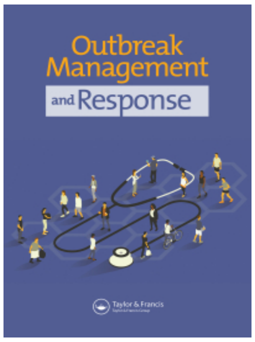

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Outbreak Management and Response

ISSN: 2994-7677 (Online) Journal homepage: www.tandfonline.com/journals/tomr20

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OUTBREAK MANAGEMENT AND RESPONSE
2025, VOL. 1, NO. 1, 2466531
https://doi.org/10.1080/29947677.2025.2466531

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Disease Outbreaks in India (2017–2023): Key Inferences from an Analysis of Weekly Records for Effective Outbreak Management and Response

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ABSTRACT

Understanding the prevailing landscape of disease outbreaks at a country level is crucial for effective outbreak management and prompt response. This research objective is to analyze and portray India's disease outbreak landscape by considering available social action reports, thereby identifying (1) the predominant transmission mode of the disease outbreaks, (2) prevailing disease outbreaks, (3) year-wise trend of prevailing disease outbreaks, and (4) the regions with high-frequency outbreaks. Nine thousand three hundred ninety confirmed public health concern records between 2017 and 2023 that are available from the open-access national surveillance program were considered and fed to data science algorithms for further analysis. Additionally, these records contain location information, enabling the mapping of hotspots using the Geographic Information System. Nearly 50% of disease outbreaks stem from foodborne/waterborne infections, including fecal-oral routes. Our research highlights a rise in Leptospirosis outbreaks following extreme weather events. In India, mosquito-borne diseases like Dengue and Chikungunya are now endemic, causing widespread outbreaks. Chickenpox, measles, and mumps remain prevalent, underscoring the need for vaccine availability in the national immunisation program. The results from this research help policymakers pinpoint the regions at high risk for outbreaks, facilitating effective preparedness and policy development to contain the future spread.

ARTICLE HISTORY
Received 3 July 2024
Accepted 2 February 2025

KEYWORDS
Disease outbreaks; outbreaks landscape; spatial data analysis; social action reports

Introduction

Infectious disease outbreaks recapitulate biology by emerging through multi-level interactions of hosts, pathogens, and the environment [1]. They are generally recognised when more cases than expected occur in a specific location over a particular period [2]. Even an occurrence of a single case can be an outbreak if the condition is found somewhere it has not been before [3]. Outbreaks spreading over a larger geographical area are termed epidemics, and while spreading globally, they are termed pandemics. A disease condition occurring at a predictable rate among a population is endemic [4].

The United Nations (UN) emphasises the need for a global focus on disease outbreaks, aligning with the Sustainable Development Goals (SDGs). Specifically, SDG 3 aims to "Ensure healthy lives and promote well-being for all ages," targeting the end of epidemics like AIDS, tuberculosis, malaria, and other communicable diseases [5]. However, climate change complicates disease management and response due to the resurgence of vector and pathogen reservoirs [6–9].

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Extreme weather disasters and global climate change are significant threats to public health in various ways [10]. Long-term and high-quality datasets are needed to analyze and comprehend the relationship between disease outbreaks and climate change, enabling the development of prediction models. These prediction models may further assist in drafting region-specific action plans to combat infectious disease risks [11].

Understanding, preparing, and addressing local health emergencies, especially during the onset stage of an outbreak, can prevent widespread transmission of diseases [12]. Broadcasting the information related to human infectious disease outbreaks at community, regional, and continent scales should be a mandatory action item that is vested with the health authorities as a part of disease surveillance; this, in turn, enables public health practitioners to portray the hotspots of outbreaks, its diversity, and transmission pattern. The recent pandemic episode of COVID-19 has accentuated the importance of collecting and analyzing outbreak data [13].

Developed countries have dedicated public health mitigation centers for health threats. The Centers for Disease Control and Prevention (CDC) in the United States of America monitors global outbreaks and shares updates via social media [14]. The European Centre for Disease Prevention and Control (ECDC) analyzes data on over 50 infectious diseases and guides the member states of the European Union (EU) in managing the outbreaks [15]. In Africa, the African Risk Capacity (ARC) helps governments enhance their responses to extreme weather events and disasters [16]. The World Health Organization (WHO) releases Disease Outbreak News (DONs) informing the event of public health concerns as per Article 11.4 of the International Health Regulations (IHR) [17,18]. Global Infectious Diseases and Epidemiology Online Networks (GIDEON) offer subscription-based access to the data for academia and public health professionals to perform research and diagnostic activities [19].

Smith et al. [20] analyzed 33 years (1980-2013) of GIDEON data with over 44 million cases across 219 nations, finding that outbreaks were primarily linked to bacteria, viruses, zoonotic diseases, and vector-borne pathogens. Similarly, Torres Munguía et al. [21] examined WHO's DON dataset covering 70 diseases and 2227 outbreak events from 1996 to 2022 in 233 countries; their exploratory spatial data analysis revealed high-incidence hotspots in Africa, America, and Asia.

Social action records can be transformed into knowledge-inferable datasets, during which invisible process/activity in the former turns into information that can be useful for monitoring, tracking, analyzing, and optimising [22–24]. The works of Smith et al. [20] and Torres Munguía et al. [21] described above are typical examples of transforming social action records into knowledge.

The objectives of this research are to analyze and portray India's disease outbreak landscape by considering available social action reports, thereby identifying:

1. The predominant transmission mode of the disease outbreaks
2. Prevailing disease outbreaks
3. The year-wise trend of prevailing disease outbreaks
4. The regions with high-frequency occurrence of epidemics

To achieve these objectives, we have used weekly outbreak records published as a part of social action reports by the country's health authorities. The motivation for this research is the realisation that there is a lack of information portraying India's outbreak landscape from any health institutes. The results from this research should enable policymakers to identify the recurring disease outbreaks and their regions, allowing them to prepare regional health policies and interventions.

Materials and methods

Datasets

In India, the National Centre for Disease Control (NCDC) under the Directorate General of Health Services (DGHS), Ministry of Health and Family Welfare (MH&FW), is the focal point for the Integrated Disease Surveillance Program (IDSP) [25,26]. Administratively, India is divided into 28 states and 8 Union Territories [27]. The 28 states together contain 806 districts. IDSP is a part of the National Health Mission (NHM), comprising state-of-the-art cyber-infrastructure connecting all states and district headquarters aimed to collect, compile, analyze, and disseminate epidemic disease data to the public. Earlier, IDSP weekly reports were used by public health researchers to investigate various outbreak patterns [28–33]. However, some researchers opined that the outbreaks reported by the IDSP are underreported [34,35]; nevertheless, currently, the only source of disease outbreak data in India is from the IDSP, which, if analyzed at the minimum can ensure giving a preliminary understanding of the trend and the landscape of prevailing outbreaks.

