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Review Article

Communicable diseases outbreaks after natural disasters: A systematic scoping review for incidence, risk factors and recommendations

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ABSTRACT

Background: Natural hazards can play a considerable role in the emergence and spread of infectious diseases (ID). There are various risk factors associated with disease outbreaks following disasters.
Objective: This study aimed to conduct a comprehensive systematic analysis of communicable disease epidemic and their associated risk factors following disasters worldwide.
Method: This is a systematic review adhering to the PRISMA Scoping Review criteria, encompassing various types of descriptive and analytical research, such as cross-sectional, case-control, cohort, and ecological studies. Published articles to the end of March 2022 were searched on the Web of Science, PubMed, and Scopus. The primary objective of this review was to examine the incidence and/or prevalence of ID following natural disasters.
Results: After screening 12,151 titles, 72 articles were included in the final analysis. Increased ID incidence rates and outbreaks after floods, earthquakes, tsunamis, tropical storms, heavy rainfall, hurricanes and tornadoes, extreme heat waves, and drought have been reported. Most commonly, outbreaks of diarrhea were reported after floods, followed by leptospirosis and malaria. After earthquakes, an increased incidence of upper and lower respiratory infections was recorded. Outbreaks of gastrointestinal infections and cutaneous leishmaniasis were noted after earthquakes. Tetanus, measles, and malaria epidemics occurred post-tsunami, while cholera and dengue fever were predominant after cyclonic events and monsoons. Socio-economic status, poor water supply, low sanitation & hygiene, poor food security, sex, age, occupation, and co-existing disease are important risk factors of epidemics after disasters.
Conclusion: This review outlines the important ID and major risk factors in the population exposed to natural disasters, providing valuable insights for policymakers and disaster risk managers.

1. Introduction

According to the classification provided by the Emergency Events Database (EM-DAT), natural hazards can be classified into various categories, including geophysical (earthquakes), hydrological (floods), meteorological (extreme temperatures), climatological (droughts), biological (epidemics) and extraterrestrial (i.e. comet collisions) [1,2]. However, it is important to note that all types, despite the variety of their characteristics, have the potential to cause casualties, injuries to people and damage to properties, and disrupt the normal routines of the affected communities [3,4]. During the past three decades, the number and intensity of natural hazards have reached unprecedented levels, whereas annually about 500 disasters happen worldwide [5]. In addition to the aforementioned consequences, natural hazards have the potential of leading to widespread infectious epidemics depending on the type of disaster and the modes of disease transmission [6]. Hence, the outbreak of contagious diseases is regarded as one of the possible adverse consequences after disasters. According to the Centers for

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Disease Control and Prevention (CDC), an epidemic is characterized as an unforeseen escalation in the incidence of cases within a particular geographical region in a specific timeframe [7].

There are several risk factors associated with disease outbreaks following disasters: overcrowding, food insecurity, lack of clean water, poor sanitation, alteration in vectors' distribution, housing and shelter issues, limited access to healthcare services, population displacement, disruptions in basic infrastructure and transportation networks [8,9]. Infections caused by contaminated water and food, respiratory infections, vector-borne diseases, and wound infections are among the most prevalent communicable diseases based on the type of disaster and the existing infrastructures in the affected area. These pathogens have the capacity to induce an outbreak and result in high mortality rate in some cases like diarrheal and respiratory diseases [10–12].

Climate change is happening faster than ever, affecting both society and environment. This leads to more frequent and severe natural disasters. [13,14]. The integration and rational classification of the most contingent epidemics, their spatial distribution, and the identification of factors that contribute to their occurrence, as well as the rapid progression of disease outbreaks following each disaster, are crucial considerations in disaster policy making and risk management. Therefore, this study aimed to conduct a comprehensive systematic analysis of communicable disease epidemics and the associated risk factors in the aftermath of disasters, worldwide.

2. Method

2.1. Eligibility criteria

The present study is a systematic scoping review that adheres to the criteria of the PRISMA Scoping Review [15] which encompasses various types of descriptive and analytical research, including cross-sectional, case-control, cohort, and ecological studies. The primary objective or component of these studies was to examine the incidence and/or prevalence of infectious/ contagious epidemics following natural disasters. Systematic review and meta-analysis, experimental (trial), time series, and single case studies, lectures, congress and conference reports, non-English papers were excluded. The articles without full text were also removed because the team could not reach and review their findings and methodology that considered as a limitation.

2.2. Search strategy

Published articles from 1928 to the end of March 2022 in the reference databases: Web of Science, PubMed, and Scopus were considered as the main sources of data collection. Syntaxes in line with the research topic and keywords in Medical Subject headings (Mesh) were searched in title, abstract, and text; both individually and in the form of using AND/OR operators. To optimize the search process within the databases, a thorough reassessment of the reference list was conducted on the finally selected papers. The keywords searched in databases were: *Droughts; Wildfires; Natural Disasters; Floods; Heat wave; Cold wave; Extreme temperature; Tornadoes; Lava flow; Cyclonic Storms; Tsunamis; Earthquakes; rock fall; Landslides; Pyroclastic flow; Lahar; Ash fall; Volcanic Eruptions; Diarrhea; Plague; Scrub Typhus; dysentery; bacillary; Measles; Typhoid Fever; Leptospirosis; Hepatitis; Rift Valley Fever; West Nile virus; Dengue; Malaria; Cholera; Arboviruses; Vector-Borne Diseases; Disease Outbreaks; Epidemics; Communicable Diseases*.

To ensure thorough synonym inclusion in our search strategy, we first identified key terms from the research objectives. We then consulted various thesauri and field-specific databases for related terms, and engaged with subject experts for their insights. Lastly, reviewing some literatures helped us identify additional terms used in the field.

2.3. Data extraction

All the ultimate selected articles were transferred to End-Note. Three researchers (A.B., N·N, and MH.M) independently reviewed all the titles and abstracts after eliminating duplicate entries. The irrelevant studies that could not meet the inclusion criteria were excluded. The full text of the remaining items in the list was provided and studied.

Any paper with inconsistencies in the methodology or findings and not in line with the study's objectives was removed. Then, the researchers individually obtained the pertinent details from the articles (title, first author, and publication year). They also collected information on the study's location, duration, design, sample size, baseline variables (mean age and gender diversity), the specific types of natural disasters and infectious diseases, mortality and infection rates (incidence, assessment, casualties), association indicators (relative risk and odds ratio), and the key findings. During each screening process, in case of a disagreement regarding the inclusion/exclusion, the title or full text was referred to another researcher (M.S or SH.A) for the final decision. The diseases were mentioned by their specific names and in the form of frequency and relative risk indicators [relative risk (RR), odds ratio (OR)], with a confidence interval of 95%. Fig. 1 illustrates the process of selecting the ultimate 72 articles.

2.4. Ethical considerations

This study did not involve human participants, human participant research ethics, or related secondary analyses; therefore, ethics approval and consent to participate were not required.

3. Results

3.1. Searching results

In the initial search of the mentioned keywords yielded 12,151 titles in ISI, PubMed, and Scopus databases. After removing duplicates, 10,679 articles were included in the first screening from which 9941 titles and abstracts did not meet the inclusion criteria. Then, in the final analysis, from 339 evaluated full texts, 267 papers were excluded due to their thematic irrelevance to the main subject of the present study. Finally, 72 articles were verified for this systematic review.

3.2. Characteristics of the included articles

The selected articles (published 1991–2022) that reported post-disaster epidemics from 1988 to 2018 were included. These articles evaluated the epidemics incidence after floods in 31 papers [16–46], following an earthquake in 21 papers [47–67], in four papers after a tsunami [68–71], in six papers after tropical storms and heavy rainfall [72–77], following hurricanes and tornadoes in five papers [78–82], in one article following an extreme heat wave [83], and in four articles after drought [84–87]. China published most of the articles 13, followed by India 7, Pakistan 6, the Philippines 5, Bangladesh and Iran with 4 each, Nepal and Japan with 3 each, Brazil, Ecuador, Turkey, Indonesia, Haiti, and the United States with 2 each, and Laos, Guyana, Australia, Sri Lanka, Uganda, Mozambique, Sudan, Malaysia, Ghana, Nigeria, Ethiopia, Central Africa, Vietnam, Italy, and Tuvalu with 1 each (Fig. 2). A total of 1,831,959 cases of communicable disease after disasters were reported in this study (Fig. 3).

