THE CHANGING TRENDS OF VECTOR-BORNE DISEASES TO CLIMATE CHANGE

Editors:
Jayalakshmi Krishnan
Sigamani Panneer
P. Thiyagarajan
Balachandar Vellingiri
Pradeep Kumar Srivastava

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Edited by

Jayalakshmi Krishnan
Vector Biology Research Laboratory
Department of Biotechnology
Central University of Tamil Nadu
Thiruvarur, India

Sigamani Panneer
Centre for the Study of Law and Governance
Jawaharlal Nehu University
New Delhi, India

P. Thiyagarajan
Department of Computer Science
Central University of Tamil Nadu
Thiruvarur, India

Balachandar Vellingiri
Department of Zoology
Central University of Punjab
Bathinda, India

&

Pradeep Kumar Srivastava
National Vector Borne Disease Control Programme
New Delhi, India

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Editors: Jayalakshmi Krishnan, Sigamani Panneer, P. Thiyagarajan, Balachandar Vellingiri and Pradeep Kumar Srivastava

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FOREWORD

Vector-borne illnesses have become a significant public health concern in recent years, highlighting the complex relationship between climate change and human health. The rising global temperatures, shifting rainfall patterns, and extreme weather events are influencing the geographical distribution and seasonality of many vectors, such as mosquitoes, ticks, and mites, which in turn affect the transmission dynamics of diseases they carry. As we stand on the brink of unprecedented environmental changes, it is vital to understand how climate change will reshape the landscape of infectious diseases.

This book, "The Changing Trends of Vector-Borne Diseases to Climate Change," provides a comprehensive exploration of how climate change is influencing some of the most significant vector-borne diseases affecting humans. By focusing on diseases such as dengue, malaria, scrub typhus, Kyasanur Forest Disease (KFD), and Crimean-Congo Hemorrhagic Fever (CCHF), the authors present a detailed examination of the environmental shifts that are expanding the range of these pathogens, altering their epidemiology, and posing new challenges for control and prevention.

Each chapter delves into a specific disease, examining the relationship between climate variability and its vector ecology, transmission patterns, and public health impact. By highlighting the urgent need for innovative strategies in disease surveillance, vector control, and public health infrastructure, this book aims to provide insights into how we can mitigate the growing threat of climate-induced vector-borne diseases.

As climate change continues to accelerate, the need for interdisciplinary research, global cooperation, and robust public health planning has never been more critical. I hope that the knowledge contained in this book will serve as a valuable resource for researchers and public health professionals alike as we face the challenges ahead.

With a greater understanding of the complex relationship between climate change and vector-borne diseases, we can work toward safeguarding human health in a rapidly changing world.

Rajesh Banu J.
Department of Biotechnology
Central University of Tamil Nadu
Thiruvarur, Tamil Nadu, India

PREFACE

Climate change has emerged as one of the most significant global challenges of our time, influencing ecosystems, public health, and human livelihoods. Among its many impacts, the shifting patterns of vector-borne diseases present a critical concern. As temperatures rise, precipitation patterns change, and extreme weather events become more frequent, the habitats and behaviors of vectors such as mosquitoes, ticks, and mites are undergoing significant transformations. These changes have profound implications for the spread of diseases like dengue, malaria, Crimean-Congo Hemorrhagic Fever (CCHF), Kyasanur Forest Disease (KFD), and scrub typhus.

This book explores the complex relationship between environmental changes and the epidemiology of vector-borne diseases. Each chapter examines a specific disease in the context of climate variability, providing insights into how fluctuations in temperature, humidity, and ecological dynamics are altering the geographical distribution and incidence of these illnesses. From the highlands where scrub typhus is making unexpected inroads to the emergence of KFD in regions previously unaffected, the book underscores the urgent need for a multidisciplinary approach to understanding the effects of climate change on public health.

Through detailed case studies, the book highlights how rising temperatures expand the range of vectors, creating new public health challenges and complicating efforts to control outbreaks. With a focus on diseases such as dengue, malaria, KFD, CCHF, and scrub typhus, this volume offers a comprehensive exploration of the complexities associated with vector-borne diseases in the era of climate change, providing invaluable insights for researchers, public health officials, and policymakers working to protect vulnerable populations.

Jayalakshmi Krishnan
Vector Biology Research Laboratory
Department of Biotechnology, Central University of Tamil Nadu
Thiruvarur, India

Sigamani Panneer
Centre for the Study of Law and Governance
Jawaharlal Nehu University
New Delhi, India

P. Thiyagarajan
Department of Computer Science
Central University of Tamil Nadu
Thiruvarur, India

Balachandar Vellingiri
Department of Zoology
Central University of Punjab
Bathinda, India

&

Pradeep Kumar Srivastava
National Vector Borne Disease Control Programme
New Delhi, India

List of Contributors

Jayalakshmi Krishnan	Vector Biology Research Laboratory, Department of Biotechnology, Central University of Tamil Nadu, Thiruvarur, India
Joel Jaison	Vector Biology Research Laboratory, Department of Biotechnology, Central University of Tamil Nadu, Thiruvarur, India
R Narendar	Vector Biology Research Laboratory, Department of Biotechnology, Central University of Tamil Nadu, Thiruvarur, India
Rajalakshmi Anbalagan	Vector Biology Research Laboratory, Department of Biotechnology, Central University of Tamil Nadu, Thiruvarur, India
S.K. Farhat	Vector Biology Research Laboratory, Department of Biotechnology, Central University of Tamil Nadu, Thiruvarur, India
S Binduja	Vector Biology Research Laboratory, Department of Biotechnology, Central University of Tamil Nadu, Thiruvarur, India

CHAPTER 1

Climate Change and Vector-Borne Diseases in General

Rajalakshmi Anbalagan[1] and **Jayalakshmi Krishnan**[1,*]

[1] *Vector Biology Research Laboratory, Department of Biotechnology, Central University of Tamil Nadu, Thiruvarur, India*

Abstract: Many arthropod species, including ticks, fleas, sand flies, mosquitoes, triatomine bugs, and black flies, serve as vectors for numerous diseases that affect humans and animals. These vectors transmit pathogens such as bacteria, viruses, and protozoa, which cause diseases like dengue fever, West Nile Virus, Lyme disease, and malaria. As cold-blooded animals, arthropod vectors are highly sensitive to fluctuations in climatic factors. Climate change significantly impacts several aspects of vector biology and ecology, including survival and reproduction, abundance and distribution, pathogen development and survival, as well as spatiotemporal distribution. Generally, climate change is a crucial factor influencing the survival, reproduction, distribution, and density of disease vectors, subsequently affecting the epidemiology of vector-borne diseases.