This research considered seven years of IDSP weekly outbreak records between 2017 and 2023 to achieve its objectives. The rationale for selecting the period between 2017 and 2023 is to identify secondary insights (if any) regarding the effects of the COVID-19 pandemic on the pattern of disease outbreaks (three years before and after 2020).

Under the aegis of IDSP, weekly outbreak reports are available to download as Portable Document Format (PDF) files [25]. Each outbreak event reported in the weekly bulletin has attributes like the state and district, the disease, the number of cases and deaths, the duration of the disease outbreak, and a commentary briefing the action taken in connection with the event. In particular, the commentary section of each outbreak event includes the village identity and the details of the health facility where the infected are receiving the treatment. IDSP releases the data in the public domain through its website at https://idsp.mohfw.gov.in/.

Methods

A total of 365 weekly reports were available between 2017 and 2023. In our research, we have excluded the events associated with COVID-19 as already numerous researchers have reported the results associated with COVID-19 [36]; also, a dedicated dashboard developed by the MH&FW, Government of India is well in place to disclose their action plans and proceedings concerning COVID-19 pandemic [37]. Excluding the COVID-19 cases, in these seven years, there are 9390 confirmed events of public health concern, with a count of 3,72,301 persons infected.

Recently, there has been an impetus in developing epidemic risk assessment toolkits and methods for ranking/scoring the regions with epidemic risks [38]. These toolkits and methods help assess the risk of health threats based on their mode of transmission, the agents of epidemiological triads, the host, and the environment. Thus, considering the most common mode of transmission, each outbreak event falls into one of the categories like zoonosis, vector-borne, person-to-person, and food/waterborne diseases [39–41]. Table 1 shows the synthesis of the 9390 disease outbreaks between 2017 and 2023, categorised according to their transmission mode.

The dataset presented in Table 1 is the basis for this research to understand India's prevailing landscape of disease outbreaks. To get a consensus about the distribution of total infections based on the transmission mode and to understand the density of individual disease outbreaks, a pie diagram and a treemap were generated using the data from Table 1 (discussed in the subsequent section). We used Plotly, an open-source graphing library for Python, to create the pie diagram and the treemap. Similarly, bar charts were generated to understand the year-wise trend of high prevailing disease outbreaks from 2017 onwards.

Using the location information in the individual event as reported in the weekly bulletins, maps were generated using Geographical Information System (GIS) software, namely, QGIS (https://www.qgis.org/). QGIS is free and open-source software that allows users to create, edit, analyze, visualise, and publish geospatial data. These maps were used to identify the districts of high-frequency outbreaks (hotspots). For this, the districts experiencing the outbreaks recursively every year with criteria that outbreaks are greater than the average outbreaks at the country level were selected for mapping.

Results

The predominant transmission mode of disease outbreaks in India

As discussed in the previous section, a pie chart, shown in Figure 1, was created to understand the predominant transmission mode of disease outbreaks using the data from Table 1. The primary inference after the classification of 9390 confirmed events of a public health concern as reported by IDSP during 2017–2023 is that nearly 50 percent of the disease outbreaks have the origin due to foodborne/waterborne infections, including those due to fecal-oral route (refer to Figure 1). The outbreaks associated with vector-borne and those transmitted from person to person are nearly 23 percent each, and those associated with zoonosis and others are nearly 4 percent of the total outbreaks.

Prevailing disease outbreaks in India

Treemaps provide a space-filling method of visualising large hierarchical datasets by dividing the canvas into a nested sequence of rectangles; each rectangle area corresponds to an attribute of the dataset [42]. The advantage of visualising the data through the treemaps is that it will unleash the visual functions of both the

Table 1. The weekly disease outbreaks (2017–2023), as reported by IDSP, are categorised according to the transmission mode—source: IDSP [25].

Mode of infection transmission	Disease/Infection	Total number of outbreak events	Total number of infected persons
Zoonosis	Leptospirosis	124	1860
	Human Rabies	62	72
	Crimean-Congo Hemorrhagic Fever (CCHF)	45	51
	Anthrax	38	209
	Kyasanur Forest Disease	17	71
	Brucellosis	10	52
	Nipah Virus (NiV)	5	52
	H3N2	1	24
Vector borne	Dengue	1060	64835
	Chikungunya	391	11015
	Acute Encephalitis Syndrome (AES)/Japanese Encephalitis (JE)	275	5922
	Malaria	179	18676
	Scrub Typhus	105	2294
	Zika Virus	29	701
	West Nile Fever	21	24
	Kala-Azar	13	52
	Leishmaniasis	21	17
	Filariasis	5	28
	Others (Visceral Leishmaniasis and Trypanosomiasis)	3	3
Person to person	Chickenpox	958	18708
	Measles	825	13010
	Mumps	179	3036
	Diphtheria	71	589
	Influenza B	11	419
	Rubella	10	574
	Influenza A	9	619
	Acute Febrile Illness	8	155
	Hand Foot & Mouth Disease	8	179
	Monkey Pox	8	11
	Acute Respiratory Illness	7	177
	Hepatitis B	6	78
	Adeno Virus	4	993
	Seasonal Influenza	4	500
	Others (H1N1, Hepatitis C, Meningitis, Allergic Conjunctivitis, Herpes Simplex Encephalitis, Noro Virus, Pertussis, Scabies)	11	224
Foodborne/waterborne, including infections through the fecal-oral route	Acute Diarrheal Diseases	2115	95552
	Food poisoning and foodborne illness	1475	80016
	Hepatitis A/E	444	12778
	Cholera	201	20965
	Acute Gastroenteritis	68	3316
	Typhoid	58	1635
	Shigellosis	32	1187
	Mushroom Poisoning	25	292
	Enteric Fever	22	854
	Others (Dysentery, Bacillary Dysentery, Epidemic Dropsy, Salmonellosis, Gastroenteritis, and Trichinellosis)	24	672
Others	Acute Flaccid Paralysis, Acute Meningoencephalitis, BHC Poisoning, Chemical Gas Poisoning, Convulsions of Unknown cause, Cutaneous Anthrax, Dog/Snakebite, DVD, Fever, Jatropha Poisoning, Melioidosis, Neonatal Tetanus, Pyrexia of Unknown Origin, and Shigellosis	405	9804

aspects of a Venn diagram and a pie chart. Figure 2 shows the treemap of India's top ten infectious disease outbreaks during 2017 and 2023. It can be interpreted from this treemap that acute diarrheal disease outbreaks, foodborne illness, and food poisoning cases are predominant, as they are nearly 39 percent of the