3.3. Hydrological disasters (*Table 1*)

3.3.1. Floods

Diarrhea as the most common epidemic after the flood was mentioned in 14 articles [16,19,23,26,29–31,34,37,39,40,42,44,45] (Fig. 4) followed by leptospirosis and malaria. According to the results, a higher prevalence of diarrheal diseases was reported in men

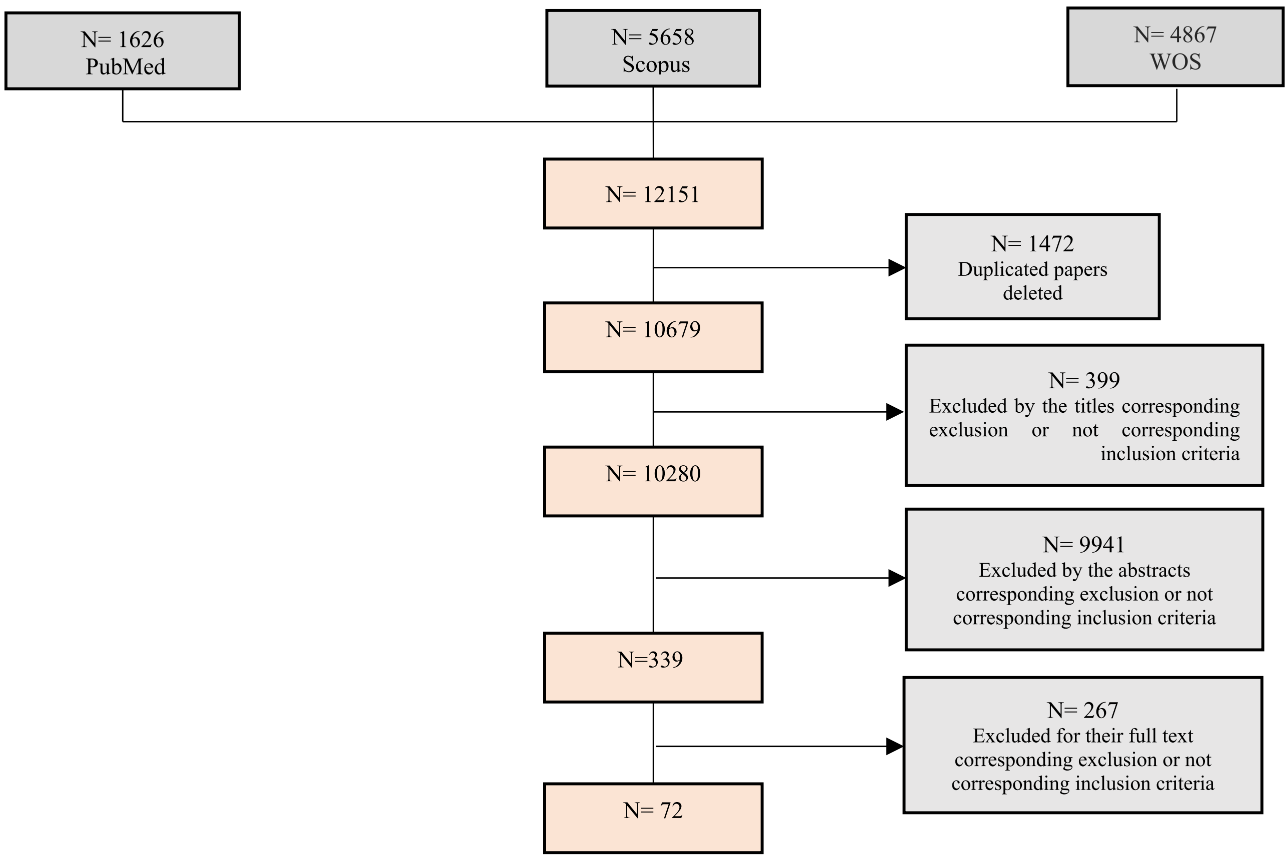

Fig. 1. Flow diagram of the systematic literature search.

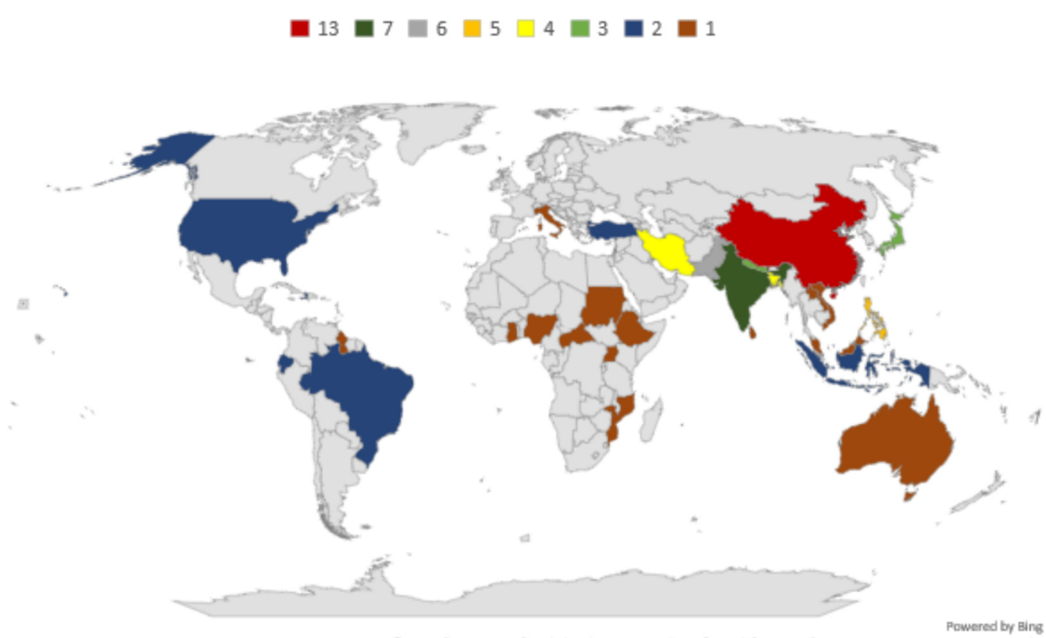

Fig. 2. Distribution of published articles by country of origin.

[16,19,24,29–31,39,40,45], except for one study that the incidence of cholera was 10% higher in women [42]. The highest frequency of diarrheal and food-borne diseases was related to dysentery [24,30,31,34,37,39,44,45] and cholera [34,39,42]. Also, a higher ratio of patients suffering from dysentery, acute and bacterial diarrhea was reported (OR: 1.17–6.74, 95% CI: (1.03–1.33)-(1.95–23.34)) compared to the healthy people with a confidence interval of 95% [24,26,44,45,88].

Improper water reservoir (OR: 3.68, 95% CI:2.16–6.27), low economic status (OR: 2.73, 95% CI:1.54–4.82) [23], aged younger than 7 years (OR: 2.0, 95% CI:1.12–3.54), and being old (OR: 1.87, CI: (1.06–3.30)) caused more diarrheal infection in the affected people

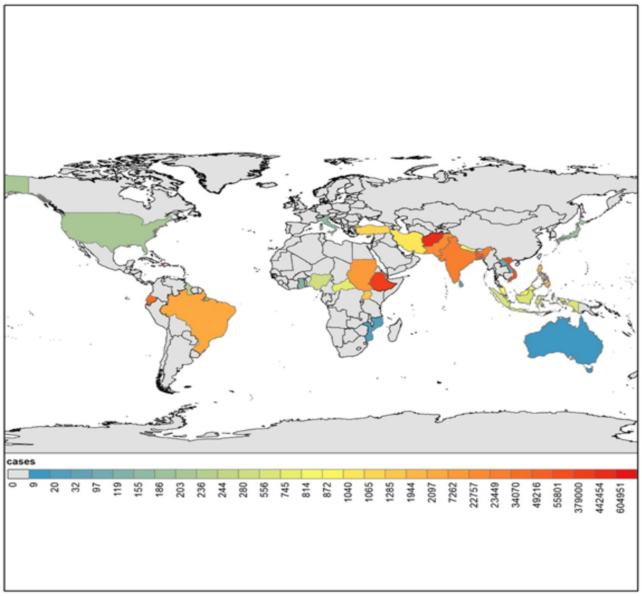

Fig. 3. Cases distribution of communicable disease after disasters by country of origin.

[45].

In one study, the relative risk of dysentery and typhoid fever was 1.29 (95% CI:1.15–1.46), and 1.21 (95% 95% CI:1.17–1.26), respectively. This relative risk in 0–4-year-old children was 1.37 (95% CI:1.24–1.52) times more compared to the other ages, in men was 1.08 (95% CI:1.01–1.14) times more, and in farmers was 0.89 (95% CI:0.82–0.97) higher than the other people who did not face floods [30].

Eight studies reported the outbreak of leptospirosis [18,20,22,28,34,36,38,41]. One of the most common causes of leptospirosis is exposure to floods, swallowing contaminated water, and direct contact with water in the presence of wounds in the body [22,28,41] as well as contact with animals or their wastes [22,34]. The incidence of disease was reported higher in women only in one article [20] whereas it was reported to be highly prevalent (OR: 1.92, 95% CI:1.24–2.98) in men [28]. Also, in most of the studies, the mean age of the affected population was above 30 [18,20,28,38,41] except for one in which the average between 15 and 29 years old was noted [36]. Leptospirosis was reported to a greater extent in people who worked in farming and rice cultivation [12,35]. In a study, 60% of patients were housewives or unemployed [36].

The outbreak of malaria was investigated in seven articles [17,21,23,25,26,34,35]. The highest rate of patients were under 15 years old and mostly contaminated with P.Vivax species [17]. The possibility of infection in the affected group was more (OR:3.67, 95% CI:1.77–7.61) tham unaffected people [26].

