

## Emergence of Zoonotic Diseases in India: A Systematic Review

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Received Date: Aug 13, 2018; Accepted Date: Aug 23, 2018; Published Date: Aug 31, 2018

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### Abstract

**Introduction:** Zoonotic diseases are the diseases originating from animals wherein humans acquire infectious diseases from zoonotic reservoirs, either naturally or through zoonotic vectors. The newly emerged or existing zoonotic diseases like Kyasanur Forest Disease, Scrub typhus and Japanese Encephalitis are frequently expanding to non-endemic areas. Nipah Virus was first encountered in West Bengal (India) in 2001 and recently has been reported from Kerala in May 2018.

**Method:** Multiple databases like PubMed, Google Scholar, Research Gate, Embase and Web of Science were searched to collect scientific research articles on emerging and reemerging 'Zoonoses' in India using various keywords like Emerging Zoonoses, Reemerging Zoonoses, High-priority Zoonoses, Neglected Zoonoses, natural Zoonoses and occupational Zoonoses in India. Articles were identified through a comprehensive search of the literature and by reviewing references from 127 review articles identified through the search process.

**Result:** On the basis of this review, the 'knocking' property of high-priority Zoonoses and neglected Zoonoses in India is compared through a line graph. Emphasis is given on the increasing annual burden of Zoonoses on public health in India.

**Conclusion:** The impacts of various factors such as Animal farming, Urbanization, Poverty, Climate change and Adaptation of pathogens on emergence of Zoonoses are discussed in this paper. Public health sectors of India need to be pro-active by emphasizing on effective periodic surveillance, pre-assessment or forecasting of zoonotic diseases and capacity building of stakeholders.

**Keywords:** Emerging Zoonoses; Reemerging Zoonoses; High-priority Zoonoses; Neglected Zoonoses; Annual disease burden; Public health

### Abbreviations

A&N: Andaman and Nicobar; AP: Andhra Pradesh; AR: Arunachal Pradesh; AS: Assam; DL: Delhi; GJ: Gujarat; GO: Goa; HY: Haryana; J&K: Jammu and Kashmir; KA: Karnataka; KE: Kerala; MH: Maharashtra; ML: Meghalaya; MN: Manipur; NL: Nagaland; OR: Orissa; PC: Pondicherry; PJ: Punjab; RJ: Rajasthan; SK: Sikkim; TN: Tamil Nadu; UK: Uttarakhand; UP: Uttar Pradesh; WB: West Bengal

### Introduction

Zoonotic Diseases (ZD) are defined as the diseases originating from animals wherein humans acquire infectious diseases from Zoonotic Reservoirs (ZR) either naturally or through zoonotic vectors. The emerging ZD can be newly evolved diseases most particularly in the developing nations, or may have been occurred in the past and are now expanding rapidly to new geographic, host or vector ranges [1] due to their changing ecology [2], such as Scrub typhus, Cutaneous Leishmaniasis and Japanese Encephalitis. ZD are major public health issue in several countries of the world and India is among the top geographical hotspots for such diseases [3]. Poor personal hygienic

practices, improper farming practices, lack of awareness, poor diagnostic facilities, under reporting system, poverty and lack of medical facilities, all this causes high burden of morbidity and mortality, particularly in infants and children [4] living in rural parts of developing countries. In India, incidence and prevalence of ZD like Plague, Rabies and Anthrax have affected human health throughout times. In recent past, India has seen emergence and reemergence of high priority and neglected Zoonoses. As a case of point a highly infectious disease called Nipah Virus was first emerged in West Bengal (India) in 2001 and recently it has been reported from Kerala in May 2018.

Emergence of new zoonotic pathogens have caused heavy toll of life in the areas where locals doesn't have natural or artificial (from vaccination) immune response for them [5]. High priority ZD like Brucellosis have been emerged from Haryana to Goa; Japanese Encephalitis from Tamil Nadu to Uttar Pradesh (Gorakhpur); Leptospirosis from Maharashtra to Punjab; Listeriosis from Maharashtra to Delhi, Jammu and Kashmir, and Tamil Nadu, whereas neglected ZD like Cutaneous Leishmaniasis had been emerged from Delhi to Rajasthan to Jammu and Kashmir; Kyasanur Forest Disease from Karnataka to Kerala, Tamil Nadu and Goa; Nipah Virus from West Bengal to Kerala; Scrub typhus from Himachal Pradesh to Tamil Nadu. Extension of these ZD to non-endemic areas has increased the complexity of their forecast. According to World Health Organization

(WHO) [6], “there is a coexistence of humans in a complex, interdependent relationship with the companion, production, and wild animals we depend on for our food, livelihoods, and well-being, as well as with the environments we live and work in together”. The increasing annual burden of Zoonoses on public health in India can be prevented only by effective periodic surveillance, pre-assessment or forecasting of zoonotic diseases and capacity building.

