DOI: 10.7860/JCDR/2023/61624.17718

Review Article

Microbiology Section

Impact of Monsoon on the Pattern of Infectious Diseases in the Indian Setting- A Review

MARIE VICTOR PRAVIN CHARLES[1], ARUNAVA KALI[2], SANTHANAM VIDYALAKSHMI[3]

ABSTRACT

The survival of life on earth depends on equilibrium between the organisms and the environment. The monsoon is a seasonal variation prevailing in the Indian sub-continent. Monsoon has two seasons which are separated by a transition. The infectious diseases epidemiology is affected by both climatic and societal influences. An interaction of climatic and societal influence favours the infectious disease exposure in a population. The infectious diseases affecting the population can be broadly classified as vector borne diseases, food borne diseases, water borne diseases, and respiratory diseases. The rainfall associated change in temperature and floods favours the survival of infectious diseases and their transmitting vectors. The changing global climatic trends including the EL nino Southern oscillation bring undue rainfall during other seasons. The drastic events associated with these climatic changes affect the health and sanitation infrastructure. India being a developing country has more vulnerability to such infections. A better strengthening of the infrastructure and health policies is the need of the hour to curb the infections.

Keywords: Climate change, Elevated temperature, Environment, Food borne disease, Infectious agents, Rainy season, Vector borne disease, Water borne disease

INTRODUCTION

The evolution of mankind and its survival on the globe is based on the interaction between the diversified biomes, including microbes, animals, and the climatic influence. The ecological equilibrium attained between these organisms and environment claims the survival of life on earth. However, the Anthropocene epoch which is a unique modification created by human on the environment and climate has deranging effects on health and disease [1]. The urbanisation and domestication have a direct influence on infectious diseases in this regard [2]. The pathogen and its interaction with the host are also driven by the climatic variation and associated geographical events along with the other factors [3]. The average global temperature has increased by 0.85°C due to the greenhouse effect [4]. The associated climate change alters the ecology of the pathogens and their vectors which raises the infectious disease spread. As per the World Health Organisation (WHO) report, around 12.6 million mortality are estimated in relation with climate change and pollution [5]. The monsoon is a seasonal variation prevailing in the Indian sub-continent. It has two seasons which are separated by a transition. The South-West monsoon is from June to September and the North-East monsoon is from December-March. This brings highest rainfall to the western states, (Maharashtra, Goa, Karnataka, and Kerala) and eastern states (Arunachal Pradesh, Assam, Manipur, Mizoram, Tripura, and Meghalaya). Moderate rainfall in the Southern-East states of Tamil Nadu, Andhra Pradesh, Telangana, and Puducherry. During this period, the changing wind current, decrease in temperature, and rainfall affect various ecological niches promoting infections. The geographic location of the sub-continent which is surrounded by the ocean in all direction makes it vulnerable to unpredictable events such as cyclone and flood [6]. In addition, the EL nino Southern oscillation drastically affects the seasonal cycle bringing heavy rain during summer. These unforeseen seasonal events predispose to water borne, vector borne, food borne, zoonotic, and respiratory diseases. There are very few data on the climate change and the infectious disease pattern. Hence, the aim of the review is to discuss the common infectious agents which affect humans during the monsoon.

RISK FACTORS PREDISPOSING INFECTIOUS DISEASE

The infectious disease epidemiology is affected by both climatic and societal influences. The climatic modifications such as precipitation, flood, temperature extremes, and drought affect the infectious disease epidemiology [7]. Furthermore, the societal influences such as geographic location, socio-economic status, demography, and general health condition predispose the infectious diseases [8]. An interaction of climatic and societal influences favours the infectious disease exposure in a population.

Climatic Factors

Precipitation and flooding: The flood and extreme precipitation damage the water infrastructure available. The flood water can damage the good water supply and breach the sanitation infrastructure. In addition, population movement and lack of sanitation measures can lead to infectious diseases. The stagnant water becomes the potential source of mosquito breeding. The rising sea level can affect the drinking water supply. The salinity of the intruding sea water can affect the soil and water quality [7,8]. In addition, the infrastructure of transportation, airport, harbour, telecommunication, agriculture, and electricity generation may be affected.

Drought: During drought the scarcity of water damages the livelihood of both human, plants and animals. The agricultural failure and undernutrition predispose to infections. The alternative water sources have high chance of contamination and pathogens could be concentrated in these areas. The limited contaminated water sources could be exchanged between human and livestock leading to infection [7]. The cross contamination of water lines and vector breeding on the limited household water could be added disadvantage.

Elevated temperature: The higher temperature reduces the water resources available for human use. The vector borne diseases have higher chance of transmission. The extrinsic incubation of the pathogen and replication is favoured. The marine and animal pathogens are highly prevalent due to higher multiplication rates [8]. These pathogens could be easily transmitted at the recreational sites. The reduced crop yield and food spoilage are the other factors.

