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A SYSTEMATIC REVIEW OF BACTERIAL ZOONOTIC DISEASES IN THE LIGHT OF 'ONE HEALTH' APPROACH WITH MULTIDRUG RESISTANCE STATUS IN BANGLADESH

M. A. Samad, PhD, WHO Fellow

Rajuk Uttara Apartment Project (RUAP), Kamini Bhabon, 14D 305, Diyabari, Uttara-18, Dhaka, Bangladesh
e-mail: lepvmbj@gmail.com, vetmedbd@yahoo.com

ABSTRACT

Background: Zoonotic diseases are globally distributed and have important public health, animal health, and economic implications. People in low-income agriculture-based countries, including Bangladesh, are frequently exposed to zoonotic pathogens due to close interaction with domestic and peri-domestic animals. Antibacterial resistance (ABR), including multi-drug resistance (MDR) problems, has been reported in Bangladesh. Without updated knowledge of ABR, no drugs could be prescribed for effective treatment and management of different zoonotic diseases. Different emerging, re-emerging, and endemic zoonotic diseases have been reported in Bangladesh but are hardly presented systematically based on the 'One Health' perspective.

Objective: This search aimed at a systematic review to produce a comprehensive, up-to-date report on bacterial zoonotic diseases (BZD), clarify their antibacterial resistance status, and identify the major areas for future research in Bangladesh.

Materials and Methods: A systematic review investigated the prevalence of ZBD and their ABR status over 50 years from 1970 to 2024, considering Bangladesh's 'One Health' concept. The predominant resources were journal publications either available in the library as hard copies or all available in scientific databases, including PubMed, ResearchGate, and Google Scholar. Research reports on ZBD reported in domestic animals, birds, humans and wildlife were reviewed thoroughly to assess the quality of reporting items for inclusion in the systematic review.

Results: The results of the prevalence, effects, and ABR status of BZD in humans, animals, and birds in Bangladesh are reviewed and analyzed from 434 published research reports supported by 97 foreign-related research reports. The prevalence of significant ZBDs from Bangladesh are anthrax, brucellosis, tuberculosis, salmonellosis, *E. coli* infection, Staphylococcus infection, campylobacteriosis, and leptospirosis. From 1982-2024, 228 outbreaks of anthrax in animals, especially cattle, caused zoonotic cutaneous anthrax in 3066 humans in Bangladesh. Analysis of the Veterinary Hospital Records of 64 districts showed 13.49% case fatality of livestock caused by anthrax, and mortality varied from 12.9 to 100% in cattle along with two affected human cases died of anthrax in Bangladesh. Tuberculosis was recorded in an overall 11.78% (737/6258) cattle, 3.33% (6/180) buffaloes, 7.75% (32/413) sheep, 1.29 % (2/155) goats, 6.67% (6/90) humans and 100% (2/2) monkeys. Out of nine serological tests used, i-ELISA and PCR are considered reliable for accurate diagnosis of brucellosis. An overall 2.69% seroprevalence of brucellosis in cattle, 3.65% in buffaloes, 3.70% in goats, 2.32% in sheep, 4.0% in pet dogs, and 13.33% in stray dogs, and 3.14% in humans were detected by i-ELISA. In contrast, PCR detected 1.99% brucellosis in cattle and was not applied in other species. The milk ring test (MRT) detected an overall 4.38% Brucella-positive milk in lactating cows and 13.64% in lactating goats and reported 3.96% in culture/PCR-positive milk samples. Higher seroprevalence of brucellosis in occupational groups, especially 31.3% in slaughterhouse workers, 11.11% in abattoir butchers, 3.42% in livestock farm workers, 6.45% in milkers/dairy workers, and 9.67% in veterinarians were recorded. An analysis of 85 reports shows that Bangladesh has a high prevalence of 42.86% (5209/12154) *E. coli* infection, 31.37% (468/1492) *Staphylococcus* spp., and 19.09% (2228/11594) *Salmonella* spp. in livestock and humans. Antibiogram studies were conducted with 52 antibacterial drugs against *Salmonella* spp., *E. coli,* and *Staphylococcus* pp. The ABR of *Salmonella* spp. exhibited the highest resistance to trimethoprim (100%), followed by penicillin (93.22%), cloxacillin (90.35%), tetracycline (89.94%), pefloxacin (88.08%), clindamycin (84.00%), erythromycin (87.19%), and rifampicin (85.33%). *E. coli* isolates expressed the highest resistance to oxacillin (100%%), followed by cloxacillin (98.48%), trimethoprim (91.10%), rifampicin (90.00%), cephalexin (84.45%), ampicillin (83.97%) amoxicillin (82.13%), and erythromycin (80.36%). *Staphylococcus* spp. isolates resisted ampicillin (72.58%%), doxycycline (60.29%), cefixime (57.14%), and penicillin (54.81%). MDR at a high level were reported against isolates of these three bacteria, which indicates a high risk of transmission of resistance genes from microbial contamination of livestock origin.

Conclusion: Antimicrobials are life-saving drugs, but increasing resistance levels seriously compromise their effectiveness in nearly all bacteria causing infection in food animals and humans. Horizontal gene transfer and/or evolutionary mutations, antimicrobials primarily exert selection pressure that contributes to ABR. The 'One Health' holistic and coordinated approach in human and veterinary medicine, environmental sciences and public health is required to develop effective surveillance techniques with appropriate diagnostic and therapeutic interventions. Research to control zoonotic diseases is neglected in low-income countries and similarly 'One Health' approach to prevent and control zoonotic diseases is also neglected. However, the spread of ABR bacteria in livestock farms can be prevented by effective biosecurity measures, responsible antibiotic use, and strict regulations in livestock production, whereas infection and drug resistance of ZBD in humans can be prevented by food hygiene, hand hygiene, environmental cleaning, contact precautions, active surveillance cultures, education, antimicrobial stewardship and personal protective equipment.

Keywords: Bacterial zoonotic diseases, Prevalence, Antibacterial resistance, Multidrug resistance, One Health approach, Bangladesh

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INTRODUCTION

A comprehensive literature review identifies 1415 species of infectious organisms pathogenic to humans, including 217 viruses and prions, 538 bacteria and rickettsia, 307 fungi, 66 protozoa, and 287 helminths. Out of these, 868 (61.0%) are zoonotic (transmitted between animals and humans), and 175 pathogenic species are associated with diseases considered to be 'emerging' of which 132 (75.0%) are emerging and re-emerging infections being considered as zoonotic pathogens.[1,2] Globally, it is estimated that 2.5 billion cases related to zoonotic infections are reported yearly, resulting in 2.7 million deaths.[3] Classification of zoonotic diseases is mainly based on etiology, which includes microbial (bacterial, viral, fungal, rickettsial, chlamydial, mycoplasmal), parasitic (nematodes, trematodes, cestodes, protozoal) and acellular non-viral pathogenic agents. Global literature on zoonotic diseases is voluminous, as is inland literature. Writing a manuscript on all zoonotic diseases will make the manuscript voluminous, even with inland literature. Accordingly, attempts have been made to write review articles based on groups of zoonotic diseases like bacterial zoonotic diseases, viral zoonotic diseases, etc. The WHO / WOAH has classified the bacterial zoonotic diseases A (anthrax, botulism, plague, and tularemia) and B (brucellosis, foodborne agents- E. coli 0157:H7, salmonellosis & shigellosis, glanders, psittacosis, melioidosis, Q-fever and typhus fever) categories. The zoonotic bacterial pathogens, especially Campylobacter, Salmonella, Listeria monocytogenes, and the Enterobacteriaceae family, are frequently recorded in livestock animals and poultry bird species, as well as in wildlife, pet, and rodents, causing foodborne diseases.[4] Zoonotic bacterial diseases are those diseases caused by bacterial pathogens that can be very commonly transmitted naturally between vertebrate animals and humans. The development of antimicrobial resistance due to overuse and misuse of antibiotics has caused increasing public health problems globally. Changes in human lifestyle and closer contact with animals have caused some bacterial infections to re-emerge. Some bacterial zoonotic diseases re-emerged after they were eradicated or under control in most industrial countries. The spread and importance of some bacterial zoonoses are increasing globally, with more problems occurring in low-income countries, including Bangladesh. However, both emerging and re-merging bacterial zoonoses have gained increasing incidence globally, including in Bangladesh. People with close contact with many animals, such as pet owners, farmers, abattoir workers, zoo/pet shop workers, and veterinarians, are at a higher risk of contracting a zoonotic disease. Food-borne zoonoses are a significant public health concern globally, and every year, many people are affected by diseases caused by animal sources of food consumption. Antibiotic-resistant zoonotic bacterial diseases are of particular importance for at-risk groups of people who are either temporarily immunosuppressed owing to pregnancy, infant age, or long-term immunosuppressed because of cancer treatment or organ transplant, diabetes, alcoholism, or an infectious disease like AIDS.[5] The 'One Health' concept interconnected humans, animals, and the environment in a complex and diversified manner, and the resistant bacteria, including resistance genes, spread in the environment, including soils, surface, and groundwater.[6,7] The prevalence of zoonotic diseases associated with public health threats has been reported earlier in Bangladesh,[8] followed by 'One Health' zoonotic disease prioritization of six diseases including anthrax, brucellosis, Nipah, Rabies, Zoonotic influenza, and Zoonotic tuberculosis.[9] Also, some reviews have described zoonotic diseases with etiology, impact, and control,[10] and significant zoonotic diseases of public health importance.[11] This comprehensive review describes a systematic overview of bacterial zoonotic diseases with a special emphasis on prioritizing zoonotic diseases in Bangladesh.

MATERIALS AND METHODS

The review article, 'Public health threat caused by zoonotic diseases in Bangladesh,' was published based on a review of all the available inland-related articles up to 2010.[8] In addition to this review report, some similar reports have been published from Bangladesh.[10,11] However, this paper includes a view of all available inland reports on zoonotic diseases supported by international-related research reports, mainly published in peer-reviewed journals locally in Bangladesh and abroad up to early 2024. A literature search using the digital archives Google Scholar, PubMed, ScienceDirect, Web of Science, and Bangladesh Journal online uses different terms of zoonotic diseases based on different bacterial zoonotic diseases. All the related review articles, original papers, case reports, and short communications on all aspects of zoonotic bacterial diseases were reviewed. In addition, zoonotic disease reports from the WHO, FAO, IAE, CDC, and IEDCR were also reviewed using Google search.

RESULTS AND DISCUSSION

Humans have had intimate relationships with animals and birds since they were domesticated in ancient times. Some animals and birds are reared to provide food like meat, milk, or clothing, some for recreational purposes and others for companionship or as guards like dogs. Although humans benefit from these interactions, there are occasionally disadvantages to humans due to the transmission of zoonotic infections from animals. Zoonotic diseases are diseases and infections naturally transmitted between humans and vertebrate animals. There are three classes of zoonotic diseases: (a) Endemic zoonotic diseases, which are present in many places and affect many people and animals; (b) Epidemic zoonotic diseases, which are sporadic in temporal and spatial distribution; and (c) Emerging and re-emerging zoonotic diseases, which are newly appearing in a population or have existed previously but are rapidly increasing in incidence or geographical range.[12] Globally, about 2.5 billion cases of human illness and 2.7 million human deaths occur every year from zoonotic diseases.[13] An estimated 60.0% of known infectious diseases and up to 75.0% of new emerging infectious diseases (EIDs) are zoonotic in origin. Over 30 new human diseases have been detected in the last three decades, 75.0% of which have originated in animals.[2] Zoonotic diseases are essential in both human and veterinary medicine because animals share 61.0% (868/1415) of human pathogens, 64.0% (14/22) of infectious agents identified from 1973 to 1994 are zoonoses, and 73.0% (130/177) of emerging infectious diseases are zoonotic in origin.[14] Table 1 shows the bacterial zoonotic diseases with their hosts, etiology, and clinical findings in humans.

Table 1. Bacterial zoonotic diseases with their pathogens, hosts and major symptoms in humans [9]

S/N	Zoonotic disease	Causal agent	Animal hosts	Rank score* (Table 2)	Major symptoms, systems and organs involved
01.	Anthrax	*Bacillus anthracis*	Wide host range-ruminants, humans	0.85	Skin, respiratory & GI tract symptoms
02.	Brucellosis	*Brucella abortus, B. melitensis, B. suis, B. canis*	Cattle, goats, sheep, pigs & dogs	0.63	Fever, back & joint pain, poor appetite & weight loss
03.	Tuberculosis	*Mycobacterium bovis M. caprae, M. microti, M. orygis*	Cattle, sheep, swine, deer, wild boars, camels, & bison	0.20	Respiratory organs, bone marrow
04.	Bubonic plague	*Yersinia pestitis*	Rock & ground squirrels, wood rats, prairie dogs, mice, voles, chipmunks, & rabbits	0.59	Fever, chills, abdominal pain, diarrhea, vomiting, and bleeding from natural opening, pain & swollen lymph nodes
05.	Glanders and Melioidosis	*Burkholderia mallei*	Horse, donkeys, and mules	0.70	Fever, sweating, muscle aches, chest pain, muscle tightness & headache
06.	Leprosy	*Mycobacterium leprae*	Monkeys, rats, mice, cats		Endemic skin lesions[15]
07.	Leptospirosis	*Leptospira interrogans*	Wild & domestic animals including pet dogs	0.57	Fever, abdominal pain, jaundice, and with red eyes

Contd. Table 1.

08. Tularemia	*Francisella tularensis*	Rabbits, squirrels, muskrats, deer, sheep, bull snakes, wild rodents, beavers, cats & dogs	-	Joint pain, diarrhea, and dry cough
09. Aliarcobacter infections	*Aliarcobacter butzleri* *A. cryaerophilus* *A. skirrowii*	Cattle, sheep, pigs and chickens		Reported bdominal pain, fever, and vomiting in BD[16]
10. Actinomycosis	*Actinomyces bovis*	Cattle, sheep, horses, pigs, dogs and other mammals	Reported in BD	Swelling lymph nodes, soft tissues, skin, and abscesses [17-19]
11. Bordetellosis	*Bordetella bronchiseptica*	Cats and dogs	-	Respiratory problems
12. Lyme disease	*Borrelia burgdorferi*	Cats, dogs & horse	-	Fever, headache, skin rash, erythema
13. Campylobacter enteritis	*Campylobacter jejuni* *Campylobacter coli*	Cattle, sheep, chickens, turkeys, dogs, cats, mink, ferrets and pigs	0.19	Enteric disorders, acute flaccid paralysis (AFP)[20]
14. *Campylobacter fetus* infection	*C. f. subsp. fetus* *C. f. subsp. testudinum*	Cattle, sheep & goats	Reported in BD	Enteric disorders [21]
15. *Clostridioides difficile* infection	*Clostridioides difficile*	Cattle, horse & birds	Reported in BD	Pseudomembranous colitis, and diarrhea [22]
16. Corynebacterium infection	*C. ulcerans* *C. pseudotuberculosis*	Cattle, dogs and cats	Reported in BD	Diphtheria[23]
17. Enterohemorrhagic *E. coli* infection	*Escherichia coli* 0157:H7	Cattle, sheep, pigs, deer, dogs, and poultry	0.26	Enteritis and Hemolytic-uremic syndrome (HUS)
18. Helicobacter infection	*Helicobacter pullorum* *Helicobacter suis*	Poultry and pigs	-	Peptic ulcer
	Helicobacter pylori	Humans	Reported in BD	Peptic ulcer[24]
19. Vibriosis	*Vibrio parahaemolyticus*	Farm animals	0.19	Enteritis
	Vibrio cholerae	Humans	Reported in BD	Enteritis[25]
20. Salmonellosis	*Salmonella enterica* *Salmonella bongor*	Domestic animals, birds, and dogs	0.46	Enteritis[26]
21. Ehrlichiosis (Rickettsia)	*Anaplasma phagocytophilum* *Ehrlichia ewingii*	Sheep, cattle, deer, dogs and cats Ticks	Reported in BD	Fever, headache, fatigue, muscle aches, and occasionally rash [27]
22. Pasteurellosis	*Pasteurella multocida*	Poultry, pigs, cattle, buffaloes, sheep, goats, deer, cats, dogs, antelope	-	Fever, vomiting, diarrhea, and gangrene. Local wound infection, usually followed by an animal bite or scratch.

*Rank score in Bangladesh (out of 1.0)   BD = Bangladesh
Others! = *Ehrlichia ewingii, Ehrlichia chaffeensis, Ehrlichia canis, Neorickettsia sennetsu*

Most of the review reports on zoonotic diseases have been published based on limited data from the research reports but included the priority zoonotic diseases in Bangladesh, including anthrax, tuberculosis, brucellosis, salmonellosis, campylobacteriosis, leptospirosis, and food-borne diseases.[8,10,11,28,29] There are 41 zoonotic diseases have been recognized in Bangladesh, and their ranking has been made based on five criteria, which include (a) Severity of disease, (b) Intervention ability, (c) Economic burden, (d) Transmissibility and (e) Response capacity (Table 2). A ‘One Health’ approach that considers humans, domestic and peri-domestic animals, and the environment is required to control zoonotic diseases effectively globally, including in Bangladesh.

Table 2. Ranked zoonotic disease list from the 'One Health' zoonotic disease prioritization workshop for Bangladesh [9]

Rank	Zoonotic diseases	Ranked Score	Rank	Zoonotic diseases	Ranked Score	Rank	Zoonotic diseases	Ranked Score
01	Rabies	1.00	15	MERS-CoV	0.49	30	Giardiasis	0.26
02	Zoonotic influenza	1.00	16	Salmonellosis	0.46	31	Trematodiasis	0.24
03	Anthrax	0.85	17	Rotavirus	0.44	32	Toxoplasmosis	0.24
04	Japanese encephalitis	0.81	18	Leishmania	0.44	33	Amoebiasis	0.22
05	Nipah	0.76	19	Yellow fever	0.44	34	Cryptosporidiosis	0.20
06	Ebola	0.71	20	Psittacosis	0.44	35	Zoonotic tuberculosis	0.20
07	Glanders and Melioidosis	0.70	21	Nematodiasis	0.42	36	CCHF	0.19
08	Bovine spongiform Encephalopathy (BSE)	0.67	22	Kyanasur forest disease	0.41	37	Campylobacteriosis	0.19
			23	Rift Valley fever	0.37	38	Schistosomiasis	0.16
09	Brucellosis	0.63	24	Q fever	0.34	39	Hepatitis E	0.15
10	Plague	0.59	25	West Nile virus	0.42	40	Lymphatic filariasis	0.15
11	Leptospirosis	0.57	26	Orf & Pseudocowpox	0.31	41	Typhus	0.07
12	SARS	0.52	27	Cysticercosis	0.29			
13	Hydatid disease	0.51	28	*Escherichia coli* (EC)	0.26			
14	Listeriosis	0.49	29	Balantidiasis	0.26			

SARS = Severe acute respiratory syndrome
CCHF = Crimean-Congo Hemorrhagic Fever
EC = including EHEC, ETEC and 0:157
MERS-CoV = Middle East Respiratory Syndrome Coronavirus
Typhus - including Scrub Typhus, Murine Typhus, and Cat-flea Typhus

Livestock production associated with environmental and public health hazards

Livestock production has long been associated with possible threats to human health regarding zoonotic diseases, food safety hazards from infectious agents, and antibiotic resistance in humans arising from indiscriminate use of antibiotics in both livestock and humans. Livestock farmers and consumers of livestock products risk contracting zoonotic infections, including foodborne infections and intoxications. Gaseous pollutants and bioaerosols are emitted directly from livestock, and pollutants that are excreted with livestock waste, including nutrients, pathogens, natural and synthetic hormones, veterinary antimicrobials, and heavy metals that can enter local soil, surface, and groundwater, and pose direct and indirect public health hazards. Among the environmental bacterial pathogens, food and waterborne E. coli causes diarrhea, hemorrhagic colitis, and hemolytic-uremic syndrome in humans. E. coli 0157:H7 has evolved behaviors and strategies to persist in the environment. The impact of livestock-keeping practices and their implications on public health and environmental issues of *E. coli* infections are presented in Table 3.

Table 3. *Escherichia coli* isolated from different hosts and its virulence study in chicken embryos[30]

S/N	Samples collected host	No. of samples collected	Embryo inoculated	Embryo death (%)	S/N	Samples collected host	No. of samples collected	Embryo inoculated	Embryo death (%)
01.	Human urine	10	6	3 50.00)	07.	Duck	10	6	3 (50.00)
02.	Human stool	10	6	1 (16.67)	08.	Pigeon	10	6	4 (66.67)
03.	Cattle	10	6	2 (33.33)	09.	Drain sewage	10	6	1 (16.67)
04.	Sheep	10	6	2 (33.33)	10.	Soil	10	6	0
05.	Goat	10	6	2 (33.33)	11.	KVEC isolates	10	6	6 (100)
06.	Chicken	10	6	6 (100)	12.	KAEC isolates	10	6	0

KVEC = Known virulent *E. coli* KAEC = Known avirulent *E. coli*

Antibiogram study of isolated *E. coli* from different sources with gentamicin (GM), azithromycin (AZM), levofloxacin (LVX), tetracycline (TE), ampicillin (AP), ciprofloxacin (CIP), erythromycin (E),amoxicillin (MX), nalidixic acid (NA) and metronidazole (MNZ) showed that the *E. coli* infection of different animals and birds and also of human beings may be treated effectively with LVX and CIP followed by GM and AZM.[31]

The impact of urban livestock-keeping practices and their implications on public health and environmental issues have been assessed in municipalities in certain districts in Bangladesh.[32] The local political leaders usually kept the highest number of animals, and about 66% of these animals depended on grazing and scavenging for feed from government and municipal lands, unfenced open land, roadsides, and rubbish dumps that caused different types of human health hazards including dung and urine disposal (20%), malodor (16%), blocked road (14%), flies, parasites and dust (12.0), noise (10%), accidents (9%), water pollution (4%), zoonotic diseases (2%), gas emissions (1%), compromising animal welfare (1%) and others (11%).[32]

Heavy metals in the human food chain from animal-source foods

Emerging evidence has shown that municipal garbage waste contains higher amounts of heavy metals and increases health and environmental hazards. Most roaming cattle in municipal areas eat mixed forms of waste, such as food and kitchen leftovers, green waste, papers, paints, chemicals, fertilizers, pesticides, herbicides, tannery, and medical waste.[32] All types of municipal waste contain heavy metals, and roaming cattle in urban areas usually take those wastes. The composite form of waste may contain significant heavy metals such as zinc, copper, nickel, lead, cadmium, chromium, and mercury (Table 4).

Table 4. Average heavy metal levels in garbage waste, feces, and milk of urban dairy cows in Mymensingh[33]

S/N	Types of samples	No. of samples	Chromium mg/kg	Zinc mg/kg	Lead mg/kg	Cadmium mg/kg
1.	Garbage	08	34.27	6.91	9.30	7.93
2.	Feces	16	38.87	14.07	17.53	12.53
3.	Milk	16	11.00	3.79	3.46	1.88

It appears that roaming dairy cattle consume garbage wastes that possess heavy metals such as Cr, Zn, Pb, and Cd to a major extent resulting in the introduction of trace elements in the human food chain.[33]

Human health hazards from animal sources methane greenhouse gas

The enteric fermentation of livestock contributes the highest proportion (59%) of greenhouse gas (GHG) emitted from agriculture, followed by rice cultivation (23%), manure management (5%), burning of agricultural crop residue (1%), and soils (12%). Fermentation of carbohydrates in the rumen generates free hydrogen, which is utilized by methanogenic bacteria (like *Methanobrevibacter ruminantium* and *Methanomicrobium mobile*) to reduce carbon dioxide and emit methane. With their symbiotic association, the bacteria in the rumen and the methanogens increase digestion and total microbial production. About 8-12% loss of total dietary energy occurs due to methane formation. Methane production in ruminants depends on the quality, quantity, and digestibility of feed and the type of animal concerned. They can utilize lower-quality forages and crop residues, especially rice straw and weeds from cropland. These low-quality feeds incur low digestibility and significantly contribute to producing high quantities of methane.

Ruminant livestock is one of the key elements for the agriculture-based economy of Bangladesh, although these animals are often condemned as a source of greenhouse gases, mainly methane (CH_4). It was observed that the ration supplied to bovines consisted of 50-60% green roughage, 31-41% rice straw, and 4-5 to 10% concentrate mixture. In terms of DMI, rice straw has contributed the highest (51-65%) proportions, followed by green forage (24-31%) and concentrate mixture (7-17%). In small ruminant ration, 90-95% feed (DMI 75-86%) was supplied from green grasses and concentrate mixtures. Although buffalo, individually, irrespective of sex and age, emitted the highest amount of methane, followed by crossbred and indigenous cattle, goats, and sheep, the males produced more methane than those females in all species.[33] Total methane emissions in Gazipur, Tangail, and Mymensingh districts were 13359.15, 13250.65, and 13653.75 kg/day and 4876.11, 4836.50 and 4983.62 ‘000’ kg/year, respectively. In total, 48,320 kg/day and 309,630 ‘000’ kg/year methane was measured to be emitted in Bangladesh by 56.33 million ruminant livestock, where 64.79% had come from indigenous cattle, followed by crossbred cattle (20.82%), goat (8.79%), buffalo

(5.17%) and sheep (0.43%).[33]

Currently, WHO focuses on the WHO blueprint list of priority diseases, which include Crimean-Congo hemorrhagic fever, Ebola, Marburg, Lassa fever, Middle East respiratory syndrome, Rift Valley fever, Nipah virus, and Henipaviral diseases, but there are some essential zoonotic diseases in the developing world neglected zoonoses include anthrax, brucellosis, tuberculosis, and others.[34] Some review articles on zoonotic diseases have been published based on inland reports on single diseases like brucellosis,[35,36] anthrax,[37] or some major zoonotic diseases with limited periods, even with incomplete review of reports but up-to-date comprehensive reports are minimal.[8]

Major zoonotic bacterial diseases

Anthrax, tuberculosis, brucellosis, leptospirosis, and listeriosis are the major bacterial diseases associated with livestock production and public health importance. The pathological and molecular study on the affected organs, including mesenteric lymph nodes, lungs, and liver, collected from 50 slaughtered cattle reported that 18.0% of cattle had tuberculosis, 10.0% leptospirosis, and 10.0% listeriosis infection, whereas all samples were negative for brucella infection.[38]

Anthrax

Anthrax is a zoonotic disease transmitted between animals and humans. Still, only sporadic cases have occasionally been reported in developed countries, including Australia, Sweden, the USA, Italy, and several European countries where it is not a major health issue in animals and humans.[39] However, anthrax remains a severely under-reported disease in Africa, Asia, and South America, where humans frequently butcher and eat animals infected with infectious diseases, including anthrax.[34] It is still a major health concern for animals and humans in developing and under-developing countries based on agricultural and livestock dependence. An estimate showed every year, 2000 to 20000 human anthrax cases occur globally.[40] Anthrax outbreaks in animals and humans have been reported in Southeast Asian countries, including Bangladesh, India, Pakistan, Nepal, and elsewhere.[40] Anthrax is caused by a Gram-positive, spore-forming, non-motile bacterium, *Bacillus antharcis*, which is considered an attractive weapon for bioterrorism because its spores are extremely resistant to natural conditions and can survive for several decades in the environment. Anthrax causative agent is ubiquitous and can survive as a viable spore under extreme weather conditions in the soil for 100 years; thus, it cannot be eradicated.[41] Comparative genomic analysis focusing on single-nucleotide polymorphism (SNP) discovery revealed a close genetic relationship between these strains from Bangladesh and historic strains collected between 1991 and 2008 in The Netherlands and Germany, respectively.[42] Isolated strain Tangail-1 harbored both *B. anthracis* virulence plasmids pX01 and pX02 as confirmed by RT-PCR assays.[42]

Genotyping based on canonical single-nucleotide polymorphism (canSNF) grouped strain Tangail-1 into the A.Br.001/002 branch, which has previously been isolated in Bangladesh[43] and other South Asian countries including China and Central Europe, and this can SNP group of *B. anthracis* seems to be predominant in Bangladesh.[42-44]

Anthrax is an endemic zoonotic disease in Bangladesh primarily affecting ruminant animals, caused by the spore-forming, aerobic, gram-positive, non-motile bacterium *Bacillus anthracis.* Anthrax was reported in Bengal in 194845, but its zoonotic prevalence was first reported in humans and cattle in Bangladesh in 1980.[46] The recurring anthrax outbreaks have been reported in both animals and humans in Bangladesh, where rural animal owners often slaughter their infected animals at the moribund stage and subsequently, sell the infected meat directly to people to compensate for financial losses.[47-50] Recently, zoonotic anthrax has been identified in 15 of 64 districts in Bangladesh (Table 5 & 6). Anthrax outbreaks in animals, primarily cattle (76.62%), have been reported in certain districts in Bangladesh. Occasionally, other animals, including buffaloes (4.98%), goats (16.19%), and sheep (2.22%), have also been affected by anthrax.[51] Similarly, a higher case fatality rate has been reported in cattle (12.9%) than in buffaloes (3.6%) and goats (1.4%) with no case fatality in sheep.[51] Feeding animals with uprooted and unwashed grass and feeding water hyacinth (*Eichhornia crassipes*) were independent risk factors for anthrax in cattle.[52] Humans are generally affected by anthrax organisms by slaughtering, handling, and processing the meat of infected animals. Knowledge, attitude, and practices towards anthrax among livestock farmers in different districts in Bangladesh have been evaluated and reported half of the animal farmers did not know the mode of transmission of zoonotic anthrax. In addition, the vaccination supply was reported inadequate, and most of the farmers did not show interest in vaccinating their animals. Therefore, it is necessary to ensure increased awareness and modify attitudes on vaccination of the livestock population along with sufficient coverage of the anthrax vaccine to control the anthrax outbreaks.[53,54] It appears that people in the affected communities had no awareness of the transmission of pathogens from infected animals to humans.[55]

Slaughtering sick animals and selling meat from sick animals at a lower price are commonly observed in Bangladesh.[47] Types of anthrax exposure in humans in Bangladesh have been reported to be by butchering (20%), contact with meat (46.7%), and live animals infected with anthrax.[56] People usually do not follow proper carcass disposal of dead animals in Bangladesh, which are mostly thrown in the open fields, rivers, canals, flood water, and ditches of the road, contaminating the newly grown grasses and grazing fields and the environment.[55] A review of the literature reveals that multiple cutaneous forms of anthrax outbreaks have been reported in more than 1500 humans with no death during the period from 2009 to 2015 in Bangladesh.[55-57] Anthrax is a vaccine-preventable disease in animals. Still, a shortage of vaccines and inadequate vaccination programs in the animal population make non-vaccinated animals susceptible to natural infection under field conditions in Bangladesh. Anthrax is a primary disease of animals. If it is controlled in animals by using a scheduled vaccination program, it could help control the infection in humans due to the absence of a source of infection.

Table 5. Reported anthrax outbreaks in animals in Bangladesh[8]

S/N	Outbreak year	Districts	No. of out-breaks	No. of cattle affected	Site of outbreaks	Case fatality No. (%)	Ref. No.
01.	1980-'84	Pabna Milk Shed Area	02	62	Villages	43 (69.0)	46
02.	1984	Dhaka	01	01E	Dhaka Zoo	01	58
03.	2009-10	Sirajgonj, Pabna & Tangail	14	140	Villages	98 (70.0)[1]	47
04	2009-10	Sirajgonj, Pabna & Tangail	14	140	Villages	98 (70.0)[1]	55
05.	2010	Sirajgonj	08	104	Dairy farms	-	43
06.	2010-12	Sirajgonj	-	159	Upazilas	48 (30.2)	49
07.	2010-14	Data – Department of Livestock Services	800-1100	-	VHD	March-Sept	59
08.	2010-12	Secondary survey (Whole Bangladesh)	64*	5937	VHD	801 (13.49)	62
09.	2011	Pabna, Sirajgonj, Bogra, Faridpur, Meherpur, & Tangail	11	1278	Villages	165 (12.9)	51
10.	2013-16	Rajshahi, Meherpur, Kushtia, Sirajgonj, Tangail	19	50	Villages	-	61
11.	2016-17	Sirajgonj (n=2), Tangail (n=1) & Rajbari (n=1)	04	06	Villages	06 (100)[1]	48
12.	1980-2023	Bangladesh	06	6354	-	998 (15.7)	39+

[1]Sick animals are slaughtered for meat consumption E = Elephant *64 districts VHD = Vet Hos. data 39+ = 6 articles

In Bangladesh, humans are mainly affected by a cutaneous form of anthrax. The Institute of Epidemiology, Disease Control and Research (IEDCR) has maintained the list of outbreak investigations done by IEDCR since 2007. In addition to journal reports, all other available reports, including IEDCR reports on cutaneous anthrax in humans, are also collected and analyzed (Tables 6-9).

Table 6. Reported cutaneous anthrax outbreaks in humans in Bangladesh[8]

S/N	Outbreak year	Location / Districts	No. of outbreaks	Site of outbreaks	No. of human affected	Ref. No.
01.	1982-'84	Pabna Milk Shed Area	002	Villages	027	46
02.	2009	Santhia, Pabna & Shahjadpur, Sirajgonj	002	Villages	055	57
03.	2010	12 districts	012	Villages	607	57
04.	2011	7 districts	007	Villages	278	57
05.	2009-10	Pabna, Sirajgonj & Tangail	014	Villages	273	47
06	2009-10	Pabna, Sirajgonj & Tangail	014	Villages	273	55
07.	2010	Sirajgonj	008	Dairy farms	219	43
08.	2011	Pabna, Sirajgonj, Bogra, Faridpur, Meherpur, Tangail	122	-	002	51
09.	2011	Rajshahi Medical College Hospital, Rajshahi	Case reports	Hospital	015	56
10.	2010-12	Sirajgonj	-	Upazilas	258	49
11.	2012	Sirajgonj, Kushtia, Bogra, Tangail & Meherpur	005	-	176	57
12.	2012	Sirajganj, Pabna and Tangail	003	-	039	52
13.	2013	Sirajgonj, Tangail, Meherpur, Chuadanga	005	-	327	57
14.	2014	Sirajgonj, Narayanganj, Meherpur, Tangail	004	-	225	57
15.	2015	Meherpur, Naryanganj, Rajshahi, Kushtia	004	-	189	62
16.	2013-16	Rajshahi, Meherpur, Kustia, Sirajgonj & Tangail	-	17 villages	-	61
17.	2016	Rajshahi	Case reports	-	013	63
18.	2016	Sirajgonj, Meherpur, Tangail, Kushtia & Rajshahi	009	Upazilas	-	57
19.	2017	Rajbari	001	C & H	017	64
20.	2016-17	Sirajgonj, Tangail & Rajbari	004	Upazila	070	48
21.	2023	Meherpur, IDH Dhaka (Oculocutaneous)	002	Hospitals	002	65
22	2024	DMCH, Dhaka (Periorbital lesion)	001	Hospital	001	66
23	2024	Gazipur (Cutaneous anthrax)	001	Hospital	-	66
	Total		**220**	**-**	**3066**	

C & H = Community (n =11) and Hospital (n = 6)

Table 7. Occurrence of cutaneous anthrax cases in humans in different districts in Bangladesh [57]

S/N	Districts	Years of outbreaks and No. of cases 2010	2011	2012	2013	2014	S/N	Districts	Years of outbreaks and No. of cases 2010	2011	2012	2013	2014
01.	Pabna	069	32	-	-	-	09.	Rajshahi	008	21	-	-	-
02.	Sirajgonj	219	65	74	023	42	10.	Narayangonj	012	-	-	-	008
03.	Kushtia	049	-	05	-	-	11.	Laxmipur	025	-	-	-	-
04.	Tangail	026	29	14	077	26	12.	Chittagong	001	-	-	-	-
05.	Meherpur	082	53	67	187	149	13.	Boghra	-	40	16	-	-
06.	Manikganj	008	-	-	-	-	14.	Chapai-Nawabgonj	-	38	-	-	-
07.	Shatkhira	001	-	-	-	-	15.	Chuadanga	-	-	-	040	-
08.	Lalmonirhat	107	-	-	-	-		Total	**607**	**278**	**176**	**327**	**225**

The anthrax outbreaks in animals and humans from 2010 to 2012 in the different upazila in Sirajgonj district showed that the occurrence of anthrax cases in both animals and humans decreased gradually in the succeeding years from 2011 to 2012, which might be due to vaccination campaigns in the earlier year and motivational activities about the transmission of the disease in animals and humans (Table 8).

Table 8. Occurrence of the number of anthrax cases in ruminants and humans from 2010 to 2012 in the Sirajgonj district in Bangladesh[8,55,60]

S/N	Risk factors	2010 Animals	2010 Humans	2011 Animals	2011 Humans	2012 Animals	2012 Humans	Total Animal	Total Humans
A.	Upazila								
1.	Belkuchi	056	054	015	00	07	22	078	076
2.	Chouhali	000	000	000	00	00	00	000	000
3.	Kamarkhanda	010	099	001	00	02	00	013	099
4.	Kazipur	000	000	000	00	00	00	000	000
5.	Raiganj	000	000	000	00	01	00	001	000
6.	Shahazadpur	042	056	006	65	06	52	054	173
7.	Sirajgonj Sadar	000	000	000	00	00	00	000	000
8.	Tarash	000	000	000	00	00	00	000	000
9.	Ullapara	003	010	006	00	04	00	013	010
	Total	**111**	**219**	**028**	**65**	**20**	**74**	**159**	**358**
B.	Host species								
1.	Cattle	096	-	024	-	18	-	**138**	-
2.	Buffalo	002	-	000	-	00	-	**002**	-
3.	Goat	011	-	002	-	02	-	**015**	-
4.	Sheep	002	-	002	-	00	-	**004**	-

Table 9. Major characteristics of bovine and cutaneous human anthrax cases recorded in three districts* during 2016 and 2017 in Bangladesh[48]

S/N	Characteristics	Bovine anthrax (n = 6)	S/N	Characteristics	Human anthrax (n = 70)	SN	Characteristics	Human anthrax (n = 70)
1.	Fever	6 (100)	**A.**	**General signs**		**B.**	**Site of skin lesion**	
2.	Fallen on the ground	6 (100)	1.	Skin lesion	70 (100)	1.	Back side	03 (03.20)
3.	Loss of appetite	6 (100)	2.	Itching skin	50 (71.43)	2.	Upper arm	15 (16.00)
4.	Bloody diarrhea	6 (100)	3.	Fever	30 (42.86)	3.	Lower arm	32 (34.00)
5.	Muscle tremor	4 (66.67)	4.	Headache	27 (38.57)	4.	Finger	44 (46.00)
6.	Respiratory distress	3 (50.00)	5.	Nausea	13 (18.57)	**C.**	**Source of infection**	
7.	Slaughtered sick animals	6 (100)	6.	Abdominal pain	03 (04.29)	1.	Slaughtering!	38 (54.30)
8.	Anthrax vaccination	0	7.	Diarrhea	02 (02.86)	2.	Handled!!	32 (45.70)
9.	PMB +ve	6 (100)	8.	Vaccination	0			

*Sirajgonj, Tangail & Rajshahi PMB = Polychrome methylene blue ! = Dressed sick animals !! =Processed meat

Transmission of anthrax

Humans generally acquire zoonotic anthrax directly or indirectly from infected animals or through occupational exposure to infected or contaminated animal products (Fig. 1).

Feeding animals with uprooted and unwashed grass and feeding water hyacinth (*Eichhornia crassipes*) were independent risk factors for anthrax in cattle.[52] Another study reported that the cattle became sick after eating Kolmi shake (water spinach) collected from a nearby flooded area.[64]

Smallholder livestock farmers often slaughter ruminant animals that are in a moribund state, even those affected by anthrax, and subsequently sell the meat of anthrax-affected animals to compensate for financial losses. Slaughtering and butchering anthrax-infected animals and contact with contaminated raw meat, blood, hides, and skins are the key risk factors for human cutaneous anthrax in Bangladesh.

