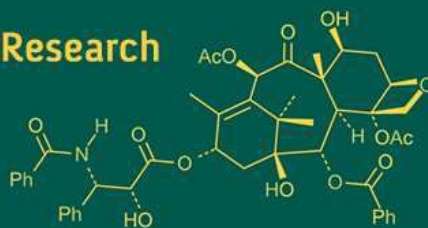


International Journal of Advanced Biochemistry Research



ISSN Print: 2617-4693
ISSN Online: 2617-4707
IJABR 2024; SP-8(11): 711-716
www.biochemjournal.com
Received: 01-08-2024
Accepted: 05-09-2024

Rahul Sheoran
B.V.Sc. and AH (Internship
Student), ICAR-Indian
Veterinary Research Institute,
Bareilly, Uttar Pradesh, India

Priyanka Sheoran
Wildlife Veterinarian (Junior),
RESQ Charitable Trust, Pune,
Maharashtra, India

Corresponding Author:
Rahul Sheoran
B.V.Sc. and AH (Internship
Student), ICAR-Indian
Veterinary Research Institute,
Bareilly, Uttar Pradesh, India

A review on emerging parasitic and viral zoonotic diseases in India: Mitigating strategies and one health approach

Rahul Sheoran and Priyanka Sheoran

DOI: <https://doi.org/10.33545/26174693.2024.v8.i11Sj.3008>

Abstract

There are many new human pathogens that have emerged or re-emerged worldwide from animals. The emergence of zoonotic diseases is associated with a range of underlying causal factors, and represents a global threat to human and animal health. As human societies continue to develop, the pathogens from animal hosts have continued to spill over into our population. The increasing close contact between animals and humans in both work and living environments creates hotspots in peri-urban areas. From past few years, there have been increase in demand of usable land, leading to an increase in the human/wildlife interactions. Defining and prioritizing research on zoonotic pathogens in wildlife is essential, particularly in a multidisciplinary one-world one-health approach. A close collaboration is needed between animal keepers, farmers, veterinarians and other health professionals, including epidemiologists, specialists in environmental control and laboratory personnel.

Keywords: Emerging diseases, public health, zoonosis, animal health

1. Introduction

The majority of human diseases that are transmitted between people via arthropods, insects, other invertebrates or vertebrates, have their origins in animals. The socioeconomic progression leading to forest cutting, urbanization on previously unused lands has led to sudden change in ecosystem. These ecological changes are causing alterations in the epidemiology of diseases. The transformation of wild animals' habitats can result in more frequent human-animal encounters, which may pose a health risk to the public due to potential zoonotic diseases. Over the past 20 to 30 years, several diseases that had been largely overlooked or confined to specific areas have resurfaced, spreading widely. In India, there has been a heightened sense of alertness towards the emergence of zoonotic and other re-emerging diseases in recent times (Pavani, 2014) ^[25]. The emerging zoonotic diseases can either be newly emerged or might have been already existing in the past and are now expanding quickly to new terrains or host due to their evolving ecology, such as Scrub typhus, Malaria, Cutaneous Leishmaniasis, West Nile, Crimean-Congo hemorrhagic fever (CCHF) and Japanese Encephalitis (Taylor *et al.*, 2001) ^[37]. One Health approach seeks to harmoniously balance and enhance the health of humans, animals, and their interconnected ecosystems. The health of humans, domestic animals, wild animals, plants and the environment are understood to be closely linked (WHO, 2021) ^[40]. Understanding the pathogen ecology of natural host and human-host interactions are must in order to inform surveillance and public health interventions for preventing and/or mitigating future zoonotic outbreaks (Cunningham *et al.*, 2017) ^[9].

2. Zoonotic Diseases

According to WHO, zoonotic infections are those diseases which are naturally transmissible from vertebrate animals to humans through direct or indirect contact (Ryu *et al.*, 2017) ^[29]. There are 5 stages of spreading zoonotic diseases to humans, ranging from only spread among animals (stage 1) to fully human pathogens (stage 5) (Fig. 1) (Wolfe *et al.*, 2007) ^[46].