Except for the aforementioned three common epidemics, some other outbreaks were also reported: a) respiratory tract infection [19,29,40]; b) Typhoid fever in general was 1.46 times higher (95% CI: 1.10–1.92) in the afflicted population [30,33]. It was significantly more prevalent in men (OR: 1.61, 95% CI: 1.18–2.22), 0–4-year-old children (OR: 2.39, 95% CI: 1.02–5.60), individuals aged between 15 and 64 years old (OR: 1.57, 95% CI: 1.17–2.11), and farmers (OR: 1.57, 95% CI: 1.12–2.20) [33]; c) skin infection [29,40]; d) Japanese encephalitis cases [26,46] that significantly increased from the day 23rd(OR: 2.00, 95% CI:1.14–3.52) after facing the floods [46]; e) higher infection risk of hepatitis type A [26,34] (OR:6.11, 95% CI:1.04–35.84) [26], and Hepatitis E [34,43]; f) eye infections [40] like hemorrhagic conjunctivitis (OR: 2.00, 95% CI:1.14–3.52) [26]; g) ear infection [40]; and h) Rift Valley fever [27].

Among all the mortality rates (500 deaths in 10 articles) of infectious epidemics after the floods [20,22,29,35,36,38,40,42,46], Cholera with 276 deceased cases was regarded as the main lethal cause among diarrheal diseases [42].

3.4. Geophysical disasters (Table 2)

3.4.1. Earthquake

The most frequent epidemics reported after earthquakes consisted of respiratory, digestive, and diarrheal diseases, cutaneous Leishmaniasis, Malaria, Zika, and Scabies, urinary, parasitic, and ear infections, Hepatitis A, E, and C, coccidioidomycosis, skin infections, Jaundice Wounds, and fungal infections.

The incidence of upper and lower respiratory infections explained in ten articles [48–50,53–55,58,59,61,63], among which pneumonia was reported in three [49,53,59] and influenza type A in one [54]. Coccidioidomycosis spread was mentioned in an article from America that showed the attack rate of $30/10^5$ and the risk of infection in the affected people if older than 40 years was (OR: 2.80, 95% CI: 2.10–3.70). The risk was even more than the healthy unaffected group (OR: 3.00, 95% CI: 1.6–5.4) where they had longer contact with the dust after the disaster [61].

Gastrointestinal infections and diarrhea were also investigated in 9 articles [48,50,51,53,55,58–60,63]; where gastroenteritis [53,55,58,59], and acute diarrhea [48,50,63] salmonellosis [60] and cholera [51] were the most common epidemics.

Cutaneous leishmaniasis was another infection that was reported in four articles from Iran [47,52,64,65]. The average incidence had increased 4.4 times in 5 year interval after Bam earthquake compared to the same period before the disaster. The highest incidence rate (88%) was seen in 6-year-old children [64]. Also, the incidence of the infection increased from $58/10^5$ cases in the year before the Fars earthquake to $864/10^5$ cases in the year after, that about 70% of infected patients were 10-year-old children and younger [52].

Hepatitis A and E outbreaks in Turkey [56,62] and hepatitis C in Pakistan [57] were reported. One study suggested that the prevalence of hepatitis A and E in individuals younger than 17 years was related to socioeconomic conditions, crowded living environments, and family education levels that would increase in elderly patients [56].

Two vector-transmitted diseases were also reported; malaria in Haiti [66] and Zika in Ecuador [67]. Post-earthquake rising number of Zika cases in affected areas and pregnant women was (OR: 8.0, CI: (4.4–14.60)) and (OR: 30.0, 95% CI: 3.30–60.50), respectively [67]. Scabies was considered in two studies [59,63]. After the earthquake in Pakistan, the disease was observed in 31.2% of 12,016 hospital admissions [63].

Other post-earthquake contagious diseases were urinary [59,63], parasitic [63], skin [48,59], tetanus [49], jaundice, fungal [59], and conjunctivitis [59,63] infections.

The highest rate of infection and mortality was linked to the outbreak of cholera after the earthquake in Haiti (7436 deaths) of which 580 deaths were children younger than 5 years old [51].

3.4.2. Tsunami

Tetanus, measles, and malaria epidemics after tsunami were studied in four articles [68–71]. In India, 85 measles cases were reported in children younger than 8 years old in the affected areas [69,71]. After tsunami in Indonesia, 106 tetanus cases were identified resulting to 20 deaths, of which 40% aged ≥50 [68]. The number of confirmed malaria cases in the Nicobar Islands has increased from 1093 in 3 years before to 2562 3 years after the tsunami. Also mentioned was a substantial increase in Plasmodium falciparum species from 23% to 53% [70].

3.5. Meteorological disasters (Table 3)

3.5.1. Cyclone and heavy monsoon rains

Diarrhea, cholera, and dengue fever have been identified as the

Table 1
Summary results of included studies (Hydrological disaster and communicable disease epidemic).

1st Author/ Pub. Year	Location/ Year	Study Design	Type of Disaster	Cases	Death Rate	Main Result
Siddique et al., 1991 [40]	Bangladesh/1988	Survey	Flood	46,740	84	Diarrhea: 34.7%; Respiratory infection:17.4%; Intestinal worm: 10.1%; Skin infection: 5.8%; Eye and ear infection: 4%. Male: 56.2%; Patients <5 years: 27.5%
Sur et al., 2000 [42]	India/1998	Survey	Flood	16,590	276	Cholera (*V. cholerae* O1); Male:45%; Patients <5 years:28% Attributable Risk (AR): 1.1%; Case Fatality Rate (CFR): 1.7%; Highest death rate among <5 years (in 12 h: 45%, in 24 h: 55%, in 3 days: 5%)
Kunii et al., 2002 [29]	Bangladesh/1998	Survey	Flood	517	2	Respiratory infection: 46.8%; Diarrhea: 44.3%; Skin infections: 41.0%. Economic status: (OR) = 2.73 (95% CI: 1.54–4.82, $p < 0.001$) Water storage: OR = 3.68 (95% CI: 2.16–6.27, $p < 0.001$)
Schwartz et al., 2006 [39]	Bangladesh/ 1988,1998,2004	Survey	Flood	20,395 (2229 patients)	6	Diarrhea (Cholera, shigellosis, *salmonellosis, rotavirus)* V.cholerae from dry season to flood peak: 1988: 25% from 15% ($P \leq 0.01$), 1998: 42% from 20% ($P \leq 0.001$); 2004 first epidemic: 23% from 11% ($P \leq 0.001$); second epidemic: 41% from 32% ($P = 0.03$).
Kawaguchi et al., 2008 [28]	Laos/2006	Cross sectional survey	Flood	97		Leptospirosis, prevalence among 406 subjects: OR = 23.9 (95% CI: 19.70–28.0, $P < 0.001$). 15 serogroups tested: 12 detected Independent risk factors: male: OR = 1.92 (95% CI: 1.24–2.98); Median (age): 35 years
Ahmed et al., 2011 [19]	Pakistan/2010	Cross sectional study	Flood	7814		Acute Diarrhea: 30%; Skin and Soft tissue infection: 33%; Conjunctivitis: 7%; Nose and Throat Infection: 5%; Respiratory Tract Infection: 21%; Suspected Malaria: 4%. Males: 60%; Age (16 to 45 years): 48%.
Dechet et al., 2012 [22]	Guyana/2005	Survey	Flood	236	34	236 patients with suspected leptospirosis: Of the 236 patients, 105 (44%) tested: 2 confirmed, 53 probable, 50 suspected. Median age: 32 years; male: 43% 201 patients interviewed:direct contact with flood waters (89%)
Amilasan et al., 2012 [20]	Philippines/2009	Retrospective	Flood	471	51	Leptospirosis: Causes of death = pulmonary hemorrhage: 35%; ARDS/SRF: 24%; Acute Renal Failure: 20%; multiple organ failure/DIC:16%.
Afzal and Sultan, 2013 [17]	Pakistan/2010–11	Cross Sectional	Flood	2406		Malaria (in children aged ≤15 years) *P. vivax*:1562(65%); P. falciparum: 759 (31%); co-infection in 85, 27 cases of P; falciparum malaria: cerebral malaria. The most affected age group (5–9 years.): 41%.
Ding et al., 2013 [24]	China/2007	A time-stratified case-crossover analysis	Flood	197		**Infectious diarrhea: 64.7% bloody; other type: 29.3%** Male: 63.96%; aged (< 14 years): 59.90%. Incidence rates (in Fuyang): $2.048/10^5$ and Bozhou: $4.609/10^5$; The highest incidence rates (in children <4 years): $5.257/10^5$ in Fuyang and $38.541/10^5$ in Bozhou. The strongest effect on lag days (lag 2 days in Fuyang): OR = 3.77 (95% CI: 1.65–8.59); lag 5 days in Bozhou: OR = 5.859 (95% CI: 1.44–26.17). infectious diarrhea after adjusting for other meteorological factors: OR = 3.17 (95% CI: 1.12–8.95) in Fuyang: OR = 6.75 (95% CI: 1.95–23.34) in Bozhou.
Smith et al., 2013 [41]	Australia/2010–11	Surveillance	Flood	9		Leptospirosis: Median age: 37 years; Male:100%; 2/3 cases: employed within the agricultural sector; Resident on farms.
Ding et al., 2014 [23]	China/2007	Mix-Method study	Flood	3683		Malaria: increased risk with flooding alone adjusted hazard ratio (AHR) = 1.467 (95% CI = 1.257, 1.713), waterlogging alone AHR = 1.879 (95% CI = 1.696, 2.121), flooding and waterlogging AHR = 2.926 (95% CI = 2.576, 3.325). Male:58.2%; Age:(<14 years): 22.7%; age (15–59 years):55.4%.
Memon et al., 2014 [35]	Pakistan/2011	Prospective observational study	Flood	74	14	Malaria: 74 (8.38%) diagnosed from 883 patients with symptoms Overall mortality (18.9%). High mortality rate in pregnant women and in patients with complications: pneumonia ($P = 0.04$); renal failure ($P = 0.04$); Unconsciousness ($P = 0.001$); Septicemia ($P = 0.001$).
Ni et al., 2014 [37]	China/2004–09	Prospective	Flood	NA		Dysentery: significantly different between non-flooded and flooded months ($p < 0.05$); in the whole region: Relative Risk (RR) =1.66 (95% CI: 1.52–1.82).
Agampodi et al., 2014 [18]	Srilanka/2011	Cross-sectional	Flood	32		Leptospirosis: Age: 40 ± 12; gender: Male: 61(63.5%) engaged in paddy farming activities: 27 (84.4%).
Boyce et al., 2016 [21]	Uganda/2013	Quasi-experimental design	Flood	1285		Malaria: approximately 30% increased risk of positive test results in villages bordering an affected river vs. farther villages
Zhang et al., 2016 [45]	China/2007	Symmetric bidirectional case-crossover study	Flood	902		Bacillary dysentery: Median age: 7 years. increased risk: OR = 1.84 (95% CI: 1.22–2.78) at 2-day lag;

