

## Mini Review

# Public health significance of companion animals in emergence and re-emergence of bacterial zoonoses

Mohammed Dauda Goni<sup>1#</sup>, Ibrahim Jalo Muhammad<sup>2</sup>, Asinamai Athliamai Bitrus<sup>3</sup>, Saleh Mohammed Jajere<sup>4</sup>, Mian Khaqan Shah<sup>5</sup>, Abdulwahab Aliyu<sup>6</sup> and Mohammed Goje<sup>4</sup>

• Received: May 21, 2017 • Revised: May 25, 2018 • Accepted: May 26, 2018 • Published Online: May 29, 2018



## AFFILIATIONS

<sup>1</sup>Department of Microbiology and Parasitology, School of Medical Sciences, Universiti Sains Malaysia Health Campus, Kubang Kerian Kelantan Malaysia.

<sup>2</sup>Department of Veterinary Services, Ministry of Agriculture, IBB Secretariat Complex Yobe State Nigeria.

<sup>3</sup>Research Unit in Microbial Food safety and Antimicrobial resistance, Department of Veterinary Public Health, Faculty of Veterinary science, Chulalongkorn University, 10330 Pathumwan Bangkok, Thailand.

<sup>4</sup>Department of Veterinary Public Health and Preventive Medicine, Faculty of Veterinary Medicine, University of Maiduguri, P M B 1069, Maiduguri, Borno State, Nigeria. & Department of Pathology and Microbiology, Faculty of Veterinary Medicine, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia.

<sup>5</sup>Department of Pathology and Microbiology, Faculty of Veterinary Medicine, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia.

<sup>6</sup>Department of Pharmaceutical Microbiology and Biotechnology, Faculty of Pharmaceutical Sciences, Gombe State University, Nigeria.

## CORRESPONDENCE:

# Mohammed Dauda Goni,  
Department of Microbiology and Parasitology, School of Medical Sciences, Universiti Sains Malaysia Health Campus, Kubang Kerian Kelantan Malaysia.  
E-mail: [dandagoni@gmail.com](mailto:dandagoni@gmail.com)

## ABSTRACT

Companion animals especially cats and dogs can provide a bridge for transmission of emerging bacterial diseases that are zoonotic in nature. Zoonotic diseases had posed numerous risk to ownership of companion animals by human either through direct or indirect contact especially in recent years where livestock species are being used as pets. Furthermore, companion animals could play a significant role in zoonosis as a potential reservoirs of various infections. These diseases have impacted greatly to the definition of new paradigms posed by emerging and re-emerging infectious diseases particularly relating to biosecurity policies and broadly to the protection of public health. Multi-sectorial collaboration for disease containment should be emphasized towards curtailing and managing health risks regarding infectious zoonotic diseases.

## KEYWORDS

Bacterial zoonoses; Companion animals; Pet; Public health

**How to cite:** Goni MD, Muhammad IJ, Bitrus AA, Jajere SM, Shah MK, Aliyu A, Goje M. Public health significance of companion animals in emergence and re-emergence of bacterial zoonoses. Journal of Advanced Veterinary and Animal Research. 2018; 5(2):101-109.

## INTRODUCTION

---

Over the recent years, there are numerous cases of emergence of new infectious diseases and re-emergence of existing ones across different geographical region with changes in their epidemiology almost yearly ([Bloom et al., 2017](#)). These have attracted great public health concern at national and international levels from both developing and developed countries ([Cantas and Suer, 2014](#)). Majority of emerging diseases are zoonotic in nature and they are becoming widely used to refer to the manifestation of a presently obscured disease or an earlier known disease that has broadened in a different population or geographical region and oftentimes appended by a distinct alteration in virulence and increase in incidence ([Gortazar et al., 2014](#)). Similarly, these infections are often associated with emergence of antimicrobial resistance against chemotherapeutic agents which is also a major public health problem ([Abatcha, 2017](#)). Emerging diseases which could be due to changes or evolution of an existing pathogens has no limit of its spread across national boundaries ([Machalaba et al., 2018](#)).

Companion animals encompass a wide array of species that are kept as part of a household or other useful purposes which includes dogs, cats, horses, ferrets, guinea pigs, reptiles, rodents, rabbits, birds and ornamental fish, as well as food production animal species, such as domestic pigs and wild-caught animals ([Damborg et al., 2016](#); [Reperant et al., 2016](#)). However, cats and dogs appeared to be the most frequently kept of all the companion animals with an estimated population of 185 millions in Europe followed by pet birds (39 million) (FEDIAF, 2016). Moreover, among the estimated population of 71 million and 74 million for dogs and cats respectively in the US, 50% of households have these as pets. (AVMA, 2012). Companion animals are potential source of emerging and re-emerging infectious diseases for man and have a great public health significance ([Rijks et al., 2016](#)).

Issues regarding the emergence of diseases such as antibiotic resistance, influenza, tuberculosis are a multifaceted and all-encompassing efforts with the Centers for Disease Control and Prevention (CDC) of the United States being at the forefront of tackling challenges posed by them. Its represents CDC's effort in addressing scientific publications towards the menace of emerging infections. These publications are continues and evolving across the globe, they present elusive views and reports from wide authorship base and extensive

independent peer-reviewing ([Drotman and Hughes, 2015](#)). The Organization for Animal Health (OIE) and the World Trade Organization's (WTO) further strengthened and reinforced the protocols and guidelines provided by the source organization for global models on animal health and zoonoses. Based on this, between the year 2012 and 2014, the European Union (EU) established a structure 7-funded blueprint known as Companion Animal multi-sectorial inter-professional and Interdisciplinary Strategic Think tank On zoonoses (CALLISTO) including researched on zoonotic infections spread among companion pets and human and food-producing animals ([Cito et al., 2016](#)).