Keywords: Arthropods, Climate changes, Diseases, Distribution, Pathogens, Vector.

INTRODUCTION

Climate Change and Vector-Borne Diseases

Climate change is directly contributing to a range of humanitarian emergencies, including heatwaves, wildfires, floods, tropical storms, and hurricanes. These natural disasters are not only becoming more frequent but are also increasing in scale and intensity. The increasing severity of these events underscores the critical need for robust climate action and disaster preparedness strategies to mitigate their impact on vulnerable populations.

The change in climatic conditions, including an increase in heat waves, floods, and storms, has had a significant impact on human health. The evolving zoonotic

* **Corresponding author Jayalakshmi Krishnan:** Vector Biology Research Laboratory, Department of Biotechnology, Central University of Tamil Nadu, Thiruvarur, India; E-mail: jayalakshmi@cutn.ac.in

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diseases and other vector-borne diseases have also played a major role in the changing effects of climate change [1].

The climatic factors that directly influence VBDs ecosystems are primarily temperature and rainfall. These factors play a crucial role in the life cycles of vectors and pathogens, as well as in the environments [2]. The transmission of VBDs requires a vector population, and diseases caused by pathogens such as parasites, viruses, bacteria, and in some cases, nematodes [3]. A vector is known to be an organism acting as a vehicle, which transmits or carries the pathogen from infected vector hosts to the uninfected hosts. Major global VBDs have been identified by the World Health Organization (WHO) and other research. Malaria, transmitted by *Anopheles* (*An.*) mosquitoes, remains one of the deadliest VBDs worldwide. Dengue, spread by *Aedes* mosquitoes, causes severe flu-like illness and sometimes leads to deadly complications. *Aedes* mosquitoes also transmit chikungunya, causing fever and severe joint pain. Yellow fever, a viral hemorrhagic disease, is spread by *Aedes* and *Haemagogus* mosquitoes. Zika spreads primarily by *Aedes* mosquitoes, and it can cause birth defects when transmitted from a pregnant woman to her fetus. Lymphatic filariasis is caused by parasitic worms transmitted through the bites of infected mosquitoes, leading to severe swelling and disability. Leishmaniasis, which is spread by sandflies, can cause skin sores or affect internal organs. Japanese encephalitis is a viral infection spread by mosquitoes carrying the Japanese encephalitis virus, which can cause inflammation of the human brain. These diseases pose significant public health challenges and contribute to substantial morbidity and mortality worldwide, as claimed by WHO.

Human activities, such as fossil burning, deforestation, and industrial processes, have led to an increase in greenhouse gases and caused an impact on ecosystems and biodiversity. Direct consequences of climate change, which are easier to observe, include excessive weather events such as hurricanes, floods, droughts, and changes in temperature and rainfall patterns. These events can have direct and visible impacts on human and ecological systems. Indirect consequences of climate change are also visible but can be equally overwhelming. One important indirect consequence is the alteration of the endemic range of parasitic diseases. Climate change can lead to shifts in the distribution of disease vectors (such as mosquitoes, ticks, and tsetse flies) and their reservoir hosts, as shown in Fig. (**1**) [4].

Non-climatic Factors

Several other factors have also been implicated in the emergence and recurrence of vector-borne diseases. The major non-climatic factors include urbanization, international trade, global human populations, travel-intensive livestock keeping systems, modernization of agricultural practices, and the proliferation of reservoirs. Studies on climate change and its impact on vector-borne diseases have also highlighted the effects of agricultural practices on human health. Several studies have reported that infectious diseases and human-induced land-use changes in agricultural practices are significantly linked. Agricultural works are associated with emerging zoonotic diseases, with more than 50% of human cases. Development projects, such as irrigation and the construction of dams, have also affected vector population densities, inducing the reappearance of zoonotic diseases (*e.g*., Rift Valley Fever) [5 - 10].

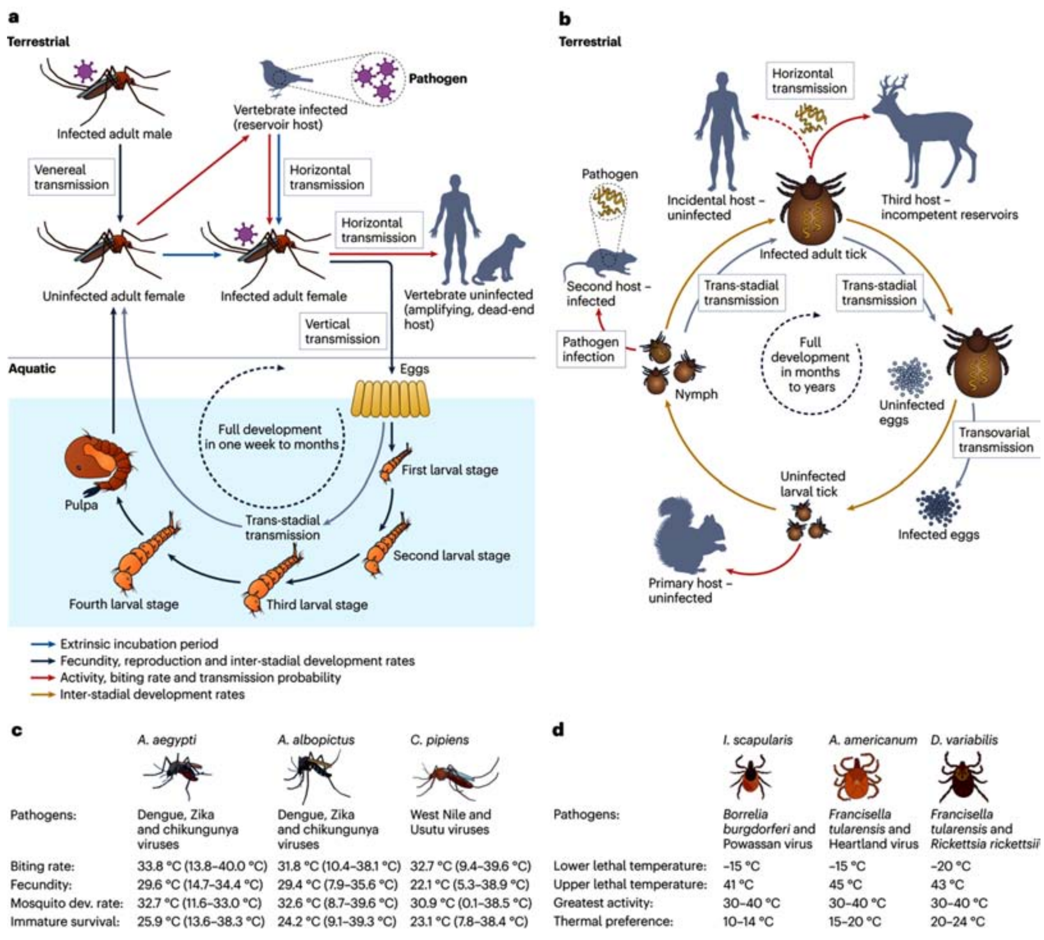

Fig. (1). Impact of human activities and climate change on vector-borne diseases.
Source: [de Souza *et al*., 2024]