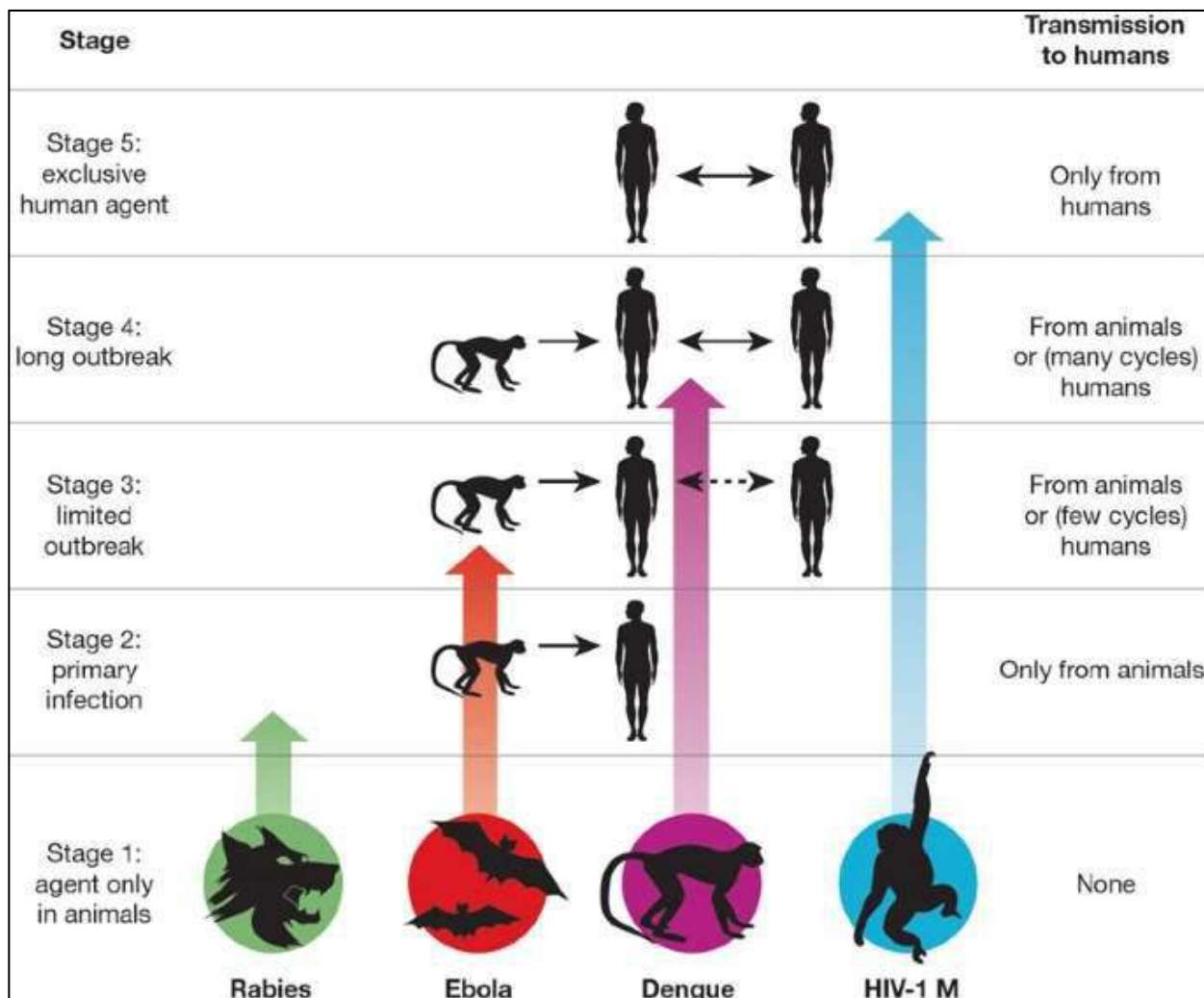


Fig. 1 Figure depicts the stages through which animal pathogens evolve to infect and produce disease in humans. The four agents depicted have reached different stages in the process, ranging from rabies (still acquired only from animals) to HIV-1 (now acquired only from humans) (Wolfe *et al.*, 2007) ^[46].