Societal Factors

Geographic location and socio-economic status: The geographic location can predispose the population to infectious diseases. The location near a flood risk zone, cyclone risk zone and drought risk zones make the population prone to infection [7]. Similarly, the population with poor socio-economic status and poverty are affected by these infections. The reduced health care access, unsafe water, poor sanitation, inadequate shelter, and lack of education are other socio-economic determinants.

Demography: The extremes of age including the neonates and senior citizens are highly prone for infection. Similarly, the prevalence of infectious disease varies with gender. Women are more prone for certain infections compared to men and vice versa. The movement of population to other areas can spread the infectious disease to other population group [7].

General health condition: The general well-being of the population decides their vulnerability to infection. The malnourished or undernourished population is widely affected by infections. The pregnant women, breast feeding women, immunocompromised individuals, and those with chronic diseases are prone for infectious disease [7].

INFECTIOUS DISEASES IN MONSOON

The infectious diseases affecting the population can be broadly classified as vector borne diseases, food borne diseases, water borne diseases, and respiratory diseases [9]. The disease under each category is shown in [Table/Fig-1].

Category		Disease
Vector borne	Mosquito borne	Malaria, Dengue, Chikungunya, West Nile fever
	Tick borne	Lyme disease, Crimean congo hemorrhagic fever, Kyasanur Forest Disease (KFD), tick typhus
	Mite borne	Scrub typhus
	Sand fly borne	Leishmaniasis
Food borne		Enteric fever, Camplylobacteriosis, botulism, Hepatitis A, Hepatitis E
Water borne		Cholera, Shigellosis, leptospirosis, Schistosomiasis, Toxoplasmosis, taeniosis, Echinococcosis
Respiratory disease		Influenza

[Table/Fig-1]: List of infectious agents prevalent in monsoon [9].

1. Vector Borne Diseases

The altered climatic conditions have a direct and indirect influence on the vector population. It can modify the reproduction rate of vector, increase its biting rate as well as reduce the incubation period of the pathogen [10]. In addition, the societal factors decide the susceptibility of the host to infection. The common vectors transmitting infection are mosquitoes, ticks, and sand fly.

1.1 Mosquito Borne Diseases

Malaria: Malaria is caused by the protozoan parasite comprising of five common species *Plasmodium falciparum, Plasmodium vivax, Plasmodium ovale, Plasmodium malariae, and Plasmodium knowelsi* which are transmitted by the bite of the female anopheles mosquito. The major malaria vector in India is *Anopheles stephensi, Anopheles fluviatilis, Anopheles sundaicus, Anopheles minimus and Anopheles dirus* [11]. Malaria is endemic in Odisha, Chhattisgarh, Jharkhand, Meghalaya, and Madhya Pradesh. The temperature, precipitation and humidity are the climatic factors which influence transmission of the disease [12]. The dynamics of infection rate depends on the sporogony or extrinsic incubation period which is related to the environmental temperature. The optimal temperature range for development of *P. falciparum* is 19°C and *P. vivax* is 15°C. However, malaria cases are not observed to have a direct relationship with the annual rainfall [13]. It is proposed that the wetness prevailing after the rainfall favours the multiplication of the *Plasmodium spp*. The mosquito survives in the relative humidity of 55-80% failing which transmission fails. However, a perineal conducive climate prevails throughout the country favouring the prevalence of positive cases [14]. Malaria is reported with annual incidence of 146559 cases in the year 2021 [15].

Dengue: Dengue is an arboviral disease of tropical and sub-tropical countries. It is caused by the dengue virus comprising of five serotypes (DENV1-5) belonging to the flaviviridiae family. It is transmitted by two major vectors *Aedes aegypti* and *Aedes albopictus* in India [16]. The epidemics of the disease have spread across various states (Orissa, Arunachal Pradesh, Mizoram) of the country since its identification [17]. It is found that, a strong association exists between the precipitation and the mosquito breeding. It is found that, mosquitoes have better expansion of their spatial range in wet climate [18]. In a study conducted by Nair DG et al., comparison of rainfall with dengue cases reveals a strong association. It is found that the dengue cases rise during the monsoon and reduce during the postmonsoon [19]. An increase of rainfall greater than 1 mm per day to 10 mm shows strong association. However, it is also reported that the transmission intensity also depends on the warm temperature and high humidity which shortens the extrinsic incubation period and the feeding intervals [20]. Dengue is reported with annual incidence of 110437 cases in the year 2022 [15]. Among the premonsoon, monsoon, postmonsoon and winter seasons of the Indian sub-continent, Kerala shows lowest extrinsic incubation period (8-12.5 days) during monsoon, Gujarat shows extrinsic incubation period of 5-13.5 days, Rajasthan 3-12.6 days, Haryana 4-14.68 days and Punjab 5-22.7 days [21].

Chikungunya: In 1952 the first case of Chikungunya virus infection was identified in Tanzania. Among the several serogroups of alphavirus (Togaviridae family) Chikungunya virus belongs to the Selmiki forest antigenic complex [22]. *Aedes aegypti* and *Aedes albopictus* is the two major vector which transmit the infection [23]. The average temperature range for propagation of the same ranges from 20-30°C [24]. In a study conducted from years 2010-2014 showed that, there is a strong association between rainfall and incidence of chikungunya cases. During 2017 outbreaks in the region of Tamil Nadu (131 cases) and Kerala (78 cases) were during the monsoon period with heavy rainfall [25]. The recent estimate in the year 2022 shows annual incidence of 108957 cases [15].