CHAPTER 2

Climate Change and Scrub Typhus

S.K. Farhat[1] and **Jayalakshmi Krishnan**[1,*]

[1] *Vector Biology Research Laboratory, Department of Biotechnology, Central University of Tamil Nadu, Thiruvarur, India*

Abstract: Vector-borne diseases are infections transmitted to humans through the bite of vectors, which are transmitted by arthropods such as mosquitoes, ticks, fleas, and mites. These zoonoses have become a major public health alarm affecting millions of people globally. According to recent reports from the World Health Organization (WHO), the estimated number of cases of vector-borne diseases, namely malaria and Dengue, was 247 million and 390 million, respectively, with cases reported globally. The change in environmental conditions like climate change with variations in the temperature, humidity, rainfall, and precipitation has impacted the change in disease dynamics. This chapter explores the relationship between the impact of climate change and Scrub typhus as well as the risk factors that contribute to Scrub typhus and climate change.

Keywords: Chigger mites, Climate change, Rickettsial infection, Scrub typhus, Seasonal change.

INTRODUCTION

According to the United Nations Framework Convention on Climate Change (UNFCCC), the term "climate change" is defined as the alterations in global temperature conditions that alter human activities and cause harm to the environment [1]. The use of industrialization and urbanization has led to the greenhouse effect, where the emission of harmful gases, such as CO_2, methane, and CFCs, thins the ozone layer by capturing these gases, thus leading to Global warming [2, 3]. Climate change leads to a rise in temperature and a change in rainfall patterns, affecting chigger mite vectors.

For any vector-borne zoonotic disease to occur, it requires an interaction of the epidemiological triad comprising the Agent, Host, and environment [4]. It is the basic model used in all epidemiological studies to identify the root cause of

* **Corresponding author Jayalakshmi Krishnan:** Vector Biology Research Laboratory, Department of Biotechnology, Central University of Tamil Nadu, Thiruvarur, India; E-mail: jayalakshmi@cutn.ac.in

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disease transmission and facilitate its early detection and diagnosis. Upon disturbance in this triad, the so-called diseases known as epidemics, endemics, and pandemics cause havoc to the public health population.

Agent

The agent is the primary cause of the disease, primarily comprising infectious microorganisms such as bacteria, viruses, and parasites that cause illness. Eliminating or eradicating the agent will help control the disease at the primary level. The gram-negative bacterium *Orientia tsutsugamushi* is the agent of Scrub typhus, which is transmitted through the saliva of infected chigger mites [5].

Host

The host is the susceptible or vulnerable living animal or human on which these agents enter to complete their life cycle, thereby transmitting the pathogenic agents into human cells. Humans are the primary hosts of Scrub typhus, while some small mammals serve as secondary hosts [6]. Rodents, on the other hand, are the usual reservoirs that carry the larval chigger mites and are termed reservoir hosts, acting as natural reservoirs for *Orientia tsutsugamushi*, the bacterium responsible for the disease [7, 8]. Additionally, humans serve as incidental hosts when they come into contact with the chigger mites (larval stage of mites) that transmit the bacterium (Fig. **1**).

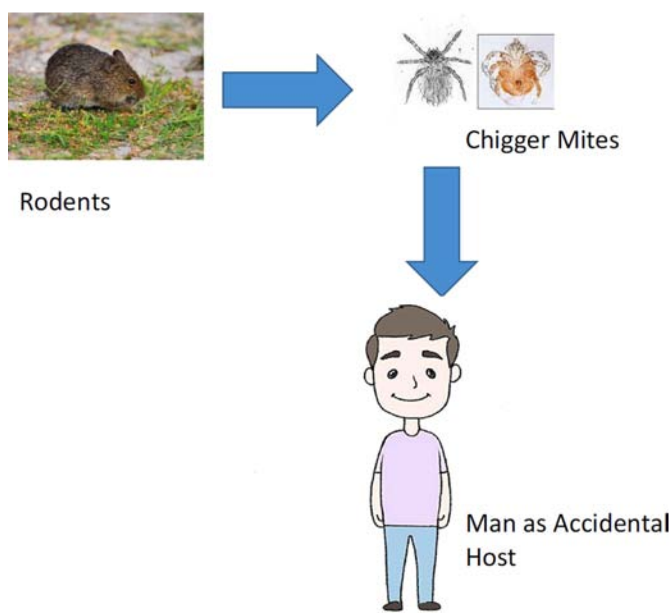

Fig. (1). Lifecycle of scrub typhus.

Rodents (Primary Hosts/Reservoirs)

- ***Rattus* species** (rats)
- ***Apodemus* species** (field mice)
- ***Bandicota* species** (bandicoot rats)

These rodents are found in a wide range of habitats, from forests to farmlands and urban areas, and are the primary source of infection for the larval mites (chiggers) [9].

Chigger Mites (Vector)

Although not a "host," chigger mites (larval stage of **trombiculid mites**) play a crucial role as the vector of scrub typhus. The larvae feed on the blood of infected rodents and subsequently transmit the bacteria to humans. Notable species of chigger mites include [10, 11]:

- ***Leptotrombidium deliense***
- ***Leptotrombidium akamushi***

The mites remain infected for life, but they primarily feed on rodents. Humans are only incidental hosts when they come into contact with mite-infested environments, such as forests, scrublands, or farmlands.

Humans (Incidental Hosts)

Humans are not natural hosts for *Orientia tsutsugamushi*, but they become **incidental hosts** when exposed to infected chigger mites. This exposure often occurs in rural or forested areas, especially where human activities, such as farming, bring them into proximity with rodent populations or mite-infested environments [12].