It is clear that the relationship between humans, animals and the environment create conditions for the emergence of diseases that affect the public health and socio-economic well-being of the world's population. The incidence of zoonotic diseases increases as humans live in close contact with animals and as they encounter animals in new

geographical areas. Examples include Lyme disease transmitted by ticks and Salmonella (CDC, 2017).

Zoonotic pathogens can be classified into four types based on the nature of pathogens: bacterial, viral, fungal and parasitic, along with their hosts (Table 1) (Bardhan *et al.*, 2023) ^[5].

Table 1: Classification of zoonotic pathogens based on pathogen type

Bacterial pathogens-hosts	Viral pathogens-hosts	Fungal pathogens-hosts	Parasitic pathogens
- Brucella- Raccoon, Hare - Leptospira- Rats, Cattle, Buffalo - Salmonella- Poultry and Eggs - Bubonic Plague- Rats	- Rabies- Dogs, bats - Influenza- Bats, Camels - Dengue and Chikunguniya- Aedes Mosquito - Japanese Encephalitis Virus- Pond Herons, Cattle Egrets - Hanta Virus- Bandicots, Rats, Shrews - Crimean Congo Hemorrhagic virus- Shrews, bats - Kyasanur Forest Disease Virus- Sick/Dying Monkeys, Birds, Ticks	Cryptococcus and Histoplasmosis- Bats	- Hydatid Disease- Dogs - Leishmaniasis- Sandfly - Schistosoma- Snails - Toxoplasma- Cats

3. Emerging parasitic and viral diseases

3.1 Parasitic zoonotic diseases

a) Malaria

Malaria is a parasitic disease mainly caused by four species of *Plasmodium*: *P. vivax*, *P. falciparum*, *P. malariae* and *P. ovale* and transmitted by genus *Anopheles* mosquitoes. In addition, rodent malaria parasites (*P. berghei* and *P.*

chabaudi) and avian malaria parasites (*P. gallinaceum*) also circulate in nature. Singh *et al.*, 2004 ^[36], the first naturally acquired human outbreak of *P. knowlesi* was reported in Malaysia. The authors also described the first human outbreak of *P. knowlesi* malaria and demonstrated that wild monkeys in the Kapit Division of Sarawak, Malaysian Borneo, were infected with malaria parasites, including *P.*

knowlesi. The number of *P. knowlesi* genotypes per infection in monkeys is much higher than in humans, providing indirect evidence that *P. knowlesi* malaria is primarily a zoonotic disease. In the Andaman and Nicobar Islands (India), the co-infection rate with *P. knowlesi* was observed to be 11.9%, of which 5.3% were *P. knowlesi* mono-infections. In the island, where human habitation is close to forests, it is imperative to understand the role of monkeys in the epidemiology of *P. knowlesi* malaria in India to support prevention and control measures.

b) Leishmaniasis

Leishmaniasis is caused by various species of *Leishmania* protozoa. In India, two forms of leishmaniasis are prominent, visceral leishmaniasis (VL) and cutaneous leishmaniasis (CL). Visceral leishmaniasis (VL), commonly known as Kala-azar, is caused by *Leishmania donovani*. It is mainly prevalent in Bihar, Uttar Pradesh, West Bengal and Jharkhand. *Phlebotomus argentipes*, a species of sandfly, is vector for this disease (Naik *et al.*, 1979) [21]. In India, the epicenter of visceral leishmaniasis is known to be western Rajasthan (WHO, 2010), where the reservoir of infection is *Meriones hurrianae*, a desert rodent, and the vector is *P. salehi*. On the other hand, in urban areas, dogs are reservoir host for *Leishmania donovani* and *P. papatasi* or *P. sergenti* act as vectors.