(*continued on next page*)

Table 1 (*continued*)

1st Author/ Pub. Year	Location/ Year	Study Design	Type of Disaster	Cases	Death Rate	Main Result
						(<7 years: ORs >1 from lag 1 to lag 3); (>7 years: ORs >1 at lag 1 and lag 3)
Gao et al., 2016 [89]	China/2007	A spatial and temporal analysis	Flood	8689		Malaria: 5904 cases, OR = 3.67 (95% CI: 1.77–7.61), Lag days: OR = 4.62 (95% CI: 2.83–6.41); Diarrhea: 2681cases, OR = 2.16 (95% CI: 1.24–3.78), Lag days: OR = 1.70 (95% CI: 1.29–2.10); Hepatitis A: 104 cases, OR = 6.11 (95% CI: 1.04–35.84) Huai River flood (2007), Lag days: OR = 3.75 (95% CI: 1.78–5.72).
Liu et al., 2016 [31]	China/2012	Survey	Flood	184		Bacillary dysentery: increased risk of infection: OR = 3.27 (95% CI: 1.299–8.228) in Jishou; OR = 2.21 (95% CI: 1.05–4.65) in Huaihua
Zhang et al., 2016 [46]	China / 2007–2012	A time-stratified case-crossover study	Flood	370	26	Japanese Encephalitis (JE): Median age: 4.2 years; Male/Female: 1.3/1 Increased number of JE cases from lag 23–24, the strongest effect at lag 23: OR = 2.00 (95% CI: 1.14–3.52).
Gudo et al., 2016 [27]	Southern Mozambique/2013	Cross sectional	Flood	20		Rift valley fever Virus:10% case; Age: 21–36 years; Male:56.7%
Xu et al., 2017 [44]	China/2004–10	Prospective study	Flood	18,976		Bacillary dysentery: Two weeks' lagged effect of flood impact: RR = 1.17 (95% CI: 1.03–1.33). Weekly numbers of bacillary dysentery cases: 7–211
Elsanousi et al., 2018 [25]	Sudan/2013	Observational retrospective study	Flood	7262		Malaria cases and Incidence rate: [(2013:7262 and 8.24), (2012: 5549 and 6.48)]/10^5; (2011/5069 and 6.09). Incidence of malaria increased in both age groups (<5 years and > 5 years) in the 12-week period of the flood year ($P < 0.0001$)
Mohd Radi et al., 2018 [36]	Malaysia/2014	Observational ecological study	Flood	872	5	Leptospirosis: 12% occurred during and 59% post flood; Age group (15–29 years.): about 1/3 of all; male, Malaysians and/or Malay race group: 60%; Unemployed/homemaker occupation category:60%
Liu et al., 2018 [33]	China/2005–12	Survey	Flood	1682		Typhoid fever: Male/female: 1.44/1; Aged (15–64 years): 69%; Increased risk (at lag 1 week): RR = 1.46 (95% CI: 1.10–1.92).
Abu and Codjoe, 2018 [16]	Ghana/2012	Survey	Flood	119		Mean Perceived Risk of Diarrhea in Household with at least one case: 22.94 ± 23.05; Male: 13.28 (20.01%); Female: 8.62 (13.63%); Age: (28.96 ± 12.53); gender: Male: 227 (56.6%); Female:174 (43.4%).
Louw et al., 2019 [34]	Nigeria/2012	Mix method	Flood	280		Diarrheal outbreak (cholera and dysentery): 47.1%; Typhoid fever: 21.7%; Malaria fever: 17.5%; Skin rashes: 4.3%; Hepatitis A: 3.6%; Hepatitis E: 1.1%; Leptospirosis: 1.8%; Schistosomiasis: 0.4%; Other water-related infections: 2.5%. Interview: Devastating effects on people's well-being and derailing the community's economic development.
Tricou et al., 2020 [43]	Central African Republic/2008–12	Retrospective Study	Flood	745		Hepatitis E: Male:56%; Median age: 23 years. Seasonal pattern with correlation between HEV incidence and rainfall in Bangui (~70% positive test in rainy season)
Liao et al., 2020 [30]	China/2016	A quasi-experimental study	Flood	359,580		Diarrhea: Dysentery, Typhoid, Other infection All-cause daily diarrhea during-flood period, 18 June - 31 Aug 2016: 7.81/10^6; post-flood period, 1 Sep; 2016–31 Aug. 2017: 6.10/10^6; During-flood: increased risk of dysentery; Post-flood: increased risk of all diarrheal infections.
Rajendran et al., 2021 [38]	India/2018	Survey	Flood	133	2	Leptospirosis: Males: 79 (59.4%); Females: 54 (40.6%). Max. cases (41–50 years): 24.81%.
Liu et al., 2020 [32]	China/2005–12	Survey	Flood	407		Acute Hemorrhagic Conjunctivitis (AHC): Attack rate: 198.461/105; Increased morbidity risk of AHC: RR = 2.136 (95% CI: 2.109–2.163). The attributable Years lived with disability (YLD) / 1000 of AHC: 0.0434 (95% CI: 0.0425–0.0442); The highest YLD/ 1000 of AHC: ages 5 and 14 years; Females and youngsters; more vulnerable to the flood-related disease

predominant communicable diseases after cyclonic events and monsoons.

Five articles investigated diarrheal disease [72–74,76,77], where being a child (<5 yrs) [74], and rainfall >50 mm [73] were among the risk factors. The infection risk was higher in the affected people after 25 (OR: 3.25, 95% CI: 1.45–7.27)) and 50 (OR: 3.05, 95% CI: 2.20–4.23)) milimeters of monsoon rains [73]. The contingent diarrheal infection has augmented (OR: 1.35, CI: (1.14–1.60)) in the presence of heavy monsoon rains, as well [74]. The unavailability of hygienic clean water resulted to the Cholera epidemic in India [74,76]. Bacillary dysentery epidemics are also significantly more possible (OR: 2.30, 95% CI: 1.81–2.93)) in people who encountered tropical storms and heavy rains [73].

Dengue fever was reported in China with the highest pathogenicity rate among 18 to 59-year-old patients. The risk of infection spread has risen (OR: 1.62, CI: (1.45–1.80)) when exposed to tropical storms [75].

3.5.2. Hurricanes and storms

Post-storm/hurricane epidemics encompassed gastroenteritis, infectious diarrhea, respiratory infection, Dengue fever, urinary tract infection, soil-borne parasitic and helminth infections, leptospirosis, and sexually transmitted diseases.

