TECHNICAL SERIES ON ADAPTING TO CLIMATE-SENSITIVE HEALTH IMPACTS

# DIARRHOEAL DISEASES

World Health Organization

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Technical series on adapting to climate sensitive health impacts: diarrhoeal diseases

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# Abbreviations

| | |
|---|---|
| **DALY** | disability-adjusted life-year |
| **DHS** | Demographic and Health Surveys |
| **ENSO** | El Niño Southern Oscillation |
| **ETEC** | enterotoxigenic *Escherichia coli* |
| **GIS** | geographical information system |
| **GLAAS** | Global Analysis and Assessment of Sanitation and Drinking-Water |
| **IPCC** | Intergovernmental Panel on Climate Change |
| **JMP** | Joint Monitoring Programme for Water Supply, Sanitation and Hygiene |
| **MICS** | Multiple Indicator Cluster Survey |
| **RCP** | representative concentration pathway |
| **SDGs** | Sustainable Development Goals |
| **UNFCCC** | United Nations Framework Convention on Climate Change |
| **UNICEF** | United Nations Children's Fund |
| **V&A** | vulnerability and adaptation |
| **WASH** | water, sanitation and hygiene |
| **WHO** | World Health Organization |

# 1 Series introduction

A vulnerability and adaptation (V&A) assessment is a vital first step in adapting to climate change. This technical guide on V&A assessment for diarrhoeal diseases and climate change is part of a series of World Health Organization (WHO) guidance aiming to inform the management of high-priority climate-sensitive health impacts to climate change. This document is intended for use in conjunction with the general WHO guidance on conducting health V&A assessments *(1)*.

This technical series was created with two purposes: to clarify the relationships and causal links that exist between climate change and high-priority health outcomes; and to offer specific direction and resources for assessing these associations and designing adaptation options for protecting health in a changing climate.

Each guide follows the same V&A assessment process and provides specific resources and information on the theme:

- Chapter 2 describes how to use this guide in conjunction with the main V&A assessment guidance and includes additional considerations for setting up a thematic assessment.
- Chapter 3 comprises a general introduction of the targeted topic, including definitions, the scope and scale of its global burden, and causal mechanisms.
- Chapter 4 explains how the specific health outcome is influenced by climate variability and climate change.
- Chapter 5 follows the main V&A assessment guidance and explains each step of conducting a V&A assessment for the health issue:
  - Step 1 provides guidance on getting started and planning the assessment.
  - Step 2 explains how to describe the current burden of the high-priority health outcome and related vulnerabilities to climate variability and recent climate change:
    - Step 2A provides guidance on different options and variables to identify, describe and prioritize the health outcome of interest.
    - Step 2B describes how to analyse the relationships between current and past weather and climate conditions and the health outcome of interest.
    - Step 2C explains how to describe risk distribution and identify trends in upstream determinants.
    - Step 2D provides suggestions on how to determine populations and regions vulnerable to the health impacts of climate variability and change.
    - Step 2E suggests relevant dimensions and metrics that can be used to understand current health and risk conditions and form the basis of a study that can be monitored over time.
  - Step 3 provides suggestions for assessing the capacity of health and health-relevant systems.
  - Step 4 explains ways to understand how changing climatic conditions may influence future health status for high-priority populations and regions.
  - Step 5 describes how to identify and prioritize policies, programmes and actions to address current and projected health risks.
  - Step 6 presents considerations for informing decisions and monitoring relevant changes in population health status, exposure to climate hazards, relevant risk factors, and the effectiveness of protective measures in place.

# 2 Conducting a thematic V&A study on diarrhoeal diseases

This guide presents a basis for understanding how diarrhoeal diseases are currently influenced by climate and weather and may be further exacerbated by climate change. It provides guidance on how to:

- identify populations and regions vulnerable to diarrhoeal diseases and the reasons for their vulnerability;
- establish relevant baselines that can be analysed and monitored;
- conduct analyses to project how diarrhoeal diseases may be impacted in the future due to climate change;
- identify appropriate responses to mitigate and monitor these risks over time.

The guide provides information specific to the analysis of diarrhoeal diseases and climate change and should be used in conjunction with the general WHO V&A guidance *(1)*.

You are likely using this guide because diarrhoeal diseases were identified as a thematic priority during the scoping and framing steps of a national V&A assessment or other climate impact assessment. Additional thematic teams or consultants may be conducting similar assessments on other high-priority issues as part of an overall V&A process. Appropriate coordination, particularly with undernutrition assessment teams, is advised because similar data and analyses may be used for multiple analyses within the study. Within this technical series, a thematic guide for conducting a V&A study on undernutrition has been published *(2)*.