West Nile fever: West Nile fever is caused by the West Nile Virus (WNV) belonging to the faviviridae family. The virus was first isolated from West Nile district in Uganda during 1937 [26]. The virus circulates among human, horses, and mosquitoes. The natural or enzootic cycle exists between birds and mosquitoes. Human and horses are the dead-end host. The *Culex vishnui* mosquitoes are the vectors for the virus in India. The Aedes albopictus mosquito act as a bridging vector. The virus has also been isolated from frugivorous bats and domestic pigs in India. Heavy rainfall followed by dry temperature facilitates the vector breeding and disease spread [27]. WNV has been isolated sporadically from parts of Tamil Nadu and Bombay. In 1952 the first case was identified in Bombay followed by other cases from Vellore and Kolar [28].

1.2 Tick Borne Diseases

Tick borne viral infections including Crimean Congo Haemorrhagic Fever (CCHF), Kyasanur Forest Disease (KFD), tick typhus and Lyme disease have been reported from the Indian Sub-continent [29]. CCHF is transmitted by the ixodid tick belonging to the genus Hayalomma. Outbreaks of CCHF have been reported from Gujarat, Rajasthan, and Uttar Pradesh [30]. Similarly, KFD caused by bite of *Haemaphysalis spinigera* ticks is reported from Karnataka, Kerala, Goa, Maharashtra, and Tamil Nadu. The tick typhus (etiological agent: *Rickettsia conori*) is transmitted by *Rhipicephalus sanguineus* ticks whereas, Lyme disease (etiological agent: *Borrelia burgdorferi*) is transmitted by Ixodes ticks. Lyme disease is increasingly reported from Indian states

[31]. The prevalence of these tick-borne diseases could be affected by vector range, pathogen prevalence, transmission dynamics, and climatic impact. However, studies are lacking on the association of precipitation and these tick-borne infections.

1.3 Mite Borne Infection

Scrub typhus is caused by *Orientia tsutsugamushi* which is transmitted by the trombiculid mite. It is the leading cause of acute febrile illness prevalent in most parts of the country. However, the disease in under-reported compared to the global rate of incidence [32]. The scrub typhus infections are mostly reported during the premonsoon and postmonsoon season though there is evidence of perineal transmission [33]. In a study conducted from 2012-2015 around 41.3% of scrub typhus cases were reported from Pondicherry. Similarly, 16.1% cases were reported from Tamil Nadu during 2004-2005 [34].

1.4 Sand Fly Borne

Leishmaniasis is caused by the protozoan parasite *Leishmania donovani* which is transmitted by the sand fly (*Phlebotomus argentipus*). The disease is endemic in states of Bihar, West Bengal, Uttar Pradesh, Jharkhand, Delhi, Gujarat, Madhya Pradesh and Kerala. The annual incidence reported during 2022 in these states are 490 cases in Bihar, 166 cases in Jharkhand, 18 cases in Uttar Pradesh, and 40 cases in West Bengal [15]. The chronic Visceral leishmaniasis or Kala azar causes 50% mortality among the infected in the Indian sub-continent [35]. The vector stays in the places where humidity and temperature are prevalent at regular intervals such as tree holes, crevices, dung and domestic waste. The changing climatic conditions such as rainfall, rise in temperature, and humidity have a direct effect on the vector population. It increases their survival and distribution thereby spread to newer areas which are non endemic. The migration of the population during monsoon and flood also predispose to infection [36].

2. Food Borne Infections

Enteric fever: Enteric fever is a febrile illness caused by Salmonella enterica serovar Typhi, Salmonella enterica serovar Paratyphi A, B, C. The estimated global incidence of the infection ranges from 6.9-48.4 million [37]. The common mode of transmission of enteric fever is via ingestion of contaminated food and water [38]. The associated co-factors include the host behaviour, and environmental factors predisposed by the seasonal dynamics [39]. It is shown that the prevalence of infection increases with higher temperature, rainfall, and water stagnation [40]. In a systematic review conducted by Saad NJ et al., it is found that the peak incidence of enteric fever was from May-October in most of the Asian countries [41]. It is found that there is a strong association of peak incidence following the monsoon. The reason being the floods postmonsoon which contaminate the drinking water sources causing infection [42]. The estimate of annual incidence of enteric fever in the year 2022 is around 4.5 million cases [43]. The high incidence was reported in Maharashtra, Tamil Nadu, Delhi, and Chandigarh whereas, lower incidence was reported in Arunachal Pradesh and Himachal Pradesh [44]. The data on incidence of various diseases during the last 5 years has been presented in [Table/Fig-2] [15,44].