This paper provides a systematic review of the emergence of ZD in India, their ‘knocking’ trend for 68 years (1951-2018), negative impact on public health and the way forward.

## Methodology

During June 2018, a systematic search was conducted to collect scientific research articles on Emerging and Reemerging Zoonoses in India through Pub Med, Google Scholar, Research Gate, Global Health, Embase and Web of Science using key-words like Emerging Zoonoses, Reemerging Zoonoses, High-priority Zoonoses, neglected Zoonoses, natural Zoonoses and occupational Zoonoses in India. Epidemiological profile and geographical risk map for emergence and reemergence of four high-priority Zoonoses and four neglected Zoonoses from 1951 to 2018 (68 years) was done in context of India. To further understand the ‘knocking’ trend of these diseases, graphs were generated. We also summarized the location of studies, to examine whether some areas were over- or under-represented in the literature.

## Literature search

The review was carried out according to a proposal and analytical plan. A systematic search of all the published literatures was initiated by using key word like, high-priority Zoonoses, neglected Zoonoses, emerging Zoonoses and reemerging Zoonoses in context of India. Abstract of all the relevant records were studied carefully, to identify and collect the most suitable research works to be reviewed.

## Study inclusion and exclusion criteria

Research reports were assessed for inclusion and exclusion criteria, to choose correct and most relevant studies. Only English-language articles were included. Case reports were excluded. Meta-analyses and reviews were included if they provided a novel analysis of the data from the studies. Reports with information regarding emergence, reemergence and prevalence of ZD in India were included, whereas reports related to animal to animal infection, pathological and serological studies were excluded. Figure 1 is a flowchart representing the study inclusion and exclusion for this review paper.

## Data extraction and analysis

Data extracted from various research articles regarding the year, geographical hotspot, emergence and prevalence of selected high-priority Zoonoses and neglected Zoonoses in India was used to create their epidemiological profile. On the basis of these profiles, a geographical risk map was designed for the emerging Zoonoses and reemerging Zoonoses during the period of 68 years. Graphs were designed in Microsoft Word to analyze the trend for reemergence of selected high-priority Zoonoses and neglected Zoonoses in India.

## Risk of bias and study quality assessment

There is no risk of bias in this review paper as all the possible key words were used to search the relevant research articles. All the articles were found in English language. The articles selected were full text and contained information suitable for this review.

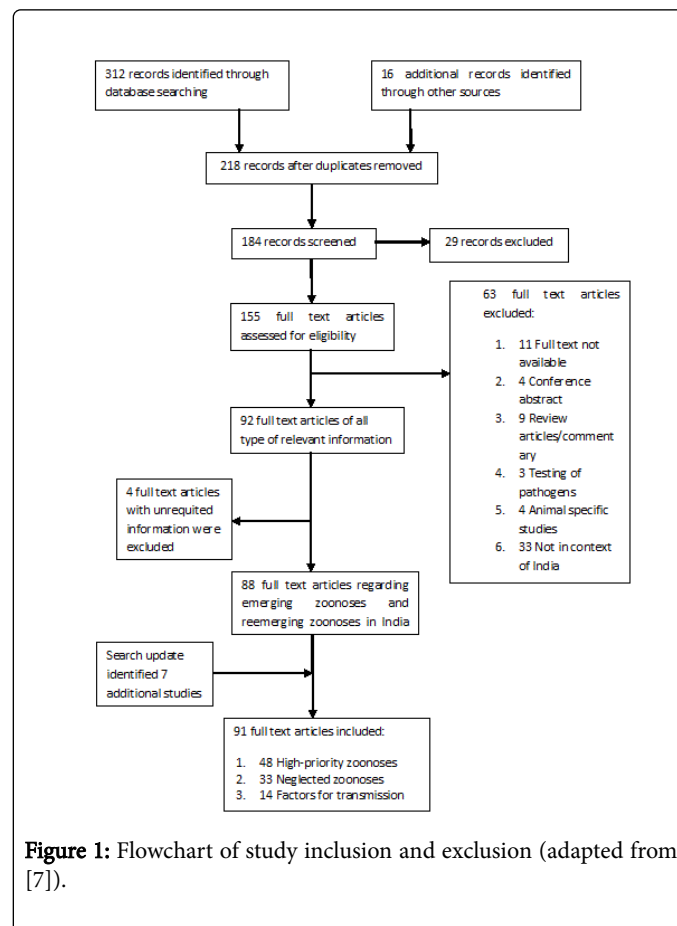


Figure 1: Flowchart of study inclusion and exclusion (adapted from [7]).