However, in contrast to man and animal diseases, no any international health organization are authorized to regulate monitoring of infections in pets with the exception of the surveillance systems for a few small animal zoonosis which basically comprises the bulk of companion animals. Therefore companion animals can as well be at risk of contracting the infections from these animals species ([Day, 2011](#)). Recently, human and animal health suffered great consequences from diseases linked with outbreaks of emerging or re-emerging infections ([NIH, 2007](#)). The zoonotic infections could be transmitted either through direct animals to humans transmission in which an animal or human is infected. It can also be attributed to diseases in which companion animals serve as a source of spreading infections, including possessing the potential for infecting source of food and water for human consumption. To achieve optimum prevention and control strategy in developed countries, basic enforcement of existing rules to enhance responsible pet-ownership. Similarly, the rules should be enacted in some countries that they are lacking ([van Knapen and Overgaauw, 2015](#)).

A major focus now is on the concept of "One Health" which has attracted greater attention in the field of emerging and re-emerging infectious diseases. This concept entails seamless interaction between veterinarians and medical practitioner toward infections transmitted by humans, livestock, pets, and wildlife in particular relation to the environment ([Day, 2011](#)). However, their are paucity of data on the role of companion animals in the emergence and spread of infectious diseases in man both in research and in surveillance.

### Factors in the emergence of infectious zoonoses

Most emerging infectious diseases of bacterial origin are due to their persistent presence in the environment and are known to have included some of the most scourge of

the previous epidemic ([NIH, 2007](#)). Disease emergence is primarily due to a change in the ecology of host, pathogen, or both ordinarily induced by anthropogenic determinants, such as worldwide trade and high human-wildlife contact frequency via increasing human population density and encroachment into wildlife habitat and phylogeny or the change of an infectious agent or a current parasite. Numerous factors that have been identified and associated as risk factors for the emergence of zoonotic diseases include the continuous booming of international travel and trade across the world, high rate of mingling among human, wildlife, exotic, domesticated and companion animals, production of novel diagnostic instruments, rise in individual susceptibility to bacterial agents as well as emergence of more virulent bacterial strains and opportunistic infections ([Vouga and Greub, 2016](#)).

Similarly, other factors such as human behavior, rapid microbial adaptation, changes in climates and ecosystems as well as changes in livestock management methods ([Cleaveland et al., 2001](#)). Rise in the true incidence of emerging pathogens can also be related to the pathogenicity of the strain or vector. Furthermore, the emergence of a bacterial disease is contributed by factors such as precise social, ecological, climatic, environmental or demographic determinants, however, the mechanism and ranking of causes of infections remain unachievable. ([Weiss and McMichael, 2004](#)). Moreover, pathogens that persist in the environment, therefore, have a more selective affinity and the potential to infect a higher number of host and taxonomic order that makes them more prone to emergence when compared with pathogens of restricted host ([Cleaveland et al., 2001](#)). Technology and industrial development has resulted in high-volume rapid urbanization and movement characterized by travel across different borders ([Morse, 2001](#)).

Recent use of biological food processing production has greatly potentiate the productivity and chances of accidental contamination with zoonotic organisms in the line of food production. These processes or application results of genetically modified origin, modern production techniques result in higher efficiency and decreased finances but can raise the likelihood of unintentional infection and increase the effects of such disease ([Economou and Gousia, 2015](#)). Globalization further compound this effect through the introduction of agents that are new from a far or entirely different region. An infectious agent existent in any of these new bodies may gain its access inside a huge group of the final result ([Wu et al., 2016](#)).

Opportunistic host plays a role in the re-emergence of diseases as major source of spreading diseases to human. Improved and efficient surveillance is a key strategy in the public health sector focused on the locations with high chances of disease outbreak (emergence). These strategies comprises of effective reporting of diseases and detection of microbes, rapid outbreak detection, elaborate research to identify factors that favour re-emergence, and effective preventive measures ([Fraser et al., 2004](#)).

### ***Campylobacteriosis***

The genus *Campylobacter* is a diverse and large group with numerous species and sub-species. Majority of *Campylobacter* species are considered as emerging human and animal pathogens across the globe and they are the preeminent etiology of gastroenteritis in developed countries ([Humphrey et al., 2007](#); [Man, 2011](#)). They are very vital infectious emerging bacterial zoonotic agent that are known to be foodborne pathogens that causes gastrointestinal illness in humans ([Humphrey et al., 2007](#)). However, they have been shown to be isolated from companion animals such as cats, dogs, and birds; and are known to be shed in the feces which in turn may contaminate and spread in the environment. This could be associated with the high incidence in stray dogs and cats due to their exposure to environmental sources of *Campylobacter* infection. A high prevalence (up to 97%) of *Campylobacter* in companion animals are known to have published from research conducted in Malaysia, Spain, Nigeria and North America ([Chaban et al., 2010](#); [Goni et al., 2017a](#)). In some cases, companion animals are fed infected meat from livestock animals as well as association with pets poses a vital hazard for the sharing of *Campylobacter* species ([de Perio et al., 2013](#)). However, the prevalence of *Campylobacter* species in pets posed a major public health concern due to there closeness with humans and therefore they act as a potential reservoir and risk factor for human infections ([Goni et al., 2017b](#)).

