

# Insect Vectors of Bacterial Pathogens: A Schematic Review of Transmission Dynamics and Public Health Implications

Idigo, M. A.<sup>1</sup>, Iheukwumere, I. H.<sup>2</sup>, Iheukwumere, C. M.<sup>3</sup>, Nwakoby, N. E.<sup>2</sup> and Ike, V. E.<sup>4</sup>



<sup>1</sup>Department of Biological Sciences, Faculty of Natural Science, Chukwumeka Odumegwu Ojukwu University, Anambra State, Nigeria.

<sup>2</sup>Department of Microbiology, Faculty of Natural Sciences, Chukwumeka Odumegwu Ojukwu University, Anambra State, Nigeria.

<sup>3</sup>Department of Applied Microbiology & Brewing, Faculty of Biosciences, Nnamdi Azikiwe University, Awka, Anambra State, Nigeria.

<sup>4</sup>Department of Microbiology, University of Agriculture and Environmental Sciences, Umuagwo, Imo State, Nigeria.

\*Corresponding author email: [ma.idigo@coou.edu.ng](mailto:ma.idigo@coou.edu.ng)/ [ik.iheukwumere@coou.edu.ng](mailto:ik.iheukwumere@coou.edu.ng)

Abstract	Article History
<p>Insect vectors play a critical role in the transmission of bacterial pathogens that cause significant morbidity and mortality worldwide. This comprehensive review examines the current understanding of transmission dynamics between insect vectors and bacterial pathogens, focusing on the physiological, ecological, and environmental factors that facilitate disease spread. We analyze the diverse mechanisms of transmission employed by major insect vectors including mosquitoes, flies, lice, fleas, and ticks, highlighting both historical context and emerging public health threats. The review explores the complex interactions between bacterial pathogens and their arthropod vectors, from initial infection and persistence within the vector to successful transmission to human hosts. Special attention is given to the growing threat of antimicrobial resistance in vector-borne bacterial diseases and the potential role of insects in disseminating resistance genes. Additionally, we discuss the impact of climate change, urbanization, and global travel on the expanding geographic range of vector-borne diseases. The public health implications are substantial, with vector-borne diseases collectively accounting for more than 17% of all infectious diseases globally. This review synthesizes current knowledge on intervention strategies and identifies critical gaps in understanding that merit further research. By integrating perspectives from entomology, microbiology, and public health, this review aims to inform more effective strategies for prevention, surveillance, and control of insect-vector-borne bacterial diseases.</p> <p><b>Keywords:</b> Insect vectors, bacterial pathogens, transmission dynamics, public health, antimicrobial resistance, vector-borne diseases</p>	<p>Received: 12 Oct 2025 Accepted: 20 Oct 2025 Published: 25 Oct 2025</p>  <p>Scan QR Code to view<sup>1</sup></p> <p>License: CC BY 4.0<sup>24</sup></p>  <p>Open Access article.</p>
<p><b>How to cite this paper:</b> Idigo, M. A., Iheukwumere, I. H., Iheukwumere, C. M., Nwakoby, N. E., &amp; Ike, V. E. (2025). <i>Insect vectors of bacterial pathogens: A schematic review of transmission dynamics and public health implications</i>. <i>IPS Journal of Public Health</i>, 5(4), 447–455. <a href="https://doi.org/10.54117/xpfmkv03">https://doi.org/10.54117/xpfmkv03</a></p>	

## 1. Introduction

Vector-borne diseases have historically represented some of the most devastating threats to human health, with insects serving as efficient transporters of pathogenic microorganisms that cause significant morbidity and mortality worldwide. The complex relationships between insect vectors, bacterial pathogens, and human hosts continue to challenge public health systems globally, particularly in tropical and subtropical regions where ecological conditions favor vector proliferation. According to the World Health Organization, vector-borne diseases account for **more than 17% of all infectious diseases** and cause more than 700,000 deaths annually, representing a substantial portion of the global infectious disease burden. While much attention has historically focused on mosquito-vector-borne viral and parasitic diseases such as malaria, dengue, and yellow fever, bacterial diseases transmitted by insects remain a relatively neglected area of medical entomology despite their significant impact on human health through the centuries.

The **resurgence and emergence** of vector-borne diseases in recent decades can be attributed to multiple interconnected factors, including the rapid expansion of global travel and trade, unplanned urbanization, climate change, and the evolution of insecticide resistance in vector populations. These trends have facilitated the geographic spread of both vectors and the bacterial pathogens they carry, introducing diseases into new regions and populations. The continuous discovery of new vector-pathogen relationships further complicates the epidemiological landscape, requiring ongoing vigilance and research to develop effective countermeasures.

This review aims to synthesize current knowledge on the transmission dynamics of bacterial pathogens by insect vectors and their implications for public health. We examine the diverse mechanisms by which insects acquire, maintain, and transmit bacterial agents, the ecological and evolutionary factors that influence these relationships, and the burden of resulting diseases on human populations. Additionally, we explore emerging challenges such as the role of insects in the

dissemination of antimicrobial resistance and the impact of environmental change on disease distribution. Finally, we discuss integrated approaches to disease prevention and control, highlighting the importance of One Health strategies that address the interconnectedness of human, animal, and environmental health. By providing a comprehensive overview of the current state of knowledge in this field, this review seeks to identify critical gaps and future directions for research and public health intervention.

## 2. Major Insect Vectors of Bacterial Pathogens

Various insect species serve as competent vectors for bacterial pathogens, each with unique biological characteristics that influence their efficiency in disease transmission. Understanding the ecology, behavior, and physiological adaptations of these vectors is essential for developing targeted control strategies (Iheukwumere *et al.*, 2025a). The major insect vectors of medical importance include mosquitoes, flies, lice, fleas, and several other arthropods that interact with humans in ways that facilitate pathogen transmission.