CL is mainly caused by *Leishmania donovani* and *L. tropica*. Humans are accidentally infected with CL while working in the fields. Due to lack of knowledge about the signs and symptoms of CL, the prevalence of the disease is not known, leading to neglect of the problem. The detection of a new outbreak of CL in Himachal Pradesh has highlighted the role of zoonotic reservoirs, increased human-vector contact due to deforestation and construction activities in the area (Sharma *et al.*, 2003) [35]. The recording of stray cases of CL and VL in the Indian states underscores the need to study the role of zoonotic reservoirs in the disease transmission and to conduct an epidemiological investigation of other outbreaks from the ecological perspective.

c) Scrub typhus

Scrub typhus is a Rickettsial disease caused by the *Orientia tsutsugamushi* and spread by trombiculid mite *Leptotrombidium deliense*. The term tsutsugamushi is a Japanese term; tsutsuga signifies dangerous, and mushi denotes insect or mite. The geographic distribution is limited to Southeast Asia, including Japan and Korea. In India, the sickness was thought to be widespread among army personnel and was first documented in 1934 (Vivekanandan *et al.*, 2010) [43]. Scrub typhus symptoms include a non-specific high-grade fever lasting 1-2 weeks, eschar/papule at the mite bite site, headache, myalgia, dry cough, lymphadenopathy, hepatosplenomegaly, apathy, dyspnea and myocarditis. The Weil-Felix test, indirect immunofluorescence test, quantitative ELISA and polymerase chain reaction are used for diagnosis (Dhiman, 2014) [10]. Scrub typhus is a zoonotic disease and rickettsia infection persists in small rodents living in recently cut forest/scrub habitats. The nymph and adult mites do not feed on humans, and transmission occurs by accident through the mite's larval stage. When the ecological conditions of a forest are altered owing to deforestation, and humans enter the cleared forest, the larval mite bites man. Scrub typhus is

linked to farm worker population density, timber management, recreational forests and natural reserves (Tsai *et al.*, 2013) [41]. Though scrub typhus has been reported to be endemic throughout India (Padbidri and Gupta 1978) [23], reports of the disease have increased since 2004, particularly in Himachal Pradesh (Sharma *et al.*, 2005) [32], Darjeeling (Sharma *et al.*, 2009) [34], Jammu and Kashmir (Kumar *et al.*, 2010) [18], Andhra Pradesh (Issac *et al.*, 2004) [16], Uttarakhand (Ahmad *et al.*, 2010) [1], Pondicherry (Vivekanandan *et al.*, 2010) [43] and West Bengal (Sharma *et al.*, 2014).

3.2 Viral zoonotic diseases

a) Japanese Encephalitis

One of the major public health concerns in Asia is Japanese encephalitis (JE) (Umenai *et al.*, 1985) [42]. Approximately 25 percent infective cases are fatal, and nearly 50 per cent of the cases reportedly suffer from permanent neuropsychiatric dysfunction (Campbell *et al.*, 2011) [6]. *Culex vishnui*, subgroup of mosquitoes acts as vector and transmits the causative agent, JE virus (JEV) to humans. Clinical symptoms of JE include high fever, chills, headache, myalgia and confusion; seizures can be experienced by approximately 75 per cent of the affected individuals. Till date, there is no specific treatment for JE, hence its prevention and control only depend upon the vaccination (Scholer *et al.*, 2007) [31]. In India, first recognition of JE was in Nagpur, Maharashtra, in 1952 (Banerjee, 1996) [4]. In 1955, the accumulation of serological evidence in southern India, resulted in rise in the number of cases in approximately 16 States including Andhra Pradesh, Assam, Bihar, Delhi, Goa, Haryana, Karnataka, Kerala, Maharashtra, Manipur, Nagaland, Punjab, Uttarakhand, Tamil Nadu, Uttar Pradesh and West Bengal (Tiwari *et al.*, 2012) [39]. JE has been documented in Tamil Nadu, Andhra Pradesh and Karnataka. In contrast, its cases also have been showing escalating trend of incidence in north India (Saxena *et al.*, 2009) [30]. In 2011, this disease spread to 15 states and in 2013, 13 states reported JE cases with 1086 cases indicating geographical spread.