In the Philippines, the outbreak of gastroenteritis and diarrhea was described after Typhoon Haiyan [79,82] whereas 72% of patients used unsterilized water sources. The risk of acute diarrhea and gastroenteritis in the storm-affected areas was higher with no sanitized water sources

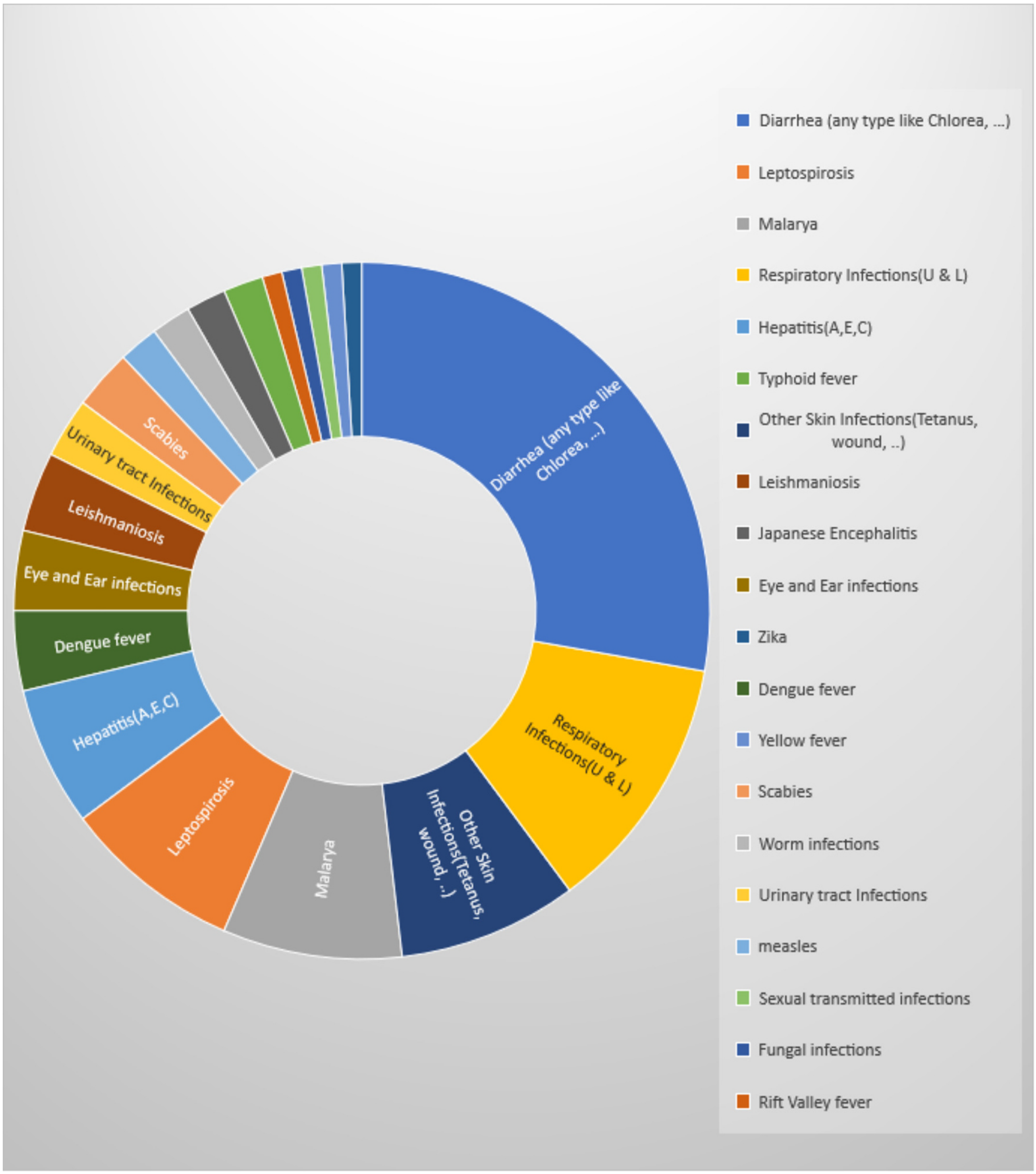

Fig. 4. Distribution of types of communicable diseases after disasters.

(OR: 18.2, 95% CI: 4.8–68.8), inappropriate drinking water (OR: 2.4, 95% CI: 0.25–22.6), and toilets (OR: 0.6, 95% CI: 0.14–2.67)). Meanwhile, after the hurricane, several gastroenteritis cases rose up to 7 times in adults and 4.5 times in children compared to the same period before that disaster [82].

Pneumonia has intensified 3.6 times in adults and 2.7 times in children and Dengue fever boosted 7.6 and 20 times in adults and children, respectively [79]. The most prevalent soil-borne parasitic and helminth infections were caused by Ascaris, trichorrhiasis, and Ringworm which have been observed in 431 cases in the aftermath of storms [78].

Leptospirosis was another post-hurricane contagious epidemic in which 14 deaths and 259 patients who had skin wounds with direct exposure to contaminated water and/or animal excrement were registered [80]. In the United States after Hurricane Katrina in the New Orleans area, it was also observed that the rate of sexually transmitted infections specifically gonorrhea and chlamydia cases have risen from 2.3% up to 5.1% and from 12.4% up to 14.1%, respectively [81].

3.5.3. Heat waves

A study from Vietnam showed that the risk of Dengue fever has been dramatically increased up to 85% among people suffering from heat wave stroke. The risk of infection after exposure to the temperatures 22.6, 24.1, and 1.33 degrees would rise (OR: 1.85, 95% CI: 1.44–2.39), (OR: 1.40, 95% CI: 1.22–1.61), and (OR: 1.83, 95% CI: 1.09–3.08), respectively [83].

3.6. Climatological disasters (Table 4)

3.6.1. Drought

The epidemics of diarrhea [84], Scabies [85], Dengue fever [86], and yellow fever [87] have been observed after the drought. The attack rate

Table 2
Summary results of included studies (Geological disasters and communicable disease epidemic).

1st author/Pub. year	Location/year	Study design	Type of disaster	cases	NO. Death	Main Result
Schneider et al., 1997 [61]	USA/1994	Case control study.	Earthquake	203	3	Coccidioidomycosis: RR (age $\geq$ 40 years) = 2.8 (95% CI: 2.1–3.7, $P < 0.001$) dust cloud exposure: OR = 3.0 (95% CI: 1.6–5.4, $P < 0.001$) Total Attack Rate (AR): 30/ 10^5; AR: Race (Asian, Pacific): 43/ 10^5; Race (White, non-Hispanic): 37/10^5; Age: ($\geq$40 years): 52/10^5; Sex: (male) 34/10^5.
Sencan et al., 2004 [62]	Turkey/1999	Cross sectional study	Earthquake	476		Hepatitis A (HAV) and hepatitis E (HEV) in children (2–15 years.) HAV prevalence (living in Düzce and Golyaka temporary houses): 44.4 and 68.8% respectively, OR = 0.37 (95% CI: 0.22–0.61, $p = 0.0005$). HEV prevalence: 4.7 and 17.2% respectively, OR = 0.24 (95% CI: 0.11–0.51, $p = 0.0007$).
Kaya et al., 2008 [56]	Turkey/2003	A prospective study	Earthquake	589		Hepatitis A and E in children (6 months to 17 years.) The sero-prevalence rates of hepatitis A: 63.8%; hepatitis E: 0.3%; both increased with age, no significant difference in genders ($P > 0.05$). Hepatitis A: crowded living environment and education level of the family ($P < 0.01$), hepatitis E: not related to these factors ($P > 0.05$)
Khan et al., 2008 [57]	Pakistan 2005–06	Cross sectional study	Earthquake	24		Hepatitis C (HCV) 1 round HCV antibody positive by ELISA)245 subjects): 8 (3.26%); Male: 155 (63.3%) from positive cases. 2 round (11 months after earthquake): 16 (5.51%); HCV antibody positive from 290 subjects. Positive Males: 136 (46.9%).
Bai and Liu, 2009 [50]	Pakistan/2005	Cross sectional study	Earthquake	423		Upper respiratory infection: 329 (14%); Diarrhea: 94 (4%); Wound infection among the injured patients; Adults:(Male: 72%; Female: 64%); children: 78%.
Shah et al., 2010 [63]	Pakistan/2005	Retrospective study	Earthquake	12,016		Viral upper respiratory tract infection (URTI): 42%; Scabies: 31.2%; Urinary tract infection (UTI): 10%; Bacterial URTI:4.2%; Diarrhea: 5.5%; Otitis media: 3.45%; Conjunctivitis:1.95%; Parasitic infestation:1.7%; Male: 43.8%.
Fakoorziba et al., 2011 [52]	Iran/2003	Case-control	Earthquake	836		Cutaneous Leishmaniosis:58 cases/10^5–864 /10^5 (2002–2004) aged $\leq$10 years: 70%.
Sharifi et al., 2011 [64]	Iran/1999–2008	Survey Comparative Evaluation of Pre- / Post-Earthquake	Earthquake			post-earthquake mean annual incidence of anthroponotic cutaneous leishmaniasis (ACL): 7.6/1000; pre-earthquake mean annual incidence of ACL: 1.9/1000; Most infected: Age (<20 years); Males: 56.3%.
Sharifi et al., 2011 [65]	Iran/2008	Survey	Earthquake	204		Cutaneous Leishmaniosis: 3884 examined Highest rate ($P = 0.0001$): Age ($\leq$10 yrs.); overall prevalence rate: 5.3%; Female: 6.3%; Male: 4.3%; face lesions: 47%; one lesion: 77.9%.
Townes et al., 2012 [66]	Haiti/2010	Survey	Earthquake	317		Malaria: 1629 suspected patients, (96%) rapid diagnostic tests (RDTs): positive result: 317 (20.3%). Male: 55.2%; Age: 8.2% (< 5 years); 27.4% (5–14 years); 61.2% (>15 years); positive and pregnant: 3.5%.
Barzilay et al., 2013 [51]	Haiti/2010–12	Survey	Earthquake	604,634	7436	Cholera (*V. cholerae* O1, serotype Ogawa, biotype El Tor) Hospitalization: 329,697; cumulative attack rate: 5.1% in first and 6.1% in second year; Age (<5 years): 78,938 (13.1%); hospital admission: 34,394 (10.4%); deaths: 580 (7.8%); Cumulative fatality rates in 2-year: 0.6% - 4.6%.
Aoyagi et al., 2013 [49]	Japan/2011	Retrospective	Earthquake		81	Pneumonia: (81.5%); skin and subcutaneous tissue infection (i.e. tetanus): 18.5%; Double number of hospitalizations after the first week comparing to the same period in 2010; Highly prevalent in elderly patients (median age: 78 years)
Aflatoonian et al., 2013 [47]	Iran/2010	Survey	Earthquake	67		Cutaneous Leishmaniosis: interviewed and physically examined for active lesions or scars: 5544; infected: 1.2% of the inhabitants, active: 0.5%, scars: 0.7%; female: 1.7%, males: 0.8% ($P = 0.003$); age groups: equally affected; face lesions: 37%.
Kawano et al., 2014 [55]	Japan/ 2011	Retrospective Study	Earthquake and tsunami	418		Acute Respiratory Infection (ARI) (in 37 shelters) Cumulative incidence rate of ARI: Into the crowded shelters (mean space<5.5 m2/per person): 5·4/10000 person-days, interquartile range (IQR) 0–24·6, P = 0·04 Into the non-crowded shelters (mean space>5.5 m2/per person): 3·5/10000 person-days, IQR 0–8·7 Daily incidence rate of ARI: crowded vs. non-crowded shelters: 19·1/10000 person-days (95% CI 5·9–32·4, $P < 0·01$)

