Public Health Significance of Major Bacterial Zoonotic Diseases: A One Health Perspective

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ABSTRACT

Bacterial zoonotic diseases lead to a serious threat to global public health, particularly in low- and middle-income countries where close human-animal interactions and insufficient surveillance systems increase the risk of transmission. This review describes the five-key bacterial zoonotic diseases like brucellosis, leptospirosis, tuberculosis, salmonellosis, and listeriosis. It is explaining mainly their causes, transmission pathways, clinical features, diagnostic methods, treatments, and control measures. These infections not only endanger human and animal health but also cause huge economic loss, especially in livestock-reliant communities. Disease emergence can be affected by factors such as population growth, human behavior, technological advances, industrial activities, economic development, global travel and trade and microbial evolution. Climate change and environmental destruction are also common factors to the spread and persistence of these infections. The review also shows the importance of the One Health approach, mostly about the collaboration between human and animal health sectors to manage and control these diseases. It deliberates the new diagnostic tools, the growing issue of antibiotic resistance, and gives some examples of successful control programs. Improvement of proper disease monitoring, public education, hygiene practices, and vaccination are essential to reduce the burden of these diseases. Continued research, coming up with new ideas and cooperation among veterinary and medical sectors can greatly reduce the impact of bacterial zoonotic diseases worldwide.

1. INTRODUCTION

The interaction between humans, animals, and the environment play a key role in transmission of infectious diseases. As Rudolf Virchow (1821–1902) stated, "Between animal and human medicine, there is no dividing line, nor should there be." He also introduced the term zoonoses in the late 19th century to describe diseases shared between humans and animals (Filho et al., 2022). The term "Zoonoses" is derived from the Greek word "Zoon", which means animal, and "nosos", which means illness (Rahman et al., 2020). Later, the Expert Committee on Zoonoses defined these as "diseases and infections that are naturally transmitted between vertebrate animals and man". More than 200 zoonotic diseases have been identified and they are responsible for both emerging and existing human illnesses. It is now shown that around 60% of human diseases are pathogenic in nature and 75% are emerging infectious diseases originating from animals (Filho et al., 2022). In this paper we are reviewing the literature connected to five bacterial zoonotic diseases and emphasize the need to monitor and control those diseases.

2. BURDEN OF ZOONOSES

Zoonotic infections can be transmitted in both directions either from animals to humans or from humans to animals. Animal-to-human transmission presents major clinical challenges while human-to-animal transmission can threaten wildlife conservation. Asia Pacific Emerging Diseases reports that around 60% of newly emerging human infections are of zoonotic origin. These diseases affect livestock farmers in low- and middle-income countries and it was estimated that zoonoses cause 2.4 billion illnesses and 2.7 million deaths annually. Not only the health impact but it also caused major economic loss and reduced productivity (Rahman et al., 2020). Zoonotic pathogens can come from domestic animals or wildlife. Hunters and forest visitors are at higher risk. A landmark analysis of human pathogens in 2001 showed that out of 1,415 species, 868 (61%) were zoonotic, which highlights their major role in global infectious disease patterns (Di Bari et al., 2023).

To assess the public health impact of these diseases, experts use measures like Health-Adjusted Life Years (HALYs). The Disability-Adjusted Life Year (DALY) is a way to measure the burden of disease. It combines years lost due to early death and years lived with illness or disability. This method is widely used by the World Health Organization (WHO). Bacterial zoonoses like brucellosis, leptospirosis, and bovine tuberculosis (bTB) cause a large part of the global disease burden, especially in

areas with poor healthcare (Torgerson et al*.,* 2018).

2.1 Bacterial Zoonoses

A list of bacterial zoonotic diseases with its causative agent, host and symptoms in humans are given in Table 1. Similarly, some of the bacterial foodborne zoonotic diseases are detailed in Table 2.

2.1.1 Brucellosis

Brucellosis is a globally prevalent zoonotic disease caused by Gram-negative, facultative intracellular bacteria belonging to the genus *Brucella.* It is a serious concern in public health and ranks among the most common occupational infections worldwide. The disease is also called Undulant fever or Bang's disease or Mediterranean fever (Dadar, 2023).

Table 1. Major bacterial zoonotic diseases (Rahman et al., 2020)

Disease	Causative Agents	Animals Affected	Main Symptoms in Human
Anthrax	*Bacillus anthracis*	Cattle, horses, sheep, pigs, dogs	Affects skin, lungs, or stomach
Tuberculosis	*Mycobacterium* species	Cattle, sheep, pigs, deer	Lung and bone issues
Brucellosis	*Brucella* species	Cattle, goats, pigs, dogs	Fever, joint and pain
Bubonic plague	*Yersinia pestis*	Rodents, rabbits	Fever, stomach pain, vomiting
Glanders	*Burkholderia mallei*	Horses, donkeys, mules	Fever, chest pain, muscle ache
Leprosy	*Mycobacterium leprae*	Monkeys, rodents, cats	Skin lesions
Leptospirosis	*Leptospira interrogans*	Wild/domestic animals	Fever, jaundice, red eyes
Tularemia	*Francisella tularensis*	Rabbits, rodents, sheep	Joint pain, diarrhea, cough
Arcobacter infection	*Arcobacter* species	Cattle, pigs, chickens	Fever, vomiting, stomach pain
Actinomycosis	*Actinomyces bovis*	Cattle, horses, pigs	Lumps, abscesses
Bordetellosis	*Bordetella bronchiseptica*	Cats, dogs	Cough, dyspnoea
Lyme disease	*Borrelia burgdorferi*	Cats, dogs, horses	Fever, skin rash, headache
Campylobacter enteritis	*Campylobacter jejuni/coli*	Cattle, poultry, pets	Diarrhea
Campylobacteriosis	*Campylobacter fetus*	Cattle, sheep, goats	Digestive upset
C. difficile infection	*Clostridioides difficile*	Cattle, horses, birds	Severe diarrhea
Corynebacterium infections	*C. pseudotuberculosis*	Cattle, dogs, cats	Diphtheria
Escherichia coli infection	*E. coli*	Cattle, sheep, pigs, poultry	Bloody diarrhea, kidney issues
Helicobacter infection	*Helicobacter pullorum/suis*	Poultry, pigs	Stomach ulcers
Vibriosis	*Vibrio parahaemolyticus*	Farm animals	Diarrhea
Salmonellosis	*Salmonella species*	Farm animals, pets	Diarrhea
Ehrlichiosis	*Ehrlichia species*	Sheep, cattle, dogs, cats	Fever, fatigue, rash
Pasteurellosis	*Pasteurella multocida*	Poultry, pigs, cattle	Fever, diarrhea, skin damage