### 2.1 Mosquitoes

Despite their well-established role as vectors for viral and parasitic diseases, mosquitoes' capacity to transmit bacterial pathogens has been less thoroughly investigated. Recent research, however, has demonstrated that mosquitoes can serve as competent vectors for certain bacterial species of particular significance, is *Rickettsia felis* (Iheukwumere *et al.*, 2025b). This obligate intracellular bacterium causes febrile illness in humans. Studies have shown that *Anopheles gambiae* mosquitoes, primary vectors of malaria in Sub-Saharan Africa, can acquire *R. felis* through infected blood meals and maintain the bacteria for at least 15 days post-infection (Iheukwumere *et al.*, 2025c). The bacteria have been detected in the salivary glands and ovaries of infected mosquitoes, suggesting potential transmission through biting and possibly transovarial transmission. Additionally, mosquitoes have been investigated as potential mechanical vectors for *Francisella tularensis*, the causative agent of tularemia, with speculation that adult mosquitoes might acquire the pathogen from aquatic larval habitats (Iheukwumere *et al.*, 2025d). The **vector competence** of different mosquito species for various bacterial pathogens represents an important area for further investigation, particularly given the global distribution of mosquitoes and their frequent contact with human populations.

### 2.2 Flies

Flies, particularly houseflies (*Musca domestica*), are notorious mechanical vectors of bacterial pathogens due to their synanthropic nature and feeding habits. The biology and behavior of flies make them ideal candidates for pathogen transmission; they feed on animal and human feces, decaying organic matter, and garbage, subsequently contaminating human food and environments. Houseflies can carry more than 130 human pathogens, including *Klebsiella* spp., *Salmonella*, *Pseudomonas aeruginosa*, *Campylobacter jejuni*, and *Escherichia coli* (Iheukwumere *et al.*, 2025e; Iheukwumere *et al.*, 2025f). Their ability to transmit pathogens is enhanced by several morphological adaptations, including **sticky leg pads**, **body hairs**, and

an **electrostatically charged exoskeleton** that facilitate external carriage of bacteria. A single housefly can carry up to  $2 \times 10^{12}$  *E. coli* cells and transfer approximately 0.1 mg of contaminated material between landing sites (Iheukwumere *et al.*, 2025g). Beyond mechanical transmission, evidence suggests that flies may also serve as biological vectors for some pathogens, with bacteria multiplying within the digestive tract before being shed in feces. The **internal carriage** of pathogens in flies presents an additional transmission route, with studies demonstrating that bacterial loads in the digestive tract can be three times higher than on external surfaces due to bacterial replication. The mobility of flies, with documented movement up to 20 miles during their lifespan, further enhances their potential to disseminate pathogens across considerable distances.

### 2.3 Lice

Lice have played a significant role in human history as vectors of devastating bacterial diseases. Three ecotypes parasitize humans: head lice, body lice, and pubic lice, with body lice being the primary vectors of infectious diseases. Lice are responsible for transmitting the agents of several serious diseases, including **epidemic typhus** caused by *Rickettsia prowazekii*, **trench fever** caused by *Bartonella quintana*, and **louse-borne relapsing fever** caused by *Borrelia recurrentis* (Iheukwumere *et al.*, 2025h; Iheukwumere *et al.*, 2025i). These diseases have caused explosive outbreaks throughout history, particularly in conditions of overcrowding and poor hygiene, such as during wars and humanitarian crises. Paleomicrobiological evidence has detected *B. quintana* DNA in human remains dating back 4,000 years, illustrating the long-standing relationship between lice and human disease. More recently, research has suggested that body lice may also serve as vectors for *Yersinia pestis*, the causative agent of plague, potentially explaining the rapid dissemination of historical plague pandemics that conventional rat-flea transmission models struggle to account for completely (Iheukwumere *et al.*, 2025j). The continued presence of lice in vulnerable populations, such as homeless communities and conflict zones, maintains the potential for resurgence of these diseases under conducive conditions.

### 2.4 Fleas and Other Vectors

Fleas are renowned vectors of *Yersinia pestis*, the bacterium responsible for plague, which has caused devastating pandemics throughout human history. Plague transmission occurs through a unique mechanism in which blocked fleas regurgitate bacteria into bite sites while attempting to feed. Beyond *Y. pestis*, fleas also transmit *Rickettsia felis*, the agent of flea-borne spotted fever, with the cat flea (*Ctenocephalides felis*) being the primary vector (Iheukwumere *et al.*, 2025k). Other insects of medical importance include triatomine bugs, which transmit *Trypanosoma cruzi* (the causative agent of Chagas disease) through fecal contamination, and ticks, which transmit numerous bacterial pathogens including those causing Lyme disease, anaplasmosis, and rickettsial diseases. While ticks are arachnids rather than insects and thus beyond the scope of this review, their role in bacterial disease transmission underscores the diversity of arthropod vectors impacting human health (Iheukwumere *et al.*, 2025l). The **vector competence** of each species depends on a complex interplay

of factors including host preference, feeding behavior, immune response, and ecological adaptability, all of which influence their efficiency in acquiring, maintaining, and transmitting bacterial pathogens.

Table 1: Major Insect Vectors and Their Associated Bacterial Pathogens

Vector	Bacterial Pathogen	Disease	Transmission Mechanism
Body Lice	<i>Rickettsia prowazekii</i>	Epidemic typhus	Fecal contamination of bite sites
Body Lice	<i>Bartonella quintana</i>	Trench fever	Fecal contamination of bite sites
Body Lice	<i>Borrelia recurrentis</i>	Louse-borne relapsing fever	Crushing lice or fecal contamination
Fleas	<i>Yersinia pestis</i>	Plague	Regurgitation during feeding
Fleas	<i>Rickettsia felis</i>	Flea-borne spotted fever	Salivary transmission
Mosquitoes	<i>Rickettsia felis</i>	Flea-borne spotted fever	Potential salivary transmission
Houseflies	<i>Salmonella spp.</i>	Salmonellosis	Mechanical transmission via body parts and feces
Houseflies	<i>E. coli</i>	Various intestinal illnesses	Mechanical transmission via body parts and feces

### 3. Mechanisms of Transmission

The transmission of bacterial pathogens by insect vectors occurs through diverse mechanisms that can be broadly categorized as either mechanical or biological transmission (Ekechukwu *et al.*, 2025a; Ekechukwu *et al.*, 2025b). These pathways determine the dynamics of disease spread and have important implications for prevention and control strategies. Understanding these mechanisms at the physiological, cellular, and molecular levels is essential for developing interventions to disrupt transmission cycles.