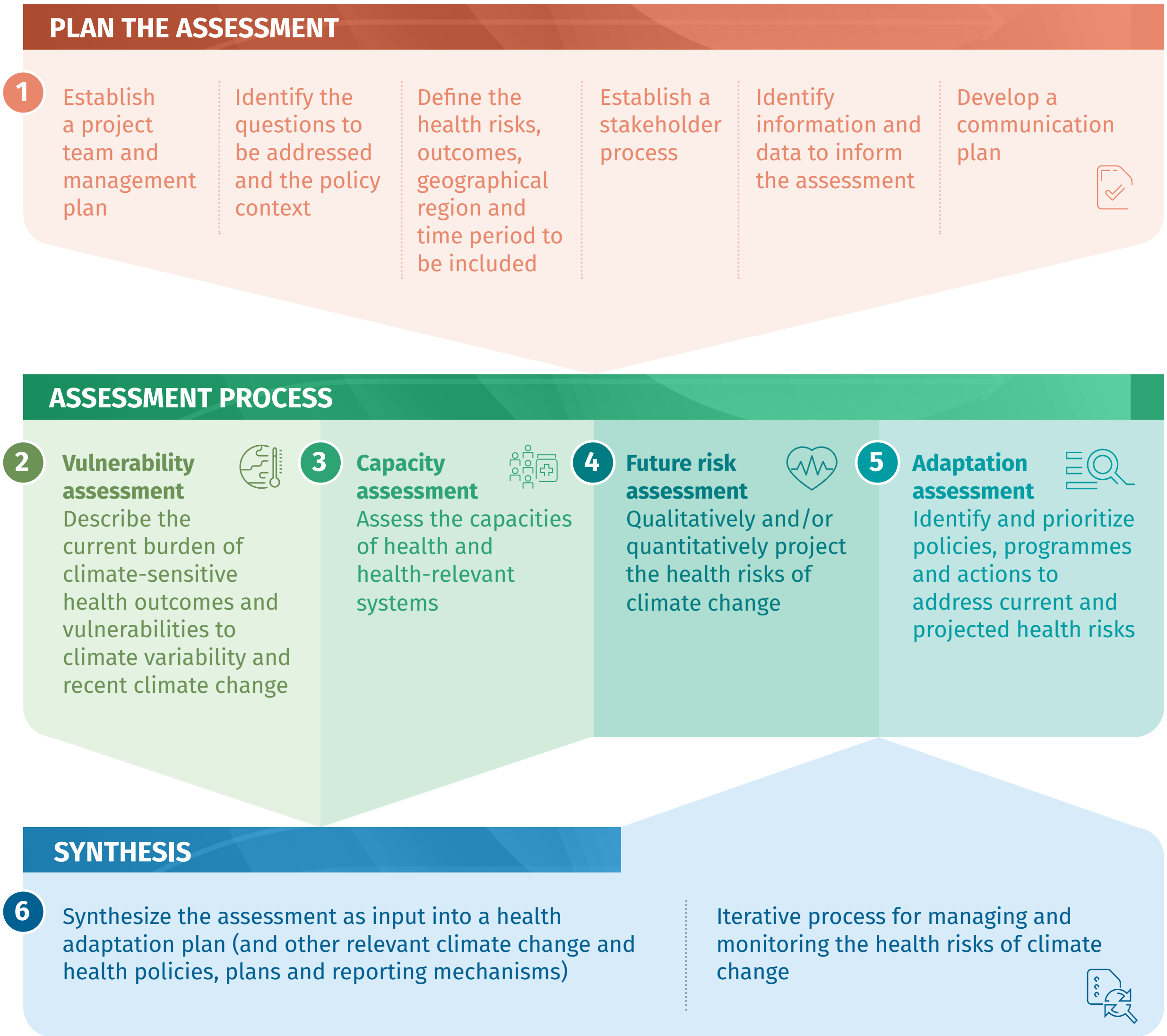
Although the ultimate effects of diarrhoeal diseases are on individuals' health, the underlying causes reflect household behaviours and result from conditions in other sectors, particularly water and sanitation. The complex nature of diarrhoeal diseases means that a multisectoral approach is essential to assess, predict, monitor and reduce the risks of diarrhoeal diseases. Assessment of climate and diarrhoeal diseases thus requires the input, data and experience of stakeholders, decision-makers and experts from various fields. Stakeholders involved in the assessment process as data providers, analysts or reviewers may include:

- government infectious diseases and water and sanitation programmes and working groups;
- local and international nongovernmental organizations and United Nations agencies with national water, hygiene and sanitation data and experience;
- hospitals and medical and health personnel;
- food safety experts;
- water, sanitation and diarrhoeal diseases experts;
- agriculture and livestock specialists;
- climate and national meteorological experts;
- local universities and research institutes.

There are no set rules or formats for carrying out a V&A assessment. Each study will be unique to the national situation, the mandate of the study, and the data and analytical resources available. The study should serve to bridge existing research and assessments of water and sanitation, water- and foodborne diseases, and climate impact studies.

The steps of a V&A assessment on climate change and health are shown in Figure 1.