## Results and Discussion

The highest peak of ‘knocking’ of high-priority Zoonoses was for 5 years in case of Japanese Encephalitis and Leptospirosis during 1981-1990, again for Leptospirosis during 1991-2000, and that of neglected Zoonoses was for 8 years in case of ST during 2001-2010. For the same years it was also found that there was extremely high prevalence of high-priority Zoonoses and neglected Zoonoses in non-endemic areas of India. Figure 2 represents the geographical risk map for emergence and reemergence of high-priority Zoonoses and neglected Zoonoses in India, since 1951 (68 years\*), Figures 3 and 4 are graphical representation of trend of ‘knocking’ of high-priority and neglected Zoonoses in India respectively.

High Priority Zoonoses in India - Diseases in this category are considered significant as they can cause high disease burden and mortality among Indian population. Table 1 represents four HPZ in India as reported in literature [3], which ranked them through composite index (CI).

Zoonotic Diseases	Major factors for emergence/reemergence	1951-1960	1961-1970	1971-1980	1981-1990	1991-2000	2001-2010	2011-2018
<b>Brucellosis (BR)</b>	Dairy products [8] Animal trading [9] Common laboratory-acquired infection [10]	Studies/Cases not found	1968 HY [11]	1971 (Vellore) TN [12]	1986 GJ [13], 1988 KA [14]	Studies/Cases not found	2007 (Bikaner) RJ [15]	2014 GO [16]
<b>Japanese Encephalitis (JE)</b>	Bird migration, certain irrigation projects, animal smuggling, and global warming increases its prevalence [17]	1952 (Nagpur) MH and (Chingleput) TN, 1955 (Vellore) TN and PC [18]	1966 TN [19]	1973 (Bankura), WB [18,19], 1978 (Gorakhpur) UP [20]	1982 GO [19], 1985 [17], 1988 [21] (Gorakhpur and Deoria), 1989 (Siddharth nagar), 1990 (Maharajganj) UP [22]	1997 AP and (Kushinagar) UP [23]	2005 (Gorakhpur) UP [24]	2011 DE [25], 2016 (Gorakhpur) UP [26]
<b>Leptospirosis (LE)</b>	Areas with poor hygiene, rodents and stagnant dirty water as well as drier parts of country [27]	1960 (Mumbai) MH [28]	1966 (Kalra) PJ [29], 1967 (Mumbai) MH [30]	Studies/Cases not found	1983 [31], 1984, 1985 [32], 1988 [33], 1990 (Madras) TN [34]	1991 [34], 1998 [35] (Chennai) TN [36], 1993 (North Andaman) A&N [37], 1994 (Madurai) TN [38], 1995 PC [39]	2004 DE [40] UP [41] and (Chennai) TN [42], 2005 (Chandigarh) [43], 2006 [42], 2008 (Ludhiana) PJ [44]	Studies/Cases not found
<b>Leptospirosis (LE)</b>	Domestically acquired food borne illness which results in death [45]	Studies/Cases not found	1966 (Mumbai) MH [46]	1973 [47] and 1975 DL [48]	1981 (Mumbai) MH [49]	1997 [50] and 1998 DL [51]	2003 (Chandigarh) PJ [52], 2010 HP [53], (Kashmir) J&K [54]	2011TN [55]