### ***Leptospirosis***

Leptospirosis is a bacterial and a common zoonotic disease with etiological agents by microbes of the genus *Leptospira* which is a distinct branch of gram-negative bacteria that can affect both man and animal. It is generally regarded as an emerging disease across the world and is endemic in most companion animals particularly dogs and often under reported, with rodents being the major reservoirs of the pathogen ([Jittapalapong](#)

[et al., 2009](#)). Although curable if treated early, it is often misdiagnosed and can be fatal if left untreated. However, the re-emergence of *Leptospira* species in companion animals populations has been a great concern across different geographical zones due its severity ([Damborg et al., 2016](#)). The incidence in human is reported to be low in different countries and are mild and asymptomatic although is associated with kidney failure especially in risk individuals ([Dupouey et al., 2014](#)). *Leptospira* species can be transmitted by oral administration or close contact of mucous membranes or damaged skin with the pathogen, however, the majority of infections are contracted from water and environmental sources that are contaminated with urine ([Adler and de la Peña Moctezuma, 2010](#)). Symptoms of Leptospirosis vary from fever, nonproductive cough, headache, musculoskeletal pain, diarrhea, nausea, vomiting, alveolar hemorrhage, and even meningitis ([Terpstra, 2003](#)).

### **Salmonellosis**

*Salmonella* is a gram-negative bacteria that can withstand warm and most environmental condition for months ([Abatcha et al., 2014a](#)). Companion animals such as dogs, cats and especially reptiles species are important reservoirs of the pathogen ([Mistry 2013](#)). They are major public health concern in both developed and developing countries ([Abatcha et al., 2014b](#)). However, figures on the prevalence of *Salmonella* species in household pets are relatively low. Data from some studies showed the prevalence rate in dogs, cats and other companion animals ranging from as low as 0 to 9% ([Marks et al., 2011](#); [Abatcha et al., 2014b](#)). The incidence and intestinal occurrence of *Salmonella* species among companion animals is of public health interest across the globe. Several studies have confirmed the shedding and spreading of *Salmonella* to humans ([Wright et al., 2005](#); [Lowden et al., 2015](#); [van Knapen and Overgaauw, 2015](#)). Similarly, a study reported *Salmonella* prevalence among pedigree dogs and shown 43.5% of pets were colonized with it, however, a study elsewhere showed the prevalence rate among racing Alaskan dogs at 60% ([Hoelzer et al., 2011](#)).

The emergence of antimicrobial-resistant *Salmonella* and other enteric pathogens has become a major public concern worldwide. However the role of other companion animals in transmission of *Salmonella* spp. to humans is unclear and probably of less concern. Some companion animals are potentially at greater risk of infection by *Salmonella* due to their indiscriminate feeding character mainly related to scavenging and hunting.

Human Salmonellosis have been attributed to contact with infected dogs or cats at home or in veterinary premises ([Hoelzer et al., 2011](#)). Therefore constitute a risk of cycling infection by *Salmonella* which is mainly harbored in the small intestine from where it can excreted into the environment via feces ([Mistry, 2013](#)).

### **Methicillin-resistant *Staphylococcus aureus* (MRSA)**

Methicillin-resistant *Staphylococcus aureus* (MRSA) is considered as an emerging nosocomial pathogen that is zoonotic in nature and was first reported in the United Kingdom. It was isolated as when semi-synthetic beta lactams antibiotics that were used for therapeutics of infection by strain *S. aureus* became resistant ([Chen et al., 2014](#); [Asinamai et al., 2016](#)). Currently, substantial strains of *S. aureus* have developed resistance to most penicillin derivatives and other common antibiotics ([Chen et al., 2014](#)). The epidemic potentials of MRSA according to some studies have showed that the rapid emergence of novel MRSA clones is at a rapid pace which has redefined the knowledge of its clonality ([Saleha and Zunita, 2010](#); [Graveland et al., 2011](#)). Recently, new strains of MRSA were initially coined to cause human diseases but it was later found out to be associated with a clone of MRSA related to farm animals ([Asinamai et al., 2016](#)). Due to the similarities of the strains of pets and human isolates of MRSA, it is reported that pets could serve as source of infection of humans and vice versa ([Bramble et al., 2011](#)). The occurrence of MRSA and cross infection and transmission between horse, cats, dogs, and man as well as animals hospital were extensively demonstrated in several studies which were reviewed by [Rendle and Page \(2018\)](#).

MRSA were isolated at 1.5% occurrence rate from samples of companion animals across the UK with dogs and cats being the most infected/colonized ([Loeffler et al., 2005](#)). However, risk factors that could predisposed risk groups as potential reservoirs of infection are associated with ownership of companion animals, veterinary practice and farmers. Therefore, human stands a great possibility of occurrence or infection with MRSA ([Mustapha et al., 2014](#)). The rapid changes linked with emergence of numerous global attention MRSA clones generated worldwide, the epidemiologic variation is on a major scale and could affect the patient, health care workers and pharmaceutical companies. For these reasons, new clones harbors various determinants for virulence and antibiotic resistance and dissemination in the environment ([Grema et al., 2015](#)).

## ***Arcobacter***

*Arcobacter* belongs to the family *Campylobacteriaceae* and it was initially referred to as aerotolerant *Campylobacter* due to the fact that its organisms could thrive aerobically before it was later moved to genus *Arcobacter* (Shah et al., 2012). Recently, *Arcobacter* species are now regarded as an emerging food-borne zoonotic pathogen across the world and categorized to be of serious hazard to human health. (Ramees et al., 2017). Several studies have elaborated the carriage of *Arcobacter* species in pets and their role in transmission to human (Goni et al., 2016). The most common species of this genus is *A. butzleri* and have gained popularity from researchers in different parts of the world as an important foodborne organism linked with diseases in man such as severe diarrhea, enteritis, bacteremia, and septicemia. They are also been associated in the etiology causative organism of traveler's diarrhea with *Campylobacter*, *E. coli*, *Shigella*, and *Salmonella* (Collado et al., 2014). But recently, studies on carriage rate in various animals across the world reported 54.4% (dogs), 78.8% (cats) (Fera et al., 2009; Goni et al., 2016). However, their occurrence in companion animals are vital due to the fact that the presence of these emerging foodborne pathogens pose a risk to the human population and constitutes a public health concern (Goni et al., 2017c). The prevalence of *Arcobacter* species in companion animals may be deprecated possibly due to its misidentification in the past years.