Table 2. Major Foodborne zoonotic bacterial Diseases (Abebe et al., 2020)

Disease	Causative Agent	Transmission	Clinical Signs in Humans
Listeriosis	*Listeria monocytogenes*	Contaminated milk, cheese, ready-to-eat (RTE) foods, vegetables	Fever, diarrhoea, septicaemia, meningitis, abortion, stillbirth
Salmonellosis	*Salmonella enterica*	Contaminated eggs, poultry, raw milk, meat	Nausea, vomiting, abdominal cramps, diarrhoea, fever
Campylobacteriosis	*Campylobacter jejuni*	Undercooked poultry, raw milk, contaminated water	Watery or bloody diarrhoea, fever, abdominal pain, malaise
Brucellosis	*Brucella spp.*	Raw milk, unpasteurized dairy products, meat	Undulant fever, joint pain, malaise, weight loss, reproductive failure in pregnant women

Table 3. Etiology (Mambote, 2024; Addis, 2015)

Brucella Species	Primary Animal Hosts	Transmission to Humans
Brucella melitensis	Goats and sheep	Ingestion of unpasteurized dairy products, direct contact with infected animals or aborted materials
Brucella abortus	Cattle	Contact with infected placentas, aborted foetuses, raw milk consumption
Brucella suis	Pigs (domestic and feral)	Handling infected pigs, consumption of undercooked pork, occupational exposure
Brucella canis	Dogs	Contact with infected reproductive discharges
Brucella inopinata	Humans	Direct human infection possible

The disease was named after David Bruce, who discovered the bacteria *Brucella melitensis* in 1887. Bernhard Bang identified *Brucella abortus*, which causes abortion in cattle, and it is called 'Bang's disease'. Later Zammit showed that unpasteurized goat milk can transmit the disease and Alice Evans confirmed that raw cow's milk could also be a source. The World Health Organization (WHO) reported that there are 5,00,000 new human brucellosis cases every year (Sayer, 2016). The different species of *Brucella* are described in Table 3.

2.1.1.1 Zoonotic and occupational health hazard

Brucellosis causes a major health issue, particularly in developing countries, where proper biosecurity measures are not followed and where the improper disease control strategies in livestock are in force and where limited public health infrastructures are in place. The disease impacts not only human and animal health but also causes economic losses due to reduced livestock productivity, and trade restrictions. This is the reason brucellosis is considered as an occupational disease for individuals who work closely with animals or animal products. These mainly include veterinarians, livestock handlers, farmers, slaughterhouse workers, and laboratory personnel (Addis, 2015).

Brucellosis is a zoonotic disease often seen in rural areas and low-income groups. The World Organization for Animal Health (WOAH) estimated that there are 1.6 to 2.1 million new human cases of brucellosis occurring each year and most of the cases are reported from Asia (around 1.2–1.6 million) and Africa (approximately 0.5 million). Disease is endemic in Latin America and parts of Europe and the Mediterranean countries. High incidence is reported in Iran (80,000 cases/year). In Jordan, human cases were around 31.1%, California showed 492 cases from 1993–2017, Bosnia and Herzegovina showed 263 cases from 2008–2018 and China 3 per 1,00,000 population annually. The EU reports a lower rate (0.09 per 1,00,000 population). Although some countries like the USA, Canada, Australia, and Northern Europe have eliminated brucellosis in livestock, but global trade, travel, and the use of unpasteurized

dairy products can increase the risk of the disease transmission (Laine et al., 2023; Qureshi et al., 2023).

2.1.1.2 Brucellosis cases in India

Brucellosis, first reported in India in 1942. It is now endemic across the country. It is mainly caused by *Brucella melitensis* and *B. abortus. B. melitensis* is more common in humans. Human brucellosis is mostly present in rural areas where close human-animal contact and poor hygiene are observed. In India, the disease is more prevalent in Punjab, Madhya Pradesh, Assam, and Uttarakhand. Punjab has the highest human brucellosis rate (26.6%), followed by Maharashtra (19.8%) and Andhra Pradesh (11.5%). Children, young adults and women in Karnataka are commonly affected. Often the disease is undetected due to lack of awareness, limited diagnostics and poor surveillance (Upadhyay et al*.,* 2019).

2.1.1.3 Clinical signs

Brucellosis causes fever, fatigue, headache, chills, muscle, and joint pain in humans. Joint pain, backache, fatigue, and night sweats are frequently reported. It can also cause orchitis, abortions and other reproductive disorders, renal failure, endocarditis, splenic abscess, spondylitis, arthritis, meningitis (Priyantha, 2021).