(continued on next page)

Table 2 (*continued*)

1st author/Pub. year	Location/year	Study design	Type of disaster	cases	NO. Death	Main Result
Kamigaki et al., 2014 [54]	Japan/2011	Survey	Earthquake	105		Influenza A (H3N2) in 5 evacuation centers (ECs) Mean AR: 5.3% (range, 0.8%–11.1%); Male-to-female ratio of confirmed cases: 0.88; Majority of cases: aged 15–64 years
Malla et al., 2016 [59]	Nepal/2015	Prospective observational study	Earthquake	122		Acute gastroenteritis: 23.7%; URTI: 20.6%, Impetigo: 16.5%, UTI: 8.2%, Conjunctivitis: 6.5%, Pneumonia: 6.5%, Scabies: 6.5%, Tinea fungal infection: 9%, Chicken pox: 2.5%. Most common infectious disease pattern: 82% in children
Nigro et al., 2016 [60]	Italy/2013	Survey	Earthquake	155		*Salmonellosis:* Male: 47%; Age (1–15 years.); Children hospitalized: 28.4%
Lachish et al., 2016 [58]	Nepal/2015	Survey	Earthquake	106		Gastroenteritis:73 (53%); Acute Respiratory Infection (ARI): 22 (16%); Fever: 11 (8%); Age: 35 ± 9.1; Male:109 (79%).
Vasquez et al., 2017 [67]	Ecuador/2016	Survey	Earthquake	143		Zika: Male: 44%; Females: 67.8%. Cumulative incidence: $11.1/10^5$ in affected vs. control area ($P < 0.01$): $1.79/10^5$; Living in the affected area + ZIKA: OR = 8.0 (95% CI: 4.4–14.6, $P < 0.01$); Pregnant women + ZIKV: OR = 30.0 (95% CI: 3.3–60.5, P < 0.01) in the affected area
Giri et al., 2018 [53]	Nepal/2015		Earthquake	586	3	Pneumonia: 26.6%; Gastroenteritis: 2.6%; Respiratory Infections: 33.8% and other infections: 37%
Almira and Hidajah, 2020 [48]	Indonesia/2018	Cross sectional study	Earthquake	450	89	ARI: 23%; Diarrhea: 15%; Skin infection: 6%; 1 Measles, 4 Varicella suspects; Female patients: 52%
Aceh Epidemiology Group, 2006 [68]	Indonesia/ 2004	Survey	Tsunami	106	20	Tetanus Male: 63.2%; median age:40 years; age < 5 years: 6.6% CFR: 18.9%; ≥50 years: 40.0%
Mohan et al., 2006 [71]	India/2004–05	Cross sectional study	Tsunami	71		Measles attack rate:1.3 /1000; Onset date (14 days after tsunami): 42% of affected villages; Median age of patients: 54 months
Manimunda et al., 2011 [70]	Nicobar group of Islands/Dec. 2004	Retrospective Analysis	Tsunami	2562		Malaria (2005–2008): large increase in the incidence of malaria/ Plasmodium falciparum: 23% to 53%; Endemic area: high transmission setting, high-risk area for malaria. The significantly higher (P < 0.01) monthly incidence of malaria during January, February and March 2008 among migrant laborers
Balasubramaniam and Roy, 2012 [69]	India/2005	Survey	Tsunami	14		Measles = 51.85% Age: 3–8 years

of 17.5% for diarrheal disease was seen in very young children (< 2 years). Children with diarrhea were significantly more (OR: 12.8, 95% CI: 9.3–17.7)) exposed to the drought crisis. The risk of infection in adults with low personal hygiene was also (OR: 3.0, 95% CI: 1.5–6.1)) more than a healthy population with no exposure [84]. The risk of Dengue fever was also higher (OR: 1.60, 95% CI: 1.33–1.92) in affected urban areas [86].

The results about yellow fever suggested that men (OR: 2.58, 95% CI: 2.28–2.92), at working age (OR: 2.03, 95% CI: 1.76–2.35)), living in urban areas (OR: 5.02, 95% CI: 3.76–6.69) would be more infected if faced with drought [87]. The Scabies incidence rate also went up to 60% in adolescents (<18 years) and 51.6% in women [85].

Furthermore, Table 5 delineates the most significant risk factors influencing disease outbreaks following disasters, as determined by the results and categorized by disease type.

4. Discussion

The present study is a systematic scoping review of published articles to investigate the influencing factors and recommendations of the communicable diseases outbreak after natural disasters. The majority of the reviewed papers have studied the epidemics following floods and earthquakes. The Incidence of gastrointestinal, all kinds of diarrhea, and respiratory infections were the most prevalent post-disaster outbreaks. This study identified the significant risk factors as follows: the type and nature of the hazard, the geographical location, the socioeconomic status of the affected area, the age and gender of the afflicted population, the state of disaster management, and the preparedness level.

Earthquakes are the most common geophysical disasters; therefore, their subsequent epidemics and the number of related publications were considerable. About half of the studies on communicable diseases after earthquakes cited the outbreak of respiratory diseases caused by biological factors, including upper respiratory system infection, pneumonia, influenza type A, and Coccidiomycosis-induced lung infection (the native disease of South America and Mexico). Inadequate physical distance between people, overcrowding, living in camps, insufficient/ inappropriate ventilation, and deficiencies in health care were the triggering factors that have predominantly precipitated respiratory infections following a seismic event. Based on these findings, the affected people, residents of emergency accommodation camps, and those living in communal settings are recommended to keep adequate physical space as part of preventive measures against the spread of communicable diseases in post-disaster situations.

Air ventilation and air circulation are essential for preventing the increase in pathogen load and reducing the risk of disease transmission. Additionally, distributing face masks among individuals is highly recommended if necessary.

Active screening and the establishment of a syndromic surveillance are essential to identify the patients, control or restrict contacting to the individuals who have suspected symptoms, and provide immediate treatment for the infected ones. Educating people about personal hygiene practices, frequent handwashing, and reporting symptoms in themselves or their close contacts is emphasized. Additionally, health authorities must plan and provide the necessary hygiene supplies for individuals.

Another finding of this study is the outbreak of diarrheal diseases after the earthquake.When such disasters occur, the predisposing factors to diarrhea infection could be the disruption in access to healthy clean water, inadequate cleaning of dishes, improper hand washing after toilet and before eating, decreased adherence to preventive and sanitary behavioral principles, having contaminated foods, insufficient cooking of food, and so on.

Table 3
Summary results of included studies (Metrological disasters and communicable disease epidemic).