Unlike rodents, humans do not contribute to the natural life cycle of the bacterium because they are not involved in its long-term transmission. However, scrub typhus can cause severe illness in humans, leading to fever, rash, and multi-organ complications if left untreated.

Other Mammals (Incidental Hosts)

While rodents are the primary hosts, other small mammals, such as shrews or wild animals, may also act as secondary or incidental hosts in some ecosystems [12 - 14]. However, they play a lesser role in the overall transmission dynamics compared to rodents and humans.

CHAPTER 3

Climate Change and Kyasanur Forest Disease (KFD)

Sathya Jeevitha Balakrishnan[1] and **Jayalakshmi Krishnan**[1,*]

[1] *Vector Biology Research Laboratory, Department of Biotechnology, Central University of Tamil Nadu, Thiruvarur, India*

Abstract: Climate change is significantly impacting the epidemiology of Kyasanur Forest Disease [KFD], a viral tick-borne hemorrhagic fever indigenous to India's Western Ghats area. Alterations in temperature and precipitation patterns directly affect the survival, development, and activity of *Haemaphysalis spinigera*, the primary vector for KFDV, as well as the distribution and behavior of animal hosts. Warmer and more humid conditions, driven by climate change, create favorable environments for tick proliferation, potentially expanding their geographical range and increasing human-tick interactions. Deforestation and habitat fragmentation also exacerbate the situation by disrupting the balance between vectors, hosts, and humans. This environmental degradation forces animal reservoirs, such as monkeys, and human populations into closer touch, heightening the risk of virus transmission. Seasonal variations play a crucial role, with KFD incidence peaking during the drier, hotter months when tick activity is at its highest. The annual transmission cycle in regions like Shivamogga district shows cases emerging in January, peaking in March, and declining by June, with a resurgence in November, demonstrating a clear link between climate patterns and disease spread. Understanding the intricate relationship between climate change, tick ecology, and KFD transmission is essential for developing effective public health strategies and alleviating future outbreaks. This chapter underscores the urgent need for integrated approaches to address the complex interplay of environmental changes and disease dynamics.

Keywords: Climate change, Diapause, *Haemaphysalis spinigera*, Kyasanur forest disease, Precipitation patterns, Tick.

INTRODUCTION

One of the significant public health and global disease concerns is the vector-borne zoonotic illness that accounts for a larger impact of over 17% of all infectious diseases, including about 700,000 deaths annually. These diseases are

* **Corresponding author Jayalakshmi Krishnan:** Vector Biology Research Laboratory, Department of Biotechnology, Central University of Tamil Nadu, Thiruvarur, India; E-mail: jayalakshmi@cutn.ac.in

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highly transmissible with the help of vectors, such as mosquitoes, mites, fleas, and ticks, which can gather pathogens from infected hosts and transmit them to new hosts. About 75 percent of infectious diseases are zoonotic as they possess the potential for widespread transmission, severe health consequences, and economic impact. Complex factors, including global travel and trade, unplanned urbanization, and environmental changes, drive the emergence and spread of vector-borne diseases. Many zoonotic diseases have serious human health and economic consequences, especially in developing countries with poor diagnostic facilities, lack of medical services, and inadequate hygiene practices [1]. The probability of emerging zoonotic diseases increases with the growing volume of animal trade. Addressing the threat of vector-borne and zoonotic diseases requires a multifaceted approach, including strengthening vector control, improving disease surveillance, reporting, and advancing research on disease ecology, epidemiology, and control strategies. Collaboration between public health agencies, clinicians, and disease ecologists is crucial for early detection and effective management of these emerging health threats. The interaction between human activities and wildlife habitats, coupled with changes in environmental conditions, can increase the likelihood of zoonotic disease outbreaks [2].

One of the most significant vectors for zoonotic illness is ticks, mainly because they are capable of transmitting protozoa, bacteria, and viruses. They transmit critical zoonotic illnesses like Lyme disease, babesiosis, tick-borne encephalitis, anaplasmosis, Kyasanur forest disease, *etc*. Their ability to carry multiple pathogens simultaneously, known as co-infection, can complicate the diagnosis and treatment of tick-borne diseases in humans and animals. They are recognized as the most prevalent ectoparasites that live outside of animals and require feeding on their blood to survive. Recently, the number of recorded instances has increased, with ticks spreading globally and expanding into new regions. These arachnids serve as vectors for various rickettsial and viral diseases. As their bites are undetectable, people often do not even realize they have been bitten in many cases. There are already over 800 species of ticks known to exist, categorized into three families: Argasidae, Ixodidae, and Nuttalliellidae. Climate and environmental factors considerably impact tick dispersion and the diseases they carry. Various factors, including biotic and abiotic elements, the optimal climate for each tick species, and the relationships that ticks have with the diseases they carry are essential to understanding the tick population's global distribution. The worldwide increase in Tick-Borne Diseases [TBDs] is associated with expanding tick habitats, including woody areas, plains, and fields. Furthermore, human activities, such as leaning on logs in parks or resting near trees in tick-containment areas, heighten the possibility of acquiring these infections [3].

Despite widespread tick control methods and advancements in diagnosing Tick-Borne Diseases [TBDs], their numbers are rising globally, with an annual incidence of 50,000 human-reported cases in Europe caused by *Ixodes ricinus*. Chemical options for controlling and managing these diseases may not be enough. A more comprehensive approach is needed to combine chemical control with natural predators, such as spiders, for integrated pest control and improved diagnostics. Additionally, continuous research is crucial for understanding the diverse TBD landscape worldwide [4].

Climate change is exacerbating the spread and transmission of tick-borne diseases like Lyme disease, Kyasanur forest disease, *etc*., and creating more favorable conditions for tick populations to thrive and expand their geographic range. The two most important climatic factors influencing the regional distribution and abundance of tick species are climate change-related changes in precipitation patterns and warmer temperatures. Milder winters and longer spring and fall seasons enable ticks to be active for a greater portion of the year, allowing them to breed more successfully. Studies have found that the average temperature, diurnal temperature range, and precipitation levels of the hottest quarter are the most important predictors of tick establishment in new areas. Ticks thrive in areas with temperatures above 45°F and at least 85% humidity. As the climate changes, ticks are expanding their range northward by 35-55 km per year in North America and to higher altitudes in Europe. This increases the potential risk of tick-borne illnesses in previously barren areas for ticks [5].