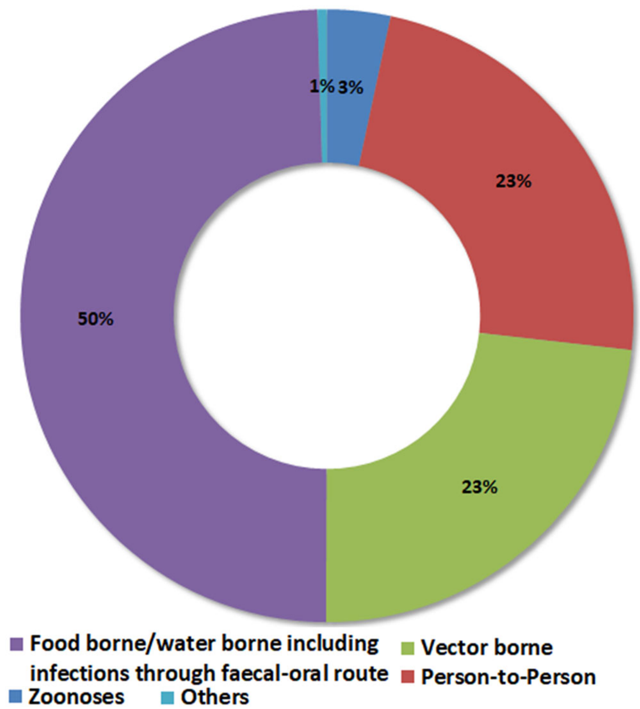

Figure 1. Pie chart showing the distribution of disease outbreaks in India (2017–2023) based on their mode of infection transmission. Notably, 50% of outbreaks are associated with foodborne/waterborne infections, including those due to the fecal-oral route.—source: IDSP [25].

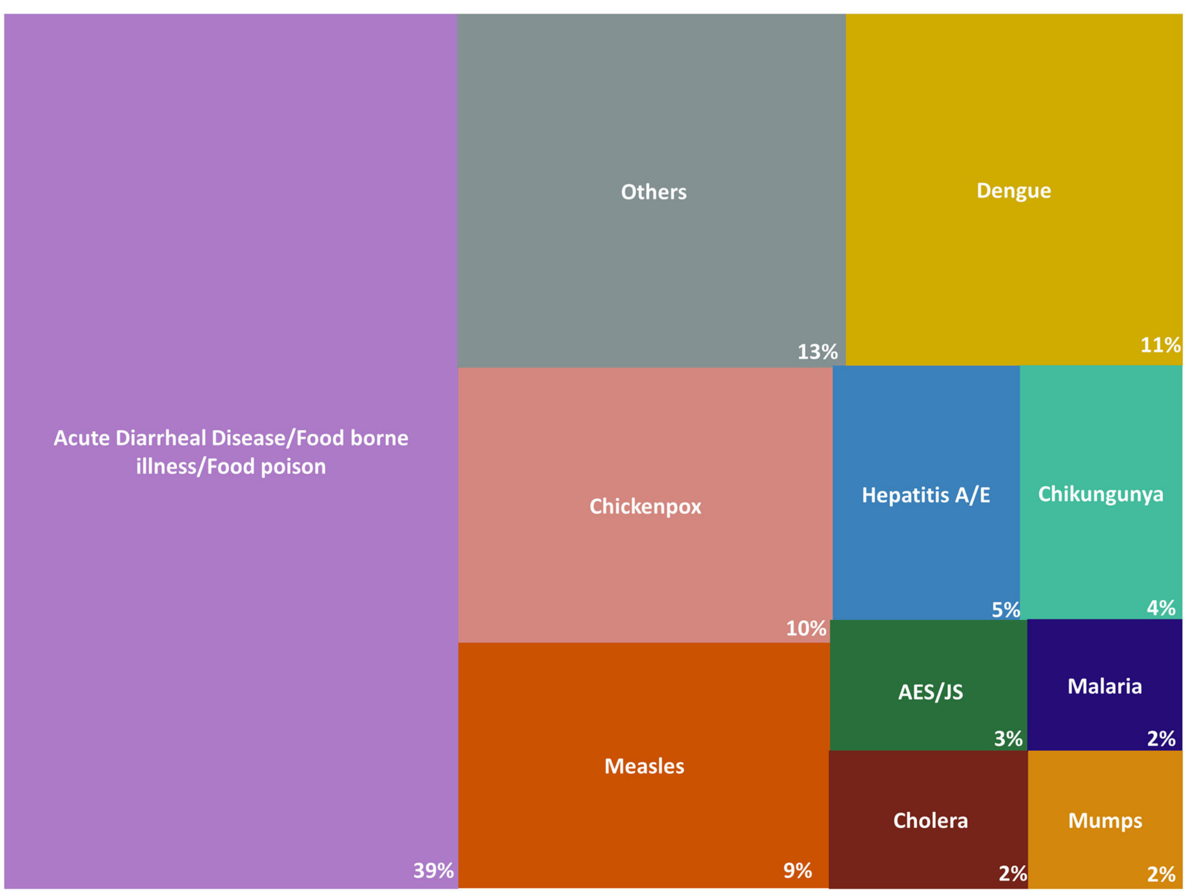

Figure 2. A treemap showing India's prevailing infectious disease outbreaks (2017–2023). Notably, 39% of outbreaks are associated with acute diarrheal diseases, foodborne illness, and food poisoning cases.—source: IDSP [25].

total outbreaks (refer to Figure 2). Chickenpox, measles, and mumps, generally transmitted from person to person, account for nearly 21 percent of the cases. Vector-borne diseases like Dengue, Chikungunya, and Malaria account for 17 percent of the cases.

The year-wise trend of prevailing disease outbreaks in India

Figure 3 shows the year-wise trend of India's top ten disease outbreaks during 2017–2023. The primary observation from the trend of disease outbreaks from these seven years of data is that acute diarrheal diseases and associated infections due to foodborne/food poisonings accounts for a significant portion of outbreaks during all these years. Disease outbreaks of Dengue, Chickenpox, Measles, Hepatitis A/E, Chikungunya, Acute Encephalitis Syndrome (AES)/Japanese Encephalitis (JE), Cholera, Malaria, and Mumps have always prevailed on the list of the top infections next to acute diarrheal diseases (refer to Figure 3). During 2020 and 2021, there is a probability that the outbreaks occurred less, or the IDSP has underreported the outbreaks; the reasons may be because of the country-wide lockdown imposed due to the COVID-19 pandemic.

