ISSN: 2536-7153 SJMLS

Sokoto Journal of Medical Laboratory Science 2024; 9(4): 151 - 168

SJMLS - 9(4) - 018

Emerging and Re-Emerging Bacterial Infections: An Overview

Faith Gbemisola Ademulegun[1*], Paulinus Osarodion Uyigue[1], Samson Ohwonohwo Onemu[1], Bola Ojo[2], Olabisi Adejibike Oduwole[1]
Achievers University, Owo, Ondo State [1], Federal Medical Centre, Ido-Ekiti [2]

Author for Correspondence: faithademulegun@gmail.com/+234-911-304-6652/+234-906-906-0305
https://dx.doi.org/10.4314/sokjmls.v9i4.18

Summary
Bacterial infections have been a major cause of morbidity and mortality for centuries, and they continue to evolve and pose new challenges to public health. In recent years, there has been an increase in the number of emerging and re-emerging bacterial infections, many of which are resistant to antibiotics and difficult to diagnose and treat. Examples of emerging bacteria include *Corynebactherium diphtheria*, Carbapenem-resistant Enterobacteriaceae (CRE), *vibrio vulnificus*, vancomycin-resistant *Staphylococcus aureus*, multidrug-resistant *Streptococcus pneunoniae*, Drug-resistant *Mycobacterium tuberculosis*. Examples of re-emerging bacteria include multidrug-resistant *Escherichia coli*, *Yersinia pestis*, *Salmonella* serovars, *Bartonella* spp, *Brucella hensalae*, *Neisseria meningitidis*, *Clostridium difficile.* The emergence and re-emergence of bacterial diseases are attributed to several factors, including antibiotic resistance due to the misuse of antibiotics, socio-demographic alterations, global development, human tour and conduct, ecological alteration, decreased vaccine uptake, microbial film formation, and invasion of microorganisms ecosystems. Various measures need to be implemented to address the prevalence of emerging and re-emerging bacterial infections in Nigeria. These encompass fortifying medical facilities, augmenting medical expertise, advancing monitoring systems, advocating immunization initiatives, executing efficient management strategies, and establishing a one-wellness approach to improve diagnostics skills.

Keywords: Emerge, Re-emerge, Bacterial Infections, One-wellness Concept

Introduction

Bacterial infections have been a significant public health concern throughout history. Around fifty years ago, many people believed that the age-old battle of humans against infectious disease was virtually over, and that humankind was the winner (Mukherjee, 2017). Over time, certain bacterial infections have emerged or re-emerged, posing new challenges to healthcare systems worldwide. These factors not only have a detrimental impact on the patients' health but impose a significant economic burden on both individuals and healthcare systems.

All infectious agents (bacteria, viruses, parasites, fungi) can emerge or re-emerge in human populations because they reproduce rapidly, mutate frequently, cross the species barrier between animal hosts and humans, and adapt easily to their new environments. Because of these traits, these infectious bacteria agents can alter their epidemiological and clinical characteristics (virulence and susceptibility to anti-infective drugs), thus exerting huge public health concerns in both developed and developing countries (WHO,2019). It is estimated that 73% of currently emerging and re-emerging pathogenic agents cause zoonoses (Yakubu *et al.*, 2011; Cantas & Suer, 2014). The increasing human population and fragmentation of natural habitats compels wildlife into significant contact, both directly and indirectly, with humans and their livestock or pets, resulting

in more opportunities for transmission of infection between and within populations (Arnold *et al*.,2016). It is estimated that the livelihood of more than 600 million people globally is livestock-dependent. These communities represent up to 70% of the marginalized and poor population that is most exposed to the risk of zoonoses, but which is typically isolated from the delivery of adequate healthcare (Ngutor, 2012).

Bacterial zoonoses represent a class of often-neglected human infections that may be responsible for a significant proportion of febrile illnesses without localizing features, especially in malaria-endemic areas of sub-Sahara Africa, where frequently they may be misdiagnosed as the more prevalent protozoan infections (Crump *et al*.,2013). Although there are no published estimates of incidence of fever of unknown origin (FUO) in Nigeria, the condition remains a challenging medical problem and reports have shown indications of common occurrence and subsequent misdiagnoses in aetiological determination (Oladosu and Oyibo, 2013; Kamani, *et al.*,2014). Notwithstanding the prevalence of FUO, potentially important fever-causing pathogens have not been investigated rigorously in many low- and middle-income nations, especially in rural locations, despite the apparent exposure of humans to animal reservoirs and vectors of zoonotic infections (Prasad *et al*.,2015).

It has thus been speculated that present and future generations may face the highest risk of exposure to zoonotic infections in human history, requiring us to address the impact this may have on life expectancy and quality of health (Yakubu *et al*, 2011; Cantas and Suer, 2014).

According to the US CDC, emerging bacterial infections are defined as infections whose incidence numbers in humans have increased in the past two decades or are appearing and affecting a population for the first time or introduced to a new geographical area, causing public health problems either locally or internationally (Mackey *et al*.,2014; Bloom *et al.*, 2017; US CDC, 2018).

Re-emerging bacterial infections can be defined as infections that were formerly under control but have returned; infections that were once serious health issues and then sharply declined but are reoccurring, posing a serious risk to a significant portion of the population; infections that have only impacted a small number of people in remote locations; infections that have previously been reported but have only recently been identified as distinct diseases; or infections caused by new mutant strains (US. CDC,2018) or are infections that have just lately been identified as different illnesses, or are infections that have historically existed but have been identified recently in limited numbers of isolated sites; or are infections brought on by novel mutant strains (Tabish *et al*.,2009)

These infections were formerly believed to be contained, but in recent years, they have returned for a variety of reasons, including host vulnerability, modifications to bacterial virulence, antimicrobial resistance, external variables, and the dissemination of antibiotic-resistant bacteria, The proliferation of new bacterial strains or the dispersal of already-existing bacteria into previously uninhabited areas might cause these diseases. They are frequently brand-new or have developed into complex forms. Emerging bacterial infections have become more common recently; many of these diseases are resistant to medications and can be challenging to identify and manage. Despite the tremendous advancements in vaccinations and antimicrobials, the challenge isn't over (Mukherjee, 2017).

History

At least 50 novel pathogenic agents have been discovered in the previous 40 years, with bacteria accounting for 10% of these pathogens. The impact of infectious diseases on people's well-being has been ongoing, with numerous cases documented over the years. Notable examples include the plague that decimated Europe in the Middle Ages and yellow fever that destroyed Napoleon's forces in Haiti in the early 1800s. Also, in 1918, influenza resulted in high pandemic mortality (roughly 50 million deaths) (Zumla & Hui, 2019).

The global incidence of infectious illnesses significantly decreased throughout the 20th century, especially in more developed nations, because of advances in public health understanding and initiatives. As a result of restricting contact with certain disease agents, improved hygiene, structural improvements to homes (such as netting-screened windows), and vector control reduced the spread of these infections. Furthermore, a period of global health advancement began with the 1928 discovery of penicillin and the production of many vaccinations, which greatly aided in the elimination of several infectious illnesses (Neiderud,2015).

Following World War II, numerous health institutions were founded, such as the World Health Organization (WHO) and the US Centres for Disease Control (CDC), which spearheaded numerous initiatives to eradicate particular infectious diseases (Melamed *et al.,*2018).

Epidemiology

Numerous factors related to climate, ecology, agriculture, and socioeconomics have been linked to the establishment and resurgence of bacterial zoonoses, posing an unknown threat to human health (Kamani *et al*., 2013). Neglected zoonotic diseases are regarded as prevalent in underdeveloped countries and have the potential to cause both outbreaks and more widespread epidemics (Welburn *et al*.,2015). The spreading pathways of these illnesses have been linked to many vectors and animals; however, a growing number of reports of unknown febrile illness underscore the pressing necessity for a thorough evaluation of additional reservoirs, vectors, and transmission phases that could raise the probability of getting infected. Because of their amazing ability to resurface even after being declared eliminated or managed, bacterial zoonotic diseases represent persistent and substantial risks to human health. Bacterial zoonosis can occasionally also appear suddenly in a previously undiagnosed location. Emerging bacterial infections have become more common; many of these diseases are resistant to medicines and can be challenging to identify and manage.