#### 3.1 Mechanical Transmission

**Mechanical transmission** represents the passive carriage of pathogens on the external surfaces or within the digestive tract of insects without replication or biological development of the pathogen within the vector. This process is largely incidental, resulting from the insect's contact with contaminated substances followed by subsequent contact with human food, water, or living environments. Houseflies exemplify efficient mechanical vectors due to their attraction to feces, decaying organic matter, and human food. Their morphological characteristics, including **hairy bodies**, **sticky pulvilli** on their feet, and **sponging mouthparts**, facilitate the pickup and transfer of pathogenic bacteria. Studies have demonstrated that flies can mechanically transmit diverse bacterial pathogens including *Salmonella enterica*, *Klebsiella pneumoniae*, and *Staphylococcus aureus* (Dim *et al.*, 2025a; Dim *et al.*, 2025b; Dim *et al.*, 2025c). The efficiency of mechanical transmission depends on factors such as the bacterial load acquired, the duration of bacterial survival on the insect's body or in its digestive system, and the frequency of contact between the insect and human substrates. Unlike biological transmission, mechanical transmission does not require a specific incubation period within the vector, potentially enabling immediate transmission following pathogen acquisition.

#### 3.2 Biological Transmission

**Biological transmission** involves more complex interactions between pathogens and vectors, typically requiring the bacteria to complete part of their life cycle within the insect before transmission can occur. This process often includes replication of the bacteria within the vector and may involve passage through various tissues and biological barriers. The **vector competence** of an insect—its intrinsic ability to acquire, maintain, and transmit a pathogen—depends on overcoming these barriers, which include the midgut, hemocoel, and salivary glands (Ike *et al.*, 2025a). For example, *Rickettsia felis* must infect the salivary glands of *Anopheles gambiae* mosquitoes to be transmitted during feeding, as demonstrated by immunofluorescence detection of the bacteria in this tissue. The **extrinsic incubation period**—the time between acquisition of the pathogen by the vector and when the vector becomes infectious—varies depending on the pathogen-vector combination and environmental conditions, particularly temperature (Ike *et al.*, 2025b). Biological transmission can be further categorized into several modes:

**Salivary transmission:** Pathogens are injected directly into the host during probing or blood feeding, as occurs with many arboviruses and some bacterial pathogens like *R. felis* in mosquitoes.

**Fecal transmission:** Pathogens are excreted in vector feces and enter the host through contamination of bite wounds or mucous membranes, characteristic of louse-borne diseases like epidemic typhus.

**Regurgitative transmission:** Pathogens are expelled from the vector's foregut during feeding, as exemplified by flea transmission of *Yersinia pestis*.

The specific mechanisms of biological transmission often reflect complex co-evolutionary relationships between pathogens and their vectors, resulting in adaptations that

enhance transmission efficiency while minimizing pathogenicity to the vector.

### 3.3 Horizontal and Vertical Transmission

Beyond the transmission from vectors to vertebrate hosts, the maintenance of bacterial pathogens within vector populations involves both horizontal and vertical transmission pathways (Ike *et al.*, 2025c). **Horizontal transmission** occurs when vectors acquire pathogens from infected hosts during blood feeding or from their environment. This represents the typical route of initial infection for vectors and maintains the circulation of pathogens between vectors and reservoir hosts (Ike *et al.*, 2025d). Recent research has revealed that the **digestive tract of insects** can serve as a site for horizontal gene transfer between bacteria, facilitating the dissemination of antimicrobial resistance genes (Ike *et al.*, 2025e). Studies have demonstrated the transfer of tetracycline resistance genes among *Enterococcus faecalis* and the exchange of Shiga toxin and antibiotic resistance genes in *E. coli* within the gut of houseflies (Ugwu *et al.*, 2025a; Ugwu *et al.*, 2025b). This phenomenon raises concerns about insects as potential amplifiers of antimicrobial resistance in the environment.

**Vertical transmission**, also known as transovarial transmission, occurs when infected female vectors pass pathogens to their offspring, directly infecting subsequent generations. This transmission route is particularly important for maintaining pathogens in the environment when suitable vertebrate hosts are scarce or seasonal. Evidence suggests that vertical transmission occurs in several vector-pathogen systems, including *Salmonella enterica* and *Cronobacter sakazakii* in houseflies, with bacteria detected in the eggs of the next generation (Nwike *et al.*, 2017). Similarly, insect-specific viruses (ISVs) within mosquitoes are known to be maintained primarily through efficient vertical transmission. The efficiency of vertical transmission varies among pathogen-vector combinations and can be influenced by environmental factors, vector physiology, and the specific tissues infected in the parent vector. The capacity for both horizontal and vertical transmission enhances the persistence of bacterial pathogens in nature and complicates control efforts.