Campylobacteriosis: It is a zoonotic infection transmitted from domestic animals and birds. It is caused by *Campylobater jejuni* and *Campylobacter coli*. The gastroenteritis caused by Campylobacter spp is following consumption of infected chicken, raw, milk, and contaminated water. The incidence of this infection is reported among 10% of diarrhoea cases [45]. In a study conducted in India, around 71.87% of paediatric Campylobacter cases were isolated both during summer and monsoon months [46]. Similarly, study conducted in animals had shown a peak incidence of infection during the summer (57%) followed by the South-West monsoon season (26.2%) [47]. Campylobacteriosis among human is reported from states of Tamil Nadu, Chandigarh, Maharashtra, and Karnataka [45].

Diseases	2018	2019	2020	2021	2022
Malaria [15]	429928 cases	338494 cases	186532 cases	161753 cases	146559 cases
Dengue [15]	101192 cases	157315 cases	44585 cases	193245 cases	110473 cases
Chikungunya [15]	57813 cases	81914 cases	43424 cases	119070 cases	108957 cases
Leishmaniasis [15]	4386 cases	3145 cases	1967 cases	1276 cases	715 cases
Enteric fever [44]	831515 cases	958244 cases	254625 cases	164021 cases	165665 cases
Hepatitis A [44]	12479 cases	15428 cases	4726 cases	3548 cases	4282 cases
Hepatitis E [44]	7037 cases	8415 cases	2170 cases	1017 cases	1141 cases
Cholera [44]	2767 cases	3280 cases	926 cases	1522 cases	343 cases
Leptospirosis [44]	7378 cases	7652 cases	3137 cases	5441 cases	7402 cases
Influenza [44]	9513 cases	27879 cases	2706 cases	401 cases	6820 cases

[Table/Fig-2]: Data of common Infectious diseases during the last 5 years [15,44].

Botulism: Food borne botulism is caused by anaerobic spore forming rod shaped bacilli *Clostridium botulinum.* The botulinum toxin inhibits the acetyl choline release from synaptic vesicles at the neuromuscular junction. The spore of the organism is present in contaminated soils, algae, plants, and invertebrates [48]. The spores are also present in freshwater sediments of lake, river, and wetlands. Heavy rain and wind are important predisposing factors which mobilise the spores causing human infection. The association of botulism and monsoon needs to be studied in the Indian settings.

Hepatitis: Hepatitis A and E are the viruses which are transmitted by contaminated food and water. The viral hepatitis surveillance data conducted in India from 2011-2013 shows incidence of 7.4% for Hepatitis A and 10.4% for Hepatitis E [49]. Most of these cases were from rural areas and contaminated drinking water had association with most outbreaks. A peak in the cases (17%) was seen from June-September denoting the association with rainfall and contamination of drinking water [49]. In a study conducted from central India (2015-2017), 31.4% acute hepatitis cases were reported. Around 29% cases were Hepatitis E, and 5.1% cases were Hepatitis A [50]. Both virus outbreaks are reported from states of Uttar Pradesh, West Bengal, and Gujarat.

3. Water Borne Diseases

Cholera: Cholera is a diarrhoeal disease caused by the Gram-negative bacilli *Vibrio cholerae*. The disease is transmitted by consumption of contaminated water. The low socio-economic status, utilisation of common water sources for bathing, cooking, drinking and washing utensils predispose to infection [51]. The consumption of copepod carrier present in such water sources cause infection. The fluctuation of the climatic conditions has a direct relation on the survival of the same. Climate is one of the contributing factors for cholera infection in India [52]. In a systematic review conducted in India, it was found that the cholera outbreaks peak (61%) during the monsoon [53]. However, the only exception was the state of Tamil Nadu which peaked during winter. It was also identified that the common modes of transmission were leaking pipeline, inadequate sanitation, and food source in social gatherings. Among the Indian states-Gujarat, Karnataka, Maharashtra, Punjab, and West Bengal had a recurrence of cholera every year from 2011-2019. Around 18% of cases were reported from Karnataka, 17% from West Bengal, 10% from Maharashtra, 9% from Gujarat, 9% from Punjab, 6% from Assam, 5% from Madhya Pradesh, 4% from Tamil Nadu, and 3% from Odisha [53].

Shigellosis: Shigellosis is caused by the gram-negative bacilli *Shigella* spp. The organism was named *Shigella spp.,* in the

memory of Shiga K who identified the organism from cases of bacillary dysentery in Japan [54]. These isolates were named as *Shigella dysenteriae*. Soon similar species were identified and placed under this genus were named after Flexner, Sonne, and Boyd [55]. Among the Shigella species, *Shigella boydii* is restricted to India and neighboring countries [56]. However, other species are also reported from the country. The Shigella species have a cyclical pattern of occurrence over the years as reported from the National Institute of Cholera and Enteric Diseases (NICED) Kolkata [57]. The most prevalent was *S.flexneri* (60%) followed by *S.sonnei*, (23.8%) *S.dysenteriae* (9.8%), and *S.boydii* (5.7%) [57]. Several outbreaks have been reported from West Bengal, Tripura, Kerala, Maharashtra, Chandigarh, Tamil Nadu, and Andaman and Nicobar island [57]. Outbreaks of Shigella are attributed to poor hygiene, contaminated water, close personal contact with infected person, and climate. The average increase in rainfall and temperatures is shown to influence the transmission of the infection [58].