Examples of Emerging Bacteria:

1. **Carbapenem-resistant Enterobacteriaceae (CRE)**: Bacteria classified as carbapenem-resistant (CRE) are resistant to this class of medicines, which is typically reserved for the most serious cases. Healthcare environments are seeing an increase in CRE infections, which can be fatal and hard to cure. (Falagas *et al*.,2014). These bacteria have developed resistance mechanisms, such as the production of carbapenemases, that allow them to evade the effects of carbapenems (Martirosov, 2016).
2. **Drug-resistant *Mycobacterium tuberculosis*:** Tuberculosis (TB) is one of the most prominent bacterial illnesses that are resurfacing in Nigeria. TB mostly affects the lungs and is brought on by Mycobacterium tuberculosis. With an expected 407,000 new cases recorded in 2019 alone, Nigeria has one of the worst rates of tuberculosis in all of Africa (Ojewuyi *et al.,* 2021; Chijioke-Akaniro *et al*., 2022). The emergence of drug-resistant tuberculosis (TB) in Nigeria can be attributed to many factors such as insufficient healthcare infrastructure, inadequate diagnostic skills, restricted treatment accessibility, and the rise of antibiotic-resistant strains. Antibiotic-resistant microorganisms that cause tuberculosis (TB) are getting harder to treat. A kind of TB known as extensively drug-resistant tuberculosis (XDR-TB) is resistant to at least four of the most potent medicines, while multidrug-resistant tuberculosis (MDR-TB) is resistant to a minimum of two of the most effective medications.
3. ***Vibrio vulnificus****:* When humans consume infected seafood, V. vulnificus, a kind of bacterium frequently found in oysters and other shellfish, can lead to severe diseases. V. vulnificus infections can pose a special risk to those with compromised immune systems, such as those suffering from HIV/AIDS or liver illness (WHO 2019; CDC 2020).

Other emerging zoonoses are brucellosis, *Bordetella bronchiseptica* infections, arthropod-

transmitted rickettsioses, bartonellosis, and leishmaniasis.

These infections were once formerly controlled but have resurfaced in recent years due to various factors such as antibiotic resistance, poor hand hygiene, and the spread of drug-resistant bacteria.

Examples of Re-Emerging Bacterial Infections:

1. Tuberculosis (TB): The bacterial illness known as tuberculosis (TB) mostly affects the lungs, however it can sometimes spread to other body areas. Although it was formerly believed to be under control in many nations, the re-emergence of drug-resistant strains has caused a comeback in recent years. The World Health Organization (WHO) reports that 1.5 million people died, and 10 million new incidences of tuberculosis were reported globally in 2019(Global Tuberculosis Programme, 2022). Due to its high rate of transmission and difficulty of treatment, it poses a serious threat to human health. The WHO reports that 210,000 people died and 558,000 cases of MDR-TB occurred globally in 2019 (Global Tuberculosis Programme, 2022). Tuberculosis has re-emerged as a result of the evolution of the causative bacteria. Through mutation and prolonged use of antibiotics, the infection has developed resistance to the antibiotics used to treat TB, thereby promoting the spread of the disease.
2. Drug-resistant *Streptococcus pneumoniae*: Pneumonia, and other illnesses can be brought on by the bacterium Streptococcus pneumoniae. Treatment for these ailments has become increasingly challenging due to the emergence of drug-resistant strains of S. pneumoniae in the past few decades (Kellner & Low, 2020). The Centre for Disease Control and Prevention (CDC) reports that drug-resistant S. pneumoniae is a leading cause of invasive pneumococcal illness in the US and can be especially harmful to young patients, the elderly, and those with compromised immunity (CDC,2022).
3. *Neisseria gonorrhoea*: The bacteria *Neisseria gonorrhoea* is the underlying etiologic agent of gonorrhoea, a sexually transmitted illness (STI). Drug-resistant forms of *N. gonorrhoea* have surfaced in the past few decades, making treatment of this condition more challenging (Lovett & Duncan, 2019). CDC reported over 560,000 instances of gonorrhea in the US in 2020, and if the illness is not treated, it can have catastrophic consequences (CDC, 2020).
4. ***Pseudomonas aeruginosa***: Some individuals with compromised immune systems, such as those suffering from HIV/AIDS or cystic fibrosis, are susceptible to deadly infections caused by the bacterium Pseudomonas aeruginosa (Li *et al*., 2023). *P. aeruginosa* infections are often resistant to antibiotics and can be difficult to treat.
5. ***Staphylococcus aureus***: *S. aureus* is a type of bacteria that can result in severe illnesses. Methicillin-resistant *S. aureus*, otherwise called MRSA, is a bacteria that can cause serious and perhaps fatal infections. It is resistant to a wide range of medicines.
6. *Clostridium difficile* (CD): As an increasingly common illness linked to healthcare, CD mostly affects those who have taken antibiotics. Antibiotic abuse or overuse disturbs the balance of the gut microbiota, which permits the growth of *C. difficile* resulting in colitis and severe diarrhoea (Day *et al*., 2012; Chomel, 2014**).**
7. *Bacillus anthracis:* The illness known as anthrax is a global health concern because of its high fatality rate in cattle and wildlife, underreported instances, and potential use as a bioterrorism agent. The World Organization Animal Health also classifies it as a disease that should be taken seriously. December 31, 2004, when the last outbreak was reported, the re-emergence of anthrax was confirmed in Nigeria thirty-one days after an epidemic was declared in Northern Ghana.
8. *Corynebacterium diphtheriae*: Nigeria has also recorded an unusual increase in cases of diphtheria across several states. From 30 June to 31 August 2023, 5898 suspected cases were reported from 59 Local Government Areas (LGAs) in 11 states (WHO,2023). The bacteria Corynebacterium diphtheriae is the primary cause of the extremely infectious vaccinable diphtheria and can be deadly in 5–10% of cases, with a greater death rate in adolescents. WHO's most recent risk assessment

of the diphtheria outbreak in Nigeria has maintained the risk as high at the national level, and low at the regional and global levels. Symptoms often come on gradually, beginning with a sore throat and fever. In severe cases, the bacteria produce a poison (toxin) that causes a thick grey or white patch at the back of throat. This can block the airways, making it hard to breathe or swallow, and also creates a barking cough. The neck may swell in part due to enlarged lymph nodes. A contributing factor to the resurgence of illnesses like whooping cough caused by *Bordetella pertussis* and *Corynebacterium diphtheria* is insufficient population immunization. When the proportion of immune individuals in a population drops below a particular threshold, introduction of the pathogen into the population leads to an outbreak of the disease.

Public health measures such as vaccination response, enhanced surveillance for early case detection, case management and risk communication coordinated by the Nigeria Centre for Disease Control (NCDC), in collaboration with WHO and other partners, are being implemented in response to the outbreak. It is well recognized across the globe that animals such as dogs, goats, rats, cows, pigs, and sheep excrete the bacteria in their urine, which remain viable in the surroundings for decades. Nonetheless, there have been relatively little efforts to look into how rodents may have contributed to the disease's distribution in Nigeria; the most recent report on the subject dates back to 1990 (De Vries *et al*.,2014).

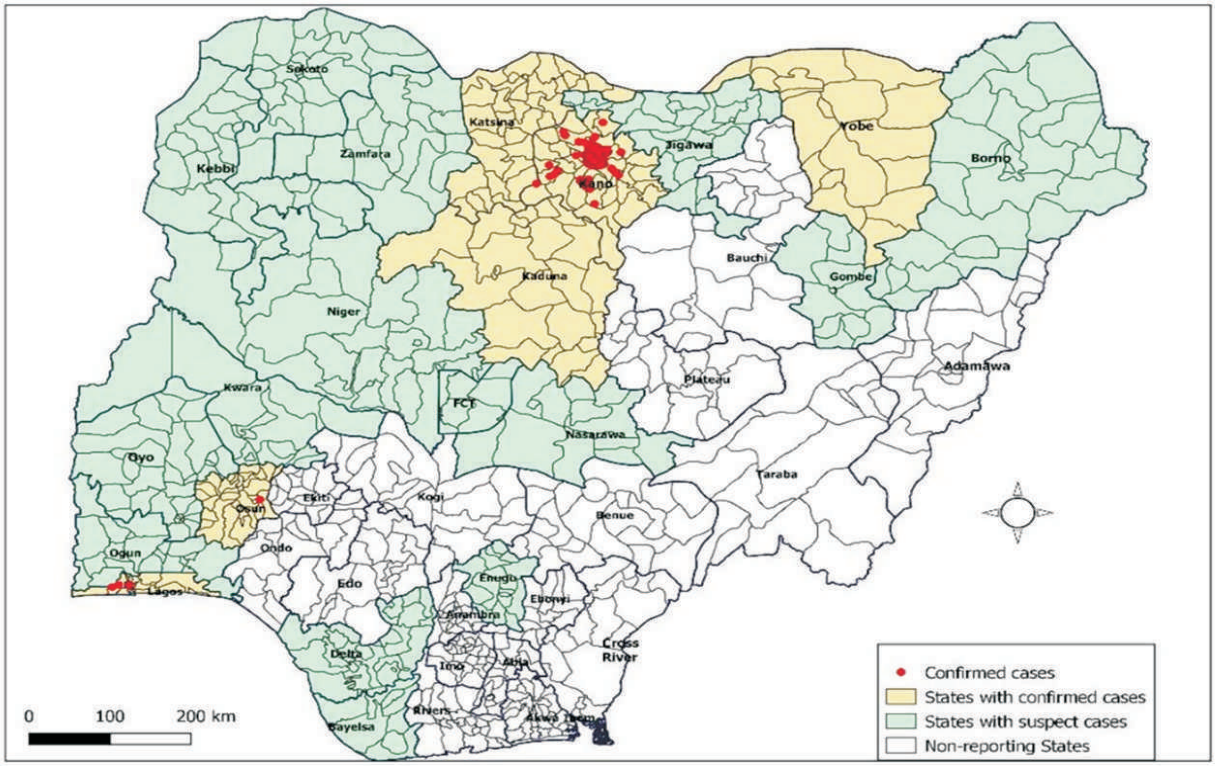

Figure I: **Distribution of Diphtheria cases by state in Nigeria from Epi week 19, 2022 to Epi week14, 2023**

