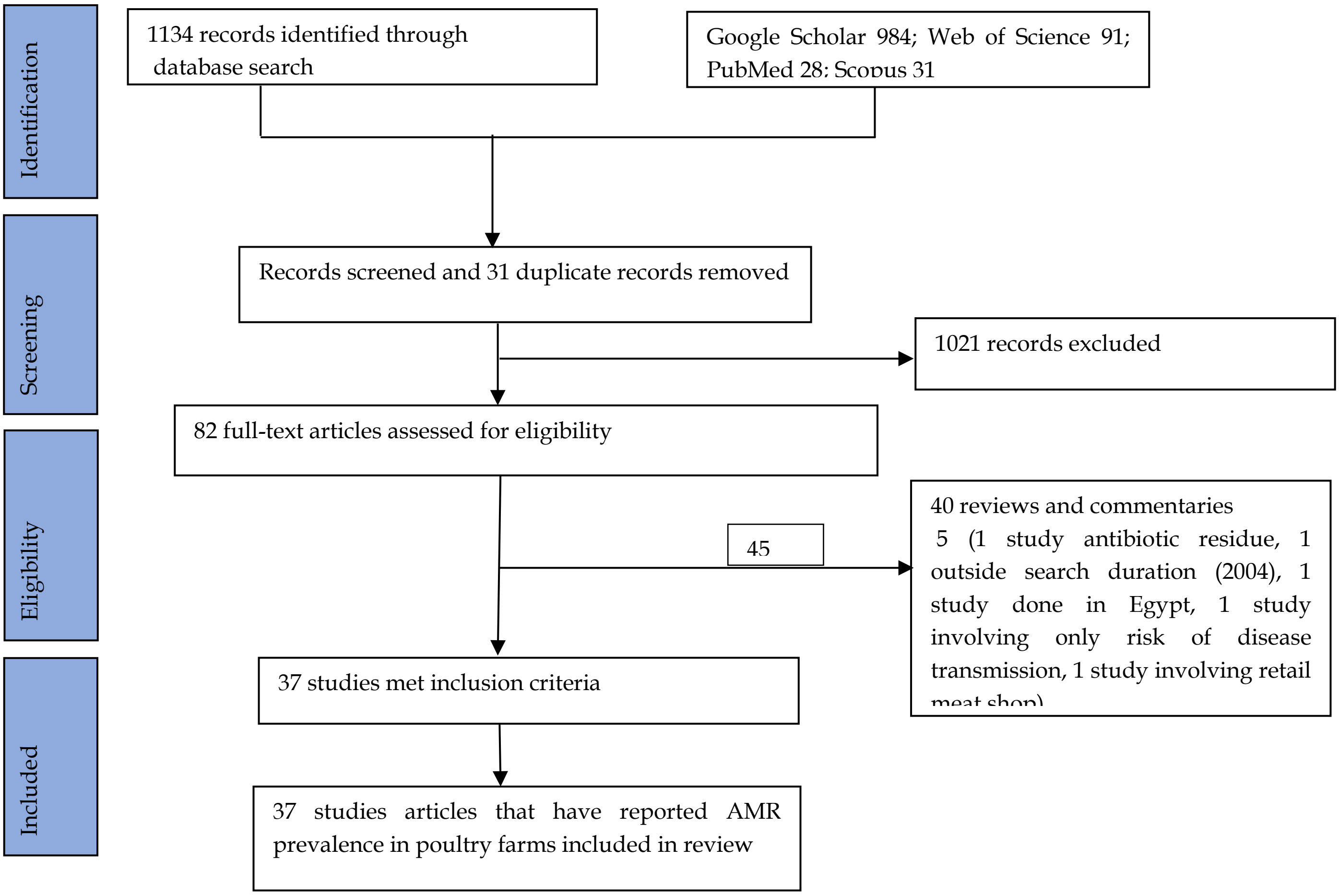

Figure 1: Article selection