2.1.1.4 Diagnosis

History, clinical signs and laboratory examination are required for confirmatory diagnosis. Gram staining, modified Ziehl-Neelsen staining, oxidase and urease activity tests, and dye sensitivity assays also help. Molecular detection using PCR gives faster results. Earlier serological tests like the Rose Bengal Plate Test (RBPT), Serum Agglutination Test (SAT), Complement Fixation Test (CFT), and Enzyme Linked Immunosorbent Assay (ELISA) were widely used. Among laboratory tests ELISA is more sensitive and specific. Rapid tests like lateral flow and latex agglutination tests are also effective in diagnosing cases of brucellosis (Kiros et al., 2016).

2.1.1.5 Treatment

Treatment for brucellosis includes doxycycline (100 mg BID) combined with rifampicin (600–900 mg daily) for 6 weeks. Doxycycline can be combined with streptomycin (1 g daily for 2–3 weeks) or gentamicin (5 mg/kg for 7 days). In mild cases, a two-week course of tetracycline (500 mg every 12 hours) has also shown good results (Berhanu and Pal, 2020).

2.1.1.6 Prevention and control strategies

The One Health approach leads to coordinated efforts among human, animal, and environmental health sectors to control zoonotic diseases effectively. As *Brucella* infects both domestic and wild animals and can be transmitted to humans, collaborative approach is required from various fields such as veterinary, medical, and environmental sectors for the effective control. Meat should be thoroughly cooked; milk must be pasteurized and heated properly to reduce contamination. Farmers, lab workers, and others are at high risk and should use protective clothes and equipment while handling animals or their tissues. Regular monitoring of livestock, creation of public awareness and animal vaccination programs are essential for controlling the disease. Although vaccines are available for animals, no licensed vaccine is there for human brucellosis control (Godfroid, 2017; Pal, 2018).

2.1.2 Leptospirosis

Leptospirosis is a globally significant zoonotic disease caused by Gram-negative spiral-shaped *Leptospira* spp. These organisms affect both humans and animals, leading to a major public health concern, particularly in tropical and subtropical regions (Pinto et al., 2022; Md-Lasim et al., 2021). *Leptospira* was first noted in 1812 by D.J. Larrey among Napoleon's soldiers in Cairo. However, in 1886, Adolph Weil described the disease from kidney tissue, and the disease was known as 'Weil's disease'. After that in 1907, Arthur Stimson identified and named the bacteria as *Spirochaeta interrogans* which are isolated from the kidneys of yellow fever patients. In 1940, *Leptospira* was confirmed as the causative agent of 'cattle yellow fever'. In the 1980s, the disease was recognized as a major veterinary issue affecting dogs, cattle, pigs, horses, and possibly sheep. Later the disease was named as rice field jaundice in China, autumn fever in Japan, cane-cutter's disease, swine-herd's disease, and mud fever in Europe. Disease is known by different names *viz*. canicola fever, harvest fever and Fort Bragg fever in various parts of the world (Karpagam and Ganesh, 2020). Different species of *Leptospira* are given in Table 4.

Table 4. Etiology (Md-Lasim et al., 2021)

Causative Agents	Animal Reservoirs	Transmission to Humans
Leptospira interrogans	Rodents, dogs, cattle, pigs	Direct contact or contaminated
Leptospira borgpetersenii	Rodents, livestock	soil or urine
Leptospira kirschneri	Wildlife	
Leptospira noguchii	Domestic and wild animals	
Leptospira santarosai	Livestock, rodents	
Leptospira weilii	Rodents, livestock	

The genus *Leptospira* includes pathogenic, intermediate, and non-pathogenic strains. Pathogenic species like *Leptospira interrogans* are mostly responsible for human disease. It consists of more than 300 serovars. The bacteria are slender, helical shaped and motile due to internal flagella. It can survive in moist environments for longer periods (Pal et al., 2021).

2.1.2.1 Public health impact

Leptospirosis is a neglected tropical disease recognized by the Centres for Disease Control and Prevention (CDC), USA. It causes nearly 1 million human infections and approximately 60,000 deaths each year, with tropical and low-income areas. According to the WHO, the disease affects about 5 to 14 people per 1,00,000 population each year. About 30% of cases may result in long-term health problems. Due to poor surveillance and difficulties in diagnosis disease incidence remains less clear (Bradley and Lockaby, 2023).

2.1.2.2 Leptospirosis cases in India

Leptospirosis in India is reported mostly from the states of Kerala, Gujarat, Maharashtra, Tamil Nadu, and Karnataka, which are prone to heavy rainfall and flooding. In the late 1980s, seasonal outbreaks with severe coughing with blood were reported in the Andaman Islands. This illness, first called Andaman Haemorrhagic fever, was later (1995) confirmed as Leptospirosis. It was the first known case in India where leptospirosis led to serious lung bleeding. Since 1994 it has been endemic in Gujarat. Maharashtra has reported leptospirosis regularly since 1998, with a major outbreak in 2005 resulting in 2,355 cases and 167 deaths. In Kerala also, cases were found since 1987, especially in Kolenchery. In Tamil Nadu, cases have been reported in Chennai since 1980. Puducherry, Odisha, Uttar Pradesh, Hyderabad, West Bengal and Delhi also reported a high fatality rate with renal and liver disturbances (Routray et al., 2018; Antima and Banerjee, 2023).

2.1.2.3 Clinical manifestations

The incubation period is usually 2 to 30 days. Most infections may show no symptoms or mild symptoms with fever, chills, headache, muscle pain (especially in calves), nausea, and conjunctival redness. In human, Leptospirosis can cause jaundice and renal failure, pulmonary hemorrhage, meningitis, myocarditis, and acute respiratory distress in severe cases (Chacko et al., 2021).