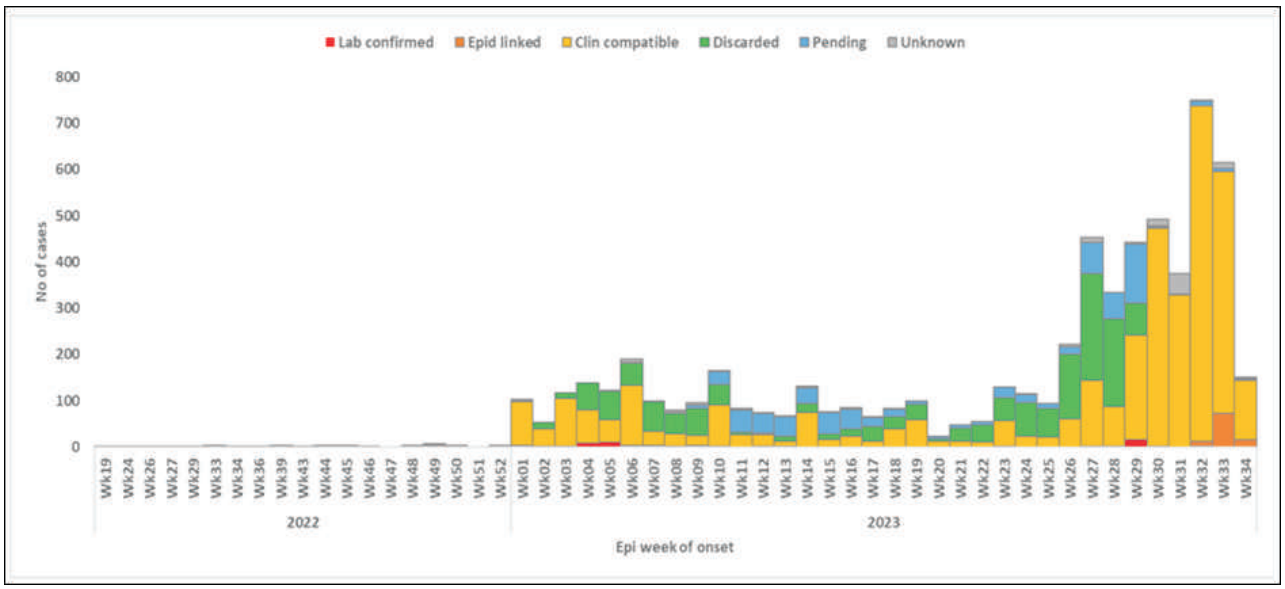

Figure II: **Diphtheria cases by year/epi-week in Nigeria, 1 May 2022 – 27 August 2023**

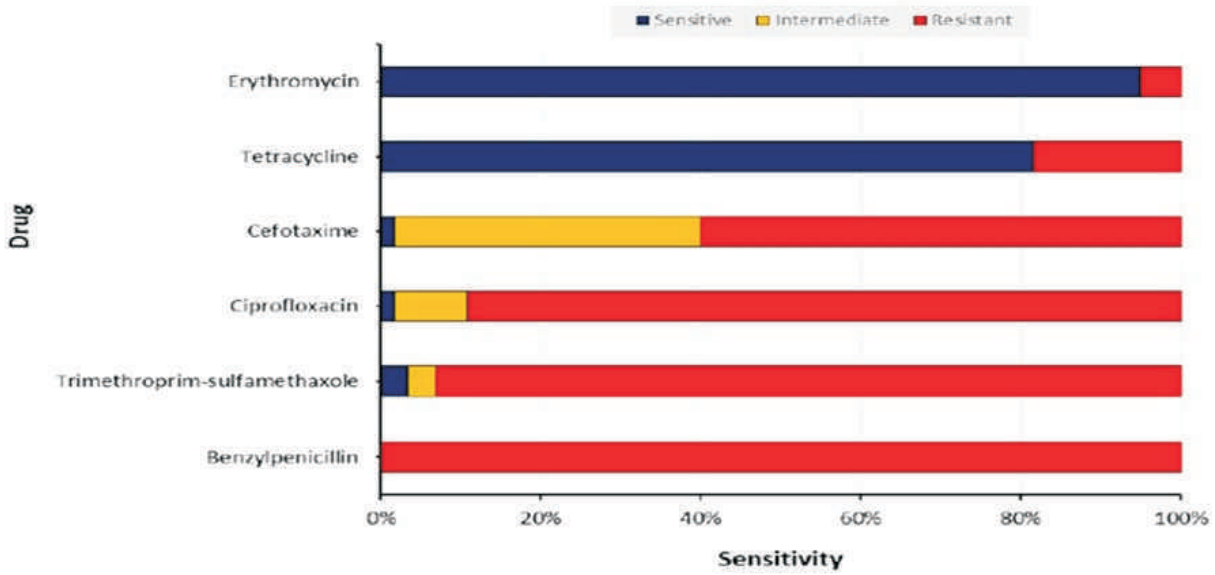

Figure III: Drug sensitivity results of toxigenic Corynebacterium diphtheriae isolated in Nigeria, May2022– July, 2023 (Source: Nigeria Centre for Disease Control and Prevention, 2023)

Factors Contributing to the Emergence and Re-Emergence of Bacterial Infections

The higher incidence of bacterial infections that emerge and reemerge is caused by many variables, which include increased international travel, urbanization, changes in human lifestyle, increased global population, climate change (Macke *et al.,*2014; Bloom *et al.*,2017) emigration, animal migration, ecological disturbance, habitat invasion, human leisure activities, and a rise in interactions between animals and humans for mutual benefit (Allen *et al.*, 2017). A number of these recently discovered infectious illnesses have changed epidemiological and clinical features, raising serious implications for society in both industrialized and developing nations (Allen *et al.*, 2017). The majority of newly discovered bacterial illnesses have been linked to bacteria that have long existed in our surroundings which humans have just lately come in contact with or have not yet been able to identify. Listed are a

few factors thought to promote the development and dissemination of new and reemerging bacterial diseases.

1. **Riskier Human Access To Bacteria**
   There are endless prokaryote species in our surroundings, some of which may harm humans. Since the majority of newly discovered bacterial illnesses are animal-derived, they are referred to as zoonoses (Vouga & Greub,2016).

   Cuts or scuffs, eating infected food, touching corpses or feces-infested environmental sources including water sources or soil, bacteria-contaminated water, and arthropod vectors are among the channels through which zoonotic pathogens may infect people (Chikeka and Dumler, 2015). The equilibrium between the single-celled organisms, human beings, and the environs has become unbalanced leading to increased bacteria-human and human-human contact.

2. **Resistance to antibiotics**
   Antibiotic resistance is a significant concern associated with bacterial infections, that have been progressively escalating recently. This has culminated in individuals infected with bacteria resistant to antibiotics, leading to extended hospitalizations and the necessity for expensive and multiple therapies. Furthermore, the excessive use and improper application of antibiotics in humans and animals have significantly contributed to the formation and proliferation of antimicrobial-resistant microorganisms. The efficacy of widely utilized antibiotics has diminished, complicating the efficient treatment of bacterial illnesses. The extensive use of medicines for viral diseases, including the common cold and influenza, has exacerbated resistance to medication in bacteria. Moreover, the resurgence of some bacterial illnesses that were formerly manageable has exacerbated the worldwide medical problem. New drug-resistant strains of TB and pneumonia-causing bacteria have reemerged, presenting a significant danger to society. Despite initiatives to combat antibiotic resistance, including the creation of novel pharmaceuticals and the enforcement of infection control protocols in medical environments, the issue remains prevalent and needs continuous awareness and intervention (Vouga & Greub, 2016). Besides antibiotic resistance, the development of bacterial microbiota has been a considerable obstacle in the management of bacterial illnesses. Biofilms are organized assemblies of bacteria that attach to surfaces and can develop on healthcare devices, implants, and in many regions of the body. These biofilms create a protective milieu for bacteria, enhancing their resistance to drugs and allergic reactions. The intrinsic structure of biofilms renders them challenging to eradicate, hence facilitating the maintenance and occurrences of infectious bacteria. Emerging and reemerging bacterial infections, driven by antimicrobial resistance and the buildup of biofilm represent a significant challenge in the realm of health (Malik *et al.,* 2023).