Table 2: Comparison of Transmission Mechanisms for Insect-Vectored Bacterial Pathogens\*

Transmission Mechanism	Description	Examples	Key Characteristics
<b>Mechanical Transmission</b>	Passive carriage without pathogen replication	Houseflies transmitting <i>E. coli</i> and <i>Salmonella</i>	Immediate transmission potential; no specific vector-pathogen adaptation required
<b>Biological Transmission Salivary</b>	Pathogen injected with saliva during blood feeding	<i>Rickettsia felis</i> transmission by mosquitoes	Requires pathogen to infect salivary glands; specific vector-pathogen relationships
<b>Biological Transmission - Fecal</b>	Pathogen excreted in feces, enters through bite wounds or mucous membranes	Body lice transmitting <i>Rickettsia prowazekii</i>	Requires contamination of feeding site; pathogen survival in vector digestive tract
<b>Biological Transmission Regurgitative</b>	Pathogen expelled from foregut during feeding	Fleas transmitting <i>Yersinia pestis</i>	Associated with foregut infection and blockage; unique to specific vector-pathogen systems
<b>Vertical Transmission</b>	Pathogen passed from infected female to offspring	<i>Salmonella enterica</i> in houseflies	Maintains pathogen in vector populations; independent of vertebrate hosts

## 4. Public Health Burden and Epidemiology

Vector-borne diseases collectively represent a significant burden on global public health, with bacterial pathogens transmitted by insects contributing substantially to morbidity, mortality, and economic costs, particularly in resource-limited settings. The epidemiology of these diseases is influenced by a complex interplay of demographic, environmental, and social factors that determine their distribution and impact on human populations.

### 4.1 Global Impact and Distribution

The World Health Organization estimates that **vector-borne diseases account** for more than 17% of all infectious diseases globally, causing more than 700,000 deaths annually. While this burden includes viral and parasitic diseases, bacterial vector-borne diseases contribute significantly to these figures.

Diseases such as plague, typhus, and trench fever have caused massive epidemics throughout history, with the potential to reemerge under conducive conditions. The distribution of vector-borne bacterial diseases is disproportionately concentrated in **tropical and subtropical regions**, where environmental conditions favor vector proliferation and where socioeconomic factors may limit access to effective prevention and health care services. The poorest populations typically bear the greatest burden, as conditions of poverty often include limited access to housing that provides protection from vectors, inadequate water and sanitation infrastructure that may create breeding sites, and reduced access to health care services for diagnosis and treatment. Recent decades have witnessed the **expansion of vector-borne diseases** into new geographic regions, attributed to factors including climate change, increased global travel and trade, and unplanned

urbanization. This changing distribution pattern introduces diseases into populations with no prior immunity and health systems with limited experience in diagnosis and management, potentially leading to more severe outcomes.

#### 4.2 Historical and Resurgent Diseases

Several bacterial diseases transmitted by insects have played significant roles in human history, with the capacity to resurge under appropriate conditions. **Epidemic typhus**, caused by *Rickettsia prowazekii* and transmitted by body lice, has been associated with mortality rates up to 40% in untreated cases during historical epidemics. This disease has typically flourished in settings of overcrowding and poor hygiene, such as during wars, famines, and natural disasters. Similarly, **plague**—caused by *Yersinia pestis* and primarily transmitted by fleas—has caused three major pandemics throughout history, resulting in hundreds of millions of deaths. Despite its historical reputation, plague remains endemic in many parts of the world, with periodic outbreaks that require rapid public health response. In the late 20th century, civil conflicts in Rwanda and Burundi facilitated the proliferation of body louse populations, leading to **resurgences of epidemic typhus** that caused approximately 10,000 deaths. During these outbreaks, *Bartonella quintana*—the agent of trench fever—was found to be co-circulating with *R. prowazekii* in the same population, illustrating how similar social and environmental conditions can favor the transmission of multiple vector-borne diseases simultaneously. These historical examples underscore the continued relevance of these diseases and their potential to reemerge when conditions deteriorate.

#### 4.3 Economic and Social Impact

Beyond their direct health consequences, vector-borne bacterial diseases impose substantial economic costs on affected individuals, communities, and health systems. These costs include both direct medical expenses for diagnosis and treatment and indirect costs related to lost productivity, disability, and premature mortality. The economic impact is particularly severe in low-income countries, where these diseases may affect working-age adults, potentially undermining economic development and perpetuating cycles of poverty. Outbreaks of vector-borne diseases can also disrupt travel and trade, as witnessed during plague outbreaks in India and other regions, where concerns about disease spread led to restrictions on movement and commerce. The social impacts of these diseases extend beyond economics, including stigma associated with conditions like plague, chronic disability resulting from inadequately treated diseases, and the disruption of social structures during epidemics. The fear and uncertainty generated by outbreaks of diseases with historical reputations for high mortality, such as plague, can magnify their social impact far beyond their actual epidemiological footprint, challenging public health communication and response efforts.

### 5. Emerging Challenges and Future Directions

The epidemiology of insect-vector-borne bacterial diseases continues to evolve in response to changing environmental conditions, human behavior, and pathogen adaptation. Several emerging challenges threaten to complicate prevention and

control efforts, requiring innovative approaches and strengthened public health infrastructure.

#### 5.1 Antimicrobial Resistance

The emergence and spread of **antimicrobial resistance** represents one of the most serious challenges in managing bacterial diseases, including those transmitted by insect vectors. Insects may play multiple roles in the epidemiology of antimicrobial resistance, serving not only as vectors of resistant bacterial pathogens but also as potential sites for the transfer of resistance genes between bacteria. Studies have demonstrated that the **digestive tract of flies** provides a suitable environment for horizontal gene transfer, with the successful transfer of extended-spectrum beta-lactamase genes observed between *E. coli* and other bacterial species within houseflies (Amadi *et al.*, 2017). This phenomenon raises the concerning possibility that insects may act as **mobile reservoirs** for the amplification and dissemination of antimicrobial resistance genes across different environments. The presence of multidrug-resistant bacteria in insects has been documented in healthcare settings, with studies revealing robust colonization of insect vectors with resistant pathogens, though direct links to transmission require further investigation. The globalization of resistance mechanisms underscores the need for enhanced surveillance of resistance in both clinical and environmental settings, including monitoring of insect populations that may serve as sentinels or contributors to resistance dissemination.