2.1.2.4 Diagnosis

Samples such as blood, urine, cerebrospinal fluid (CSF), infected tissues, and other body fluids can be used to detect *Leptospira*. The bacteria are usually present in the blood during the early stage of infection (1–7 days), which is the most effective time for treatment. Dark-field microscopy is used to detect *Leptospira* in blood or CSF during early phase and it is having a sensitivity of around 95.5% than ELISA (64.7%). Ellinghausen–McCullough–Johnson–Harris (EMJH) media is commonly used for growing *Leptospira*. The microscopic agglutination test (MAT) is considered as the gold standard for diagnosing leptospirosis, while ELISA is also commonly used for detecting antibodies, especially IgM and IgG (Karpagam and Ganesh, 2020).

2.1.2.5 Treatment

Severe leptospirosis is treated with antibiotics, and corticosteroids, even in case of complications like acute respiratory distress syndrome (ARDS). Recently scientists have created a number of novel natural and synthetic chemicals against *leptospira* spp. Although natural plant extracts including *Andrographis paniculata*, Piper betel, and *Eclipta alba* have shown potent anti-leptospiral qualities, synthetic medications include quinoxaline derivatives, Oxime Schiff bases, and azithromycin are also highly effective (Petakh et al., 2024).

Table 5. Etiology (Couto et al., 2019; Kock et al., 2021)

Causative Agents	Animal Reservoir(s)	Human Infection	Geographical area
Mycobacterium bovis	Cattle, buffalo, deer, badgers, wild boar, goats, camels, *etc.*	Ingestion of unpasteurized milk, inhalation, contact	Africa, Asia, Americas, Europe
Mycobacterium orygis	Indian cattle (*Bos indicus*), primates, rhinos	Ingestion/contact with infected animals or environment	South Asia (India, Bangladesh), isolated globally
Mycobacterium caprae	Goats, sheep	Inhalation or ingestion	Mostly Europe
Mycobacterium microti	Rodents (voles), cats, wild animals	Likely environmental or foodborne	UK, Europe
Mycobacterium pinnipedii	Seals, sea lions	Close contact, aerosols from marine mammals	Coastal areas (zoos, marine parks)
Mycobacterium canettii	Environmental causes	Unknown	East Africa (Djibouti, Somalia)
Mycobacterium africanum	Humans; animal reservoir unclear	Inhalation (like *M. tuberculosis*)	West Africa
Mycobacterium tuberculosis	Humans (reverse zoonosis to animals)	Human-to-animal contact; animals as secondary hosts	Global, especially Africa and India

2.1.2.6 Prevention and control

Effective control needs early detection in both humans and animals through joint surveillance. It also requires coordinated teamwork with veterinarians, doctors, environmental experts, and health officials in programmes such as animal vaccination, rodent control, and improved sanitation practices. Animal vaccination especially of dogs and livestock is critical in reducing contamination. Routine vaccination programs in countries like New Zealand have successfully lowered human cases. Although in humans, vaccines are limited but have been used in countries like Japan and China. Effective rodent control, sanitation, use of protective clothing, creation of public awareness, and promoting hygiene help to reduce disease cases (Goarant et al., 2019; Hernández-Rodríguez and Trujillo-Rojas, 2022).

2.1.3 Tuberculosis

Zoonotic tuberculosis (zTB) is caused by *M. tuberculosis, M. africanum, M. bovis, M. caprae* and *M. orygis.* These infections mainly result from direct contact with infected animals or through consumption of contaminated animal products. Even though it is a public health concern, zTB is often missed and not well recorded, especially in areas with poor disease monitoring. However, growing veterinary, medical, and agricultural research efforts are improving understanding and shaping global strategies for better control (Kock et al., 2021).

Tuberculosis (TB) is a contagious disease caused by *Mycobacterium tuberculosis* that causes a serious health problem. It was thought that genus *Mycobacterium* first originated more than 150 million years ago. During the middle ages, a form of TB that affected cervical lymph nodes was known as scrofula. In England and France, it was known as king's evil, as people believed that royal touch could cure the disease. In 1720, Benjamin Marten was the first to propose that TB could be caused by an infectious agent and on March 24, 1882, Robert Koch isolated the bacteria. The first successful treatment for TB was the use of sanatoriums. On March 24, 1882, Robert Koch discovered the bacteria responsible for TB in Berlin. Diagnostic tests such as tuberculin skin test were developed by Pirquet and Mantoux, the BCG vaccine by Albert Calmette and Camille Guerin, and anti-TB drugs like streptomycin was developed by Selman Waksman and others (Loddenkemper and Murray, 2021). zTB has historically been linked to extra pulmonary TB and was mostly transmitted through unpasteurized milk. Between 1901 and 1932 in England and Wales, most human infections caused by *M. bovis* appeared as swollen cervical lymph nodes and meningitis. In 2016, about 1,47,000 new zTB cases were reported worldwide, with most of them found in Africa and Southeast Asia (Couto et al., 2019).

The various species of *Mycobacterium* are listed in Table 5.

2.1.3.1 Global burden and economic impact

TB is the most common bacterial infectious disease, affecting about 25% of the world's population. Around 1,40,000 TB cases (1.4%) each year are due to zTB, leading to 11,400 deaths (Couto et al., 2019). The largest number of zTB cases have been reported in Africa and South-East Asia of upto 44% of all TB cases. *Mycobacterium orygis* has become one of the major causes of zTB in India which is transmitted from cattle. In Europe, TB rates are very low, less than 0.01% cases are zoonotic and mostly *M. bovis* and *M. caprae* are the causative agents (Kock et al., 2021). 12% of the 9,689 bovine TB cases lead to human cases reported in Kenya in 2016, with 70% of those cases occurring in livestock keepers. In Michigan, human TB cases have been linked with deer hunting where *M. bovis* is endemic. In New Zealand, feral ferrets are also considered as TB vectors for cattle. *M. avium* causes Avian TB, which mainly affects birds. It was also found that *M. avium* subspecies can potentiate human health issues, including inflammatory bowel diseases, asthma, type 1 diabetes, rheumatoid arthritis, celiac disease, and potentially Crohn's disease (Recht et al., 2020).