## ***Listeriosis***

The genus *Listeria* consists of species that are the etiological agent for Listeriosis which comprises 17 different species that are presently marked as an emerging food-borne zoonosis which posed a great threat to the public health. (Dhama et al., 2013; Weller et al., 2015). Among these species, only *L. monocytogenes* is known to cause infections in human and numerous animal species, while *L. ivanovii* is rarely caused a disease to humans. Listeriosis is characterized with meningo-encephalitis, septicaemia, resulting in abortion in animals and humans (Dhama et al., 2015). The organisms are well disseminated in the environment and can be isolated from soil, silage, and sewage. *Listeria monocytogenes* is also found in the faecal culture of healthy pets and man (Kocabiyik et al., 2006). *Listeria* infections was reported to be responsible for 47% of the deaths recorded in 2011 among foodborne pathogens (Abatcha, 2017). Companion animals especially infected birds are regarded as a major source of human infection through contact and ingestion of contaminated poultry products with

pregnant women, immunocompromised individuals, aged persons and new born being at high risk of infections (Popovic et al., 2014).

## ***Escherichia coli***

The enterohaemorrhagic *Escherichia coli* (EHEC) species are a subgroup of Shiga toxin-producing *E. coli* species that have usually resulted in human and animals diseases. As a result of contamination from faeces, it is often found in soil, water and food. One of the rich sources of the spread and emergence of antibiotic resistance is the commensal *E. coli* flora (da Costa et al., 2013). However, extended-spectrum  $\beta$ -lactamases (ESBLs) can be considered as a rapidly emerging set of  $\beta$ -lactamases which that partake the capability to hydrolyze third-generation cephalosporins and aztreonam but are hindered with clavulanic acid (Bitrus et al., 2018). They represent the prime instance that  $\beta$ -lactamase-mediated resistance to  $\beta$ -lactam antibiotics produced from basic variations in the substrate spectra of the enzymes (King et al., 2012). Recently, there is an emergence of Multidrug drug resistant *E. coli* ST131 across the globe in human as a pandemic clone. Numerous strains of ST131 *E. coli* species from pet animals are comparable to human strains ST131 *E. coli* confirmed based on their pathogen genotype, resistance properties, plasmid content and PFGE characterization (Pomba et al., 2017).

The risk group of developing a severe infection are the children and the and therefore a particularly important concern in public health and traverse the food and agricultural productions. (CDC, 2001). Several species of animals such as sheep, goats, heifer, birds, deer, geese, turkey, seabirds, dogs, cat, gull, chicken, pig, monkey, reptiles, llama, and horses, as well as on flies serves as reservoir for verotoxin-producing *E. coli* O157 with cattle being the major one (Johnsen et al., 2001; Lenahan et al., 2009). Isolates of variety of strains of *E. coli* around the world were reported to be closely related to each other based on genotypic analysis. This suggests the roles played by rapid and global dissemination. Several factors contributed to the globalization of the pathogens such as direct human-to-human transmission, international travel, environmental dissemination, fecal carriage in livestock and carriage by companion pets which apparently aid in the spread of strains of human importance (Platell et al., 2011). The re-emergence of antimicrobial resistance may hinder the therapy of *E. coli* infections in pet animals. Thus the treatment options of humans infections with *E. coli* from their pets may be limited (Shaheen et al., 2013).

## Tuberculosis

Tuberculosis is regarded as an important disease both man and animals which results in morbidity, mortality and economic loss worldwide (Thoen et al., 2009). The genus *Mycobacterium* consists of diverse species that are the etiological agents of tuberculosis in humans and other animals. The *Mycobacterium tuberculosis* complex comprises of *M. tuberculosis*, *M. canettii*, *M. africanum*, *M. bovis*, *M. pinnipedii*, *M. caprae* and *M. microti* and they constitute a great public health concern especially in developing countries due to the presence of comorbidities. (LoBue et al., 2010). Its re-emergence in parts of the United Kingdom had led to its occurrence which has been documented in broad range of animals including companion animals hence its zoonotic nature (Chomel, 2014). Tuberculosis due to *M. bovis* in human is rare, however the pathogen is of high economic importance in domestic animals around the globe (De Kantor and Ritacco, 2006; Jajere et al., 2018).

It is widely regarded that the dogs can harbor *M. bovis* and *M. tuberculosis* similar to the case of transmitting human infection (Monies et al., 2006). However, infection with *M. tuberculosis* in cats is rare due to resistance of cat to the infection. Although ingestion of contaminated food materials in presence of infected cattle has been reported to be the reservoir of infection for cats (Ramdas et al., 2015).