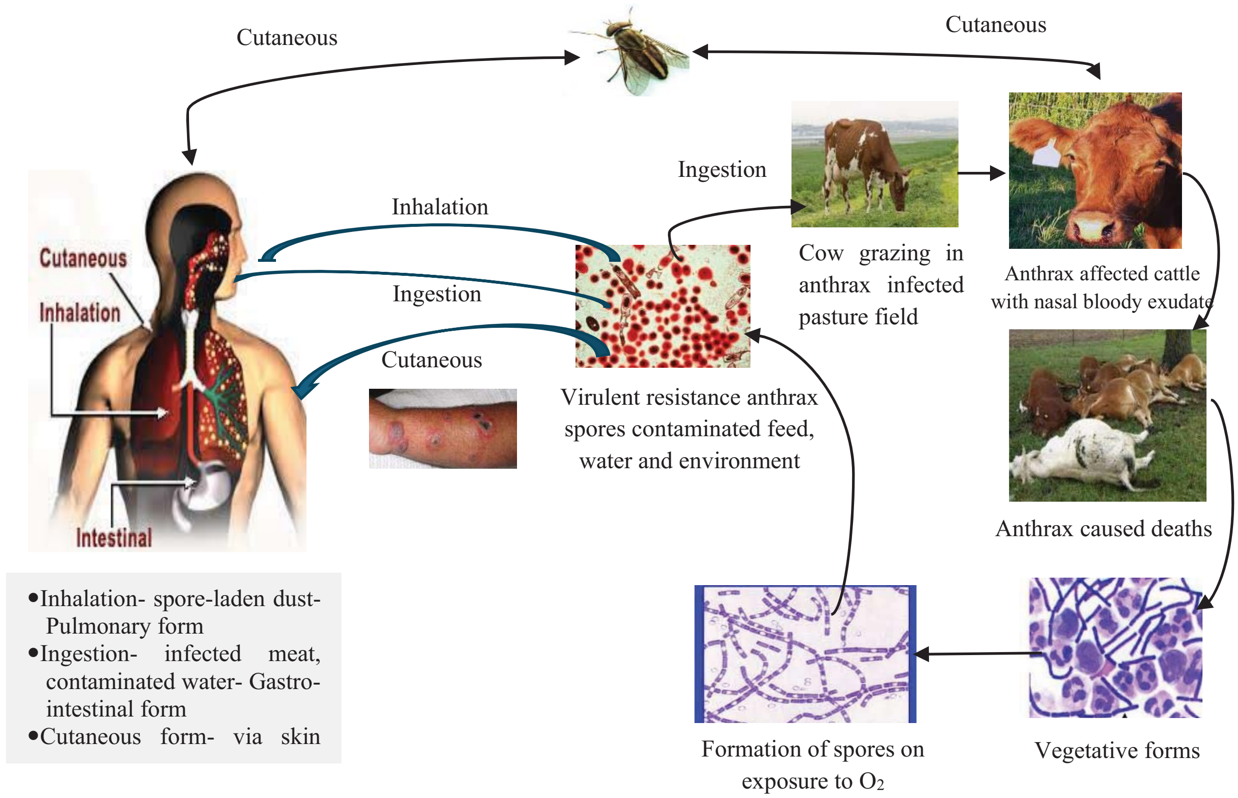

Fig. 1. Transmission cycle of zoonotic anthrax in cattle and humans

Of the 11 cases of cutaneous anthrax in humans, five females cleaned meat, nine males butchered the animals, three males carried the meat of infected animals, and 59% of affected humans had lesions on their hands.[64]

A surveillance study recorded 104 animal cases of anthrax and 607 associated human cases in the eight investigated dairy farms in the district of Sirajgonj in 2010. The anthrax causative agent *Bacillus anthracis* was recovered from soil samples and turbinate bones on six farms. Of the 17 soil samples collected from burial sites and three from turbinate bones, 13 (76.47%) and three (100%) samples were positive for *B. anthracis,* respectively, with the highest number of isolates in a turbinate bone.[43]

Animal owners usually slaughtered anthrax-affected moribund animals, ate the meat, and sold it to neighbors; skinners removed and sold hides from discarded carcasses and disposed of butchering waste and carcasses in environments where ruminants live ambient and graze, combined with limited vaccination, provided a context that permitted repeated anthrax outbreaks in animals and humans.[47] Another study reported that sick animals on the farm or a nearby farm slaughtered in the recent past, a history of heavy rains occurring in the last two weeks preceding an outbreak, and disposal of dead animals into nearby water bodies were independent risk factors for anthrax outbreaks in cattle.[59]

Anthrax spores could be isolated from 11.67% (n = 14/20) of the soil samples collected from the previous outbreaks of anthrax in the districts of Sirajgonj, Bogra, Kushtia, Tangail, and Mymensingh in Bangladesh.[53] Another study showed that 7 of 50 soil samples contained anthrax spores.[67] The soil of Sirajgonj district showed 29.17% (n = 14/48) positive for *B. anthracis* spores.[68] Inadequate washing of grasses collected with contaminated soil and the occurrence of flood in the study area have been reported to be significantly correlated with anthrax outbreaks.[69]

This study revealed that poor knowledge, lack of awareness, improper carcass disposal, inadequate vaccination, high calcium content and moisture in the soil, high ambient temperature, and rainfall during the anthrax-prone season were the possible factors of repeated anthrax outbreaks in the investigated areas.[53] Another study showed that increasing the ambient temperature and the occurrence of heavy rainfall as well as cloud coverage and wind speed acceleration in the monsoon season, significantly contribute to the anthrax outbreaks in Bangladesh.[70]

Most people (91%) affected with cutaneous anthrax had a history of butchering sick animals for meat, handling raw meat, having contact with animal skin, or being present at slaughter ring sites were the risk factors for human infections. The identical *Bacillus anthracis* genotypes were isolated and identified in animal and human cases.[55]

An investigation of anthrax in humans and animals in four villages in the district of Sirajgonj showed that 49.8% of animals, 44.0% of humans, and 6.2% of birds were affected by anthrax.[54] Limited community people (2.9 to 20.9%) obtained information on anthrax outbreaks in animals and humans from media, NGO workers, and community health workers.[54] The control of anthrax in humans depends on infection control in animals. In addition to veterinary medical extension services and hygienic management, targeting at-risk animal populations for vaccination against anthrax may be the most effective strategy to reduce anthrax outbreaks in animals, which protects the supply chain and reduces the risk of exposure to *B. anthracis* in humans.[71]

Another study suggested proper grass washing, increased awareness towards zoonosis of anthrax and vaccination, and proper treatment by veterinarians should be ensured to reduce anthrax outbreaks in Bangladesh.[72] Approximately 71.5% of cattle owners have reported having a level of awareness of anthrax, and 79.2% of cattle owners would not consume meat from dead animals and suggested introducing meat inspection services to prevent human anthrax outbreaks.[73]

The immunization of cattle with locally available anthrax spore vaccine showed a high level of anti-anthrax IgG antibody at day 30 and reached its peak at day 90 of post-immunization. Anthrax vaccine bacteria has been reported to be sensitive to penicillin, streptomycin, amoxicillin, and kanamycin, and therefore, anthrax-vaccinated animals should not be treated with drugs at least 90 days of vaccination.[74] A similar immunization experiment in goats showed peak IgG antibody levels at day 30 and maintained that level up to the end of the study at 90 days of immunization.[75]

Anthrax is an emerging zoonotic bacterial disease in Bangladesh.[76] In addition to ruminant animals and humans, it has occasionally been reported death in a zoo elephant[58] and a Safari Park tiger[77] in Bangladesh. Human anthrax exposure to by-products from animals suspected to have died of anthrax in Bangladesh has been reported.[61] Factors associated with repeated outbreaks of anthrax in Bangladesh have also been reported.[78] The use of Novel multiplex PCR for rapid detection of *B. anthracis* spores present in soil and genotype of *B. anthracis* strain circulating in Bangladesh have been reported.[79,80]

Anthrax is a preventable disease caused by vaccines and can be treated with antibiotics; however, specific control procedures on carcass disposal are necessary to contain the disease and prevent its spread.[81] Management of anthrax-infected sick animals and carcasses, as well as antibacterial therapy and vaccination, are the major methods for preventing and controlling anthrax in animals. Management measures include the correct disposal of carcasses, disinfection and decontamination of contaminated materials, and decontamination of the environment. Ruminant livestock animals respond well to penicillin injections if treated in the early stages of the disease, and oxytetracycline injection daily in divided doses was also reported to be effective. Anthrax can be controlled largely by the annual vaccination of all grazing animals in the endemic areas. Vaccination should be done at least 2-4 weeks before the season when outbreaks may be expected. Zoonotic anthrax in humans is controlled by the control of anthrax in food animals, veterinary supervision of food animal slaughter, and meat processing to reduce human contact with infected animals and animal products. The epidemiology of anthrax involves environmental components, livestock animals, wildlife, and human components. This makes anthrax an ideal example for discussion in the One Health concept.[82]

An integrated approach has been sought to establish an anthrax-free model, which included regular vaccination of ruminant animals, increased public awareness, rapid confirmatory diagnosis, prompt disposal of carcasses, setting up an effective surveillance system, developing an emergency prevention system, enforcing regulations, and enhancing veterinary services' collaboration. Implementing the anthrax-free model showed that most community members (97.5%) were aware of the nature, occurrence, importance of public health, and management of the disease. The risky habits and attitudes of the farmers toward slaughtering sick cattle reduced significantly (< 85.0%). Vaccination coverage expanded from 40 to 85%, and animal farmers who can presumptively diagnose anthrax clinically have increased from 30 to 85%. The soil of the grazing land contaminated with pathogenic anthrax spores was restricted for either grazing or feeding grasses of the land to cattle. Slaughtering of cattle in the model area was performed after an ante-mortem examination by a qualified veterinarian in locally set-up slaughterhouses. A committee with members from the administration, law enforcement agencies, local government, livestock, health departments, and political elites monitored this disease control program in the model area. As a result of these works, the model area has been free of anthrax infection for four years. This anthrax research finding concluded that the integrated approach is an efficient, effective, and suitable method to establish an anthrax-free model area where there will be no anthrax.[83]

Tuberculosis

The name tuberculosis comes from the nodules, called 'tubercles,' which form in the lymph nodes and other affected tissues of affected animals. Tuberculosis is caused by several closely related bacteria in the *Mycobacterium tuberculosis* complex in mammals, which are Gram-positive, acid-fast bacterial rods in the family *Mycobacteriaceae*. The Mycobacterium organisms maintained in animals include *M. bovis* (bovine tuberculosis, bTB), *M. caprae* (caprine tuberculosis, cTB), *M. pinnipedii, M. orygis*, *M. microti, M. caprae*, and *M. pinnipedii* and *M. orygis* were a member of *M. bovis* before being designated separate species these occasionally affect pets, zoo animals, free-living wildlife and people, whereas *M. tuberculosis* and *M. africanum* are maintained in humans but occasionally affect animals.[84] However, the taxonomy of the *M. tuberculosis* complex can be controversial and M. bovis and *M. caprae* are sometimes called *M. bovis subspecies bovis* and *M. subspecies caprae*, respectively. Some authors argue that all the organisms in the *M. tuberculosis* complex should be considered a single species due to their close genetic relationships. Under this system, *M. bovis* and *M. caprae* would be renamed *M. tuberculosis* subspecies bovis and *M. tuberculosis subspecies caprae*.[85] Accordingly, most of the species in the M. tuberculosis complex, including M. bovis, *M. caprae*, *M. origins*, *M. pinniped*, and *M. microtia*, are zoonotic shares between humans and animals.[84]

Although human tuberculosis is one of the listed priority diseases, zoonotic tuberculosis (TB) remains poorly monitored and a critical, unaddressed, neglected global human and animal health problem. There is a higher incidence of zTB in low-income, under-developing, and developing countries, especially Africa and South Asia, including Bangladesh, where dairy products are consumed unpasteurized.[86]

A retrospective study of dairy cattle mortality on the Central Cattle Breeding and Dairy Farm (CCBDF) between 1992 and 2007 reported a 5.60% average overall mortality rate, with most deaths caused by diseases of the respiratory tract, mainly pneumonia (39.91%) followed by tuberculosis (20.58%) in death cattle.[87] Some cross-sectional surveys have reported an 8 to 27% prevalence of bTB in cross-bred cattle using the standard tuberculin test in Bangladesh.[88-91]

Zoonotic tuberculosis (zTB) is a form of tuberculosis in humans, predominantly caused by *Mycobacterium bovis* but to a lesser extent by *M. tuberculosis*, *M. caprae* and *M. orygis* (*Mycobacterium tuberculosis* complex, MTC.[92,93] Recently, the detection of *M. orygis* from cattle, captured monkeys, and humans originating from South Asia potentially indicates endemic distribution in South Asia.[93] *M. bovis* causes chronic TB in cattle (bTB); however, it may cause infection in goats and other mammalian species,[94] impacting milk and meat production in these animals. Humans can be infected with zTB via direct contact with infected animals, airborne transmission, or by consuming contaminated raw milk or meat.[95] Specific groups such as veterinarians, farmers, cattle handlers, slaughterhouse workers, and butchers are at occupational risk for zTB.[96-98]

Tuberculosis (TB) is an infectious disease caused by *Mycobacterium tuberculosis*, causing the highest number of deaths as a single infectious agent globally.[99] Approximately 10 million people were infected with TB globally, 79% were in the 30 high-burden countries, and 1.2 million people died from TB in 2019.[99] Each year, tuberculosis claims more than 38,000 people's lives in Bangladesh, and among every 100,000 individuals, 221 new cases of TB are identified annually, resulting in 24 deaths.

Bangladesh ranks seventh among the 30 countries with the highest risk.[100] Approximately 80% of all TB cases in Bangladesh are pulmonary TB.[101] The Global TB Report 2020 estimated that 0.7% of new cases and 11% of previously treated cases are found to be positive for multi-drug-resistant TB (MDR-TB), which has an incidence rate of 2.0 per 100,000 population in Bangladesh.[99] bTB is endemic to Africa, South Asia, and Central and South America and significantly more prevalent in dairy cattle.[102] Of the 188 countries and territories reporting their bTB situation to the OIE, 82 countries (44.0%) were affected. Of the 82 affected countries, 29 (35.4%) reported bTB in livestock and wildlife. Two (2.4%) countries reported bTB present only in wildlife, compared to 51 (62.2%), which indicated that only livestock was affected.[103] Over 50 million cattle are infected worldwide, and it is estimated that economic losses due to bTB add up to about US$ 3.0 billion annually.[104] An estimated 140,000 new cases and 11,400 deaths occurred due to zTB in humans in 2019 in the world. In contrast, there were 43,400 cases and 2,020 deaths caused by bTB in Southeast Asia, including Bangladesh.99 Zoonotic tuberculosis in humans is caused mainly by *M. bovis*, which remains neglected in developing countries, including Bangladesh, where the actual status of the zTB is underestimated due to limited epidemiological reports.[105,106] In addition, the impact of zTB on human health has also been underestimated in the national tuberculosis control program in Bangladesh. This bacterium is usually transmitted in humans through close contact with infected cattle and consumption of unpasteurized milk.[105] Cattle are the main reservoir of *M. bovis*, which remains latent but occasionally produces lesions characterized mainly by cervical lymphadenopathy, intestinal lesions, and chronic skin lesions like lupus vulgaris.[106]

The overall animal-level prevalence of bTB has been estimated to range from 2 to 11.3% in Bangladesh (Table 10).[89,90,107,108] The yearly reports on the prevalence of bTB in Bangladesh submitted to WHO revealed that the disease is endemic in animals in Bangladesh.[109] This zoonotic disease has a dual impact on human and animal health, and the effects on animal health are associated with reduced milk and meat production, intensifying poverty in marginalized animal farmers.[91] The milk of infected cows may contain *M. bovis*. Although consumption of raw milk is rare in humans, it is not uncommon. In contrast, the milk pasteurization system is inadequate to meet Bangladesh's human consumption demand.[91] However, pasteurization system is inadequate to meet Bangladesh's human consumption demand.[91] However, pasteurized milk and meat occasionally contain this organism, but Ultra Heat Treatment (UHT) could destroy most of the contaminated bacteria in milk, including TB organisms.[110] Moreover, the demand for milk has increased due to rapid urbanization in Bangladesh, influencing the farmers to rear high-yielding crossbred cows. Still, these exotic and their cross-bred have been reported to be more susceptible to bTB than zebu cattle.[111]

The major drawback of the tuberculin skin test (TST) is the inability to detect the energy state of the animal, which is a failure to detect the latent stages of infection and to distinguish between vaccinated and infected individuals.[112] The IFN-γ assay (Bovigam®) can detect very early stages of the disease by producing IFN-γ in (*in vitro*) stimulated blood samples. It can be used as a promising biomarker in cattle TB diagnosis.[113] The use of both the SICTT and IFN-γ assay in parallel increased the sensitivity of bTB detection (~ 94%) compared with SICTT alone.[114,115] The result of the PCR technique revealed that out of nine bovine samples, seven (88.0%) gave an amplified band, indicating positive and higher sensitivity of the method.[116]

Table 10. Prevalence of zoonotic tuberculosis in humans and animals in Bangladesh

S/N	Reagent used/ Species	Name of host	No. of hosts tested	Source of hosts	Test used	Positive No. (%)	References No.
01.	*M. bovis*	Cattle	009	Savar &BAUDF	PCR	07 (88.0)	116
02.	bPPD & aPPD	Sheep	273	Dinajpur	CFT	25 (09.15)	117
					CCTT	04 (01.46)	
		Goats	155	(Parbotipur)	CFT/CCTT	02 (01.29)	
03.	bPPD	Cattle ½ -1yr L	39	Rangpur	CFT	06 (02.34)	118
		C	10	Rangpur	CFT	01 (0.10)	
		Cattle 5-7yr L	71	Rangpur	CFT	27 (19.17)	
		C	30	Rangpur	CFT	03 (00.90)	
04.	bTB	Cows (milk)	300	Sylhet	PCR	37 (12.33)	119
	bTB	Human (sputum)	90	Sylhet	PCR	06 (06.67)	119
05.	*M. orygis*	Cattle	18	Dairy farms	PM & molecular	18 (100)	93
		Monkeys	02	Zoo		02 (100)	
06.	bPPD	Cattle	183	BLRI cattle	Caudal fold TT	16 (08.74)	120
	aPPDd		183	BLRI cattle	CCTT	13 (07.10)	
				BLRI cattle		03 (01.64)	
		RCC	044	BLRI cattle	Caudal fold TT	0	
		Local Pabna	133	bPPD	Caudal fold test	13 (09.77)	
		Cross	006	bPPD	Caudal fold test	0	
		Lactating	067	bPPD	CFT	07 (10.45)	
		Dry cows	043	bPPD	CFT	01 (02.32)	
		Heifers	021	bPPD	CFT	02 (09.52)	
		Calf	052	bPPD	CFT	03 (05.77)	
07.	bPPD	Dairy cattle	1865	5 districts	SICTT	211 (11.30)	121
08.	bPPD	Dairy cows	470	3 districts	CFT	101 (21.49)	122
09.	CFT +ve	Dairy cows	101	3 districts	CCT (bPPD, aPPD)	36 (07.66)	122
10.	Serotest (bTB)	Dairy cattle	570	3 districts	BART	05 (0.88)	122
11.	Microscopic	MBT	138	3 districts	Zeihl-Neelsen staining	07 (07.97)	122
12.	bPPD	Sheep	140	Dinajpur district	CFT	07 (5.0)	123
13.	bPPD	Cattle	510	Mymensingh	CFT	105 (20.6)	124
					CCTT	037 (07.3)	

Contd. Table 10. Prevalence of zoonotic tuberculosis in humans and animals in Bangladesh

S/N	Reagent used/ Species	Name of host	No. of hosts tested	Source of hosts	Test used	Positive No. (%)	References
14.	bPPD	Buffaloes	180	Bhola	SIDT	06 (03.33)	125
15.	*M. bovis*	Cattle	512	Sylhet district	CFT	01 (00.19)	126
16.	bTB	Cattle	442	Chattogram	ELISA	33 (07.5)	127
17.	bPPD	Cattle	577	Dhaka city	SICTT	81 (14.2) +ve 44 (7.6) ± 452 -ve	114
			63+ve 08 ± 03 -ve	Dhaka city	IFN-γ assay -ELISA	52 (82.54) 05 (62.50) 01 (33.33)	
18.	bPPD	Cattle	*125 +ve 17 ± 06 -ve	Dhaka city	IFN-γ assay ELISA	104 (83.2) 11 (64.7) 01 (16.67)	115

*SICTT = Single intradermal comparative tuberculin test ± Inconclusive CFT = Caudal fold test
5 districts= Dhaka, Gazipur, Munshiganj, Mymensingh & Jamalpur 3 districts = Mymensingh, Sirajgonj & Dhaka
CCTT = Comparative cervical tuberculin test BART = Bovine antibody rapid test MBT = Milk, blood & tissue

Risk factors of zoonotic TB

The risks of bTB have been reported to be 3.3 times higher in non-grazing than grazing cows, 2.9 times higher in cross-bred than indigenous cows, and 2.3 times higher in cows with cough than cows without cough.[97] In the Comparative cervical tuberculin (CCT) test, the reactors were 0.36%, 1.29% for bTB, 1.09%, 1.29% for aTB, and 0%, 1.29% for mixed type for the sheep and goats, respectively. In addition, the Jamunapari (2.85%) goat breed had 3.5 times higher percentages of reactors than the Black Bengal (0.83) breed.[117] The bTB and aTB may cause dangerous effects on human health as well as livestock in Bangladesh so prevention and eradication steps must be taken against tuberculosis.

Transmission cycle of zoonotic tuberculosis

Fig. 2 shows the transmission cycle of zoonotic tuberculosis between humans and animals.

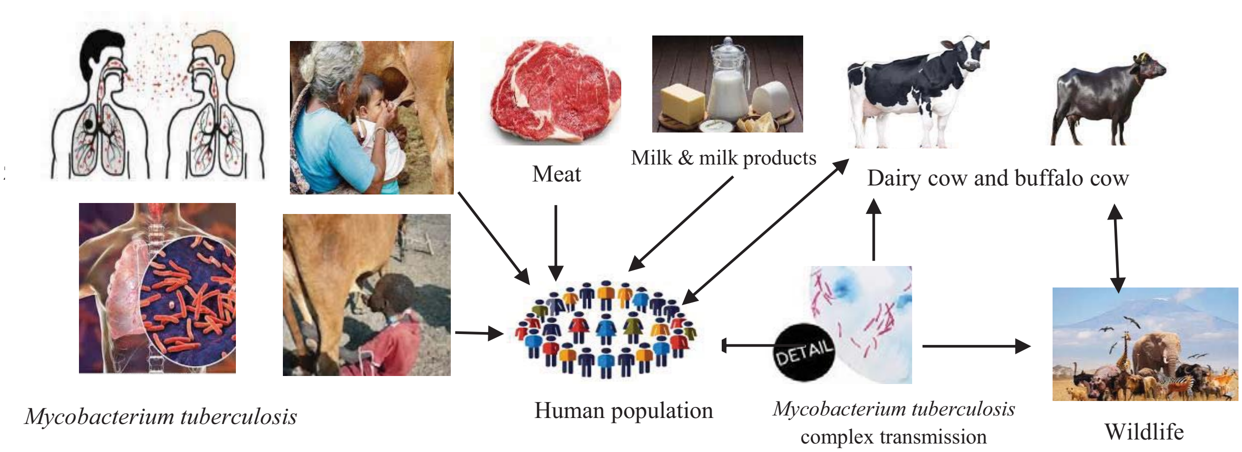

Fig. 2. Transmission cycle of zoonotic tuberculosis between humans and animals

Reverse zoonoses – human-to-animal transmission (Zooanthroponoses)

A reverse zoonosis, also known as zooanthroponosis (Greek 'zoo' means 'animal' 'anthropos' means man, 'nosis' means disease). Zoonotic diseases are caused by pathogens occasionally transmitted to animals from humans and then back from animals to humans, which are reverse zoonoses (Table 11).[10] A global increase in commercial animal production, the rapid movement of humans and animals, and the habitats of humans and wild animals intertwining with great complexity, the future promises more opportunities for humans to cause reverse zoonoses.

Table 11. Some examples of bacterial reverse zoonoses[10,] e89055

S/N	Agent	Human diseases	Animal diseases	Animal affected
1.	*Mycobacterium tuberculosis*	Tuberculosis	Tuberculosis	Deer, dogs
2.	Mycobacterium bovis	Tuberculosis	Bovine tuberculosis	Wildlife
3.	Methicillin resistant *S. aureus*	Endocarditis, pneumonia	Mastitis	Livestock (Cattle)
4.	*Str. pyogenes, Str. pneumoniae*	Pharyngitis, pneumonia	Mastitis, meningitis	Cattle, NHP
5.	Campylobacter, Salmonella	Diarrhea	Diarrhea, salmonellosis	Livestock, Wildlife
6.	Escherichia coli	Diarrhea, UTI, pneumonia	Colibacillosis	Pets, livestock
7.	*Corynebacterium diphtheriae*	Diphtheria	Ulcers on teats, mastitis	Cattle

M. bovis and *M. tuberculosis* have been reviewed as reverse zoonoses between humans and bovines.[86] *M. tuberculosis* (MANU strain) was reported to be more prevalent in cattle than *M. bovis* in India.[128] Analysis of data from 61 countries on the occurrence of zoonotic *M. bovis* infection in humans found a median of 1.4% in connection with overall TB incidence ≤ 71 / 100,000 population /year in regions outside Africa, whereas in the areas in Africa, the median rate of zoonotic TB cases 2.8% with an overall TB incidence 264/100000 population per year, which resulted in a crude estimate of 7 zoonotic TB cases /100,000 population/year.[105] Zoonotic *M. bovis* infection has been detected in human sputum and bovine milk using the PCR technique in Bangladesh119, indicating the risk of zoonotic transmission between humans and cattle (Table 11). Rearing of livestock in households, unpasteurized milk consumption, and smoking were identified as potential risk factors for zoonotic *M. bovis* transmission in Bangladesh.[119] Inappropriate practices of the animal owners and handlers, especially not using protective devices (98%), smoking, drinking or eating food whilst working with cattle (69%), and sharing the same premises with animals (83%) were identified to be associated with zoonotic tuberculosis in Bangladesh.[97]

Mycobacterium orygis was first reported as a causative agent of TB in an oryx (*Oryx gazelle*, Family: *Bovidae*) in 1987 from a captive oryx in the Netherlands Zoo.[129] Subsequently, this organism and other genetically similar bacteria were named *M. orygis* in 2012 and recognized to be a distinct member of the MTBC.[130] *M. origins* has been isolated from captive spotted deer, blue bull, and free-ranging rhinoceros in Nepal,[131,132] from rhesus monkeys and cattle in Bangladesh,[93] from cattle in South India,[133] spotted deer in Western India and bison in central India[134] and it has since been identified in many other species.[86] It has been detected in 18 cattle from a dairy farm and two captured rhesus macaques (*Macaca mulatta*) in a zoo that died of TB in Bangladesh.[93] In contrast, human disease due to *M. orygis* has been chiefly described on other continents. This includes one reported case of human-to-animal transmission from New Zealand,[135] eight cases of human tuberculosis in Australia,[136] a human case of lymphadenitis due to *M. orygis* in the USA,[137] a retrospective of 24 clinical isolates of *M. orygis* from the UK[138] and five instances in Morway.[139]

M. orygis is a genetically distinct animal-adapted subspecies of the *M. tuberculosis* complex that causes tuberculosis in animals and humans.[129] It has been isolated from many animals, including livestock, zoos, and free-ranging wild animals, suggesting endemicity in South Asian countries.[93,129,131,132] Direct evidence of *M. orygis* transmission between livestock and humans has been reported from an Indian immigrant working on a cattle farm in New Zealand.[135] Similarly, it has also been reported in immigrants from India, Nepal, and Pakistan who live in the USA which also indicates the origin of this bacterial infection in South Asia.[134,135] Recently, eight human cases of TB due to *M. orygis* were isolated from 1105 patients attending Christian Medical College Hospital, Vellore, India.[140]

Reports of tuberculosis caused by *M. orygis* in animals and humans in South Asia, and the discovery of *M. orygis* in South Asia migrants, highlight an overlooked threat from *M. orygis* in South Asia and beyond.[141] More recently (during February- May 2023), an outbreak of tuberculosis caused by *M. orygis* has been detected during CDC quarantine among 26 cynomolgus macaques (*Macaca fascicularis*) from a shipment of 540 imported from Southeast Asia to the United States for research purposes.[142] The occurrence of new zoonotic *M. orygis* in South Asia and Africa warrants urgent surveillance to clarify the epidemiology of the *M. tuberculosis* complex at the human-livestock-wildlife interference with assessing prevalence, potential drivers, and risk to develop appropriate interventions.

Seroprevalence, risk factors, economic importance,[143-145] hematobiochemical changes,[146] prevalence of bTB and its effects on milk production147, and significance of bTB on human health[148] have been reported. In addition, isolation and identification of *M. tuberculosis* from pulmonary lesions[149] and detection of specific causes of bTB[150] have also been reported. Humans, livestock, wildlife, and ecology are involved in the epidemiology of zoonotic tuberculosis (zTB), and accordingly, the 'one health' approach is the ideal concept for the control of this zoonotic disease.

Brucellosis

Brucellosis is an ancient and one of the most widespread zoonotic diseases affecting global public health and animal production. Although brucellosis has been controlled in most industrially developed countries, it remains an endemic neglected zoonotic disease in many under-developing and developing countries of Asia, Africa, and Latin America, including Bangladesh. It is one of the hidden dangers in both animal and human health, caused by intracellular bacteria of the genus Brucella. Brucella infection usually persists as a carrier and latent infection with an asymptomatic state, but in infected pregnant animals, it causes abortion and infertility. Brucella organisms reported to have zoonotic importance include *Brucella melitensis*, *Brucella abortus*, *Brucella suis*, and *Brucella* canis.[151]

The transmission of Brucella in humans is either because of occupational exposure or consumption of unpasteurized milk and dairy products. Zoonotic brucellosis causes a chronic debilitating illness with fever, sweating, fatigue, weight loss, headache, and joint pain. In contrast, Brucella *abortus*, especially in dairy cattle, causes abortion in the last trimester of gestation and infertility.[151] Since the first report on brucellosis was published in the then East Pakistan (now Bangladesh) in 1970, many reports on brucellosis seroprevalence in different species of animals and humans, even some reviews of seroprevalence on brucellosis in animals and humans have been reported from Bangladesh.[35,36] However, the sensitivity and specificity of these used sero-tests for detecting seroprevalence of brucellosis are varied. The i-ELISA and SAT have been suggested to detect seroprevalence of brucellosis in animals for serial interpretation for culling and parallel interpretation for import decisions (Table 12).[152] In addition, most of the articles on seroprevalence of brucellosis have tried to discover the risk factors associated with seroprevalence of brucellosis in both animals and humans. The seroprevalence of brucellosis has been reported to be varied based on occupations of people (2.5 to 18.6%) and species of animals (3.7% in cattle, 4.0% in buffalo, 3.6% in goats, and 7.3% in sheep). The occupational influence on the seroprevalence of brucellosis has been reported as 2.6 to 21.6% in livestock farmers, 18.6% in milkers, 2.5% in butchers, and 5.3 to 11.1% in

Table 12. Reported seroprevalence of brucellosis in cattle in Bangladesh

S/N District	No. of cattle tested	Tests used and Prevalence No. (%) TAT	RBT	PAT	RBATK	iELISA	cELISA	PCR	BAA	BMA	Ref. No.
01. Mymensingh	412	76 (18.4)	-	-	-	-	-	-	-	-	153
02. Chittagong, Comilla, Jeshore, Manikgonj	350	TAT	RBT	PAT	-	-	17 (4.9)	-	-	-	154
03. Mymensingh	250	TAT	RBT	PAT	-	05 (2.0)	-	-	-	-	155
04. Mymensingh	120	TAT	RBT	PAT	-	04 (3.3)	-	-	-	-	156
05. Chittagong	500	-	25 (5.00)	-	-	25 (5.00)	-	-	-	-	157
06. Mymensingh	200	09 (4.5)	08 (4.00)	-	-	-	-	-	-	-	158
07. Mymensingh	200	-	-	-	-	-	-	-	10 (5.0)	01 (0.5)	159
08. Bagherhat, Bogra, Gaibandha, Mymensingh & Sirajgonj	188	-	04 (2.13)	-	-	5 (2.66)	-	-	-	-	160
09. Bagherhat, Bogra, Gaibandha, Mymensingh & Sirajgonj	465	-	-	-	-	04 (0.9)	-	-	-	-	161
10. Mymensingh	135	-	02 (1.48)	-	-	02 (1.5)	-	-	-	-	162
11. Bogra	060	-	0	-	-	0	-	-	-	-	162
12. Bagherhat	090	01(1.10)	01 (1.11)	-	-	-	-	-	-	-	162
13. Gaibandha	070	-	0	-	-	-	-	-	-	-	162
14. Sirajgonj	110	-	01 (0.91)	-	-	-	-	-	-	-	162
15. Five districts	465	-	04 (0.86)	-	-	-	1 (0.22)	-	-	-	162
16. Mymensingh & Pabna	260	08 (3.07)*	11 (4.23)	-	-	06 (2.31)	-	-	-	-	163
17. Greater Mymensingh	150	-	23 (15.33)	-	-	-	-	-	-	-	164
18. Sirajgonj	270	-	23 (8.51)	-	-	-	-	-	-	-	165
19. Mymensingh	190	-	05 (2.63)	-	-	2 (1.05)	-	-	-	-	166
20. Jessore, Sirajgonj, Dhaka	552	-	18 (3.26)	-	18 (3.26)	18 (3.26)	-	11 (1.99)	-	-	167
21. Dinajpur, Mymensingh	182	-	RBT?	-	-	06 (3.3)	-	-	-	-	168
22. Sylhet	386	46 (11.9)	*36 (9.33)	-	-	-	-	-	-	-	169
23. Bangladesh	-		-	-	-	-	-	-	-	-	170!
24. Mymensingh & Dinajpur	160	-	07 (4.37)	-	-	07 (4.37)	07 (4.37)	-	-	-	171
25. Dhaka	334	-	14 (4.20)	-	-	04 (01.2)	-	-	-	-	172
26. Chittagong	158	-	52 (32.91)	-	-	-	14 (8.86)	-	-	-	173
27. Bangladesh	887	-	34 (3.83)	-	-	-	-	-	-	-	174
28. Mymensingh, Patuakhali	120	-	-	09 (7.5)	-	5.0 (6)	-	-	-	-	175
29. Bangladesh	700	-	38 (5.42)	-	-	-	-	-	-	-	176
30. Dhaka (Savar)	1003	-	43 (4.29)	-	-	-	-	-	-	-	177
31. Three districts	533	-	11 (2.06)	-	-	-	-	-	-	-	178
32. Five districts	1043	-	23 (2.21)	-	-	-	-	-	-	-	179
33. Six districts	913	-	48 (5.3)	-	-	-	-	-	-	-	180
34. Mymensingh	460	-	18 (3.9)	-	18 (3.9)	-	-	-	-	-	181
35. Pabna Milk Shed area	050	-	16 (32.0)	-	-	-	-	-	-	-	182
36. Ten districts	1290	91 (5.1)	44 (4.5)	379 (36.1)	-	-	-	-	-	-	183
Overall	13256 21628	**231 (8.76)** [2638]	**388 (3.52)** [11027]	**388 (27.52)** [1410]	**36 (3.57)** [1012]	**93 (2.69)** [3456]	**39 (3.44)** [1133]	**11 (1.99)** [552]	**10 (5.0)** [200]	**1 (0.5)** [200]	

Three districts = Dhaka (CCBS&DF, MDF, Savar), Mymensingh & Gaibandha

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Five districts = Dhaka (CCBS &DF), Mymensingh, Rangpur, Jamalpur, & Gaibandha

Six districts = Dhaka (CCBSDR, Savar), Mymensingh, Jamalpur, Gaibandha, Tangpur and Bagerhat

Ten districts = Pabna, Faridpur, Bogra, Mymensingh, Jeshore, Rajshahi, Rangpur, Comilla, Manikgonj,& Dhaka (Savar)

*SAT = Serum agglutination test RBT = Rose Bengal Test iELISA = Indirect ELISA cELISA = Competitive ELISA

FPA = Fluorescence polarization assay PAT = Plate agglutination test TAT = Tube agglutination test [ ] = No. of samples tested

RBATK = Rapid Brucella antibody test kit BAA = B. abortus antigen BMA = *B. melitensis* antigen

veterinarians who have direct contact with animals and their products or with those who consume raw milk.[35,36] Dairy farms, animal farm workers, artificial inseminators, slaughterhouse workers, and animal practitioners are at high risk of getting zoonotic Brucella infection.

Table 13. Reported seroprevalence of brucellosis in buffaloes in Bangladesh

S/N	District	No. of buffalo tested	Tests used and prevalence No. (%) SAT	RBT	CFT	iELISA	cELISA	References No.
01.	Bagherhat, Bogra, Gaibandha, Mymensingh & Sirajgonj	105	-	02 (1.90)	-	03 (2.87)	-	160
02.	Bagherhat	070	-	2 (2.85)	-	-	-	162
03.	Bogra	020	-	0	-	-	-	162
04.	Gaibandha	014	-	0	-	-	-	162
05.	Sirajgonj	019	-	1(5.26)	-	-	-	162
06.	Greater Mymensingh	060	-	8 (13.33)	-	-	-	164
07.	Bangladesh	011	-	-ve	-	-	-	174
08.	Different districts	099	-	7 (7.07)	-	-	-	176
09.	Six districts	099	4 (4.0)	7 (.10)	5 (5.1)	4 (4.0)	-	180
10.	Bagerhat & Mymensingh	070	-	4 (5.71)	-	3 (4.28)	-	184
11.	Bangladesh	-	-	2.87	-	-	-	185*
	Overall		**99/4 (4.0)**	**556/38 (6.83)**	**99/5 (5.1)**	**274/10 (3.65)**		

Six districts = Dhaka (CCBDF Savar), Mymensingh, Jamalpur, Gaibandha, Rangpur & Bagherhat
*Article not available on Google search

Prevalence of brucellosis in humans

Studies on brucellosis were initiated for the first time in the then East Pakistan (now Bangladesh) in 1970[153], and up to 2024, approximately 82 reports were published, of which only seven were on humans and six concurrently on humans and animals (Tables 12-20). Most research works were based on seroprevalence using more than a dozen serological and molecular tests. Accordingly, the prevalence of brucellosis in animals and humans has been reported, associated risk factors in animal and human brucellosis and some occupational influences have also been reported, such as zoonotic brucellosis in Bangladesh. Although the outbreak of human brucellosis has been noted elsewhere,[187] clinical cases of brucellosis have never been reported either in animal or human populations in Bangladesh until February 23, 2023. The first outbreak of zoonotic brucellosis has been reported by ICDDR'B scientists who have identified a recent brucellosis outbreak in Teknaf.[188] According to the study, the outbreak has resulted in eight confirmed cases of brucellosis in the area. In 2021, the Teknaf Hospital received 120 patients with symptoms of brucellosis, including fever, joint pain, fatigue, and headache. Seven patients were confirmed to have brucellosis through the triple antigen test and further confirmed by the Taq Man RT-PCR test in Dhaka. An additional confirmed case was identified after collecting 33 more samples, which included an affected small female child. This outbreak of zoonotic brucellosis transmission in humans has been identified as the practice of drinking raw milk by the people residing in Teknaf and accordingly recommended that individuals avoid consuming raw milk from domestic animals in Bangladesh.[188]

Brucellosis is an occupational hazard for livestock farmers, dairy workers, slaughterhouse workers, Laboratory workers, and veterinarians (Fig. 3 & 4). A study was conducted with 500 individuals who had contact with animals, of which 4.4% were affected with occupational Brucella infection. The study emphasized contact with livestock, especially goats, where brucellosis seropositivity was about 60 times higher than contact with cattle only. It appears that goats are a significant risk factor for the transmission of brucellosis among individuals in the high-risk occupational group in Bangladesh.[189]

The true prevalence of brucellosis in livestock farmers and prolonged pyrexia patients has been estimated to be 1.1% in the district of Mymensingh with three sero-tests (i-ELISA, RBT & STAT) with the highest positive predictive value of 36.3% for i-ELISA and 42.7% for RBT in livestock farmers and PPP, respectively.[190]

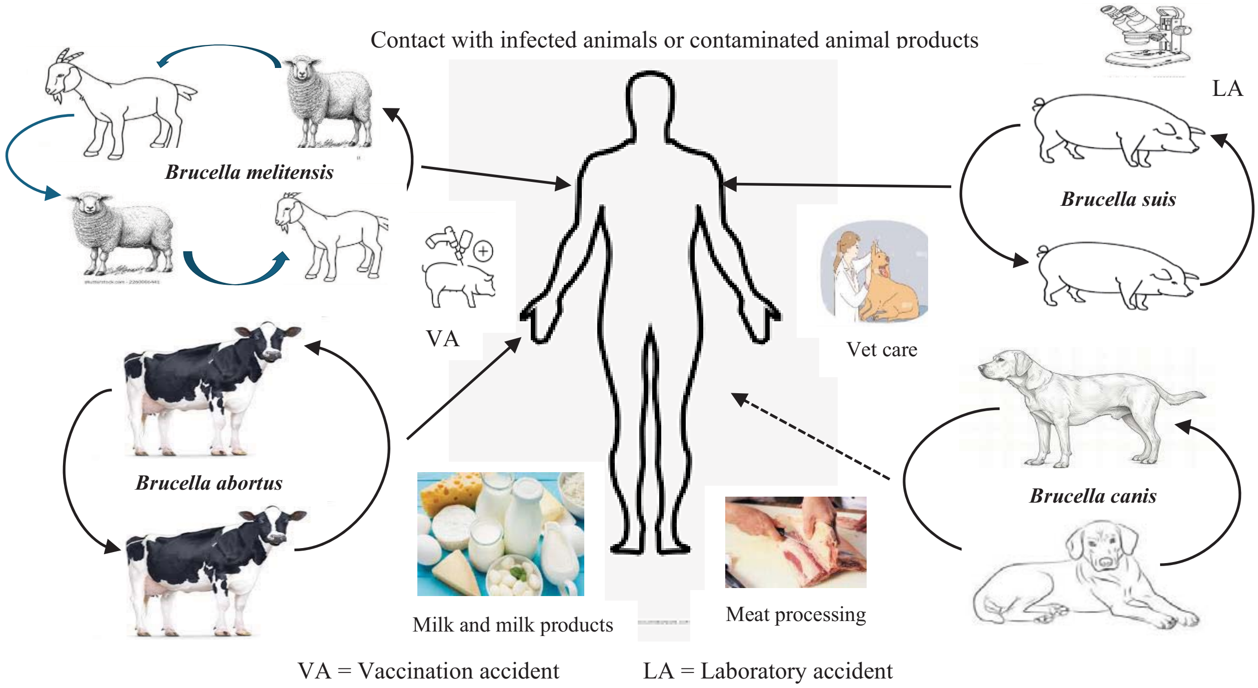


Fig. 3. Zoonotic transmission of Brucella from animals to humans

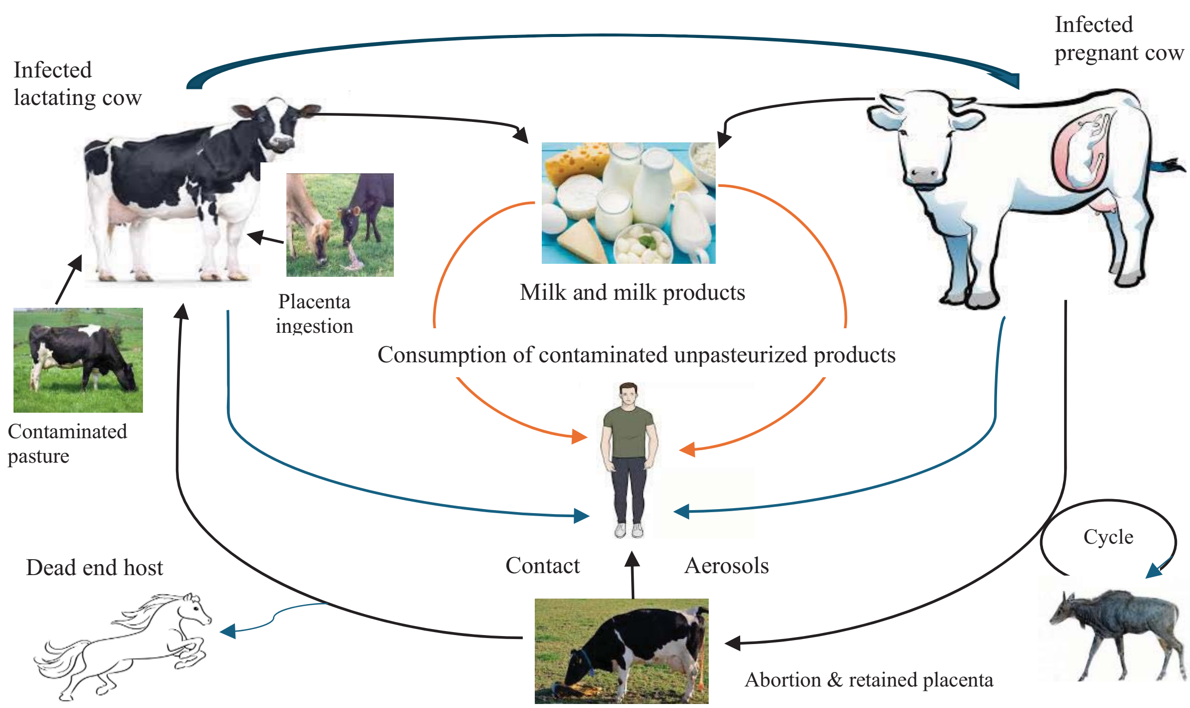


Fig. 4. Zoonotic transmission of brucellosis from animal and animal products to humans

Based on the performance of the three serological tests validated in a setting where the prevalence of brucellosis is low in humans and animals, no single test can be recommended for routine diagnosis of human brucellosis in Bangladesh. Applying a second test with high specificity and/or testing patients with a history of exposure to known risk factors and/or testing patients having some clinical signs and symptoms of brucellosis may increase the positive predictive value of the serologic tests.[190]

Three serological-test-positive human sera (3 out of 500) and all the collected animal serum samples (n = 62) were screened by Brucella genus-specific real-time PCR (RT-PCR), and IS711 RT-PCR then tested the RT-PCR positive samples to detect *B. abortus* and *B. melitensis* DNA. Only *B. abortus* and DNA were amplified from 13 human and six animal samples, which indicates that *B. abortus* is the etiological agent of brucellosis in occupationally exposed humans in Bangladesh.[191]

Table 14. Prevalence and risk factors of brucellosis in animals and humans in Bangladesh

S/N	Types of reports	Reported period	No. of reports analyzed	No. of tests used	Positive, No. (%)							Reference No.
					Humans*	Cattle	Buffalo	Goat	Sheep	Pigs	Dogs	
1.	Review	-	-	9 tests	2.5-18.6	3.7	4.0	3.6	7.3	-	-	35[A]
2.	Review	-	-	12 tests	2.5-18.6	3.7	4.0	3.6	7.3	4.8	4.0	36B
3.	Review	2001-2022	69	MRT, PCR	33.9-100	1.86-81.7	10.4-61.67	0.0-88.8	-	-	-	192

[A]Tabular data on livestock population (2005-2012) and annual production of meat & milk (2004-2011) are included. The tabular form does not include original or analyzed seroprevalence data on brucellosis. Period of study and total No. of reports evaluated are missing in the article.
B
9 tests = RBT, PAT, TAT, MET, STAT, SAT, MRT, I-ELISA, C-ELISA *Milk and milk products
12 tests = RBT, PAT, TAT, MET, STAT, SAT, MRT, I-ELISA, C-ELISA, CFT, FPA, RT-PCR

In Bangladesh, Brucellosis is endemic in humans and animals (Table 15 & 16). Brucellosis has been recognized as an occupation hazard for livestock farmers, dairy workers, veterinarians, slaughterhouse workers, and laboratory workers (Table 15). Livestock farmers of brucellosis-positive herds had a significantly higher probability of being seropositive for brucellosis. A study emphasized that contact with livestock, especially goats, is a significant risk factor for brucellosis transmission among individuals in the high-risk occupational group.[189] Brucellosis One Health actors include Public Health and Veterinary Services, microbiologists, medical and veterinary practitioners, and animal breeders.