Leptospirosis: Leptospirosis is a febrile illness caused by aerobic, motile delicate bacilli of the genus *Leptospira*. They are transmitted by direct contact of water contaminated by urine of rodents [59]. The survival of the organism requires optimum temperature of 30°C. The incidence of Leptospirosis increases >100 cases per 100000 population in a humid temperature [60]. The incidence of Leptospirosis has a direct link with the monsoon. The number of cases in India peak following heavy rainfall. In a systematic review the overall 23% (23/127) of global outbreaks were due to increased rainfall and flood [61]. Similar peaks were reported from many states in India following the monsoon [62]. In a study conducted in Kerala, the peak cases were in August, September, and October which was preceded heavy rainfall of 7-10 days ahead [62].

Schistosomiasis: Schistosomiasis is a parasitic infestation caused by *Schistosoma* species which are mostly indigenous to the African continent [63]. The common species which are present in Asian continent are *S.japonicum, S.mekongi,* and *S.malayensis.* The organism is transmitted by the cercaria present in the snails. The first case of Indian Schistosomiasis was identified in 1903 followed by several sporadic cases. Three endemic foci of infection have also been identified in parts of India. It has been reported from Madhya Pradesh, Maharashtra, Kashmir, and Tamil Nadu [64]. The presence of snails in aquatic bodies such as rivers, ponds, dams, with associated unhygienic practice predispose to infection. These water bodies and snail population could be influenced by the prevailing rainfall.

Other infections: The extreme events such as precipitation and flooding during the monsoon could cause faecal contamination of water predisposing to diseases such as echinococcosis, taeniasis, and toxoplasmosis [65].

4. Respiratory Infections

Influenza: Influenza is a seasonal infection caused by the virus which can undergo antigenic variation. The virus also shows temporal and geographic variation which determines the control strategies [66]. The estimated global mortality ranges from 250,000-500,000 mortality annually [67]. It causes influenza like illness (fever, cough, and sore throat) or Severe Acute Respiratory Illness (SARI) with breathlessness or pneumonia [68]. In study conducted in Tamil Nadu various types of influenza virus including 86% of A/(H1N1) pdm09, 13.8% of A/H3N2, and 0.12% seasonal A/H1N1 were isolated over a seven-year period [69]. It was also observed that the increase in cases were with the onset of monsoon with a peak during the highest rainy days. This was correlating with most studies from other parts of South-East Asia including Singapore, Thailand, Vietnam, and Myanmar [70]. The virus survives in lower temperature and during the premonsoon and postmonsoon and has effective transmission due to increase in the half-life [71]. Low humidity and temperatures are the factors favouring the transmission. In addition, the decreased activity of proteases aids the stability and survival of the virus in the epithelial cells.

CONCLUSION(S)

Monsoon is a periodic seasonal climatic change which brings ample rainfall to the Indian subcontinent. The rainfall associated change in temperature and floods favours the survival of infectious diseases and their transmitting vectors. India being a developing country has more vulnerability to such infections. A better strengthening of the infrastructure and health policies is the need of the hour to curb the infections in the Indian setting. Implementation of vector control measures, effective disaster management, improvement of socio-economic status is critical. In addition, relation of monsoon and infectious diseases remains yet unfamiliar. Further studies on the association of infectious agents would aid decision makers in better management during crisis. Though there is limited data on climate change associated infectious disease pattern. The aim of this review is to provide an overview of the infectious disease pattern during the monsoon in the Indian setting. However, meta-analysis or systematic review on the same topic could provide better insights.