According to the WHO Global Tuberculosis Report (2020), 10 million people developed TB in 2019, leading to 1.2 million deaths, in addition to 2,08,000 deaths from TB-HIV co-infections. The COVID-19 pandemic has worsened the situation and there were 6.3 million TB cases and a 20% in deaths over the next five years (WHO, 2020). Of the 179 countries and territories that reported on bovine tuberculosis (bTB) between 2015 and 2016, more than half confirmed the presence of the disease in wild or domestic animals.

2.1.3.2 Tuberculosis cases in India

India has the highest number of human TB cases and the largest cattle population in the world. In 2018-2019, out of 940 TB samples isolated from Vellore, Tamilnadu; 0.7% were *M. orygis* and 0.5% were *M. bovis* BCG (vaccine strain). *M. orygis,* found in Southeast Asia due to multiple risk factors including high human-animal contact and unpasteurized milk consumption. An estimated population of 21.8 million cattle in India are infected and most of these are from eastern India (Duffy et al., 2020; Kock et al., 2021).

2.1.3.3 Diagnosis

Diagnosis can be based on clinical signs, post mortem lesions. Microscopical lesions may show some tubercle-like granuloma formation. Ziehl–Neelsen staining is a quick method to detect these acid-fast bacteria. Intradermal skin test is used in animals to see the skin thickness after Tuberculin injection. Cultural method is the gold standard for diagnosis of TB, but PCR is faster and highly sensitive. Antibody-based tests like ELISA and rapid tests like Dual Path Platform VetTB (DPP VetTB) are simple, cost-effective, and suitable (Thomas et al., 2021).

2.1.3.4 Treatment

Zoonotic tuberculosis in humans is treated with common anti-TB drugs such as isoniazid, streptomycin, and para-aminosalicylic acid. If the treatment is not followed properly, there is a risk of developing multidrug-resistant (MDR) bacteria. This MDR-TB can be treated with drugs like aminoglycosides and fluoroquinolones. Treatment usually involves at least four effective drugs and continues for at least 18 months after the infection is under control (Jemal, 2016).

2.1.3.5 Control

The most effective strategy to reduce human exposure to *M. bovis* is pasteurization of milk, which prevents gastrointestinal infections more reliably than slaughterhouse inspections or animal tuberculin testing. While meat inspections help to identify visibly infected carcasses, tuberculin skin testing identifies infected livestock for culling. However, such interventions are limited in some countries due to economic constraints, lack of infrastructure, or cultural resistance to culling (WHO, 2020).

International organizations such as WHO, FAO, and OIE state that control of zoonoses is essential in each country through coordinated efforts. The United Nations also highlights that collaborative approaches are essential to achieve global health by 2030 *i.e.,* Goal 3, especially to end the TB epidemic. The WHO's End TB Strategy (2016–2035) focuses on effective care, diagnosis and treatment of TB patients. Therefore, zTB cases should be included in these efforts to enhance better control and prevention (Luciano and Roess, 2020).

Table 6. Etiology (Teklemariam et al., 2023; Pal et al., 2024)

Causative Agents	Human Clinical Signs	Source of Transmission
S. Typhimurium	Gastroenteritis, fever, abdominal distress, diarrhoea, vomiting	Contaminated poultry, eggs, beef, and pork. Flies, rodents, cockroaches also help in transmission
S. Enteritidis	Similar to *S.* Typhimurium Mild to moderate gastroenteritis	Eggs and poultry meat Found in wild birds and rodents
S. Dublin	Invasive disease: septicemia, bacteremia, respiratory symptoms More common in immunocompromised patients	From cattle and unpasteurized dairy products
S. Choleraesuis	Bacteremia without enteritis Extraintestinal infections: meningitis, UTIs, pneumonia	Pigs and pork products Faecal contamination

2.1.3.6 Prevention

New vaccines are giving hope for better TB control. M72/AS01E subunit vaccine has been effective in lowering the risk of active TB in people with latent TB infection. Traditionally, bTB has been controlled by testing and culling infected animals. But this is not always practical where killing of animals is not acceptable. Oral BCG vaccines have shown protection in both farm animals and wildlife such as badgers, wild boars, deer, and possums making a possible strategy to reduce zTB (Kock et al., 2021).

2.1.4 Salmonellosis

Salmonella is considered as one of the most common causes of foodborne illnesses, mainly associated with poor sanitation and limited access to clean water. *Salmonella enterica* and *Salmonella bongori* are zoonotic in nature (Adem et al., 2022). The genus *Salmonella* comprises around 2,600 serovars. The serovars are classified as typhoidal and non-typhoidal. Typhoidal serovars are *S.* Typhi and *S.* Paratyphi spread from human contact through faecal-oral route, while non-typhoidal serovars (NTS) are zoonotic and usually come from animals or contaminated food (Galán-Relaño et al., 2023). *Salmonella* is a rod-shaped, gram-negative bacterium under Enterobacteriaceae family. These bacteria are facultative anaerobes. They are motile because of their flagella and use organic compounds for energy production through oxidation and reduction reactions (Adem et al., 2022).