Table 15. Brucella seropositivity by occupational groups of people tested

SN	Location/ District	Type of report	No. of samples tested	Test used	Positive workers, No. (%)					Ref. No.
					Slaughter-houses	Abattoir /Butcher	Livestock/ Dairy farmers	Milkers/ Dairy workers	Veterinarians	
1.	Bangladesh	Review	NA	Sero-test	00	2.5	2.6-21.6	18.6	5.3-11.1	35
2.	Bangladesh	Review	NA	Sero-test	00	2.5	2.6-21.6	18.6	5.3-11.1	36
3.	Mymensingh	Original	335 LF	3 Sero-tests	-	-	04 (1.1)	-	-	190
			300 PPP	3 Sero-tests	-	-	03 (1.1)	-	-	190
4.	Mymensingh	Original	210	4 sero-tests	-	-	14 (6.45)	14 (6.45)	23 (11.11)	193
5.	Sylhet	Original	90	ELISA	16/05 (31.3)	90/10 (11.11)	18/11 (61.1)	-	12/06 (50.0)	194
	Overall		-	-	**16/05 (31.3)**	**90/10 (11.11)**	**935/32 (3.42)**	**14 (6.45)**	**300/29 (9.67)**	

4 Sero-tests = SAT, RBPAT, STAT & ELISA 3Sero-tests = i-ELISA, RBT and STAT NA = Not available
LF = Livestock farmers PPP = Prolonged pyrexia patients

Initial report on the 18.4% seroprevalence of brucellosis in cattle using a tube agglutination test (TAT) in Mymensingh,[186] followed by similar an overall 3.7% in cattle, 4.0% in buffaloes, 3.6% in goats and 7.3% in sheep in Bangladesh in both the review reports.[35,36] However, the seroprevalence of brucellosis in cattle has been reported to be 20.3% and 8.9%. The herd-level seroprevalence ranged from 10.0 to 26.3% and 5.0 to 20.7% using RBPT and cELISA in cattle, respectively.[173] The wide variations of seroprevalence of brucellosis have been reported in inland literature, even 0.6% seroprevalence in Mymensingh[152] and up to 62.5% in cattle in Bangladesh.[173] Different factors have been suggested for the variations of seroprevalence rates in various articles, including using different study designs, sampling methods, and diagnostic tests, as well as variations in the climate and management system of the animals.[173]

Human brucellosis associated with consumption of milk and milk products

A review of 69 reports published from 2001 to 2022 reveals that consuming unpasteurized milk and milk products causes 33.9 to 100% of human brucellosis.[192] Several outbreaks of human brucellosis have been reported to be linked to consuming raw milk and cheese elsewhere,[195,196] and even raw milk consumption in Bangladesh.[188] The following consumption of unpasteurized milk and milk products resulted in the highest incidence of Brucella infection in humans with cow milk (1.86 to 81.7%), followed by buffalo milk (10.4 to 61.67%), camel milk (0 to 24%), goat milk (0 to 88.8%), and cheese 0 to 39.1%).[192] Zoonotic brucellosis occurs in three steps: firstly, the occurrence of Brucella organisms in milk and milk products, and secondly, human brucellosis resulting from consuming contaminated milk. Accordingly, the Milk Ring Test (MRT) and Enzyme-Linked Immunoassay (ELISA) are the two most widely used methods for the detection of Brucella antibodies in milk (Table 16). Recently developed dual biosensors are a powerful approach for early diagnosis of Brucella from milk. Real-time PCR can rapidly detect Brucella organisms, reducing the risk of laboratory contamination and false positive results.[192]

Table 16. Prevalence of brucellosis in cows detected by using milk ring test (MRT) and culture-PCR of milk in Bangladesh

S/N	District	No. of samples Serum	Milk	Types of milk	MRT +ve No. (%)	RBPT +ve No. (%)	RBPT+ve Culture +ve	RBPT-ve Culture +ve	Culture/ PCR	Ref. No.
01.	Dhaka (CCBSDF), Mymensingh, Tangail	-	492	Bulk	42 (08.6)	-	-	-	-	197
02.	Milk Shed Area, Sirajgonj	-	234	Herd	23 (9.83)	50/16 (32.0)	-	-	-	182
03.	Dhaka (CCBSDF), Mymensingh	-	485	Farms	40 (8.25)	-	-	-	12 (2.47)	198
			042	Villages	0	-	-	-	0	198
04.	Pabna, Faridpur, & Bogra	-	973	-	60 (0.62)	-	-	-	-	199
05.	Dhaka, Tangail, Mymensingh	-	1992	Single	80 (4.2)	-	-	-	-	183
06.	Chittagong	-	500	Single	25 (5.0)	-	-	-	-	157
07.	Dhaka (Savar), Gazipur, Mymensingh	360	360	Dairy farms	-	24 (6.6)	24/11 (45.83)	342/6 (1.75)	24 (6.6)	199
08.	Mymensingh, Dhaka, Gazipur, Jamalpur & Dinajpur	-	115	Dairy farms	-	-	-	-	02 (1.73)	200
09.	Savar, Dhaka	1003	1003	-	14 (1.39)	46 (4.59)	-	-	-	177
10.	Five districts	1043	1043	Herd	28 (2.68)	23 (2.21)	-	-	-	179
11.	Mymensingh (Sadar & Bhaluka)	460	460	Rural	13 (2.8)	18 (3.9)	-	-	-	181
12.	Dhaka, Jamalpur & Rangpur	510	510	Bulk	14 (2.7)	12 (2.4)	-	-	-	202
	Overall	**3376**	**8209**		**339 (4.38)** [7734]	**139 (4.06)** [3426]	**11 (45.83)** [24]	**06 (1.75)** [342]	**38 (03.96)** [960]	

Five districts = Dhaka (CCBSDF, Savar), Mymensingh, Rangpur, Jamalpur & Gaibandha

An investigation based on interviews of 420 dairy farm attendants and farm owners where 93.55% and 99.08% of commercial and backyard dairy personnel reported not knowing brucellosis, and 9.67% and 87.77% consumed raw milk and yogurt of unpasteurized milk, respectively, were highly vulnerable to zoonotic brucellosis.[157]

The prevalence of caprine and ovine brucellosis was estimated to be 1.6 %, whereas it was 1.56% in goats and 1.64% in sheep (Table 17 & Table 18). The total losses attributed to the disease was BDT 48436400/- annually in the Mymensingh district, whereas BD 46462900/- in goats and BDT 1973500/- in sheep annually.[201] This indicates that brucellosis silently constitutes a heavy economic loss in the livestock industry in Bangladesh. Animal farmers have insufficient knowledge of the disease, inadequate diagnostic facilities, and a lack of awareness of an effective control strategy against brucellosis in Bangladesh.

Table 17. Reported seroprevalence of brucellosis in goats in Bangladesh

S/N	District	No. of blood tested	Tests used and prevalence; No. (%) TAT	RBT	PAT	iELISA	MET	SAT	No. of milk tested	MRT +ve No. (%)	Ref No.
01.	Bagerhat, Bogra, Gaibandha, Mymensingh & Sirajgonj	127	-	06 (4.72)	-	04 (3.15)	-	-	-	-	160
02.	Bagerhat, Bogra, Gaibandha, Mymensingh & Sirajgonj	230	06 (2.61)	8 (3.48)	-	5 (2.17)*	-	-	-	-	162
03.	Mymensingh	1847	-	29 (1.56)	-	-	-	-	-	-	201
04.	Mymensingh, Tangail, Manikgonj	350	102 (29.4)	-	102 (29.4)	-	-	-	-	-	203
05.	Dhaka, Mymensingh	300	06 (2.0)	05 (1.7)	05 (1.7)	-	07 (2.33)	-	-	-	204
06.	Bangladesh	300	06 (2.0)	05 (1.67)	05 (1.67)	-	07 (2.33)	-	-	-	205
07.	Mymensingh & Dhaka	300	06 (2.0)	05 (1.67)	05 (1.67)	-	07 (2.33)	-	-	-	206
08.	Mymensingh & Dhaka*	362	08 (2.21)	07 (1.93)	07 (1.93)	-	-	-	-	-	207
09.	Dhaka and Lalmonirhat	020	-ve	-ve	-	-ve	-	-ve	-	-	208
10.	Dhaka, Mymensingh, Rajshahi	208	-	08 (3.85)	-	-	7 (3.37)	-	242	33 (13.64)	209
11.	Bogra and Mymensingh	120	-	7(5.83)	-	3 (2.50)	-	5(4.17)	-	-	210
12.	Nilphamari	154	-	5 (3.24)	-	04 (2.59)	-	-	-	-	211
13.	Mymensingh	113	-	07 (6.2)	-	-	-	-	-	-	212
14.	Mymensingh	1710	-	163 (9.53)	-	31/92 (33.7)*	-	-	-	-	213
15.	JJTDTB	208	-	09 (4.33)	-	05 (2.40)	-	-	-	-	214
16.	Bangladesh	636	-	+	-	6.0 (01.0)	-	+	-	-	224
		6985	**134 (7.27)** [1842]	**264 (4.41)** [5979]	**124 (7.69)** [1612]	**58 (3.70)** [1567]	**28 (2.53)** [1108]	**5 (4.17)** [120]	**242**	**33 (13.64)**	

RBT = Rose Bengal Test iELISA = Indirect ELISA cELISA = Competitive ELISA FPA = Fluorescence polarization assay *cELISA
PAT = Plate agglutination test TAT = Tube agglutination test MET = Mercaptoethanol test *iELISA showed 33.7% of RBT reactors
*Sheep (n = 62) and goats (n = 3000) tested combined results JJTDTB = Jashore, Jhenidah, Tangail, Savar (Dhaka), Thakurgaon and Bandarban

Table 18. Reported seroprevalence of brucellosis in sheep in Bangladesh

S/N	District	No. of sheep tested	Tests used and prevalence; No. (%) TAT	RBT	PAT	MET	SAT	iELISA	cELISA	Ref. No.
01.	Bagerhat, Bogra, Gaibandha, Mymensingh & Sirajgonj	130	-	4(3.08)	-	-	-	03(2.31)	-	160
02.	Bagerhat, Bogra, Gaibandha, Mymensingh & Sirajgonj	170	14 (8.24)	16 (9.41)	-	-	-	-	15 (8.82)	162
03.	Mymensingh (Test used)	746	-	306 (1.65)	-	-	-	-	-	201
04.	Dhaka, Mymensingh	62	2(3.25)	2(3.25)	2 (3.25)	3(4.84)	-	-	-	206
05.	Bogra and Mymensingh	80	-	3(3.75)	-	-	2(2.50)	1 (1.25)	-	210
06.	Mymensingh	101	-	06 (5.94)	-	-	-	-	-	212
07.	Gaibandha	206	-	7 (3.39)	-	-	-	6 (2.91)	-	215
08.	Mymensingh & Netrokona	102	-	10 (9.8)	-	-	-	6 (5.88)	-	216
09.	10/6 districts	637	-	11 (1.7)	-	-	11 (1.7)	22 (3.5)	-	217
10.	Bangladesh	1044	-	+	-	-	+	13 (01.2)*	-	224
	Overall	**3278**	**232/16 (6.9)**	**2234/365 (16.34)**		**-**	**717/13 (1.81)**	**2199/51 (2.32)**		

RBT = Rose Bengal Test iELISA = Indirect ELISA cELISA = Competitive ELISA FPA = Fluorescence polarization assay
PAT = Plate agglutination test TAT = Tube agglutination test SAT = Slow agglutination test
Tests used = RBT, Rapid Brucella Ab test kit, Mab-ELISA *True prevalence

Swine and canine brucellosis

Swine brucellosis is a zoonotic disease caused by infection with *Brucella suis*, which may occur in domestic animals other than pigs. It is mainly transmitted via ingestion of infected tissues or fluids. Boar semen may contain this organism and can be transmitted during services. Infection may cause abortion, infertility, lameness, orchitis, and swelling of male accessory sex glands. Research reports on brucellosis are very limited in Bangladesh (Table 19).[218] However, a significantly higher prevalence of brucellosis in aborted pigs (42.9%) in comparison to 1.6% in non-aborted pigs in Bangladesh.[218]

Canine brucellosis is an infectious zoonotic disease caused by *Brucella canis*. It is distributed globally and causes major public health concerns due to close contact between dogs and humans. However, minimal research has been conducted in Bangladesh (Table 19).

Table 19. Seroprevalence of brucellosis in pigs and dogs in Bangladesh

S/N	District	Species of animals tested	No. of animals tested	Test used to detect seroprevalence					References No.
				RBPT	SAT	STAT	i-ELISA	Overall	
01.	Sirajgonj & Bogra	Pigs	105	7 (06.70)	5 (4.80)	-	-		218
02.	Mymensingh	Stray dog	030	4 (13.33)	2 (6.67)	2 (6.67)	3 (10.00)	4 (13.33)	219
03.	Dhaka	Pet dogs	050	2 (04.00)	-	-	2 (04.00)	2 (04.00)	220

RBPT = Rose Bengal Plate Test SAT = Slow Agglutination Test STAT = Standard Tube Agglutination Test
i-ELISA = Indirect Enzyme-Linked Immunosorbent Assay

Table 20. Reported seroprevalence of brucellosis in humans in Bangladesh

S/N	District	Variables/RF	Category	No. of human tested	Tests Used and Prevalence: No. (%)						Ref. No.
					LAT	SAT	RT-PCR	RBPAT	STAT	i-ELISA	
01.	Mymensingh	Overall	-	50	-	-	-	3 (6.0)	3 (6.0)	-	158
02.	MMH	+	+	300p	-	-	6 (2.0)*	6 (2.0)	6 (2.0)	6 (2.00)	190
03.	Mymensingh	RG	-	210	-	9 (4.28)	-	7 (3.33)	07 (3.33)	10 (4.76)	193
04.	Sylhet	HRG	IgM	65	-	-	-	-	06 (9.2)	-	194
			IgG	65	-	-	-	-	32 (49.2)	-	
		NRG	IgM	25	-	-	-	-	0	-	
			IgG	25	-	-	-	-	10 (40.0)	-	
05.	Mymensingh	RG	-	300	40 (13.33)	-	-	-	-	-	221
		NRG	-	300	15 (05.00)	-	-	-	-	-	
		RG	ICT +ve	040	13 (32.50)	-	-	-	-	-	
			ICT -ve	040	27 (67.50)	-	-	-	-	-	
		NRG	ICT +ve	015	02 (13.33)	-	-	-	-	-	
			ICT -ve	015	13 (86.67)	-	-	-	-	-	
		RG	PCR +ve	40	03 (07.50)	-	55/02 (3.64)	-	-	-	
			PCR -ve	40	37 (92.50)	-	-	-	-	-	
		NRG	PCR +ve	15	0	0	-	-	-	-	
			PCR -ve	15	15 (100)	-	-	-	-	-	
	Overall			**1560**	**300/55 (18.33)**	**210/9 (2.25)**	**355/8 (2.25)**	**560/11 (1.96)**	**740/64 (8.65)**	**510/16 (3.14)**	

SAT = Slide agglutination test LAT = Latex agglutination test RBPAT = Rose Bengal plate Agglutination test
STAT = Standard tube agglutination test ICU = Intensive care unit ICT = Immunochromatographic test
MMH = Mymensingh Medical Hospital p = Pyretic patients **B. abortus* DNA was amplified but not *B. melitensis*
RG = Risk group HRG = High-risk group NRG = Non-risk group RF = Risk factors

Brucellosis associated with reproductive disorders in animals

Reported evidence shows that brucellosis is related to reproductive disorders like abortion, placental retention, repeat breeding, infertility, and prolonged inter-calving periods in animals (Table 21-23). Tables 21-23 show significantly higher seroprevalence of brucellosis in farm animals with a history of abortion,

Table 21. Risk factors and effects of brucellosis on reproduction in cattle

S/N	Variables	Category	No. of cows tested	Sero-test results Positive No. (%)	Negative No. (%)	Ref. No.
01.	Breeds	Local*	250	06 (02.40)	244 (97.6)	157
		Local	089	03 (03.37)	086 (96.6)	159
		Local	111	04 (03.60)	107 (96.4)	161
		Local	164	28 (17.07)	136 (82.93)	169
		Local	558	50 (08.96)	508 (91.04)	183
		Sub-total	**1172**	**91 (07.76)**	**1081 (92.24)**	
		Cross	250	19 (07.60)	231 (92.40)	157
		Cross	111	07 (06.31)	104 (93.69)	159
		Cross	289	05 (1.73)	284 (98.27)	161
		Cross	222	38 (17.12)	184 (82.88)	169
		Cross	202	31 (15.35)	171 (84.65)	183
		Cross	923	31 (3.36)	892 (96.64)	222
		Sub-total	**1997**	**131 (6.56)**	**1866 (93.44)**	
02.	Parity	1	028	05 (17.86)	023 (82.14)	173
		1	157	10 (06.37)	147 (93.63)	169
		2	111	25 (22.52)	086 (77.48)	173
		2	116	16 (13.79)	100 (86.21)	169
		3	041	15 36.59)	026 (63.41)	169
		1-2	247	11 (04.45)	236 (95.55)	181
		1-2	123	01 (00.81)	122 (99.19)	178
		3-4	213	07 (03.29)	206 (96.71)	181
		3-5	410	10 (02.44)	400 (97.56)	178
		≥ 4	044	25 (56.82)	019 (43.18)	169
		Sub-total	**1490**	**125 (8.39)**	**1365 (91.61)**	
03.	Rearing system	Backyard	250	06 (02.4)	244 (97.6)	157
		Commercial	250	19 (07.6)	231 (92.4)	157
04.	Pregnancy	Pregnant	087	03 (03.45)	84 (96.55)	155
			034	02 (05.88)	32 (94.12)	156
			057	05(08.77)	52 (91.23)	159
			077	15 (19.48)	62 (19.48)	173
			031	03 (09.68)	28 (90.32)	175
			124	12 (9.68)	112 (90.32)	183
			112	04 (03.57)	108 (96.43)	223
			087	10 (11.49)	077 (88.51)	199
		Sub-total	**609**	**54 (08.89)**	**555 (91.13)**	
		Non-pregnant	163	02 (01.23)	161 (98.77)	155
			086	04 (04.65)	082 (95.35)	156
			081	19 (23.46)	062 (76.54)	173
			068	02 (02.94)	066 (97.06)	175
			226	17 (7.52)	209 (92.48)	183
			188	07 (3.72)	181 (96.28)	223
			273	14 (05.13)	259 (94.87)	199
		Sub-total	**1085**	**65 (05.99)**	**1020 (94.01)**	
05.	Abortion	Present	025	03 (12.00)	22 (88.00)	155
			007	04 (57.14)	03 (42.87)	160
			024	02 (08.33)	22 (91.67)	161
			018	02 (11.11)	16 (88.89)	168
			032	29 (43.94)	03 (09.38)	169
			004	02 (50.00)	02 (50.00)	173
			006	03 (50.00)	03 (50.00)	171
			007	02 (28.57)	05 (71.43)	175
			118	11 (09.3)	107 (90.68)	181
			055	17 (14.46)	38 (69.09)	183
			057	16 (28.07)	41 (71.83)	199
			020	03 (15.0)	17 (85.00)	223
		Sub-total	**373**	**94 (25.20)**	**279 (74.80)**	

Contd. Table 21. Risk factors and effects of brucellosis on reproduction in cattle

S/N	Variables	Category	No. of cows tested	Sero-test results Positive No. (%)	Negative No. (%)	Ref. No.
	Abortion	Absent	156	01 (0.64)	155 (99.36)	160
			130	02 (01.54)	128 (98.46)	168
			354	37 (56.06)	317 (89.55)	169
			155	32 (20.65)	123 (79.35)	173
			116	06 (5.17)	110 (94.83)	171
			113	04 (03.54)	109 (96.46)	175
			342	07 (02.0)	335 (97.95)	181
		Sub-total	**1366**	**89 (06.52)**	**1277 (93.48)**	
06.	Reproductive disorders	Present	024	09 (37.50)	015 (62.50)	173
			103	50 (48.54)	053 (51.46)	169
		Sub-total	**127**	**59 (46.46)**	**068 (53.54)**	
		Absent	134	25 (18.66)	109 (81.34)	173
			283	16 (24.24)	267 (94.35)	169
		Sub-total	**417**	**41 (09.83)**	**376 (90.17)**	
07.	Anestrous	Present	064	0	064 (100)	161
			003	02 (66.67)	001 (33.33)	173
		Sub-total	**067**	**02 (02.99)**	**065 (97.01)**	
		Absent	155	32 (20.65)	123 (79.35)	173
08.	Repeat breeding	Present	061	01 (1.64)	060 (98.36)	155
			250	07 (02.80)	143 (57.20)	161
			048	38 (57.58)	010 (20.83)	169
			006	02 (33.33)	004 (66.67)	173
			105	12 (11.4)	093 (88.57)	181
			095	03 (3.16)	092 (96.84)	183
			069	01 (1.45)	068 (98.55)	223
		Sub-total	**634**	**64 (10.04)**	**470 (74.13)**	
		Absent	036	32 (88.89)	004 (11.11)	173
			338	28 (08.28)	310 (91.72)	169
		Sub-total	**374**	**60 (16.04)**	**314 (83.96)**	
09.	Retained placenta	Present	127	02 (1.57)	125 (98.43)	155
			022	0	022 (100)	161
			012	03 (25.00)	009 (75.00)	173
			014	02 (14.29)	012 (85.72)	171
			362	13 (03.59)	349 (96.41)	181
			027	04 (14.81)	023 (85.19)	183
			035	02 (05.71)	033 (94.29)	199
			023	03 (13.04)	020 (86.96)	223
		Sub-total	**622**	**29 (04.66)**	**593 (95.34)**	
		Absent	146	31 (21.23)	115 (78.77)	173
			108	07 (06.48)	101 (93.53)	171
		Sub-total	**254**	**38 (14.96)**	**216 (85.04)**	
10.	Infertility	Present	030	04 (13.33)	026 (86.67)	199
11.	Breeding practices	Natural	047	04 (08.51)	043 (91.49)	159
		Natural	030	04 (13.33)	026 (86.67)	168
		Natural	254	43 (16.93)	211 (83.07)	169
		Natural	038	07 (18.42)	031 (81.58)	171
		Natural	085	05 (05.88)	080 (94.12)	175
		Sub-total	**454**	**63 (13.88)**	**391 (86.12)**	
		AI	102	06 (05.88)	096 (94.12)	159
		AI	114	09 (07.89)	105 (92.11)	168
		A I	132	23 (17.42)	109 (82.58)	169
		AI	084	02 (2.38)	082 (97.62)	171
		AI	035	01 (02.86)	034 (97.14)	175
		Sub-total	**467**	**41 (08.78)**	**426 (91.22)**	
12.	Others	Present	238	02 (00.84)	236 (99.16)	199

Table 22. Risk factors and effects of brucellosis on reproduction in buffaloes in Bangladesh[184]

S/N	Variables	Sub-Category	No. of buffalo tested	Tests used & prevalence; No. (%) RBT	iELISA
01.	Age	< 4 yrs	48	2 (4.17)	1 (2.08)
		> 4 yrs	22	2 (9.09)	2 (9.09)
02.	Gender	Male	26	1 (3.85)	1 (3.85)
		Female	44	3 (6.82)	2 (4.55)
03.	Pregnancy	Pregnant	08	1 (12.5)	1 (12.5)
		Non-pregnant	36	2 (5.55)	1 (3.33)
04.	Grazing	Yes	28	1 (3.57)	1 (3.57)
		No	42	3 (7.12)	2 (4.76)
05.	Breeding	AI	26	1 (3.84)	1 (3.84)

Contd. Table 22.
Table 22. Risk factors and effects of brucellosis on reproduction in buffaloes in Bangladesh[184]

S/N	Variables	Sub-Category	No. of buffalo tested	Tests used & prevalence; No. (%) RBT	iELISA
	Natural breeding	-	12	2 (16.67)	1 (8.33)
06.	Anestrous	-	06	1 (16.67)	1 (16.67)
07.	Retained placenta	-	04	1 (25.00)	0
08.	Abortion	-	03	1 (33.33)	1 (33.33)
09.	Repeat breeding	-	07	0	0
10.	Vaginal discharge	-	08	0	0
11.	Dystocia	-	02	0	0
12.	Balanophosthitis	-	01	0	0

Table 23. Risk factors and effects of brucellosis on reproduction in goats in Bangladesh

S/N	Variables	Sub-category	No. of goat tested	Tests used and prevalence No. (%) TAT	RBT	PAT	MET	MAT	MRT	i-ELISA	Overall*	Ref. No.
01.	Breeds	Local	300*	-	-	-	-	-	-	07 (2.3)	-	204
			080	-	2 (02.50)			-	-	1 (1.25)	-	211
			124	-	-	-	-	-	-	-	3 (2.42)	171
		Cross/ Exotic	074	-	3 (03.84)			-	-	3 (4.05)		211
			036	-	-	-	-	-	-	-	4 (11.11)	171
02.	Gender	Male	050	-	1 (02.00)	-	-	-	-	0	-	211
		Female	104	-	4 (03.84)	-	-	-	-	4 (3.84)	-	211
03.	Pregnancy	Pregnant	090	-	4 (04.44)	-	-	-	-	3 (3.33)	-	211
			030	1 (03.33)	1 (03.33)	1 (3.33)	1 (03.33)	-	-	-	-	206
			048	-	5 (10.41)	-	-	4 (8.33)	-	-	-	209
			078	-	-	-	-	-	18 (23.08)	-	-	209
		Non-pregnant	064	-	1 (01.56)	-	-	-	-	1 (1.56)	-	211
			270	5 (01.85)	4 (01.48)	4 (1.48)	6 (02.22)	-	-	-	-	206
			164	-	-	-	-	-	15 (9.14)	-	-	209
			130	-	2 (01.53)	-	-	6 (3.37)	-	-	-	209
04.	Previous abortion	Yes	015	2 (13.3)	3 (20.00)	2 (13.30)	3 (20.00)	-	-	-	-	204
			009	-	4 (44.44)	-	-	-	-	03 (33.33)	-	211
			003	-	3 (100)	-	-	-	-	3 (100)	-	210
			007	-	+	-	-	-	-	+	2 (28.5)	171
			058	-	-	-	-	-	15(25.86)	-	-	209
			022	-	6 (27.27)	-	-	5 (22.72)	-	-	-	209
			020	-	-	4 (23.52)	-	-	-	-	-	225
		No	285	4 (01.4)	2 (00.70)	3 (01.10)	4 (01.40)	-	-	-	-	204
			089	-	+	-	-	-	-	+	4 (4.50)	171
			184	-	-	-	-	-	18 (9.78)	-	-	209
			156	-	2 (01.28)	-	-	2 (1.28)	-	-	-	209
			117	-	4 (03.41)	-	-	-	-	0	-	210
05.	Placental expulsion	Retained (RP)	015	1 (06.7)	2 (13.30)	2 (13.30)	2 (13.30)	-	-	-	-	204
			008	0	-	-	-	-	-	0	-	211
			005	-	+	-	-	-	-	+	2 (40.0)	171
			042	-	-	-	-	-	12(28.57)	-	-	209
			020	-	6 (30.00)	-	-	-	5 (25.0)	-	-	209
		Normal	285	5 (01.8)	3 (01.10)	3 (01.10)	5 (01.80)	-	-	-	-	204
			091	-	+	-	-	-	+	-	4 (4.40)	171
			200	-	-	-	-	-	21(10.5)	-	-	209
			158	-	2 (01.27)	-	-	2 (1.27)	-	-	-	209
06.	Uterine discharge	Abnormal	010	1 (10.0)	1 (10.00)	1 (10.00)	1 (10.00)	-	-	-	-	204
		Normal	290	5 (01.7)	4 (01.40)	4 (1.4)	6 (2.1)	-	-	-	-	204
07.	Others	Metritis+	119	-	1 (00.84)	-	-	-	1 (0.84)	-	-	211

*Animals positive for all four tests (RBT, SAT, cELISA & i-ELISA) MAT = Microscopic Agglutination Test

*Local goat = Black Bengal goats M-DH-D = Metritis, delayer estrus and dystocia

repeat breeding and reproductive abnormalities. These findings support the first report on bovine infertility published in 1967[186] to provide up-to-date analysis on the seroprevalence of brucellosis associated with reproductive disorders in Bangladesh.[35,36,169,181] However, different serological tests have been used for serosurvey of brucellosis in different animal species. Still, these tests may also produce false positive serological reactions with lipopolysaccharide (LPS) of *Yersinia enterocolitica* 0:9 and *Escherichia coli* 0157:H7 or cross-reactive antigens from other bacteria such as Salmonella species and Pasteurella species.[222] Serological, cultural, and molecular assays have been used to detect Brucella infection in animals and humans. The Bruce Ladder PCR and multi-locus molecular phylogeny have been suggested to be more reliable methods of brucellosis diagnosis in dairy cows in Bangladesh.[177] Recently, the identification and genetic characterization of 10 *Brucella abortus* biovar three from uterine discharge (n=7), milk (n=2), and vaginal swabs (n=1) of 10 dairy cattle that were aborted at the third trimester of gestation in Bangladesh.[200]

Seroprevalence of bovine brucellosis was first conducted in 412 adult cattle of BAU Dairy Farm, BAU Veterinary Clinic and surrounding villages by using Tube Agglutination Test (TAT) with *Brucella abortus* antigen (Sylvana Co., USA) showed that 76 (18.4%) positive and 36 (11.2%) suspicious results and review of inland literature on brucellosis indicate as a first report on the seroprevalence of brucellosis in Bangladesh.[153]

The prevalence of bovine infertility was reported to be 37% in the then East Pakistan in 1967 (now Bangladesh), and an economic loss of 40.46 crores of rupees was estimated to be caused by bovine infertility.[186] However, some authors suggest that this report is the first report of brucellosis in bovine species in Bangladesh. Recently, the RBT was used to detect seroprevalence of equine brucellosis in 112 horses in Dhaka and Tangail, of which only two (1.79%) horses showed positive reactions in Bangladesh. [226]

The first isolation, identification, and genetic characterization of *Brucella* abortus biovar three from dairy cattle in Bangladesh have been documented.[200,227] The classical biotypic method confirmed that all 100 *B. abortus* isolates belonged to the biovar 3. The species and biovar identification data and genetic characterization of Brucella field isolates may help formulate policies and strategies for controlling bovine brucellosis in Bangladesh. [200] The genome sequence of *Brucella abortus* biovar three strain BAU21/S4023, isolated from a dairy cow that suffered an abortion in Savar, Dhaka, Bangladesh, has been reported. This technique helps to understand its virulence, pathogenesis, host specificity, biotypic difference, and phylogenetic relationships and helps identify potential targets for developing vaccines and diagnostics to prevent and control brucellosis.[228]

Worldwide economic losses due to brucellosis are extensive regarding livestock health, production, and public health. Brucellosis is an endemic zoonosis in Bangladesh, and recent studies demonstrated that the total annual monetary loss among indigenous cows caused by brucellosis in Bangladesh was calculated to be Taka 60 million. The expected yearly monetary loss per 1000 exotic and cross-bred cows was estimated to be Taka 0.88 million and Taka 0.16 million, respectively.[229] In another study, the total losses attributed to the brucellosis of small ruminants were estimated to be Taka 48436400 (US$ 605455) annually in the district of Mymensingh, whereas Taka 46462900 (US$ 580786.25) and Taka 1973500 (US$ 24668.75) in goats and sheep, respectively.[201]

The seroprevalence of brucellosis varies on occupations of people at risk (2.5 to 18.6%), including livestock farmers (2.6-21.6%), milkers (18.6%), butchers (2.5%), and veterinarians (5.3-11.1%) in Bangladesh based on RBT, STAT, and ELISA either alone or in combination of tests were used.[35,36,193,225,230] None of these tests are perfect; thus, they cannot be used for these studies.[231] Recently, the true prevalence of brucellosis in livestock farmers and prolonged pyrexia patients (PPP) has been estimated to be 1.1% and 1.7%, respectively.[231] However, the performance of these serological tests (RBT, STAT & i-ELISA) has been reported to similar diagnostic values. Therefore, no single serological test can be used for routine diagnosis of human brucellosis. Applying a second test with high specificity and/or testing patients with a history of exposure to known risk factors and /or testing patients with clinical findings of brucellosis may increase the positive predictive value of the serological tests.[231]

The most effective prevention strategies for brucellosis are surveillance and risk factors prevention. Eliminating brucellosis-positive cattle will contribute to the control of brucellosis as a public health risk in Bangladesh. Both *B. abortus* strain RB51 commercial lives vaccine[232] and *B. abortus* killed vaccine have been tried in cattle in Bangladesh.[233] However, vaccination of ruminant animals against brucellosis is recommended in enzootic areas with high prevalence rates. In contrast, a low true prevalence of brucellosis detected by serological and molecular tests in farms and areas will allow test and slaughter policies to control this disease. In countries where eradication of animal brucellosis through vaccination and culling of infected animals is not feasible, prevention of human infection is primarily based on raising awareness, food-safety measures, occupational hygiene and laboratory safety. Consumption of pasteurized milk and milk products like cheese and educational campaigns can be effective for the prevention of brucellosis in humans.

Salmonellosis

Salmonella is a foodborne pathogen that is a global public health problem, as it causes almost 1.3 billion cases of illness each year, leading to more than 3 million deaths.[234] In the USA alone, approximately 1.2 million human infections, 23000 hospitalizations, and 450 deaths occur each year.[235] Salmonellae are extensive food-borne pathogens that majorly impact public health, especially life-threatening for infants, pregnant women, and unborn babies.[236] *Salmonella* spp. are Gram-negative, rod-shaped bacteria belonging to the family *Enterobacteriaceae* and order *Enterobacterales.* The genus Salmonella is divided into two broad species named *S. enterica* and *S. bongori*, of which *S. enterica* consists of six subspecies: (i) enterica (ii), salamae (iii), arizonae (iv) diarizonae (v), houtenae (vi) and indica.[237,238] Approximately 2659 Salmonella serovars have been identified, and many serovars (1547) have been reported in subsp. enterica, responsible for more than 99%, may cause infection in animals and humans.[239] Other *Salmonella enterica* serovars are unevenly distributed among the following subspecies: salamae- 522 serovars, diarizonae- 338 serovars, arizonae- 102 serovars, houtenae- 76 serovars and indica- 13 serovars.[240,241]

Salmonella serovars are classified into typhoidal and non-typhoidal Salmonella (NTS) serovars based on their ability to develop specific pathologies in humans.[242] The severity of human salmonellosis varies depending on the serotype, immune status of the host, and infection with typhoidal and non-typhoidal types. Typhoidal Salmonella serovars, including Typhi, Sendai, and Paratyphi, are highly adapted to humans, whereas animals are not their carriers. The NTS is a zoonotic disease caused by multiple Salmonella serovars other than Typhi, Sendai, and Paratyphi. The NTS can be divided into non-invasive and invasive (iNTS) based on differential disease symptoms. The vast majority of the non-invasive NTS can cause gastroenteritis that is generally self-limiting in humans and does not require antibiotic treatment[243] but can lead to an invasive infection (same serovars as non-invasive infections) affect people at higher risk groups as children and elderly, people with health defects (AIDS, liver cirrhosis) and pregnant women that present a greater health risk and may require antimicrobial treatment.[244] The number of foodborne illnesses and deaths caused by NTS globally in 2010 has been estimated at over 78 million and >59,000 deaths, respectively.[245] Poultry and poultry products are a common source of human infection by NTS. Important *S. enterica subspecies enterica* serovars include *S. Typhimurium, S. enteritidis, S. Kentucky, and S. infantis, among others.246 Every motile serovar of Salmonella enterica of poultry derivation is zoonotic,* and contaminated meat and raw eggs are a significant source of human infections. Salmonella infection affects nearly 30 million people globally every year, whereas it is estimated to be between 292 and 395 cases per 100,000 persons each year in Bangladesh.[247] Table 24 shows humans and animals' most common *Salmonella enterica* serovars.

Table 24. The most common zoonotic Salmonella serovars affect both humans and animals[247]

S/N	Host	District/ Location	No. of samples tested	Types of samples	Positive No. (%)	Serovars	Major disease	Ref N
1.	Humans	Dhaka	1425	Blood culture	665 (45.0)	*S. enterica serovar typhi* (*S. typhi*)	Typhoid fever	257
		Dhaka	601	Blood culture	261 (43.42)	*S. enterica serovar paratyphi* (*S. paratyphi*)	Paratyphoid fever	258
		Dhaka	-	Stool samples	16 (02.66)	*S. paratyphi B var java*[1]	NTS/ Enteritis	251
					06 (01.00)	*S. kentucky*[2]	NTS/ Enteritis	251
					06 (01.00)	*S. enteritidis*[3]	NTS/ Enteritis	251
					04 (00.67)	*S. virchow*[4]	NTS/ Enteritis	251
					02 (00.33)	*S. Newport*	NTS/ Enteritis	251
					02 (00.33)	*S. Litchfield*	NTS/ Enteritis	251
					01 (00.17)	*S. emek*	NTS/ Enteritis	251
					01 (00.17)	*S. weltevreden*[5]	NTS/ Enteritis	251
					19 (33.3)	*S. typhimurium*	NTS / Enteritis	251
					Sub-total	9 serotypes		
					-	*S. enteritidis*	NTS / Enteritis	
2.	Poultry	11 districts	765	All samples	197 (25.8)	*S. gallinarum*	Fowl typhoid	252
			535	Claecal swabs	129 (24.1)	*S. gallinarum*	Fowl typhoid	252
			050	Visceral organs	021(42.0)	*S. gallinarum*	Fowl typhoid	252
			180	Droppings	47 (26.1)	*S. gallinarum*	Fowl typhoid	252
						S. pullorum	Pullorum disease	
						S. typhi	Salmonellosis	
		Savar, Dhaka	67	-	59 (88.00)	*S. enteritidis*	NTS/ Enteritis	250
		Dhaka	870	Caecal swabs	00 (00.57)	*S. enteritidis*	NTS/ Enteritis	254
		Dhaka	300	Samples*	91 (60.70)	*S. enteritidis*	NTS/ Enteritis	255
		Dhaka	300	Samples*	59 (39.30)	*S. typhimurium*	NTS/ Enteritis	255
					07 (02.33)	*S. typhimurium*	NTS/ Enteritis	250
		Dhaka	870	Caecal swabs	32 (03.67)	*S. typhimurium*	NTS/ Enteritis	254
		Mymensingh	100	CS, litter, feed	30 (30.00)	*S. typhimurium*	NTS/ Enteritis	256
		Mymensingh	150	Cloacal swabs	06 (04.0)	*S. typhimurium*	NTS/ Enteritis	253
			20	Feed samples	10 (50.0)	*S. typhimurium*	NTS/ Enteritis	253
					02 (10.00)	*S. heidelberg*	NTS/ Enteritis	250
		Dhaka, CTG	500	-	18 (03.60)	*S. kentucky*	Salmonellosis	249
					-	5 Serovars[1-5]	Salmonellosis	249
3.	Ducks	-	-	-	-	*S. anatum*	Keel disease	
4.	Sheep & goats	-	-	-	-	*S. abortusovis*	Salmonellosis	
		-	-	-	-	*S. anatum*	Salmonellosis	
		-	-	-	-	*S. montevideo*	Salmonellosis	
5.	Cattle	-	-	-	-	*S. dublin*	Salmonellosis	
		-	-	-	-	*S. typhimurium*	Salmonellosis	
		-	-	-	-	*S. newport*	Salmonellosis	
6.	Horse	-	-	-	-	*S. anatum*	Salmonellosis	
		-	-	-	-	*S. agona*	Salmonellosis	
		-	-	-	-	*S. enteritidis*	Salmonellosis	

NST = Non-typhoidal salmonellosis 1-5 = Poultry isolates are indistinguishable from poultry
11 Districts = Mymensingh, Tangail, Gazipur, Bogura, Jamalpur, Netrokona, Dinajpur, Moulvibazar, Habigonj, Feni, and Chattogram.
C = Cloacal swab samples F= Feed samples
Samples* = Cloacal swabs, intestinal fluid, egg surface, handwash of chicken workers and soil of chicken markets

Poultry chickens are a potential source of transmission of zoonotic Salmonella into the human food chain, causing food-borne illness and hindering the development of poultry in Bangladesh.[248] The occurrence of Salmonella in poultry and poultry products in Bangladesh has been well documented (Table 24) and includes serovars of public health significance such as *S. Typhimurium*, *S. enteritidis*, and *S. kentucky*.[249,250]

The predominant sources of Salmonella are certain foods, the environment, animals, and birds. Many foods have been implicated in foodborne illness attributed to *Salmonella enterica*. Food animal origin, especially poultry, poultry products, and raw eggs, are often involved in human salmonellosis. In addition, fruits and vegetables, water, handling of farm animals and pets, and human person-to-person when hand-mouth contact occurs without proper washing of hands.[250] The overall prevalence of Salmonella infection in chicken was 48%, with the highest prevalence in raw meat (62.5%) and the lowest in liver (37.5%) samples (Table 25).

Zoonotic salmonellosis

Salmonella can be transmitted from animals and birds to humans and vice versa (Figs. 5 & 6). The route of infection from animals to humans is usually through contaminated food and water. Contaminated food of livestock origin, such as meat, eggs, or vegetables, is all a source of infection. In addition, contact with infected humans or animals, especially reptiles and birds, is also a source of infection. Most species of mammals and birds are susceptible to Salmonella infection. However, children, the elderly, and people with impaired immune systems are more vulnerable.

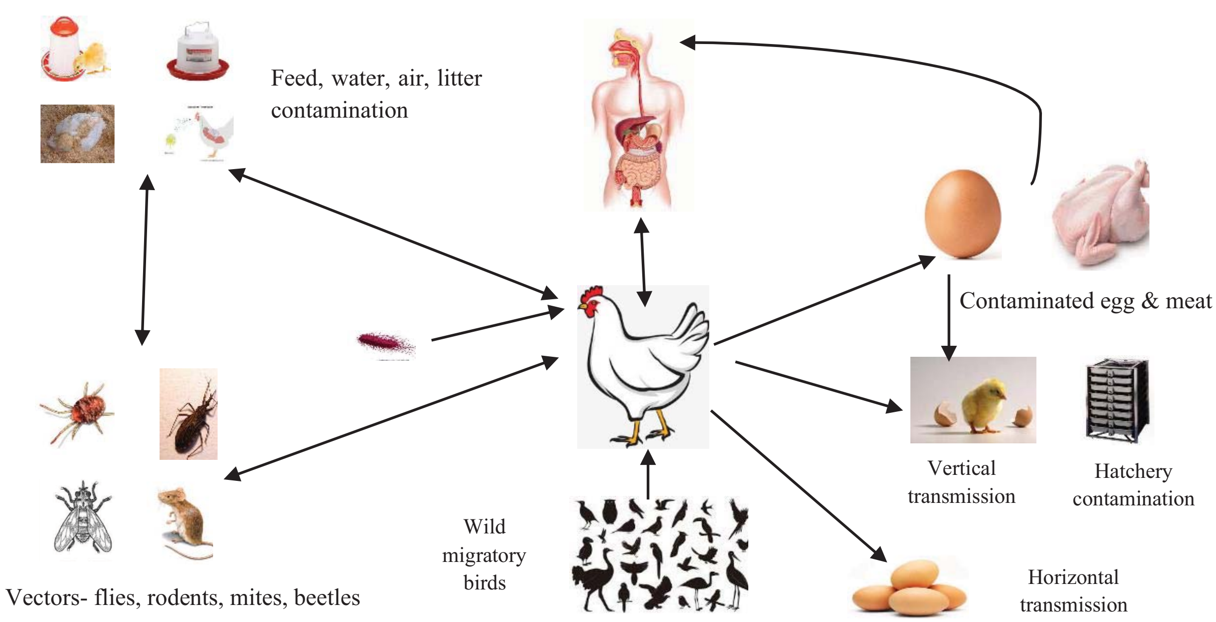


Fig. 5. Methods of transmission of zoonotic Salmonella between humans and poultry birds

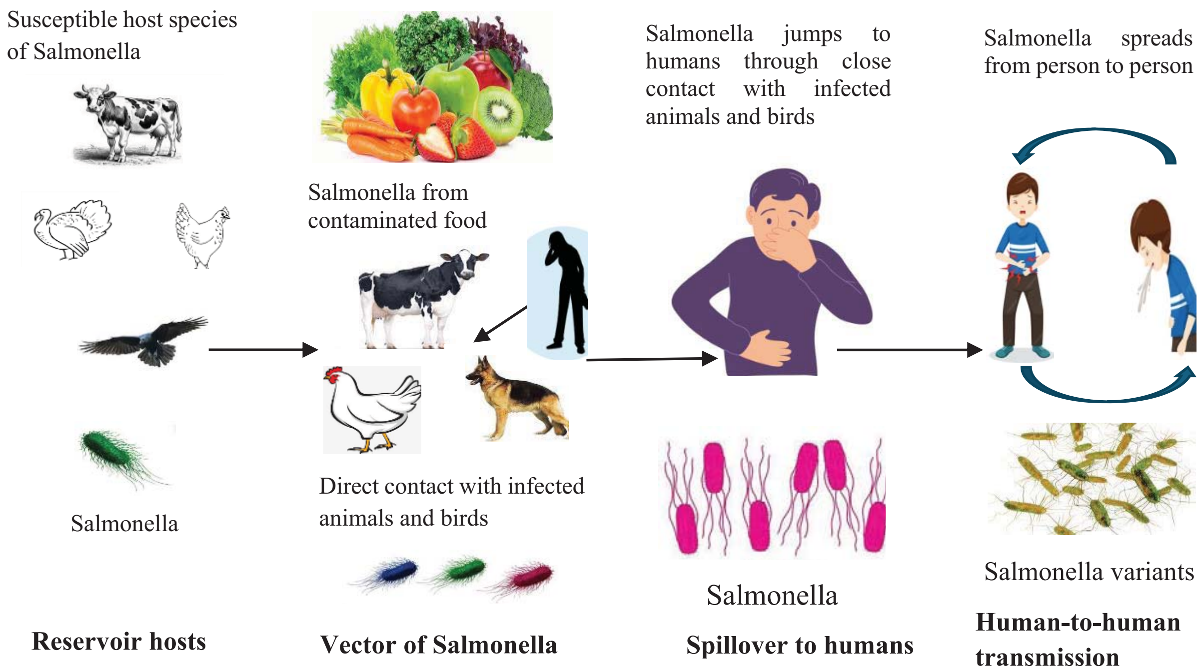


Fig. 6. Zoonotic transmission of Salmonella infection

Bovine salmonellosis

Salmonella infections are primarily caused by two groups of serotypes (strains) in dairy herds, which include ① Host-adapted strains- *Salmonella Dublin*- adapted explicitly to cattle, causes more severe symptoms and significant health issues in dairy cows. This strain has the potential to lead to chronic carriers, and ② Non-host-adapted strains- *S. Typhimurium*- a strain that can affect various animal species, including humans.

S. Dublin is a zoonotic bacterial pathogen that significantly impacts the dairy industry through calf losses, abortion, and reduced milk yield. It can cause high morbidity and mortality in young calves and reduce the performance of mature animals. Affected young calves suffer from pneumonia, diarrhea, swollen joints, fever, or sudden death.

Salmonella Dublin is difficult to control and eradicate from herds, as animals can become carriers and shed bacteria from clinically normal animals. S. Dublin is a zoonotic bacterium that can be lethal for humans and pose a risk to human and animal health due to its multi-drug-resistant characteristics.[259]

Salmonella Dublin is a zoonotic bacterium that can cause rare but severe illness in humans, and it is characterized by acute gastroenteritis and bacteremia. Humans can get infected with S. Dublin from direct contact with an infected animal or consumption of infected milk products. The case fatality for *S. Dublin* has been reported as the highest compared to other *Salmonella enterica* serotypes and has been described as six times greater than *S. Typhimurium*. The consumption of raw milk and unpasteurized dairy products has been associated with outbreaks of human salmonellosis caused by serovar Dublin. However, farm workers, veterinarians, and any person who can make direct contact with cattle are at risk of infection by accidentally ingesting animal feces or fluids.[259]

Symptomatic infected animals and latent carriers shed the bacterium to the environment under stress conditions, primarily in the peripartum. Once *S. Dublin* is shed in feces and secretions (saliva, colostrum, and milk) can survive in the environment. The newborn calf may uptake the bacterium via the fecal-oral route at calving or by consumption of raw colostrum or milk from infected cows. The infected calf will shed the bacterium to the environment, where susceptible calves will ingest *S. Dublin* through direct contact or fomite (contaminated surfaces or objects). In addition, the intrauterine infection of the fetus in the last trimester of gestation may occur, resulting in abortion or the birth of an infected calf. Finally, the zoonotic route will occur mainly in caretakers working with symptomatic animals and latent carriers at calving. The human will uptake S. Dublin from feces and secretions during calving assistance, cleaning equipment or facilities, manipulating raw colostrum and milk, or close contact with sick animals (Fig. 7).