REFERENCES

[1] Crutzen PJ, Stoermer EF. The Anthropocene. Int Geosph-Biosphere Programme Newsl. 2000;41:17-18.
[2] Daszak P, Cunningham AA, Hyatt AD. Emerging infectious diseases of wildlife--threats to biodiversity and human health. Science. 2000;287(5452):443-49. Doi: 10.1126/science.287.5452.443. Erratum in: Science 2000 Mar 10;287(5459):1756. PMID: 10642539.
[3] Hoberg EP, Brooks DR. A macroevolutionary mosaic episodic host switching, geographic colonisation and diversification in complex host-parasite systems. J Biogeogr. 2008;35:1533-50.
[4] IPCC. Climate change 2014 synthesis report summary for policy makers. Geneva: Inter-Governmental Panel on Climate Change, 2014.
[5] An estimated 12.6 million deaths each year are attributable to unhealthy environments [Internet]. Geneva: World Health Organization; 2016; March 15, 2016 [cited March 21, 2016].
[6] USAID. Bangladesh Climate Vulnerability Profile. USA: Climate Link: A Global Knowledge Portal for Climate Change & Development Practitioners, 2012.
[7] Lindgren E, Andersson Y, Suk JE, Sudre B, Semenza JC. Public health. Monitoring EU emerging infectious disease risk due to climate change. Science. 2012;336(6080):418-19. Doi: 10.1126/science.1215735. PMID: 22539705.
[8] Semenza JC. Cascading risks of waterborne diseases from climate change. Nat Immunol. 2020;21(5):484-87. Doi: 10.1038/s41590-020-0631-7. PMID: 32313241.
[9] Semenza JC, Rocklöv J, Ebi KL. Climate change and cascading risks from infectious disease. Infect Dis Ther. 2022;11(4):1371-90. Doi: 10.1007/s40121-022-00647-3. Epub 2022 May 19. PMID: 35585385; PMCID: PMC9334478.
[10] McMichael AJ, Lindgren E. Climate change: Present and future risks to health, and necessary responses. J Intern Med. 2011;270(5):401-13. Available at: https://Doi.org/10.1111/j.1365-2796.2011.02415.xPMID: 21682780.
[11] Rao TR. The anophelines of India. New Delhi: Indian Council of Medical Research, 1981. Pp. 594.
[12] Pampana E. Textbook of malaria eradication. 2nd edition. London: Oxford University Press, 1969.
[13] Singh N, Sharma VP. Patterns of rainfall and malaria in Madhya Pradesh, central India. Ann Trop Med Parasitol. 2002;96(4):349-59.
[14] Sharma RS, Sharma GK, Dhillon GPS (eds). National Malaria Eradication Programme (NMEP), Epidemiology and Control of Malaria in India, 1996, Directorate of National Malaria Eradication Programme, Directorate General of Health Services, Ministry of Health and Family Welfare, Government of India, 1996.
[15] National Centre for Vector borne Disease Control. India: Vector borne disease situation in India. 2021. Available at: https://nvbdcp.gov.in/index.php.
[16] Gubler DJ. Dengue and dengue hemorrhagic fever. Clin Microbiol Rev. 1998;11:480-96.
[17] Chakravarti A, Arora R, Luxemburger C. Fifty years of dengue in India. Trans R Soc Trop Med Hyg. 2012;106:273-82.
[18] Kolivras KN. Changes in dengue risk potential in Hawaii, USA, due to climate variability and change. Climate Res. 2010;42:01-11.
[19] Nair DG, Aravind NP. Association between rainfall and the prevalence of clinical cases of dengue in Thiruvananthapuram district, India. International Journal of Mosquito Research. 2020;7(6):46-50. Doi: 10.22271/23487941.2020.v7.i6a.488.
[20] Tseng WC, Chen CC, Chang CC, Chu YH. Estimating the economic impacts of climate change on infectious diseases: A case study on dengue fever in Taiwan. Climatic Change. 2009;92:123-40.
[21] Mutheneni SR, Morse AP, Caminade C, Upadhyayula SM. Dengue burden in India: recent trends and importance of climatic parameters. Emerg Microbes Infect. 2017;6(8):e70. Doi: 10.1038/emi.2017.57. PMID: 28790459; PMCID: PMC5583666.
[22] Calisher CH, Karabatsos N. Arbovirus serogroups: Definition and geographic distribution. In: Monath TP, editor. The arboviruses: Epidemiology and ecology, vol. I. Boca Raton: CRC Press; 1988. Pp. 19-58.
[23] Burt FJ, Rolph MS, Rulli NE, Mahalingam S, Heise MT. Chikungunya: A re-emerging virus. Lancet. 2012;379:662-71.