Regions with high-frequency occurrence of epidemics

Figure 4 shows maps depicting the districts with high-frequency outbreaks of zoonosis, vector-borne diseases, person-to-person infectious diseases, and foodborne/waterborne infections, including fecal-oral diseases. Table 2 lists the districts with disease outbreaks with a higher frequency of occurrence (more than the average number of outbreaks that occurred during 2017–2023; in each case, infected persons are significantly more than the average value during each event).

Figure 4(a) shows the districts with high-frequency zoonosis disease outbreaks; the prevailing zoonosis outbreaks are Leptospirosis, Kyasanur Forest Disease (KFD), Anthrax, Crimean-Congo Haemorrhagic Fever (CCHF), Nipah Virus (NiV), and Rabies. Leptospirosis generally results from direct or indirect exposure to infected reservoir host animals, potentially the brown rats (*Rattus norvegicus*) that carry the pathogen in their renal tubules and shed pathogenic Leptospira in their urine. These pathogens can cause large epidemics while mixed with flood water [43]. Thereby, individuals living in urban slum environments are highly vulnerable to Leptospirosis. Table 2 lists districts recursively exposed to Leptospirosis outbreaks; future research can observe the pre-environmental conditions in the locations where the infected have geographically occupied. Martone & Kaufmann [44], while investigating human Leptospirosis in the United States, confirmed that most of the infected persons are agriculture workers and migrant labourers, predominantly working with water-intensive crops and living alongside livestock.

India accounts for 36% of the global deaths due to rabies, though there is a dedicated program to eliminate it through the National Rabies Control Program; researchers have alarming the issue of rising rabies cases through various studies [45,46]. Our research has prioritised certain districts in Karnataka that need greater attention to combat rabies cases.

Four districts, Amreli, Bhavnagar, Surendranagar, and Rajkot of Gujarat state, were high-frequency CCHF zones and require immediate government intervention. A similar observation was recorded earlier by Mourya et al. [47], wherein their research through the development of spatial risk maps has identified the density of buffalo, minimum land surface temperature, and elevation as risk determinants for CCHF in Gujarat state.

Those districts identified in this research as high-frequency prone to anthrax (refer to Table 2) have also been mentioned earlier by Jayaprakasam et al. [48] while performing a systematic review and risk mapping activity. Koraput district in Orissa state, identified as a high-frequency zone for anthrax through this research, was also mentioned earlier by Nayak et al. [49] and revealed that there is a good correlation between eating and handling of ill animals and the presence of anthrax-like organisms in lesions.

KFD was first recognised as a febrile illness in the Shimoga district of Karnataka state; the causative agent, KFD virus, is a highly pathogenic member of the family Flaviviridae, producing a haemorrhagic disease in infected human beings [50] - KFD is now endemic in the Shimoga and its surrounding districts. Our research confirmed that the KFD outbreaks have appeared in newer districts like Wayanad in Kerala, Goa, and Sindhudurg in Maharashtra. Interestingly, these newer districts are within the surroundings of the Shimoga district.

Our research recognises the Kozhikode district of Kerala as a region most frequently affected by the NiV. Earlier, research by Kumar et al. [51] and Prakash et al. [52] confirmed the primary reason for NiV outbreaks in Kozhikode to be the spill-over events from infected bats followed by person-to-person transmission.