#### 5.2 Climate Change and Environmental Factors

**Climate change** is profoundly influencing the distribution and incidence of vector-borne diseases through multiple pathways. Changes in temperature, precipitation patterns, and the frequency of extreme weather events can alter the geographic range of insect vectors, their population dynamics, and their feeding behavior. Several vector species have already demonstrated expansions in their **latitude and altitude ranges**, and the length of season during which they are active is increasing in many regions. These trends are expected to continue as global temperatures rise, potentially introducing vector-borne diseases into previously unaffected populations with limited immunity. Beyond climate change, other environmental factors such as **deforestation, urbanization, and changes in land use** can create new opportunities for contact between humans, vectors, and reservoir hosts (Ekesiobi *et al.*, 2025). Unplanned urbanization in particular may create ideal environments for some vector species, such as the proliferation of container-breeding mosquitoes in areas with inadequate water storage and waste management. Understanding and predicting the impact of these environmental changes on vector-borne disease transmission requires multidisciplinary approaches that integrate entomology, epidemiology, climatology, and ecology to develop proactive strategies for prevention and control.

#### 5.3 Diagnostic and Surveillance Limitations

Accurate diagnosis and effective surveillance are fundamental components of public health response to vector-borne diseases, yet significant limitations persist in both areas. Many vector-borne bacterial diseases present with **non-specific febrile illness** that can be difficult to distinguish clinically

from other common infections, leading to underdiagnosis or misdiagnosis. This challenge is particularly acute in resource-limited settings where access to laboratory confirmation may be limited. Surveillance systems for vector-borne diseases face multiple challenges, including the need to integrate human case data with entomological surveillance, the logistical difficulties of monitoring vector populations and infection rates, and the limited resources dedicated to these activities in many endemic countries. The development and implementation of **rapid diagnostic tests** for vector-borne bacterial diseases has lagged behind similar advances for other infectious diseases, though molecular techniques such as PCR have improved detection capabilities in reference laboratories. Strengthening surveillance capacity will require not only improved laboratory infrastructure but also training of personnel in medical entomology and vector biology, fields that have experienced declining expertise in recent decades. The implementation of **integrated surveillance systems** that adopt a One Health approach, connecting human, animal, and environmental health, holds promise for more effective detection of and response to emerging threats.

## 6. Prevention and Control Strategies

Effective management of insect-vector-borne bacterial diseases requires a multifaceted approach that integrates vector control, personal protection, clinical management, and community engagement. The development and implementation of evidence-based strategies must consider local epidemiology, vector ecology, and available resources to achieve sustainable impact.

### 6.1 Vector Control Approaches

Vector control remains the primary approach for reducing transmission of insect-vector-borne diseases, employing a variety of chemical, biological, and environmental methods. **Chemical control** through insecticides has historically played a central role in vector control programs, but the emergence and spread of **insecticide resistance** in many vector species has diminished the effectiveness of this approach in some settings. This challenge has stimulated increased interest in **alternative control strategies**, including biological control using natural predators or pathogens, genetic approaches such as the release of sterile or genetically modified males, and environmental management to reduce breeding sites. The **Global Vector Control Response (GVCR) 2017–2030** adopted by the World Health Assembly provides strategic guidance for strengthening vector control as a fundamental approach to preventing disease and responding to outbreaks. This comprehensive framework emphasizes the need for increased technical capacity, improved infrastructure, strengthened monitoring and surveillance systems, and greater community mobilization. Effective vector control typically requires **integrated vector management** that combines multiple approaches based on local vector ecology and disease epidemiology, moving beyond reliance on any single method. The implementation of vector control programs must also

address community acceptance and participation, as the success of many interventions depends on changes in behavior and practices at the household and community levels.

### 6.2 Personal Protection and Community Mobilization

**Personal protection measures** play a crucial role in reducing individual exposure to insect vectors, particularly in endemic areas or during outbreaks. These measures include the use of insecticide-treated bed nets, wearing protective clothing, application of insect repellents, and installation of window and door screens to prevent vector entry into living spaces. The effectiveness of personal protection depends on consistent and correct use of these measures, which in turn relies on community knowledge, attitudes, and practices related to vector-borne diseases. **Community mobilization** and education are therefore essential components of comprehensive prevention strategies, empowering individuals and communities to take ownership of vector control and protection measures. Successful health education campaigns should be culturally appropriate, linguistically accessible, and tailored to local understandings of disease and prevention. Engaging communities in **participatory surveillance** and control activities can enhance the sustainability of interventions and foster capacity building at the local level. The crucial element in reducing the burden of vector-borne diseases is **behavioral change**, which requires ongoing education and increased public awareness so that people know how to protect themselves and their communities from vectors.

### 6.3 Novel Approaches and Research Directions

The evolving challenges in controlling insect-vector-borne bacterial diseases have stimulated research into novel approaches that leverage advances in biotechnology, ecology, and social science. One promising area involves the use of **insect-specific viruses (ISVs)** that can modulate vector competence or reduce vector populations. Some ISVs have been shown to induce **superinfection exclusion**, whereby infection with an ISV inhibits subsequent infection with pathogenic arboviruses. While most research in this area has focused on viral diseases, similar approaches might be developed for bacterial pathogens, potentially using endosymbiotic bacteria such as *Wolbachia* to reduce vector competence. Advances in **genetic technologies** such as gene drive systems offer the potential for modifying vector populations to reduce their ability to transmit pathogens, though these approaches raise important ethical and regulatory considerations. The development of **new diagnostic tools**, including rapid tests for field use and molecular techniques for pathogen detection in vectors, can enhance surveillance and early response capabilities. Additionally, **ecological interventions** that restore predator populations or modify habitats to reduce vector breeding sites offer sustainable approaches to vector control. Implementation research is needed to determine how best to integrate these novel approaches with existing strategies and to scale successful interventions across different ecological and social contexts.