Salmonellosis has existed for centuries. The *Salmonella* bacteria are named after Daniel E. Salmon, an American veterinarian. Theobald Smith first isolated the bacteria from a pig with hog cholera in 1885, naming it *Salmonella* Choleraesuis. The first study of *Salmonella* in humans was by Karl Eberth, who linked it to typhoid fever. His findings were later confirmed by Georg Gaffky, and the bacteria were once called the Gaffky-Eberth bacillus, now known as *S.* Typhi (Kuria, 2023). Different species of *Salmonella* are given in Table 6.

2.1.4.1 Public health and economic impact

Non-Typhoidal Salmonellosis (NTS) is a major global concern in veterinary public health because of its zoonotic nature and worldwide occurrence. Poultry, cattle, rodents and reptiles are the primary reservoirs. Transmission to humans occurs through ingestion of contaminated food or water, and through direct or indirect contact with infected animals or their products. It has been estimated that 93.8 million human cases occur each year, mostly self-limiting gastroenteritis. It has also been seen that Salmonellosis causes 1,55,000 deaths each year. Most infections are arising from contaminated food, while about 10 % from direct contact with infected animals (Adem et al., 2022; Teklemariam et al., 2023). The U.S. alone recorded around 1.4 to 2 million cases annually with economic losses of about $400 million. Children under one year of age are mostly affected. In 1994, a major outbreak occurred in the U.S. where 2,24,000 people were infected from contaminated ice cream. *Salmonella* is present in the environment, particularly in farm waste, sewage, and fecal contaminated materials. It is particularly common in regions of livestock farming, especially poultry and swine (Pal et al., 2015). However, NTS can cause severe systemic infections, especially in children

and immunocompromised individuals, such as those with HIV. In sub-Saharan Africa, NTS is endemic and causes around 4,100 deaths yearly and around 85.8% of NTS deaths reported from this region. In the Middle East and North Africa, about 6.6% of cases involve *Salmonella*, with higher rates in Morocco, Tunisia, and Sudan. In Iran 94% of *Salmonella* have been isolated from children under five years, where 99% identified as NTS. In Brazil, 30% of the NTS have been found to be resistant to aminoglycosides. Resistance to antibiotics like ciprofloxacin and ceftriaxone has become a serious issue. In Europe, 53,674 cases were reported in 2020, mostly due to *Salmonella* Enteritidis. The main sources of infection were eggs, pork, and bakery products and the case fatality rate was 0.17%. From a veterinary public health view, controlling NTS needs a One Health approach with better farm biosecurity measures, safe food practices, antibiotic resistance monitoring, and creating public awareness. From 2001 to 2005, *Salmonella enterica* was the leading cause of NTS infections worldwide, responsible for 12% of clinical cases, followed by *S.* Typhimurium at 4%. *S. enterica* was frequently detected in clinical isolates from Latin America (31%), Asia (38%), and Europe (87%). In Africa, *S.* enterica and *S.* Typhimurium was found in 26% and 25% of cases, respectively. The economic impact of salmonellosis was high, with estimated annual costs reaching $2.71 billion for 1.4 million cases in 2010. In the United States, yearly expenses including healthcare, lost productivity, and sick leave were estimated between $1.3 and $4.0 billion (Ayuti et al., 2024).

2.1.4.2 Salmonellosis cases in India

In India also NTS is becoming a serious public health problem. It is common in poultry and some strains are resistant to many antibiotics. A study from Northern India found that 9.43% of samples from chicken meat were contaminated with NTS. The highest contamination found in chicken meat (14.89%), followed by faeces and environmental samples. The most common type found was *Salmonella* Kentucky (74.29%), followed by *S.* Virchow and *S.* Typhimurium (Sharma et al., 2019). In India, NTS has become emerging zoonotic pathogens which are transmitted through contaminated food of animal origin like meat, eggs, milk, seafood and direct contact with infected animals or their environments. The most common serotype found is *Salmonella* Typhimurium, which causes gastroenteritis and serious infections like septicemia and meningitis

in newborns. *Salmonella* Senftenberg has been linked to septicemia, lung abscesses, and hospital outbreaks. There are some cases of Salmonellosis outbreak among tea garden workers in Assam as well as in Delhi and neonatal meningitis outbreaks in Mumbai and Chandigarh which were mainly caused by *Salmonella* Weltevreden, *Salmonella* Worthington respectively. *Salmonella* Enteritidis has been connected to septic arthritis and meningitis. Other serotypes like *S.* Dublin*, S.* Virchow, and rare ones like *S.* Anatum*, S.* Bareilly*, S.* Havana, and *S.* Kentucky have also been linked to serious infections and hospital outbreaks, especially in newborns and people with weak immune systems. It has also been found that 99 different serotypes of *Salmonella* are identified from over 8,000 samples. Many of these strains were found in both humans and animals. States with specific reports include Assam, Delhi, Mumbai (Maharashtra), and Chandigarh. So better hygiene, controlled use of antibiotics in animals, and regular monitoring are essential to reduce the public health threat of zoonotic *Salmonella* in India (Antony, 2022).

2.1.4.3 Clinical manifestations

Salmonellosis in cattle causes fever, anorexia, diarrhea, abortion and drop in milk yield. Calves may develop pneumonia or CNS signs. In pigs, *S.* Choleraesuis causes fever, depression, and cyanosis while *S.* Typhimurium causes yellow diarrhea. Dogs and cats may show fever, vomition, diarrhea, and in severe cases, pneumonia or abortion. Rodents and wild birds harbour the pathogen and help in transmission of the disease (Kuria, 2023). In humans, *Salmonella* infections usually develop within 6 hours to a few days (Pal et al.*,* 2024). They can cause mild to severe stomach illness and in severe cases it can lead to septicemia. It is more serious or even fatal in young children, the elderly or immunocompromised individuals which makes it a major cause of gastrointestinal and systemic infections worldwide (Adem et al.*,* 2022). Clinical signs may include diarrhea, fever, nausea, vomiting, stomach cramps, headache, cough, and bradycardia (Abd El-Ghany, 2020).