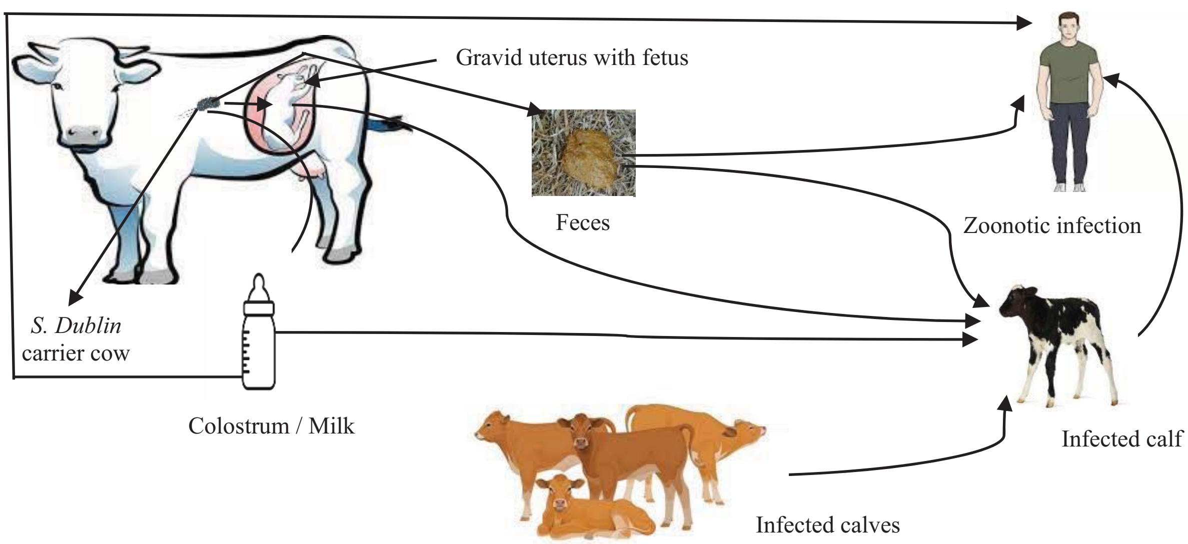


Fig. 7. Transmission routes of zoonotic *S. Dublin* infection in cattle and human

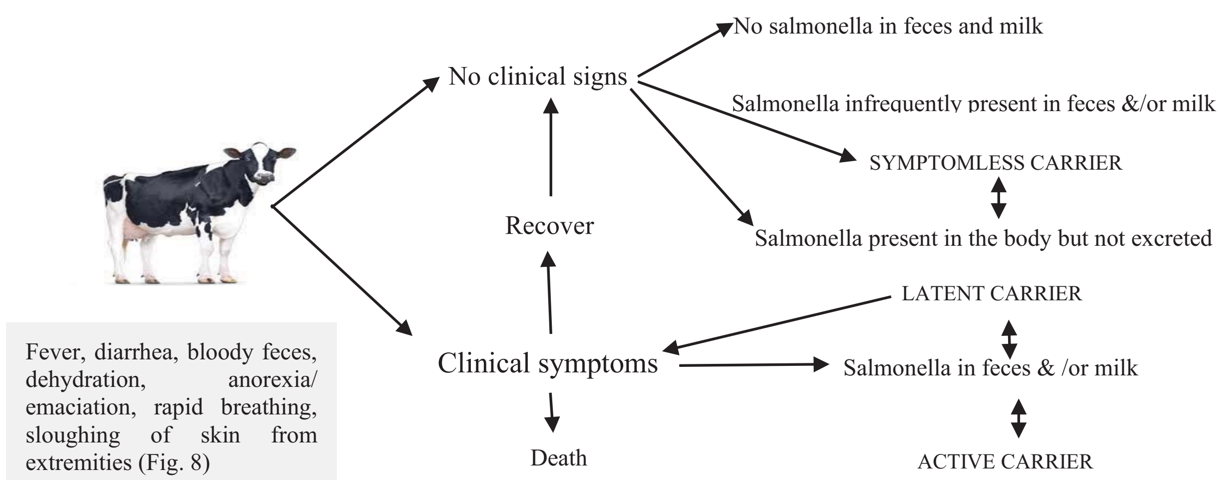


Fig. 8. Outcome of Salmonella infection in cattle

Antibiotic resistance patterns against Salmonella in food animals and poultry in Bangladesh

Various antimicrobial agents are indiscriminately used for the treatment and prevention of salmonellosis. An increasing rate of antimicrobial resistance in Salmonella has been reported globally, including in Bangladesh (Table 25). In addition, resistance to combinations of several antimicrobials has led to the emergence of Multidrug-resistant (MDR) strains that may pass from food animals and birds to humans.[250] The spread of antibiotic resistance plasmids in Salmonella from poultry birds to human handlers or antibiotic-resistant microorganisms from poultry to humans in various countries has been reported.[260] Increasing resistance to commonly used antimicrobials in human and veterinary medicine certainly poses a threat to public health associated with zoonotic diseases in Bangladesh.[261]

Table 25. Antibacterial resistance status of major bacterial pathogens isolated from humans, animals and poultry

S/N	Antibacterials & Districts	Host & types of samples used	No. of samples tested	*Escherichia coli*		*Salmonella* spp.		*Staphylococcus* spp.		Ref. No.
				Positive No. (%)	Resistance No. (%)	Positive No. (%)	Resistance No. (%)	Positive No. (%)	Resistance No. (%)	
A.	**Penicillin (inhibit cell wall synthesis)**									
01.	**Penicillin**									
	Dhaka	Layer-CS, IF, ESS	300	-	-	08 (02.67)	08 (100)	-	-	255
	Rajshahi	Chicken-CS	120	-	-	49 (40.83)	49 (100)	-	-	280
	B, P & B	Meat samples	205	061 (29.76)	009 (14.75)	19 (09.27)	11 (57.89)	77 (37.56)	12 (15.58)	290
	Dhaka	Chicken feces	250	166 (66.40)	146 (88.00)	-	-	-	-	298
	Jashore	Broiler- CS	005	005 (100)	005 (100)	-	-	-	-	300
	Sylhet	Chicken-CS, L	100	035 (35.00)	035 (100)	-	-	-	-	301
	Rajshahi	Chicken eggs	060	021 (35.00)	021 (100)	17 (28.33)	17 (100)	12 (20.00)	12 (100)	303
	Mymensingh	Milk- mastitis	016	005 (31.25)	005 (100)	-	-	10 (62.5)	05 (50.00)	312
	Chittagong	Dead broilers	275	150 (54.55)	113 (75.33)	-	-	-	-	316
	Panchagarh	Calf diarrhea	114	044 (38.60)	044 (100)	25 (21.93)	25 (100)	15 (13.16)	15 (100)	320
	Mymensingh,	Animals	100	-	-	-	-	54 (54.00)	35 (64.81)	345
	& Sirajgonj	Humans	100	-	-	-	-	40 (40.00)	35 (87.50)	345
	Sub-total		**1025/799/595**	**487 (47.51)**	**378 (77.62)**	**118**	**110 (93.22)**	**208 (34.96)**	**114 (54.81)**	
02.	**Oxacillin**									
	Savar, Dhaka	Poultry samples	-	-	-	67*	56 (84.00)	-	-	250
	Barishal City	Chicken- meat	020	-	-	13 (65.00)	13 (100)	-	-	263
	Mymensingh	Chicken	075	043 (57.33)	43 (100)	33 (44.00)	33 (100)	38 (50.67)	16 (42.10)	276
	Pirojpur	Dead layers	048	-	-	11 (22.92)	0	-	-	288
	Mymensingh,	Animals	100	-	-	-	-	54 (54.00)	04 (07.40)	345
	& Sirajgonj	Humans	100	-	-	-	-	40 (40.00)	15 (37.50)	345
	Sub-total		**75/124/275**	**043 (57.33)**	**43 (100)**	**124 (39.86)**	**102 (82.26)**	**132 (48.00)**	**35 (26.51)**	
03.	**Ampicillin**									
	Dhaka	Chicken-Cecal C	870	-	-	37 (04.25)	30 (81.08)	-	-	254
	Dhaka	Layer-CS, IF, ES	300	-	-	08 (02.67)	07 (88.00)	-	-	255
	Mymensingh	Chicken-CS	100	-	-	35 (35.00)	29 (82.85)	-	-	256
	Five districts	Broiler-frozen meat	113	-	-	74 (65.49)	47 (63.50)	-	-	264
	Four districts	Chicken (dead)	100	-	-	82 (82.00)	08 (09.76)	-	-	265
	Dhaka	Layer-egg surface	100	-	-	08 (08.00)	07 (87.50)	-	-	266
	Dhaka City	Chicken, man	-	-	-	10*	10 (100)	-	-	267
	Dhaka City	Broiler- meat	100	052 (52.00)	49 (94.23)	36 (36.00)	31 (86.11)	42 (42.00)	38 (90.48)	268
	Dhaka City	Chicken- eggs	200	018 (09.00)	14 (77.78)	18 (09.00)	14 (77.88)	18 (09.00)	15 (83.33)	269
	Dhaka	Chicken- eggs	050	-	-	50 (100)	35 (70.0)	-	-	270
	Dhaka	Chicken- meat	052	-	-	07 (13.46)	07 (100)	-	-	271
	Savar, Dhaka	Pigeon-oral & CS	040	021 (52.50)	15 (71.43)	11 (27.50)	03 (27.27)	-	-	272
	Mymensingh (M)	Pigeon-CS, FP, F	112	-	-	10 (08.93)	08 (80.00)	-	-	273
	Mymensingh	Pigeon-CS, PS	050	-	-	17 (34.00)	15 (88.23)	-	-	274
	Mymensingh	Layer-CS, IC, ES	060	-	-	032 (53.33)	19 (60.00)	-	-	275
	Mymensingh	Broiler-D, L, FW,	075	043 (57.33)	24 (55.81)	033 (44.00)	22 (66.67)	38 (50.67)	27 (71.05)	276
	Naogoan	Layer-egg samples	180	-	-	014 (07.78)	10 (71.42)	-	-	277
	Chattogram	Pigeon- CS	100	-	-	029 (29.00)	27 (93.1)	-	-	278
	Chittagong	Layer- ECS, ET	310	-	-	111 (35.81)	111 (100)	-	-	279

Contd. Table 25. Antibacterial resistance status of major bacterial pathogens isolated from humans, animals and poultry

S/ N	Antibacterials & Districts	Host & types of samples used	No. of samples tested	*Escherichia coli* Positive No. (%)	*Escherichia coli* Resistance No. (%)	*Salmonella* spp. Positive No. (%)	*Salmonella* spp. Resistance No. (%)	*Staphylococcus* spp. Positive No. (%)	*Staphylococcus* spp. Resistance No. (%)	Ref. No.
	Rajshahi	Chickens- CS	120	-	-	049 (40.83)	020 (40.00)	-	-	280
	M, Feni, D	Chicken - meat	24	-	-	024 (100)	008 (33.00) F	-	-	281
	DGT	Broiler- CS,M,F,W	352	-	-	110 (31.25)	047 (42.72)	-	-	282
	Chattogram	Chicken, CW	060	037 (61.67)	037 (88.00)	-	-	-	-	297
	Dhaka	Chicken feces	250	166 (66.40)	166 (100)	-	-	-	-	298
	Jashore	Broiler. CS	005	005 (100)	005 (100)	-	-	-	-	300
	Sylhet	Chicken-CS,L	100	035 (35.00)	035 (100)	-	-	-	-	301
	Mymensingh	Chicken	099	036 (36.36)	036 (100)	-	-	-	-	302
	Rajshahi	Chicken eggs	060	021 (35.00)	021 (100)	017 (28.33)	017 (100)	12 (20.00)	12 (100)	303
	Chittagong	Cattle - RC	100	070 (70.00)	061 (87.00)	-	-	-	-	304
	Cox's Bazar	Goat- RS	150	078 (52.00)	51 (65.38)	-	-	-	-	306
	T, S & M	Calves- feces	100	049 (49.00)	37 (75.51)	-	-	-	-	310
	Mymensingh	Milk- mastitis	016	005 (31.25)	05 (100)	10??	010 (00; 00.00)	-	-	312
	Rajshahi, Dhaka	Broilers	400	400 (100)	400 (100)	-	-	-	-	314
	Chittagong	Dead broilers	275	150 (54.55)	00 (00.00)	-	-	-	-	316
	Dhaka City	Human (BS)	4115	-	-	359 (08.72)	359 (100)	-	-	318
	Mymensingh	DW, D, ES	060	-	-	027 (45.00)	027 (100)*	-	-	319
	Panchagarh	Calf diarrhea	114	044 (38.59)	44 (100)	025 (21.93)	025 (100)	15 (13.16)	15 (100)	320
	Mymensingh	Cattle feces	135	-	-	039 (28.89)	018 (47.36)	-	-	323
	Dhaka City	Human blood	100	-	-	100 (100)	019 (18.83)	-	-	326
	Dhaka	Pigeons	040	021 (52.50)	15 (71.43)	011 (27.50)	003 (27.27)	-	-	328
	Dhaka	Chicken swabs	003	-	-	007 (100)	007 (100)	-	-	329
	Bangladesh	Chickens	279	101 (36.20)	26 (25.70)	-	-	-	-	330
	Rajshahi	Poultry	055	052 (94.55)	15 (28.85)	-	-	-	-	332
		Wild ducks	041	014 (34.15)	04 (28.57)	-	-	-	-	332
	Mymensingh	Quails	050	025 (S)		009 (R)		24 (R)	-	333
	Five districts	Chicken meat	113	086 (76.11)	77 (89.50)	-	-	-	-	335
	Bangladesh	Chicken meat	150	-	-	-	-	096 (64.00)	96 (100)	337
	7 districts	Chickens feces	725	691 (95.31)	641 (93.00)	-	-	-	-	340
	7 districts	Environmental	250	163 (65.20)	134 (82.00)	-	-	-	-	340
	N, N & M	130 samples	174	114 (65.51)	85 (74.76)	-	-	-	-	341
	Sylhet division	Chicken meat	600	381 (63.50)	377 (98.95)	-	-	-	-	342
	Sylhet division	B & S meat	400	136 (34.00)	136 (100)	-	-	-	-	343
	Mymensingh,	Animals	100	-	-	-	-	54 (54.00)	14 (25.93)	345
	& Sirajgonj	Huamns	100	-	-	-	-	-	-	345
	Sub-total		**4821/7583/799**	**2989 (61.99)**	**2510 (83.97)**	**1390 (18.33)**	**1000 (71.94)**	**299 (37.42)**	**217 (72.58)**	
4. Amoxicillin										
	Five divisions	Layer-CS, VO, D	765	-	-	214 (27.97)	106 (49.70)	-	-	252
	Dhaka	Chicken- CC	870	-	-	037 (04.25)	024 (72.70)	-	-	254
	Gazipur, M	Cattle, chickens	169	-	-	037 (21.89)	017 (45.95)	-	-	262
	Barishal City	Chicken meat	020	014 (70.00)	14 (100)	013 (65.00)	013 (100)	-	-	263
	Five districts	Broiler-frozen meat	113	-	-	074 (65.49)	055 (74.30)	-	-	264
	Dhaka	Layer-egg surface	100	-	-	008 (08.00)	007 (87.50)	-	-	266
	Dhaka City	Chicken meat	100	052 (52.00)	50 (96.15)	036 (36.00)	030 (83.33)	42 (42.00)	40 (95.24)	268
	Dhaka City	Eggs (S & C)	200	018 (09.00)	16 (88.89)	018 (09.00)	017 (94.44)	18 (09.00)	16 (88.89)	269
	Dhaka	Pigeons	040	21 (52.50)	13 (61.90)	011 (27.50)	004 (36.36)	-	-	272
	Mymensingh	Pigeon-CS, FP, F	112	-	-	010 (08.93)	009 (90.00)	-	-	273
	Mymensingh	Layer-CS, IC, ES	060	-	-	032 (53.33)	019 (60.00)	-	-	275
	Naogoan	Layer-eggs	180	-	-	014 (07.78)	013 (92.86)	-	-	277
	Chittagong	Layer-ECS, ET, EC	310	-	-	111 (35.81)	111 (100)	-	-	279
	Rajshahi	Broiler & layer-CS	120	-	-	049 (40.83)	012 (25.00)	-	-	280
	DGT	Broiler-CS, WC,	352	-	-	110 (31.25)	047 (42.72)	-	-	282
	Mymensingh	Broiler - CS	050	-	-	016 (32.00)	014 (87.50)	-	-	283
	M, G & S	Dressed broiler	060	50 (83.33)	40 (80.00)	014 (23.33)	012 (83.00)	-	-	284
	Mymensingh	Quail- CS	075	-	-	010 (13.33)	001 (10.00)	-	-	285
	Mymensingh	Layer-D, CS	150	-	-	011(07.33)	009 (81.81)	-	-	286

Contd. Table 25. Antibacterial resistance status of major bacterial pathogens isolated from humans, animals and poultry

S/N	Antibacterials & Districts	Host & types of samples used	No. of samples tested	*Escherichia coli* Positive No. (%)	Resistance No. (%)	*Salmonella* spp. Positive No. (%)	Resistance No. (%)	*Staphylococcus* spp. Positive No. (%)	Resistance No. (%)	Ref. No.
	Chittagong	Dead layers-liver,	030	013 (43.33)	11 (84.62)	008 (26.67)	08 (100)	-	-	287
	Pirojpur	Dead layer-L, S, IS	048	-	-	011 (22.92)	009 (81.82)	-	-	288
	Gazipur, Tangail	Broiler-7 sources	153	-	-	036 (23.53)	014 (38.89)	-	-	289
	B, P & B	CCBG meat	305	061 (20.00)	13 (21.31)	019 (06.23)	008 (00.00)	77 (25.25)	07 (00.00)	290
	J, T, N & K	Dressed broiler	020	017 (85.00)	15 (88.24)	14 (70.00)	04 (28.57)	-	-	291
	M & Jamalpur	Broiler- Feces, meat	070	-	-	46 (65.72)	046 (100)	-	-	292
	Dhaka	Chicken feces	040	011 (27.5)	11 (100)	-	-	-	-	299
		Human urine	048	014 (29.17)	14 (100)	-	-	-	-	299
	Rajshahi	Chicken eggs	060	021 (35.00)	01 (04.77)	17 (28.33)	01 (05.88)	12 (20.00)	09 (71.43)	303
	Chittagong	Cattle - RC	100	070 (70.00)	63 (90.00)	-	-	-	-	304
	Bangladesh	Human- UTI	-	1663	1497 (90.00)	-	-	-	-	305
	Dhaka City	Human -CS	100	100 (100)	98 (98.00)	-	-	-	-	309
	Mymensingh	Milk- mastitis	016	005 (31.25)	05 (100)	-	-	10 (62.50)	00 (00.00)	312
	Mymensingh	Human-urine	4000	453 (11.33)	405 (89.40)	-	-	-	-	313
	M & Gazipur	M, B & C meat	169	064 (37.87)	38 (59.38)	-	-	-	-	315
	Chittagong	Dead broilers	275	150 (54.55)	38 (25.00)	-	-	-	-	316
	Chattogram	H, A, E & F	810	358 (44.20)	303 (84.50)	-	-	-	-	317
	Panchagarh	Calf diarrhea	114	044 (38.59)	44 (100)	25 (21.93)	25 (100)	15 (13.16)	15 (100)	320
	Sylhet	Goat feces	220	-	-	20 (09.09)	20 (100)	-	-	321
	KYAMCH	Human (Blood)	282	002 (0.71)	20 (100)	04 (01.42)	04 (100)	42 (14.89)	19 (45.24)	324
	M, N & CNB	Cattle feces	057	027 (R)	-	08 (S)	-	-	-	325
	Gazipur, Tangail	Chickens	153	-	-	36 ()	14 (38.89)	-	-	327
	Dhaka	Pigeons	040	021 (52.5)	-	13 (61.90)	40 (100)	11 (27.50)	-	328
	Mymensingh	Chickens	350	276 (R)	-	-	-	-	-	331
	Mymensingh	Quails	050	025 (R)	-	09 (R)	-	24 (R)	-	333
	Mymensingh	Pigeons	112	78 (69.64)	10/7 (70.00)	-	-	-	-	334
	Five districts	Chicken meat	113	086 (76.11)	79 (91.90)	-	-	-	-	335
	BD & Nepal	Ducks	120	085 (70.83)	-	-	-	-	-	336
	Bangladesh	Chicken meat	150	-		-	-	96 (64.00)	77 (80.00)	337
	Bangladesh	Calf feces	125	035 (28.00)	35 (100)	11 (08.80)	11 (100)	-	-	338
	Mymensingh	Children stool	083	027 (32.53)	24 (88.88)	-	-	-	-	339
	Mymensingh,	Animals	100	-	-	-	-	54 (54.00)	20 (37.04)	345
	& Sirajgonj	Huamns	100	-	-	-	-	40 (40.00)	15 (37.50)	345
	Sub-total		**7494/5161/1467**	**3475 (46.37)**	**2854 (82.13)**	**1093 (21.18)**	**724 (66.24)**	**459 (31.29)**	**218 (47.49)**	
05.	**Amoxicillin-clavulanic acid**									
	Dhaka	Chicken-CCs	870	-	-	31 (03.56)	10 (31.25)	-	-	254
	Five districts	Broiler-frozen meat	113	-	-	74 (65.49)	19 (25.70)	-	-	264
	Four districts	Chicken-liver, Intest	100	-	-	82 (82.00)	34 (41.46)	-	-	265
	Cox's Bazar	Goat- RS	150	078 (52.00)	47 (60.26)	-	-	-	-	306
	M & Gazipur	Broiler-CS+	150	114 (76.00)	23 (20.20)	-	-	-	-	308
	KYAMCH	Human (Blood)	282	002 (0.71)	20 (100)	04 (01.42)	04 (100)	42 (14.89)	18 (42.86)	324
	Sub-total		**582/1365/282**	**194 (33.33)**	**90 (46.39)**	**191 (13.99)**	**67 (35.08)**	**42 (14.89)**	**18 (42.86)**	
06.	**Piperacillin-tazobactam**									
	Five districts	Broiler- frozen meat	113	74 (65.49)	15 (20.30)	-	-	-	-	264
	Four districts	Chicken-liver, Intes-	100	82 (82.00)	08 (08.64)	-	-	-	-	265
	Sub-total:		**213**	**156 (73.24)**	**23 (14.74)**	**-**	**-**	**-**	**-**	
B.	**Cephalosporins (inhibit cell wall synthesis)**									
01.	**Cefixime**									
	Dhaka	Layer-CS, IF, ESS	210	-	-	30 (14.29)	10 (33.33)	-	-	255
	Mymensingh	Chicken -CS	100	-	-	35 (35.00)	0	-	-	256
	Five districts	Broiler-frozen meat	113	-	-	74 (65.49)	04 (05.40)	-	-	264
	Dhaka	Chicken feces	250	166 (66.40)	113 (68.00)	-	-	-	-	298
	Bangladesh	Human- UTI	-	1663	956 (57.50)	-	-	-	-	305
	KYAMCH	Human (Blood)	282	02 (0.71)	02 (100)	04 (01.42)	04 (100)	42 (14.89)	24 (57.14)	324
	Dhaka City	Human blood	100	-	-	100 (100)	36 (36.00)	-	-	326

Contd. Table 25. Antibacterial resistance status of major bacterial pathogens isolated from humans, animals and poultry

S/N	Antibacterials & Districts	Host & types of samples used	No. of samples tested	*Escherichia coli* Positive No. (%)	*Escherichia coli* Resistance No. (%)	*Salmonella* spp. Positive No. (%)	*Salmonella* spp. Resistance No. (%)	*Staphylococcus* spp. Positive No. (%)	*Staphylococcus* spp. Resistance No. (%)	Ref. No.
	Mymensingh	Children stool	083	27 (32.53)	17 (62.96)	-	-	-	-	340
	Sub-total		**615/243/282**	**195 (31.71)**	**1088 (58.56)**	**243 (100)**	**54 (22.22)**	**282 (100)**	**24 (57.14)**	
02.	**Ceftazidime**									
	Dhaka	Chicken-CC	870	-	-	31 (03.56)	04 (12.90)	-	-	254
	Five districts	Broiler-frozen meat	113	-	-	74 (64.49)	01 (01.40)	-	-	264
	Dhaka	Layer-egg surface	100	-	-	08 (08.00)	03 (37.50)	-	-	266
	M & Jamalpur	Broiler-feces, meat	70	-	-	46 (65.71)	28 (61.90)	-	-	292
	M & Gazipur	Broiler-CS+	150	114 (76.00)	002 (01.80)	-	-	-	-	308
	Mymensingh	Human-urine	4000	453 (11.33)	210 (46.36)	-	-	-	-	313
	Dhaka City	Human blood	100	-	-	100 (100)	75 (75.00)	-	-	326
	Mymensingh	Chickens	350	276 (S)	-	-	-	-	-	331
	7 districts	Chicken feces	725	691 (95.31)	12 (02.00)	-	-	-	-	340
	7 districts	Environmental	250	163 (65.20)	01 (01.00)	-	-	-	-	340
	Sub-total		**5125/1253**	**1421 (27.73)**	**225 (15.83)**	**219 (17.48)**	**111 (50.68)**	**-**	**-**	
03.	**Ceftriaxone**									
	Dhaka (Savar)	Layer samples	-	-	-	67*	07 (10.00)	-	-	250
	Dhaka	Chicken- CC	870	-	-	20 (02.30)	03 (15.00)	-	-	254
	Barishal City	Chicken meat	020	014 (70.00)	08 (57.30)	13 (65.00)	09 (69.24)	-	-	263
	Five districts	Broiler-frozen meat	113	-	-	74 (65.49)	02 (02.70)	-	-	264
	Four districts	Chicken-Liver, Intes.	100	-	-	82 (82.00)	33 (40.24)	-	-	265
	Dhaka	Layer-egg surface	100	-	-	08 (08.00)	03 (37.50)	-	-	266
	Dhaka City	Chicken meat	100	052 (52.00)	04 (07.69)	36 (36.00)	03 (08.33)	42 (42.00)	04 (09.52)	268
	Dhaka City	Eggs (S & C)	200	018 (09.00)	16 (88.89)	18 (09.00)	15 (83.33)	18 (09.00)	16 (88.89)	269
	Dhaka	Chicken meat	052	-	-	07 (13.86)	02 (08.58)	-	-	271
	Naogoan	Layer eggs	180	-	-	14 (07.78)	02 (14.29)	-	-	277
	Chattogram	Pigeon - CS	100	-	-	29 (29.00)	14 (48.28)	-	-	278
	Pirojpur	Dead layer -L, S & IS	048	-	-	11 (22.92)	09 (69.24)	-	-	288
	Chattogram	Chicken feces	050	-	-	28 (56.00)	27 (96.42)	-	-	294
	Dhaka	Chicken feces	250	166 (66.40)	00 (00.00)	-	-	-	-	298
	Bangladesh	Human- UTI	-	1663	1363 (51.2)	-	-	-	-	305
	Cox's Bazar	Goat- RS	150	078 (52.00)	17 (21.79)	-	-	-	-	306
	M & Gazipur	Broiler-CS+	150	114 (76.00)	09 (07.90)	-	-	-	-	308
	Mymensingh	Human-urine	4000	453 (11.33)	276 (60.90)	-	-	-	-	313
	Chattogram	Chicken, CS	050	-	-	28 (56.00)	27 (96.42)	-	-	322
	KYAMCH	Human (Blood)	282	002 (0.71)	20 (100)	04 (01.42)	34 (75.00)	42 (14.89)	13 (00.00)	324
	Mymensingh	Children stool	083	027 (32.53)	19 (70.37)	-	-	-	-	339
	Mymensingh,	Animals	100	-	-	-	-	54 (54.00)	07 (12.96)	345
	& Sirajgonj	Huamns	100	-	-	-	-	40 (40.00)	08 (20.00)	345
	Sub-total:		**5235/2265/782**	**924 (17.65)**	**1732 (66.92)**	**439 (19.38)**	**190 (43.28)**	**196 (25.03)**	**48 (24.49)**	
04.	**Cefotaxime**									
	Dhaka (Savar)	Layer samples	-	-	-	67*	13 (139.00)	-	-	250
	Dhaka	Chicken CC	870	-	-	15 (01.72)	02 (13.33)	-	-	254
	Five districts	Broiler-frozen meat	113	-	-	74 (65.49)	03 (04.10)	-	-	264
	Dhaka City	Chicken meat	100	052 (52.00)	04 (07.69)	36 (36.00)	04 (11.11)	42 (42.00)	03 (07.14)	268
	Dhaka	Chicken meat	052	-	-	07 (13.46)	01 (14.18)	-	-	271
	Cox's Bazar	Goat- RS	150	078 (52.00)	21 (26.92)	-	-	-	-	306
	M & Gazipur	Broiler-CS+	150	114 (76.00)	89 (78.10)	-	-	-	-	308
	7 districts	Chickens feces	725	691 (95.31)	19 (03.00)	-	-	-	-	340
	7 districts	Environmental	250	163 (65.20)	02 (01.00)	-	-	-	-	340
	Sub-total		**1375/1135/100**	**1098 (79.85)**	**135 (12.30)**	**132 (11.63)**	**23 (11.58)**	**42 (42.00)**	**03 *07.14)**	
05.	**Cefuroxime**									
	Dhaka (Savar)	Layer samples	-	-	-	67*	15 (22.00)	-	-	250
	Five districts	Broiler-frozen meat	113	-	-	74 (65.49)	02 (02.70)	-	-	264
	Four districts	Chicken-liver, Intes	100	-	-	82 (82.00)	26 (31.71)	-	-	265
	Dhaka City	Human -CS	100	100 (100)	75 (75.00)	-	-	-	-	309
	KYAMCH	Human (Blood)	282	02 (0.71)	21 (100)	04 (01.42)	02 (50.00)	42 (14.89)	13 (30.95)	324
	Dhaka City	Human blood	100	-	-	100 (100)	13 (13.00)	-	-	326

Contd. Table 25. Antibacterial resistance status of major bacterial pathogens isolated from humans, animals and poultry

S/N	Antibacterials & Districts	Host & types of samples used	No. of samples tested	*Escherichia coli* Positive No. (%)	*Escherichia coli* Resistance No. (%)	*Salmonella* spp. Positive No. (%)	*Salmonella* spp. Resistance No. (%)	*Staphylococcus* spp. Positive No. (%)	*Staphylococcus* spp. Resistance No. (%)	Ref. No.
	Rajshahi	Poultry	055	52 (94.55)	02 (03.85)	-	-	-	-	332
		Wild ducks	041	14 (34.15)	01 (07.14)	-	-	-	-	332
	Mymensingh,	Animals	100	-	-	-	-	-	-	345
	& Sirajgonj	Huamns	100	-	-	-	-	40 ()	06 (15.00)	345
	Sub-total		**478/317/382**	**168 (35.15)**	**99 (58.93)**	**327/260**	**58 (17.74)**	**82 (21.47)**	**19 (23.17)**	
06.	**Cefaclor**									
	Five districts	Broiler-frozen meat	113	-	-	74 (65.49)	10 (13.50)	-	-	264
07.	**Cefoxitin**									
	N, N & M	130 samples	174	114 (65.52)	47 (41.23)	-	-	-	-	341
	Five districts	Broiler-frozen meat	113	-	-	74 (65.49)	06 (08.10)	-	-	264
	Sub-total		**174/74**	**114 (65.52)**	**47 (41.23)**	**74 (65.49)**	**06 (08.10)**			
08.	**Cephalexin**									
	Savar, Dhaka	Layer samples	-	-	-	67*	21 (31.00)	-	-	250
	Dhaka	Layer-CS, IF, ES	300		-	08 (02.67)	05 (65.00)	-	-	255
	Five districts	Broiler-frozen meat	113	-	-	74 (65.49)	07 (09.50)	-	-	264
	Dhaka	Layer- egg surface	100	-	-	08 (08.00)	04 (50.00)	-	-	266
	Mymensingh	Pigeon-CS, PS	050	-	-	17 (34.00)	14 (82.35)	-	-	274
	Dhaka City	Chicken, man-feces	010	-	-	10 (100)	09 (90.00)	-	-	295
	Sylhet	Chicken-CS, L	100	035 (35.00)	035 (100)	-	-	-	-	301
	Bangladesh	Human- UTI	-	1663	1399 (84.10)	-	-	-	-	305
	BD & Nepal	Ducks	120	085 (I)	-	-	-	-	-	336
	Sub-total		**220/573**	**1698**	**1434 (84.45)**	**184 (32.11)**	**60 (32.61)**	**-**	**-**	
09.	**Cefradine**									
	Five districts	Broiler-frozen meat	113	-	-	74 (65.49)	09 (12.20)	-	-	264
	B, P & B	CCBG meat	305	61 (20.00)	14 (00.00)	19 (06.23)	11 (00.00)	77 (25.25)	09 (00.00)	290
	Mymensingh	Human-urine	4000	453 (11.33)	315 (00.00)	-	-	-	-	313
	KYAMCH	Human (blood)	282	02 (0.71)	02 (100)	04 (01.42)	04 (100)	42 (14.89)	26 (00.00)	324
	Rajshahi	Poultry	055	52 (94.55)	00 (00.00)	-	-	-	-	332
		Wild ducks	041	14 (34.15)	01 (00.00)	-	-	-	-	332
	Mymensingh	Children stool	083	27 (32.53)	23 (85.18)	-	-	-	-	339
	Mymensingh,	Animals	100	-	-	-	-	54 (54.00)	06 (11.11)	345
	& Sirajgonj	Huamns	100	-	-	-	-	40 (40.00)	10 (25.00)	345
	Sub-total		**4766/700/787**	**609 (12.78)**	**355 (58.29)**	**97 (13.86)**	**24 (24.74)**	**213 (27.06)**		
10.	**Cefadroxil**									
	Rajshahi	Poultry birds	55	52 (94.55)	00 (00.00)	-	-	-	-	332
		Wild ducks	41	14 (34.15)	01 (07.14)	-	-	-	-	332
	Sub-total		**96**	**66 (68.75)**	**01 (01.52)**	**-**	**-**	**-**	**-**	
11.	**Cefepime**									
	Savar, Dhaka	Layer samples	-	-	-	67*	13 (19.00)	-	-	250
	Five districts	Broiler-frozen meat	113	-	-	74 (65.49)	01 (01.40)	-	-	264
	Four districts	Chicken-liver, intes	100	-	-	82 (82.00)	15 (18.29)	-	-	265
	Five districts	Chicken meat	113	86 (76.12)	62 (72.10)	-	-	-	-	335
	Sub-total		**113 /213**	**86 (76.12)**	62 (72.10)	**156 (73.24)**	**29 (18.59)**	**-**	**-**	
C.	**Chloramphenicol (inhibit protein synthesis)**									
	Dhaka (Savar)	Layer samples	-	-	-	67*	04 (06.00)	-	-	250
	Dhaka	Chicken- CC	870	-	-	21 (02.41)	02 (09.52)	-	-	254
	Dhaka	Layer-CS, IF, ES	300	-	-	150 (50.00)!	58 (58.00)	-	-	255
	Mymensingh	Chicken- CS	100	-	-	35 (35.00)	33 (94.30)	-	-	256
	Five districts	Broiler-f meat	113	-	-	74 (65.49)	21 (28.40)	-	-	264
	Dhaka City	Chicken, man-feces,	010	-	-	10 (100)	04 (40.00)	-	-	267
	Dhaka City	Chicken meat	100	052 (52.00)	15 (28.85)	036 (36.00)	20 (55.56)	42 (42.00)	40 (95.24)	268
	Dhaka City	Eggs (S & C)	200	018 (09.00)	07 (38.89)	018 (09.00)	07 (38.89)	18 (09.00)	10 (55.56)	269
	Mymensingh (M)	Pigeon-CS, FP, F	112	-	-	10 (08.93)	1 (10.00)	-	-	273
	Mymensingh	Layer-CS, IF, ES	060	-	-	32 (53.33)	13 (40.00)	-	-	275

! Total isolates 150 but 100 isolates were used for antibiotic sensitivity test

Contd. Table 25. Antibacterial resistance status of major bacterial pathogens isolated from humans, animals and poultry

S/ N	Antibacterials & Districts	Host & types of samples used	No. of samples tested	*Escherichia coli* Positive No. (%)	Resistance No. (%)	*Salmonella* spp. Positive No. (%)	Resistance No. (%)	*Staphylococcus* spp. Positive No. (%)	Resistance No. (%)	Ref. No.
	Dhaka	Chicken-egg	50	-	-	50 (100)	25 (50.0)	-	-	270
	Mymensingh (M)	Pigeon-CS, FP, F	112	-	-	10 (08.93)	1 (10.00)	-	-	273
	Mymensingh	Layer-CS, IF, ES	060	-	-	32 (53.33)	13 (40.00)	-	-	275
	Mymensingh	Chicken	075	043 (57.33)	09 (20.93)	033 (44.00)	14 (42.42)	38 (50.67)	27 (71.05)	276
	Naogoan	Layer-eggs	180	-	-	14 (07.78)	04 (28.57)	-	-	277
	Chattogram	Pigeon-CS	100	-	-	29 (29.00)	15 (51.7)	-	-	278
	B, P & B	Meat samples	305	061 (20.00)	00 (00.00)	019 (06.23)	00 (00.00)	77 (25.25)	00 (00.00)	290
	M & Jamalpur	Broiler-feces, meat,	070	-	-	46 (65.71)	18 (38.10)	-	-	292
	Mymensingh	Cows- 6 types	240	180 (75.00)	61 (33.89)	136 (56.67)	43 (31.62)	-	-	293
	M & Tangail	Feces, CS	055	055 (100)	11 (20.00)	027 (49.09)	08 (29.63)	-	-	295
	Chittagong	Diarrheic child'	350	-	-	015 (04.29)	01 (06.67)	-	-	296
	Dhaka	Chicken feces	250	166 (66.4)	75 (45.00)	-	-	-	-	298
	Mymensingh	Chicken	099	036 (36.36)	35 (97.20)	-	-	-	-	302
	Dhaka City	Human -CS	100	100 (100)	40 (40.00)	-	-	-	-	309
	T, S & M	Calves- feces	100	048 (48.00)	03 (06.12)	-	-	-	-	310
	Mymensingh	Milk- mastitis	016	005 (31.25)	00 (00.00)	-	-	10 (62.50)	00 (00.00)	312
	Dhaka City	Human (BS)	4115	-	-	359 (08.72)	54 (15.04)	-	-	318
	Mymensingh	DW, D, ES	060	-	-	027 (45.00)	00 (00.00)*	-	-	319
	Panchagarh	Calf diarrhea	114	044 (38.60)	26 (59.10)	025 (56.82)	19 (76.00)	15 (13.16)	10 (66.67)	320
	Mymensingh	Cattle feces	135	-	-	039 (28.89)	12 (31.57)	-	-	323
	Dhaka City	Human blood	100	-	-	100 (100)	04 (04.00)	-	-	326
	Bangladesh	Chickens	279	101 (36.20)	09 (08.90)	-	-	-	-	330
	Mymensingh	Chickens	350	276 (S)	-	-	-	-	-	331
	Rajshahi	Poultry	055	052 (94.55)	04 (07.69)	-	-	-	-	332
		Wild ducks	041	014 (34.15)	00 (00.00)	-	-	-	-	332
	Mymensingh	Quails	050	025 (S)	009 (S)	24 (S)	-	-	-	333
	Mymensingh	Pigeons	112	010 (08.93)	00 (00.00)	-	-	-	-	334
	BD & Nepal	Ducks	120	085 (S)	-	-	-	-	-	336
	7 districts	Chickens feces	725	691 (95.31)	444 (64.00)	-	-	-	-	340
	7 districts	Environmental	250	163 (65.20)	54 (33.00)	-	-	-	-	340
	N, N & M	130 samples	174	114 (65.52)	59 (51.75)	-	-	-	-	341
	Sylhet division	Chicken meat	600	381 (63.50)	190 (49.86)	-	-	-	-	342
	Sub-total		**3890/8386/810**	**2610 (67.10)**	**1042 (39.92)**	**1323 (16.91)**	**251 (18.97)**	**200 (24.69)**	**87 (43.50)**	
D. Tetracyclines (inhibit protein synthesis)										
01.	Tetracycline									
	Dhaka	Chicken-CS	870	-	-	37 (04.25)	31 (83.78)	-	-	254
	Dhaka	Layer-CS, IF, ES	300	-	-	08 (02.67)	08 (100)	-	-	255
	Mymensingh	Chicken- CS	100	-	-	35 (35.00)	34 (97.14)	-	-	256
	Five districts	Broiler-frozen meat	113	-	-	74 (65.49)	64 (86.50)	-	-	264
	Dhaka City	Chicken, man-feces,	010	-	-	10 (100)	09 (90.00)	-	-	267
	Dhaka City	Chicken meat	100	052 (52.00)	052 (100)	036 (36.00)	36 (100)	42 (42.00)	42 (100)	268
	Dhaka City	Eggs (S & C)	200	018 (18.00)	018 (100)	018 (09.00)	17 (94.44)	18 (09.00)	17 (94.44)	269
	Dhaka	Chicken eggs	050	-	-	50 (100)	050 (100)	-	-	270
	Dhaka	Pigeons	040	021 (52.50)	011 (52.38)	011 (27.50)	11 (100)	-	-	272
	Mymensingh	Pigeon-CS, FP, F	112	-	-	10 (08.93)	06 (60.00)	-	-	273
	Mymensingh	Layer-CS, IC, ES	060	-	-	32 (53.33)	32 (100)	-	-	275
	Chattogram	Pigeon-CS	100	-	-	29 (29.00)	25 (86.2)	-	-	278
	Chittagong	Layer-ECS, ET, EC	310	-	-	111 (35.81)	111 (100)	-	-	279
	DGT	Broiler-CS, M, FW	352	-	-	110 (31.25)	88 (80.00)	-	-	282
	M, G & S	Dressed broiler	060	050 (83.33)	011 (21.00)	014 (23.33)	10 (69.00)	-	-	284
	Mymensingh	Quail -CS	075	-	-	010 (13.33)	010 (100)	-	-	285
	Mymensingh	Layer-D, CS	150	-	-	11 (07.33)	82 (81.81)	-	-	286
	Chittagong	Dead layers	030	013 (43.33)	013 (100)	008 (26.67)	08 (100)	-	-	287
	Gazipur, Tangail	Broiler-7 sources	153	-	-	036 (23.53)	0	-	-	289
	B, P & B	Meat samples	305	061 (20.00)	002 (03.28)	019 (06.23)	01 (05.26)	77 (25.25)	03 (03.89)	290

Contd. Table 25. Antibacterial resistance status of major bacterial pathogens isolated from humans, animals and poultry