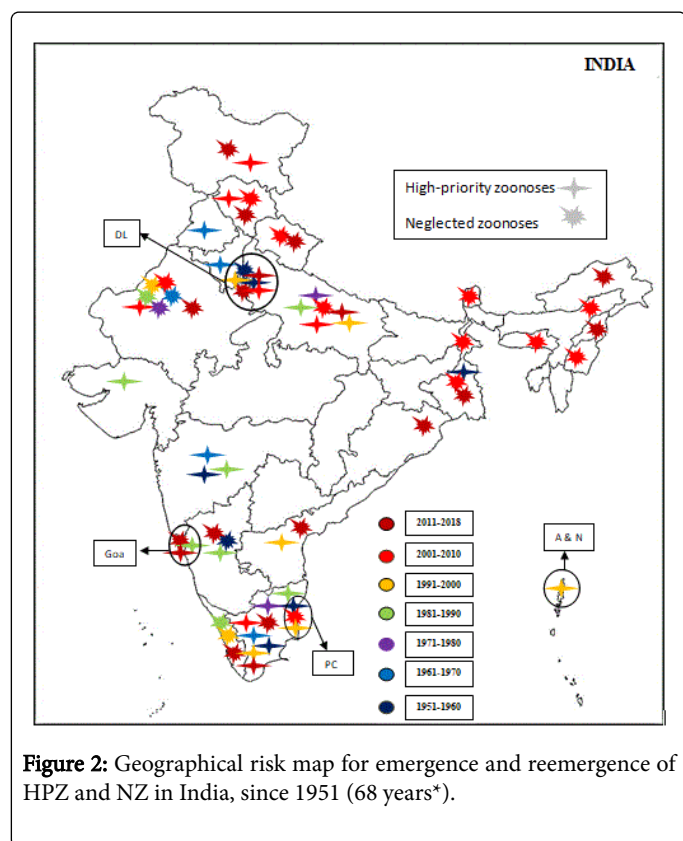
**Table 1:** Epidemiological profile of high-priority Zoonoses in India since, 1951.

Neglected Zoonoses in India-Such diseases are relatively rare in occurrence and thus were not considered significant for making policies or specific strategies to control them. Table 2 represents the Epidemiological profile of four common neglected Zoonoses occurring in India.

Zoonotic Diseases	Major factors for emergence/reemergence	1951-1960	1961-1970	1971-1980	1981-1990	1991-2000	2001-2010	2011-2018
<b>Cutaneous Leishmaniasis (CL)</b>	Occupational disease of rural residents [56] Endemic to dry North-western parts of India [57] Reported during cooler months in Southern Parts [58]	1951 DE [59]	1961, (Bikaner) RJ [60,61]	1971[62], 1973 [63] (Bikaner) RJ	1982 [64] 1990 [65] (Bikaner) RJ, 1988 KE [66]	1992 KE [67], 1993 [68] 1995 [69], 1998 [70], 1999, 2000 [71] (Bikaner) RJ	2001 (Bikaner) RJ [71], 2002 [72], 2003 [73], 2007 [74] UP	2012-13 (Jammu) J&K [75]
<b>Kyasanur Forest Disease (KFD)</b>	Destruction of local forest areas [76]. Circulation among rodents, ground birds and ticks in enzootic areas [77]	1957 [78], 1959, (Shimoga)KA [79]	Studies/Cases not found	Studies/Cases not found	Studies/Cases not found	Studies/Cases not found	Studies/Cases not found	2012 KA and (nilgiri) TN, 2013 (Bandipur) KA and (Wayanad) KE, 2014 (Shimoga) KA and (Wayanad, Malappuram and Palakkad) KE, 2015 (Nilambur, Malappuram and Wayanad) KE,