## CONCLUSION

This review demonstrated the importance and role of companion animals in the zoonotic potential of bacterial infections that are emerging and re-emerging. Emerging disease posed an enormous risk, therefore in order to reduce the related risk an enhanced robust surveillance, diagnostic and preventive measures is required especially in developing countries where veterinary settings and facilities remain inadequate and hindered by lack of resources. In recent years, sophisticated control measures such as advanced animal health care have remained frequently applied together with surveillance and standard control practices, which involve stamping out (culling) and movement confinements (including zoning, compartmentalization, isolation, and quarantine). Similarly, antimicrobial resistance in companion animals has increased as a result of the rise in number of reports of companion animals colonized with important multi-drug resistant organisms of public health importance such as methicillin-resistant *Staphylococcus aureus* (MRSA). The concept of One health and enlightenment of pet

owners would provide the impetus required for public health improvement and prevention of numerous zoonotic pathogens among companion animals and possible transmission to humans. These will also ensure proper surveillance and monitoring system for determining the occurrence of these zoonotic pathogens.

## ACKNOWLEDGEMENT

The authors would like to acknowledge the USM Global Fellowship awarded to the first author.

## CONFLICT OF INTEREST

There is no conflict of interest to declare.

## AUTHORS' CONTRIBUTION

MDG, IJM and AAB conceived and drafted the manuscript, SMJ, KMS, AA and MG reviewed the manuscript. MDG and AAB approved the final draft of this review article.

## REFERENCES

1. Abatcha M, Zunita Z, Gurmeet D, Thong K. Occurrence of antibiotic resistant *Salmonella* isolated from dogs in Klang Valley, Malaysia. *Malaysia Journal of Microbiology*. 2014b; 10:219–224.
2. Abatcha M. *Salmonella* and *Listeria monocytogenes*: A review of prevalence and antibiotic resistance in chickens and their processing environments. *Advances in Animal Veterinary Sciences*. 2017; 5(9):395–403.
3. Abatcha M., Zakaria Z, Goni D, Kaur D. Typing of *Salmonella* species: A mini-review. *Journal Natural Sciences Research*. 2014a; 4:13–17.
4. Adler B, de la Peña Moctezuma A. *Leptospira* and leptospirosis. *Veterinary Microbiology*. 2010; 140(3-4):287–296. <https://doi.org/10.1016/j.vetmic.2009.03.012>
5. Asinamai AB, Zakaria Z, Siti KB, Sarah O., Abdul-Nasir T. Molecular Epidemiology: A Valuable Tool for Determination of Emerging and clonality of Methicillin Resistant *Staphylococcus aureus* (MRSA). *Pertanika Journal of Scholarly Research Reviews*. 2016; 2(2):121–134
6. Bitrus AA, Chuanchuen R, Luangtongkum T. Emergence of colistin resistance in extended-spectrum beta lactamase producing *Enterobacteriaceae* isolated from food animals and its public health implication: A review. *Journal of Advanced Veterinary and Animal Research*. 2018; 5(1):1–11. <https://doi.org/10.5455/javar.2018.e246>
7. Bloom DE, Black S, Rappuoli R. Emerging infectious diseases: a proactive approach. *Proceedings of the National Academy of Sciences*. 2017; 114(16):4055–4059. <https://doi.org/10.1073/pnas.1701410114>