3. **Socio-Demographic alterations**
   The effective development of a new disease typically necessitates its swift spread throughout the human race. The rise in the number of people has proven a crucial element in the development of diseases, the plague outbreak of the fourteenth century and during the Second World War, there was spread of scrub typhus, caused by *Orientia tsutsugamushi.* The rising number of people, particularly in hospital environments, together with the heightened utilization of invasive techniques, such as catheters, has led to a rise in nosocomial infections, including *Clostridium difficile* infections, that pose a considerable danger to the public's health (Vouga & Greub,2016).

4. **Global Development and Travel**
   Contemporary populations have experienced both numerical growth and an accelerated pace of movement throughout the globe, facilitating the swift geographical spread of infectious agents. Globalization

has resulted in a significant rise in global commerce and shipping, migration of people, and a decrease in travel costs, thereby increasing the frequency of vacation trips to beautiful locations. Thus, leading to an increased transportation of commodities and food items, which may introduce tropical illnesses.

5. Human Tour and Conduct

The annual number of individuals travelling globally is rising, with an increased propensity for travels to distant regions of the globe. These frequently exhibit unknown health issues alongside inadequate medical treatment. Numerous tourists remain oblivious to possible dangers in various regions globally and fail to implement requisite measures such as vaccinations and preventative medication. These newly found diseases have long existed but haven't been identified by the medical personnel in epidemic regions. Due to the capacity to travel quickly with the aid of airlines, previously unknown illnesses are disseminated speedily. Recreational events have expanded before independence due to personal growth spurred by time flexibility and greater income. Two (2) research studies reported that hiking puts people in danger of arthropod-transmitted illnesses such as Lyme disease caused by *Borrelia burgdoferi*, Rocky Mountain spotted fever, and Chlamydia (Parola *et al.,* 2013). Likewise, individuals own a greater diversity of pets besides cats and dogs, including reptiles, exotic fish, and guinea pigs, which serve as reservoirs for an additional array of bacterial diseases.

6. Ecological Alterations

In the past five (5) decades, humans have experienced climatic shifts that have profoundly altered our biosphere. Contemporary milder winters generally augment rodent numbers over the summer, resulting in heightened interactions with people. Climate changes likely significantly contributed to the emergence of V. cholerae O139. Likewise, alterations to the surroundings resulting from industrialization, including forest clearing, planting trees, the construction of dams, and agricultural expansion, transform habitats and their relationship with humans. The presence of Water dams enhance the number of arthropods, agricultural land lures fauna; and it is widely recognized that planting of trees in the regions surrounding a city/town led to the emergence of Lyme disease.

7. An Increase of Highly Pathogenic Bacterial Strains and Opportunistic Infections

Due to the swift spread of these bacteria among in-patients, and the wider community over the past four decades, there has been a proliferation of multidrug-resistant species, including MRSA, multidrug-resistant or extensively resistant tuberculosis, extended-spectrum β-lactamase *E. coli,* vancomycin-resistant enterococci and carbapenemase Gram-negative bacteria. In addition, there have been significant concerns about the development of highly pathogenic bacterial strains and bioterrorism agents, especially after the 2001 anthrax attack (Barras & Greub, 2014). Cancer, chronic illnesses including renal damage, type 2 diabetes, and organ transplant treatments have improved odds of survival due to medical improvements causing emerging bacteria to infect populations with impaired immunity, such as the potentially lethal bacillary angiomatosis caused by *Bartonella henselae* or *B. quintana* in HIV patients.

8. Invasion of Microorganisms Ecosystems

Numerous novel infectious diseases emerge when zoonotic pathogens from animal reservoirs are transmitted to human populations. As the human demographic continues to grow in both density and geographic distribution, the likelihood that humans will engage in proximate interactions with animal species that may serve as reservoirs for pathogenic agents escalates. When this variable is integrated with augmentations in human population density and mobility, it becomes readily apparent that this amalgamation constitutes a significant risk to public health. As the

planet's climate undergoes warming and ecosystems are modified, pathogens may disseminate into previously unexposed geographical regions. For instance, elevated temperatures facilitate the proliferation of mosquitoes and the pathogens they carry, enabling them to extend their distribution into areas where they have historically been absent.

9. **Decreased Vaccine Uptake**
A supplementary element that may contribute to the resurgence of a disease is a reduction in vaccination rates, such that even in the presence of a safe and efficacious vaccine, an increasing proportion of individuals opt against immunization.

Wildlife Vectors and The Significance of Arthropods In Disease Spread

Agricultural livestock and various animal reservoirs are recognized as pivotal components in the modern dissemination of bacterial zoonoses. This phenomenon encompasses passive transmission mechanisms including bites and scratches, alongside environmental contamination (Abiayi *et al.*,2015). Furthermore, the transmission of pathogens via vectors is correlated with bacterial zoonotic infections. An augmented potential for zoonotic diseases can ensue from this proliferation, primarily due to heightened interactions between humans and animal habitats. (Wu *et al.,*2017). Emerging zoonotic diseases such as brucellosis, infections caused by *Bordetella bronchiseptica*, arthropod-borne rickettsioses, and bartonellosis have been documented worldwide (Santos *et al.,*2013; Kolo *et al.,*2016; Ng-Nguyen *et al.,*2020). The extensive presence of zoonotic pathogens within arthropods, and domestic and wild fauna, constitute a substantial reservoir for these pathogenic agents. Consequently, a consistently elevated risk of bacterial transmission between infected and susceptible animals, harbouring the possibility of transmission to humans.

In Nigeria, bacterial zoonoses are frequently classified as occupational diseases (farmers, nomads, hunters, veterinarians, pet merchants, wildlife personnel, families with companion animals, butchers, and workers in slaughterhouses), where close interactions with animals and exposure to their biological materials and fluids are identified as significant risk factors for infection (Abiayi *et al.*,2015). The nearness to animals, attributable to an individual's lifestyle or occupational role, is generally correlated with the resurgence and increased risk of contracting bacterial zoonoses (Cantas & Suer, 2014).

The etiological agent of cat-scratch disease, *Bartonella henselae*, is one of the estimated 20% of animal-inflicted bites that infect humans. Cats as pets have been insufficiently studied as a likely host of this pathogen in Nigeria (Maryam *et al*., 2014).

Another possible vector for bartonellosis in Nigeria is the blood-feeding bat fly (Kamani *et al.,* 2014). Bats are considered hosts of various pathogenic bacteria, yet Nigerian studies primarily focus on their role in zoonotic viral infections. The Nigerian Health Ministry's bat surveillance aims to detect both new and existing viruses in bats (Bai *et al*., 2018). In various Nigerian communities, bats inhabit areas close to humans and may play unrecognized roles in transmitting *Bartonella* and other zoonotic bacteria. *Bartonella* is also linked to rodents, which are common reservoirs and are often in close contact with the human population, especially in congested rural settings (Gutiérrez *et al*., 2015).

Rodents serve as hosts for numerous zoonotic bacteria, including *Yersinia pestis* and *Rickettsia typhi*, with the latter being responsible for murine typhus. *Y. pestis* has been documented in over 50 rodent species inhabiting natural plague foci across the globe. Importantly, rats are acknowledged as crucial reservoirs of *Leptospira interrogans*, which transmits leptospirosis through contaminated urine. Common domesticated animals, such as dogs, cattle, pigs, sheep, and goats, also excrete the bacterium in their urine, leading to prolonged environmental contamination following infection (De Vries *et al*.,2014).

Domestic animals serve as significant reservoirs for zoonotic diseases such as brucellosis and Q fever caused by a bacterium *Coxiella burnetti,* particularly through ruminants (Ducrotoy *et al.,*

2014). Research conducted in Oyo State, Nigeria suggests that cattle may act as hosts for Q fever (Reye *et al*., 2012). Additionally, sheep, goats, cattle, pigs, poultry habour pathogenic serotypes of food-borne zoonotic pathogens. Non-typhoidal salmonella infection outbreak from camels has been linked to the genomic sequencing of *Salmonella enterica* Eko isolates, highlighting their contribution with cattle to infection rates (Leekitcharoenphon *et al*., 2016).

In developing countries, where the sources and transmission routes of salmonellosis are poorly understood, common food-producing animals are regarded as the primary reservoirs of *Salmonella*. In Nigeria, chickens have emerged as prominent carriers of diverse *Salmonella* serovars, including Hadar, renowned for their prowess in colonizing poultry (Kagambèga *et al*., 2013; Raufu *et al*., 2014). Additionally, the spread of *Salmonella* has been linked to domestic reptiles, such as wall geckos, hinting at a possibly evolving role of these creatures as carriers of the infection.