Kyasanur Forest Disease [KFD] is a flaviviral illness that is tick-borne and caused by the Kyasanur Forest Disease Virus [KFDV] that has been rapidly expanding along the Western Ghats, particularly affecting the southern states of India, specifically Karnataka, Kerala, Goa, and Maharashtra. First identified in India in 1957, it is transmitted by infected *Haemaphysalis spinigera* ticks. This virus, belonging to the Flaviviridae family, causes symptoms like high fever, headaches, and bleeding within 3-8 days of infection [6] (Fig. **1**).

Climate change influences temperatures to rise and precipitation patterns to alter, making it easier for the tick vectors that spread KFD to thrive. Research has identified that the typical warmth during the warmest quarter, daily temperature variations, and precipitation levels significantly influence the allocation of *Haemaphysalis spinigera*, the primary tick vector for KFD. Insufficient rainfall and extreme heat in southern India create optimal conditions for tick survival and proliferation. The KFD transmission spans from the month of November to May, when overall total precipitation is less than 500 mm, while heavy rainfall from the month of June to October establishes a conducive ecology for the tick vector. Deforestation and changes in land use have also increased the proximity of the

CHAPTER 4

Climate Change and Dengue: A Growing Threat

S Binduja[1] and **Jayalakshmi Krishnan**[1,*]

[1] *Vector Biology Research Laboratory, Department of Biotechnology, Central University of Tamil Nadu, Thiruvarur, India*

Abstract: Climate change is a significant driver of shifts in the distribution and prevalence of vector-borne diseases, with dengue fever being a prominent example. Dengue, caused by the dengue virus and transmitted primarily by *Aedes aegypti* and *Aedes albopictus* mosquitoes, has seen a marked increase in incidence and geographic spread in recent decades. This chapter explores the multifaceted relationship between climate change and dengue transmission, highlighting how rising temperatures, altered rainfall patterns, and increased humidity contribute to mosquito proliferation and viral transmission.

Keywords: *Aedes* mosquitoes, Climate change, Deforestation, Dengue fever, Humidity, Predictive modeling, Rainfall pattern, Temperature rise, Urbanization, Vector control, Vector-borne diseases.

INTRODUCTION

Climate change refers to significant and lasting changes in temperature and weather patterns, which can be natural or due to human activities such as the burning of fossil fuels, deforestation, and industrial processes [1]. Large volumes of greenhouse gases, such as carbon dioxide and methane, are released into the atmosphere as a result of these activities, trapping heat and contributing to global warming. This phenomenon, known as global warming, is a primary driver of climate change [1]. The impacts of climate change are widespread and profound, and pose many risks to human beings and other lives on Earth [2]. Global health is particularly vulnerable, as climate change can be a reason for health problems directly and indirectly. Rising temperatures and altered weather patterns enhance heat-related illnesses and deaths. Furthermore, the distribution and activity of disease-transmitting vectors like mosquitoes can be affected by climate change, which could lead to an increase in the prevalence of vector-borne diseases [3].

* **Corresponding author Jayalakshmi Krishnan:** Vector Biology Research Laboratory, Department of Biotechnology, Central University of Tamil Nadu, Thiruvarur, India; E-mail: jayalakshmi@cutn.ac.in

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Dengue fever [break-bone fever] is a viral infection spread by mosquitoes, which poses a significant public health challenge in many parts of the world [4]. It is caused by the dengue virus, which exists in four distinct serotypes [5]. The symptoms of dengue fever range from mild to severe and include high fever, severe headache, pain behind the eyes, joint and muscle pain, rash, and mild bleeding [such as nose or gum bleeding or easy bruising. One-fourth of those infected will become sick [6]. The transmission of dengue fever primarily occurs through the bite of infected female mosquitoes of the species *Aedes aegypti* and *Aedes albopictus*. These mosquitoes are highly adapted to urban environments and breed in stagnant water sources commonly found around human habitations [7]. *Aedes aegypti*, particularly, prefers biting humans, and it has the ability to survive in close proximity to human habitations [8].

In the last five years, global incidence of dengue fever has increased dramatically. Over 7.6 million dengue cases had been recorded by the WHO as of April 30, 2024, and dengue transmission is still actively observed in 90 countries, although not all cases are formally reported [9]. Many countries are endemic to dengue, including Regions of Africa, the Americas, and South East Asia. The most seriously affected areas are The Americas, South East Asia, and Western Pacific regions, with Asia accounting for about 70% of the global disease burden. In 2023, the WHO Region of the Americas reported the highest number of dengue cases, with 4.5 million cases and 2300 deaths [4]. Since 2000, the dengue outbreak has grown throughout the region, both in newly affected areas and in previously unaffected ones. The rise in dengue cases can be attributed to various factors, including increased urbanization, international travel, and, notably, climate change [10]. Warmer temperatures and altered precipitation patterns foster the growth and multiplication of *Aedes* mosquito populations, which in turn promote the spread of dengue fever to new regions and increase the frequency of outbreaks. Moreover, monsoon season provides ideal conditions for *Aedes* mosquito breeding and survival [9].

Climate change not only poses direct health risks through extreme weather events and heatwaves but also exacerbates the spread of vector-borne diseases like dengue fever. Addressing climate change and implementing effective vector control measures are crucial steps in mitigating these health impacts and protecting global populations from the escalating threat of dengue fever.

History of Dengue Fever

Some historical texts suggest that dengue-like illnesses were present as far back as 265-420 AD in China, with symptoms resembling those of modern dengue. However, the disease was not formally recognized until much later [11] [12].

18th and 19th Centuries

- **First Recorded Outbreaks:** The first documented outbreaks of dengue occurred in the Caribbean during the late 18th century. The disease spread to various parts of the Americas and was noted in Asia and Africa [13].
- **Transmission:** During this period, it became apparent that the disease was transmitted by mosquitoes, particularly *Aedes aegypti*. However, the exact mechanisms of transmission were not well understood [13].

Early 20th Century

• **Discovery of the Vector:** In the 1900s, researchers identified *Aedes* mosquitoes as the primary vectors of dengue. In 1906, the association between the mosquito and the disease was established. The first significant global epidemic of dengue fever occurred in 1950 in the Philippines, followed by outbreaks in Thailand and other Southeast Asian nations [14].

Late 20th Century to Present

- **Reemergence and Spread:** In the 1970s, dengue reemerged as a significant public health concern, particularly in tropical and subtropical regions. The disease spread to new areas, including the Americas and the Pacific Islands.
- **Dengue Hemorrhagic Fever:** In the 1980s, Dengue Hemorrhagic Fever [DHF] and Dengue Shock Syndrome [DSS] emerged as severe forms of the disease, primarily affecting children in Southeast Asia. These forms can lead to high mortality rates if not treated promptly [14].
- **Increased Incidence:** Since the 1990s, the incidence of dengue has increased dramatically, with significant outbreaks reported in Asia, Latin America, and Africa [15] [16]. The World Health Organization [WHO] has classified dengue as a major public health problem [9].