2.1.4.4 Diagnosis

In humans, *Salmonella* organism is usually diagnosed from faecal samples. In case of systemic infection, blood or bone marrow

samples can also be tested (Pal et al., 2024). Serological tests including the Widal test is used to detect specific antibodies against *Salmonella* pathogens. It shows 70–80% sensitivity and 90% specificity. ELISA is more specific and sensitive test. Advanced methods like PCR and next-generation sequencing (NGS) are also used to detect *Salmonella* (Nazir et al., 2025).

2.1.4.5 Treatment

Treatment of NTS includes antibiotics like ampicillin, amoxicillin, gentamicin, trimethoprim, sulfamethoxazole, fluoroquinolones or third-generation cephalosporins (such as cefotaxime and ceftriaxone) and other antimicrobials (Pal et al., 2024).

2.1.4.6 Prevention and control of salmonellosis

A One Health approach to control zoonotic salmonellosis involves collaboration between human, animal, and environmental health sectors. Early outbreak detection is required for proper surveillance of human, animal, and food data and to find out the source and control of the disease. Improving farm hygiene, food safety, animal vaccination, and proper cleanliness are necessary. Infected animals should be separated and milk should be thoroughly heat treated. Children, elders and immunocompromised people should be careful while handling the animals. Public awareness and training programs are necessary to reduce the disease impact and to prevent future outbreaks (Ghai et al., 2022; Pal et al., 2024).

2.1.5 Listeriosis

Listeriosis is a foodborne infectious disease affecting both humans and animals. It affects mostly elders, pregnant women, and newborns. The disease was first identified in 1920 in rodents and other small animals. In 1926, Murraz described the disease in rabbits characterized by peripheral monocytosis and named the causative organism as *Bacterium monocytogenes*.

Monocytosis is not typically seen in human Listeriosis. The bacterium was later renamed as *Listeria monocytogenes.* Even though *L. monocytogenes* is the primary cause of human listeriosis, infections caused by *L. seeligeri* and *L. ivanovii* have occasionally been reported. In 1934, Jones and Little reported the first case of listeriosis in cattle, associated with meningoencephalitis. Listeriosis is considered a serious foodborne illness due to its high mortality rate (Gezali et al., 2016). The different species of *Listeria* are given in Table 7.

2.1.5.1 Epidemiology

Listeriosis cases have been documented in both developed and developing countries. Between 1980 and 2022, many Listeriosis outbreaks occurred especially in the United States, Canada, and several European countries. These outbreaks were mostly linked to contaminated foods like ready-to-eat meats, cheese (both unpasteurized and pasteurized), deli meats, and dairy products. Some major outbreaks like the 1985 California outbreak linked to Mexican-style cheese, 2002 cases in the USA with 54 infections and 8 deaths from turkey meat, and a large 2011 outbreak caused by cantaloupe that led to 147 cases and 4 deaths. Other notable cases also occurred mainly due to ingestion of cheese in Canada, pork roast in Spain, and ice cream in the USA. The occurrence of human listeriosis ranges from 0.1 to 11.3 cases per million people each year (Koopmans et al., 2023). In the United States, a major outbreak in 2011 resulted in 147 reported cases and 33 deaths. The mortality rate is significantly high in the U.S., England, and Wales, especially among new-borns, elders, and immunocompromised people with a fatality rate up to 40%. In India, the disease is less documented. Occupational exposure and poor food hygiene also contribute to the spread of the disease (Dhama et al., 2015). *Listeria* outbreak in various states of India is given in Table 8.

Table 7. Etiology (Dhama et al., 2015)

Species	Primary Hosts	Source of Transmission to Human
Listeria monocytogenes	Ruminants (sheep, goats, cattle), poultry, pigs	Raw milk, meat, ready-to-eat (RTE) foods, seafood
Listeria ivanovii	Mainly ruminants (sheep, goats, cattle)	

Table 8. Listeriosis cases in India (Banka and Ghosh, 2023)

Year	Places	Prevalence (%)	Source of contamination
2014	Uttar Pradesh	1.3 – 6	Raw chicken, fish, beef, curd
2014	Uttar Pradesh	5.1	Milk
2015	Tamil Nadu	4.9	Milk and its products
2015	Gujarat	9.0	Animal-based foods
2017	Rajasthan	1.1	Raw milk samples
2017	Kerala	0.7 – 3.7	Samples from slaughterhouses
2019	Punjab	1.8 – 6.6	Mutton
2019	Kerala	2.7	Seafood

2.1.5.2 Clinical signs

Clinical signs of Listeriosis include fever, headache, nausea, vomiting, stiff neck, tremors, ataxia, seizures, and altered consciousness. In severe cases, meningitis, encephalitis or septicaemia, endocarditis, brain abscesses, pneumonia, arthritis can occur. It can also lead to abortion, miscarriage, stillbirth, or neonatal death. Infected foetuses may show abscesses and granulomatous lesions in liver, lungs, and spleen. Additionally, conjunctivitis has been documented in poultry workers (Dhama et al., 2015). Neonatal Listeriosis occurs at a rate of 1.3 to 25 per 1,00,000 live births and can lead to severe meningitis or pneumonia also serious CNS disturbances in about 13% to 18% of cases (Koopmans et al., 2023). Incubation period of Listeriosis is 1-70 days with an average of 8 days. But in pregnant women, the incubation can be longer between 17 and 67 days (Chlebicz and Śliżewska, 2018).