Ticks, Fleas and Other Ectoparasites

Tick-borne pathogens are major causative agents of illness in people and animals. Ticks, recognized as vectors of Q fever since the 1930s, rank next to mosquitoes in the transmission of pathogenic pathogens, notably *Coxiella burnetii.* Current research indicates that ticks are effective vectors for *C. burnetii* (Elsa *et al*., 2015). Recent studies have reported fleas, traditionally associated with *Yersinia pestis*, as potential vectors for zoonotic agents like *Rickettsia typhi, Rickettsia felis,* and *Bartonella henselae* (Karmani *et al*., 2013). A 2011 study in Nigeria revealed *Bartonella* species in 28% of various ectoparasites, with some requiring further evaluation for pathogenicity (Karmani *et al*., 2013). The list of recognized *Bartonella* vectors is expanding, now including additional blood-sucking arthropods like sand flies, lice, and mites as intermediaries among mammals and humans.

The Function of Mosquitoes and Other Diptera in the Emergence of Diseases

Recent data reveal mosquitoes serve as vectors for *Rickettsia spp*. in West Africa. *Ae. albopictus*, an invasive species in Nigeria, predominates over *Ae. aegypti*, the vector responsible for yellow fever. Distribution study reveals that it is widespread in southern Nigeria (Adeleke *et al.,* 2015). *Ae. albopict*us was initially detected in Nigeria in 1991 and subsequently in 2006, it was discovered in Gabon, with its involvement in arboviral transmission currently under examination. To this day, researchers in Nigeria still don't know which mosquito species are responsible for transmitting rickettsial zoonoses. It is well-known that cockroaches and other arthropods may serve as mechanical vectors for zoonotic pathogens all over the world.

Table 1: Transmission Routes, Vectors and Hosts for Some Bacteria Zoonotic Diseases in Nigeria.

Zoonosis	Transmission Routes	Vectors	Hosts
Bartonellosis	Scratches or bites of cats and other animals	∗Bat flies ∗Human, cat and dog fleas Ectoparasites of rats and mice Sand flies, ticks	∗Cats ∗Bats Rats and mice
Brucellosis	Handling of animals Raw or unpasteurized milk		Livestock and wild animals
Leptospirosis	∗Contact with animals or tissue and body fluid of animals via broken skin	∗Ticks	Wild and domestic animals

	Food-borne Contaminated water and soil		∗Rats, other rodents
Q fever	Raw or unpasteurized milk ∗Inhalation of aerosolized organisms	Ticks ∗Filth flies	Livestock
Rickettsiosis		∗Fleas Ticks ∗*Ae. albopictus* ∗*An. gambiae*	Rodents
Salmonellosis	Food-borne Contact with animals Contaminated water		Livestock, camels ∗Household and captive reptiles Amphibians
Yersiniosis/ Plague	∗Food-borne Contact with animals Inhalation of aerosolized organisms	∗Human and cat fleas Other fleas	Rodents Livestock

(Omitola and Taylor-Robinson, 2020)

Management of Bacterial Infections

The laws of developed nations serve to shield the populace from infectious diseases. Usually, public health measures entail removing the pathogen from its source or its transmission pathway. Clean water supply, efficient effluent disposal management, and the start of food safety, animal management, and immunization programs are some examples of these steps.

1. **Clean Water Supply**

   Numerous microorganisms responsible for gastrointestinal disorders, such as those causing cholera and typhoid fever, are disseminated through water. Vaccination is recommended for travelers to impoverished nations for these illnesses. This is often superfluous in the United States and other industrialized nations, as the water for domestic utilization is cleaned before entering households. Purification techniques encompass sedimentation, filtering, and chlorination. Water sourced from wells or springs for residential use is often safe if regulations regarding proximity to sewage disposal systems are adhered to, still, this water should undergo routine test. In the event of failures in a purification system or when the system is inundated (such as during atypical flooding), drinking water may become unsafe and it is advised that such water should undergo boiling or chlorination prior to consumption. Due to the fact that gastrointestinal infections are usually excreted in feces, public water sources must be protected from sewage pollution. Municipal water is often analyzed for coliform organisms, which are harmless microbes indicative of sewage pollution and components of the normal gut flora. The process is essential because when water harbors diseases and poses probable risks, these pathogenic organisms are typically present in such minuscule quantities that are minute to detect.

2. **Waste Water Management**

   Sewage includes wash water, water from toilets, and storm run-off. These fluids may harbor pathogens for many waterborne diseases, including giardiasis and hepatitis A; therefore, to ensure public safety, the U.S. government (and the governments of other developed countries) requires the treatment of sewage to eliminate pathogens. The minimally acceptable level of treatment involves the collection and sedimentation of sewage waters, separating solid matter (sludge) from the liquid (effluent)

portion of sewage. The effluent is chlorinated to kill pathogens before it is released to rivers or lakes. The sludge is burned or dumped. More advanced methods of treatment use a secondary treatment following this primary treatment. The effluent is transferred to tanks containing a population of microorganisms that decompose more than 90 percent of the organic wastes and eliminate pathogens by competition (this is another example of the important role of microorganisms in preventing disease). The resulting effluent is chlorinated before it is released to the environment. Some sewage treatment plants include a tertiary treatment that involves additional chemicals that also eliminate pathogens.

3. Food Safety Programs

There is plethora of rules, inspection schedules, and standards in the US that pertain to the processing, storage, and delivery of food. Inspections of meat processing plants are conducted frequently to identify and remove any sick animals, check that all procedures, including butchering and freezing, are up to code, and look for signs of microorganisms and chemical contamination. The inspection process is the same for grocery stores, cafes, and eateries. Before being sold, pasteurized milk is dated and tested for impurities on a regular basis. Consistent and thorough inspections ensure that the standards for canning and food preservation remain elevated. When contamination is detected in a batch, officials recall the entire batch and inform the public via media outlets.

4. Animal Management Initiatives

Animals serve as vectors and reservoirs for infections thereby significantly contributing to the transmission of several illnesses that affect human well-being. Assessing farm animals for tuberculosis (attributed to the bacterium *Mycobacterium bovis*) and brucellosis (an infection resulting in accidental abortions in livestock and inflammation of organs in people) has mitigated the risk of disease transmission via contaminated dairy and meat products. Pet owners must present proof of their pet's rabies vaccinations prior to registration. Since most rabies cases in the U.S. stem from wild and wandering creatures, authorities are compelled to restrain and eradicate these animals. Numerous illnesses, including the bubonic plague, are conveyed by rats, rendering the management of rat populations, especially in urban areas, an essential component of public health initiatives. Insects serve as vectors for several illnesses, with malaria being a prominent example. Controlling insect-borne illnesses can be accomplished by removing breeding grounds, such as stagnant water, and using insecticides. Moreover, foreign animals must undergo testing for particular illnesses to avert their entry into the nation.

5. Monitoring Systems

It is important to highlight that microorganisms are linked not just to infectious diseases, but also to noninfectious conditions like cancer and asthma. Creating strong monitoring networks to track the rate, frequency, distribution, and resistance to drug patterns of bacteria-related illnesses is essential for timely identification and prompt action. The application of geomatics and satellite imagery as analytical instruments to enhance our comprehension of the interactions between the host organism, its surroundings, and diseases. Therefore, the connection between the surroundings and the transmission of diseases warrants investigation to determine the most effective strategies for preventing disease dissemination within the environment (Orusa *et al*.,2020; Carella *et al*.,2022).

6. Immunization Initiatives

Creating potent shots can aid in preventing illnesses or mitigating their severity. Immunization initiatives aimed at exposed groups can substantially reduce the incidence of developing and re-emerging bacterial diseases. The significance of immunization for personal well-being is crucial for the safety of society. If a specific threshold proportion of a population is resistant to an illness, the infectious agent responsible for that sickness will be

incapable of proliferating within the population. This occurs because after the diseased host either recovers or succumbs, there will be an insufficient number of fresh, vulnerable hosts for the virus to attack. Ultimately, the disease ceases to propagate and may be eradicated or there will be a reduction in the disease spread.

7. **Antibiotics Usage Management**
Advocating for safe antibiotic utilization via awareness, rules, and laws helps mitigate the rise of antibiotic-resistant microorganisms. Establishing drug management initiatives in patient management can enhance drug prescription practices and reduce drug resistance. The ineffectiveness of conventional antibiotics and existing treatment modalities demands the innovation of new antibacterial, antiviral, antiparasitic, and antibiofilm medications. Spending money on high-quality clinical trials to determine the exact therapeutic importance of newly discovered bacteria, provide reliable diagnostic resources, and evaluate the efficacy of antibiotic therapies is necessary to avoid unnecessary overuse of these drugs. As an additional preventative step, antibiofilm coatings have demonstrated potential in preventing bacterial adhesion and biofilm development. Coating hospital areas and equipment can help prevent biofilm development early.