S/N	Antibacterials & Districts	Host & types of samples used	No. of samples tested	*Escherichia coli*		*Salmonella* spp.		*Staphylococcus* spp.		Ref. No.
				Positive No. (%)	Resistance No. (%)	Positive No. (%)	Resistance No. (%)	Positive No. (%)	Resistance No. (%)	
	J, T, N & K	Dressed broiler	020	017 (85.00)	003 (17.64)	014 (70.00)	12 (85.71)	-	-	291
	Mymensingh	Cows- 6 types	240	180 (75.00)	161 (89.44)	136 (56.67)	118 (86.76)	-	-	293
	M & Tangail	Feces, CS	055	055 (100)	029 (52.73)	027 (49.09)	27 (100)	-	-	295
	Chittagong	Children	350	-	-	015 (04.29)	04 (26.67)	-	-	296
	Chattogram	Chicken, CW	060	037 (61.67)	037 (100)	-	-	-	-	297
	Dhaka	Chicken feces	250	166 (66.40)	086 (52.00)	-	-	-	-	298
	Dhaka	Chicken feces	040	011 (27.50)	011 (100)	-	-	-	-	299
		Human urine	048	014 (29.17)	010 (73.30)	-	-	-	-	299
	Mymensingh	Chicken	099	036 (36.36)	036 (100)	-	-	-	-	302
	Rajshahi	Chicken eggs	060	021 (35.00)	017 (80.95)	017 (28.33)	14 (82.35)	12 (20.00)	10 (85.71)	303
	Chittagong	Cattle - RC	100	070 (70.00)	070 (100)	-	-	-	-	304
	Cox's Bazar	Goat- RS	150	078 (52.00)	40 (51.28)	-	-	-	-	306
	Dhaka City	Human -CS	100	100 (100)	55 (55.00)	-	-	-	-	309
	T, S & M	Calves- feces	100	49 (49.00)	05 (10.21)	-	-	-	-	310
	Rajshahi, Dhaka	Broilers	400	400 (100)	400 (100)	-	-	-	-	314
	Chattogram	H, A, E & F	810	358 (44.20)	286 (79.9)	-	-	-	-	317
	Mymensingh	DW, D, ES	060	-	-	27 (45.00)	27 (100)*	-	-	319
	Sylhet	Goat feces	220	-	-	20 (09.09)	11 (55.56)	-	-	321
	Mymensingh	Cattle feces	135	-	-	39 (28.89)	29 (73.68)	-	-	323
	M, N & CNB	Cattle feces	057	27 (R)	-	08 (R)	-	-	-	325
	Gazipur, Tangail	Chickens	153	-	-	36 (23.53)	36 (100)	-	-	327
	Dhaka	Pigeons	040	21 (52.50)	11 (52.38)	11 (27.50)	11 (100)	-	-	328
	Dhaka	Chicken swabs	003	-	-	07!	04 (50.00)	-	-	329
	Bangladesh	Chickens	279	101 (36.20)	46 (45.50)	-	-	-	-	330
	Mymensingh	Chickens	350	276 (R)	-	-	-	-	-	331
	Rajshahi	Poultry	055	52 (94.55)	24 (46.15)	-	-	-	-	332
		Wild ducks	041	14 (34.15)	01 (07.14)	-	-	-	-	332
	Mymensingh	Quails	050	25 (R)	-	09 (R)	-	24 (S)	-	333
	Mymensingh	Pigeons	112	10 (08.93)	09 (90.00)	-	-	-	-	334
	Five districts	Chicken meat	113	86 (76.11)	73 (84.90)	-	-	-	-	335
	Bangladesh	Calf feces	125	35 (28.00)	35 (100)	11 (08.80)	11 (100)	-	-	338
	7 districts	Chicken feces	725	691 (95.31)	679 (98.00)	-	-	-	-	340
	7 districts	Environmental	250	163 (65.20)	151 (93.00)	-	-	-	-	340
	N, N & M	130 samples	174	114 (65.52)	86 (75.44)	-	-	-	-	341
	Sylhet division	Chicken meat	600	381 (63.50)	325 (85.30)	-	-	-	-	342
	Sub-total		**5781/4951/665**	**3427 (61.01)**	**2793 (81.50)**	**1037 (20.95)**	**937 (90.36)**	**173 (29.02)**	**72 (41.62)**	
02.	Oxytetracycline									
	Five divisions	Layer-CS, VO, D	765	-	-	214 (27.97)	171 (79.70)	-	-	252
	M, Gazipur	Chicken, Cow-	169	-	-	37 (21.89)	08 (21.62)	-	-	262
	Barishal City	Chicken meat	020	014 (70.00)	014 (100)	013 (65.00)	013 (100)	-	-	263
	Five districts	Broiler meat	113	-	-	74 (65.49)	74 (100)	-	-	264
	Mymensingh	Chicken	075	043 (57.33)	043 (100)	033 (44.00)	033 (100)	38 (50.67)	16 (42.10)	276
	Pirojpur	Dead layer-L, S	048	-	-	11 (22.92)	10 (90.91)	-	-	288
	B, P & B	Meat samples	305	061 (12.08)	008 (13.11)	019 (06.23)	009 (47.39)	77 (25.25)	04 (05.90)	290
	Mymensingh	Cows- 6 types	240	180 (75.00)	142 (78.89)	136 (56.67)	103 (75.73)	-		293
	M & Gazipur	M, B & C meat	169	064 (37.87)	033 (51.56)	-	-	-		315
	Chittagong	Dead broilers	275	150 (54.54)	075 (50.00)	-	-	-	-	316
	Five districts	Chicken meat	113	086 (76.11)	080 (93.00)	-	-	-	-	335
	Bangladesh	Chicken meat	150	-	-	-	-	96 (64.00)	77 (80.20)	337
	Mymensingh,	Animals	100	-	-	-	-	54 (54.00)	23 (42.59)	345
	& Sirajgonj	Huamns	100	-	-	-	-	-	-	345
	Sub-total		**1197/1735/630**	**598 (49.96)**	**395 (66.03)**	**537 (30.95)**	**421 (78.39)**	**265 (42.06)**	**120 (45.28)**	
03.	**Doxycycline**									
	Savar, Dhaka	Layer samples	-	-	-	67*	35 (52.00)	-	-	250
	M, Gazipur	Chicken, Cow-	169	-	-	37 (21.89)	29 (78.38)	-	-	262
	Dhaka	Layer-ECS, Et,	100	-	-	08 (08.00)	04 (50.00)	-	-	266

Contd. Table 25. Antibacterial resistance status of major bacterial pathogens isolated from humans, animals and poultry

S/N	Antibacterials & Districts	Host & types of samples used	No. of samples tested	*Escherichia coli* Positive No. (%)	*Escherichia coli* Resistance No. (%)	*Salmonella* spp. Positive No. (%)	*Salmonella* spp. Resistance No. (%)	*Staphylococcus* spp. Positive No. (%)	*Staphylococcus* spp. Resistance No. (%)	Ref. No.
	Five divisions	Layer-CS, VO, D	765	-	-	214 (27.97)	131(61.40)	-	-	252
	Five districts	Broiler-frozen meat	113	-	-	74 (65.49)	43 (58.10)	-	-	264
	Mymensingh	Layer-D, CS	150	-	-	11 (07.33)	09 (81.81)	-	-	286
	Chittagong	Dead layers-	030	013 (43.33)	07 (53.75)	08 (26.67)	04 (50.00)	-	-	287
	Chittagong	Children-	350	-	-	15 (04.29)	01 (06.67)	-	-	296
	M & Gazipur	Broiler-CS+	150	114 (76.00)	89 (78.10)	-	-	-	-	308
	M & Gazipur	M, B & C	169	064 (37.87)	28 (43.45)	-	-	-	-	315
	Dhaka	Chicken swabs	003	-	-	07 (100)	05 (66.66)	-	-	329
	Bangladesh	Chicken meat	150	-	-	-	-	96 (64.00)	77 (82.00)	337
	N, N & M	130 samples	174	114 (65.52)	90 (78.95)	-	-	-	-	341
	Mymensingh,	Animals	100	-	-	-	-	-	-	345
	& Sirajgonj	Huamns	100	-	-	-	-	40 (40.00)	05 (12.50)	345
	Sub-total		**349/1456/250**	**305 (87.39)**	**214 (70.16)**	**329 (22.59)**	**193 (58.66)**	**136 (54.40)**	**82 (60.29)**	
E. Fluoroquinolones (interfere with DNA synthesis)										
01.	**Ciprofloxacin**									
	Five divisions	Layer-CS, VO, D	765	-	-	214 (27.97)	64 (30.00)	-	-	252
	Dhaka	Chicken- CC	870	-	-	37 (04.25)	31 (83.78)	-	-	254
	Dhaka	Chicken-CS, IF, ESS	300	-	-	08 (02.67)	071 (20.00)	-	-	255
	Mymensingh	Chicken- CS	100	-	-	35 (35.00)	05 (14.30)	-	-	256
	M, Gazipur	Chicken, Cow- CM	169	-	-	37 (21.89)	06 (16.22)	-	-	262
	Barishal City	Chicken meat	020	014 (70.00)	13 (92.86)	13 (65.00)	13 (100)	-	-	263
	Five districts	Broiler- frozen meat	113	-	-	74 (65.49)	28 (37.80)	-	-	264
	Four districts	Chicken-Liver, Intes.	100	-	-	82 (82.00)	60 (73.17)	-	-	265
	Dhaka City	Chicken meat	100	052 (52.00)	13 (25.00)	36 (36.00)	12 (33.33)	42 (42.00)	07 (16.67)	268
	Dhaka City	Eggs (S & C)	200	018 (09.00)	00 (00.00)	18 (09.00)	01 (05.56)	18 (09.00)	00 (00.00)	269
	Dhaka	Chicken- egg	050	-	-	50 (100)	0	-	-	270
	Dhaka	Chicken meat	052	-	-	07 (13.46)	02 (28.57)	-	-	271
	Dhaka	Pigeons	040	021 (52.50)	00 (00.00)	11 (27.50)	00 (00.00)	-	-	272
	Mymensingh	Pigeon-CS, FP, F	112	-	-	10 (08.93)	0	-	-	273
	Mymensingh	Pigeon - CS, PS	050	-	-	17 (34.00)	0	-	-	274
	Mymensingh	Layer-CS, IC, ES	060	-	-	32 (53.33)	26 (80.00)	-	-	275
	Mymensingh	Chicken	075	043 (57.33)	05 (11.63)	33 (44.00)	09 (27.27)	38 (50.67)	12 (31.58)	276
	Naogoan	Layer eggs	180	-	-	14 (07.78)	01 (07.14)	-	-	277
	Chittagong	Layer-ECS, ET, EC	310	-	-	111 (35.81)	111 (100)	-	-	279
	DGT	Broiler-CS, M, FW	352	-	-	110 (31.25)	14 (12.73)	-	-	282
	Mymensingh	Broiler- CS	050	-	-	16 (32.00)	05 (31.25)	-	-	283
	M, G & S	Dressed broiler	060	050 (83.33)	04 (08.00)	14 (23.33)	01 (09.00)	-	-	284
	Mymensingh	Quail- CS	075	-	-	10 (13.33)	0	-	-	285
	Mymensingh	Layer- D, CS	150	-	-	11 (07.33)	05 (45.46)	-	-	286
	Chittagong	Dead layers	030	013 (43.33)	13 (100)	08 (26.67)	07 (87.50)	-	-	287
	Pirojpur	Dead layer-l, S & IS	048	-	-	13 (27.08)	13 (100)	-	-	288
	Gazipur, Tangail	Broiler-7 sources	153	-	-	36 (23.53)	0	-	-	289
	B, P & B	Meat samples	305	061 (20.00)	02 (03.28)	19 (06.23)	01 (02.60)	77 (25.25)	02 (02.60)	290
	J, T, N & K	Dressed broilers	020	017 (85.00)	00 (00.00)	14 (70.00)	01 (07.14)	-	-	291
	M & Jamalpur	Broiler-feces, meat	070	-	-	46 (65.71)	09 (19.05)	-	-	292
	Mymensingh	Cows- 6 types	240	180 (75.00)	29 (16.11)	136 (56.67)	19 (13.97)	-	-	293
	Chattogram	Chicken-Feces	050	-	-	28 (56.00)	20 (71.42)	-	-	294
	M & Tangail	Turkey-Feces, CS	055	055 (100)	37 (67.27)	12 (21.82)	08 (66.67)	-	-	295
	Chittagong	Children	350	-	-	15 (04.29)	03 (20.00)	-	-	296
	Dhaka	Chicken feces	250	166 (66.4)	136 (82.00)	-	-	-	-	298
	Dhaka	Chicken feces	040	011 (27.50)	09 (84.60)	-	-	-	-	299
		Human urine	048	014 (29.17)	11 (80.00)	-	-	-	-	299
	Jashore	Broiler. CS	005	005 (100)	00 (00.00)	-	-	-	-	300
	Mymensingh	Chicken	099	036 (36.36)	18 (50.00)	-	-	-	-	302
	Rajshahi	Chicken eggs	060	021 (35.00)	00 (00.00)	17 (28.33)	01 (05.88)	12 (20.00)	01 (08.33)	303
	Mymensingh	Cattle- RS	137	095 (69.34)	21 (22.10)	-	-	-	-	307
	M & Gazipur	Broiler-CS+	150	114 (76.00)	80 (70.20)	-	-	-	-	308

Contd. Table 25. Antibacterial resistance status of major bacterial pathogens isolated from humans, animals and poultry

S/N	Antibacterials & Districts	Host & types of samples used	No. of samples tested	*Escherichia coli* Positive No. (%)	*Escherichia coli* Resistance No. (%)	*Salmonella* spp. Positive No. (%)	*Salmonella* spp. Resistance No. (%)	*Staphylococcus* spp. Positive No. (%)	*Staphylococcus* spp. Resistance No. (%)	Ref. No.
	Dhaka City	Human -CS	100	100 (100)	34 (34.00)	-	-	-	-	309
	T, S & M	Calves- feces	100	049 (49.00)	05 (10.21)	-	-	-	-	310
	Mymensingh	Human-urine	4000	453 (01.13)	270 (59.60)	-	-	-	-	313
	Rajshahi, Dhaka	Broilers	400	400 (100)	400 (100)	-	-	-	-	314
	M & Gazipur	M, B & C meat	069	064 (92.75)	16 (25.00)	-	-	-	-	315
	Chittagong	Dead broilers	275	150 (54.55)	00 (00.00)	-	-	-	-	316
	Chattogram	H, A, E & F	810	358 (44.20)	219 (61.20)	-	-	-	-	317
	Dhaka City	Human (BS)	4115	-	-	359 (08.72)	01 (00.27)	-	-	318
	Mymensingh	DW, D, ES	060	-	-	027 (45.00)	00 (00.00)*	-	-	319
	Panchagarh	Calf diarrhea	114	044 (38.60)	08 (18.18)	25 (21.93)	05 (20.00)	15 (13.16)	05 (33.33)	320
	Sylhet	Goat feces	220	-	-	20 (09.09)	00 (00.00)	-	-	321
	Chattogram	Chicken, CS	050	-	-	28 (56.00)	20 (71.42)	-	-	322
	Mymensingh	Cattle feces	135	-	-	39 (28.89)	12 (31.57)	-	-	323
	KYAMCH	Human (Blood)	282	002 (0.71)	01 (50.00)	04 (01.42)	01 (25.00)	42 (14.89)	06 (38.10)	324
	Dhaka City	Human blood	100	-	-	100 (100)	04 (04.00)	-	-	326
	Gazipur, Tangail	Chickens	153	-	-	36 (23.53)	00 (00.00)	-	-	327
	Dhaka	Pigeons	040	021 (52.50)	00 (00.00)	11 (27.50)	00 (00.00)	-	-	328
	Bangladesh	Chickens	279	101 (36.20)	13 (12.90)	-	-	-	-	330
	Mymensingh	Chickens	350	276 (S)	-	-	-	-	-	331
	Rajshahi	Poultry	055	52 (94.55)	03 (05.77)	-	-	-	-	332
		Wild ducks	041	14 (34.15)	01 (07.14)	-	-	-	-	332
	Mymensingh	Quails	050	25 (S)	-	09 (S)	24 (S)	-	-	333
	Mymensingh	Pigeons	112	10 (08.93)	00 (00.00)	-	-	-	-	334
	BD & Nepal	Ducks	120	85 (S)	-	-	-	-	-	336
	Bangladesh	Chicken meat	150	-	-	-	-	96 (64.00)	74 (77.50)	337
	Mymensingh	Children stool	083	27 (32.53)	08 (29.62)	-	-	-	-	339
	7 districts	Chickens feces	725	691 (95.31)	640 (93.00)	-	-	-	-	340
	7 districts	Environmental	250	163 (65.20)	110 (67.00)	-	-	-	-	340
	N, N & M	130 samples	174	114 (65.52)	51 (44.75)	-	-	-	-	341
	Sylhet division	B & S meat	400	136 (34.0)	00 (00.00)	-	-	-	-	344
	Mymensingh,	Animals	100	-	-	-	-	-	-	345
	& Sirajgonj	Huamns	100	-	-	-	-	40 (40.00)	06 (15.00)	345
	Sub-total		**10623/11003/1386**	**3935 (37.04)**	**2270 (57.69)**	**1993 (18.11)**	**526 (26.39)**	**380 (27.42)**	**113 (29.74)**	
02.	**Norfloxacin**									
	Five divisions	Layer-CS, VO, D	765	-	-	214 (27.97)	29 (13.7)	-	-	252
	Dhaka	Chicken- CS, IF,	300	-	-	08 (02.67)	02 (20.00)	-	-	255
	Five districts	Broiler-frozen meat	113	-	-	74 (65.49)	14 (18.90)	-	-	264
	DGT	Broiler- CS, M,	352	-	-	110 (31.25)	11 (10.00)	-	-	282
	M, G & S	Dressed broiler	060	050 (83.33)	04 (08.00)	14 (23.33)	00 (00.00)	-	-	284
	Gazipur, Tangail	Broiler- 7 sources	153	-	-	36 (23.53)	0	-	-	289
	B, P & B	Meat samples	305	061 (20.00)	01 (00.00)	19 (06.23)	02 (10.53)	77 (25.25)	02 (02.60)	290
	J, T, N & K	Dressed broiler	020	017 (85.00)	01 (05.88)	14 (70.00)	00 (00.00)	-	-	291
	Dhaka	Chicken feces	250	166 (66.40)	00 (00.00)	-	-	-	-	298
	Mymensingh	Chicken	099	036 (36.36)	18 (50.00)	-	-	-	-	302
	Dhaka City	Human -CS	100	100 (100)	39 (39.00)	-	-	-	-	309
	T, S & M	Calves- feces	100	049 (49.00)	08 (16.32)	-	-		-	310
	Mymensingh	DW, D, ES	060	-	-	027 (45.00)	000 (00.00)*	-	-	319
	Gazipur, Tangail	Chickens	153	-	-	036 (23.53)	000 (00.00)	-	-	327
	Sub-total		**934/2281/77**	**479 (51.28)**	**71 (14.82)**	**552 (24.20)**	**058 (10.51)**	**77 (100)**	**02 (02.60)**	
03.	**Enrofloxacin**									
	Five divisions	Layer-CS, VO, D	765	-	-	214 (27.97)	094 (43.70)	-	-	252
	Chittagong	Layer-ECS, ET, EC	310	-	-	111 (35.81)	111 (100)	-	-	279
	Chittagong	Dead layers	030	013 (43.33)	13 (100)	08 (26.67)	07 (87.50)	-	-	287
	Southern districts	CCBG- meat	205	-	-	019 (09.27)	09/1 (11.11)	-	-	290
	Mymensingh	Chicken	099	036 (36.36)	18 (55.50)	-	-	-	-	302

Contd. Table 25. Antibacterial resistance status of major bacterial pathogens isolated from humans, animals and poultry

S/N	Antibacterials & Districts	Host & types of samples used	No. of samples tested	*Escherichia coli* Positive No. (%)	*Escherichia coli* Resistance No. (%)	*Salmonella* spp. Positive No. (%)	*Salmonella* spp. Resistance No. (%)	*Staphylococcus* spp. Positive No. (%)	*Staphylococcus* spp. Resistance No. (%)	Ref. No.
	Mymensingh	Cattle feces	135	-	-	39 (28.89)	04 (10.52)	-	-	323
	Sub-total		**129/1445/0**	**49 (37.98)**	**31 (63.27)**	**391 (27.06)**	**225 (57.54)**	**-**	**-**	
04.	**Ofloxacin**									
	Dhaka (Savar)	Layer - samples	-	-	-	67*	56 (84.00)	-	-	250
	Five divisions	Layer-CS, VO, D	765	-	-	214 (27.97)	60 (27.90)	-	-	252
	Five districts	Broiler- frozen meat	113	-	-	74 (65.49)	26 (35.10)	-	-	264
	Mymensingh	Cattle- RS	137	95 (69.34)	35 (36.84)	-	-	-	-	307
	Sub-total		**137/74/0**	**69.34**	**35 (36.84)**	**74 (100)**	**82 (58.16)**	**-**	**-**	
05.	**Levofloxacin**									
	Dhaka (Savar)	Layer samples	-	-	-	67*	34 (50.00)	-	-	250
	Five districts	Broiler-frozen meat	113	-	-	74 (65.49)	08 (10.80)	-	-	264
	Dhaka	Chicken meat	052	-	-	07 (13.46)	0	-	-	271
	Savar (Dhaka)	Pigeon-Oral & CS	040	-	-	11 (27.50)	02 (18.18)	-	-	272
	M & Tangail	Feces, CS	055	055 (100)	15 (27.27)	27 (49.09)	06 (22.22)	-	-	295
	Dhaka	Chicken feces	040	011 (27.50)	09 (81.82)	-	-	-	-	299
		Human urine	048	014 (29.17)	09 (66.70)	-	-	-	-	299
	Mymensingh	Cattle- RS	137	095 (69.34)	14 (14.80)	-	-	-	-	307
	M & Gazipur	Broiler-CS+	150	114 (76.00)	93 (81.60)	-	-	-	-	308
	Mymensingh	Human-urine	4000	453 (11.33)	246 (00.00)	-	-	-	-	313
	Rajshahi, Dhaka	Broilers	400	400 (100)	332 (00.00)	-	-	-	-	314
	KYAMCH	Human (Blood)	282	002 (00.71)	01 (50.00)	04 (01.42)	01 (25.00)	42 (14.89)	04 (09.52)	324
	Dhaka City	Human blood	100	-	-	100 (100)	03 (03.00)	-	-	326
	Dhaka	Pigeons	040	021 (52.50)	00 (00.00)	11 (27.50)	02 (18.18)	-	-	328
	Mymensingh	Children stool	083	027 (32.53)	19 (70.37)	-	-	-	-	339
	Sylhet division	B & S meat	400	136 (34.00)	00 (00.00)	-	-	-	-	343
	Sub-total		**5635/1447/282**	**1328 (23.57)**	**738 (55.57)**	**448 (30.96)**	**116 (22.52)**	**42 (14.89)**	**04 (09.52)**	
06.	**Pefloxacin**									
	Five districts	Broiler-frozen meat	113	-	-	074 (65.49)	52 (70.30)	-	-	264
	Chittagong	Layer-ECS, ET, EC	310	-	-	111 (35.81)	111 (100)	-	-	279
	Chittagong	Dead layers	030	13 (43.33)	13 (100)	008 (26.67)	07 (87.50)	-	-	287
	Mymensingh	Cattle- RS	137	95 (69.34)	36 (37.90)	-	-	-	-	307
	Five districts	Chicken meat	113	86 (76.11)	76 (88.40)	-	-	-	-	335
	Sub-total		**280/453/-**	**194 (69.29)**	**125 (64.43)**	**193 (42.60)**	**170 (88.08)**	**-**	**-**	
07.	**Gatifloxacin**									
	Five districts	Broiler-frozen meat	113	-	-	74 (65.49)	22 (29.70)	-	-	264
	Mymensingh	Cattle rectal swabs	137	95 (69.30)	33 (34.70)	-	-	-	-	307
	Sub-total		**113/137**	**95 (69.30)**	**33 (34.70)**	**74 (65.49)**	**22 (29.70)**			
08.	**Moxifloxacin**									
	Mymensingh	Cattle- RS	137	095 (69.34)	035 (36.80)	-	-	-	-	307
	Mymensingh	Human-urine	4000	453 (11.33)	252 (00.00)	-	-	-	-	313
	Mymensingh	Children stool	083	027 (32.53)	016 (59.25)	-	-	-	-	339
	Sub-total		**4220**	**575 (13.63)**	**303 (52.70)**	**-**	**-**	**-**	**-**	
F.	**Aminoglycosides (inhibit protein synthesis)**									
01.	**Amikacin**									
	Dhaka (Savar)	Layer samples	-	-	-	67*	04 (06.00)	-	-	250
	Five divisions	Layer-CS, VO, D	765	-	-	214 (27.97)	15 (07.10)	-	-	252
	Dhaka	Chicken- CC	870	-	-	31 (03.56)	04 (12.90)	-	-	254
	Gazipur, M	Cattle, chickens	169	-	-	37 (21.89)	11 (29.73)	-	-	262
	Barishal City	Chicken meat	020	14 (70.00)	04 (28.60)	13 (65.00)	00 (00.00)	-	-	263
	Five districts	Broiler- frozen meat	113	-	-	74 (65.49)	14 (18.90)	-	-	264
	Four districts	Chicken-liver, intes-	100	-	-	82 (82.00)	22 (26.83)	-	-	265
	Dhaka	Chicken feces	250	166 (66.40)	00 (00.00)	-	-	-	-	298
	Bangladesh	Human- UTI	-	1663	47 (02.80)	-	-	-	-	305
	Mymensingh	Human-urine	4000	453 (11.33)	36 (07.94)	-	-	-	-	313
	M & Gazipur	M, B & C meat	169	64 (37.87)	00 (00.00)	-	-	-	-	315
	KYAMCH	Human (Blood)	282	02 (00.71)	00 (00.00)	04 ()	02 (50.00)	42 (100)	07 (16.67)	324
	Sub-total		**4721/2319/42**	**699 (14.81)**	**87 (12.45)**	**455 (19.62)**	**72 (13.79)**	**42 (100)**	**07 (16.67)**	

Contd. Table 25. Antibacterial resistance status of major bacterial pathogens isolated from humans, animals and poultry

S/ N	Antibacterials & Districts	Host & types of samples used	No. of samples tested	*Escherichia coli* Positive No. (%)	*Escherichia coli* Resistance No. (%)	*Salmonella* spp. Positive No. (%)	*Salmonella* spp. Resistance No. (%)	*Staphylococcus* spp. Positive No. (%)	*Staphylococcus* spp. Resistance No. (%)	Ref. No.
02.	**Gentamicin**									
	Five divisions	Layer-CS, VO, D	765	-	-	214 (27.97)	68 (32.00)	-	-	252
	Dhaka	Chicken-CC	870	-	-	37 (04.25)	28 (75.68)	-	-	254
	Dhaka	Layer- CS, IF, ES	300	-	-	08 (02.67)	0	-	-	255
	M, Gazipur	Chicken, Cow- CM	169	-	-	37 (21.89)	04 (10.81)	-	-	262
	Barishal City	Chicken meat	020	014 (70.00)	05 (35.70)	13 (65.00)	02 (15.38)	-	-	263
	Five districts	Broiler-frozen meat	113	-	-	74 (65.49)	16 (21.60)	-	-	264
	Four districts	Chicken-liver, Intes	100	-	-	82 (82.00)	27 (32.93)	-	-	265
	Dhaka City	Chicken meat	100	052 (52.00)	24 (46.15)	36 (36.00)	18 (50.00)	42 (42.00)	30 (71.43)	268
	Dhaka City	Eggs (S & C)	200	018 (09.00)	04 (22.22)	18 (09.00)	04 (22.22)	18 (09.00)	06 (33.33)	269
	Dhaka	Chicken-egg	050	-	-	50 (100)	30 (60.0)	-	-	270
	Dhaka	Pigeons	040	021 (52.50)	04 (19.05)	11 (27.50)	00 (00.00)	-	-	272
	Mymensingh	Pigeon-CS, FP, F	112	-	-	10 (08.93)	02 (20.00)	-	-	273
	Mymensingh	Pigeon-CS, PS	050	-	-	17 (34.00)	04 (23.53)	-	-	274
	Mymensingh	Chicken	075	043 (57.33)	20 (46.51)	33 (44.00)	14 (42.42)	38 (50.67)	08 (21.05)	276
	Naogoan	Layer-eggs	180	-	-	14 (07.78)	03 (21.43)	-	-	277
	DGT	Broiler-CS, M, FW	352	-	-	110 (31.25)	10 (09.09)	-	-	282
	M, G & S	Dressed broiler	060	050 (83.33)	04 (08.00)	14 (23.33)	00 (00.00)	-	-	284
	Mymensingh	Layer-D, CS	150	-	-	11 (07.33)	09 (81.81)	-	-	286
	Chittagong	Dead layers	030	013 (43.33)	00 (00.00)	08 (26.67)	00 (00.00)	-	-	287
	Gazipur, Tangail	Broiler- 7 sources	153	-	-	36 (23.53)	0	-	-	289
	B, P & B	Meat samples	305	061 (20.00)	00 (00.00)	19 (06.23)	00 (00.00)	77 (25.25)	00 (00.00)	290
	J, T, N & K	Dressed broiler	020	017 (85.00)	02 (11.75)	14 (70.00)	00 (00.00)	-	-	291
	M & Jamalpur	Broiler- feces, meat	070	-	-	46 (65.71)	04 (09.52)	-	-	292
	Mymensingh	Cows- 6 types	240	180 (75.00)	16 (08.89)	136 (56.67)	09 (06.62)	-	-	293
	M & Tangail	Feces, CS	055	055 (100)	09 (16.36)	27 (49.09)	05 (18.52)	-	-	295
	Dhaka	Chicken feces	250	166 (66.40)	33 (20.00)	-	-	-	-	298
	Sylhet	Chicken-CS,L	100	035 (35.00)	35 (100)	-	-	-	-	301
	Mymensingh	Chicken	099	036 (36.36)	03 (08.30)	-	-	-	-	302
	Rajshahi	Chicken eggs	060	021 (35.00)	00 (00.00)	17 (28.33)	00 (00.00)	12 (20.00)	00 (00.00)	303
	Cox’s Bazar	Goat- RS	150	078 (52.00)	29 (37.18)	-	-	-	-	306
	Dhaka City	Human -CS	100	100 (100)	39 (39.00)	-	-	-	-	309
	T, S & M	Calves- feces	100	049 (49.00)	00 (00.00)	-	-	-	-	310
	Mymensingh	Milk- mastitis	016	05 (31.25)	05 (100)	-	-	10 ()	07 (70.00)	312
	Mymensingh	Human-urine	4000	453 (11.33)	129 (28.48)	-	-	-	-	313
	Rajshahi, Dhaka	Broilers	400	400 (100)	204 (51.00)	-	-	-	-	314
	M & Gazipur	M, B & C meat	169	064 (37.87)	04 (06.25)	-	-	-	-	315
	Chittagong	Dead broilers	275	150 (54.55)	113 (75.00)	-	-	-	-	316
	Mymensingh	DW, D, ES	060	-	-	27 (45.00)	16 (59.26)*	-	-	319
	Panchagarh	Calf diarrhea	114	044 (38.60)	06 (13.64)	25 (21.93)	05 (20.00)	15 (13.16)	01 (06.67)	320
	Sylhet	Goat feces	220	-	-	20 (09.09)	00 (00.00)	-		321
	Mymensingh	Cattle feces	135	-	-	39 (28.89)	08 (21.0)	-	-	323
	KYAMCH	Human (Blood)	282	002 (0.71)	02 (100)	04 (01.42)	03 (75.00)	42 (14.89)	11 (26.19)	324
	M, N & CNB	Cattle feces	057	27 (S)	-	08 (S)	-	-	-	325
	Gazipur, Tangail	Chickens	153	-	-	36 (23.53)	00 (00.00)	-	-	327
	Dhaka	Pigeons	040	021 (52.50)	04 (19.05)	11 (27.50)	00 (00.00)	-	-	328
	Dhaka	Chicken swabs	003!	-	-	07 (100)	01 (14.29)	-	-	329
	Bangladesh	Chickens	279	101 (36.20)	02 (02.00)	-	-	-	-	330
	Mymensingh	Chickens	350	276 (S)	-	-	-	-	-	331
	Rajshahi	Poultry	055	52 (94.55)	00 (00.00)	-	-	-	-	332
		Wild ducks	041	14 (34.15)	01 (07.14)	-	-	-	-	332
	Mymensingh	Quails	050	25 (R)	-	09 (R)	-	24 (S)	-	333
	Mymensingh	Pigeons	112	10 (08.93)	00 (00.00)	-	-	-	-	334
	Bangladesh	Chicken meat	150	-	-	-	-	96 (64.00)	13 (13.33)	337
	Mymensingh	Children stool	083	27 (32.53)	02 (07.40)	-	-	-	-	339
	7 districts	Chicken feces	725	691 (95.31)	152 (22.00)	-	-	-	-	341

Contd. Table 25. Antibacterial resistance status of major bacterial pathogens isolated from humans, animals and poultry

S/N	Antibacterials & Districts	Host & types of samples used	No. of samples tested	*Escherichia coli* Positive No. (%)	*Escherichia coli* Resistance No. (%)	*Salmonella* spp. Positive No. (%)	*Salmonella* spp. Resistance No. (%)	*Staphylococcus* spp. Positive No. (%)	*Staphylococcus* spp. Resistance No. (%)	Ref. No.
	7 districts	Environmental	250	163 (65.20)	22 (13.00)	-	-	-	-	340
	N, N & M	130 samples	174	114 (65.52)	30 (26.32)	-	-	-	-	341
	Sylhet division	Chicken meat	600	381 (63.50)	105 (27.55)	-	-	-	-	342
	Sylhet division	B & S meat	400	136 (34.00)	00 (00.00)	-	-	-	-	343
	Mymensingh,	Animals	100	-	-	-	-	54 (54.00)	14 (25.93)	345
	& Sirajgonj	Huamns	100	-	-	-	-	40 (40.00)	08 (20.00)	345
	Sub-total		**10019/5733/1502**	**3837 (38.30)**	**1008 (26.27)**	**1278 (22.29)**	**290 (22.69)**	**468 (31.16)**	**98 (20.94)**	
03.	**Neomycin**									
	Five divisions	Layer-CS, VO, D	765	-	-	214 (27.97)	80 (37.60)	-	-	252
	M, Gazipur	Chicken, Cow- CM	169	-	-	37 (21.89)	05 (13.51)	-	-	262
	Five districts	Broiler- frozen meat	113	-	-	74 (65.49)	26 (35.10)	-	-	264
	Mymensingh	Quail- Cloacal swab	075	-	-	10 (13.33)	02 (20.00)	-	-	285
	Chittagong	Dead layers	030	013 ()	03 (23.08)	008 (26.67)	00 (00.00)	-	-	287
	Mymensingh	Cows- 6 types	240	180 (75.00)	61 (33.89)	136 (56.67)	47 (34.56)	-	-	293
	Dhaka	Chicken feces	250	166 (66.40)	33 (20.00)	-	-	-	-	298
	Jashore	Broiler. CS	005	005 (100)	05 (100)	-	-	-	-	300
	Mymensingh	Milk- mastitis	016	005 (31.25)	00 (00.00)	-	-	10 (100)	00 (00.00)	312
	M & Gazipur	M, B & C meat	169	064 (37.87)	04 (06.25)	-	-	-	-	315
	Sylhet	Goat feces	220	-	-	020 ()	00 (00.00)	-	-	321
	Sub-total		**710/1612/10**	**433 (60.99)**	**106 (24.48)**	**499 (30.96)**	**160 (32.06)**	**10 (100)**	**00 (00.00)**	
04.	**Streptomycin**									
	Dhaka	Chicken- CC	870	-	-	37 (04.25)	30 (08.11)	-	-	254
	Mymensingh	Chicken- CS	100	-	-	35 (35.00)	27 (77.10)	-	-	256
	Barishal City	Chicken meat	020	014 (70.00)	09 (64.30)	13 (65.00)	11 (84.62)	-	-	263
	Five districts	Broiler-frozen meat	113	-	-	74 (65.49)	23 (31.10)	-	-	264
	Dhaka City	Chicken meat	100	052 (52.00)	40 (76.92)	36 (36.00)	26 (72.22)	42 (42.00)	40 (95.24)	268
	DGT	Broiler-CS, M, FW	352	-	-	110 (31.25)	06 (05.46)	-	-	282
	M, G & S	Dressed broiler	060	050 (83.33)	19 (38.00)	14 (23.33)	06 (42.85)	-	-	284
	Gazipur, Tangail	Broiler-7 sources	153	-	-	36 (23.53)	0	-	-	289
	J, T, N & K	Dressed broiler	020	017 (85.00)	03 (17.64)	14 (70.00)	07 (50.00)	-	-	291
	M & Tangail	Turkey: Feces, CS	055	055 (100)	09 (00.00)	27 (49.09)	06 (16.22)	-	-	295
	Dhaka	Chicken feces	250	166 (66.40)	149 (90.00)	-	-	-	-	298
	Mymensingh	Chicken	099	036 (36.36)	07 (19.40)	-	-	-	-	302
	Cox's Bazar	Goat- RS	150	078 (52.00)	37 (47.44)	-	-	-	-	306
	T, S & M	Calves- feces	100	049 (49.00)	36 (73.46)	-	-	-	-	310
	Mymensingh	Milk- mastitis	016	005 (31.25)	02 (40.00)	-	-	10 (62.50)	01 (10.00)	312
	Rajshahi, Dhaka	Broilers	400	400 (100)	400 (100)	-	-	-	-	314
	Mymensingh	DW, D, ES	060	-	-	27 (45.00)	27 (100)*	-	-	319
	Sylhet	Goat feces	220	-	-	20 (09.09)	13 (62.96)	-	-	321
	Mymensingh	Cattle feces	135	-	-	39 (28.89)	16 (41.03)	-	-	323
	M, N & CNB	Cattle feces	057	027 (R)	-	08 (S)	-	-	-	325
	Gazipur, Tangail	Chickens	153	-	-	36 (23.53)	00 (00.00)	-	-	327
	Bangladesh	Chickens	279	101 (36.20)	21 (20.80)	-	-	-	-	330
	Mymensingh	Chickens	350	276 (R)	-	-	-	-	-	331
	Rajshahi	Poultry	055	052 (94.55)	03 (05.77)	-	-	-	-	332
		Wild ducks	041	014 (34.15)	01 (07.14)	-	-	-	-	332
	Sylhet division	Chicken meat	600	381 (63.50)	270 (70.89)	-	-	-	-	342
	Sylhet division	B & S meat	400	136 (34.00)	71 (78.89)	-	-	-	-	343
	Mymensingh,	Animals	100	-	-	-	-	54 (54.00)	14 (25.93)	345
	& Sirajgonj	Huamns	100	-	-	-	-	40 (40.00)	08 (20.00)	345
	Sub-total		**2645/2466/316**	**1633 (61.74)**	**1077 (65.95)**	**553 (22.42)**	**204 (3689)**	**146 (46.20)**	**63 (43.15)**	
05.	**Kenamycin**									
	Dhaka (Savar)	Layer samples	-	-	-	67*	05 (07.00)	-	-	250
	Dhaka City	Chicken meat	100	52 (52.00)	29 (55.57)	36 (36.00)	16 (44.44)	42 (42.00)	16 (38.10)	268
	Dhaka City	Eggs (S & C)	200	18 (09.00)	06 (33.33)	18 (09.00)	06 (33.33)	18 (09.00)	04 (22.22)	269
	Mymensingh	Pigeon-CS, FP, F	112	-	-	10 (08.93)	1 (10.00)	-	-	273
	Mymensingh	Layer-CS, IC, ES	060	-	-	32 (53.33)	19 (60.00)	-	-	275

Contd. Table 25. Antibacterial resistance status of major bacterial pathogens isolated from humans, animals and poultry

S/N Antibacterials & Districts	Host & types of samples used	No. of samples tested	*Escherichia coli* Positive No. (%)	*Escherichia coli* Resistance No. (%)	*Salmonella* spp. Positive No. (%)	*Salmonella* spp. Resistance No. (%)	*Staphylococcus* spp. Positive No. (%)	*Staphylococcus* spp. Resistance No. (%)	Ref. No.
Mymensingh	Layer-D, CS	150	-	-	11 (07.33)	09 (81.81)	-	-	286
Chittagong	Dead layers	030	13 (43.33)	09 (69.24)	08 (26.67)	04 (50.00)	-	-	287
Mymensingh	Cows- 6 types	240	180 (75.00)	59 (32.78)	136 (56.67)	39 (28.68)	-	-	293
Dhaka	Chicken feces	250	166 (66.40)	126 (76.00)	-	-	-	-	298
Mymensingh	Quails	050	25 (S)	-	09 (R)		24 (S)	-	333
Mymensingh	Pigeons	112	10 (08.93)	00 (00.00)	-	-	-	-	334
Sub-total		**982/892/300**	**446 (45.42)**	**229 (51.35)**	**251 (28.14)**	**99 (30.28)**	**84 (28.00)**	**20 (23.81)**	
06. Tobramycin									
Five districts	Broiler-frozen meat	113	-	-	74 (65.49)	10 (13.50)	-	-	264
B, P & B	Meat samples	305	61 (20.00)	03 (04.92)	19 (06.23)	04 (21.05)	77 (25.25)	02 (02.60)	290
Mymensingh,	Animals	100	-	-	-	-	54 (54.00)	14 (25.93)	345
& Sirajgonj	Huamns	100	-	-	-	-	40 (40.00)	08 (20.00)	345
Sub-total		**305/418/505**	**61 (20.00)**	**03 (04.92)**	**93 (22.25)**	**14 (15.05)**	**171 (33.86)**	**24 (14.04)**	
07. Netilmicin									
Mymensingh	Human-urine	4000	453 (11.33)	93 (20.53)	-	-	-	-	313
08. Fosfomycin									
Rajshahi	Poultry samples	055	052 (94.55)	00 (00.00)	-	-	-	-	332
	Wild ducks	041	014 (34.15)	01 (07.14)	-	-	-	-	332
G. Lincosamides (inhibit protein synthesis)									
01. Clindamycin									
Dhaka (Savar)	Layer- samples	067	-	-	67 (100)	56 (84.00)	-	-	250
H. Nitrofuran									
01. Nitrofurantoin									
Four districts	Chicken- liver, Intes-	100	-	-	82 (82.00)	14 (17.07)	-	-	265
Dhaka	Chicken meat	052	-	-	07 (13.46)	07 (100)	-	-	271
Dhaka	Chicken feces	250	166 (66.40)	-	42 (25.30)	-	-	-	298
Dhaka	Chicken feces	040	011 (27.50)	04 (36.36)	-	-	-	-	299
	Human urine	048	014 (29.17)	06 (42.86)	-	-	-	-	299
Bangladesh	Human- UTI	-	1663	263 (15.81)	-	-	-	-	305
Mymensingh	Human-urine	4000	453 (11.33)	072 (15.89)	-	-	-	-	313
Dhaka	Chicken swabs	003	-	-	07 (100)	04 (57.14)	-	-	329
Bangladesh	Chickens	279	101 (36.20)	02 (02.00)	-	-	-	-	330
Rajshahi	Poultry	055	052 (94.55)	00 (00.00)	-	-	-	-	332
	Wild ducks	041	014 (34.15)	00 (00.00)	-	-	-	-	332
N, N & M	130 samples	174	114 (65.52)	72 (63.16)	-	-	-	-	341
Sub-total		**4887/405/-**	**925 (18.93)**	**419 (16.19)**	**138 (34.07)**	**25 (18.12)**	**-**	**-**	
I. Macrolides (inhibit protein synthesis)									
01. Azithromycin									
Dhaka (Savar)	Layer samples	-	-	-	67*	17 (25.00)	-	-	250
Five divisions	Layer-CS, VO, D	765	-	-	214 (27.97)	66 (31.00)	-	-	252
Dhaka	Chicken- CC	870	-	-	31 (03.56)	04 (12.90)	-	-	254
Gazipur, M	Cattle, chickens	169	-	-	37 (21.89)	24 (64.86)	-	-	262
Barishal City	Chicken meat	20	14 (70.00)	09 (64.30)	13 (65.00)	10 (76.93)	-	-	263
Five districts	Broiler-frozen meat	113	-	-	74 (65.49)	34 (45.90)	-	-	264
Dhaka City	Chicken meat	100	52 (52.00)	12 (23.08)	36 (36.00)	10 (27.78)	42 (42.00)	11 (26.19)	268
Dhaka City	Eggs (S & C)	200	18 (09.00)	04 (22.22)	18 (09.00)	03 (16.67)	18 (09.00)	02 (11.11)	269
Dhaka	Pigeons	040	21 (52.50)	05 (23.81)	11 (27.50)	03 (27.27)	-	-	272
Mymensingh	Pigeon-CS, PS	050	-	-	17 (34.00)	03 (17.65)	-	-	274
DGT	Broiler-CS, M, FW	352	-	-	110 (31.25)	52 (47.27)	-	-	282
M, G & S	Dressed broiler	060	50 (83.33)	06 (12.00)	14 (23.33)	03 (21.00)	-	-	284
Gazipur, Tangail	Broiler-7 sources	153	-	-	36 (23.53)	17 (47.22)	-	-	289
B, P & B	Meat samples	305	61 (20.00)	04 (06.58)	19 (06.23)	03 (15.79)	77 (25.25)	02 (02.59)	290
J, N, T & K	Broiler meat	020	-	-	14 (70.00)	004 (28.57)	-	-	291
Mymensingh	Cows- 6 types	240	180 (75.00)	180 (100)	136 (56.67)	136 (100)	-	-	293
Chittagong	Diarrheic child'	350	-	-	15 (04.92)	06 (40.00)	-	-	296
Dhaka City	Human -CS	100	100 (100)	49 (49.00)	-	-	-	-	309
T, S & M	Calves- feces	100	49 (49.00)	46 (93.85)	-	-	-	-	310

Contd. Table 25. Antibacterial resistance status of major bacterial pathogens isolated from humans, animals and poultry