Table 3: Integrated Prevention and Control Strategies for Insect-Vectored Bacterial Diseases\*

Strategy Category	Specific Approaches	Key Considerations	Implementation Challenges
<b>Vector Control</b>	Insecticide application, environmental management, biological control, genetic approaches	Must be based on local vector ecology and behavior; resistance monitoring essential	Insecticide resistance; environmental impact; community acceptance; sustainability
<b>Personal Protection</b>	Insecticide-treated nets, protective clothing, repellents, household screening	Requires consistent and correct use; cultural acceptability important	Adherence; cost; availability; re-treatment of nets
<b>Community Engagement</b>	Health education, participatory surveillance, community-based control activities	Should build on local knowledge and practices; empowerment approaches	Resource mobilization; sustaining participation; measuring impact
<b>Health System Strengthening</b>	Improved diagnosis, clinician education, surveillance systems, outbreak response	Integration with primary health care; cross-sectoral collaboration	Resource limitations; laboratory capacity; training needs
<b>Research and Innovation</b>	Novel insecticides, biological control, genetic approaches, vaccine development	Balancing immediate needs with long-term solutions; ethical considerations	Funding; regulatory frameworks; technology transfer

## 7. Conclusion

Insect vectors play an indispensable role in the transmission of bacterial pathogens that cause significant disease burden worldwide. This review has examined the complex transmission dynamics between insect vectors and bacterial pathogens, highlighting the diverse mechanisms that facilitate disease spread and the substantial public health implications of these relationships. From the mechanical transmission of enteric pathogens by houseflies to the sophisticated biological transmission of rickettsial pathogens by lice and fleas, the interactions between insects and bacteria represent the outcome of long evolutionary relationships with profound consequences for human health.

The **major challenges** in controlling insect-vector-bacterial diseases include the expanding geographic range of many vectors due to climate change, the emergence and spread of antimicrobial resistance, and the limitations of current diagnostic and surveillance systems. Addressing these challenges requires **integrated approaches** that combine vector control, personal protection, clinical management, and community engagement within a One Health framework that acknowledges the interconnectedness of human, animal, and environmental health. The continued burden of these diseases, particularly among the world's most vulnerable populations, underscores the urgency of strengthening public health systems and devoting resources to prevention and control.

Several **critical research needs** emerge from this review. First, a better understanding of the vector competence of different insect species for bacterial pathogens would help identify potential vectors before disease emergence in new regions. Second, investigation into the role of insects in the amplification and dissemination of antimicrobial resistance genes could inform strategies to mitigate this growing threat. Third, development of novel control approaches, including

biological and genetic strategies, might provide additional tools to complement existing methods. Finally, implementation research is needed to determine the most effective and sustainable ways to deliver prevention and control interventions in different social and ecological contexts.

The history of insect-vector-bacterial diseases reminds us of their potential to cause immense human suffering, while contemporary trends highlight their continuing capacity to emerge and reemerge in response to environmental and social change. Addressing these diseases effectively will require sustained commitment to surveillance, research, and control, backed by sufficient resources and political will. By building on current knowledge and pursuing innovative solutions, we can reduce the burden of these diseases and move closer to the goal of health equity for all populations affected by insect-vector-bacterial pathogens.

## References

- Amadi, R.E., Iheukwumere, I.H. and Unaeze, B.C. (2017). Effects Of Crude Alkaloid Extracted From *Ocimum Gratissimum* On The Activity Of Ciprofloxacin Against *Salmonella Enterica* Serovar Typhi. *Advances in Life Science and Technology* 58.
- Dim, C. N., Iheukwumere, I. H., Iheukwumere, C. M., Ugwu, C. H., Ike, V. E., Ezendianefo, J. N., Egbe, P. A., Oragwu, I. P., Orji, C. C., Ogbonnaya, O. C., Onwuasoanya, U. F., Okereke, F. O., Oduenyi, P. M., & Ochibulu, S. C. (2025a). Multiple Antibiotic Resistance Bacterial Strains in Frozen Meat Sold at Abagana, Anambra State: A Public Health Concern. *IPS Journal of Applied Microbiology and Biotechnology*, 4(3), 181–186. <https://doi.org/10.54117/ijamb.v4i3.75>
- Dim, C. N., Iheukwumere, I. H., Iheukwumere, C. M., Ugwu, C. H., Ike, V. E., Ezendianefo, J. N., Egbe, P. A., Oragwu, I. P., Orji, C. C., Ogbonnaya, O. C., Onwuasoanya, U. F., Okereke, F. O., Oduenyi, P. M., & Ochibulu, S. C. (2025b). The Burden of Antibiotic Resistance: Evaluating the Impact of Multiple Antibiotic-Resistant Enteric Bacteria in Academic Environments.