One-Wellness Strategy

The ecology and etiology of emerging infectious diseases (EIDs) and re-emerging infectious diseases (REIDs) are intricate, necessitating a comprehensive interdisciplinary approach to mitigate disease effects. The term 'One-Wellness' has been introduced as a strategy to tackle this issue (Bhatia, 2019). The prioritization of diseases and subsequent allocation of resources in Nigeria hinges on the assessment of health impacts on both human beings and animal population. Initial studies highlighted the critical collaboration between clinical and veterinary experts in managing zoonoses that harm the societal health in Nigeria (Ahmed *et al*., 2019). The intricate connections among human, animal, and environmental health have led to the emergence of the 'One Wellness' framework. In this model, several tiers of government work together with a wide range of specialists—from doctors and veterinarians to ecologists and public health advocates—to achieve better public health results. Discovering multidisciplinary synergies, especially between veterinarians and doctors, remains a challenge in Nigeria, despite worldwide support for the One Health concept. A major roadblock to successfully combating zoonotic illnesses in the country is this gap. To help domestic one wellness programs get off the ground, the US Centres for Disease Control and Prevention initiated the Animal-Human Interface Project (AHIP) in Nigeria in 2009. This program provides training and interactions. The AHIP was a major facilitator of many joint initiatives with regional organizations to combat viral zoonotic illnesses. This attention is likely because viral zoonoses have more far-reaching political and economic consequences, as shown by the COVID-19 pandemic in Nigeria and the Ebola outbreaks (Obilade, 2015; Omoleke & Saidu, 2016). Researchers will be able to carry out strong investigations that provide definitive results through international cooperation, which is crucial because industrialization has accelerated the spread of infectious illnesses.

The One-Wellness strategy advocates for farm-level interventions to address food-borne animal diseases. This includes vaccination, immune stimulants, probiotics, animal care policies, and measures against antibiotic resistance. In Nigeria, the execution of these strategies encounters problems, such as continuity stemming from the dissolution of health care initiatives. Additionally, the culling of livestock and compensating farmers has not been effective in Nigeria, unlike in developed countries. The majority of the farmers are reluctant to incur losses to the infection control, particularly Fulani pastoralists, However, changing lifestyles within rural societies may increase their readiness to participate in subsequent animal wellness. Also, birthing the NCDC promotes the communication of knowledge and thoughts among these professions, thereby enhancing societal health.

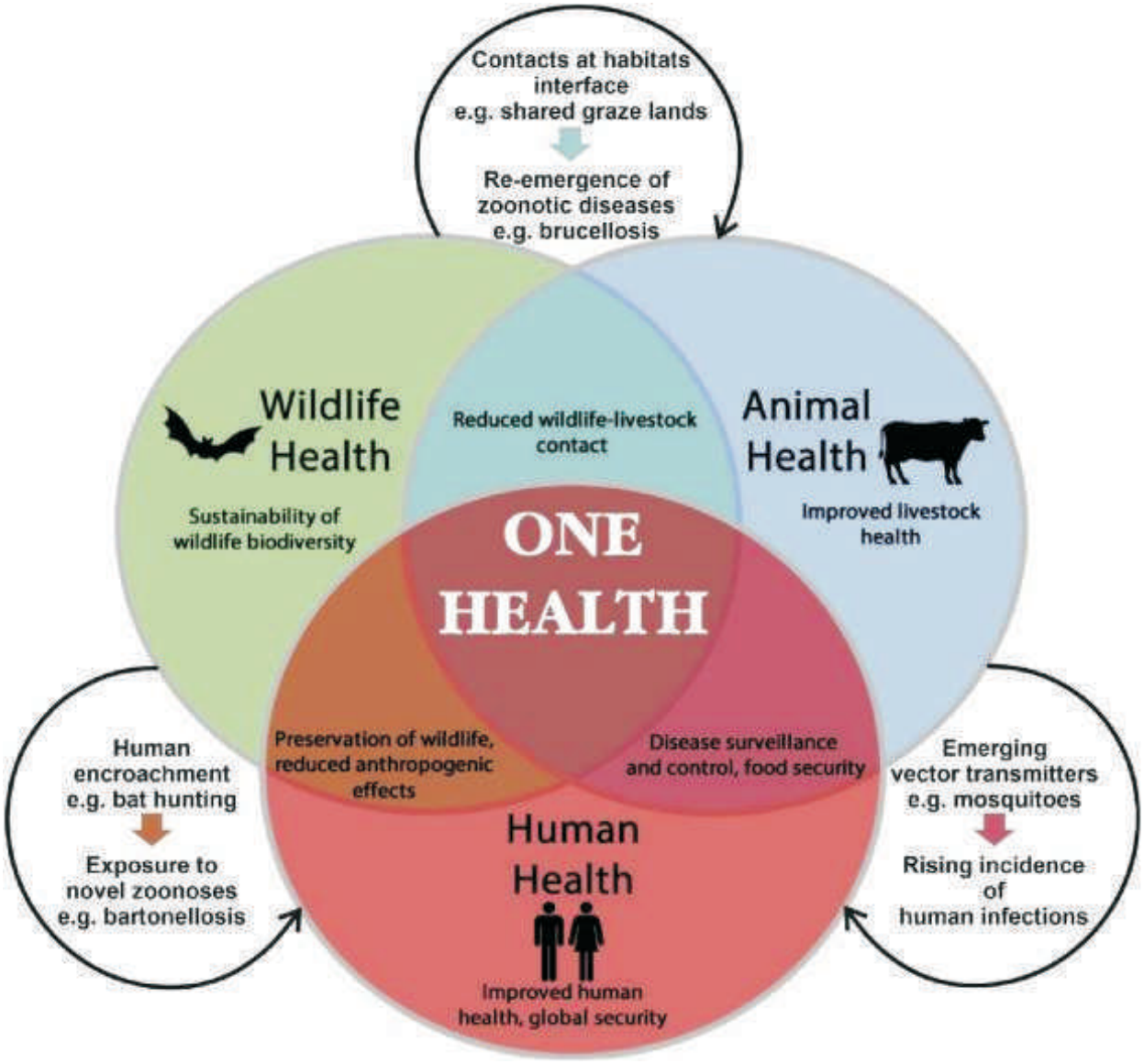

Figure 1V: Schematic representation of the one health concept (Omitola and Taylor-Robinson, 2020).

Conclusion

There is a deficiency of epidemiological data and monitoring for bacterial zoonoses, impeding the progress of One Wellness. This deficit hinders collaboration efforts across pertinent fields and trained experts, including veterinarians and physicians. Nigeria has identified several species and types of both prevalent and uncommon pathogenic zoonotic bacteria in vectors and animal reservoirs, while evidence about their potential effects on human well-being is lacking. A significant information deficit about bacterial zoonoses in Nigeria exists, requiring resolution for effective subsequent healthcare measures. Policies must incorporate a One Wellness concept and revise investigation and diagnostics protocols within the Nigerian medical sector, guaranteeing that diagnostic assessments by clinicians and veterinary doctors include zoonotic infections to improve disease management.

Recommendations

- Greater interaction among healthcare and veterinary specialists is crucial for diagnosis, research, surveillance, and control zoonotic diseases in Nigeria.
- The incorporation of health policies across all sectors is highly recommended. The Government should emphasize financing for public health in both human and animal care fields to enhance medical services, equip healthcare facilities, train employees for

quick diagnosis, and also differentiate zoonotic illnesses from other febrile cases.
- Enhancing public awareness regarding emerging bacterial diseases and to deliver a scientifically substantiated message. This will ensure that individuals appropriately seek medical care following exposure and adhere to preventive precautions.
- International collaborations are of utmost importance because of globalization.
- Policies should be made against the purchase of unprescribed drugs.
- Allocation of resources for quality clinical studies

Conflict of Interest

Authors hereby declare no conflict of interest

References

Abiayi, E.A., Inabo, H.I., Jatau, E.D., Makinde, A.A., Sar, T.T., & Ugbe, D.A. (2015). Knowledge, attitudes, risk factors and practices (KARP) that favor *Leptospira* infection among abattoir workers in North Central Nigeria. *Asian Journal of Epidemiology;* **8(4):**104–113.

Adeleke, M.A., Sam-Wobo, S.O., Garza-Hernandez, J.A., Oluwole, A.S., Mafiana, C.F., & Reyes-Villanueva F. (2015). Twenty-three years after the first record of *Aedes albopictus* in Nigeria: its current distribution and potential epidemiological implications. *African. Entomology;* **23(2):**348–355.