b) West Nile fever

West Nile fever is caused by West Nile virus and the virus exists in a bird-mosquito transmission cycle in nature, with humans and horses as incidental/accidental hosts. *Culex* spp. mosquitoes are the vector for the transmission. India is endemic for West Nile fever and southern India reports most infections in human beings. Antibodies against West Nile fever were first detected from Bombay in 1952 (Paramasivan *et al.*, 2003) [24]. Pigs and horse have also been found with antibodies against West Nile fever. Clinical manifestations include mild influenza, fever, general body ache, headache, nausea and vomiting including encephalitis syndrome. Transovarial transmission has been reported in *Culex* spp. Up to 2002, cases of West Nile fever were reported mainly from southern India, but according to a study by Thakare *et al.*, 2002 [38], the prevalence of West Nile fever from non-endemic (Maharashtra and Rajasthan) and endemic area of JE (Goa and Orissa) were reported. Khan *et al.*, 2011 [17], reported the West Nile fever from Dibrugarh, Golaghat, Sivasagar, and Tinsukia districts of Assam. West Nile fever may be a cause of acute encephalitis syndrome in JE endemic areas. Its re-emergence with severe neuro-invasive pathogenic potential

in humans in Assam, Kerala, West Bengal and Tamil Nadu states indicates the need for immediate action to comprehend the dynamics of circulating strains in relation to their environment, hosts, and vector.

c) Chikungunya

Aedes aegypti mosquito spreads the CHIK virus, which causes chikungunya fever (Wimalasiri-Yapa *et al.*, 2019) [15]. In 1824, an illness that resembled chikungunya symptoms was described from India; nevertheless, chikungunya outbreaks were observed in 1963. Man-mosquito-man (urban cycle) or animal-mosquito-man (sylvatic cycle) are the two possible transmission cycles for CHIK virus. In Africa, chikungunya is spread by a sylvatic cycle that involves humans, mosquitoes, and monkeys. In India, however, man-to-man transmission via *A. aegypti* mosquitoes is known to occur. In Africa, *A. albopictus* has also been identified as a chikungunya vector (Diallo *et al.*, 1999) [11]. In the 1960s, neutralizing antibodies were discovered in wild monkeys in Malaysia, suggesting that the CHIK virus may be preserved in the wild by animals (Apandi *et al.*, 2009) [2]. In India, chikungunya outbreaks were documented during the 1960s and 1970s (Parvi *et al.*, 1963) [26]. In 1965, Banerjee reported that sera obtained from Madras state in 1956 contained antibodies to the CHIK virus. In 2005, there was a resurgence of chikungunya in India, with severe outbreaks recorded throughout the southern region and a gradual spread to the northern region (Banerjee 1956) [3]. Prior to the 2005 epidemics, the CHIK virus was isolated from *A. aegypti* in Yawat town, Pune district, in 2001. There have been reports of chikungunya illnesses from 13 to 18 Indian states since the outbreak in 2005, with 18,639 cases in 2013 that were clinically suspected (Mourya and Banerjee 1987) [20]. The majority of the papers have detailed the epidemiological profile of cases, but they have not explained the causes of outbreaks from the perspectives of socioeconomic development, ecology and climate. Given the documented importance of the periurban-dwelling *A. albopictus* mosquito in transmission, there may be a chikungunya sylvatic cycle in India that merits more research. Till, 11th September, 2016 a total of 14,656 clinically suspected cases (including 1724 in Delhi) from 18 states and 2 UT's have been reported (Chhabra *et al.*, 2008) [14].

d) Crimean-Congo hemorrhagic fever

Crimean-Congo hemorrhagic fever is caused by Crimean-Congo hemorrhagic fever virus (CCHF). The virus is transmitted by *Hyalomma* spp. ticks or by direct contact with humans or animals that serve as reservoirs (Mardani *et al.*, 2007) [19]. Since the ticks live close to cattle and other wild animals, people living in rural areas are more likely to get CCHF. There have also been reports of nosocomial outbreaks among medical personnel. The disease, which is found in Africa, Asia, Europe, and the Middle East, was first documented in 1944 in Crimea, Russia. Its symptoms are similar to those of dengue hemorrhagic fever, and during outbreaks, its fatality rate can reach 80% (Mardani *et al.*, 2007) [19]. In 2010, the first recorded case of CCHF occurred in Ahmedabad, India; while an epidemic in a cluster of Gujarati villages of Amreli and Patan area was reported in 2014 (Yadav *et al.*, 2014) [48]. *Hyalomma* ticks tested positive by RT-PCR, and the animals' IgG antibody positivity reached 43.9%. In order to diagnose, treat CCHF

cases promptly and to stop their transmission, public health stakeholders must be made aware of the symptoms, diagnosis and preventive actions.