- IPS Interdisciplinary Journal of Biological Sciences*, 4(4), 144–149. <https://doi.org/10.54117/ijibs.v4i4.78>
- Dim, C. N., Iheukwumere, I. H., Iheukwumere, C. M., Ugwu, C. H., Ike, V. E., Ezendianefo, J. N., Egbe, P. A., Oragwu, I. P., Orji, C. C., Ogbonnaya, O. C., Onwuasoanya, U. F., Okereke, F. O., Oduenyi, P. M., & Ochibulu, S. C. (2025c). Antimicrobial resistance in aquaculture: evaluating pseudomonas aeruginosa from fish ponds. *IPS Intelligentsia Multidisciplinary Journal*, 4(1), 32–36. <https://doi.org/10.54117/iimj.v4i1.10>
- Ekechukwu, C. C., Umeh, S. O., Iheukwumere, I. H., & Iheukwumere, C. M. (2025a). Bacterial Loads of Smoked Fish and Chicken: Role of pH and Moisture Content. *IPS Applied Journal of Nutrition, Food and Metabolism Science*, 3(1), 44–49. <https://doi.org/10.54117/iajnfms.v3i1.102>
- Ekechukwu, C. C., Umeh, S. O., Iheukwumere, I. H., & Iheukwumere, C. M. (2025b). Biological Inhibition of Pathogenic Bacteria Isolated from Smoked Fish and Chicken: An In Vitro Study. *IPS Interdisciplinary Journal of Biological Sciences*, 4(2), 85–92. <https://doi.org/10.54117/ijibs.v4i2.50>
- Ekechukwu, C. C., Umeh, S. O., Iheukwumere, I. H., & Iheukwumere, C. M. (2025c). Prophylactic Potential of the Most Potent Synergistic Biological Agent against Bacterial Infections from Smoked Fish and Chicken. *IPS Journal of Applied Microbiology and Biotechnology*, 4(2), 153–160. <https://doi.org/10.54117/ijamb.v4i2.57>
- Ekesiobi, A. O., Iheukwumere, C. M., Iheukwumere, I. H., Ejike, C. E., Ilechukwu, C. C., Ike, V. E., Okereke, F. O., & Ochibulu, S. C. (2025). Hying the Inhibitory Activity of *Xylopiia aethiopia* against *Vibrio cholerae* using Azithromycin. *IPS Journal of Basic and Clinical Medicine*, 2(3), 93–98. <https://doi.org/10.54117/ijbcm.v2i3.16>
- Frontiers in Microbiology. (2025). *Insect-specific viruses: Transmission dynamics and biological control strategies against arboviruses*. *Frontiers in Microbiology*.
- Iheukwumere, I. H., Ajeh, J. C., Iheukwumere, C. M., Ike, V. E., Obianom, A. O., Ihenatuoha, U. A., Igboanugo, E. U., Onwuasoanya, U. F., Okereke, F. O., Nnadozie, C. H., Agbaugo, C. F., Nwike, M. I., Nwakoby, N. E., & Ilechukwu, C. C. (2025). Exploring the Phytochemical and Antimicrobial Properties of Fruit Vinegar: A Study on Phoenix Dactylifera and Malus Sylvestris. *IPS Journal of Applied Microbiology and Biotechnology*, 4(1), 115–122. <https://doi.org/10.54117/ijamb.v4i1.48>
- Iheukwumere, I. H., Iheukwumere, C. M., Idigo, M. A., & Ezekwueche, S. N. (2025a). *Lactobacillus* fermentation of chicken feather: Impact on structural development and immune system of albino Wistar rats. *IPS Applied Journal of Nutrition, Food and Metabolism Science*, 3(2), 75–83. <https://doi.org/10.54117/qabcj082>
- Iheukwumere, I. H., Iheukwumere, C. M., Idigo, M. A., & Ezekwueche, S. N. (2025b). Evaluation of *Lactobacillus* fermented chicken feather meal on blood lipoproteins and lymphocyte count in rats. *IPS Journal of Nutrition and Food Science*, 4(4), 569–577. <https://doi.org/10.54117/012d8612>
- Iheukwumere, I. H., Iheukwumere, C. M., Idigo, M. A., & Ezekwueche, S. N. (2025c). Exploring the impact of *Lactobacillus*-fermented chicken feather on organ weights and functions in albino Wistar rats. *IPS Journal of Toxicology*, 3(3), 68–75. <https://doi.org/10.54117/zc1h5865>
- Iheukwumere, I. H., Iheukwumere, C. M., Idigo, M. A., & Ezekwueche, S. N. (2025d). Corollary of *Lactobacillus* Fermented Chicken Feather on Organ-Weight and Leukocyte Indices of Broiler Chicks. *IPS Intelligentsia Multidisciplinary Journal*, 4(1): 46-53. <https://doi.org/10.54117/iimj.v4i1.12>
- Iheukwumere, I. H., Iheukwumere, C. M., Idigo, M. A., & Ezekwueche, S. N. (2025e). Fermented Chicken Feather Meal as a Potential Feed Supplement: Effects on Body Weight and Immune Function. *IPS Intelligentsia Multidisciplinary Journal*, 4(1), 37–45. <https://doi.org/10.54117/iimj.v4i1.11>
- Iheukwumere, I. H., Iheukwumere, C. M., Idigo, M. A., & Ezekwueche, S. N. (2025f). Corollary of *Lactobacillus* Fermented Chicken Feather on Growth Performance of Rats. *IPS Journal of Biotechnology and Applied Biochemistry*, 1(2), 57–65. <https://doi.org/10.54117/ijbab.v1i2.85>
- Iheukwumere, I. H., Iheukwumere, C. M., Idigo, M. A., & Ezekwueche, S. N. (2025g). Corollary of *Lactobacillus* Fermented Chicken Feather on Growth Performance of Rats. *IPS Journal of Biotechnology and Applied Biochemistry*, 1(2), 57–65. <https://doi.org/10.54117/ijbab.v1i2.85>
- Iheukwumere, I. H., Iheukwumere, C. M., Idigo, M. A., & Ezekwueche, S. N. (2025h). Fermented Chicken Feather as a Sustainable Feed Ingredient: Effects on Broiler Chick Health and Growth. *IPS Interdisciplinary Journal of Biological Sciences*, 4(4), 157–165. <https://doi.org/10.54117/ijibs.v4i4.84>
- Iheukwumere, I. H., Iheukwumere, C. M., Idigo, M. A., & Ezekwueche, S. N. (2025i). Assessment of Fermented Corn Mixed with Fish Meal as a Chicken Additive for Healthy Broiler Chicks. *Journal of Agriculture, Food Technology and Sustainability*, 2(1), 60–68. <https://doi.org/10.54117/jafts.v2i1.82>
- Iheukwumere, I. H., Iheukwumere, C. M., Idigo, M. A., & Ezekwueche, S. N. (2025j). Evaluation of Fermented Corn Residue as a Growth Promoter in Broiler Chicken Diets. *Journal of Agriculture, Food Technology and Sustainability*, 2(1), 69–77. <https://doi.org/10.54117/jafts.v2i1.83>
- Iheukwumere, I. H., Iheukwumere, C. M., Obianom, A. O., Nnadozie, C. H., Okereke, F. O., Onwuasoanya, U. F., ... Destiny, E. C. (2025k). Cross-Sectional Study of Major Strains of *Salmonella enterica* Subspecies *Enterica* Serovar Typhi among Borehole Used in Uli Community. *IPS Journal of Public Health*, 5(2), 205–210. <https://doi.org/10.54117/ijph.v5i2.40>
- Ike, V. E., Iheukwumere, I. H., Iheukwumere, C. M., Dim, C. N., Ezendianefo, J. N., Egbe, P. A., Oragwu, I. P., Orji, C. C., Ogbonnaya, O. C., Onwuasoanya, U. F., Okereke, F. O., & Ochibulu, S. C. (2025a). Prevalence of *Bacillus cereus* in Powdered Soybean Sold in Uli Community, Anambra State: A Cross-Sectional Study. *IPS Journal of Basic and Clinical Medicine*, 2(3), 108–114. <https://doi.org/10.54117/ijbcm.v2i3.18>
- Ike, V. E., Iheukwumere, I. H., Iheukwumere, C. M., Dim, C. N., Ezendianefo, J. N., Egbe, P. A., Oragwu, I. P., Orji, C. C., Ogbonnaya, O. C., Onwuasoanya, U. F., Okereke, F. O., & Ochibulu, S. C. (2025b). *Bacillus cereus* in Uli's cornflour: A prevalence study. *IPS Journal of Nutrition and Food Science*, 4(3), 544–548. <https://doi.org/10.54117/8bttte840>
- Ike, V. E., Iheukwumere, I. H., Iheukwumere, C. M., Dim, C. N., Ezendianefo, J. N., Egbe, P. A., Oragwu, I. P., Orji, C. C., Ogbonnaya, O. C., Onwuasoanya, U. F., Okereke, F. O., & Ochibulu, S. C. (2025c). Pathogenic Profile Analysis: In Vitro Screening of Enteric Bacteria from University Dusters. *IPS Journal of Applied Microbiology and Biotechnology*, 4(3), 187–191. <https://doi.org/10.54117/ijamb.v4i3.76>
- Ike, V. E., Iheukwumere, I. H., Iheukwumere, C. M., Dim, C. N., Ezendianefo, J. N., Egbe, P. A., Oragwu, I. P., Orji, C. C., Ogbonnaya, O. C., Onwuasoanya, U. F., Okereke, F. O., & Ochibulu, S. C. (2025d). Frozen Fish Pathogens: Antimicrobial Resistance and Public Health Implications. *IPS Interdisciplinary Journal of Biological Sciences*, 4(4), 138–143. <https://doi.org/10.54117/ijibs.v4i4.77>
- Ike, V. E., Iheukwumere, I. H., Iheukwumere, C. M., Dim, C. N., Ezendianefo, J. N., Egbe, P. A., Oragwu, I. P., Orji, C. C., Ogbonnaya, O. C., Onwuasoanya, U. F., Okereke, F. O., & Ochibulu, S. C. (2025e). Stream water quality assessment: Antibiotic resistance of Lac-positive enteric bacterial isolates. *Journal of Pollution Monitoring, Evaluation Studies and Control*, 4(2), 120–125. <https://doi.org/10.54117/jpmesc.v4i2.21.2025>