Ahmad, I. A., Muftau, O., Ahmed, T. A., Bamidele,F. & Ibrahim, H.(2023). The re-emergence of anthrax in Nigeria. *International Journal of Infectious Diseases One Health:* 100010. https://doi.org/10.1016/j.ijidoh.2023.100010

Ahmed N., Ahmed S. & Sami, A.S. (2019). Adverse health events after natural disasters and the 'One Health' approach: Animals as vectors for human disease. *Journal of Infectious Disease and Health*; **24**:177–178.

Allen, T., Murray, K.A., Zambrana-Torrelio, C., Morse, S.S., Rondinini, C., Di Marco, M., … & Daszak, P.(2017). Global hotspots and correlates of emerging zoonotic diseases. *Nature Communications*; ***8:*** 1124.

Arnold, K.E., Williams, N.J. & Bennett, M. (2016). 'Disperse abroad in the land': The role of wildlife in the dissemination of antimicrobial resistance. *Biology Letters;* **12**:20160137.

Bai, Y., Osinubi, M.V., Osikowicz, L., McKee, C., Vora, N.M. & Rizzo, M.R.(2018). Human exposure to novel *Bartonella* species from contact with fruit bats. *Emerging Infectious Diseases;* **24(12):**2317–2323.

Barras, V. & Greub, G. (2014). History of biological warfare and bioterrorism. *Clinical Microbiology and Infection*; **20**: 497-502.

Bhatia, R.(2019). Implementation framework for one health approach. *Indian Journal of Medical Research;* **149**:329–331.

Bloom, D.E., Black, S. & Rappuoli, R. (2017). Emerging infectious diseases: A proactive approach. *Proceedings of the National Academy of Sciences of the United States of America*; ***114:*** 4055–4059.

Cantas, L., & Suer, K. (2014). Review: the important bacterial zoonoses in "One Health" concept. *Frontiers in Public Health;* **2**: 144.

Carella, E., Orusa, T., Viani, A., Meloni, D., Borgogno-Mondino, E. & Orusa, R. (2022). An integrated, tentative remote-sensing approach based on NDVI entropy to model canine distemper virus in wildlife and to prompt science-based management policies. *Animals*, ***12***:1049.

Centers for Disease Control and Prevention. (2020). Multidrug-resistant tuberculosis (MDR TB). Retrieved from <https://www.cdc.gov/tb/publications/factsheets/mdrtb.html. Accessed 23 November 2023.

CDC. (2020). Carbapenem-resistant Enterobacteriaceae (CRE). Retrieved from <>. Accessed 23 November, 2023.

Chikeka, I. & Dumler, J.S. (2015). Neglected bacterial zoonoses. *Clinical Microbiology and Infection;*21: 404-415.

Ojewuyi. A.R., Odeyemi, A.O., Odeyemi A.O., Olotu, A.A., & Oladipo, T. (2021). Prevalence of rifampicin-resistant tuberculosis and its associated factors in a tertiary health care center, South-west Nigeria: A 5-year review, PREPRINT (Version 2) available at Research Square [https://doi.org/10.21203/rs.3.rs-153296/v2].

Chijioke-Akaniro, O. O., Ubochioma, E., Omoniyi, A., Fashade, O., Olarewaju, O., Asuke, S., … & Anyaike, C. (2022). Improving TB case notification and treatment coverage through

data use. *Ingenta Connect;* **12**: 3.
Global Tuberculosis report, 2022. World Health Organization. *Global Tuberculosis Report* 2022 (who.int). Accessed September 16, 2024.
Kellner, J., & Low, D. (2020). Antimicrobial Resistant Streptococcus pneumoniae Infections: Clinical and Epidemiological Trends. *McGill Journal of Medicine*; ***4*(1)**.
Chomel, B.B. (2014). Emerging and re-emerging zoonoses of dogs and cats. *Animals*; ***4***:434–445.
Crump, J., Morrissey, A.B., Nicholson, W.L., Massung, R.F., Stoddard, R.A., & Galloway, R.L *(2013).* Etiology of severe non-malaria febrile illness in Northern Tanzania: a prospective cohort study. *PLOS Neglected Tropical Diseases;* **7(7):** e2324.
Day, M.J., Breitschwerdt, E., Cleaveland, S., Karkare, U., Khanna, C., Kirpensteijn, J., … & Thiermann, A. (2012). E. Surveillance of zoonotic infectious disease transmitted by small companion animals. *Emerging Infectious Diseases*;**18(12):** e1.
De Vries, S.G., Visser, B.J., Nagel, I.M., Goris, M.G.A., Hartskeerl, R.A. & Grobusch M.P.(2014). Leptospirosis in sub-Saharan Africa: a systematic review. *International Journal of Infectious Diseases;* **28(1):**47–64.
Ducrotoy, M.J., Bertu, W.J., Ocholi, R.A., Gusi, A.M., Bryssinckx, W., Welburn, S. & Moriyon, I. (2014). Brucellosis as an emerging threat in developing economies: lessons from Nigeria. *PLOS Neglected Tropical Diseases;* **8(7)**: e3008.
Elsa, J., Duron, O., Séverine, B., González-Acuña, D. & Sidi-Boumedine K. (2015). Molecular methods routinely used to detect *Coxiella burnetii* in ticks cross-react with *Coxiella*-like bacteria. *Infection Ecology and. Epidemiology*; **5**:29230.
Falagas, M. E., Tansarli, G. S., Karageorgopoulos, D. E., & Vardakas, K. Z. (2014). Deaths Attributable to Carbapenem-Resistant Enterobacteriaceae Infections. *Emerging Infectious Diseases*; **20(7)**: 1170-1175. https://doi.org/10.3201/ eid2007.121004.
Centre for Disease Control and Prevention(2022). .Accessed September 16,2024.
Felkai, P.(2021). History of quarantine II. *Orvosi Hetilap*; ***162*:** 474–478.
Li, X., Gu, N., Huang, T. Y., Zhong, F., & Peng, G. (2023). Pseudomonas aeruginosa: A typical biofilm forming pathogen and an emerging but underestimated pathogen in food processing. *Frontiers in Microbiology*; ***13:*** 1114199. https://doi.org/10.3389/fmicb. 2022. 1114199.
Lovett, A., & Duncan, J. A. (2019). Human Immune Responses and the Natural History of Neisseria gonorrhoeae Infection. *Frontiers in Immunology*; ***9***: 435254.
Gado, D.A., Ehizibolo, D.O., Meseko, C.A., Lurz, P.W & Anderson, N.E. (2023). Review of Emerging and Re-Emerging Zoonotic Pathogens of Dogs in Nigeria: Missing Link in One Health Approach. *Zoonotic Diseases*; **3(2):**134-161.
Ghose, C. (2013). *Clostridium difficile* infection in the twenty-first century. *Emerging Microbes and Infections*; **2**: e62.
Guardia, A., Garcia, J. & Torrelles, J. (2021). Evolution of Drug-Resistant Mycobacterium tuberculosis strains and their adaptation to the human Lung Environment. *Frontiers in Microbiology;* **12: 612675.**
Gutiérrez, R., Krasnov, B., Morick, D., Gottlieb, Y., Khokhlova, I.S. & Harrus S.(2015). *Bartonella* infection in rodents and their flea ectoparasites: an overview. *Vector Borne Zoonotic Diseases;* **15(1):**27–39.
Isere, E.E., Fatiregun, A.A. & Ajayi, I.O. (2015). An overview of disease surveillance and notification system in Nigeria and the roles of clinicians in disease outbreak prevention and control. *Nigerian Journal of Medicine;* **56(3):**161–168.
Kagambèga, A., Lienemann, T., Aulu, L., Traoré, A.S. & Barro, N. (2013). Prevalence and characterization of Salmonella enterica from the faeces of cattle, poultry, swine and hedge hogs in Burkina Faso and their comparison to human Salmonella isolates. *BMC Microbiology*; **13**: 253.
Kamani, J., Baneth, G., Mumcuoglu, K.Y., Waziri, N.E., Eyal, O. & Guthmann Y.(2013). Molecular detection and characterization of tick-borne pathogens in dogs and ticks from Nigeria. *PLOS Neglected Tropical Diseases;* **7(3):** e2108.
Kamani, J.,Morick, D., Mumcuoglu, K.Y. & Harrus, S. (2013). Prevalence and diversity of Bartonella species in commensal rodents and ectoparasites from Nigeria, West Africa. *PLOS Neglected Tropical Diseases;* **7(5):** e2246.