4. Factors contributing to emergence of outbreaks:

As listed below, a number of variables contribute to the prevalence of zoonotic diseases in the various regions of the nation (Quigley, 2006) [27]:

- Import or export of live animals
- Infection during veterinary treatment/animal-based research
- Working in slaughter houses, tanneries or wool factories
- Natural migration of animals
- Deforestation and urban expansion
- Climate change and disaster
- Globalization of food market and manufacturing
- Agricultural practices and livestock farming

5. Mitigating Strategies

5.1 Prevention and control of disease

Prevention: Measures to prevent animals and humans from acquiring disease. Prevention can be done by following measures (Dubal *et al.*, 2014):

- Quarantine
- Immunization
- Environmental hygiene
- Chemoprophylaxis.
- Education of people about disease prevention.
- Early diagnosis and prompt treatment

Control: Steps that can reduce the incidence of zoonotic diseases (Dubal *et al.*, 2014) [12]:

- Effective and early diagnosis and prompt treatment
- Isolation of disease animals from healthy stock
- Vaccination of healthy stock
- Chemoprophylaxis including deworming
- Awareness campaign
- slaughtering/culling of diseased animal

5.2 One Health approach

The idea that the health of humans, animals, and plants is interconnected and linked to the health of the ecosystems in which they live is summed up by "One Health" approach (WOAH, 2022) [22]. Indian government approved "National One Health Program" for Prevention and Control of Zoonoses (NOHP-PCZ) in 2013 as central sector scheme with goal of protecting communities and minimizing socioeconomic losses due to emerging and re-emerging zoonotic threats (Jhandai *et al.*, 2023) [13].

By collaborating with medical professionals, veterinarians, ecologists, and others, Center for Disease Control and Prevention (CDC) uses the one health strategy to track and manage public health risks and understand how diseases spread across humans, animals, and the environment.

6. Conclusion

Zoonoses is a major challenge to public health in view of rapid deforestation, urbanization, population movement and changing climatic scenarios. Chikungunya, scrub typhus, swine flu, dengue, CCHF, and CL are among the unknown and re-emerged diseases that have affected both developed and developing nations. Given that the majority of diseases

are life-threatening, it is necessary to comprehend each disease using an eco-epidemiological approach, with a focus on the habitats of infection reservoirs, the micro niche of arthropod/insect vectors, and vulnerable areas from the perspective of climatic determinants for pathogen and vector development. Early action, awareness-raising, and prompt preparation will aid in outbreak containment. It is crucial to investigate and extract the elements that contribute to the epidemic and advance knowledge of the dynamics of zoonotic infections.