S/N	Antibacterials & Districts	Host & types of samples used	No. of samples tested	*Escherichia coli* Positive No. (%)	*Escherichia coli* Resistance No. (%)	*Salmonella* spp. Positive No. (%)	*Salmonella* spp. Resistance No. (%)	*Staphylococcus* spp. Positive No. (%)	*Staphylococcus* spp. Resistance No. (%)	Ref. No.
	M & Gazipur	M, B & C	169	64 (37.87)	19 (29.69)	-	-	-	-	315
	Dhaka City	Human (BS)	4115	-	-	359 (08.72)	20 (05.57)	-	-	318
	Mymensingh	DW, D, ES	060	-	-	27 (45.00)	17 (62.96) *	-	-	319
	Panchagarh	Calf diarrhea	114	44 (38.60)	04 (09.10)	25 (21.93)	02 (08.00)	15 (13.16)	03 (20.00)	320
	M, N & CNB	Cattle feces	057	27 (I)	-	08 (R)	-	-	-	325
	Dhaka City	Human blood	100	-	-	100 (100)	100 (100)	-	-	326
	Gazipur, Tangail	Chickens	153	-	-	36 (23.53)	17 (47.22)	-	-	327
	Dhaka	Pigeons	040	21 (52.50)	05 (23.81)	11 (27.50)	03 (27.27)	-	-	328
	Mymensingh	Children stool	083	27 (32.53)	23 (85.18)	-	-	-	-	339
	7 districts	Chickens feces	725	691 (95.31)	452 (65.00)	-	-	-	-	340
	7 districts	Environmental	250	163 (65.20)	109 (67.00)	-	-	-	-	340
	N, N & M	130 samples	174	114 (65.52)	36 (31.58)	-	-	-	-	341
	Sub-total		**2777/8553/719**	**1649 (59.38)**	**963 (58.40)**	**1377 (16.10)**	**703 (37.48)**	**152 (21.14)**	**18 (11.84)**	
02.	**Erythromycin**									
	Dhaka	Layer-CS, IF, ES	300	-	-	08 (02.67)	07 (82.00)	-	-	255
	M, Gazipur	Chicken, Cow- CM	169	-	-	37 (21.89)	36 (97.30)	-	-	262
	Dhaka	Layer- egg surface	100	-	-	08 (08.00)	05 (62.50)	-	-	266
	Dhaka City	Chicken, man	010	-	-	10 (100)	10 (100)	-	-	267
	Dhaka	Chicken meat	052	-	-	07 (13.46)	07 (100)	-	-	271
	Dhaka	Pigeons	040	21 (52.50)	013 (61.90)	11 (27.50)	05 (45.45)	-	-	272
	Mymensingh (M)	Pigeon- CS, FP, F	112	-	-	10 (08.93)	08 (80.00)	-	-	273
	Mymensingh	Layer-CS, IC, ES	060	-	-	32 (53.33)	32 (100)	-	-	275
	Chittagong	Layer-ECS, ET, EC	310	-	-	111 (35.81)	111 (100)	-	-	279
	MFD	Chicken meat	024	-	-	024 (100)	024 (100)	-	-	281
	DGT	Broiler- CS, M,	352	-	-	110 (31.25)	90 (81.82)	-	-	282
	Mymensingh	Broiler- CS	050	-	-	16 (32.00)	16 (100)	-	-	283
	M, G & S	Dressed broiler	060	50 (83.33)	041 (81.00)	14 (23.33)	12 (85.71)	-	-	284
	Mymensingh	Quail- CS	075	-	-	10 (13.33)	010 (100)	-	-	285
	Gazipur, Tangail	Broiler-7 sources	153	-	-	36 (23.53)	36 (100)	-	-	289
	B, P & B	Meat samples	305	61 (20.00)	014 (22.95)	19 (06.23)	13 (00.00)	77 (100)	07 (09.09)	290
	J, T, N & K	Dressed broiler	020	17 (85.00)	012 (70.78)	14 (70.00)	06 (64.28)	-	-	291
	Mymensingh	Cows- 6 types	240	180 (75.00)	160 (88.89)	136 (56.67)	119 (87.50)	-	-	293
	M & Tangail	Feces, CS	055	055 (100)	055 (100)	027 (49.09)	027 (100)	-	-	295
	Chittagong	Children	350	-	-	15 (04.29)	013 (86.067	-	-	296
	Dhaka	Chicken feces	250	166 (66.40)	133; 80.00)	-	-	-	-	298
	Jashore	Broiler- CS	005	005 (100)	05 (100)	-	-	-	-	300
	Sub-total		**975/3189/77**	**555 (56.92)**	**446 (80.36)**	**765 (23.26)**	**667 (87.19)**	**77 (100)**	**07 (09.09)**	
J.	**Monobactams (β-Lactam antibiotics)**									
01.	**Aztreonam**									
	Dhaka (Savar)	Layer- samples	-	-	-	67*	17 (25.00)	-	-	250
	Dhaka	Chicken- CC	870	-	-	15 (01.72)	01 (06.67)	-	-	254
	Five districts	Broiler- frozen meat	113	-	-	74 (65.49)	03 (04.10)	-	-	264
	Mymensingh	Human-urine	4000	453 (11.33)	264 (58.28)	-	-	-	-	313
	Sub-total		**4000/983/-**	**453 (11.33)**	**264 (58.28)**	**89 (09.05)**	**21 (13.46)**	**-**	**-**	
K.	**Beta-lactamase resistant penicillin**									
01.	Cloxacillin									
	Dhaka (Savar)	Layer - samples	-	-	-	67*	56 (84.00)	-	-	250
	Dhaka	Chicken- meat	52	-	-	07 (13.46)	07 (100)	-	-	271
	MFD	Chicken- meat	24	-	-	24 (100)	024 (100)	-	-	281
	Mymensingh	Broiler- CS	50	-	-	16 (32.00)	16 (100)	-	-	283
	Sub-total:		**126**	**-**	**-**	**47 (37.30)**	**103 (90.35)**	**-**	**-**	
L.	**Polymyxin antibiotic**									
41.	Colistin (Polymyxin E)									
	Four districts	Chicken-liver, intes.	100	-	-	82 (82.00)	76 (92.68)	-	-	265
	Mymensingh	Chicken	075	43 (57.33)	21 (48.84)	33 (44.00)	18 (54.55)	-	-	276
	Chittagong	Layer-ECS, ET, EC	310	-	-	111 (35.81)	111 (100)	-	-	279
	Mymensingh	Quail- CS	075	-	-	10 (13.33)	09 (90.00)	-	-	285

Contd. Table 25. Antibacterial resistance status of major bacterial pathogens isolated from humans, animals and poultry

S/N	Antibacterials & Districts	Host & types of samples used	No. of samples tested	*Escherichia coli* Positive No. (%)	*Escherichia coli* Resistance No. (%)	*Salmonella* spp. Positive No. (%)	*Salmonella* spp. Resistance No. (%)	*Staphylococcus* spp. Positive No. (%)	*Staphylococcus* spp. Resistance No. (%)	Ref. No.
	Chittagong	Dead layers	030	13 (43.33)	07 (53.75)	08 (26.67)	04 (50.00)	-	-	287
	B, P & B	Meat samples	305	61 (20.00)	02 (03.28)	19 (06.23)	01 (05.26)	77 (25.25)	00 (00.00)	290
	M & Jamalpur	Broiler- feces, meat	070	-	-	46 (65.71)	15 (33.33)	-	-	292
	Chattogram	Chicken, CW	060	37 (61.67)	16 (43.24)	-	-	-		297
	Jashore	Broiler. CS	005	05 (100)	05 (100)	-	-	-		300
	Mymensingh	Chicken	099	36 (36.36)	04 (11.10)	-	-	-	-	302
	Bangladesh	Human- UTI	-	1663	48 (02.90)	-	-	-	-	305
	M & Gazipur	Broiler-CS+	150	114 (76.00)	17 (14.90)	-	-	-	-	308
	Rajshahi, Dhaka	Broilers	400	400 (100)	106 (00.00)	-	-	-	-	314
	Chittagong	Dead broilers	275	150 (54.55)	00 (00.00)	-	-	-	-	316
	Chattogram	H, A, E & F	810	358 (44.20)	49 (15.90)	-	-	-	-	317
	Mymensingh	Cattle feces	135	-	-	39 (28.89)	35 (89.47)	-	-	323
	Dhaka	Chicken swabs	003!	-	-	07 (100)	00 (00.00)	-	-	329
	7 districts	Chickens feces	725	691 (95.31)	80 (12.00)	-	-	-	-	340
	7 districts	Environmental	250	163 (65.20)	16 (10.00)	-	-	-	-	340
	Sylhet division	B & S meat	400	136 (34.00)	00 (00.00)	-	-	-	-	343
	Sub-total		**3584/1153/305**	**2207 (61.58)**	**371 (09.59)**	**371 (32.18)**	**277 (74.66)**	**77 (25.25)**	**00 (00.00)**	
02.	**Polymyxin B**									
	Dhaka (Savar)	Layers samples	-	-	-	67*	04 (06.0)	-	-	250
M. Carbapenem										
01.	Ertapenem									
	Mymensingh	Chicken - CS	100	-	-	35 (35.00)	02 (05.70)	-	-	256
	Four districts	Chicken-Liver, int-	100	-	-	82 (82.00)	05 (06.10)	-	-	265
	Mymensingh	Cows- 6 types	240	180 (75.00)	120 (66.67)	136 (56.67)	68 (50.00)	-	-	293
	Sub-total:		**240/440**	**180 (75.00)**	**120 (66.67)**	**253 (57.50)**	**75 (29.64)**	**-**	**-**	
02.	**Meropenem**									
	Dhaka	Chicken- CC	870	-	-	17 (01.95)	02 (11.76)	-	-	254
	Five districts	Broiler- frozen meat	113	-	-	74 (65.48)	10 (13.50)	-	-	264
	Four districts	Chicken- liver, intes-	100	-	-	82 (82.00)	28 (34.15)	-	-	265
	Mymensingh	Cows- 6 types	240	180 (75.00)	49 (27.22)	136 (56.67)	31 (22.39)	-	-	293
	M & Tangail	Feces, CS	055	55 (100)	40 (72.72)	27 (49.09)	11 (40.74))	-	-	295
	Bangladesh	Human- UTI	-	1663	47 (02.80)	-	-	-	-	305
	M & Gazipur	Broiler-CS+	150	114 (76.00)	58 (50.90)	-	-	-	-	308
	Dhaka City	Human -CS	100	100 (100)	30 (30.00)	-	-	-	-	309
	Dhaka	Chicken swabs	003!	-	-	07 (100)	00 (00.00)	-	-	329
	7 districts	Chickens feces	725	691 (95.31)	00 (00.00)	-	-	-	-	340
	7 districts	Environmental	250	163 (65.20)	00 (00.00)	-	-	-	-	340
	Sub-total:		**1520/1381**	**1303 (86.72)**	**224 (17.19)**	**343 (24.83)**	**82 (23.91)**	**-**	**-**	
03.	**Imipenem**									
	Dhaka (Savar)	Layers samples	-	-	-	67*	04 (06.0)	-	-	250
	Five districts	Broiler- frozen meat	113	-	-	74 (65.49)	36 (48.60)	-	-	264
	Four districts	Chicken- liver, Intes-	100	-	-	82 (82.00)	21 (25.61)	-	-	265
	Mymensingh	Cows- 6 types	240	180 (57.00)	34 (18.89)	136 (56.67)	18 (13.23)	-	-	293
	M & Tangail	Feces, CS	055	55 (100)	00 (00.00)	27 (49.09)	08 (00.00)	-	-	295
	Dhaka	Chicken feces	250	166 (66.40)	00 (00.00)	-	-	-	-	298
	Bangladesh	Human- UTI	-	1663	32 (01.90)	-	-	-	-	305
	M & Gazipur	Broiler-CS+	150	114 (76.00)	75 (65.80)	-	-	-	-	308
	Dhaka City	Human -CS	100	100 (100)	38 (38.00)	-	-	-	-	309
	Mymensingh	Human-urine	4000	453 (11.33)	33 (00.00)	-	-	-	-	313
	KYAMCH	Human (Blood)	282	02 (00.71)	00 (00.00)	04 (01.42)	00 (00.00)	42 (100)	00 (00.00)	324
	Dhaka	Chicken swabs	003!	-	-	07 (100)	00 (83.33)	-	-	329
	N, N & M	130 samples	174	114 (65.52)	26 (22.81)	-	-	-	-	341
	Sub-total		**5251/897/42**	**1184 (22.55)**	**238 (20.10)**	**330 (36.79)**	**77 (23.33)**	**42 (100)**	**00 (00.00)**	
N. Quinolone antibiotic										
01.	**Nalidixic acid**									
	Dhaka	Chicken - CC	870	-	-	37 (04.25)	23 (62.16)	-	-	254

Contd. Table 25. Antibacterial resistance status of major bacterial pathogens isolated from humans, animals and poultry

S/N	Antibacterials & Districts	Host & types of samples used	No. of samples tested	*Escherichia coli* Positive No. (%)	*Escherichia coli* Resistance No. (%)	*Salmonella* spp. Positive No. (%)	*Salmonella* spp. Resistance No. (%)	*Staphylococcus* spp. Positive No. (%)	*Staphylococcus* spp. Resistance No. (%)	Ref. No.
	Dhaka	Chicken-CS, IF, ESS	300	-	-	08 (02.67)	02 (20.00)	-	-	255
	Five districts	Broiler frozen meat	113	-	-	74 (65.49)	62 (83.80)	-	-	264
	Dhaka	Layer- egg surface	100	-	-	08 (08.00)	02 (25.00)	-	-	266
	Dhaka City	Chicken, man-feces	010	-	-	10 (100)	07 (70.00)	-	-	267
	Dhaka City	Chicken meat	100	52 (52.00)	16 (30.77)	36 (36.00)	14 (38.89)	42 (42.00)	15 (35.71)	268
	Dhaka City	Eggs (S & C)	200	18 (09.00)	04 (22.22)	18 (09.00)	05 (27.78)	18 (09.00)	06 (33.33)	269
	Savar (Dhaka)	Pigeon- oral & CS	040	-	-	11 (27.50)	09 (81.82)	-	-	272
	Mymensingh	Pigeon- CS, FP, F	112	-	-	10 (08.93)	0	-	-	273
	Mymensingh	Pigeon- CS, PS	050	-	-	17 (34.00)	04 (23.53)	-	-	274
	Mymensingh	Layer-CS, IC, ES	060	-	-	32 (53.33)	32 (100)	-	-	275
	Chattogram	Pigeon- CS	100	-	-	29 (29.00)	21 (72.40)	-	-	278
	Rajshahi	Broiler & layer CS	120	-	-	49 (40.83)	49 (100)	-	-	280
	M, Feni, Dhaka	Chicken meat	024	-	-	24 (100)	15 (63.00) D	-	-	281
	Chattogram	Chicken, CW	060	37 (61.67)	34 (91.89)	-	-	-	-	297
	Dhaka	Chicken feces	250	166 (66.40)	166 (100)	-	-	-	-	298
	Sylhet	Chicken- CS, L	100	35 (35.00)	35 (100)	-	-	-	-	301
	Chittagong	Cattle - RC	100	70 (70.00)	60 (86.00)	-	-	-	-	304
	Bangladesh	Human- UTI	-	1663	1309 (78.70)	-	-	-	-	305
	Mymensingh	Cattle-RS	137	95 (69.34)	49 (51.60)	-	-	-	-	307
	T, S & M	Calves- feces	100	49 (49.00)	03 (06.12)	-	-	-	-	310
	Mymensingh	Broiler & Layers	110	66 (60.00)	66 (100)	-	-	-	-	311
	Mymensingh	Human-urine	4000	453 (11.33)	360 (79.47)	-	-	-	-	313
	Dhaka City	Human (BS)	4115	-	-	359 (08.72)	359 (100)	-	-	318
	Mymensingh	DW, D, ES	060	-	-	27 (45.00)	27 (100)*	-	-	319
	Dhaka City	Human blood	100	-	-	100 (100)	100 (100)	-	-	326
	Dhaka	Pigeons	040	21 (52.50)	05 (23.81)	11 (27.50)	09 (81.82)	-	-	328
	Dhaka	Chicken swabs	003!	-	-	07 (100)	05 (66.66)	-	-	329
	Bangladesh	Chickens	279	101 (36.20)	26 (25.70)	-	-	-	-	330
	Mymensingh	Chickens	350	276 (R)	-	-	-	-	-	331
	Rajshahi	Poultry	055	52 (94.55)	11 (21.15)	-	-	-	-	332
		Wild ducks	041	14 (34.15)	01 (07.14)	-	-	-	-	332
	Mymensingh	Quails	050	25 (R)	-	09 (R)	-	24 (S)	-	333
	Mymensingh	Pigeons	112	10 (08.93)	00 (00.00)	-	-	-	-	334
	BD & Nepal	Ducks	120	85 (I)	-	-	-	-	-	336
	7 districts	Chickens feces	725	691 (95.31)	624 (90.00)	-	-	-	-	340
	7 districts	Environmental	250	163 (65.20)	106 (65.00)	-	-	-	-	340
	N, N & M	130 samples	174	114 (65.52)	87 (76.32)	-	-	-	-	341
	Sub-total		**6833/6517/300**	**3870 (56.64)**	**2962 (76.54)**	**867 (13.30)**	**745 (85.93)**	**60 (20.00)**	**21 (35.00)**	
0. Rifampicin (interferes with the synthesis of RNA)										
	Dhaka (Savar)	Layer samples	-	-	-	67*	59 (88.00)	-	-	250
	Dhaka	Layer- CS, IF, ES	300	-	-	08 (02.67)	05 (60.00)	-	-	255
	Dhaka	Chicken feces	250	166 (66.40)	149 (90.00)	-	-	-	-	298
	Mymensingh,	Animals	-	-	-	-	-	-	-	345
	& Sirajgonj	Huamns	100	-	-	-	-	40 (40.00)	03 (07.50)	345
	Sub-total		**250/300/100**	**166 (66.40)**	**149 (90.00)**	**08 (02.67)**	**64 (85.33)**	**40 (40.00)**	**03 (07.50)**	
P. Glycylcycline antibiotic (Tigecycline)										
	Five districts	Broiler- frozen meat	113	-	-	74 (65.49)	03 (04.10)	-	-	264
	Four districts	Chicken- liver, Intes-	100	-	-	82 (82.00)	51 (62.20)	-	-	265
	M & Jamalpur	Broiler- feces, meat	070	-	-	46 (65.71)	42 (90.48)	-	-	292
	Bangladesh	Chickens	279	101 ()	00 (00.00)	-	-	-	-	331
	Rajshahi	Poultry	055	052 (94.55)	00 (00.00)	-	-	-	-	332
		Wild ducks	041	014 (34.15)	00 (00.00)	-	-	-	-	332
	Sub-total		**96/283**	**066 (68.75)**	**00 (00.00)**	**202 (71.38)**	**96 (47.52)**	**-**	**-**	
Q. Glycopeptide antibiotic (Vancomycin)										
	Dhaka (Savar)	Layers samples	-	-	-	67*	52 (77.61)	-	-	250
	B, P & B	Meat samples	305	61 (20.00)	02 (00.00)	12 (03.93)	05 (41.67)	77 (25.25)	04 (05.19)	290

Contd. Table 25. Antibacterial resistance status of major bacterial pathogens isolated from humans, animals and poultry

S/N	Antibacterials & Districts	Host & types of samples used	No. of samples tested	*Escherichia coli* Positive No. (%)	*Escherichia coli* Resistance No. (%)	*Salmonella* spp. Positive No. (%)	*Salmonella* spp. Resistance No. (%)	*Staphylococcus* spp. Positive No. (%)	*Staphylococcus* spp. Resistance No. (%)	Ref. No.
	Mymensingh,	Animals	100	-	-	-	-	-	-	345
	& Sirajgonj	Huamns	100	-	-	40 (40.00)	07 (17.50)	-	-	345
	Sub-total		**305/405/305**	**61 (20.00)**	**02 (00.00)**	**52 (12.84)**	**64 (53.78)**	**77 (25.25)**	**04 (05.19**	
R. Sulfonamides and others										
50.	**Sulfamethoxazole**									
	Five divisions	Layer- CS, VO, D	765	-	-	214 (27.97)	102 (47.70)	-	-	252
	Five districts	Broiler- FC, MS	113	-	-	74 (65.49)	66 (89.20)	-	-	264
	Mymensingh	Pigeon- CS, FP, F	112	-	-	10 (08.93)	0	-	-	273
	Mymensingh	Layer - CS, IC, ES	060	-	-	32 (53.33)	19 (60.00)	-	-	275
	Rajshahi	Broiler & layer - CS	120	-	-	49 (40.83)	20 (40.00)	-	-	280
	Chittagong	Cattle - RC	100	070 (70.00)	70 (100)	-	-	-	-	304
	7 districts	Chickens feces	725	691(95.31)	654 (95.00)	-	-	-	-	340
	N, N & M	130 samples	174	114 (65.52)	51 (44.74)	-	-	-	-	341
	Sub-total:		**999/1170**	**875 (87.59)**	**775 (88.57)**	**379 (32.39)**	**207 (54.61)**			
00.	**Trimethoprim**									
	Dhaka	Chicken meat	052	-	-	07 (13.46)	07 (100)	-	-	271
	7 districts	Chickens feces	725	691 (95.31)	653 (95.00)	-	-	-	-	340
		7 districts- EVM	250	163 (65.20)	125 (77.00)	-	-	-	-	340
	Sub-total		**975/52**	**854 (87.59)**	**778 (91.10)**	**07 (13.46)**	**07 (100)**	-	-	
52.	**Sulfa-trimethoprim / Co-trimoxazole**									
	M, Gazipur	Chicken, Cow-CM	169	-	-	37 (0.22)	25 (67.57)	-	-	262
	Barishal City	Chicken meat	020	014 (70.00)	013 (92.86)	13 (65.00)	11 (84.62)	-	-	263
	Five districts	Broiler- frozen meat	113	-	-	74 (65.49)	66 (89.20)	-	-	264
	Four districts	Chicken-liver, Intes-	100	-	-	82 (82.00)	50 (60.98)	-	-	265
	Dhaka City	Chicken, man- feces	010	-	-	10 (100)	07 (70.00)	-	-	267
	Dhaka	Chicken egg	050	-	-	50 (100)	0	-	-	270
	Dhaka	Chicken meat	052	-	-	07 (13.46)	07 (100)	-	-	271
	Chattogram	Pigeon- CS	100	-	-	29 (29.00)	25 (86.2)	-	-	278
	Rajshahi	Broiler & layer- CS	120	-	-	49 (40.83)	27 (55.00)	-	-	280
	Pirojpur	Dead layer-L, S & IS	048	-	-	11 (22.92)	11 (84.62)	-	-	288
	B, P & B	Meat samples	305	061 (20.00)	006 (09.84)	19 (06.23)	05 (26.32)	77 (25.25)	04 (05.19)	290
	Chittagong	Children	350	-	-	15 (04.92)	06 (40.00)	-	-	296
	Chattogram	Chicken, CW	060	037 (61.67)	035 (94.59)	-	-	-	-	297
	Dhaka	Chicken feces	250	166 (66.40)	166 (100)	-	-	-	-	298
	Dhaka	Chicken feces	040	011 (27.50)	010 (92.30)	-	-	-	-	299
		Human urine	048	014 (29.17)	013 (90.00)	-	-	-	-	299
	Bangladesh	Human- UTI	-	1663	783; 47.10)	-	-	-	-	305
	Cox's Bazar	Goat- RS	150	078 (52.00)	41 (52.56)	-	-	-	-	306
	Dhaka City	Human -CS	100	100 (100)	62 (62.00)	-	-	-	-	309
	Mymensingh	Human-urine	4000	453 (11.33)	354 (78.15)	-	-	-	-	313
	Rajshahi, Dhaka	Broilers	400	400 (100)	400 (100)	-	-	-	-	314
	M & Gazipur	M, B & C meat	169	064 (37.87)	38 (59.38)	-	-	-	-	315
	Chittagong	Dead broilers	275	150 (54.55)	150 (100)	-	-	-	-	316
	Sylhet	Goat feces	220	-	-	20 (09.09)	16 (81.48)	-	-	321
	Dhaka City	Human blood	100	-	-	100 (100)	04 (04.00)	-	-	326
	Bangladesh	Chickens	279	101 (36.20)	27 (26.70)	-	-	-	-	330
	Rajshahi	Poultry	055	52 (94.55)	17 (00.00)	-	-	-	-	332
		Wild ducks	041	14 (34.15)	02 (14.29)	-	-	-	-	332
	Mymensingh	Quails	050	25 (S)	-	09 (I)	-	24 (S)	-	333
	Mymensingh	Pigeons	112	10 (08.93)	09 (90.00)	-	-	-	-	334
	Five districts	Chicken meat	113	86 (76.11)	76 (88.40)	-	-	-	-	335
	BD & Nepal	Ducks	120	85 (I)	-	-	-	-	-	336
	Sylhet division	Chicken meat	600	381 (63.50)	207 (54.33)	-	-	-	-	342
	Sylhet division	B & S meat	400	136 (34.00)	00(00.00)	-	-	-	-	343
	Sub-total		**7417/1757/305**	**3991 (53.80)**	**2409 (60.36)**	**516 (06.96)**	**260 (50.39)**	77 (25.25)	04 (05.19)	
	Metronidazole									
	Chittagong	Children	350	-	-	15 (04.92)	14 (00.00)	-	-	296

MFD = Mymensingh (M), Feni (F) & Dhaka (D) MG = Mymensingh & Gazipur MGS = Mymensingh, Gazipur & Sherpur
J, N, T & K = Jamalpur, Netrokona, Tangail & Kishoreganj DGT = Dhaka, Gazipur & Tangail BP = Barishal, Pirojpur
Southern districts = Barishal, Pirojpur and Bhola (BPB) T, S & M = Tangail, Sirajgonj & Mymensingh
B, P & B = Barishal, Pirojpur & Bhola MG & S = Mymensingh, Gazipur & Sherpur
JTNK = Jamalpur, Tangail, Netrokona & Kishoreganj
KYAMCH = Khwaja Yunus Ali Medical College and Hospital, Sirajgonj M, N & CNB = Mymensingh, Natore & Chapai Nawabgonj
Five districts = Dhaka, Chattogram, Sylhet, Mymensingh & Rajshahi N, N & M = Narsingdi, Narayangonj & Manikgonj
Four districts = Gzipur, Narsingdi, Tangail and Brahmanbaria, Sylhet division = Sylhet, Moulavibazar, Sumangonj & Habiganj
Five divisions = Dhaka (Gazipur, Tangail), Mymensingh (Jamalpur, Netrokona)
Rangpur (Dinajpur, Bogura), Sylhet (Habiganj, Moulvibazar) and Chattogram (Feni)
ESS = Egg shell surface ET = Egg tray EC = Egg content CS = Cloacal swabs FP = Foot pad F = Faeces
IF = Intestinal fluid PS = Pharyngeal swabs CM = Chicken meat M = Milk *Selected strains (isolates) B = Beef
CD = Cow dung FM = Frozen milk DW = Dressing water ES = Environmental swabs D = Droppings
L = Litter WC = Whole carcass DS = Dead & Sick DBC = Dressing broiler carcass FW = Feed & water
IC = Intestinal content FC = Frozen chicken MS = Meat sample EVM = Environmental CC = Cecal content
R = Resistant I = Intermediate S = Sensitive UTI = Urinary tract infection RS = Rectal swabs
H, A, E & F = Human, animal, environment & feed BS = Blood samples DW, D, ES = Dressing water, device & environmental samples
M, B & C = Milk, Beef & Chicken meat B & S meat = Beef & Sheep meat
7 sources = Chick meconium, cloacal swab, carcass, feed, water, transport swab, floor swab CCBG = Chicken, cattle, buffalo & goat
1Ciprofloxacin- ECS (n = 55; 49.1%), ET (n = 40; 27.5) & EC (n = 16; 31.3%)
*Included *Salmonella pullorum* (n = 6), *S. gallinarum* (n = 5) and *S. typhimurium* (n = 16) 3! = 7 isolates from three samples

Salmonella enteritidis is the most prevalent serovar circulating in poultry in Bangladesh. The Salmonella isolates (*S. enteritidis*, *S. typhimurium* & *S. heidelberg*) of poultry showed MDR properties at alarming levels and the potential to impose zoonoses (Table 26). The *S. enteritidis* was highly prevalent (88.0%) of the poultry isolates. Among the 67 Salmonella isolates, 12 were plasmid-free and resistant to as high as seven groups of antibiotics (Table 26). Their chance of forming a stable resistant bacterial community is high enough as many are plasmid-free.[250]

Table 26. Occurrence of Salmonella in food samples[346]

S/N	Food items	No. of samples	Salmonella +ve No. (%)	S/N	Food items	No. of samples	Salmonella +ve No. (%)
A. Dry foods				B. Wet foods			
1.	Vegetable role	12	3 (25)	1.	Salad	12	7 (58.33)
2.	Kabab	12	0	2.	Water	12	6 (50.00)
3.	Beef stick	12	0	3.	Raw milk	12	4 (33.33)
4.	Burger	12	1 (8.33)	4.	Chicken raw meat	12	5 (41.67)
5.	Egg chop	12	3 (25)	5.	Shop raw beef	12	4 (33.33)
					Total	120	33 (25.5)

Salmonellosis is one of the significant issues for public health, especially in low-income developing countries, including Bangladesh, due to a lack of safe drinking water, inadequate hygiene facilities, and incorrect antimicrobial drug use. Salmonella infection affects nearly 30 million people globally every year, whereas the scenario in Bangladesh is estimated to be between 292 and 395 cases per 100,000 persons yearly.[247] Food-borne zoonoses like salmonellosis pose a dangerous threat to the food industry and food safety worldwide. Human infection with Salmonella, MDR, could be costly due to the cost of effective alternative medicines and long-time patient care in hospitals unless covered by health insurance.[247] The emergence of antibiotic-resistant Salmonella variants suggests a potential food safety crisis.

Salmonella isolates resistant to three or more antimicrobials are defined as multi-drug resistant (MDR) isolates. The anti-microbial resistance tests revealed that all the Salmonella isolates exhibited 100% resistance to vancomycin and cephalexin, followed by ampicillin (75%), nalidixic acid (58.33%), chloramphenicol (41.66%), doxycycline (50%), and neomycin (50%).[248] The high prevalence of Salmonella infection and MRD strains highlights Bangladesh's chicken flock management system (Table 27). The wide

Table 27. Multidrug resistance bacteria isolated from poultry birds in Bangladesh

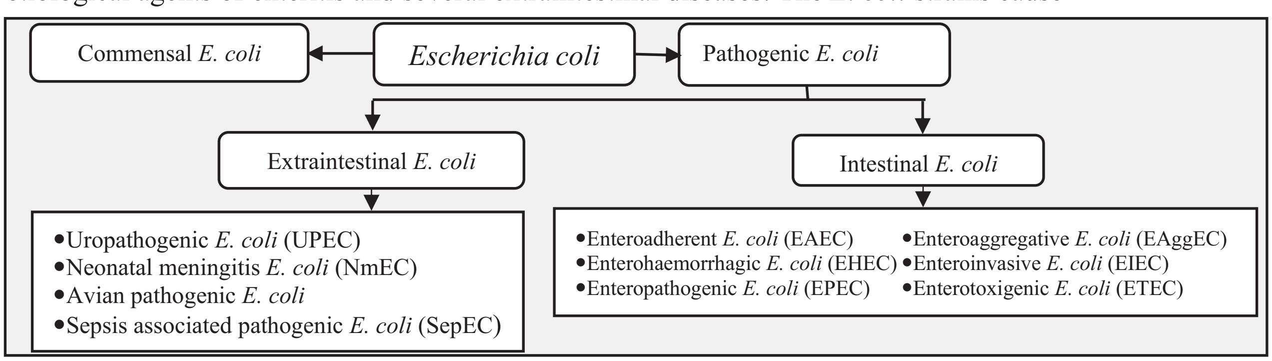
S/N	District/ Location	Types of birds	No. of samples tested	Positive No/ (%)	No. of isoaltes tested	Antibiogram studies on bacteria	No. of antibiotics tested	MDR isolates No. (%)	Ref. No.
01.	Chattogram	Chicken	025	012 (48.00)	012	*Salmonella* spp.	10	011 (91.67)	248
02.	11 districts	Layer	765	197 (25.75)	197	*S. gallinarum*	13	131 (66.50)	252
03.	Dhaka	Broiler	290	025 (08.62)	025	*Salmonella* spp.	25	021 (84.00)	254
		Sonali	290	020 (06.89)	020	*Salmonella* spp.	20	015 (75.00)	254
		Native	290	009 (03.10)	009	*Salmonella* spp.	09	004 (44.40)	254
04.	M & Gazipur	PMB &M	169	037 (21.89)	037	Salmonella spp.	11	033 (89.19)	262
05.	5 districts	FCM	113	074 (65.50)	074	Salmonella spp.	15	074 (100)	264
06.	4 districts	Chickens-LI	100	082 (82.00)	005*	Salmonella spp.	19	005 (100)	265
07.	Dhaka, Savar	Pigeons	040	011 (27.50)	011	Salmonella spp.	08	006 (54.54)	272
08.	Chattogram	Pigeons	100	029 (100)	029	Salmonella	10	028 (96.60)	278
09.	Chittagong	Eggs	310	111 (35.81)	111	Salmonella spp.	08	111 (100)	279
10.	3 districts	Broiler	352	110 (31.25)	110	*Salmonella* spp.	10	089 (80.91)	282
11.	M & Tangail	Turkeys	055	027 (49.09)	027	Salmonella spp.	09	024 (88.89)	295
	Overall	-	**2899**	**744 (25.66)**	**667**	**Salmonella spp.**	-	**550 (82.86)**	-

11 districts = Mymensingh, Tangail, Gazipur, Bogura, Jamalpur, Netrokona, Dinajpur, Moulvibazar, Habigonj, Feni and Chattogram.
3 districts = Gazipur, Tangail & Dhaka 5 districts = Chattogram, Dhaka, Mymensingh, Rajshahi & Sylhet M = Mymensingh
4 districts = Gazipur, Narsinfgi, Tangail & Brahmanbaria
MDR = Multidrug resistance PM, B & M = Poultry meat, beef & milk FCM = Frozen chicken meat LI = Liver & intestine
*Only mcr-1 +ve Salmonella isolates tested

prevalence of multidrug-resistant NTS in the poultry industry may be the source of the high risk of zoonotic infection among poultry workers and consumers. Therefore, judicial uses of antibiotics in the poultry industry and the introduction of routine antibiogram studies could help to prevent emerging multidrug resistance and to select effective, appropriate therapeutic measures. Many high-income countries have implemented surveillance programs for Salmonella in livestock due to its global importance, allowing the acquisition of important information about antimicrobial resistance.

Escherichia coli **infection**

E. coli is a Gram-negative bacterium belonging to the *Enterobacteriaceae* family and is particularly important in the human-animal-environment triad. *E. coli* can be classified into two main groups: ① Commensal *E. coli* and ② Pathogenic *E. coli*. This bacterium typically colonizes the gastrointestinal tract of humans and animals within a few hours after birth. Accordingly, *E. coli* is a normal inhabitant of the gastrointestinal tract of all warm-blooded animals. Still, a variant of this species is among the important etiological agents of enteritis and several extraintestinal diseases. The *E. coli* strains cause



diarrheal agents of enteritis and several extraintestinal diseases. The five main categories include enterotoxigenic *E. coli* (ETEC), enteropathogenic *E. coli* (EPEC), enteroaggregative *E. coli* (EAggEC), enteroinvasive *E. coli* (EIEC), and Shiga (Vero) toxin-producing *E. coli* (STEC/VTEC). From a zoonotic point of view, STEC is the only *E. coli* pathogenicity group of major interest, as the Shiga toxin-producing strain can cause severe disease in humans, including bloody diarrhea and hemolytic uremic syndrome. This serious condition can lead to kidney failure and be fatal. People get infected with VTEC by consuming or handling contaminated food or water or through contact with infected animal reservoirs.[347] Person-to-person transmission is also possible among close contacts (in families, childcare centers, nursing homes, and others). This organism is mainly associated with raw or undercooked bovine-derived foods, particularly ground meat, and unpasteurized milk outbreaks. *E. coli* 0157:H7 is commonly found in food transmitted in the environment, giving rise to a cycle of infection that may enable the maintenance of the organism in cattle herds (Fig. 9).

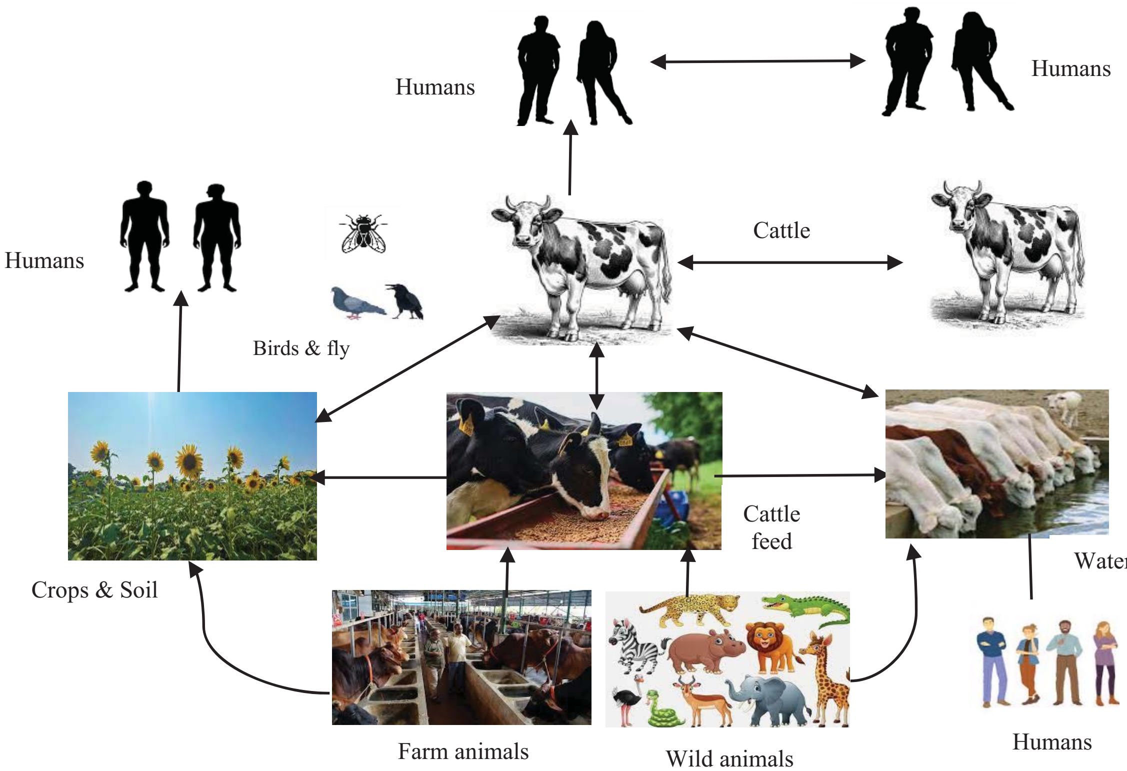


Fig. 9. Transmission of zoonotic *Escherichia coli* from cattle to humans

It is one of the common gastrointestinal flora of mammals and birds. Rapid urbanization has led to a growing sanitation crisis in urban areas of Bangladesh and potential exposure to fecal contamination in the urban environment due to inadequate sanitation and poor fecal sludge management. Dhaka is one of the most densely populated cities in the world, and fecal contamination in the environment is common due to poor sanitation and sewerage systems, rapid unplanned urbanization, frequent flooding, and inefficient solid waste management. A study on the bacteriological analysis of different environmental samples showed almost all drain water (98%) and street foods (93%) samples, nearly 80% of fresh produce, surface water, soil, and flood water samples and more than 50% of municipal drinking water, non-municipal drinking water and bathing water samples were contaminated with *E. coli*.[348] Extensive *E. coli* contamination has been reported in most of the environmental samples collected throughout the 10 regions suggesting that all residential areas of Dhaka may be prone to fecal contamination regardless of geographic location or socio-economic status.

Microbiological studies on street vendors prepared foods showed over 90% of such food samples were contaminated in Bangladesh,[346,349-351] of which 94% of street food vendors in Dhaka city reported that they used the municipal water supply to prepare food and did not take any measures to treat the water. The report also found that nearly 58% of the vendors did not cover their food while selling, and most vendors did not wash their hands with soap while preparing the food. Approximately 68% of vendors are located on footpaths, 30% of vending carts are placed near drains, and 18% are placed near sewerage; these street food vending sites could serve as breeding points for rodents, insects, and flies and could promote the proliferation of microorganisms and increase the risk of food contamination and disease transmission.[348] However, practical food safety training, motivation, and continuous monitoring can ensure street food hygiene practices and reduce the risks of food hazards.

Poultry shares some infectious diseases with humans, and most of the zoonotic diseases in poultry have additional reservoirs in other mammals than humans, complicating their control. There are three groups of zoonoses that humans can acquire from poultry. The first group includes food-borne diseases, mainly caused by Salmonella serovars and *Campylobacter* spp. In addition, *E. coli* from poultry can cause human disease, so *E. coli* would have to be considered a potential food-borne pathogen.

The first group comprises diseases transmitted by direct contact between birds and humans, including avian influenza, Newcastle disease, and Chlamydiosis. The third group includes diseases transmitted by insects, especially ticks, from mammals and birds, including poultry, to humans, including West Nile virus and Eastern and Western equine encephalitis.

Escherichia coli is one of the most common bacterial pathogens commonly exists in the gut microbiota, and some *E. coli* strains are responsible for a wide variety of common bacterial diseases like colibacillosis in poultry birds, mastitis in dairy animals, urinary tract infection, neonatal meningitis, septicemia in humans. ESBL-producing *E. coli* in humans, animals, and environments is a public health concern.[344]

Different classes of antibacterial drugs have been widely used in both human and veterinary medicine, primarily to treat other bacterial diseases. Still, indiscriminate use of these antibacterial drugs has developed antibacterial resistance (ABR) against various bacteria, including Salmonella spp. and E. coli, in humans, livestock, poultry, birds, and even wildlife.[352] To find out about ABR status and its solution to the problem, a large number of research studies have been conducted and continuing and published both research and review articles at global and national levels (Table 28).[344-350,352] Figs. 10-17 shows the summary data on ABR in bar diagrams. Different classes of antibacterial drugs are used to treat various bacterial diseases, including salmonella spp. and *E. coli* infections in humans, livestock, poultry, and even wildlife.

‘One Health’ approach to zoonotic *E. coli* infection

The antimicrobial resistance (AMR) phenomenon has been developed at the human-animal-wildlife-environmental interface, and subsequently, the resistance gene or the bacteria enter the human food chain. Hence, ‘One Health’ is essential for getting insights and improving the AMR problem.