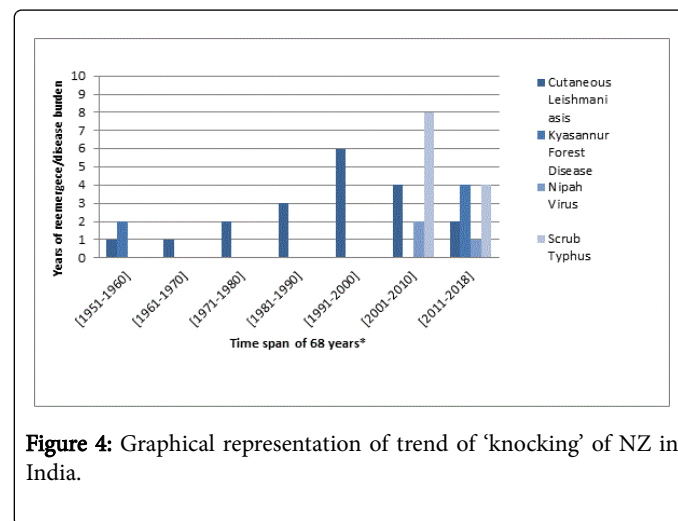
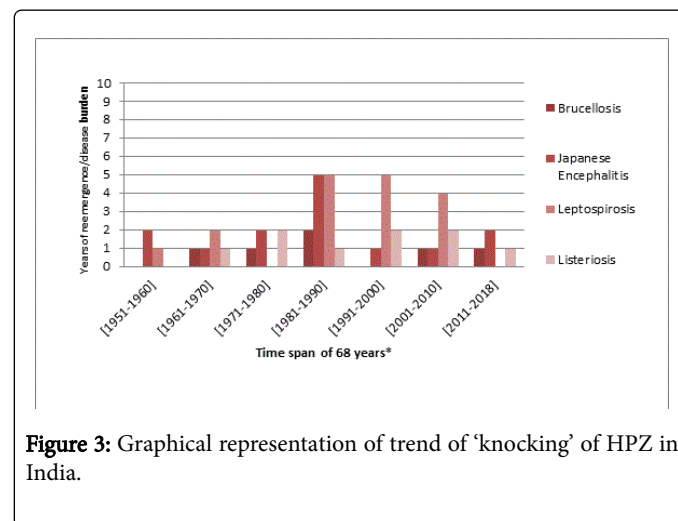
									(Shimoga) KA and GO [80]
<b>Nipah Virus (NiV)</b>	Change in ecological conditions [81]	Studies/Cases not found	Studies/Cases not found	Studies/Cases not found	Studies/Cases not found	Studies/Cases not found	Studies/Cases not found	2001 (Siliguri) [82] and 2007 (Nadia) WB [83]	2018 KE [84]
<b>Scrub typhus (ST)</b>	Bushy and unhygienic areas [85]	Studies/Cases not found	Studies/Cases not found	Studies/Cases not found	Studies/Cases not found	Studies/Cases not found	Studies/Cases not found	2003, 2004, 2007 SK, HP and (Darjeeling) WB [86], 2005 HP, NL, 2006 HP, MN 2008 UK, 2009 ML, 2010 PC, AS [87]	2011 HP, KA, NL, UK, 2012 AR, HP, TN, RJ, UK, WB, 2013 DE, (Vellore) TN, AP and OD 2014 (foot hills) HP, UK, (Vellore) TN [87]

**Table 2:** Epidemiological profile of neglected Zoonoses in India since, 1951.



Existing diseases coupled with newer emergence have increased the task of researchers, scientists, pathologists and field veterinarians to make India pro-active regarding sudden outbreaks. Continuous or sudden emergence and re-emergence of major public health ZD like Japanese Encephalitis, Leptospirosis, and Kyasanur Forest Disease were found to be highly life threatening due to their lesser known epidemiological features. According to the geographical risk map it was found that the high priority ZD were endemic in UP, DL, MH, GO, TN and PC, whereas they were epidemic to J&K, HP, HR, PJ, RJ, GJ, KA, A&N, AP and WB. Also, the NZ were found endemic to RJ, DL, KA and KE, whereas they were epidemic to J&K, HP, UK, UP, GO,

AP, TN, PC, WB, OR, SK, AP, AS, NG, MN and ML. Cases for Zoonoses in central states (Madhya Pradesh and Chhattisgarh) and eastern states (Bihar and Jharkhand) of India were either underreported or less prevalent.



### Increased emergence/reemergence of zoonotic agents

India is under the burden of emergence of new pathogens and overstretched health infrastructure [88]. To increase the immunity of the people against the unknown dangers of future due to reemergence or 'knocking' of zoonotic diseases in the country, there is a need to increase the efficiency of health sectors during outbreaks. There are various factors which are responsible for prevalence of ZD in the different parts of the country as mentioned below.

#### Occupational risk

**Agricultural practices and livestock farming:** Being the second most populous country in the world, there is a high demand for food and water in India. The expansion of agriculture or livestock farming is disturbing the natural ecosystem of wild-animals and thus increases the burden of ZD [89] in the population.

**Import or export of live animals:** A close contact with phylogenetically distant animals may result in evolution of animal pathogens as human pathogens [90]. The perseverance is higher among the livestock which are farmed together [91]. People engaged in such occupation are major sufferers of ZD such as Kyasanur Forest Disease, Brucellosis and Leptospirosis to name a few.