2.1.5.3 Treatment

Listeriosis is treated with antibiotics like ampicillin or amoxicillin or can be combined with gentamicin. Cotrimoxazole or Meropenem, Rifampin may be used, though cotrimoxazole should be avoided in early and late pregnancy due to foetal risks. Cephalosporins, clindamycin, and chloramphenicol are ineffective against *Listeria*. In pregnant women, early treatment can prevent fetal infection. Newborns are treated with ampicillin or penicillin, sometimes with gentamicin, for 2–3 weeks. Linezolid is used in cases of neurolisteriosis (Allerberger and Huhulescu, 2015; Pagliano et al., 2017).

2.1.5.4 Diagnosis

Diagnosis of Listeriosis can be done by using culture methods and molecular techniques.

Selective media such as University of Vermont Medium (UVM), Fraser broth, Oxford agar, Polymyxin Acriflavine Lithium Chloride Ceftazidime Esculin Mannitol Agar (PALCAM agar) are used. The *Listeria* pathogens are confirmed using rapid detection techniques including PCR and RT-PCR. Particularly in clinical diagnostics and food safety, ELISA, immunofluorescence, and biosensor-based detection are helpful methods that provide faster and more sensitive results (Munir et al., 2023).

2.1.5.5 Control of listeriosis

One health approach helps in controlling Listeriosis through proper monitoring, identifying risk factors associated with the disease including environmental sources, animal reservoirs, by promoting strict hygiene throughout the food chain and by increasing the awareness among the people.

In animals, *Listeria monocytogenes* remains a challenge in food safety due to its ability to survive in soil, silage, water, bedding materials, and faeces. Therefore, proper monitoring particularly in cattle, sheep, goats, and pigs, is important to prevent transmission into meat and dairy products. Testing of aborted foetus materials and carcasses, rodent and bird control, disinfection of post-outbreak materials and enhancing the awareness among farmers and veterinarians helps in control.

In humans, preventing Listeriosis mainly depends on minimizing exposure from the environment. Since contamination mostly begins at the farm level, a farm-to-fork safety strategy is essential. Public health efforts should focus on better monitoring and surveillance systems, raising awareness among consumers and food handlers about good hygiene are essential. WHO provides some basic principles to reduce

occurrence of food-borne zoonotic diseases among the people. These include proper hygiene and cleanliness, cooking food properly and storing at right temperature, separating raw and cooked food to avoid contamination and regular sanitation is required (Banka and Ghosh, 2023; Končurat and Sukalić, 2024).

2.1.5.6 Current Research Focus and Requirements

In India, although the monitoring system for *L. monocytogenes* is not very strong various medical and scientific professionals are actively working to strengthen it including:

Indian Veterinary Research Institute (IVRI), Lucknow and Bareilly, Uttar Pradesh

Assam Agricultural University, Assam

ICAR Institutes in Goa and New Delhi

Dayalbagh Educational Institute, Agra

Karnataka Veterinary, Animal and Fisheries Sciences University, Mangalore

University of Mysore, Mysore

Guwahati University, Guwahati

Nagpur Veterinary College, Maharashtra

ICAR Research Complex for the North Eastern Hill Region, Shillong, Meghalaya (Banka and Ghosh, 2023).

3. CONTROL STRATEGIES FOR ZOONOSES

Zoonoses control is important for both human and animal health, as it reduces the risk of disease outbreaks and minimizes economic and public health impacts. Disease control and eradication mainly focus on preventing entry of disease agents in a specific region; control focuses on reducing disease levels to manageable limits; and eradication involves the complete elimination of the infectious agent from the population. Effective zoonoses control requires a combination of strategies, including the removal of infected animals through test-and-slaughter methods, mass treatment to the large animal population, and to limit pathogen survival

in vectors by maintaining proper hygiene and safety. Environmental hygiene measures include waste management and pasture rotation to reduce transmission risks (Teshome et al., 2019).

4. ONE HEALTH AND ZOONOSES

The One Health approach is a collaborative approach at global, national, and local levels that works to improve health by understanding the connection between humans, animals, and the environment which was first introduced by Rudolf Virchow in the 19th century and widely used after the 2004 "One World, One Health" meeting. It was supported by International organizations such as WHO, FAO, OIE, and UNEP. One Health helps in early disease detection, food safety, antimicrobial resistance management and control of the disease through coordinated efforts. Since more than 75% of new diseases in people are transmitted from animals, this approach is the key in preventing and controlling zoonotic diseases like COVID-19, rabies, and brucellosis (Erkyihun and Alemayehu, 2022).

5. CONCLUSIONS

Zoonotic diseases pose serious risks to global health, affecting both humans and animals. Bacterial zoonotic diseases like brucellosis, leptospirosis, tuberculosis, salmonellosis, and listeriosis represent diverse pathogens with different transmission routes. These diseases cause major illness and death. These diseases can weaken a nation's economy by reducing livestock productivity, increasing healthcare costs. Close human-animal contact and poor disease surveillance increase the risk of transmission. Their diverse transmission routes and ability to cause long-term health issues are making them hard to control. So, there is a need for a One Health approach that combines human, animal, and environmental health efforts. Integrated surveillance allows for early detection of outbreaks and supports quick, effective action to control them. Strong disease monitoring, quick and reliable testing methods and timely use of animal vaccination play an important role in reducing the spread. Antimicrobial resistance must be closely monitored for effective treatment. With global cooperation and investment, the burden of bacterial zoonotic diseases can be greatly reduced in the years ahead.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declares that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, *etc.*) and text-to-image generators have been used during the writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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