First author/ publication year	Location/year	Study design	Type of disaster	cases	NO. Death	Main Result
Bhunia and Ghosh, 2011 [72]	India/2009	Case control study	Cyclone & rain fall	1076	14	Cholera (AR / 10^4): <5 years: 54%; ≥45 years: 53%. Male: 54.8%, AR: 47%.
Deng et al., 2015 [73]	China/ 2005–11	Unidirectional case-crossover	Cyclone & typhoon			Bacillary dysentery and other infectious diarrhea in seven tropical cyclones. Typhoons: the greatest impacts on bacillary dysentery on lag 6 days: OR = 2.30 (95% CI: 1.81–2.93) and lag 5 days: OR = 3.56 (95% CI: 2.98–4.25). Tropical storms: highest impacts on lag 2 days: OR = 2.47 (95% CI: 1.41–4.33) and lag 6 days: OR = 2.46 (95% CI: 1.69–3.56). Tropical cyclone: a risk factor for both bacillary dysentery: daily precipitation reached 25 mm and 50 mm with the largest: OR = 3.25 (95% CI: 1.45–7.27) and OR = 3.05 (95% CI: 2.20–4.23).
Mukhopadhyay et al., 2019 [76]	India/2015	Survey	Heavy rainfall	3003		Diarrhea: 164 cases under the surveillance; All age groups;(<5 yrs.): ≈25%. The most commonly isolated organism: *V. cholerae* O1
Rafa et al., 2021 [77]	Bangladesh/ 2020	Survey	Cyclone		–	Diarrhea:42.5%; Skin infection: 42.5%; **Dysentery: 7.5%**; Eye irritation: 10%; Jaundice: 2.5%; Other diseases: 22.5%. No diseases after cyclone: 7.5%.
Li et al., 2021 [75]	China/ 2013–18	Case-crossover study	Tropical cyclones	47,784	–	Dengue fever: (20 tropical cyclones) Increased risk: RR = 1.62 (95% CI:1.45–1.80), lag 5 day. 18 and 59 yrs. old: 78.9%; No difference in effect estimates between genders.
Deshpande et al., 2020 [74]	Ecuador/ 2013–14	Survey	Heavy rainfall	33,927	–	Diarrhea: Male: 49.9%; Patients: <5 years old: 61.4%; Heavy rainfall events (HREs) with dry antecedent conditions: elevated incidence vs. Similar conditions without HREs: RR = 1.35 (95% CI:1.14–1.60);.
Ventura et al., 2015 [82]	Haiyan, Philippines	Case-control	Hurricane &typhoon	105		Acute gastroenteritis Male:51%; Median age: 2 years; The most affected age group: 1 to 5 years: 49%. Factors associated with acute gastroenteritis: Untreated drinking-water OR = 21.7 (95% CI:7.6–62.1); Toilet facility: OR = 6.4 (95% CI: 1.3–32.9); Water Source: OR = 5.0 (95% CI: 1.2–20.1).
Chang et al., 2016 [79]	Haiyan, Philippines	Surveillance	Hurricane &typhoon	672		Gastroenteritis: 44%; Respiratory infection (Pneumonia, Tuberculosis): 41.4%; Dengue Fever 6.4%; UTI 8.2%.
Belizario et al., 2021 [78]	Philippines	Cross-sectional Study	Hurricane &typhoon	437		soil-transmitted helminth infections (Ascaris lumbricoides, Trichuris trichiura, and the hookworms) Schistosomiasis: preschool-age children: 166; school-age children: 271
Nsuami et al., 2009 [81]	New orlean, USA	Screening	Hurricane &typhoon		–	Screened (346: 60.1% males; median age 17.0 years) before, (333: 54.1% males; median age 17.0 years) after hurricane. The prevalence of gonorrhea: 2.3% (8/346, 95% CI: 1.3% -4.6%) before; 5.1% (17/333, 95% CI: 3.1% - 8.2%) after Hurricane. Gonorrhea in female: OR = 2.6 (95% CI 1.0–6.3; $p = 0.04$), with chlamydia infection: OR = 9.2 (95% CI 3.9–21.7; $p < 0.001$).
Mendoza et al., 2013 [80]	Philippines/ 2009	Cross sectional	Typhoon	259	14	Leptospirosis:591 probable cases; Mean age: 38.9 years; males: 82%; Causes: Waded/Swam in flood waters, 253 (98.0%); Swallowed flood water: 58 (22.4%); Presence of wound: 95 (37.3%); Exposure to animal carcass: 39 (15.0%).
Cheng et al., 2020 [83]	Vietnam/ 2008–16	Survey	Heat waves	55,801	0	Average Dengue fever: 119 / week. large outbreak: 59.9%; medium: 22.9%; small: 12.7%, The largest effect estimates: small outbreaks: 24.1 °C, RR = 1.40 (95%CI: 1.22–1.61); medium outbreaks: 33.1 °C, RR = 1.83 (95% CI: 1.09–3.08); large outbreaks: 22.6 °C, RR = 1.85 (95%CI: 1.44–2.39).

The impact of the disaster on the increased incidence of cutaneous leishmaniasis in Iranwas reported [47,52,64,65] besides the environmental factors like the weather conditions, temperature, rainfall, precipitation, and humidity that have been explained to determine the severity of this skin infection [90]. Aflatoonian et al. explained that the improper environmental and health conditions, individual and behavioral changes, and entry of an unsafe population following the Bam earthquake activated the old foci and induced new emerging foci of this epidemic [91]. Rostamian et al. have also suggested the population displacement caused by natural disasters could expose people to mosquitoes (leishmaniasis vector) and increase the incidence of the infection. Therefore, it is essential to provide certain protocols to prevent and control the risk of infection after natural disasters in countries where the disease is endemic. These protocols should include practical instructions for using an appropriate mosquito net to prevent bites, constructing temporary safe shelters, educating the affected population, and treating the infected people [92].

Despite the rare prevalence, we found and analyzed the outbreak reports of measles, malaria, and tetanus after tsunamis which has not been investigated in any previous review studies so far. Diaz's study reported several infections (skin and systemic) in the tsunami survivors and affected people [93]. Mavroli et al. explained the severely injured survivors of earthquakes and tsunamis are exposed to a large number of pathogens in soil and water which makes the preventive and protective measures necessary [94]. Reduced physical distance, staying in camps, and disrupting the common health routines in the affected people are considered the risk factors that increase the incidence of the aforementioned infections, as well as contact with contaminated soil or being bitten by wild animals (in tetanus). Enhancing vaccination coverage, improving wound care treatment, and establishing a regular surveillance system, in addition to competent disaster management, and providing supportive care according to the national guidelines could prevent post-disaster Tetanus outbreaks, as Pascapurnama has also declared. Moreover, health education is required to inform the communities how to reduce the risk of tetanus [95].

It is indispensable that health policymakers and disaster risk

Table 4
Summary results of included studies (Climatological disasters and communicable disease epidemic).

First author/ publication year	Location/year	Study design	Type of disaster	cases	NO. Death	Main Result
Emont et al., 2017 [84]	Tuvalu, South Pacific Island, 2011	Epidemiological Investigation	Drought	244		Diarrhea: Male: 51%; AR: 3.93% (from 1.5% for >65 years to 17.5% for 0–2 years); Risk in children (0–2 yrs.): 12.8 (95% CI: 9.3–17.7) times more than (> 15 yrs.) individuals. Risk factors: Water tank level < 20% full, OR = 2.31 (95% CI:1.16–4.60); Decreased frequency of handwashing: OR = 3.00 (95% CI:1.48–6.08).
Enbiale and Ayalew, 2018 [85]	Ethiopia/2015	A cross-sectional house-to-house census	Drought	379,000		Scabies: screened 1,125,770 individuals; Male:48.4%; <18 years of age: 60% of confirmed cases; Of the 474 subjects: 6 (98.3%) confirmed cases by a dermatologist
Lowe et al., 2021 [86]	Brazil/2001–19	Spatiotemporal modelling study	Drought (and wet condition)	12,895,293	0	Dengue fever: increased risk 0–3 months after extremely wet conditions (maximum RR at 1 month lag): RR = 1.56 (95% CI: 1.41–1.73) and 3–5 months after drought conditions (maximum RR at 4 months lag): RR = 1·43 (95% CI:1.22–1.67)
Rosser et al., 2022 [87]	Brazil/2017–18	Survey	Drought	2097	0	Yellow fever (YFV): Confirmed cases: increased in men: OR = 2.58 (95% CI: 2.28–2.92); working age: OR = 2.03 (95% CI: 1.76–2.35); recent travel from an urban to a rural area: OR = 5.02 (95% CI: 3.76–6.69).

managers should be prepared enough and take the necessary measures to prevent respiratory, gastrointestinal, and vector-borne epidemics based on the existing standards and guidelines before geophysical disasters happen. These measures include implementing strategies to control carriers, ensuring the maintenance of appropriate physical distancing, conducting active screening of individuals with symptoms, isolating people having respiratory and gastrointestinal symptoms from healthy ones, prompt diagnosing and treating patients, delivering health education to affected populations, providing safe sanitary water and the supplementary items and necessities for hygiene and washing, equipping with nets and repellants for insects, improve the environment, and continuous monitoring of the health status of the affected community.

4.1. Hydrological disasters

Here, the reviewed articles on post-flood communicable diseases mainly showed the escalation in diarrheal epidemics: shigellosis, salmonellosis, and typhoid. These results are in line with the previous findings [95–100]. Disruption in the public access to healthy sources of drinking water, contaminated water ponds, mixed water with sewage, using polluted surface water, reduced preventive hygiene measures such as washing hands after toilet and before eating, biological contamination of food, and improper washing dishes were cited as the major causes of diarrheal diseases after floods. Children and the elderly are more vulnerable to the aforementioned infections. Therefore, it is necessary to take preventive measures which entail providing sanitary water and educating parents about adherence to health recommendations especially frequent hand washing after defecation and before any eating and/or drinking, etc. to diminish or impede the infection spread in these groups. Wolf et al., have also concluded that health interventions that cover water sanitation improvement programs, hand washing with soap, and other hygienic measures following the WASH program can reduce the risk of diarrheal diseases in low and middle-income countries [101].

Our study indicated a notable rise in Leptospirosis outbreak after floods which were in accordance with the results of previous review studies [96,98,100,102,103]. Humans become infected through direct contact with animal hosts (rodents, domestic pets, and cattle) or through an environment contaminated with animal urine. In floods, increased transmission is likely to be multifaceted, involving closer contact between animal hosts and humans, direct contamination of floodwaters, and impairment of water and sewage infrastructure [104]. Considering the mechanism of transmission, it is recommended that providing clean water in flood conditions and preventing contact with or drinking unclean water should be the priority for health service providers.