The bacterial pathogens, especially *E. coli*, *Salmonella* spp., and Campylobacter species, carry antibiotic-resistant genes and can spread between livestock, humans, and the environment.[357] The extensive and indiscriminate use of antibiotics in livestock, including poultry farming, generates antibiotic-resistant bacteria and genes that can potentially transmit to humans through the food chain, posing a threat to the treatment of human infections.[357]

Table 28. Summary of antibacterial resistance status of major zoonotic bacterial pathogens isolated from livestock and humans in Bangladesh

S/N Antibacterials with groups	*Salmonella* spp.			*Escherichia coli*			*Staphylococcus* spp.		
	No. of isolates	Resistance status **X** Range, %	Mean (%)	No. of isolates	Resistance status **Y** Range, %	Mean (%)	No. of isolates	Resistance status **Z** Range, %	Mean (%)
A. Penicillin									
1. Penicillin	118	57.89-100	110 (93.22)1	0487	14.75-100	0378 (77.62)1	208	15.58-100	114 (54.81)1
2. Oxacillin	124	00.00-100	102 (82.26)2	0043	100	0043 (100)2	132	07.40-42.10	035 (26.51)2
3. Ampicillin	1390	00.00-100	1000 (71.94)3	2989	00.00-100	2510 (83.97)3	299	00.00-100	217 (72.58)3
4. Amoxicillin (AMX)	1093	05.88-100	724 (66.24)4	3475	00.00-100	2854 (82.13)4	459	00.00-100	218 (47.49)4
5. AMX-clavulanate	191	25.70-41.46	067 (35.08)5	0194	20.20-100	0090 (46.39)5	042	42.86	018 (42.86)5
6. PC-Tazobactam	-	-	-	0156	08.64-20.30	0023 (14.74)6	-	-	-
B. Cephalosporins									
1. Cefixime	243	00.00-100	054 (22.22)7	1914	57.50-100	1088 (58.56)7	282	57.14	024 (57.14)7
2. Ceftazidime	219	01.40-75.00	111 (50.86)8	1421	01.00-46.36	0225 (15.83)8	-	-	-
3. Ceftriaxone	439	01.42-82.00	190 (43.28)9	2587	00.00-88.89	1732 (66.92)9	196	00.00-88.89	048 (24.49)9
4. Cefotaxime	199	04.10-19.40	023 (11.58)10	1098	01.00-78.10	0135 (12.30)10	042	07.14	003 (07.14)8
5. Cefuroxime	327	02.70-50.00	058 (17.74)11	0168	03.85-100	0099 (58.93)11	082	15.00-30.95	019 (23.17)9
6. Cefaclor	074	65.49	010 (13.50)12	-	-	-	-	-	-
7. Cefoxitin	074	65.49	006 (08.10)13	0114	41.23	0047 (41.33)12	-	-	-
8. Cephalexin	210	09.50-90.00	060 (32.61)14	1698	84.10-100	1434 (84.45)13	144	38.19	037 (38.19)10
9. Cefradine	097	09.27-100	024 (24.74)15	0609	00.00-100	0355 (58.29)14	213	00.00-25.00	051 (23.94)11
C. Chloramphenicol	1323	00.00-94.30	251 (18.97)16	2610	00.00-97.20	1042 (39.92)15	200	00.00-66.67	087 (43.50)12
D. Tetracyclines									
1. Tetracycline	1037	26.67-100	937 (90.36)17	3427	03.28-100	2793 (81.50)16	173	03.89-100	072 (41.62)13
2. Oxytetracycline	537	21.62-100	421 (79.58)18	0598	13.11-100	0395 (66.03)17	265	05.90-80.20	120 (45.28)14
3. Doxycycline	329	06.67-81.81	193 (58.66)19	0305	43.45-78.95	214 (70.16)18	136	12.50-82.00	082 (60.29)15
E. Fluoroquinolones									
1. Ciprofloxacin	1993	00.00-100	526 (26.39)20	3935	00.00-100	2270 (57.69)19	380	00.00-77.50	113 (29.74)16
2. Norfloxacin	552	00.00-20.00	058 (10.51)21	0479	00.00-50.00	0071 (14.82)20	077	02.60	002 (02.60)17
3. Enrofloxacin	391	11.11-100	225 (57.54)22	0049	55.50-100	031 (63.27)21	-	-	-
4. Ofloxacin	141	36.80-65.49	082 (58.16)23	0095	36.80	035 (36.84)22	-	-	-
5. Levofloxacin	448	00.00-27.90	116 (22.52)24	1328	00.00-81.82	738 (55.57)23	042	09.52	004 (09.52)18
6. Pefloxacin	193	70.30-100	170 (88.08)25	0194	37.90-100	125 (64.43)24	-	-	-
7. Gatifloxacin	074	29.70	022 (29.70)26	0095	34.70	033 (34.70)25	-	-	-
8. Moxifloxacin	-	-	-	0575	00.00-59.25	303 (52.70)25a	-	-	-
F. Aminoglycosides									
1. Amikacin	455	00.00-50.00	072 (13.79)27	0699	00.00-28.60	087 (12.45)26	42	42 (100)	07 (16.67)18a
2. Gentamicin	1278	00.00-81.81	290 (22.69)28	3837	00.00-100	1008 (26.27)27	468	00.00-71.43	098 (20.94)19
3. Neomycin	499	00.00-74.56	160 (32.06)29	0433	00.00-100	106 (24.48)28	010	00.00	000 (00.00)20
4. Streptomycin	553	00.00-84.62	204 (36.39)30	1633	00.00-100	1077 (65.95)29	146	10.00-95.24	063 (43.15)21
5. Tobramycin	093	13.50-22.22	014 (15.05)31	0061	04.92	003 (04.92)30	171	02.60-25.93	024 (14.04)22
6. Kanamycin	251	07.00-81.81	099 (30.28)32	0446	00.00-76.00	229 (51.35)31	084	22.22-38.10	020 (23.81)23
G. Lincosamides									
1. Clindamycin	067	84.00	056 (84.00)33	-	-	-	-	-	-
H. Nitrofuran									
1. Nitrofurantoin	138	17.07-100	025 (18.12)34	925	00.00-63.10	419 (16.19)32	-	-	-
I. Macrolides									
1. Azithromycin	1377	12.90-100	703 (37.48)35	1649	06.58-100	963 (58.40)33	152	02.59-26.19	018 (11.84)24
2. Erythromycin	765	43.45-100	667 (87.19)36	555	00.00-100	446 (80.36)34	077	09.09-78.58	07 (09.09)25
J. Monobactams									
1. Aztreonam	089	04.10-25.00	21 (13.46)37	453	58.28	264 (58.28)35	-	-	-
K. Beta-lactamase resistant penicillin									
1. Cloxacillin	114	84.00-100	103 (90.35)38	0066	97.14-100	065 (98.48)36	040	37.50	015 (37.50)26
L. Polymyxin									
1. Colistin (Polymyxin)	371	07.14-100	277 (74.66)39	2207	00.00-100	371 (09.59)37	077	00.00	000 (00.00)27
2. Polymyxin B	067	06.0	004 (06.00)40	-	-	-	-	-	-
M. Carbapenem									
1. Ertapenem	253	05.70-50.00	075 (29.64)41	0180	66.67	120 (66.67)38	-	-	-
2. Meropenem	343	00.00-63.63	82 (23.91)42	1303	00.00-72.72	224 (17.19)39	468	20.00-25.93	98 (20.94)28

Contd. Table 28. Summary of antibacterial resistance status of major zoonotic bacterial pathogens isolated from livestock including poultry and humans in Bangladesh

S/N	Antibacterials with groups	*Salmonella* spp.			*Escherichia coli*			*Staphylococcus* spp.		
		No. of	Resistance status **X**		No. of	Resistance status **Y**		No. of	Resistance status **Z**	
		isolates	Range, %	Mean (%)	isolates	Range, %	Mean (%)	isolates	Range, %	Mean (%)
	3. Imipenem	330	00.00-85.71	077 (23.33)43	1184	00.00-65.80	238 (20.10)40	042	00.00	00 (00.00)29
	N. Quinolone									
	1. Nalidixic acid	866	00.00-100	645 (74.48)44	3891	00.00-10	2967 (76.25)41	060	33.33-35.71	21 (35.00)30
	O. Rifampicin	075	60.00-88.00	064 (85.33)45	0166	90.00	0149 (90.00)42	040	07.50	03 (07.50)31
	P. Tigecycline	202	04.10-90.48	096 (47.52)46	0167	00.00	0000 (00.00)43	-	-	-
	Q. Vancomycin	86	41.67-66.28	62 (59.05)47	0061	00.00	0002 (00.00)44	117	05.19-17.50	11 (09.40)32
	R. Sulfonamides									
	1. Sulfamethazine	379	00.00-89.20	207 (54.62)48	0875	44.74-100	775 (08.99)45	-	-	-
	2. Trimethoprim	007	100	007 (100)49	0854	77.00-95.00	778 (91.10)46	-	-	-
	3. Co-trimoxazole	516	00.00-89.20	260 (50.39)50	3991	00.00-100	2409 (60.36)47	077	05.19	04 (05.19)33

X

1 = 255,280,290,298,300,301,303,312,316,320,351; **2** = 263,276; **3** = 254-256,264-282,303,318-320,323,326,328,330; **4** = 252,254,262,263, 264,266,268,269,272,273,275,277,279,280,282-292,303,320,324,339; **5** = 254,264,265,324; **6** = 264,265; **7** = 255,256,264,324,326; **8** = 254,264, 266,292,326; **9** = 250,254,263-266,268,269,271,277,278,288,294,322,324; **10** = 250,254,264,268,271; **11** = 250,264,265,324,326; **12** = 264; **13** = 264; **14** = 250,255,264,266,274,295; 15 = 264,290,324; **16** = 250,254-256,264,267-270,273,275-278,290,292,293,295,296,318-320,323, 326,329; 17 = 254-256,264,267-270,272,273,275,278,279,282,284-287,289-291,293,295,296,303,319,321,323,327,328,329,330,339; **18** = 252,262-264,276,288,290,293; **19** = 250,252,262,264,266,286,287,296,330; **20** = 252,254-256,262-265,268-277,279,282-296,303,318-324,326-329; **21** = 252,255,264,282,284,289-291,319,327; **22** = 252,279,287,290; **23** = 250,264,307; **24** = 250,252,264,271,272,295,324,326,328; **25** = 287, 307,336; **26** = 264; **27** = 250,252,254,262-265,324; **28** = 252,254,255,262-265,268-270,272-274,276,277,282, 284,286,287,289-293,295,303, 319-321,323, 324,327,328-330,351; **29** = 252,262,264,285,287,293,321; **30** = 254,256,263,264,268,282,284,289,291,295, 319,321,323,327; **31** = 264, 290; **32** = 250,268,269,273,275,286,287,293,329; **33** = 250; **34** = 265,271,330; 35 = 250,252,254,262-264,268,269,272,274,282,284,289-291,293,296,318-320,326,327,328,329; **36** = 255,262,266,267,271-273,275,279,281-285,289-291,293,295,296.303,318-321,323,327-329; **37** = 250, 254,264; **38** = 250,271,281,283; **39** = 265,276,279, 283,285,287,290,292,323,330; **40** = 250; **41** = 256,265,293; **42** = 254,264,265,293,295,330; **43** = 250,264,265,285,293,295,329,330; **44** = 254,255, 264,266-269,272-275,278,280,281, 318,319,326,328,330; **45** = 298,351; **46** = 264,265,292; **47** = 250,290; **48** = 252,264,273,275, 280; **49** = 271; **50** = 262-265,267,270,278,280,288,290

Y

1 = 290,298,300,301,303,312,316,320; **2** = 263,276; **3** = 268,269,272,276,297,298,300-304,306,310,312,314,316,320,328,331,333,336,341,342, 343, 344; **4** = 263,268,269,272,284,287,290,291,299,303,304,305,309,312,313,315-317,320,324,328,335,336,339,340; **5** = 306,308,324; **6** = 309,336; **7** = 298,305,324,340; **8** = 308,313,341; **9** = 263,268,269,298,305,306,308,313,324,340; **10** = 268,306,308,341; **11** = 309,324,333; **12** = 342; **13** = 301,305; **14** = 290,313,324,333,340; **15** = 268,269,276,290,293,295,298,302,309,310,312,320,329,331,333,335,341-343; **16** = 268,269,272,284, 287,290,293,295,297-299,302-304,306,309,310,314,317,328,329,331,333,335,336,339,341-343; **17** = 263,276,290,293,315,316,336; **18** = 287,308, 315,342; **18a** = 324; **19** = 263,268,269,272,276,284,287,290,291,293,295,298-300,302,303,307-310,313-317,320,324,328,329,331,333,335,340, 341,342344; **20** = 284,290,291,298,302,309,310; **21** = 287,302; **22** = 307; **23** = 295,299,307,308,313,314,324,328,340,344; **24** = 287,307,336; **25** = 307; **25a** = 307,313,340; **26** = 263,298,305,313,324; **27** = 263,268,269,272,276,284,287,290,291,293,295,298,301-303,306,309,310,312, 328,329,313-316,320,324,331,333,335,340-344; **28** = 287,293,298,300,312,315; **29** = 263,268,284,291,295,298,302,306,310,312,314,331,333, 343, 344; **30** = 290; **31** = 268,269,287,293,298,329,335; **32** = 298,299,305,313,331,333,342; **33** = 263,268,269,272,284,290,293,309,310,315,320,328329, 340,341,342; **34** = 272,284,290,291,293,295,298,301,302,303,304,310,311,313,314,315,320328,329; **35** = 313; **36** = 311,351; **37** = 276,287,290,297, 300,302,305,308,314,316,317,341,344; **38** = 293; **39** = 293,295,305,308,309,341,342,343,344; **40** = 293,295,298,305,308,309,313,324,329; **41** = 268, 269,272,297,298,301,304,305,307,310,311,313,318,331,333,335,341,342; **42** = 298; **43** = 331,333; **44** = 290; **45** = 304,341,342; **46** = 341; **47** = 290,297-299,305,306,309,313-316,331,333,335,336,343,344

Z

1 = 290,303,312,320,351; **2** = 276,351; **3** = 268,269,276,303,312,320,338,351; **4** = 268,269,290,303,312,320,324,338,351; **5** = 324; **6** = 324; **7** = 268, 269,324,351; **8** = 268; **9** = 324,351; **10** = 338; **11** = 290,324,351; **12** = 268,269,276,290,312,320; **13** = 268,269,290,303; **14** = 276,290,338,351; **15** = 338,351; **16** = 276,268,269,290,303,320,324,338,351; **17** = 290; **18** = 324; **19** = 268,269,276,290,303,312,320,324,338,351; **20** = 312; **21** = 268, 312,351; **22** = 290,351; **23** = 268,269; **24** = 268,269,290,320; **25** = 290,303,320,351; **26** = 351; **27** = 290; **28** = 351; **29** = 324; **30** = 268,269; **31** = 351; **32** = 290,351; **33** = 290

The EHEC 0157:H7 strain has been isolated from feral swine, domestic cattle, surface water, sediment, and soil during the outbreak of EHEC 0157 in humans, which demonstrated the significance of the ‘One Health’ concept, including human, animal, and environmental domains. The pooled prevalence of extended-spectrum beta-lactamase (ESBL)-producing *E. coli* in Bangladesh has been reported to be 21.0%, of which 17.0% in

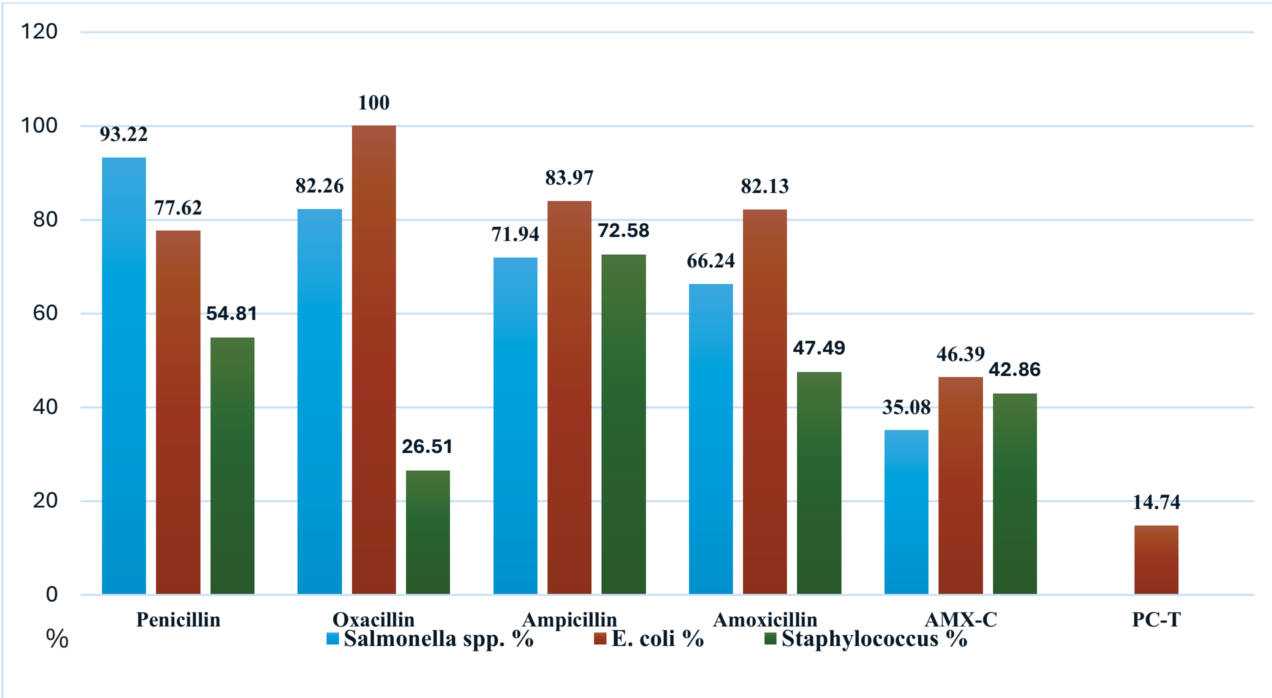


Fig. 10. Overall, penicillin classes antibiotic resistance status against Salmonella spp., E. coli, and *Staphylococcus* spp. isolated from livestock and humans

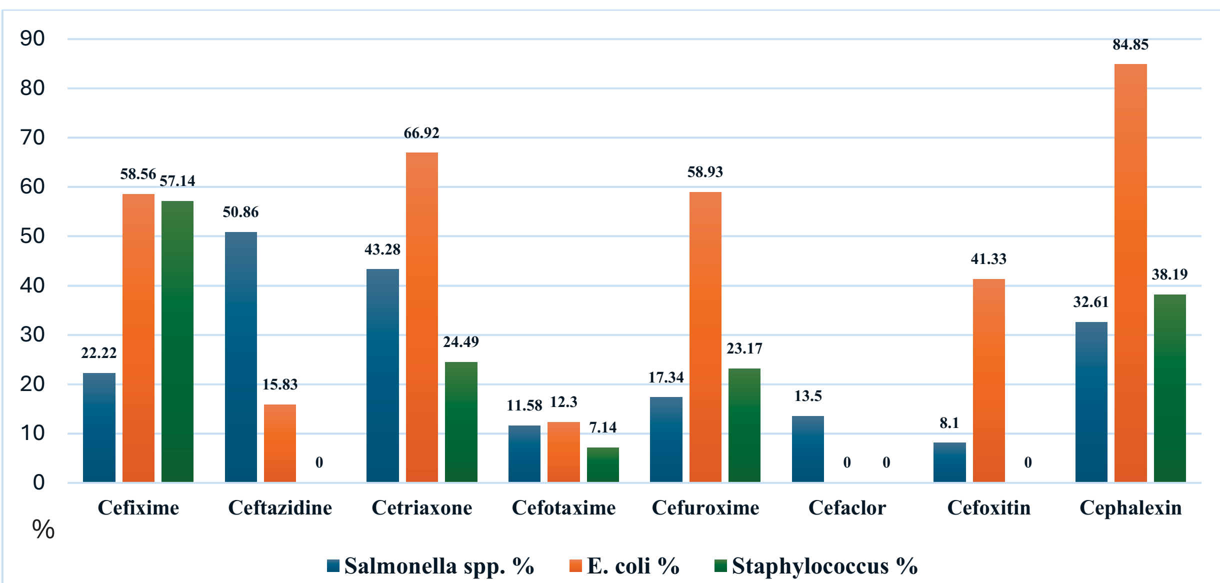


Fig. 11. Overall cephalosporins classes antibiotic resistance status against *Salmonella* spp., *E. coli* and *Staphylococcus* spp. isolated from livestock and humans

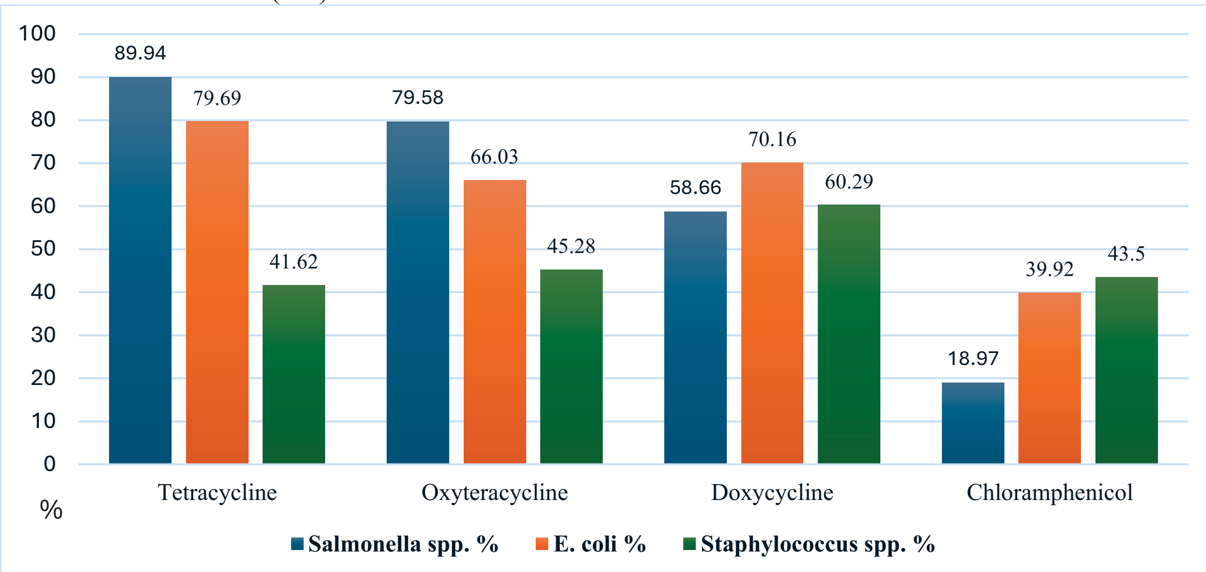


Fig. 12. Overall tetracyclines and chloramphenicol classes antibiotic resistance status against *Salmonella* spp., *E. coli* and *Staphylococcus* spp. isolated from livestock and humans

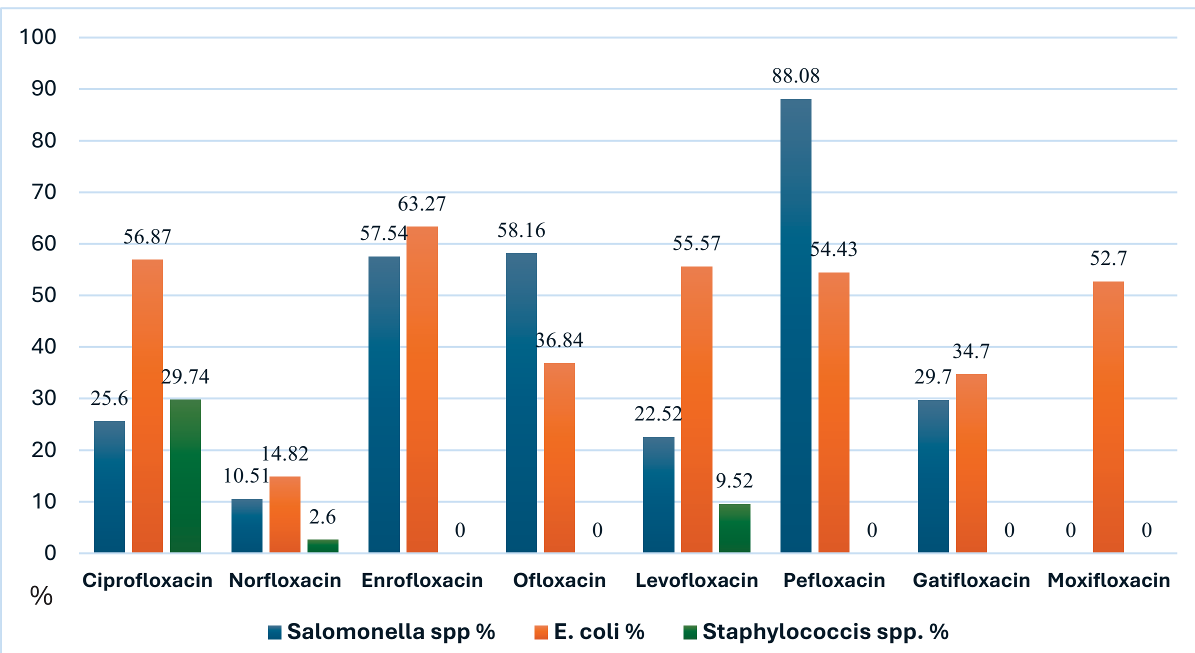


Fig. 13. Overall fluoroquinolones classes antibiotic resistance status against *Salmonella* spp., *E. coli* and *Staphylococcus* spp. isolated from livestock and humans

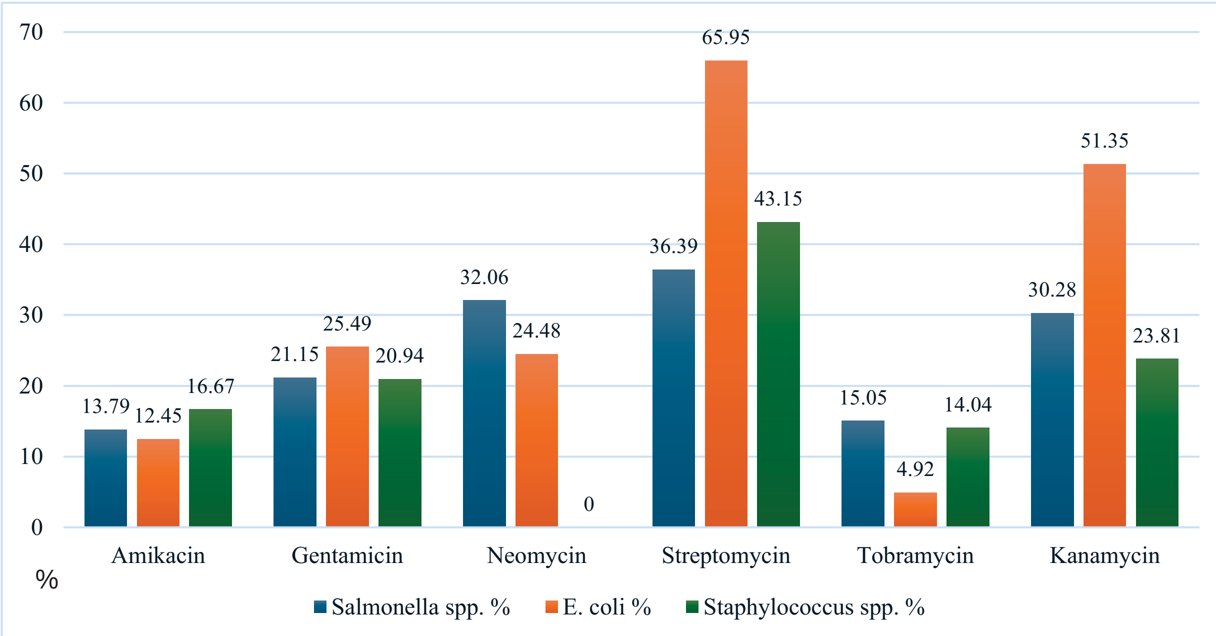


Fig. 14. Overall aminoglycosides classes antibiotic resistance status against *Salmonella* spp., *E. coli,* and *Staphylococcus* spp. isolated from livestock and humans

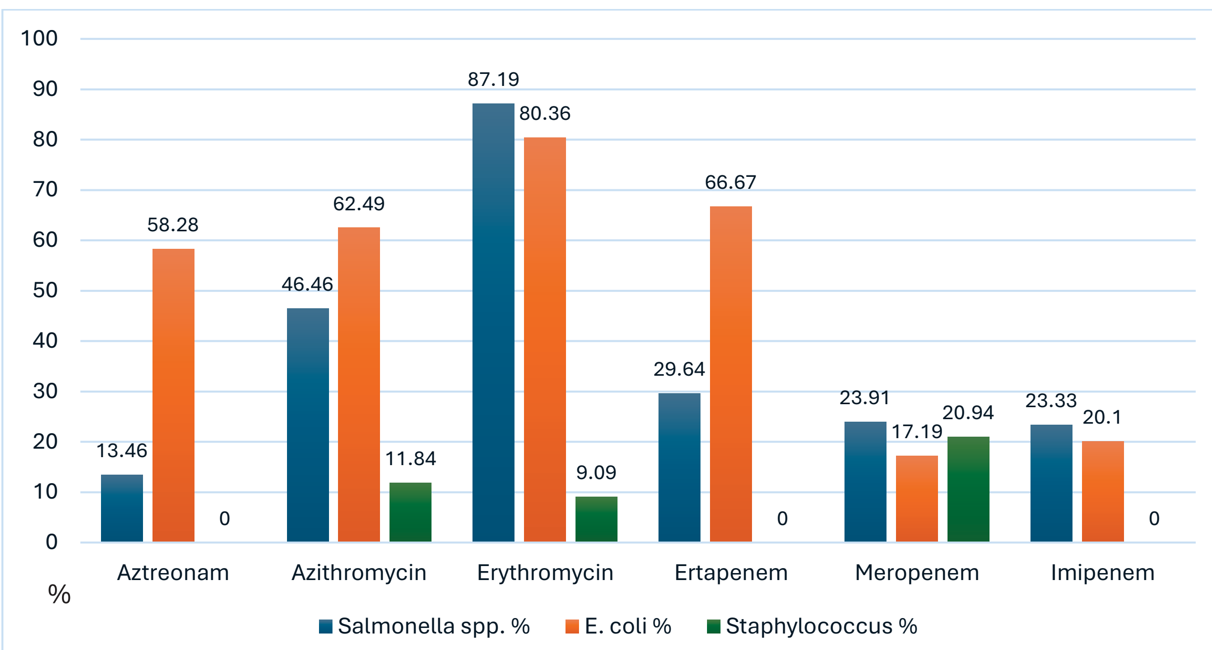


Fig. 15. Overall monobactams, macrolides, and carbapenem classes antibiotic resistance status against Salmonella spp., E. coli, and *Staphylococcus* spp. isolated from livestock and humans

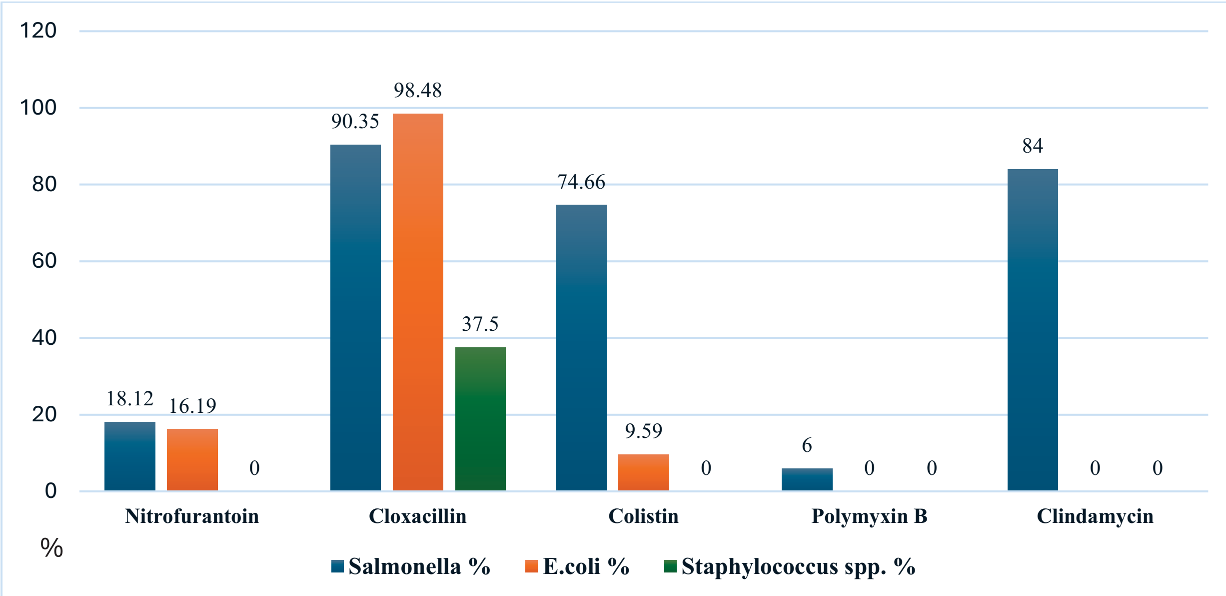


Fig. 16. Overall certain antibiotic resistance status against *Salmonella* spp., *E. coli*, and *Staphylococcus* spp. isolated from livestock and humans

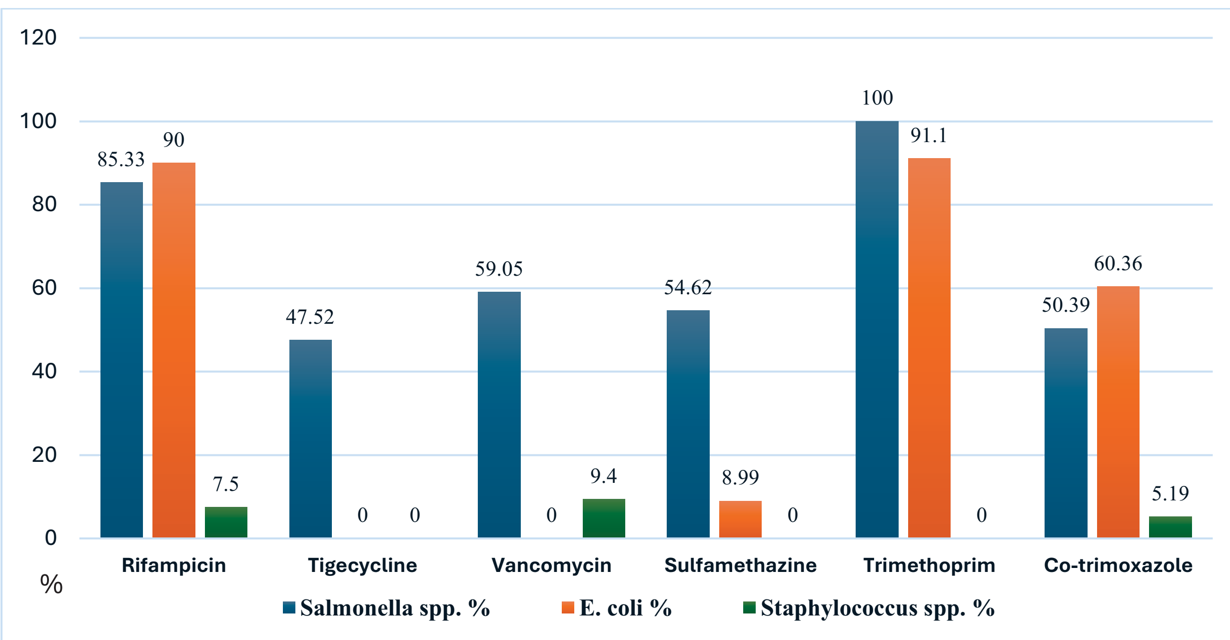


Fig. 17. Overall sulfonamides and other antibiotic resistance status against *Salmonella* spp., *E. coli*, and *Staphylococcus* spp. isolated from livestock and humans

humans, 22.0% in animals, and 39.0% in the environment source of samples.[344] Integrating and understanding the interaction of these factors linking humans, animals, and the environment will facilitate 'One Health' approaches to thwart and control the zoonotic transmission of EHEC (Fig. 18).

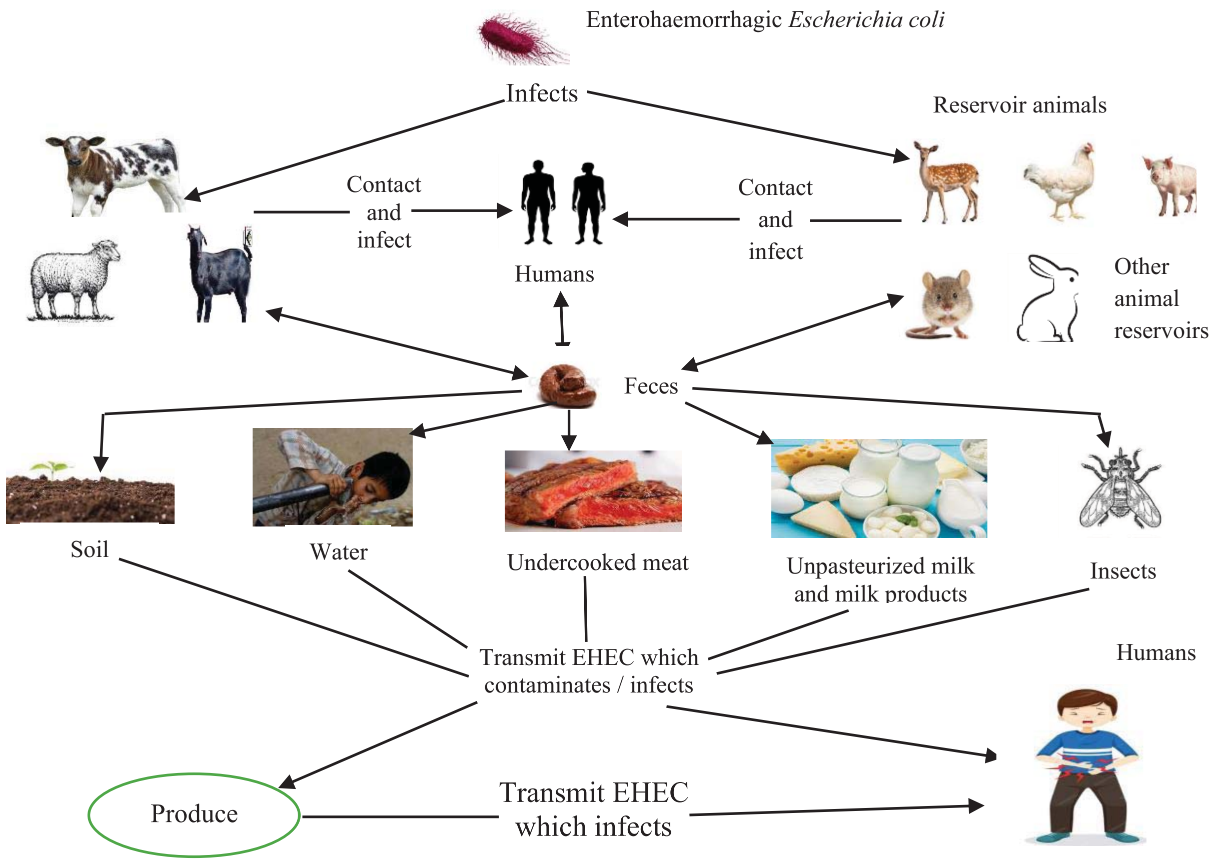


Fig. 18. The associations among the factors intricate in enterohaemorrhagic *Escherichia coli*

E. coli from both human and poultry origin showed a high resistance level against commonly used antibiotics (Table 28).[299] Table 31 shows the resistance status of *E. coli* isolated from humans and poultry.

Staphylococcus aureus infection

Ogston first discovered Staphylococci in 1880, who observed bacteria in a surgical abscess of a knee joint and called them Staphylococcus (Greek 'staphyle' 'a bunch of grapes'; 'kokkos' 'the berry.' The genus Staphylococcus currently comprises 81 species and sub-species. Most members of the genus are mammalian commensals. Still, some are opportunistic pathogens that colonize the skin and respiratory, alimentary, and urogenital tracts of animals and birds and the diverse mucosal membranes of 20-30% of the human population.[358,359] Staphylococci can be grown and multiplied everywhere, including water, soil, air, and plants. It also acts as normal flora on animals' and humans' skin and nasal cavities.[359] The prevalence of *S. aureus* varies from host species to host species, and up to 90% of chickens, 42% of pigs, 29% of sheep, and 14-35% of cows and heifers have been reported to be carriers.[345] *S. aureus* can be colonized by diverse animal species following host-switching events and subsequent adaptation through acquisition and/or less of mobile genetic elements (MGEs) and further host-specific mutations, allowing it to expand into new host populations (Fig. 11).[359] Close contact between animals and humans can facilitate host-switching events. Humans are a significant hub for *S. aureus* host jumps (Fig.19).

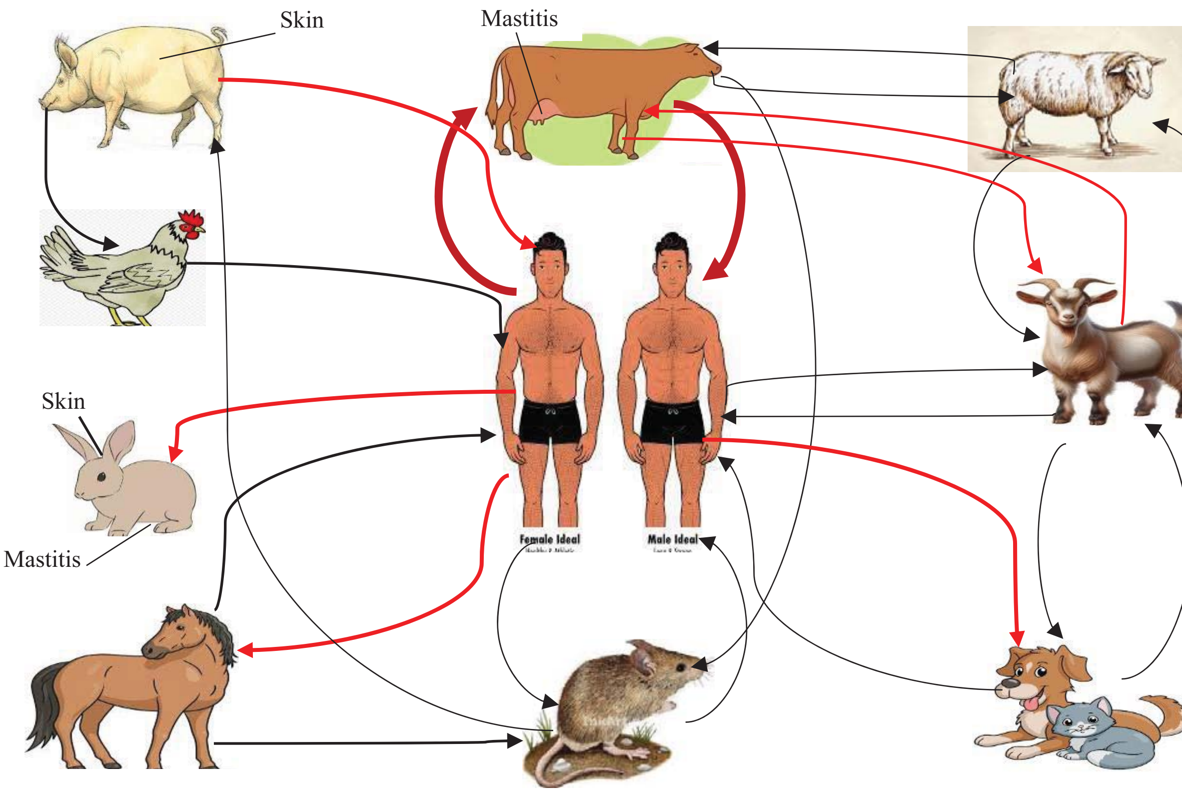


Fig. 19. Humans act as a major hub for *Staphylococcus aureus* jumps[358]

Importance of *S. aureus* in Veterinary Medicine

S. aureus is one of the primary causative agents of mastitis in ruminant animals. It causes dermatitis in small ruminants, botryomycosis in pigs and horses, and suppurative infections in cats and dogs. *S. a. subsp. anaerobius* causes lymphadenitis in sheep. *S. intermedius* causes various pyogenic diseases in dogs and cats and may cause other suppurative infections, including endometritis, cystitis, and otitis externa. This bacterium can be shed from infected udder; thus, contamination of bulk milk can lead to food poisoning from fermented raw milk products. *S. aureus* can be found in apparently healthy carrier cows on the teat skin, nasal cavity, and rectum, but the main reservoirs in a dairy herd are infected udders and teat skin. Infected animals can shed bacteria through their milk, and transmission occurs primarily from udder to udder during milking via contact with contaminated milking machines, milker's hands, or contaminated bedding. Cows are a significant reservoir for the reinfection of humans, and multiple host-switching events, both human-to-cow and cow-to-human, have occurred. It also affects the health of animals and pets, causing dermatitis, abscesses, pododermatitis, and mastitis.[358]

Otitis externa and pyoderma, endometritis, mastitis, osteomyelitis, and cystitis are reported due to *S. aureus* in pet animals. Skin infections in pigs are typically caused by *S. hyicus* and have only been occasionally

S. aureus is documented to cause MRSA, but pigs represent a major reservoir for MRSA.358 S. aureus mainly targets the skin, bones, tendons, and joints, which causes several poultry diseases, including septic arthritis, subdermal abscesses, gangrenous dermatitis, septicemia, synovitis, bumblefoot, and omphalitis, under appropriate conditions in poultry birds.

Infections in animals are deleterious to animal health, and animals can act as a reservoir for staphylococcal transmission to humans. *S. aureus subsp aureus* is coagulase-positive, which is associated with diseases of animals, whereas coagulase-negative bacteria are usually non-pathogenic to animals and humans. However, it occasionally causes bovine mastitis.[359] It appears that *S. aureus* can cause severe infections in some animals; others show less severe symptoms and are mainly colonized, acting as a staphylococcal reservoir for human reinfection, and such lineages are found in pigs and dairy cows.