8. Bramble M, Morris D, Tolomeo P, Lautenbach E. Potential role of pet animals in household transmission of methicillin-resistant *Staphylococcus aureus*: a narrative review. 2011; Vector-Borne and Zoonotic Diseases. 2011; 11(6):617–620. <https://doi.org/10.1089/vbz.2010.0025>
9. Cantas L, Suer K. Review: The important bacterial zoonoses in “One Health” concept. *Frontiers in Public Health*. 2014; 2; Article 144. <https://doi.org/10.3389/fpubh.2014.00144>
10. CDC. Outbreaks of *Escherichia coli* O157: H7 infections among children associated with farm visits--Pennsylvania and Washington, 2000. *MMWR. Morbidity and Mortality Weekly Report*. 2001; 50(15):293.
11. Chaban B, Ngeleka M, Hill JE. Detection and quantification of 14 *Campylobacter* species in pet dogs reveals an increase in species richness in feces of diarrheic animals. *BMC Microbiology*. 2010; 10:73. <https://doi.org/10.1186/1471-2180-10-73>
12. Chen CJ, Huang YC, Su LH, Wu TL, Huang SH, Chien CC, Ko WC. Molecular epidemiology and antimicrobial resistance of methicillin-resistant *Staphylococcus aureus* bloodstream isolates in Taiwan, 2010. *PloS One*. 2014; 9(6):e101184. <https://doi.org/10.1371/journal.pone.0101184>
13. Chomel BB. Emerging and re-emerging zoonoses of dogs and cats. *Animals*. 2014; 4(3):434–445. <https://doi.org/10.3390/ani4030434>
14. Cito F, Rijks J, Rantsios A, Cunningham A, Baneth G, Guardabassi L, Giovannini A. Prioritization of companion animal transmissible diseases for policy intervention in Europe. *Journal of Comparative Pathology*. 2016; 155(1):S18–S26. <https://doi.org/10.1016/j.jcpa.2015.01.007>
15. Cleaveland S, Laurenson M, Taylor L. Diseases of humans and their domestic mammals: pathogen characteristics, host range and the risk of emergence. *Philosophical Transactions of the Royal Society B: Biological Sciences*. 2001; 356(1411):991–999. <https://doi.org/10.1098/rstb.2001.0889>
16. Collado L, Jara R, Vásquez N, Telsaint, C. Antimicrobial resistance and virulence genes of *Arcobacter* isolates recovered from edible bivalve molluscs. *Food Control*. 2014; 46:508–512. <https://doi.org/10.1016/j.foodcont.2014.06.013>
17. da Costa PM, Loureiro L, Matos AJ. Transfer of multidrug-resistant bacteria between intermingled ecological niches: the interface between humans, animals and the environment. *International Journal of Environmental Research and Public Health*. 2013; 10(1):278–294. <https://doi.org/10.3390/ijerph10010278>
18. Damborg P, Broens EM, Chomel BB, Guenther S, Pasmans F, Wagenaar JA, Vanrompay, D. Bacterial zoonoses transmitted by household pets: state-of-the-art and future perspectives for targeted research and policy actions. *Journal of Comparative Pathology*. 2016; 155(1):S27–S40. <https://doi.org/10.1016/j.jcpa.2015.03.004>
19. Day MJ. One health: the importance of companion animal vector-borne diseases. *Parasites and Vectors*, 2011; 4(1):49. <https://doi.org/10.1186/1756-3305-4-49>
20. De Kantor IN, Ritacco V. An update on bovine tuberculosis programmes in Latin American and Caribbean countries. *Veterinary Microbiology*. 2006; 112(2-4):111–118. <https://doi.org/10.1016/j.vetmic.2005.11.033>
21. de Perio MA, Niemeier RT, Levine SJ, Gruszynski K, Gibbins JD. *Campylobacter* infection in poultry-processing workers, Virginia, USA, 2008–2011. *Emerging Infectious Diseases*. 2013; 19(2):286. <https://doi.org/10.3201/eid1902.121147>
22. Dhama K, Karthik K, Tiwari R, Shabbir MZ, Barbuddhe S, Malik SVS, Singh RK. Listeriosis in animals, its public health significance (food-borne zoonosis) and advances in diagnosis and control: a comprehensive review. *Veterinary Quarterly*. 2015; 35(4):211–235. <https://doi.org/10.1080/01652176.2015.1063023>
23. Dhama K, Rajagunalan S, Chakraborty S, Verma A, Kumar A, Tiwari R, Kapoor S. Food-borne pathogens of animal origin-diagnosis, prevention, control and their zoonotic significance: a review. *Pakistan Journal of Biological Sciences*. 2013; 16(20):1076–1085. <https://doi.org/10.3923/pjbs.2013.1076.1085>
24. Drotman DP, Hughes JM. A History of the Emerging infectious diseases journal. *Emerging Infectious Diseases*. 2015; 3(1):1-9.
25. Dupouey J, Faucher B, Edouard S, Richet H, Kodjo A, Drancourt M, Davoust B. Human leptospirosis: an emerging risk in Europe?. *Comparative Immunology, Microbiology and Infectious Diseases*. 2014; 37(2):77–83. <https://doi.org/10.1016/j.cimid.2013.12.002>
26. Economou V, Gousia P. Agriculture and food animals as a source of antimicrobial-resistant bacteria. *Infection and Drug Resistance*. 2015; 8:49. <https://doi.org/10.2147/IDR.S55778>
27. Fera MT, La Camera E, Carbone M, Malara D, Pennisi MG. Pet cats as carriers of *Arcobacter* spp. in Southern Italy. *Journal of Applied Microbiology*. 2009; 106(5):1661–1666. <https://doi.org/10.1111/j.1365-2672.2008.04133.x>
28. Fraser C, Riley S, Anderson RM, Ferguson NM. Factors that make an infectious disease outbreak controllable. *Proceedings of the National Academy of Sciences of the United States of America*. 2004; 101(16):6146–6151. <https://doi.org/10.1073/pnas.0307506101>
29. Goni DM, Abdulaziz S, Dhaliwa GK, Zakaria Z, Muhammad IJ, Mohamed MA, Bello AA, Bitrus AA. Occurrence of *Arcobacter* in dogs and cats in Selangor, Malaysia, and associated risk factors. *Turkish Journal of Veterinary and Animal Sciences*. 2016; 40(6):769–775. <https://doi.org/10.3906/vet-1602-7>
30. Goni MD, Abdul-Aziz S, Dhaliwal GK, Zunita Z, Bitrus AA, Jalo IM, Aung WW, Mohamed MA, Aliyu AB. Occurrence of *Campylobacter* in dogs and cats in Selangor Malaysia and the associated risk factors. *Malaysian Journal of Microbiology*. 2017a; 13(3):164–171.