Modern Developments

- **Vaccination Efforts:** The first dengue vaccine, Dengvaxia, was approved for use in several countries in 2015. However, its efficacy is limited to individuals who have had a previous dengue infection. Research is ongoing to develop more effective vaccines [17] [18].
- **Global Response:** The WHO and various health organizations have initiated global strategies to control dengue through vector management, community education, and surveillance to mitigate outbreaks [4].

CHAPTER 5

Climate Change and Malaria

Joel Jaison[1] and **Jayalakshmi Krishnan**[1,*]

[1] *Vector Biology Research Laboratory, Department of Biotechnology, Central University of Tamil Nadu, Thiruvarur, India*

Abstract: This chapter discusses the complex relationship between climate change and malaria, highlighting the deep impact of environmental shifts on vector-borne diseases. It begins by exploring the broader context of climate change and its influence on the distribution and intensity of vector-borne diseases globally. A key focus is on the impact of changing climate patterns on *Anopheles* mosquitoes, the primary vectors of malaria. The chapter examines how temperature, precipitation, and humidity variations affect mosquito behaviour, life cycle, and habitat suitability, consequently altering malaria transmission dynamics. The economic implications of these changes are analysed, emphasising the burden on healthcare systems and economies, particularly in vulnerable regions. The chapter also discusses the role of climate control and mitigation strategies in managing the spread of malaria. It outlines various interventions to reduce greenhouse gas emissions and improve adaptive capacities to mitigate the adverse effects of climate change on malaria prevalence. Disease surveillance is seen as a crucial component in this context, with an emphasis on the need for monitoring systems to track changes in disease patterns and vector populations. Innovative approaches and technologies for surveillance and data collection are presented, highlighting their importance in early detection and response to malaria outbreaks. This chapter provides current research and case studies and an overview of the challenges and opportunities in addressing the drastic effects of climate change and malaria. It emphasises the importance of integrated vector management strategies combining climate action with public health initiatives to reduce the spread of malaria.

Keywords: *Anopheles* mosquitoes, Case studies, Climate change, Climate control, Disease surveillance, Economic consequences, Malaria, Mitigation, Vector-borne diseases.

INTRODUCTION

Climate change, characterised by rising temperatures, altered precipitation patterns, and increasing frequency of harsh weather disasters, drastically affects

* **Corresponding author Jayalakshmi Krishnan:** Vector Biology Research Laboratory, Department of Biotechnology, Central University of Tamil Nadu, Thiruvarur, India; E-mail: jayalakshmi@cutn.ac.in

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public health exponentially. One of the most concerning impacts is on the epidemiology of vector-borne diseases, notably malaria. Malaria, caused by the infestation of *Plasmodium* parasites and transmitted by *Anopheles* mosquitoes, remains a significant global health challenge [1]. As climate change alters the habitats and behaviours of these vectors, the dynamics of malaria transmission are shifting, necessitating innovative approaches in disease surveillance.

The phenomenon of climate change has now become a matter of global concern, compelling societies to confront the perils of global warming that place a burden on the planet. As the average global temperatures rise, driven by anthropogenic activities, such as the burning of fossil fuels, deforestation, and industrial processes, the resulting climatic shifts are becoming increasingly evident and severe [2]. The manifestations of these changes are varied and widespread: polar ice caps are melting at unprecedented rates, sea levels are rising, and extreme weather events, like hurricanes, droughts, and such, are becoming more frequent and intense. Here, we discuss the dynamics of these changes by examining the scientific principles influencing these shifts, the evidence supporting the urgent reality of global warming, and the impacts of these changes on ecosystems, economies, and human health. Furthermore, it explores the concept of disease spread, an area that encompasses both mitigation strategies aimed at finding the factors that accelerate the transmission of malaria and adaptation measures designed to combat these conditions that have already been observed in various regions. From international policies, such as the Paris Agreement, to technological innovations in disease surveillance, the chapter provides a comprehensive overview of the efforts being made to create a more sustainable, disease-free future. Understanding the correlation between natural events and human interventions becomes crucial as the world grapples with the challenges posed by climate change and public health. This exploration seeks not only to elucidate the current state of the climate crisis but also to inspire precautionary actions and collaborative solutions that can divert these devastating effects. This chapter aims to enlighten the readers with the knowledge necessary to engage in meaningful discourse and effective action in the fight against climate change through a detailed analysis of scientific data, policy frameworks, and emerging technologies.

Climate Change and Vector-borne Diseases

Climate change affects the spread of diseases, particularly vector-borne diseases, as the climatic conditions become more favourable for vectors, leading to an increased risk of disease transmission [3]. Vector-borne diseases are illnesses transmitted by vectors, such as mosquitoes, ticks, and fleas, which thrive in specific environmental conditions. One of the most significant impacts of climate change on vector-borne diseases is the expansion of the geographic range of vectors [4]. Warmer temperatures allow vectors to survive in areas where they previously could not, thereby exposing new populations to the diseases they carry [5]. For example, malaria, a disease transmitted by mosquitoes, is spreading at a higher rate due to global warming, putting millions of people at risk who were previously not affected.

Furthermore, climate change can alter the dynamics of vector populations, leading to increased breeding rates and shorter incubation periods for pathogens within the vectors, leading to concurrent and severe malaria outbreaks [6]. For instance, the Zika virus, primarily transmitted by *Aedes* mosquitoes, dramatically increased in recent years, partly due to changing climate patterns favouring mosquito breeding [7]. The impact of these changes on human health is profound, as isolated communities and tribals that were once protected from vector-borne diseases due to their remote locations are now facing new threats. Vulnerable populations, such as those living in poverty or with limited access to healthcare, are particularly at risk. However, the economic burden of treating these diseases and implementing vector control measures can also be significant, straining already overstretched healthcare systems.

Combatting the spread of vector-borne diseases during this period of intense climate change requires a holistic approach, as this is a multifactorial problem. Firstly, there needs to be a focus on mitigating climate change itself by reducing greenhouse gas emissions and transitioning to renewable energy sources. This will help slow down the drastic climate change and limit the extent of its impacts on vector populations. Secondly, efforts must be made to strengthen public health systems and improve access to healthcare, especially in vulnerable communities. This includes investing in disease surveillance, early detection, and response mechanisms to prevent outbreaks before they escalate.