7. References

- Ahmad S, Srivastava S, Verma SK, Puri P, Shirazi N. Scrub typhus in Uttarakhand, India: A common rickettsial disease in an uncommon geographical region. *Trop Doct*. 2010;40(3):188-190.
- Apandi Y, Nazni WA, Noor Azleen ZA, Vythilingam I, Noorazian MY. The first isolation of chikungunya virus from nonhuman primates in Malaysia. *J Gen Mol Virol*. 2009;1(3):35-39.
- Banerjee K. A note on antibodies to chikungunya virus in human sera collected in Madras state in 1956. *Indian J Med Res*. 1965;53(8):715-719.
- Banerjee K. Emerging viral infections with special reference to India. *Indian J Med Res*. 1996;103:177-200.
- Bardhan M, Ray I, Roy S, Bhatt P, Patel S, Asri S, Anand A. Emerging zoonotic diseases and COVID-19 pandemic: global perspective and Indian scenario. *Ann Med Surg (Lond)*. 2023;85(8):3997-4004.
- Campbell GL, Hills SL, Fischer M, Jacobson JA, Hoke CH, Hombach JM, Ginsburg AS. Estimated global incidence of Japanese encephalitis: a systematic review. *Bull World Health Organ*. 2011;89(10):766-774.
- Centers for Disease Control and Prevention. National Center for Emerging and Zoonotic Infectious Diseases (NCEZID). One Health. 2017. Available from: <https://www.cdc.gov/onehealth/index.html>
- Centers for Disease Control and Prevention. One Health. Available from: <https://www.cdc.gov/onehealth/index.html>
- Cunningham AA, Daszak P, Wood JL. One Health, emerging infectious diseases, and wildlife: two decades of progress? *Philos Trans R Soc Lond B Biol Sci*. 2017;372(1725):20160167.
- Dhiman RC. Emerging vector-borne zoonoses: eco-epidemiology and public health implications in India. *Front Public Health*. 2014;2:168.
- Diallo M, Thonnon J, Traore-Lamizana M, Fontenille D. Vectors of chikungunya virus in Senegal: current data and transmission cycles. *Am J Trop Med Hyg*. 1999;60(2):281-286.
- Dubal ZB, Barbuddhe SB, Singh NP. Important zoonotic diseases. *Indian J Vet Public Health*. 2014;9(3):26.
- Jhanda P, Shanmugasundaram K, Gambhir D, Nale T, Shewale A, Tiwari S, Singha H. Diagnosis of various bacterial zoonotic diseases in human and bovine populations in Haryana state under the umbrella of One Health. *Indian J Vet Public Health*. 2023;9(3):26.
- Chhabra M, Mittal V, Bhattacharya D, Rana UVS, Lal S. Chikungunya fever: a re-emerging viral infection. *Indian J Med Microbiol*. 2008;26(1):5-12.
- Wimalasiri-Yapa BR, Stassen L, Huang X, Hafner LM, Hu W, Devine GJ, Frentiu FD. Chikungunya virus in Asia-Pacific: a systematic review. *Emerg Microbes Infect*. 2019;8(1):70-79.
- Isaac R, Varghese GM, Mathai E, Manjula J, Joseph I. Scrub typhus: prevalence and diagnostic issues in rural Southern India. *Clin Infect Dis*. 2004;39(9):1395-1396.
- Khan SA, Dutta P, Khan AM, Chowdhury P, Borah J, Doloi P, Mahanta J. West Nile virus infection, Assam, India. *Emerg Infect Dis*. 2011;17(5):947.
- Kumar D, Raina DJ, Gupta S, Angurana A. Epidemiology of scrub typhus. *JK Science*. 2010;12(2):60.
- Mardani M, Keshtkar JM. Crimean-Congo hemorrhagic fever. *Int J Infect Dis*. 2007;11(5):491-492.
- Mourya DT, Banerjee K. Experimental transmission of Chikungunya virus by *Aedes vittatus* mosquitoes. *Indian J Med Res*. 1987;85(2):165-168.
- Naik SR, Rao PN, Datta DV, Mehta SK, Mahajan RC, Mehta S, Chhuttani PN. Kala-azar in north-western India: a study of 24 patients. *Trans R Soc Trop Med Hyg*. 1979;73(1):61-65.
- World Organisation for Animal Health (WOAH). One Health; 2022. Available from: <https://www.woah.org>
- Padbidri VS, Gupta NP. Rickettsiosis in India. A review. *Indian J Med Res*. 1978;68(6):153-161.
- Paramasivan R, Mishra AC, Mourya DT. West Nile virus: the Indian scenario. *Indian J Med Res*. 2003;118:101-108.
- Pavani G. Zoonotic diseases with special reference to India. *Int J Appl Basic Med Sci*. 2014;4:73-87.
- Pavri KM. Presence of chikungunya antibodies in human sera collected from Calcutta and Jamshedpur before 1963. *Indian J Med Res*. 1964;52:698-702.
- Quigley MA. Commentary: Shifting burden of disease—epidemiological transition in India. *Int J Epidemiol*. 2006;35(6):1530-1531.
- Dhiman RC. Emerging vector-borne zoonoses: eco-epidemiology and public health implications in India. *Front Public Health*. 2014;2:168.
- Ryu S, Kim BI, Lim JS, Tan CS, Chun BC. One health perspectives on emerging public health threats. *J Prev Med Public Health*. 2017;50(6):411-416.
- Saxena SK, Mishra N, Saxena R, Singh M, Mathur A. Trend of Japanese encephalitis in North India: evidence from thirty-eight acute encephalitis cases and appraisal of niceties. *J Infect Dev Ctries*. 2009;3(7):517-530.
- Schiøler KL, Samuel M, Wai KL. Vaccines for preventing Japanese encephalitis. *Cochrane Database Syst Rev*. 2007;(3).
- Sharma A, Mahajan S, Kanga A, Sharma V. Investigation of an outbreak of scrub typhus in the Himalayan region of India. *Jpn J Infect Dis*. 2005;58(4):208-210.
- Sharma AK, Kumar K. Entomological surveillance for rodents and their ectoparasites with special reference to potential of scrub typhus at Kolkata Port Trust (KPT), Kolkata (India). *Arch Adv Biosci*. 2014;5(2):1-6.
- Sharma PK, Ramakrishnan R, Hutin YJF, Barui AK, Manickam P, Kakkar M, Gupte MD. Scrub typhus in Darjeeling, India: opportunities for simple, practical prevention measures. *Trans R Soc Trop Med Hyg*. 2009;103(11):1153-1158.