31. Goni MD, Muhammad IJ, Goje M, Abatcha MG, Bitrus AA, Abbas MA. *Campylobacter* in dogs and cats; its detection and public health significance: A review. *Advances in Animal and Veterinary Sciences*. 2017b; 5(6):239–248. <http://dx.doi.org/10.17582/journal.aavs/2017/5.6.239.248>
32. Goni MD, Muhammad IJ, Goje M, Bitrus AA, Jajere SM, Adam BM, Abbas MA. Occurrence of emerging *Arvobacter* in dogs and cats and its public health implications: A Review. *Advances in Animal Veterinary Sciences*. 2017; 5(9):362–370. <http://dx.doi.org/10.17582/journal.aavs/2017/5.9.362.370>
33. Gortazar C, Reperant LA, Kuiken T, de la Fuente J, Boadella M, Martínez-Lopez B, Ruiz-Fons F, Estrada-Peña A, Drosten C, Medley G, Ostfeld R. Crossing the interspecies barrier: opening the door to zoonotic pathogens. *PLoS Pathogens*. 2014; 10(6):e1004129. <https://doi.org/10.1371/journal.ppat.1004129>
34. Graveland H, Duim B, Van Duijkeren E, Heederik D, Wagenaar JA. Livestock-associated methicillin-resistant *Staphylococcus aureus* in animals and humans. *International Journal of Medical Microbiology*. 2011; 301(8):630–634. <https://doi.org/10.1016/j.ijmm.2011.09.004>
35. Grema HA, Geidam YA, Gadzama GB, Ameh JA, Suleiman A. Methicillin resistant *Staphylococcus aureus* (MRSA): a review. *Advances in Animal and Veterinary Sciences*. 2015; 3(2):79–98. <https://doi.org/10.14737/journal.aavs/2015/3.2.79.98>
36. Hoelzer K, Switt AI, Wiedmann M. Animal contact as a source of human non-typhoidal Salmonellosis. *Veterinary Research*. 2011; 42(1):34. <https://doi.org/10.1186/1297-9716-42-34>
37. Humphrey T, O'Brien S, Madsen M. *Campylobacter* as zoonotic pathogens: a food production perspective. *International Journal of Food Microbiology*. 2007; 117(3):237–257. <https://doi.org/10.1016/j.ijfoodmicro.2007.01.006>
38. Jajere SM, Atsanda NN, Bitrus AA, Hamisu TM, Goni MD. Occurrence of bovine tuberculosis among cattle herds from nomadic peri-urban settlements and cattle slaughtered at the municipal abattoir of Bauchi, North-Eastern Nigeria. *Journal of Advanced Veterinary and Animal Research*. 2018; 5(1):53–59. <https://doi.org/10.5455/javar.2018.e247>
39. Jittapalapong S, Sittisan P, Sakpuaram T, Kabeya H, Maruyama S, Inpankaew T. Coinfection of *Leptospira* spp and *Toxoplasma gondii* among stray dogs in Bangkok, Thailand. *Southeast Asian Journal of Tropical Medicine and Public Health*. 2009; 40(2):247.
40. Johnsen G, Wasteson Y, Heir E, Berget OI, Herikstad H. *Escherichia coli* O157: H7 in faeces from cattle, sheep and pigs in the southwest part of Norway during 1998 and 1999. *International Journal of Food Microbiology*. 2001; 65(3):193–200. [https://doi.org/10.1016/S0168-1605\(00\)00518-3](https://doi.org/10.1016/S0168-1605(00)00518-3)
41. King DT, Worrall LJ, Gruninger R, Strynadka NC. New Delhi metallo- $\beta$ -lactamase: structural insights into  $\beta$ -lactam recognition and inhibition. *Journal of the American Chemical Society*. 2012; 134(28):11362–11365. <https://doi.org/10.1021/ja303579d>
42. Kocabiyik AL, Çetin C, Özakin C. Faecal carriage of *Listeria monocytogenes* in stray dogs in Bursa Province, Turkey. *Turkish Journal of Veterinary and Animal Sciences*. 2006; 29(6):1357–1359.
43. Lenahan M, O'Brien SB, Byrne C, Ryan M, Kennedy CA, McNamara EB, Fanning S, Sheridan JJ, Sweeney T. Molecular characterization of Irish *E. coli* O157: H7 isolates of human, bovine, ovine and porcine origin. *Journal of Applied Microbiology*. 2009; 107(4):1340–1349. <https://doi.org/10.1111/j.1365-2672.2009.04320.x>
44. LoBue PA, Enarson DA, Thoen CO. Tuberculosis in humans and animals: an overview [Serialised article. Tuberculosis: a re-emerging disease in animals and humans. Number 1 in the series]. *The International Journal of Tuberculosis and Lung Disease*. 2010; 14(9):1075–1078.
45. Loeffler A, Boag AK, Sung J, Lindsay JA, Guardabassi L, Dalsgaard A, Smith H, Stevens KB, Lloyd DH. Prevalence of methicillin-resistant *Staphylococcus aureus* among staff and pets in a small animal referral hospital in the UK. *Journal of Antimicrobial Chemotherapy*. 2005; 56(4):692–697. <https://doi.org/10.1093/jac/dki312>
46. Lowden P, Wallis C, Gee N, Hilton A. Investigating the prevalence of *Salmonella* in dogs within the Midlands region of the United Kingdom. *BMC Veterinary Research*. 2015; 11(1):239. <https://doi.org/10.1186/s12917-015-0553-z>
47. Machalaba C, Romanelli C, Stoett P. Global Environmental Change and Emerging Infectious Diseases: Macrolevel Drivers and Policy Responses. In *Climate Change and Environmental Concerns: Breakthroughs in Research and Practice*. 2018; p. 393–426.
48. Man SM. The clinical importance of emerging *Campylobacter* species. *Nature Review Gastroenterol Hepatology*. 2011; 8(12):669–685. <https://doi.org/10.1038/nrgastro.2011.191>
49. Marks S, Rankin S, Byrne B, Weese J. Enteropathogenic bacteria in dogs and cats: diagnosis, epidemiology, treatment, and control. *Journal of Veterinary Internal Medicine*, 2011; 25(6):1195–1208. <https://doi.org/10.1111/j.1939-1676.2011.00821.x>
50. Mistry P. *Salmonella* in companion animals. Doctoral dissertation, Aston University. 2013.
51. Monies B, Jahans K, de la Rua R. Bovine tuberculosis in cats. *Veterinary Record*. 2006; 158(7):245–246. <https://doi.org/10.1136/vr.158.7.245-a>
52. Morse SS. *Factors in the emergence of infectious diseases*. In *Plagues and politics*, Palgrave Macmillan, London. 2001; p. 8–26.
53. Mustapha M, Bukar-Kolo YM, Geidam YA, Gulani IA. Review on Methicillin-resistant *Staphylococcus aureus* (MRSA)