[24] Tilston N, Skelly C, Weinstein P. Pan-European Chikungunya surveillance: Designing risk stratified surveillance zones. Int J Health Geogr. 2009;8:61.
[25] Shil P, Kothawale DR, Sudeep AB. Rainfall and Chikungunya incidences in India during 2010-2014. Virus disease. 2018;29(1):46-53. Doi: 10.1007/s13337-018-0428-6. Epub 2018 Feb 14. PMID: 29607358; PMCID: PMC5877844.
[26] Smithburn K, Hughes T, Burke A, Paul JH. A neurotropic virus isolated from the blood of a native of Uganda. Am J Trop Med Hyg. 1940;20:471-73.
[27] Paz S, Semenza JC. Environmental drivers of West Nile fever epidemiology in Europe and Western Asia- A review. Int J Environ Res Public Health. 2013;10:3543-62.
[28] Paramasivan R, Mishra AC, Mourya DT. West Nile virus: The Indian scenario. Indian J Med Res 2003;118:101-08.
[29] Singh BB, Sharma R, Gill JP, Aulakh RS, Banga HS. Climate change, zoonoses and India. Rev Sci Tech. 2011;30(3):779-88. Doi: 10.20506/rst.30.3.2073. PMID: 22435190.
[30] Mourya DT, Yadav PD, Gurav YK, Pardeshi PG, Shete AM, Jain R, et al. Crimean Congo hemorrhagic fever serosurvey in humans for identifying high-risk populations and high-risk areas in the endemic state of Gujarat, India. BMC Infect Dis. 2019;19:104.
[31] Chauhan A, Chauhan S. Lyme disease-ocular/oral scenario. J Infectious Disease Med Microbiol. 2018;2(1):1.
[32] Bonell A, Lubell Y, Newton P, Crump J, Paris D. Estimating the burden of scrub typhus: A systematic review. PLOS Neglected Tropical Diseases. 2017;11(9):e0005838.
[33] Rina T, Vivek A. Mite and tick-borne diseases in India: Challenges and the way forward. J Med Arthropodol & Public Health. 2021;1(1):09-14.
[34] Kamarasu K, Malathi M, Rajagopal V, Subramani K, Jagadeeshramasamy D, Mathai E. Serological evidence for wide distribution of spotted fevers & typhus fever in Tamil Nadu. Indian J Med Res. 2007;126(2):128-30.
[35] Sharma U, Redhu NS, Mathur P, Singh S. Re- emergence of visceral leishmaniasis in Gujarat, India. J Vect Borne Dis. 2007;44:230-32.
[36] Hlavacova J, Votypka J, Volf P. The effect of temperature on Leishmania (Kin etoplastida:Trypanosomatidae) development in sand flies. J Med Entomol. 2013;50:955-58.
[37] Buckle GC, Walker CL, Black RE. Typhoid fever and paratyphoid fever: Systematic review to estimate global morbidity and mortality for 2010. J Glob Health. 2012;2(1):010401. Doi: 10.7189/jogh.02.010401. PMID: 23198130; PMCID: PMC3484760.
[38] Antillón M, Warren JL, Crawford FW, Weinberger DM, Kürüm E, Pak GD, et al. The burden of typhoid fever in low- and middle-income countries: A meta-regression approach. PLoS Negl Trop Dis. 2017;11(2):e0005376.
[39] Dewan AM, Corner R, Hashizume M, Ongee ET. Typhoid fever and its association with environmental factors in the dhaka metropolitan area of bangladesh: A spatial and time-series approach. PLoS Negl Trop Dis. 2013;7:12-15.
[40] Tsai C, Behera SK, Waseda T. Indo-China Monsoon Indices. Sci Rep. 2015;5:8107.
[41] Saad NJ, Lynch VD, Antillon M, Yang C, Crump J, Pitzer VE. Seasonal dynamics of typhoid and paratyphoid fever. Scientific Reports. 2018;8:6870. Doi: 10.1038/s41598-018-25234.
[42] Corner RJ, Dewan AM, Hashizume M. Modelling typhoid risk in Dhaka metropolitan area of Bangladesh: The role of socioeconomic and environmental factors. Int J Health Geogr. 2013;12:13.
[43] Cao Y, Karthikeyan AS, Ramanujam K, Raju R, Krishna S, Kumar D, et al. Geographic pattern of typhoid fever in india: A model-based estimate of cohort and surveillance data. J Infect Dis. 2021;224(224 Supple 5):S475-83. Doi: 10.1093/infdis/jiab187. PMID: 35238365; PMCID: PMC8892532.
[44] Integrated Disease Surveillance Programme. India: Disease alert 2018-2022. https://www.idsp.mohfw.gov.in/.
[45] Centers for Disease Control and Prevention Vital signs: Incidence and trends of infection with pathogens transmitted commonly through food—Foodborne Diseases Active Surveillance Network, 10 US sites, 1996–2010. MMWR Morb Mortal Wkly Rep. 2011;60:749-55.
[46] Ghosh R, Uppal B, Aggarwal P, Chakravarti A, Dubey AP. Clinical profile and epidemiology of campylobacter associated diarrhea among children in New Delhi, India. International Journal of Enteric Pathogens. 2016;4(3):5-35684. Doi: 10.15171/ijep.2016.05.
[47] Rajarajan G. Seasonality of campylobacter jejuni isolated from raw milk. J Dairying, Foods & HS. 2012;31(1):20-24.
[48] Long SC, Tauscher T. Watershed issues associated with Clostridium botulinum: A literature review. J Water Health. 2006;4:277-88.
[49] Kumar T, Shrivastava A, Kumar A, Laserson K, Narain, Jai V, et al. Viral hepatitis surveillance- India, 2011-2013. MMWR. Morbidity and Mortality Weekly Report. 2015;64(28):758-62.
[50] Barde PV, Chouksey VK, Shivlata L, Sahare LK, Thakur AK. Viral hepatitis among acute hepatitis patients attending tertiary care hospital in central India. Virus Disease. 2019;30(3):367-72. Doi: 10.1007/s13337-019-00541-6. Epub 2019 Jul 26. PMID: 31803803; PMCID: PMC6863987.
[51] Ali M, Gupta SS, Arora N, Khasnobis P, Venkatesh S, Sur D, et al. Identification of burden hotspots and risk factors for cholera in India: An observational study. PLoS ONE. 2017;12:e0183100.
[52] Lipp EK, Huq A, Colwell RR. Effects of global climate on infectious disease: The cholera model. Clin Microbiol Rev. 2002;15:757-70.
[53] Muzembo BA, Kitahara K, Debnath A, Ohno A, Okamoto K, Miyoshi SI. Cholera Outbreaks in India, 2011-2020: A systematic review. Int J Environ Res Public Health. 2022;19(9):5738. Doi: 10.3390/ijerph19095738. PMID: 35565133; PMCID: PMC 9099871.
[54] Shiga K. About the causative agent of dysentery in Japan: Preliminary communication. Zentralbal Bakteriol Microbiol Hyg. 1898;23:599-600.
[55] Kruse W. About the dysentry as a widespread disease and its pathogens. Dtsch Med Wochenschr. 1900;26:637-39.
[56] Venkatesan MM, Ranallo RT. Live-attenuated Shigella vaccines. Expert Rev Vaccines. 2006;5:669-86.
[57] Pazhani GP, Ramamurthy T, Mitra U, Bhattacharya SK, Niyogi SK. Species diversity and antimicrobial resistance of Shigella spp. isolated between 2001 and 2004 from hospitalized children with diarrhoea in Kolkata (Calcutta), India. Epidemiol Infect. 2005;133:1089-95.
[58] Torres AG. Current aspects of *Shigella* pathogenesis. Rev Latinoam Microbiol. 2004;46:89-97.
[59] Faine S, Adler B, Bolin C, Perolat P. Leptospira and Leptospirosis. 2nd ed. Melbourne, Australia: Medisci Press; 1999. Pp. 296.
[60] Park K. Park's Textbook of Preventive and Social Medicine. 19th ed. Jabalpur: M/s Banarasidas Bhanot; 2007. Pp. 243.
[61] Munoz-Zanzi C, Groene E, Morawski BM, Bonner K, Costa F, Bertherat E, et al. A systematic literature review of leptospirosis outbreaks worldwide, 1970-2012. Rev Panam Salud Publica. 2020;44:e78. Available at: https://Doi.org/10.26633/RPSP.2020.78.
[62] Pappachan MJ, Sheela M, Aravindan KP. Relation of rainfall pattern and epidemic leptospirosis in the Indian state of Kerala. J Epidemiol Community Health. 2004;58(12):1054. Doi: 10.1136/jech.2003.018556. PMID: 15547074; PMCID: PMC1732650.
[63] Cox FEG, Wakelin D, Gillespie S, Despommier D. Parasitology. Volume 6. Topley & Wilson's Microbiology and Microbial Infections. 10th ed. London: Edward Arnold (Publishers) Ltd; 2007.
[64] Srivastava KK, Arora MM. Schistosoma haematobium infection in Lahager. A village in Raipur district of Madhya Pradesh. Indian J Med Res. 1969;57:2016-17.
[65] Singh BB, Sharma R, Sharma JK, Juyal PD. Parasitic zoonoses in India: An overview. Rev Sci Tech Off Int Epiz. 2010;29(3):629-37.
[66] Moura FE. Influenza in the tropics. Curr Opin Infect Dis. 2010;23:415-20.
[67] Kiruba R, Suresh Babu BV, Sheriff AK, Gunasekaran P, Anupama CP, Saran N, et al. Dynamics of the occurrence of influenza in relation to seasonal variation in Chennai, Tamil Nadu: A 7-year cumulative study. Indian J Med Microbiol. 2019;37:401-05.
[68] World Health Organization. A Practical Guide to Harmonizing Virological and Epidemiological Influenza Surveillance. Western Pacific Region: World Health Organization; 2008. Pp. 5.
[69] Viboud C, Alonso WJ, Simonsen L. Influenza in tropical regions. PLoS Med. 2006;3:e89.
[70] Pica N, Chou YY, Bouvier NM, Palese P. Transmission of influenza B viruses in the guinea pig. J Virol. 2012;86:4279-87.
[71] Lofgren E, Fefferman NH, Naumov YN, Gorski J, Naumova EN. Influenza seasonality: Underlying causes and modeling theories. J Virol. 2007;81:5429-36.