**Infection during veterinary treatment/animal based research:** The treatment of animals which contains zoonotic virus or bacteria without proper utilization of preventive measures can infect the Vets directly and can cause serious illness or death. Thus, pre-exposure immunization is recommended to people involved in certain high-risk occupations such as laboratory workers dealing with live virus or veterinarians [92].

**Working in slaughter houses, tanneries or wool factories:** India is endemic for many ZD, especially the southern states due to unprotected livestock population [93]. Risk of zoonotic infections such as anthrax, is higher for the workers in the slaughter houses and during the cleaning or processing of contaminated animal materials at carpet weaving mills, wool mills, dairies and tanneries [94].

#### Natural migration of animals

Change in ecological conditions due to the destruction of forests alters the epidemiology of disease [2] by the migration of wild-animals towards the human settlements. The human societies in the vicinity of forest or tribes are at higher risk of getting the new pathogens through the ingestion of contaminated food and water by the urine or feces of infected animal.

#### Deforestation and urban expansion

The socio-economic development of the country by the expansion of road networks, agricultural fields and, intensification of wildlife trade has caused emergence of new pathogens. Nipah Virus is the current example [95], where the fruit bats came out of their natural habitat and started feeding on agricultural produce, causing food borne Zoonoses in Kerala.

#### Travel and tourism

The containment of disease is difficult nowadays due to availability of better facilities to travel worldwide. ZD like Japanese Encephalitis, Nipah Virus, etc., can infect the non-immunized travelers on their visit to endemic countries. According to the Yellow Book of CDC [81],

"India has no risk of yellow fever but Indian government needs a proof of immunization for people arrived from a country with risk of yellow fever".

#### Climate change and disaster

The increasing temperature in northern India or excessive rainfall in north-eastern part of India due to climate change leads to higher growth of vectors such as mosquitoes [96,97], ticks [98] and Sandflies. Increase in crop and food production after rainfall increases the population of rodents and birds (small ZR near residential areas) and thus increases the chances of water and food borne Zoonoses [96].

#### Poverty and political conflicts

Shortage of resources in rural and malnourished states like Uttar Pradesh, Rajasthan, Maharashtra, Tamil Nadu, Himachal Pradesh, Uttarakhand and West Bengal, often generates civil conflicts, war and political instability. It weakens the healthcare infrastructures and upsurges the infectious diseases and thus they are considered as hotspots for 'knocking' of Zoonoses. Increase in vulnerability of people living in poverty affected areas due to limited access to quality health, safe and nutritious food and adequate housing is very well discussed by Seimenis A [99].

#### Pathogen adaptation

The increasing mortality and morbidity due to zoonosis and anthroponosis represents that the host-species barrier have already been crossed by the pathogens. Thus, expansions of Zoonoses to various non-endemic areas have made surveillance, mapping and forecasting of ZD a major challenge. Phylogenetically related hosts (anthroponosis) have more frequent adaptation and transmissions of pathogens in them [100,101].

#### Conclusion

On the basis of this review regarding emerging ZD in India since 1951, it is concluded that new ZD like Cutaneous Leishmaniasis, Japanese Encephalitis, Leptospirosis and Scrub typhus are spreading to a much wider areas at an alarming rate, which have caused greater annual disease burden on large population of India. Reemergence of neglected Zoonoses is found to be rarer than high-priority Zoonoses during these 68 years, but the sudden outbreak of these diseases of less preference after a long gap (e.g., Kyasanur Forest Disease) can be fatal due to unavailability of strategies and policies to fight against them. Knowledge and practice of preventive measures is essential for locals, patients and the health workers during the outbreaks to reduce the prevalence of these diseases. Immunization before travelling to other countries can prevent spread of ZD to non-endemic area. To avoid the worst situations like pandemic, the Health ministry and public health stakeholders in India should strengthen the public health surveillance systems and providence of quick medical facilities to control the rate of mortality and morbidity during outbreaks.

#### Acknowledgement

AT would like to acknowledge the contribution of whole research team in the Environmental Epidemiology division and in particular to Dr. R.C. Dhiman at the National Institute for Malaria Research (NIMR) as they were a great help in suggesting additional studies for inclusion in the review and were always supportive regarding all my

quarries during my literature review work. I extend my thanks to SRFP organized by three highly prestigious science academies of India (IASC, INSA and NASI), for this great opportunity and funding.

### Author Contribution

RCD, planned, created the framework and reviewed the paper; RCD; AT, analyzed the available data and wrote the paper.

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