- in Dogs and Cats. *International Journal of Animal and Veterinary Advances*. 2014; 6(2):61–73.
54. NIH (National Institutes of Health). Understanding emerging and re-emerging infectious diseases. Biological sciences curriculum study. NIH Curriculum Supplement Series. National Institutes of Health, Bethesda, MD. 2007.
  55. Platell JL, Cobbold RN, Johnson JR, Heisig A, Heisig P, Clabots C, Kuskowski MA, Trott DJ. Commonality among fluoroquinolone-resistant sequence type ST131 extraintestinal *Escherichia coli* isolates from humans and companion animals in Australia. *Antimicrobial agents and chemotherapy*. 2011; 55(8):3782–3787. <https://doi.org/10.1128/AAC.00306-11>
  56. Pomba C, Rantala M, Greko C, Baptiste KE, Catry B, Van Duijkeren E, Mateus A, Moreno MA, Pyörälä S, Ružauskas M, Sanders P. Public health risk of antimicrobial resistance transfer from companion animals. *Journal of Antimicrobial Chemotherapy*. 2017;72(4):957–968.
  57. Popovic I, Heron B, Covacin C. *Listeria*: an Australian perspective (2001–2010). *Foodborne Pathogens and Disease*. 2014; 11(6):425–432. <https://doi.org/10.1089/fpd.2013.1697>
  58. Ramdas KE, Lyashchenko KP, Greenwald R, Robbe-Austerman S, McManis C, Waters WR. *Mycobacterium bovis* infection in humans and cats in same household, Texas, USA, 2012. *Emerging Infectious Diseases*, 2015; 21(3):480–483. <https://doi.org/10.3201/eid2103.140715>
  59. Ramees TP, Dhama K, Karthik K, Rathore RS, Kumar A, Saminathan M, Tiwari R, Malik YS, Singh RK. *Arvobacter*: an emerging food-borne zoonotic pathogen, its public health concerns and advances in diagnosis and control a comprehensive review. *Veterinary Quarterly*. 2017; 37(1):136–161. <https://doi.org/10.1080/01652176.2017.1323355>
  60. Rendle D, Page S. Antimicrobial resistance in companion animals. *Equine Veterinary Journal*. 2018; 50(2):147–152. <https://doi.org/10.1111/evj.12785>
  61. Reperant LA, Brown IH, Haenen OL, de Jong MD, Osterhaus AD, Papa A, Rimstad E, Valarcher JF, Kuiken T. Companion animals as a source of viruses for human beings and food production animals. *Journal of Comparative Pathology*. 2016; 155(1):S41–S53. <https://doi.org/10.1016/j.jcpa.2016.07.006>
  62. Rijks JM, Cito F, Cunningham AA, Rantsios AT, Giovannini A. Disease risk assessments involving companion animals: an overview for 15 selected pathogens taking a European perspective. *Journal of Comparative Pathology*. 2016;155(1):75–97. <https://doi.org/10.1016/j.jcpa.2015.08.003>
  63. Saleha A, Zunita Z. Methicillin resistant *Staphylococcus aureus* (MRSA): An emerging veterinary and zoonotic pathogen of public health concern and some studies in Malaysia. *Journal of Animal and Veterinary Advances*. 2010; 9(7):1094–1098. <https://doi.org/10.3923/javaa.2010.1094.1098>
  64. Shah AH, Saleha AA, Murugaiyah M, Zunita Z, Memon AA. Prevalence and distribution of *Arvobacter* spp. in raw milk and retail raw beef. *Journal of food protection*. 2012; 75(8):1474–1478. <https://doi.org/10.4315/0362-028X.JFP-11-487>
  65. Shaheen BW, Nayak R, Boothe DM. Emergence of a New Delhi metallo-β-lactamase (NDM-1)-encoding gene in clinical *Escherichia coli* isolates recovered from companion animals in the United States. *Antimicrobial agents and chemotherapy*. 2013; 57(6):2902–2903. <https://doi.org/10.1128/AAC.02028-12>
  66. Terpstra WJ. Human leptospirosis: guidance for diagnosis, surveillance and control. World Health Organization. 2003.
  67. Thoen CO, LoBue PA, Enarson DA, Kaneene JB, de Kantor IN. Tuberculosis: a re-emerging disease in animals and humans. *Veterinary Italia*. 2009; 45(1):135–181.
  68. van Knapen F, Overgaauw P. Dogs and Transmission of Infection to Man, “Respected Member of the Family?”. *In Zoonoses-Infections Affecting Humans and Animals*. Springer, Dordrecht. 2015; p. 575–585.
  69. Vouga M, Greub G. Emerging bacterial pathogens: the past and beyond. *Clinical Microbiology and Infection*. 2016; 22(1):12–21. <https://doi.org/10.1016/j.cmi.2015.10.010>
  70. Weiss RA, McMichael AJ. Social and environmental risk factors in the emergence of infectious diseases. *Nature Medicine*. 2004; 10(12):S70. <https://doi.org/10.1038/nm1150>
  71. Weller D, Andrus A, Wiedmann M, den Bakker HC. *Listeria booriae* sp. nov. and *Listeria newyorkensis* sp. nov., from food processing environments in the USA. *International Journal of Systematic and Evolutionary Microbiology*. 2015; 65(1):286–292. <https://doi.org/10.1099/ijs.0.070839-0>
  72. Wright JG, Tengelsen LA, Smith KE, Bender JB, Frank RK, Grendon JH, Rice DH, Thiessen AM, Gilbertson CJ, Sivapalasingam S, Barrett TJ. Multidrug-resistant *Salmonella Typhimurium* in four animal facilities. *Emerging Infectious Diseases*. 2005; 11(8):1235. <https://doi.org/10.3201/eid1108.050111>
  73. Wu X, Lu Y, Zhou S, Chen L, Xu B. Impact of climate change on human infectious diseases: Empirical evidence and human adaptation. *Environment International*. 2016; 86:14–23. <https://doi.org/10.1016/j.envint.2015.09.007>

\*\*\*\*