35. Sharma RC, Mahajan VK, Sharma NL, Sharma A. A new focus of cutaneous leishmaniasis in Himachal Pradesh (India). *Indian J Dermatol Venereol Leprol*. 2003;69:170.
36. Singh B, Sung LK, Matusop A, Radhakrishnan A, Shamsul SS, Cox-Singh J, Conway DJ. A large focus of naturally acquired Plasmodium knowlesi infections in humans. *Lancet*. 2004;363(9414):1017-1024.
37. Taylor LH, Latham SM, Woolhouse ME. Risk factors for human disease emergence. *Philos Trans R Soc Lond B Biol Sci*. 2001;356(1411):983-989.
38. Thakare JP, Rao TL, Padbidri VS. Prevalence of West Nile virus infection in India. *Southeast Asian J Trop Med Public Health*. 2002;33(4):801-805.
39. Tiwari S, Singh RK, Tiwari R, Dhole TN. Japanese encephalitis: a review of the Indian perspective. *Braz J Infect Dis*. 2012;16(6):564-573.
40. World Health Organisation (WHO). UNEP supports OHHLEP's definition of "One Health". World Health Organisation: Rome, Italy. 2021. Available from: <https://www.who.int>
41. Tsai PJ, Yeh HC. Scrub typhus islands in the Taiwan area and the association between scrub typhus disease and forest land use and farmer population density: geographically weighted regression. *BMC Infect Dis*. 2013;13:1-16.
42. Umenai T, Krzysko R, Bektimirov TA, Assaad FA. Japanese encephalitis: current worldwide status. *Bull World Health Organ*. 1985;63(4):625.
43. Vivekanandan M, Mani A, Priya YS, Singh AP, Jayakumar S, Purty S. Outbreak of scrub typhus in Pondicherry. *J Assoc Physicians India*. 2010;58(1):24-8.
44. Viswanathan S, Muthu V, Iqbal N, Remalayam B, George T. Scrub typhus meningitis in South India—a retrospective study. *PLoS One*. 2013;8(6):e66595.
45. World Health Organization. Control of the leishmaniases. World Health Organization technical report series. 2010;949:xii.
46. Wolfe ND, Dunavan CP, Diamond J. Origins of major human infectious diseases. *Nature*. 2007;447(7142):279-83.
47. Shrestha K, Acharya KP, Shrestha S. One health: The interface between veterinary and human health. *Int J One Health*. 2018;4(2):8-14.
48. Yadav PD, Gurav YK, Mistry M, Shete AM, Sarkale P, Deoshatwar AR, Mourya DT. Emergence of Crimean-Congo hemorrhagic fever in Amreli district of Gujarat state, India, June to July 2013. *Int J Infect Dis*. 2014;18:97-100.