Additionally, education and community engagement are crucial for raising awareness about the risks of vector-borne diseases and promoting preventative measures, such as insecticide-treated bed nets and mosquito repellents. Furthermore, Integrated Vector Management (IVM) strategies, including habitat modification, insecticide use, and biological control methods, can help reduce vector populations and minimise disease transmission [8]. These strategies should be tailored to local contexts and consider the specific environmental conditions causing vector proliferation.

Understanding the Impact of Climate Change on Malarial Mosquito Vectors

Malaria, a lethal mosquito-borne disease caused by the *Plasmodium* parasite, remains a disease challenge that the world is still dealing with [1]. Understanding

CHAPTER 6

Climate Change and Crimean-Congo Hemorrhagic Fever (CCHF)

R Narendar[1] and **Jayalakshmi Krishnan**[1,*]

[1] *Vector Biology Research Laboratory, Department of Biotechnology, Central University of Tamil Nadu, Thiruvarur, India*

Abstract: Crimean-Congo Hemorrhagic Fever (CCHF) is a highly virulent viral disease characterized by a rapid onset of symptoms and significant mortality rates. The primary mode of transmission to humans is through tick bites, particularly from the *Hyalomma* genus, or through direct contact with infected animals or humans. Clinically, CCHF typically begins with the abrupt onset of fever, myalgia, headache, nausea, vomiting, and diarrhea. As the disease advances, patients may exhibit severe hemorrhagic manifestations, including extensive bruising, epistaxis, and uncontrolled bleeding from venipuncture sites. The progression can result in multi-organ failure, with a fatality rate of up to 40%. CCHF is endemic in regions of Africa, Asia, Eastern Europe, and the Mediterranean. Recent decades have seen an expansion of its geographic range, attributed to factors such as climate change and increased global movement. Populations at elevated risk include healthcare workers and individuals involved in livestock handling and meat processing. Currently, the management of CCHF is primarily supportive, as there are no specific antiviral treatments approved for this disease. Key preventive measures include avoiding tick bites, adhering to safe practices during meat processing, and using personal protective equipment properly. Continuous surveillance, ongoing research, and robust public health preparedness are crucial to address this escalating global health threat effectively.

Keywords: CCHFV, Climate changes, Crimean-Congo Hemorrhagic Fever, Infection control, Nairovirus, Public health, Ribavirin, Tick-borne disease, Vaccine development, Viral hemorrhagic fever.

INTRODUCTION

Crimean-Congo Hemorrhagic Fever (CCHF) is a highly virulent viral disease characterized by its swift transmission and severe clinical symptoms. Historically prevalent in Africa, Asia, and Eastern Europe, CCHF has emerged as a global health concern, drawing significant attention from the scientific and medical

* **Corresponding author Jayalakshmi Krishnan:** Vector Biology Research Laboratory, Department of Biotechnology, Central University of Tamil Nadu, Thiruvarur, India; E-mail: jayalakshmi@cutn.ac.in

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communities [1]. Upon infection, CCHF initially presents with flu-like symptoms, including high fever, severe headache, muscle pain, and malaise. Patients may experience gastrointestinal symptoms, such as nausea, vomiting, and diarrhea, as the disease progresses. Notably, hemorrhage is a hallmark feature of CCHF, leading to petechiae, ecchymosis, epistaxis, gingival bleeding, and gastrointestinal bleeding, highlighting the disease's severity and potential for devastating outcomes [2]. In severe cases, CCHF can cause organ dysfunction, including liver and kidney failure, ultimately resulting in death. The fatality rate of CCHF ranges from 10% to 30%, influenced by factors such as the virus strain and the availability of medical care. Despite advances in supportive care, specific antiviral treatments for CCHF are lacking, emphasizing the importance of preventive measures and early intervention strategies [1, 3]. CCHF is mainly transmitted to humans through the bite of infected ticks, especially those from the *Hyalomma* genus, which act as vectors and reservoirs for the virus. Healthcare workers and individuals engaged in animal husbandry, slaughter, or veterinary practices face substantial risks when they come into direct contact with the blood or bodily fluids of infected individuals. Additionally, occasional reports of aerosol transmission have been documented in healthcare settings and laboratory environments [3, 4].

The historical range of CCHF reflects the distribution of its primary vector, *Hyalomma* ticks, which thrive in warm climates and suitable habitats. The expansion of globalization and the effects of climate change have facilitated the transmission of CCHF into previously unaffected areas, highlighting the evolving landscape of infectious disease epidemiology and emphasizing the need for continuous monitoring and management of emerging risks, such as CCHF [5].

Crimean-Congo Hemorrhagic Fever [CCHF] is a significant and growing global health threat characterized by an increase in its geographic range and incidence in the 21st century [6]. The CCHF Virus [CCHFV] is responsible for the disease. It is primarily transmitted *via* ticks, posing a significant threat of multiple outbreaks, particularly in regions across Africa, Asia, the Middle East, and certain parts of Europe [2, 5].

Scientists first described Crimean-Congo Hemorrhagic Fever in the 20th century, but the disease likely affected people long before it was recognized. Crimean-Congo Hemorrhagic Fever is a potentially fatal virus initially spotted in the Crimean region during the 1940s [7]. Later, they identified it as the same pathogen responsible for what was once known as Congo Hemorrhagic Fever. The detection of the CCHF virus in regions of ancient Celtic settlements in Germany suggests its presence dating back to antiquity [8].

Known for being the most significant human disease spread by ticks, CCHF has affected people from western China to the Middle East, southeastern Europe, and throughout Africa. Over the last two decades, the disease has emerged in multiple locations, including Eastern Europe, particularly in post-Soviet states, the Mediterranean, Central Asia, Southern Europe, Africa, the Middle East, and the Indian subcontinent [1, 7].

Greece reported its first CCHF case in 2008, which resulted in the death of a woman. The disease has a long-standing presence in regions such as Africa, the Balkans, and South Asian countries below the 50th parallel north, which marks the habitat boundary for its primary carrier, the tick [9].

Transmission typically occurs through the bite of an infected tick or exposure to bodily fluids from an infected person or animal [7]. In various outbreaks, the fatality rate for CCHF among those hospitalized has varied widely, from as low as 9% to as high as 70%. However, the World Health Organization notes that it generally falls between 10% and 40% [10].