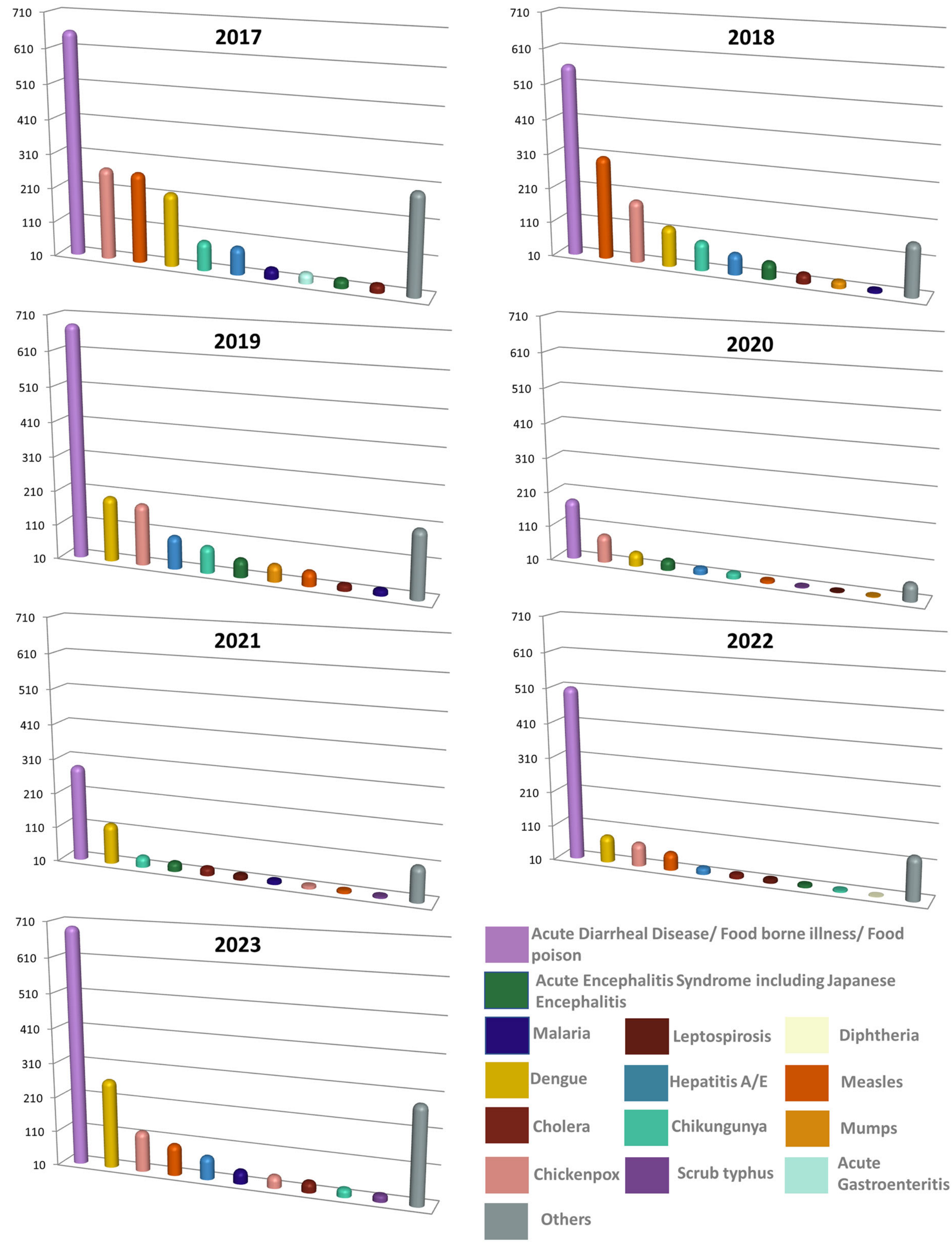

Figure 3. The year-wise trend of high prevailing disease outbreaks in India (2017–2023). A unique set of infectious diseases with the domination of acute diarrheal diseases regularly constitutes the outbreaks annually. Vector-borne diseases like Dengue and highly contagious chickenpox caused by the varicella-zoster virus prevail yearly; they are among the top contributors to the prevailing disease outbreaks after acute diarrheal diseases.—source: IDSP [25].

Concerning vector-borne disease outbreaks, an additional analysis was performed by generating a chart showing their distribution, as in Figure 5. The priority districts needing immediate control measures for combating vector-borne disease outbreaks are reported in Table 2 and Figure 4b.

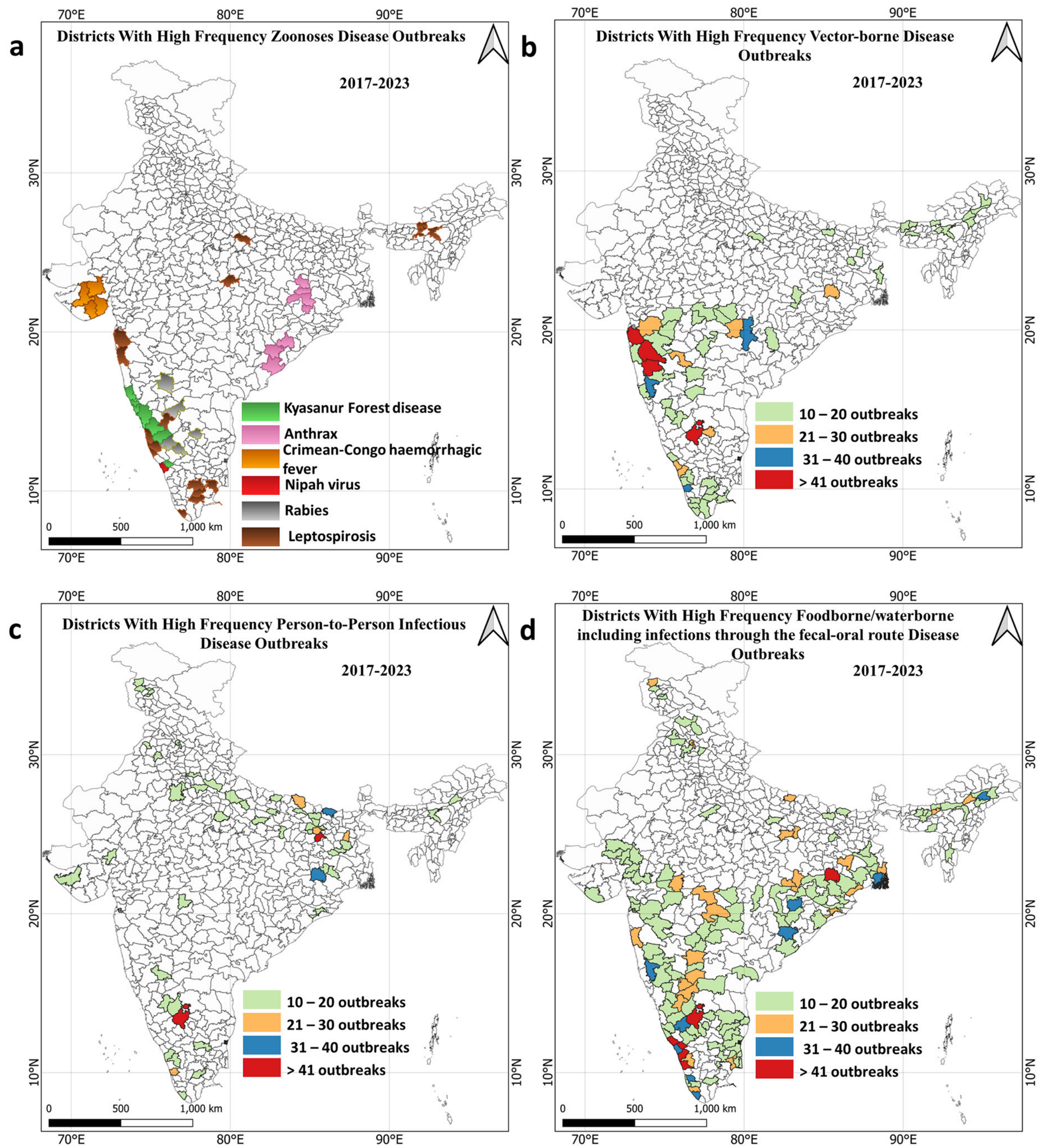

Figure 4. Maps showing districts with high-frequency infectious disease outbreaks (2017–2023). (a) Districts with high-frequency zoonosis disease outbreaks. (b) Districts with high-frequency vector-borne disease outbreaks. (c) Districts with high-frequency person-to-person infectious disease outbreaks. (d) Districts with high-frequency foodborne/waterborne, including infections through fecal-oral disease outbreaks.—source: IDSP [25].

Regions with high dominant occurrences of person-to-person infections are also listed in Table 2. During this research for 2017–2023, from the collection of viral disease outbreaks that can be transmitted from person to person, it was inferred that chickenpox, measles, and mumps are also dominant in India. Districts like Madhubani and Nawada in Bihar state, Pashchimi Singhbhum in Jharkhand state, and Tumkur in Karnataka state are identified as high-frequency outbreak zones that need immediate attention.

Foodborne/waterborne diseases are either infectious or toxic and are caused by agents entering the body through ingestion; infectious are those whose etiologic agents are viable pathogenic organisms like bacteria, viruses, parasites, and fungi that can establish infection when ingested with food. Foodborne poisoning/intoxications arise from ingesting toxins released by microorganisms, intoxication from poisoned plants or toxic animal tissues, or consuming food contaminated by chemical poisons [53]. Our research has prioritised 15 districts in India, as specified in Table 2, that are highly prone to foodborne and waterborne infectious

Table 2. Districts with high-frequency disease outbreaks in India (2017–2023). Districts that experienced 30 or more outbreaks during 2017–2023, and in each outbreak event, if the infected persons are more than 20, are considered high-frequency outbreak zones in this research.