PARTICULARS OF CONTRIBUTORS:
1. Professor, Department of Microbiology, Mahatma Gandhi Medical College and Research Institute, Puducherry, India.
2. Professor, Department of Microbiology, Mahatma Gandhi Medical College and Research Institute, Puducherry, India.
3. Professor, Department of Microbiology, Indira Gandhi Institute of Dental Sciences, Puducherry, India.

NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:
Dr. Marie Victor Pravin Charles,
Professor, Department of Microbiology, Mahatma Gandhi Medical College and Research Institute, Pondicherry-607402, India.
E-mail: antonieolee@gmail.com

PLAGIARISM CHECKING METHODS: [Jain H et al.]
- Plagiarism X-checker: Nov 19, 2022
- Manual Googling: Dec 02, 2022
- iThenticate Software: Dec 20, 2022 (10%)

ETYMOLOGY: Author Origin

AUTHOR DECLARATION:
- Financial or Other Competing Interests: None
- Was Ethics Committee Approval obtained for this study? NA
- Was informed consent obtained from the subjects involved in the study? NA
- For any images presented appropriate consent has been obtained from the subjects. NA

Date of Submission: **Nov 18, 2022**
Date of Peer Review: **Dec 06, 2022**
Date of Acceptance: **Dec 24, 2022**
Date of Publishing: **Apr 01, 2023**