No commercial vaccines or specific approved treatments are available for CCHF, and care for those affected mostly involves supportive measures. Although neither the FDA nor the WHO has officially sanctioned it, some have suggested that the antiviral ribavirin may be beneficial [11]. Various factors contribute to the emergence and re-emergence of Crimean-Congo Hemorrhagic Fever [CCHF] in new regions.

Climate change and landscape transformations have impacted the abundance and spatial distribution of CCHFV animal hosts and vectors, significantly influencing transmission dynamics and increasing the likelihood of disease emergence [12]. Environmental changes, such as those seen in Turkey, have led to shifts in small mammal communities, resulting in the spillover of CCHF into human populations [13]. The Eastern Mediterranean Region has seen an emergence or re-emergence of CCHF in several countries over the last decade, with an increasing risk of extension into new areas. CCHF is increasingly recognized by the World Health Organization [WHO] as a significant and escalating health concern in the Eastern Mediterranean Region, as evidenced by new regions reporting cases and the disease spreading geographically. While strict adherence to infection control measures is essential for containing healthcare-associated outbreaks, these protocols are only sometimes followed, even in advanced settings [14].

In summary, CCHF poses an escalating global health risk due to its expanding geographic range, increasing incidence, and potential for outbreaks driven by environmental changes and inadequate infection control practices. Continued

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Jayalakshmi Krishnan

Dr. Jayalakshmi Krishnan Postdoc from Ajou University South Korea, 2006-2008, PhD from DRDO, Delhi 2002-2006 Research Assistant Professor, Ajou University, South Korea, 2008-2009 Assistant Professor, SRM University, Chennai, Tamil Nadu India 2011 Assistant Professor, Department of Life Sciences, CUTN, Thiruvarur, Tamil Nadu, India 2012-at present Head, Department of Life Sciences, CUTN, Thiruvarur, Tamil Nadu, India 2012-2016 Coordinator, Department of Epidemiology and Public Health, CUTN, Thiruvarur, Tamil Nadu, India 2016-2020 Organized various programs in vector control , including WHO expert consolation for Kala-Azar elimination in 2016 Organized 13th International conference for vector borne diseases , 2017 Organized various workshops , outreach activities Produced one P.hD in the field of entomological surveillance and insecticide resistance Have guided 19 master students in the field of entomology Have completed two projects from ICMR and TIGS on vector surveillance at Lakshadweep islands Teaching various papers in life sciences including vector biology and management

Sigamani Panneer

Dr. Sigamani Panneer is a Professor of Public Policy at the Centre for the Study of Law and Governance, Jawaharlal Nehru University (JNU), New Delhi. He has previously served as Dean, School of Behavioural Sciences; Head, Department of Social Work; and Coordinator, Centre for Happiness at the Central University, Tamil Nadu. He has held international visiting professorships at the School of Public Health, University of Minnesota (USA); Jishou University (China); and Tianjin University of Finance and Economics (China). Author of over 120 publications with leading publishers, and recipient of the Raman Fellowship and the Global Spotlight Grant. His research spans public health policy, disaster risk reduction, climate change adaptation, occupational health and social determinants of health.

P. Thiyagarajan

Dr. P. Thiyagarajan is currently working as Assistant Professor in the Department of Computer Science, Central University of Tamil Nadu, Thiruvarur from 2016. By holding on-lien at CUTN, he served as Associate Professor & Head in the Department of Computer Science Cyber Security, Rajiv Gandhi National Institute of Youth Development (RGNIYD), Ministry of Youth Affairs and Sports, GoI, Sriperumbudur from June 2022 to Feb 2024. To his credits Dr. P. Thiyagarajan has published 53 papers in various reputed Journals/Conferences/Workshops. He has completed project worth 10 lakhs and in 2023 obtained 1 crore worth fund from MeiTY for Visvesvaraya PhD Scheme. He has obtained around 5.5 lakhs from various funding agencies for organizing Conferences, Workshops and FDPs. He has developed one MOOC course and published one patent. He has received the Young Scientist Award from Tamil Nadu State Council for Science and Technology, Government of Tamil Nadu. Under his guidance one Ph.D. and one M.Phil. scholar was awarded.

Balachandar Vellingiri

Dr Balachander Vellingiri did his PhD in (Zoology [Human Genetics]).,Course on Basics in Human Genetic Diagnostics - A course for CLGs in education, European Society of Human Genetics (ESHG), Portugal. ICMR - International Biomedical (IF) Visiting Scientist, Denmark. UGC Dr. D.S. Kothari Post-Doctoral Fellow, UGC - New Delhi.Brain Pool Program, Stem Cell Laboratory, Konkuk University, Seoul, South Korea, Next Generation Sequencing Course (NGS), European Genetics Foundation, Bologna, Italy, European Advanced Postgraduate Course in Clinical and Molecular Cytogenetics" (PGDCMC) - ECA Fellowship Award, Montpellier, Paris, France, Stem Cell Technology - iPSC training Course, CiRA, Kyoto University, Japan, 26th Course in Medical Genetics, European Genetics Foundation, Bologna, Italy. Associate Professor, Department of Zoology, Central University of Punjab, Bathinda, Punjab.Assistant Professor, Department of Human Genetics & Molecular Biology, Bharathiar University, Coimbatore, Tamil Nadu (2015-2022),DST Young Scientist Fellow, Principal Investigator, DST - FAST Track Project, Bharathiar University, Coimbatore, Tamil Nadu (2012-2015),Brain Pool Fellow, Assistant Professor, Konkuk University, Seoul, Korea (2012),UGC Dr. D. S. KOTHARI Postdoctoral Fellowship, UGC, Bharathiar University, Coimbatore, Tamil Nadu (2011-2012).

Pradeep Kumar Srivastava

Dr. Pradeep Kumar Srivastava is an award-winning entomologist and former Head of Entomology & Vector Control at India's National Vector Borne Disease Control Programme (NVBDCP). With over 35 years of experience in malaria and vector-borne disease management, he has served as the country's nodal officer for Lymphatic Filariasis elimination, a WHO consultant, and a key technical advisor for national surveillance and control strategies. He holds a Ph.D. in Insecticide Residue Analysis and specialized training from the London School of Hygiene & Tropical Medicine. A Fellow of the Royal Entomological Society (London), he has contributed to national and international technical advisory groups, authored major guidelines including India's Integrated Vector Management framework, and published over 50 scientific works. His expertise spans policy, research, surveillance, and international collaboration across SEARO, WHO Geneva, and global vector control networks.