Mode of Transport	Disease	Priority districts
Zoonosis	Leptospirosis	• Darrang, Kamrup, Nagaon, and Udalguri (Assam state) • Thiruvananthapuram and Kasaragod (Kerala state) • Davanagere, Udupi, and Dakshina Kannada (Karnataka state) • Jabalpur (Madhya Pradesh) • Thane and Raigarh districts that are adjacent to Mumbai urban agglomeration • Dindigul, Madurai, Pudukkottai, Virudhunagar (Tamil Nadu state) • Fatehpur in Uttar Pradesh state
	Human Rabies	• Ballary, Vijayapura/Bijapur, Chikkaballapur, Hassan, and Mandya (Karnataka state)
	Crimean-Congo Hemorrhagic Fever	• Amreli, Bhavnagar, Rajkot, and Surendranagar (Gujarat state)
	Anthrax	• Gumla and Simdega (Jharkhand state) • Visakhapatnam in Andhra Pradesh state • Koraput, Deogarh, Rayagada, and Sundargarh (Odisha state)
	Kyasanur Forest Disease	• Goa state • Sindhudurg (Maharashtra state) • Chikmagalur, Shimoga, Uttara Kannada (Karnataka state) • Wayanad in Kerala state
	Nipah Virus	Kozhikode district in Kerala state
Vector-borne		• Gadchiroli, Kolhapur, Pune, Satara, and Thane (Maharashtra state) • Ernakulam district (Kerala state) • Tumkur district (Karnataka state)
Person to person		• Madhubani and Nawada (Bihar state) • Pashchimi Singhbhum (Jharkhand state) • Tumkur (Karnataka state)
Foodborne/waterborne, including infections through the fecal-oral route		• Dibrugarh (Assam state) • Pashchimi Singhbhum (Jharkhand state) • Hassan and Tumkur (Karnataka state) • Kolhapur in Maharashtra state • Kannur, Wayanad, Kozhikode, Malappuram, Thiruvananthapuram, Thrissur, and Kottayam (Kerala state) • Balangir and Koraput (Orissa state) • South 24 Parganas (West Bengal state)

disease outbreaks. However, a deep dive into the literature survey confirmed that every district in India has at least once a year will have an outbreak due to foodborne/waterborne disease with a significant number of infected persons – of course, this may go unreported [29,54,55]. From our research, it is evident that frequent outbreaks associated with foodborne/waterborne infections highly prevail in the districts that favour 'rice eating with hands' (refer to Figure 4d); Suryanegara et al. [56], through their cross-sectional study confirmed that people favouring rice eating with unwashed hands are at 100 percent risk to diarrheal diseases. Certain regions of India favour eating stale food, assuming it can build immunity [57–59] – however, improper handling/storage of food can attract contamination with *Bacillus cereus* or *Staphylococcus aureus* [60].

It is observed that the disease outbreaks due to foodborne/waterborne infections, including those due to fecal-oral route, are nearly 50 percent of the total outbreaks; an emphasis has been placed on understanding the seasonal variations of the outbreak occurrences associated with this category of infections, and the resulting output is shown in Figure 6. The chart in Figure 6 contains months on the x-axis, and the y-axis constitutes the number of infectious outbreaks during 2017–2023. It shows two peaks of high-density outbreaks, one during the peak summer and the other during the monsoon season (interpretation of these peaks will be discussed in the subsequent section).

Discussion

From the analysis performed in this research, Leptospirosis, KFD, Anthrax, CCHF, NiV, and Rabies are chiefly identified as recurrent zoonosis outbreaks in India. Earlier researchers have highlighted that in recent

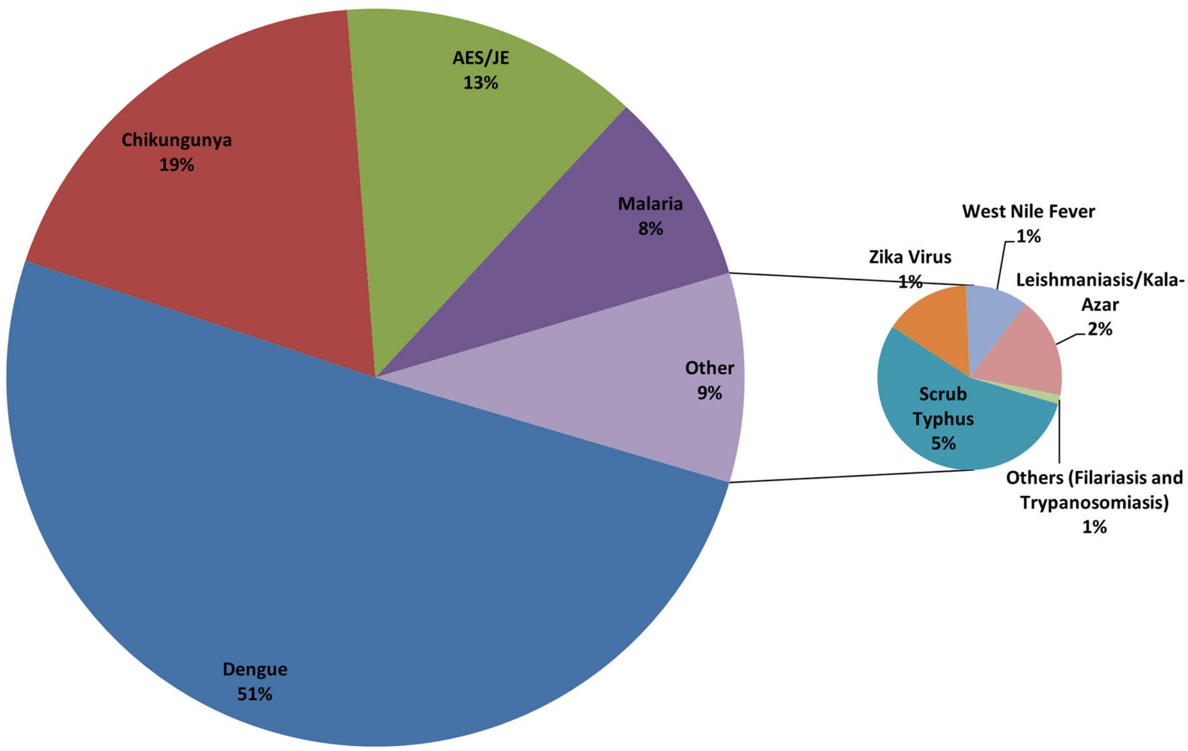

Figure 5. Distribution of vector-borne disease outbreaks in India (2017–2023). Notably, 50% of outbreaks are associated with Dengue, followed by Chikungunya and Acute Encephalitis Syndrome, including Japanese Encephalitis.—source: IDSP [25].