Staphylococci in food and non-food samples

A bacteriological study was carried out on a total of 270 food and 125 non-food samples to find out the presence of coagulase-positive Staphylococcus. Staphylococci contamination was recorded in 68.15% of food samples and non-food in 60.0% of samples, whereas coagulase-positive Staphylococci was recorded in 34.78% of food samples and 30.26% of non-food samples (Table 29).[360]

Table 29. Prevalence of Staphylococci in food and non-food samples in Bangladesh[360]

Examination of food samples

S/N	Samples	No. of samples	Staph. +ve No. (%)	Coagulase Staph +ve
1.	Raw milk	30	23 (76.66)	11 (47.82)
2.	Raw meat	30	21 (70.00)	08 (38.10)
3.	Butter milk	30	25 (83.30)	10 (40.00)
4.	Dough	30	26 (86.67)	09 (34.62)
5.	Cake	30	11 (36.66)	03 (27.27)
6.	Biscuits	30	16 (53.33)	04 (25.00)
7.	Petish	30	17 (56.67)	05 (24.41)
8.	Cream	30	21 (70.00)	08 (38.09)
9.	Cream roll	30	24 (80.00)	06 (25.00)
	Overall	270	184 (68.15)	64 (34.78)

Examination of non-food samples

S/N	Samples	No. of samples	Staph +ve No. (%)	Coagulase Staph +ve
1.	Nasal swabs	25	17 (68.00)	5 (19.44)
2.	Throat swabs	25	09 (36.00)	3 (33.34)
3.	Hand wash	25	15 (60.00)	5 (33.35)
4.	Utensil wash	25	19 (76.00)	4 (21.05)
5.	Washing from surroundings	25	16 (64.00)	6 (37.05)
	Overall	125	76 (60.00)	23 (30.26)

Antibiotic resistance status *S. aureus*

S. aureus is an opportunistic bacterium that causes nosocomial diseases, which can lead from mild skin lesions to fatal endocarditis. The most significant concern related to the worldwide spread of *S. aureus* is the emergence of methicillin-resistant S. aureus (MRSA) strains, often found in humans and animals. MRSA in animals was first isolated from the milk of dairy cows with mastitis in Belgium in the 1970s and has since been isolated from cows around the globe.[358] MRSA strains harbor an MGE known as SCCmec, containing the mec gene, which codes for an additional penicillin-binding protein with a low affinity for β-lactam antibiotics and, therefore, mediates resistance to nearly all compounds of these antibiotics. MRSA is associated with poultry meat, and it has different strains; each is resistant to a class of antibiotics. The MecA gene is reported to be responsible for MRSA, and this gene is also attributed to being transmitted from poultry to humans.[358] They are commonly isolated from chickens and can be transmitted to humans by direct contact. The antibiotic sensitivity test showed that several coagulase-positive isolates were resistant to many common antibiotics, particularly penicillin and sulfadiazine (Table 30).[360]

Table 30. Antibiotic sensitivity of coagulase-positive Staphylococci[360]

S/N	Antibiotic	Food samples (n = 64) Sensitive No. (%)	Food samples (n = 64) Resistant No. (%)	Non-food samples (n = 23) Sensitive No. (%)	Non-food samples (n = 23) Resistant No. (%)
1.	Penicillin	17 (26.56)	47 (73.44)	07 (30.43)	16 (69.57)
2.	Streptomycin	46 (71.88)	18 (28.15)	15 (62.22)	08 (34.78)
3.	Tetracycline	35 (54.85)	29 (45.31)	13 (56.57)	10 (43.47)
4.	Cloxacillin	51 (79.69)	13 920.31)	16 (59.57)	07 (30.43)
5.	Chloramphenicol	58 (90.63)	06 (09.38)	19 (82.61)	04(17.39)
6.	Gentamicine	57 (89.06)	07 (10.94)	20 (86.95)	03 (13.04)
7.	Co-trimoxazole	33 (51.56)	31 (48.43)	10 (43.47)	13 (56.52)
8.	Sulfadiazine	25 (39.06)	39 (60.93)	08 (34.78)	15 (65.22)

Table 31. Resistance (%) status of *E. coli* isolated from humans and poultry fecal samples[299]

S/N Antibiotic	Human origin (n = 14)	Poultry origin (n = 11)
01. Amoxicillin	100	100
02. Tetracycline	73.3	100
03. SMT	90.0	92.3
04. Nitrofurantoin	40.0	30.8
05. Ciprofloxacin	80.0	84.6
06. Levofloxacin	66.7	77.0

SMT = Sulfamethoxazole-trimethoprim

Zoonoses and public health importance of *S. aureus*

S. aureus is a common commensal bacterium and also an opportunistic pathogen responsible for a wide range of infections in both humans and animals, including cattle, sheep, goats, poultry, and rabbits (Fig. 20). It has been reported that nasal colonization by *S. aureus* in 30% of healthy carriers in humans.[361,362]

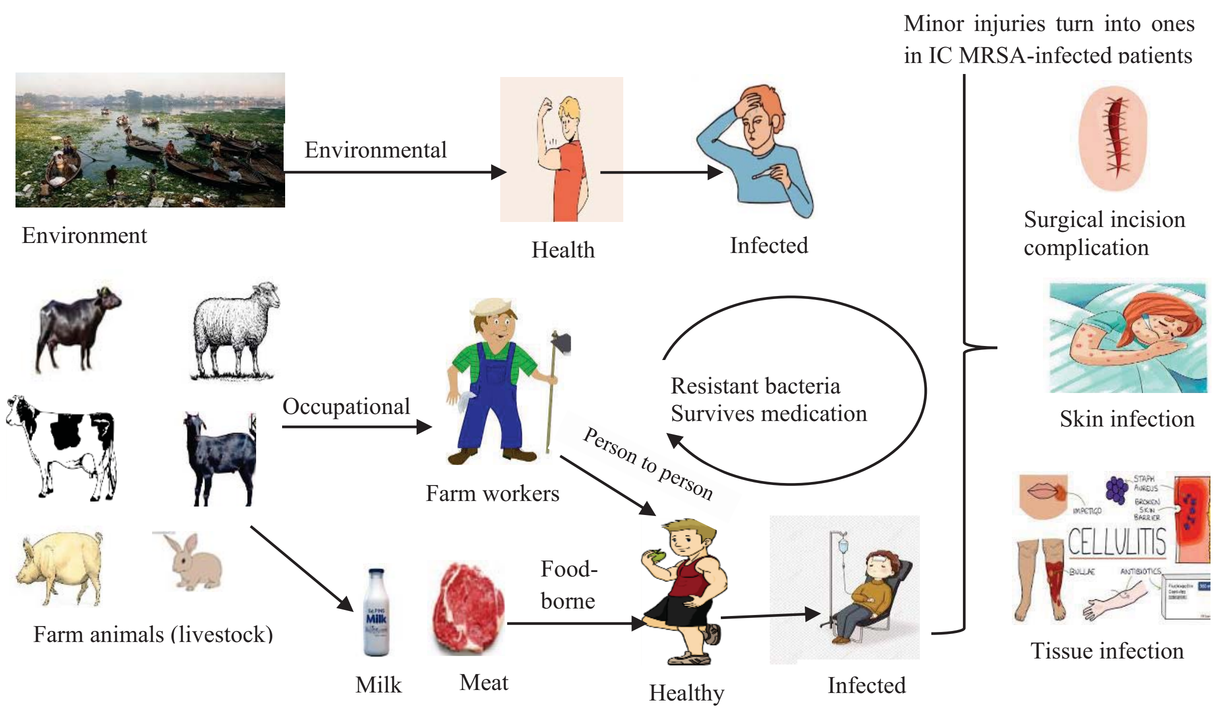


Fig. 20. Zoonotic transmission of methicillin-resistant Staphylococcus aureus (MRSA)[363]

Some strains of *S. aureus* produce toxins that cause toxic shock syndrome or may be linked to staphylococcal food poisoning. Approximately 50% of the *S. aureus* strains are responsible for human food poisoning through their enterotoxins. The risk of contact with MRSA is a major concern in nosocomial infections, as it is associated with higher mortality rates and human healthcare costs (Fig.12). Recently, the transmission of *S. aureus* from the goat to veterinarian evoked an episode of professional zoonosis.[364]

S. aureus is an excellent model bacterium for the 'One Health' concept because of its dynamics at the human-animal interface and its versatility in hosting adaptation.[365]

Table 32. Comparison to antibiotic resistance status of *Staphylococcus aureus* isolated humans and animal sources[345]

S/N	Antibiotics	Isolated from animals (n=54)	Isolated from humans (n = 40)	S/N	Antibiotics	Isolated from animals (n=54)	Isolated from humans (n = 40)
01.	Penicillin	35 (64.81)	35 (87.5)	02.	Oxacillin	04 (07.40)	15 (37.50)
03.	Ampicillin	14 (25.93)	-	04.	Amoxycillin	20 (37.04)	15 (37.50)
05.	Cloxacillin	-	15 (37.50)	06.	Ciprofloxacin	-	06 (15.00)
07.	SMX-TM	20 (37.04)	-	08.	Oxytetracycline	23 (42.59)	-
09.	Doxycycline	-	05 (12.50)	10.	Gentamicin	14 (25.93)	08 (20.00)
11.	Streptomycin	13 (24.07)	-	12.	Tobramycin	07 (12.96)	-
13.	Erythromycin	07 (12.96)	06 (15.00)	14.	Ceftriaxone	07 (12.96)	08 (20.00)
15.	Cephradine	06 (11.11)	10 (25.00)	16.	Cefuroxime	-	06 (15.00)
17.	Vancomycin	-	07 (17.50)	18.	Rifampicin	-	03 (07.50)
19.	Fusidic acid	-	02 (05.00)				

Table 32 shows that *S. aureus* isolates from animals (64.81%) and humans (87.5%) reveal a higher resistance against penicillin. This higher prevalence of penicillin-resistant *S. aureus* in animals and simultaneously in humans might increase the chance of transmitting penicillin-resistant bacterial genes to the human cycle through animal sources and food products. Other tested antibiotics showed some form of resistance (multi-drug-resistant) against *S. aureus* in both sources of the isolates (Table 32).

Campylobacter infection

Campylobacter comprises a different group of Gram-negative bacteria that cause foodborne diseases in humans, and more than 95.0 million people have been reported to be infected with these foodborne pathogens globally. The livestock (animals and poultry), including pets (dogs and cats), and environmental exposure relate to Campylobacter infection.[366] Campylobacter species are the normal inhabitants of the gastrointestinal tract of food-producing animals and poultry as commensalism and act as reservoirs. More than 90.0% of human intestinal infections are associated with either *C. jejuni* or *C. coli,* whereas *C. fetus* is a lesser contributor (2.4%) of total confirmed cases of such human infections.[366] *C. jejuni* is the paramount causative agent of diarrhea in children (25.5%) in Bangladesh,[367] which causes acute flaccid paralysis (AFP) and is associated with Guillain-Barre syndrome (GBS) with an expected incidence of 3.25 cases per 100,000 children < 15 years of age group in Bangladesh.[368,369] Campylobacter infections have been reported to be significant public health problems like diarrhea, vomiting, and Guillain-Barre syndrome.[367-369]

Prevalence of Campylobacter infection in Bangladesh

A study on a bacteriological examination of 80 fecal samples of high-yielding crossbred cattle showed that 25.0% had Campylobacter infection.[370] A more recent survey on fecal examination of crossbred farmed cattle has reported 53.3% at the herd level and 30.9% at the animal level prevalence of Campylobacter infection in Bangladesh.[371] The prevalence of Campylobacter infection in poultry and environmental samples varied from 26.4 to 75.0% in Bangladesh.[372-376] In another study on the conventional methods (culture and biochemical tests) of examination of broiler meat and frozen chicken nuggets, including chicken sausages from super shops in Dhaka city, Bangladesh, showed 62.5% (5/8) Campylobacter contamination.[377] *C. jejuni* and *C. coli* can colonize livestock's gut, including poultry birds. Human infections, of particular concern when involving chicken, are usually caused by consumption of contaminated poultry products, even though occupational transmission has been reported (Table 33 & Fig. 21).

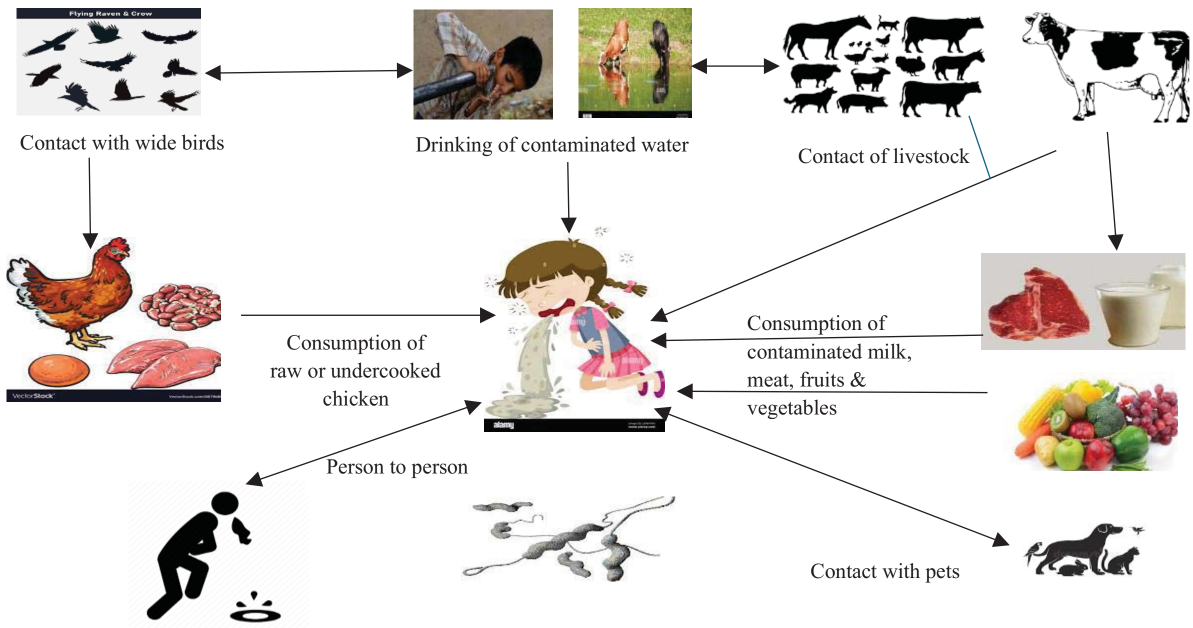


Fig. 21. Transmission of zoonotic campylobacter organisms.

Table 33. Occurrence of *Campylobacter* spp in broiler birds under farms of three districts in Bangladesh[373]

S/N	District	No. of samples	Positive No. (%)	95% CI	S/N	District	No. of samples	Positive No. (%)	95% CI
1.	Gazipur	264	70 (26.5)	21.3-32.3	2.	Tangail	044	13 (29.5)	16.8-45.2
3.	Dhaka	044	10 (22.7)	11.5-37.8					

Leptospirosis

Leptospirosis is a globally crucial re-emerging spirochete zoonotic disease of humans and animals caused by infection with any of several pathogenic serovars of the genus Leptospira that incorporates all facets of a 'one health' concept. The word has its roots in the Greek 'leptons,' meaning 'thin,' and the Latin 'Spira,' which means rolled. Over 300 pathogenic serovars have been identified based on their outer lipopolysaccharide antigens, and serovars are organized into antigenic serogroups.[378,379] Leptospira strains are also classified based on DNA sequence composition/types, and the 64 known species of Leptospira are grouped into two pathogenic subclades, ① [P1 (Pathogens 1, pathogenic species) and P2 [Pathogen 2, intermediately pathogenic) and ② Saprophytic subclades (S1 and S2).[380] Saprophytic organisms live in the environment and are poorly associated with mammalian host species. Most leptospirosis in humans and animals results from infections by P1-virulent species such as *L. interrogans*, *L. kirschneri*, *L. borgptersenii*, and *L. noguchii. However,* P2 species have sometimes been recognized as a cause of severe disease.[381,382]

All mammalian species can harbor leptospires in their kidney and act as a source of infection to humans and animals. Rodents were the first recognized carriers of leptospires, and they are the only major animal species that can shed leptospires throughout their lifespan without clinical manifestations. The pathogenic strains of Leptospira are usually maintained in nature through chronic renal infection of the carrier reservoir animals, and these animals can shed leptospires in their urine for years. Dogs and rats are probably common sources of human infection.

Leptospirosis is prevalent mainly wherever humans come into contact with the urine of infected animals or a urine-polluted environment. This organism is usually transmitted through mucous membranes or abraded skin of their susceptible hosts. These organisms contaminate soil and water and can remain viable in the environment for weeks to months when conditions are optimal.[383] Biofilm formation may contribute to the ability of the spirochete to persist in the environment and the renal tubules of reservoir hosts.[384]

Leptospirosis is a globally crucial zoonotic disease, most commonly prevalent in tropical and sub-tropical countries. Infections in high-income developed countries arise mainly from occupational exposure, travel to endemic areas, recreational activities, or importation of domestic and wild animals. In contrast, outbreaks in low-income developing countries are most frequently related to normal daily activities, overcrowding, poor sanitation, and climate conditions.[385] However, leptospirosis prevalence in the 62 reports analyzed corresponded to 28.0% in the Americas, and countries with higher prevalence were the USA (41.0%), Colombia (29.0%), and Brazil (21.0%).[386] Leptospirosis is also an endemic zoonotic disease in all the South Asian countries reported as sporadic clinical cases, sub-clinical and even outbreaks form including Bangladesh (Table 34), India (Orrisa,[387] Mumbai,[388] Kerala,[389] North Andaman[390]), Sri Lanka,[391,392] Pakistan,[393,394] Bhutan,[395] Nepal,[396-399] and Maldives.[400] Following heavy rainfall and flooding, seasonal outbreaks have been reported in most outbreaks, including India.[387-389] The coinfection of Leptospira and COVID-16[401] and Dengue and leptospirosis[402] in clinical patients have been reported in Bangladesh. The geographical distribution of pathogenic Leptospira serovars from 1930 to 2017 has identified Icterohaemorrhgiae, Canicola, Pomona, and Grippotyphosa as a common serovar in the Americas, mainly Latin America, with emphasis on Brazil (Table 34).[403]

Table 34. Most frequent serovars for humans, domestic and wild animals in 283 articles from 1930-2017 in Americas[403]

S/N	Serovars identified	Reservoir animals, No. of studies positive (%)						
		Humans (n = 69)	Dogs (n = 59)	Bovines (n = 48)	Equines (n = 25)	Pigs (n = 15)	Rodents (Rattus) (n = 07)	Wild animals (n = 86)
①	*L. Icterohaemorrhagiae*	47 (68.0)	42 (71.1)	30 (62.5)	18 (72.0)	08 (53.3)	04 (57.1)	43 (50.0)
②	*L. Canicola*	38 (55.0)	52 (88.1)	-	-	05 (33.3)	-	45 (52.3)
③	*L. Pomona*	32 (46.0)	40 (67.7)	32 (66.6)	21 (84.0)	14 (93.3)	02 (28.5)	48 (55.0)
④	*L. Grippotyphosa*	27 (39.0)	38 (64.4)	28 (58.3)	18 (72.0)	-	01 (14.2)	39 (45.3)
⑤	*L. Bratislava*	22 (32.0)	-	-	20 (80.0)	-	-	-
⑥	*L. Hardjo*	-	-	35 (72.9)	19 (76.0)	04 (26.6)	-	-
⑦	*L. Autumnalis*	-	-	-	-	07 (46.4)	02 (28.5)	-
⑧	*L. Tarassovi*	-	-	-	-	-	-	02 (28.5)

N = No. of reports analyzed

Leptospirosis in animals

Pathogenic leptospires cause disease in dogs, cattle, horses, pigs, camelids, small ruminants, and wildlife species.[379] Most Leptospira infections are subclinical in dogs, but when clinical disease occurs, which is characterized by signs of lethargy, fever, inappetence, polyurea/polydipsia, then multiorgan dysfunction with acute kidney injury, cholestatic hepatic dysfunction, pancreatitis, variable degrees of pulmonary hemorrhage, myositis, and in some cases, uveitis.

Globally, Leptospira is a significant cause of abortion, neonatal illness, and production loss, such as decreased milk production in cattle. Blood-tinged milk and agalactia can occur in lactating cows. Most diseases in cattle worldwide have been attributed to *L. borgpetersenii* serovar Hardji (Hardjobovis); others include *L. interogans* serovar Hardjo (Hardjoprajitno) and *L. interogans serovar Pomona*, as well as many other serovars that belong to other serogroups. The severe acute multisystemic disease occurs in calves with signs of fever, hemolytic anemia, hemoglobinuria, and icterus may characterize. Risk factors identified for Hardjo infection in cattle are open herds, access to contaminated water sources, co-grazing with sheep, use of natural service, and herd size. Sub-clinically affected cattle in a herd serve as a carrier and shed Leptospira intermittently for months without detectable serum antibodies.[379]

Leptospirosis affected pigs caused by serogroups Tarassovi, Pomona, and Australis, and sheep and goats are associated with production losses, reproductive failure with abortions, stillbirths, and neonatal illness. Incidental pig infection may be associated with hemorrhagic disease, hematuria, icterus, and acute kidney injury. Horse disease may be associated with febrile illness, reproductive losses, and neonatal illness. Foals may develop acute kidney injury; recurrent uveitis can follow infection in adult horses.[379]

Pathogenic Leptospira organisms live in the kidney tubules of mammals, including rodents, livestock, and pet animals, especially dogs, which act as reservoirs. Once this pathogen is shed in the urine, it can survive in the water and soil environment for weeks to months.[404] The infection results from a combination of environmental factors that affect the survival of pathogens in the environment and human exposure (Fig. 22).

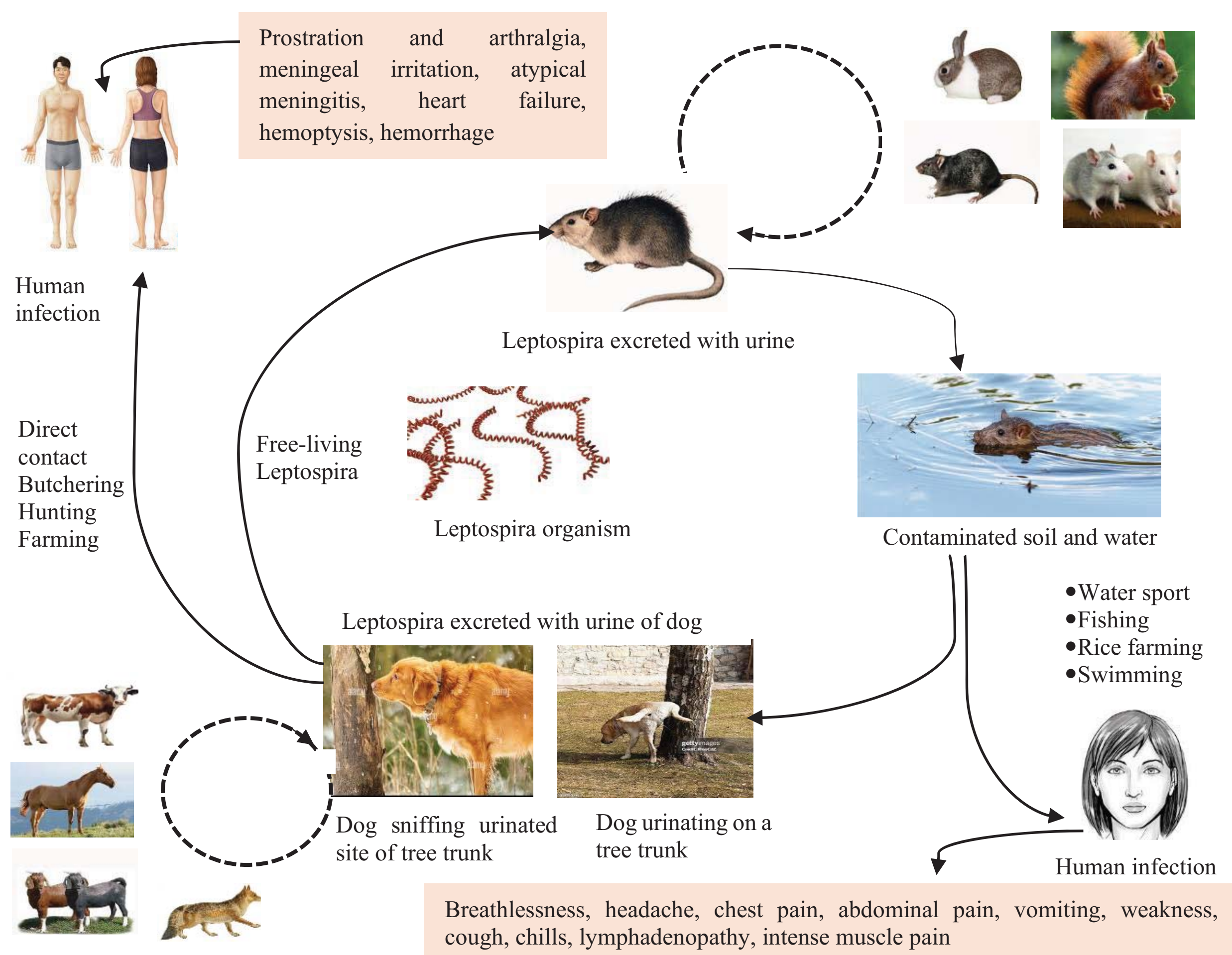


Fig. 22 Transmission cycle of Leptospira organism

Globally, rodents are the most critical reservoir hosts because of the high prevalence of infection in some rodent populations (up to 90%) and the high concentration of Leptospira in rodents' urine compared with other animal species.[405,406]

Many rodents, mainly rats, act as reservoirs of leptospira and excrete it in their urine. A study reported that 13% of rodents had Leptospira infection in Bangladesh.[407] Farm animals, dogs, and humans are exposed to Leptospira through contaminated water, food, and soil. Leptospira causes acute fever, jaundice, acute renal failure, and bleeding in humans, whereas it causes abortion, stillbirth, and low milk production in animals.[379]

Humans and animals become infected by pathogenic leptospires when intact mucous membranes, macerated skin, or abraded skin are exposed to contaminated environmental sources like water or mud. Animals can also become infected following direct exposure to infected urine or tissues of reservoir hosts. Pathogenic leptospires have been found in the reproductive tracts of domestic animals so that venereal transmission may be possible. It could maintain transmission when environmental conditions do not favor the survival of the leptospira outside the mammalian hosts. *L. borgpetersenii serovar Hardjo* has also been detected in fresh raw milk, suggesting that infection may also be transmitted by consuming unpasteurized milk and milk products.[408]

Leptospirosis in humans

Leptospirosis is a globally distributed zoonotic disease, but it has a low incidence in temperate regions and is highly prevalent in tropical and sub-tropical humid climates, where conditions are suitable for Leptospira's persistence in the environment and contact with people, mainly due to favorable environmental conditions for the pathogen to thrive.[409] The global annual prevalence of leptospirosis has been estimated to be 14.8 cases per 100,000 deaths annually.[410] The estimated global disease burden in humans is 1.03 million cases annually, with 58,900 deaths.[379] Most Leptospira infections in humans are self-limited and subclinical and often show minimal or no clinical symptoms. Patients seeking medical treatment usually develop an acute, undifferentiated febrile illness clinically. Untreated cases can drift to severe and potentially fatal Weil's disease with liver damage, kidney failure, or an often fatal severe pulmonary hemorrhage.[411] When clinical disease occurs, it ranges from a mild, febrile, flu-like illness to a severe multisystemic disease that is associated with acute renal failure, hepatic injury, and sometimes pulmonary hemorrhage, meningitis, and pancreatitis. Transplacental infections can occur during pregnancy with abortion or stillbirth. Leptospirosis remains undiagnosed due to a lack of laboratory diagnostic facilities, especially a lack of reliable, rapid, and readily available diagnostic tests in most developing countries, including Bangladesh. Human leptospirosis also resembled COVID-19, and mixed infections with SARS-CoV-2 and Leptospira have been described. The overlapping clinical picture is likely to contribute to the misdiagnosis of leptospirosis cases such as COVID-19, with insufficient attention to prevention strategies.[379]

Southeast Asia is a region where leptospirosis is endemic with a high incidence of human infections, and outbreaks have been reported in different countries, including Sri Lanka, India, Thailand, Laos, Vietnam, Myanmar411, and recently reported in Bangladesh (Table 34). Southeast Asia experiences recurrent flooding, heavy rainfall, and hot-humid weather, which are highly favorable to an increase in both the intensity and frequency of leptospirosis. In Sri Lanka, with over 700 deaths per annum and an estimated annual incidence of hospital admission of 52.1 patients / 100,000 population.[412] Rice paddy work is a significant risk factor in Sri Lanka, Thailand, and other countries, as well as other medium- and low-income countries. The disease has thus been termed 'rice field fever' in humans.[379] Leptospirosis is most often reported in people with occupational activities that involve water exposure or interactions with animal reservoir hosts or in people participating in recreational activities involving water. Wildlife trapping for research purposes, production animal work (abattoir work, dairy farming, veterinarians working with livestock), water-intensive crop farming (bananas, pineapples, taro, rice, berries), military operations, fish farming, and sewer work increase the risk for leptospirosis.[413,414] Inadequate housing infrastructure and sanitation in resource-poor communities increase risk because of exposure to infected rodents and potentially also free-roaming dog populations (Fig. 14).

Leptospirosis in Bangladesh

The first seroprevalence of leptospirosis among jaundice febrile patients and healthy control humans (34/89) was reported in rural Bangladesh in 1994.[415] In 2000, the seroprevalence of leptospirosis in hospitalized febrile patients during a dengue outbreak was reported in 18.0% of dengue-negative febrile patients at two Dhaka hospitals by PCR.[416] Then several studies detected Leptospira species infection and seroprevalence in humans[417,418] and cattle[419] in Bangladesh (Table 35). Leptospirosis has been reported as an eminent cause of fever in urban and rural Bangladesh, causing hospitalization.[417,420] A study in two hospitals in Dhaka showed that 18.0% of the dengue-negative patients were positive for leptospirosis.[416] However, the case fatality rate was reported higher in leptospirosis (5.0%) than in dengue (1.2%) in Bangladesh.[416] Some other studies have shown that 2.0 to 44.0% of febrile outpatients had leptospirosis in Bangladesh.[417,420] A battery of serogroups such as Sarmin, Mini, Australis, Louisiana, Icterohaemorrhagiae, Copenhagen, Autumnalis, Shermani, Javanica, Djasiman, Pyrogenes, Sejroe, Cynopteri, Celledoni and Panama were found in Bangladesh.[417] However, the study suggested undifferentiated serovars may be circulating in Bangladesh, resulting in the underreporting leptospirosis burden.[417] There are innumerable water stagnant ponds and shallow water that facilitate the survival and transmission of Leptospira to both maintenance hosts as well as dead-end hosts like humans.

Pathogenic Leptospira has been reported in 13.1% (61/465) of trapped rodents, and three Leptospira species have been identified as *L. interrogans*, *L. borgpetersenii*, and *L. kirschneri* using qPCR.[407] Rodents act as a natural reservoir of Leptospira in their kidneys. They are capable of excreting Leptospira in and around food storage, and people can acquire Leptospira infection via direct or indirect contact with the urine of the infected rodents.

Table 35. Prevalence of Leptospirosis in humans and animals in Bangladesh

S/N	Districts/ Institutions/ Areas	Hosts	Health status of hosts	No. of samples tested	Test used with Leptospira positive results					Ref No.
					MCAT No. (%)	MAT No. (%)	IgM LAT No. (%)	IgM ELISA No. (%)	Nested PCR No. (%)	
01.	CGH	Male-47	FP²	001	-	-	-	01 (ICT)	-	401
02.	Comilla	Rodents	Wild	465	-	-	-	-	61 (13.1)	407
03.	FPD	Humans	FP & HP	089	34+ 22±	34 /53 (64.15)!	-	-	-	415
04.	DMC & HFRCH	Humans	DFS	359	-	-	-	18/61 (29.51)	63 (18.00)	416
05.	Dhaka	Humans	FP	584	-	49 (8.4)	-	62 (11.0)	-	417
06.	CMOSH	Male- 32	FP¹	001	-	-	-	01 (ICT)	-	418
07.	Chittagong	Dairy cows	-	110	-	-	-	52 (47.27)	-	419
08.	MMCH	Humans	FP	074	-	-	-	-	13 (17.6)!!	420
09.	MMCH	Humans	FP	182	-	-	-	89 (48.9)	65 (35.7)^{X}	421
10.	Barishal	Dairy cattle	-	240	-	-	-	00 (10.00)ICT	-	423
11.	4 Hospitals	Humans	FP	441	-	07 (01.6)!!	-	-	-	424
12.	MMCH	Humans	FP	186	-	-	71 (38.2)	69 (37.1)	78 (41.9)	425

MMCH = Mymensingh Medical College Hospital   DMC = Dhaka Medical College   HFRCH = Holy Family Red Crescent Hospital
CMOSH = Chattagram Maa-O-Shishu Hospital   CGH = Chattogram Government Hospital
4 Hospitals = Sir Salimullah Medical College & Mitford Hospital, Dhaka; Osmani Medical College Hospital, Sylhet; Rajshahi Medical College Hospital, Rajshahi and Government District Hospital, Feni.
N-CBD = North-Central Bangladesh   ICT = Immunochromatographic test   FP = Febrile patients   HP = Healthy persons

DFS = Dengue fever surveillance
[1]FP clinical case with high fever, icterus, hemorrhagic manifestation, and pulmonary-renal involvement
[2]FP clinical case of co-infection with leptospirosis and SARS-CoV-2
MCAT = Microcapsule agglutination test MAT = Microscopic agglutination test + = Positive ± Doubtful
[X]Leptospira 16S ribosomal RNA gene identified Y with *L. wolffii* (93.0%)
!Serovars copenhageni, australis, cynopteri and Icterohaemorrhagiae most prevalent !!*Leptospira interrogans* serovar Copenhageni and *L. wolffii* detected
!!Serovars L. interrogans serovar Bratislava (57.0%), others serovars Canicola, Mankarso & Tarrasovi (14.0) each

Seroprevalence of *L. interrogans serovar Hardjo* has been detected in 47.27% (52/110) commercial dairy cattle by ELISA, which confirms the presence of leptospirosis in Bangladesh's animal population.[419] Recently, the prevalence of Leptospira infection has been reported in 48.9% of blood samples from 182 febrile patients in north-central Bangladesh. Most of the detected Leptospira have been classified as *L. wolffii* (93.0%) based on phylogenetic analysis of 16S ribosomal RNA genes, while others were assigned to *L. borgpetersenii* and *L. meyeri*.[422]

More recently, pathological and molecular (PCR) detection of bacterial zoonotic diseases of slaughtered cattle in Bangladesh showed that out of 50 cattle tested, 5 (10.0%) were affected with leptospirosis caused by *L. interrogans serovar Hardjoprajitno* isolate from the mesenteric lymph nodes in cattle.[38]

In another serological study, an overall prevalence of Leptospira infection has been reported to be 10.0% (24/240) using a rapid test (Genomix Vovine Leptospira Ab Rapid Detection Kit) in dairy cattle in Barishal district. Laboratory diagnosis of leptospirosis is mainly based on different approaches including (a) Bacteriologic (isolation, animal inoculation), (b) Microscopic (dark field microscopy, immunohistochemical staining, immunofluorescence, silver impregnation techniques), (c) Immunologic (microscopic agglutination test (MAT), ELISA, indirect haemagglutination test, lepto dipstick, lepto lateral flow, lepto dri-dot) and (d) Molecular (PCR, in situ hybridization). Immunologic and molecular tests have been used to detect leptospirosis in Bangladesh; however, bacteriologic and microscopic methods could be explored to diagnose leptospirosis in Bangladesh. A review of the published reports on leptospirosis in Bangladesh shows that leptospirosis is an endemic zoonotic disease of humans and animals, more critical in dairy cattle, predominantly female crossbred cows. However, leptospirosis remains vastly underestimated, under-reported (neglected) in developing countries, including Bangladesh, primarily due to variability of clinical features, some similar clinical signs, and concurrent infections with other diseases like dengue, malaria and the limited or unavailability of appropriate laboratory diagnostic facilities and poor understanding of the disease status in both human and animal populations. In addition, this infection is maintained within the population through interactions between humans, animals, and the environment (Fig. 9).

Pathogenic Leptospira organisms are usually transmitted through direct or indirect contact. Direct transmission occurs when a susceptible human's mucous membrane encounters pathogen-contaminated urine, tissues, and any organs of infected animals, often by skin contact with contaminated water or soil. Indirect transmission occurs when humans encounter a contaminated environment, such as soil and water. The transmission of pathogenic Leptospira is mainly driven by rainfall, domestic and wildlife close contact, and farming in rural areas. In contrast, in urban settings, transmission among humans is primarily perpetuated by rodent infestation, poor hygiene, and overcrowding in developing countries. Natural disasters like heavy rainfall and flooding have also been associated with leptospirosis outbreaks among humans globally.[409]

Among animals, Leptospira transmission occurs either directly through a susceptible animal getting into contact with infected urine or body fluids of another infected animal or indirectly through contact with contaminated water, vegetation, or soil. Rodents are associated with massive outbreaks of leptospirosis in animal populations like humans in urban areas. In contrast, in rural areas, outbreaks are commonly linked to animal breeding practices and extreme seasonal factors such as heavy rains and flooding.

Bangladesh has a suitable environment and conditions for Leptospira survival and breeding, which includes a long monsoon, frequent flooding, stagnant water, high temperatures, high humidity, and regular animal-human contact for zoonotic transmission. However, a specialized reference laboratory for Leptospira research is lacking in Bangladesh. It is required to detect the status of Leptospira in humans, domestic animals, and rodent populations and their transmission for prevention and control.

Acute leptospirosis should be suspected based on the sudden onset of agalactia in adult milking cattle and sheep, icterus and hemoglobinuria, especially in young animals, acute renal failure, or dog jaundice. Chronic leptospirosis should be considered when abortion, stillbirth, birth of weak offspring may be premature and infertility, chronic renal failure or chronic active hepatitis in dogs, and cases of periodic ophthalmia in horses.

Leptospirosis is a classic 'one health' disease of humans and animals caused by pathogenic spirochetes of the genus Leptospira. A thorough knowledge of epidemiology and risk factors, including transmission mechanisms, animal reservoir hosts, environmental sources of the causative agent and climatic factors that influence transmission, and the impact of human occupation and recreational behavior patterns, are required for surveillance and prevention of the disease.

Leptospirosis is endemic in Bangladesh, and this review highlighted the need to perform surveillance studies on both the clinical and reservoir (carrier) status of leptospirosis in humans, animals, and the environment in different problematic areas for prevention strategies and improving diagnosis and early treatment. All these epitomize the necessity of coordinated leptospirosis surveillance in Bangladesh.

Antimicrobials are life-saving drugs, but increasing resistance levels compromise their effectiveness in nearly all bacterial infections in people, food animals, and poultry birds. Similar antimicrobials are used in both human and veterinary medicine. Highly resistant trends against several antibiotics have been identified, including cloxacillin, ampicillin, metronidazole, oxacillin, amoxicillin, tetracycline, cotrimoxazole, and penicillin. Heat map analysis showed that nine antimicrobial agents, metronidazole, amoxicillin, tetracycline, cotrimoxazole, cephradine, penicillin, ciprofloxacin, doxycycline, and nalidixic acid, reported to be associated with public health risk due to growing bacterial resistance.

Antimicrobial use in food animals selects for antimicrobial resistance in bacteria, which can spread to people. Reducing the use of antimicrobials- particularly those deemed to be critically important for human medicine- in food production for animals and poultry birds continues to be an essential step in preserving the benefits of these antimicrobials for people. Antimicrobials considered the highest priority among the critically important antimicrobials were quinolones, third and fourth-generation cephalosporins, macrolides and ketolides, and glycopeptides. The updated ranking allows stakeholders in the livestock sector and regulatory agencies to focus risk management efforts on drugs used in food animals and poultry birds that are the most important to human medicine.[426]

Multidrug resistance status in Bangladesh

Multidrug resistance (MDR) bacteria are frequently detected in humans and livestock, including poultry globally, and are associated with serious health concerns for humans and animals. MDR bacteria have been detected in livestock products, including meat, eggs, and other fresh products. Humans may be exposed to MDR bacteria from contaminated environments at healthcare facilities and farms, livestock and companion animals and birds, human food, and exposure to other individuals carrying MDR bacteria. MDR bacteria on animal source food may have originated in veterinary health care settings and antibiotic-added feed supplements as growth promoters in livestock production. Fresh produce may be contaminated by irrigation or wash water containing MDR bacteria. Food handlers, farmers, and livestock caretakers who carry MDR bacteria may contaminate livestock, fruits, and vegetables. Infection caused by MDR bacteria may increase morbidity and mortality and require the use of expensive drugs and prolonged hospitalization.[427]

Antimicrobials are usually used for prevention and treatment and serve as growth promoters in livestock. Similar antibiotics are indiscriminately used in both humans and livestock. These antibiotics can remain in the food chain of animal origin and help develop resistant bacteria that provide an enabling environment for transmitting resistance factors. Out of 179 isolates of *E. coli*, *Salmonella* spp., and *S. aureus* were tested, of which 89 isolates were recorded as MDR and 68 as XD.[428] Multidrug resistance (MDR) was reported in 93.2% of *E. coli*, 100% of *Salmonella* spp., and 97.2% of *Staphylococcus aureus* from cloacal swab samples. In contrast, sewage samples isolated 80.0% *E. coli* and 100% of *Salmonella* spp. and *S. aureus* showed MDR.[429]

Poultry eggs, meat, and feces have been reported to be highly contaminated with MDR bacteria.[295] Therefore, strict hygienic measures should be followed when handling and processing these poultry products, and vigorous legislation and monitoring systems would be required to produce quality poultry products for human consumption.

All potential sources of MDR bacteria should be considered, and strategies should be devised to reduce their presence in foods. Better coordination of surveillance programs and strategies for controlling the use of antibacterial drugs need to be implemented in human and veterinary medicine, agriculture, countries, and globally. Effective biosecurity measures, responsible antibiotic use, and strict regulations in poultry production can prevent antibiotic resistance.

Challenges of controlling zoonotic diseases

Human activities associated with accelerated globalization include population growth, intensified farming practices, trade-in domesticated and wild animals, and environmental degradation, including climate change, deforestation, and habitat destruction. Those activities have intensified the wild and domesticated animal-human interface, creating increased spillover risks.[13] Most outbreaks of zoonotic diseases have occurred in rural areas, and the detection and diagnosis of the disease have been considerably delayed due to a lack of appropriate diagnostic laboratory facilities on-site or in-country. The primary limitations in managing zoonotic diseases in medium and low-income countries, including Bangladesh, have been reported as:

① Organizational: (a) Absence of appropriate infrastructure, including cross-link within the health sector between the surveillance, clinical services, and laboratory services departments; (b) Weakness or absence of collaboration and cooperation between the public health, veterinary, and wildlife sectors, and (c) poor awareness, insufficient information on the burden, inadequate resources and skilled manpower, and lack of transparency in the countries.

② Diagnosis and detection: (a) Inadequate or absence of diagnostic capacities to detect zoonotic pathogens and weak disease surveillance system, (b) Difficulties in conducting field investigation in rural areas where most of the zoonotic disease outbreaks occur, (c) Difficulties in international transfer of samples for logistic and economic reasons, (d) Lack of integration and collaboration of human and veterinary sector for exchange of epidemiological and laboratory surveillance data, (e) Inadequate and non-professional community engagement in the zoonotic disease control program.

The clinical findings of some zoonotic diseases in humans are often like some diseases like COVID-19 or general flu, and physicians may not recognize the disease as a zoonosis, especially since medical practitioners may be less qualified to do so. The curriculum and syllabus of veterinary and medical education and training and practice systems differ, where veterinary education and practice are based on animals and birds. In contrast, medical education and practice are based on humans serving in separate organizations and departments. Medical physicians may treat human patients who are sick from a zoonotic disease. Still, they often do not know the source of the infection and how to prevent zoonotic diseases in animals, such as brucellosis, anthrax, etc. However, if these diseases are controlled in animals, humans would have no source of infection. Thus, veterinary medical personnel are the best at preventing, controlling, and eradicating zoonotic diseases. However, some reverse zoonoses and pathogens may persist in the environment. Therefore, a collaborative, multisectoral, and transdisciplinary approach to the 'One Health' concept would be required to control zoonotic diseases.

One Health is a collaborative, multisectoral, and transdisciplinary approach at the local, regional, national, and global levels to achieve optimal health outcomes by recognizing the interconnection between people, animals, plants, and their shared environment.[430] The 'One Health' issues include emerging, re-emerging, and endemic zoonotic diseases, neglected tropical diseases, vector-borne diseases, anti-microbial resistance, food safety and food security, environmental contamination, climate change, and other health threats shared by people, animals, and the environment (CDC 2024).[430] The World Health Organization (WHO), the World Organization for Animal Health (WOAH/OIE), the UN Food and Agriculture Organization (FAO), and the UN Environment Program (UNEP have identified six areas to focus on 'One Health' concept, which include: ① Laboratory services, ② Control of zoonotic diseases, ③ Neglected tropical diseases, ④ Antimicrobial resistance, ⑤ Food Safety and ⑥ Environmental health.[431]

A 'One Health' Secretariat was established in Bangladesh in 2016 and incorporates seven key components: ① Institutional governance and program management, ② Coordinated surveillance, ③ Coordinated outbreak investigation and response, ④ Transdisciplinary research, ⑤ Networking and partnerships, ⑥ Strategic communication and advocacy, and ⑦ Capacity building. Although Bangladesh has formulated a 'One Health' strategy, the implementation faces several challenges, including inadequate governance, insufficient institutional capacity, and a lack of funding and infrastructure.[432] The One Health concept calls for a collaborative, cross-sectoral, and transdisciplinary approach, integrating human, animal, and environmental health. Therefore, governments, international organizations, health professionals, and communities worldwide must embrace and incorporate the One Health approach to safeguard our planet's and its inhabitants' health.[433]

Strategic directions for control of zoonotic diseases

Three essential steps (strategy development, strategy implementation, and strategy evaluation) should be considered when developing a strategic plan for controlling and preventing zoonotic diseases. Crucial components of strategic planning include ① Determining the mission and vision, ② Analyzing the current condition of the health system, ③ Investing in the weaknesses, strengths, opportunities, and threats of zoonotic diseases, ④ Setting short-term and long-term goals, ⑤ Determining the required staff, equipment, and financial resources, and ⑥ Implementation of strategic planning.[434]

The most critical technical areas that will need to be considered will include the strategic approaches: (a) Building effective collaboration between veterinary and human health sectors, (b) Improving surveillance for early detection of disease threats in humans, (c) Strengthening laboratory diagnostic capacities for novel pathogens, (d) Improving case management and infection control, and (e) Integrating vector control management, (f) Reducing transmission through social and behavioral interventions, and (g) Developing epidemic preparedness and response capacities for emerging zoonotic diseases.

The sustainable program for the prevention and control of emerging and re-emerging zoonotic diseases will require consideration of some critical points, which include (a) Enhancing political commitment, national planning and coordination mechanisms, (b) Strengthening preparedness, surveillance, and response, (c) National capacity building and promoting research, (d) Enhancing regional and international cooperation and collaboration and (e) Health education, risk communication and social mobilization.

Despite this growth of scientific and political commitments to addressing the growing threat of zoonotic diseases, there is a persistent gap between pledges to advance integrated action, often under the One Health banner, and practical implementation. The result is a continued focus on identifying and responding to zoonotic disease events but not engaging in primary prevention to stop them from happening in the first place.[13]

CONCLUSIONS

This review shows that numerous studies have been conducted on the prevalence and antibiogram status of primary zoonotic bacterial infection indiscriminately in Bangladesh under the research degree thesis program, research project, and even personal interest research. Government programs on feedback monitoring and surveillance systems have not yet been initiated either in human or veterinary medicine in Bangladesh; moreover, developed diagnostic laboratories, with adequate laboratory facilities and capabilities with trained manpower, would be required to tackle the occurrence of zoonotic bacterial diseases and their antibacterial resistance. The premise for a strategic framework for the control of zoonotic infections should lie in the concept of the 'One Health' approach, which is a common coordination mechanism, joint planning, joint implementation, community participation, capacity building, and joint monitoring and evaluation framework between the animal health and human health sector. The 'One Health' approach also identifies five key areas where 'One Health' is likely to make a difference, which include (a) Sharing health resources between medical and veterinary sectors, (b) Controlling zoonotic diseases in animal reservoirs, (c) Early detection of and response to emerging diseases, (d) Prevention of epidemics and pandemics, and (e) Generating insights and adding value to health research and development.

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ETHICAL APPROVAL

Reviews do not need any ethical approvals or informed consent.

CONFLICTS OF INTEREST

The author declares no conflict of interest.

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