- Insects. (2023). *Insects and public health: An overview*. *Insects*, 14(3), 240.
- National Academies of Sciences, Engineering, and Medicine. (2016). *Global health impacts of vector-borne diseases: Workshop summary*. Washington, DC: The National Academies Press.
- Nwike, M.I., Iheukwumere, I.H. and Uneze, B.C. (2017). Effect of Spices, pH and Temperature on the Survival and Multiplication of *Staphylococcus aureus* in Locally Made Soya Milk Drink. *Journal of Natural Sciences Research* 7(4):1-9
- Paperpile. (2023). *How to format your references using the Insects citation style*.
- PMC. (2018). *Insects and the transmission of bacterial agents*. *Microbiology Spectrum*, 6(5).
- PMC. (2025). *Assessment of microbial transmission by insect vectors in healthcare settings*. *PMC*, 5(Suppl 2), S118.
- ScienceDirect. (2015). *Insect vector-mediated transmission of plant viruses*. *Virology*, 479–480.
- Ugwu, C. H., Iheukwumere, I. H., Iheukwumere, C. M., Ike, V. E., Dim, C. N., Ezendianefo, J. N., Egbe, P. A., Oragwu, I. P., Orji, C. C., Ogbonnaya, O. C., Onwuasoanya, U. F., Okereke, F. O., Oduenyi, P. M., & Ochibulu, S. C. (2025a). Maternal health and antibiotic resistance: *Klebsiella pneumoniae* isolates analysis. *IPS Journal of Public Health*, 5(3), 290–295. <https://doi.org/10.54117/s3tx6v26>
- Ugwu, C. H., Iheukwumere, I. H., Iheukwumere, C. M., Ike, V. E., Dim, C. N., Ezendianefo, J. N., Egbe, P. A., Oragwu, I. P., Orji, C. C., Ogbonnaya, O. C., Onwuasoanya, U. F., Okereke, F. O., Oduenyi, P. M., & Ochibulu, S. C. (2025b). *Ocimum gratissimum* Extract's Effectiveness against *Vibrio cholerae* from Uli Streams. *IPS Journal of Phytochemistry and Medicinal Plant Research*, 1(2), 15–19. <https://doi.org/10.54117/ijpmpr.v1i2.38>
- Veterinary Sciences. (2022). *Flies as vectors and potential sentinels for bacterial pathogens and antimicrobial resistance*. *Veterinary Sciences*, 9(6), 300.
- Viruses. (2024). *Unleashing nature's allies: Comparing the vertical transmission dynamics of insect-specific and vertebrate-infecting flaviviruses in mosquitoes*. *Viruses*, 16(9), 1499.
- World Health Organization (WHO). (2023). *Vector-borne diseases*. Fact Sheet.