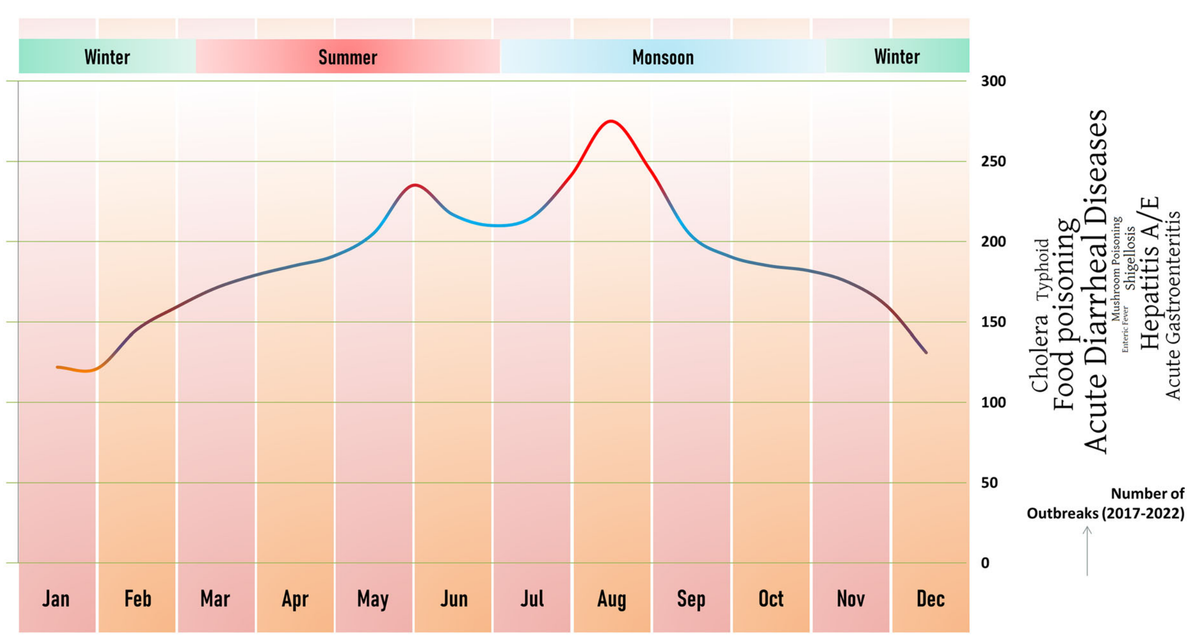

Figure 6. Seasonal variations of foodborne/waterborne outbreaks, including those of fecal-oral infections, occurred during 2017–2023 in India. Double peaks are observed during the peak summer and the other during the monsoon. The word-cloud at the right side of the figure indicates the predominance of associated diseases.—source: IDSP [25].

times, there has been an upsurge in the cases related to Leptospirosis in India [61–64], and our research too pinpointed that Leptospirosis disease outbreaks are prevailing in recent times. There needs to be a particular focus on controlling Leptospirosis through strengthening surveillance, campaigns, and interventions and advocating improved hygiene practices, especially during extreme weather events. Similarly, there is a need for focused attention to curb the KFD outbreaks as it is understood that it has become endemic in some areas of Karnataka. A retrospective analysis done by Chakraborty et al. [65] on KFD using reports from

1957 to 2017 commented that the processes by which KDF persists and spreads are yet to be given proper attention by including demographic, socioeconomic, and environmental factors. In the case of CCHF, the outbreaks currently prevail in certain districts of Gujarat. Mourya et al. [47] and Sahay et al. [66] have recommended the need for mitigation measures for CCHF in India by considering parameters like disease epidemiology, initiation of surveillance strategies based on the risk maps, and in-depth studies using Phylogenetic analysis using Next Generation Sequencing (NGS). Concerning NiV, due to its sporadic occurrence in the Kozhikode district of Kerala state, the WHO has already advocated reducing or preventing infection in people by raising awareness about the risk factors and preventive measures to protect themselves [67]. With reference to the Rabies outbreaks, though our research has prioritised certain districts only in Karnataka state, stringent efforts are needed to eliminate or minimise the cases throughout the country.

Dhiman et al. [68] commented that India is now recognised to be an endemic for vector-borne diseases and attributed climate change as a primary reason; their research predicted that the current rise in temperature could induce Dengue as a highly recurrent and can lead to intensified outbreaks in most parts of the country. Moreover, from our research, analytics on the outbreak data from 2017 to 2023 affirm Dengue as a leading vector-borne disease in India, as it shares 51% of the total vector-borne disease outbreaks (refer to Figure 5). Though the priority districts needing vector-borne disease control have been reported in this research, well-focused nationwide interventions are required to reduce the outbreaks associated with vector-borne. The National Centre for Vector Borne Disease Control (NCVBDC), under the DGHS, MH&FW, Govt. of India, has active programs for preventing and controlling critical vector-borne diseases in India. However, seeing the situation of vector-borne disease burden, continuous surveillance, increased vaccination, and research into novel therapeutics are imperative [69]. De Souza & Weaver [70] counter that there is a greater correlation between climate change and human activities on vector-borne diseases, mainly affecting people in tropical and subtropical areas – as such, climate and weather alterations influence the mechanisms of vector's reproduction and survival, geographic distribution and ability to transmit pathogens. In general, the mosquito population will increase immediately after events like floods, leading to increased outbreaks. A significant association between the outbreaks of dengue fever and monsoon rainfall was reported in India [71]. Thus, the prevalence of vector-borne disease outbreaks could be due to the magnitude of climate change.

Currently, in the Indian market, the vaccine for chickenpox is not affordable for people with lower income [72,73]; thus, an immediate intervention from the government is needed to include the vaccine for chickenpox as a part of Universal Immunization Program (UIP). Indian government's national immunization programs include vaccines free of cost for specific diseases, including measles [74]; however, a thorough review by health authorities about the prevailing measles situation is warranted to avoid any upsurge and further outbreaks. Similar to chickenpox, there is a need to include a vaccine for mumps in the UIP of India; studies done by Abu Bashar et al. [75] and Shah et al. [76], wherein the situation of outbreaks due to mumps have been assessed thoroughly, commented that mumps is still not viewed as a significant public health problem by the government of India. Hence, the Indian government must include interventions or national-level programs to eradicate mumps on an urgent basis.