Malaria is the other post-flood prevalent communicable disease mainly caused by Plasmodium vivax and then Falciparum. This is consistent with what Suhr et al. and Agunwamba et al. found about the association of close physical distance to wetlands with an increase in Malaria [100,105]. According to Ding et al., climate variables in floods and inundation are important environmental drivers of transmission, because they can affect the growth and reproduction rate of mosquitoes, the activity time pattern of the population, and the life cycle of Plasmodium which leads to a higher burden of the disease. Therefore, public health measures are necessary to prevent and control the potential risk of malaria epidemic after these hydrological disasters [23]. The World Health Organization has provided the following recommendations to control malaria in flooded areas: spraying camps with appropriate insecticides, using mosquito nets impregnated with insecticides, covering water storage containers, removing water from garbage, Larvicide in areas with surface freshwater sources, proper garbage disposal and collection [106].

In general, disaster risk managers and health policymakers must prioritize the implementation of preventive measures against gastrointestinal epidemics, Leptospirosis, and Malaria before hydrological disasters occur. This is crucial because the disruption of water supply sources and the possibility of shuffling sewage, especially for drinking water in areas where people use natural water sources (wells, springs, rivers, etc.) and do not have access to piped water, will increase the possibility of diarrheal diseases and infections that are transmitted through orofecal route in the affected population. The strict implementation of WASH programs can be placed as the main priority in the prevention of gastrointestinal diseases, specifically in hydrological disasters. Considering the possibility of leptospirosis spread, the necessary preventive measures of WHO guidelines should be prioritized in makind health policies. Furthermore, it is recommended to identify the species that carry leptospirosis within the high-risk region before disasters. This measure proactively aims to enhance the preventive efforts for post-disaster outbreaks through improved understanding and strategic planning. The prohibitory recommendations of the WHO for malaria emphasize the implementation like drying the bogs, using larvicides, and appropriate window nets.

4.2. Meteorological disasters

The outbreaks of cholera, bacillary, and other diarrheal diseases have been reported after storms and heavy rain. Kraay et al. showed that heavy rains were associated with a rise in diarrheal cases. Inadequate sanitation infrastructure, unavailability of WASH program facilities, along with no access to healthy water, direct exposure to and use the contaminated water have been proposed as the most important risk

Table 5
The most important risk factors of epidemics of communicable diseases after disasters.

	Waterborne Diseases						Airborne diseases			Vector-borne disease							Rodent borne	Other infectious			
Major risk factor following natural disasters	Diarrhea	Cholera	Leptospirosis	Hepatitis	Typhoid	Gastroenteritis	ARI (Influenza, Pneumonia)	Measles	Coccidiomycosis	Malaria	Dengue Fever	Zika	Yellow Fever	Japanese encephalitis	Scabies	Rift Valley Fever	Leishmaniosis	Tetanus	Skin Infection	Urinary Infection	ENT
Socio-Economic Status	✓			✓																	
Poor Water Supply	✓	✓				✓															
Low Sanitation & hygiene	✓	✓				✓															
Poor food security		✓			✓																
Sex	✓	✓	✓		✓		✓			✓		✓	✓	✓			✓				✓
Water Recession										✓									✓		
Exposure to dust									✓												
Exposure to water			✓																✓		
Exposure To Animal			✓																		
Age	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓					✓	✓			
Place	✓			✓						✓	✓						✓				
Occupation	✓		✓		✓								✓								
Temperature	✓										✓										
Moisture	✓																				
Race									✓												
Low Education	✓			✓																	
Poor Sanitation	✓	✓																			
Vaccines Coverage							✓														
Injury			✓																		
Co-Exist Disease										✓											
Precipitation Rate	✓																				
Poor health services												✓									
Increase of lag days	✓						✓			✓	✓			✓							

factors [98]. Based on Saulnier et al., gastrointestinal infections increase after the storm [99]. A higher risk of Dengue fever has also been reported [75,107] Which was in line with what Viana et al. declared with strong relation to meteorological variables (rainfall and temperature) [108]. Velu et al. also explained the role of various factors such as the amount and pattern of rainfall in the outbreak of mosquito-borne diseases (Dengue fever transmitted by Aedes mosquito) in Zambi [109].

The outbreaks of gastroenteritis and diarrheal diseases, respiratory infections, yellow fever, urinary infections, parasitic disorders, and Dengue fever following hurricanes and typhoons have also been documented. The transportation of dust and dirt particles, as well as frequent and prolonged exposure to them, might be regarded as notable risk factors for the mentioned diseases. According to Saulnier et al., the transmission of infectious diseases is primarily associated with the indirect consequences of floods or storms. The reported epidemics have been attributed to water contamination, overcrowding in shelters, displacement of population, and poor sanitation. Hence, public health interventions should be directed towards preventing the spread of these infectious outcomes [99].

Considering the oral-fecal transmission of diarrheal diseases, necessary prohibitory measures should be taken such as controlling transmission routes, ensuring sanitary water and healthy food supply, preventing consumption or contact with unsanitary water, providing hygiene items and detergents like soap, educating to wash hands after using the toilet and before eating or drinking, and using fast and effective treatments such as oral rehydration therapy.

Health planners and policymakers should consider the existence of vector-borne diseases like Dengue fever, yellow fever, and chikungunya (Aedes mosquito) in the region before the meteorological disasters occur; therefore, the measures that control the mosquito population (spraying insecticides, improving the environment, etc.), as well as the important preventions to reduce the exposure and bites (using suitable nets and insect repellants and lotions), should carefully be attended.

4.3. Climatological disasters

This category includes extreme temperature changes (heat wave, cold wave, and extreme winter conditions), drought, and fire (forest, land). Only one study was found that reported the outbreak of Dengue cases following the heat wave [83]. Alteration in the mosquito population due to changes in temperature and humidity and the access to water sources for insects can be considered as noteworthy risk factors. Jia et al. reported that a heat wave event facilitates population growth in the initial stage, but tends to have an overall inhibitory effect which is affected by two main factors associated with the rise in the mosquito population: the time of an unusual heat wave onset and a relatively high temperature in a long period [110].

The outbreak of communicable diseases after drought (diarrheal diseases, dengue fever, yellow fever, and scabies) was described. Malik et al. found a relation between temperature, climate, and weather with the prevalence of diarrheal diseases, but not as the main cause. The observed relationship may depend on some other factors such as rainfall, human behavior, inaccessibility to water, human autoimmunity, and socio-economic and cultural factors [111].

Considering that yellow and dengue fever were transmitted by mosquitoes and the scabies spread through arthropods, the results were consistent with the Brown et al. study. They suggested that drought has a significant impact on all conditions affecting the growth of the insects carrying Dengue and Chikungunya viruses that are naturally very adaptable and can live and grow in various aquatic habitats created in response to the drought (water storage containers) [112]. Stanke et al. also reported that one of the outcome expectancies of drought is the increase in cases of vector-borne diseases (Malaria, Dengue fever, and West Nile virus) [113], as well. According to Vos et al. systematic review study, vector-borne disease is one of the potential health consequences during drought periods; some pieces of evidence show that drought conditions increase the proliferation and also the capabilities of vectors in the remaining water ponds [114] like Sugg et al. that also noted it as one of the risk factors for the infections that are transmitted through water, food, and vectors in such natural disasters [115].

5. Conclusion

The significant risk factors in the outbreak of communicable diseases after natural disasters that should be considered by policymakers and disaster risk managers were presented as follow: the destruction of vital and sensitive infrastructures such as sanitary water supply and collection and disposal of sewage and waste, disruption in supply and access to healthy food, using unsafe and unhealthy sources of water and food, reduced air quality due to dust and other pollutants, gatherings, and overcrowding in small places and shelters without proper ventilation facilities, shortage of physical distance between people, using shared dishes and equipment, disruption in providing health services and care, decreased level of compliance with health behaviors and preventive measures in the affected population. This could help prevent post-disaster contagious disease epidemics and the subsequent creation of secondary crises.

Based on the results of this research, it is recommended to accurately identify the region's health problems, environmental conditions and endemic diseases in preventive planning before disasters occur, and get prepared as much as possible to deal with their outbreaks during disasters.

CRediT authorship contribution statement

Mohammad Saatchi: Writing – review & editing, Supervision, Project administration, Methodology, Conceptualization. **Hamid Reza Khankeh:** Writing – review & editing, Supervision, Conceptualization. **Javad Shojafard:** Writing – original draft, Investigation. **Arvin Barzanji:** Writing – original draft, Investigation. **Maryam Ranjbar:** Writing – original draft, Investigation. **Narges Nazari:** Writing – original draft, Investigation. **Mohammad Azim Mahmodi:** Writing – original draft, Investigation. **Shokoufeh Ahmadi:** Writing – original draft, Investigation. **Mehrdad Farrokhi:** Writing – review & editing, Supervision, Conceptualization.

Declaration of competing interest

There is no conflict of interest and the authors declare that they have no financial or personal ties that may have biased the research presented in this paper.

Data availability

Review article.

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