Kamani,J., Baneth, G., Mitchell, M., Mumcuoglu, K.Y., Gutiérrez, R. & Harrus, S.(2014).
Bartonella species in bats (Chiroptera) and bat flies (Nycteribiidae) from Nigeria, West Africa.*Vector Borne Zoonotic Disease;* **14(9):** 625-632.
Kolo, A.O., Sibeko-Matjila, K.P., Maina, A.N., Richards, A.L., Knobel, D.L. & Matjila, P.T.(2016). Molecular detection of zoonotic rickettsiae and *Anaplasma spp*. in domestic dogs and their ectoparasites in Bushbuckridge, South Africa. *Vector-Borne Zoonotic Diseases;* ***16*****:** 245–252.
Leekitcharoenphon, P., Raufu, I., Nielsen, M.T., Rosenqvist, B.S., Lund, Ameh, J.A., Ambali, A.G., … & Sørensen, G. *(2016)*. Investigating Salmonella Eko from various sources in Nigeria by whole genome sequencing to identify the source of human infections. *Public Library of Science One*; **11(5):** e0156212.
Lindahl, J.F & Grace, D. (2015). The consequences of human actions on risks for infectious diseases: A review. *Infection Ecology & Epidemiology*; **5**:30048.
Mackey, T.K., Liang, B.A., Cuomo, R., Hafen, R., Brouwer, K.C. & Lee, D.E. (2014). Emerging and Reemerging Neglected Tropical Diseases: A Review of Key Characteristics, Risk Factors, and the Policy and Innovation Environment. *Clinical Microbiology Rev*iews; ***27*****:** 949–979.
Martirosov, D. M., & Lodise, T. P. (2016). Emerging trends in epidemiology and management of infections caused by carbapenem-resistant Enterobacteriaceae. *Diagnostic Microbiology and Infectious Disease*; ***85*****(2):** 266-275.
Maryam, B., Gana, B.A., Ahmed, G.Y., Abubakar, W.M. and Istifanus, S.(2014). A survey of blood types of the domestic cat (*Felis catus*) in Maiduguri, North-eastern Nigeria. *Journal of Veterinary Science and Technology,***5**(1):152.
McFee, R.B. (2018). Emerging infectious diseases overview. *Disease a Month Journal,* **64**:163–169.
Melamed, S., Israely, T., & Paran, N. (2018). Challenges and achievements in prevention and treatment of smallpox. *Vaccines*; **6**:8.
Mukherjee, S.(2017). Emerging infectious diseases: Epidemiological perspective. *Indian Journal of Dermatology;* **62**:459–467.
Neiderud, C. (2015). How urbanization affects the epidemiology of emerging infectious diseases. *Infection Ecology & Epidemiology*; **5**: 27060.
Ng-Nguyen, D., Hii, S.-F., Hoang, M.-T.T., Nguyen, V.-A.T., Rees, R., Stenos, J. & Traub, R.J.(2020). Domestic dogs are mammalian reservoirs for the emerging zoonosis flea-borne spotted fever, caused by Rickettsia felis. *Scientific Reports;* ***10*****:** 1–10.
Ngutor, K.S. (2012). A multidisciplinary approach in the control of zoonoses in Nigeria. *Journal of Veterinary Advances*; **2(12):**557-567.
Obilade, T.T. (2015). The political economy of the Ebola virus disease (EVD); taking individual and community ownership in the prevention and control of EVD Healthcare; **3(1):**36-49.
Okoro, C.I., Chukwuocha, U.M., Nwakwuo, G.C. & Ukaga, C.N.(2015). Presumptive diagnosis and treatment of malaria in febrile children in parts of South Eastern Nigeria. *Journal of Infectious Diseases and Therapy;* **3(5):**240.
Oladosu, O.O. & Oyibo, W.A. (2012). Overdiagnosis and overtreatment of malaria in children that presented with fever in Lagos, Nigeria. *Infectious Disease*; **2013(1):** 914675.
Omitola, O.O. & Taylor-Robinson, A.W. (2020). Emerging and re-emerging bacterial zoonoses in Nigeria: current preventive measures and future approaches to intervention. *Heliyon;* **6(6):** e04095.
Orusa, T., Orusa, R., Viani, A., Carella, E. & Borgogno Mondino, E.(2020). Geomatics and EO data to support wildlife diseases assessment at landscape level: A pilot experience to map infectious keratoconjunctivitis in chamois and phenological trends in Aosta Valley (NW Italy). *Remote Sensing*; ***12*****:** 3542.
Parola, P., Paddock, C.D. & Socolovschi, C. (2013). Update on tick-borne rickettsioses around the world: a geographic approach. *Clinical Microbiology Review;* **26**: 657-702.
Prasad, N., Murdoch, D.R., Reyburn, H. & Crump, J.A. (2015). Etiology of severe febrile illness in low- and middle-income countries: a systematic review. *Public*

Library of Science One; **10(6):**e0127962.

Raufu, I.A., Zongur, L., Lawan, F.A., Bello, H.S. & Adamu, M.S. (2014). Prevalence and antimicrobial profiles of *Salmonella* serovars from vegetables in Maiduguri, Northeastern Nigeria. *Sokoto Journal of Veterinary Sciences;* **12(1):**23–28.

Recht, J., Schuenemann, V.J. & Sánchez-Villagra, M.R.(2020). Host diversity and origin of zoonoses: The ancient and the new. *Animals*; ***10***:1672.

Reye, A.L., Arinola, O.G., Hübschen, J.M. & Muller, C.P. (2012). Pathogen prevalence in ticks collected from the vegetation and livestock in Nigeria. *Applied and Environmental Microbiology*; **78(8):** 2562-2568.

Santos, H.A., Thomé, S.M., Baldani, C.D., Silva, C.B., Peixoto, M.P., Pires, M.S., & Massard, C.L. (2013). Molecular epidemiology of the emerging zoonosis agent *Anaplasma phagocytophilum* (Foggie, 1949) in dogs and ixodid ticks in Brazil. *Parasites & Vectors*; ***6:***348.

Sowemimo, O.A. (2012). Prevalence and intensity of gastrointestinal parasites of domestic cats in Ode – Irele and Oyo communities, Southwest Nigeria. *Journal of Parasitology and Vector Biology;* **4(1):**7-13.

US. CDC (2018). Emerging Infectious Diseases. [(accessed on 27 November 2023)] Available online: https://www.cdc.gov/niosh/topics/emerginfectdiseases/default.html.

Vouga, M. & Greub, G. (2016). Emerging bacterial pathogens:(the past and beyond). *Clinical Microbiology and Infection*; **22(1)**: 12-21.

Wang, W-H., Thititithanyanyanont, A., Urbina, A.N. & Wang, S-F.(2021). Emerging and Re-emerging Diseases. *Multidisciplinary Digital Publishing Institute*, *Pathogens*; **10(7):**827.

Welburn, S.C., Beange, I., Ducrotoy, M.J. & Okello A.L. (2015). The neglected zoonoses — the case for integrated control and advocacy. *Clinical Microbiology and Infection*; **21(5):**433–443.

WHO (2019). Tuberculosis. Retrieved from <https://www.who.int/news-room/fact-sheets/detail/tuberculosis>, Accessed November 21, 2023.

WHO. World Health Organization, Coronavirus Disease 2019 (COVID-19): Situation Report, 59. 2020. Available online: https://www.who.int/emergencies/diseases/novel-coronavirus2019?adgroupsurvey={adgroupsurvey}&gclid=EAIaIQobChMIobTOpszL_gIV75JmAh169AbHEAAYASAAEgL8hPD_BwE (accessed on October 18,2023).

Wu, T., Perrings, C., Kinzig, A., Collins, J.P., Minteer, B.A. & Daszak, P. (2017). Economic growth, urbanization, globalization, and the risks of emerging infectious diseases in China: A review. *Ambio Journal of Environment and Society*; **46**:18–29.

Yakubu, Y., Junaidu, A.U., Magaji, A.A., Salihu, M.D., Mahmuda, A. & Shehu, S. (2011). One Health — the fate of public health in Nigeria. *Asian Journal of Medical Sciences*; **3(1):** 47-49.

Yang, Z.S., Huang, S.W., Wang, W.H., Lin, C.Y., Wang, C.F., Urbina, A.N., & Wang, S.F. (2021). Identification of important N-linked glycosylation sites in the hemagglutinin protein and their functional impact on DC-SIGN mediated avian influenza H5N1 infection. *International Journal of Molecular Science*; **22(2)**:743.

Zhang, J., Kelly, P.J., Lu, G., Cruz-Martinez, L.& Wang, C. (2016). *Rickettsia* in mosquitoes, Yangzhou, China. *Emerging Microbial Infections;* **5(10):** e108.

Zumla, A. & Hui, D.S.(2019). Emerging and reemerging infectious diseases: Global overview. *Infectious Disease Clinics of North America*; **33(4): xiii–xix.**

Citation: Faith Gbemisola Ademulegun, Paulinus Osarodion Uyigue, Samson Ohwonohwo Onemu, Bola Ojo, Olabisi Adejibike Oduwole. Emerging and Re-Emerging Bacterial Infections: An Overview. ***Sokoto Journal of Medical Laboratory Science*; 9(4): 151 – 168.** https://dx.doi.org/10.4314/sokjmls.v9i4.18