Developed countries like the United States took significant setbacks in the past due to high morbidity and mortality caused by foodborne/waterborne outbreaks despite having stringent public health control measures and regulations [77]. Table 1 and Figure 2 show that foodborne/waterborne, including fecal-oral disease outbreaks, are significantly higher in India than other diseases. Outbreaks associated with acute diarrheal diseases/cholera/dysentery outbreaks are prominent in India, during which a patient usually has abnormally loose or fluid stools, which are passed more frequently than usual, and this causes depleting body fluids, resulting in profound dehydration. Most foodborne/waterborne diseases result in many episodes of infectious diarrhoea, which have a rapid onset and span of 4 to 14 days. Nearly 4400 outbreaks that have linkages with foodborne/waterborne disease have been reported by IDSP during 2017–2023 and include more than 2,00,000 infected persons. Estimates of the economic burden for this many infected include the direct cost of medication/treatment, non-medical costs like transportation, indirect costs regarding productivity loss, and other intangible costs, particularly those associated with the family members/dependents. A significant dent in the nation's economy will prevail if we ignore foodborne/waterborne infections [78,79]. Recently, Das et al. [80], in their research on foodborne diseases and outbreaks, termed that these diseases' impacts should be addressed with more carefulness. Given the frequent outbreaks leading to high morbidity and mortality rates, it is crucial to generate robust data through well-established surveillance networks and a strong food safety policy that can yield better public health. Importantly, interventions at the mass level are highly needed to create awareness of basic hygiene practices that can help reduce foodborne/waterborne diseases – the rationale for this is that food/water-related activities within the domestic environments are essential factors in determining the survival and multiplication of pathogens.

Disease outbreaks immediately after extreme weather or flood-related natural disasters are highly related. In general, the reproduction of causative agents and their survival rates are strongly linked to temperature and rainfall fluctuations. For example, the second peak during the monsoon season, shown in Figure 6, can be attributed to rainfalls. Although monsoon rains in India usually occur regularly, recent reports mention an increase in the frequency and magnitude of extreme rain events [81]. The contamination of drinking water during the rainfall seasons may contribute to increased food-borne/waterborne infectious diseases.

Research done by Unnithan et al. [82] and Dwivedi et al. [83] suggested an urgent need for education and training reforms concerning disease outbreaks in India. To counter the effects of disease outbreaks and crises, such as the rapid spread of emerging viruses, the effectiveness of public health measures becomes paramount, and thus, there is a need for strategies encompassing a range of interventions, from early detection and surveillance, healthcare infrastructure enhancement, and public communication [83,84]. Notably, the respective state-level government agencies should consider improved strategies for sharing up-to-date data about regional disease outbreaks, enabling the development of forecasting models that can predict the disease spread and help counter the impacts of disease outbreaks.

Though this study considered disease outbreaks between 2017–2023 (three years before and after 2020) to derive a spin-off study on the effect of the COVID-19 pandemic on the pattern of disease outbreaks, there is no significant pattern shift in outbreaks has been observed before and after the COVID-19 pandemic. Incidentally, research with a similar objective was carried out by contemporary researchers [28], who also observed no deviated pattern of disease outbreaks in India before and after the COVID-19 pandemic.

Currently, disease outbreaks occurring in the urban conglomerates are not a part of the ISDP weekly outbreaks bulletin. Making this information available is highly recommended, especially in developing countries like India, which can enable demarking containment zones and rapid response to the infected areas. The controllability of disease outbreaks relies on effective disease surveillance programs and response systems adopted by health authorities, which depend upon the availability of disease outbreak data to public health practitioners. The latest technologies, such as data science and machine learning, can be adopted while analyzing disease outbreak data to yield sophisticated results.

Conclusions

Knowledge of the prevailing landscape of a region's disease outbreaks is essential for preparing and addressing effective outbreak management. In this research, we have considered data from the weekly disease outbreak records published by IDSP for seven years (2017–2023), performed datafication, and analyzed the results. The research reported the predominant disease outbreaks and the districts of frequent outbreaks in India.

Our research reported that Leptospirosis, Rabies, CCHF, Anthrax, and KFD are high-frequency zoonosis outbreaks. The geographical extent to which these zoonosis outbreaks are prevalent is mapped and reported in this research. The research confirms that in recent times, there has been an upsurge in the cases of Leptospirosis, and most of its occurrences follow extreme weather events.

Based on the records obtained from the weekly disease outbreak records, vector-borne diseases associated with mosquitoes are endemic in India. Chiefly, Dengue, followed by Chikungunya, is now recognised as a highly recurrent leading to intensified outbreaks in most parts of the country. Our research has reported the priority districts for controlling vector-borne disease outbreaks but advises a need for focused nationwide interventions to reduce mosquito-based outbreaks.

Our research pinpointed Chickenpox, Measles, and Mumps as more prominent infections that spread from person to person in the Indian sub-continent. Making availability of vaccines for these highlighted infectious diseases through UIP is suggested as an immediate remedy to reduce the outbreaks associated with these diseases.

Due to the prevalence of high-density foodborne/waterborne infections, including those of the fecal-oral route, there is an urgent need for nationwide intervention to curb their associated outbreaks. Mass campaigns are needed to create awareness of basic hygiene practices to help reduce foodborne/waterborne diseases. Our research has performed datafication entirely on the available records from the IDSP program, which is a limitation as researchers believe that IDSP may underreport the outbreak events.

Acknowledgments

The authors gratefully acknowledge the IDSP officials for providing access to the weekly outbreak bulletin data. The authors sincerely thank the Director, National Remote Sensing Centre, Hyderabad, India, and the Executive Director, AIIMS, Jodhpur, India, for permitting this research activity. The authors are grateful to the staff members of the Regional Remote Sensing Centre - West, NRSC/ISRO, for their valuable support during this work. Heartfelt thanks to Dr. Madhu Raikwar, Central Bureau of Intelligence, Ministry of Health and Family Welfare, for having timely consultation about this research.

Disclosure statement

The authors declare no competing interests.

Author contributions

Conception and design of the research: DG, PB, MVR, SKS.
Data collection: DG, TAB, SR, NS.
Data analysis and interpretation: DG, SR, GK, PB, MVR.
Drafting the article: DG, PB, MVR.
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Data availability

Weekly outbreaks bulletins that are used in this research are available at https://idsp.mohfw.gov.in/ under the section titled 'Weekly Outbreaks.' The data that support the findings of this study are available from the corresponding author, DG, upon reasonable request.

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