**Figure 1.** Steps involved in conducting a V&A assessment




Use of secondary data is encouraged, and a thorough scoping of available resources, data and partners is recommended. Qualitative and quantitative data should be used in combination to create a complete understanding of vulnerability and future impacts of climate. Data gaps are to be expected, and limitations should be noted as areas of action for future research.

It is important to keep in mind that a V&A assessment is not a one-time study but a continuous process that serves as the backbone for climate adaptation decision-making.

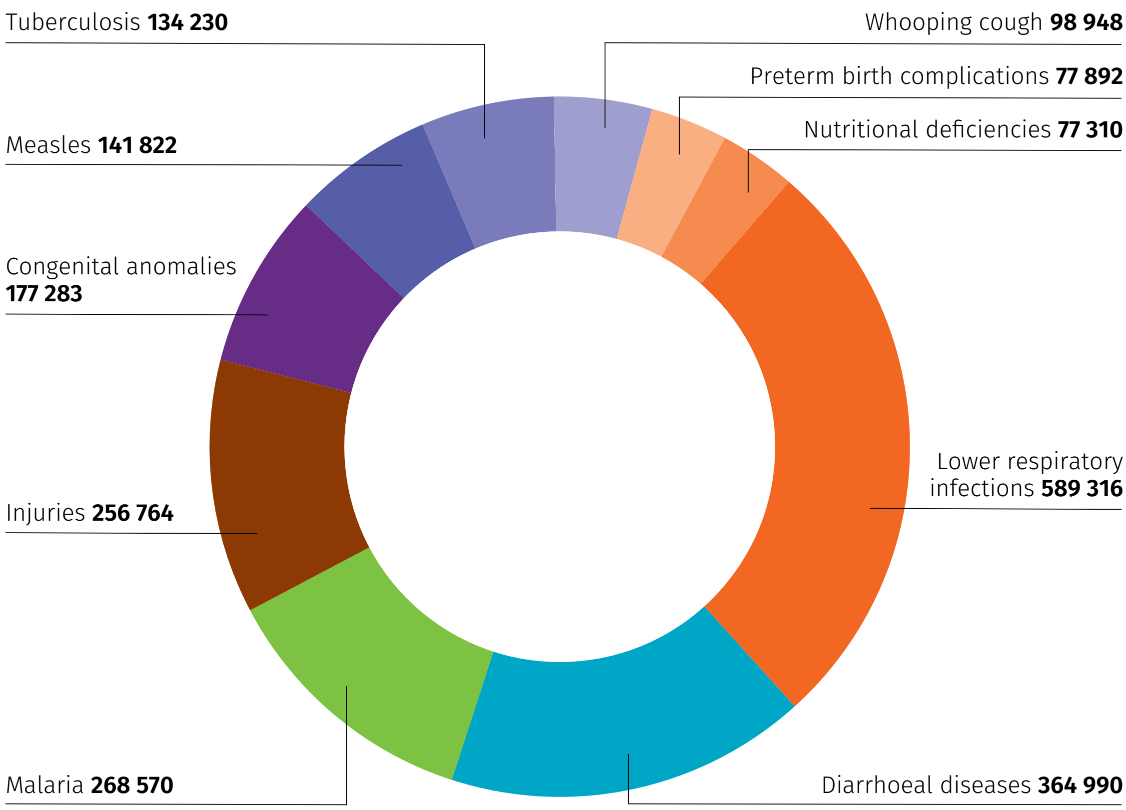
# 3 Overview of diarrhoeal diseases and scope

Diarrhoea is a symptom of an enteric (gastrointestinal) infection with bacteria, viruses, protozoa, parasites or toxins, mostly transmitted through excreta-related infections. Diarrhoea is defined as the passage of three or more loose or liquid stools per day, or more frequent passage than is normal for the individual. It is subclassified into acute watery diarrhoea (lasting several hours or days, including cholera); acute bloody diarrhoea (dysentery); and persistent diarrhoea (lasting 14 days or longer) *(3)*.

Severe diarrhoea may be life-threatening due to fluid loss, particularly in infants and young children, malnourished people, and people with impaired immunity. The occurrence of diarrhoea is closely associated with malnutrition.

Diarrhoeal diseases are preventable and treatable, but they were responsible for approximately 1.5 million deaths globally in 2019 *(4)*. In 2019, diarrhoea was the second-leading cause of post-neonatal death among children aged under 5 years (Figure 2) *(4)*. Approximately 1.7 billion cases of childhood diarrhoeal diseases are reported each year, mostly in South Asia and sub-Saharan Africa *(3, 5)*. For children who survive these illnesses, repeated episodes of severe diarrhoea in the early years of life deprive them of essential nutrition and can lead to malnutrition, stunted growth and impaired cognitive development *(6)*. Diarrhoeal diseases contribute to increased risk of death and ill health, diminished opportunities and reduced productivity over a lifetime for millions of people.

**Figure 2.** Ten leading causes of death in children aged 1 month to 5 years, global, 2019



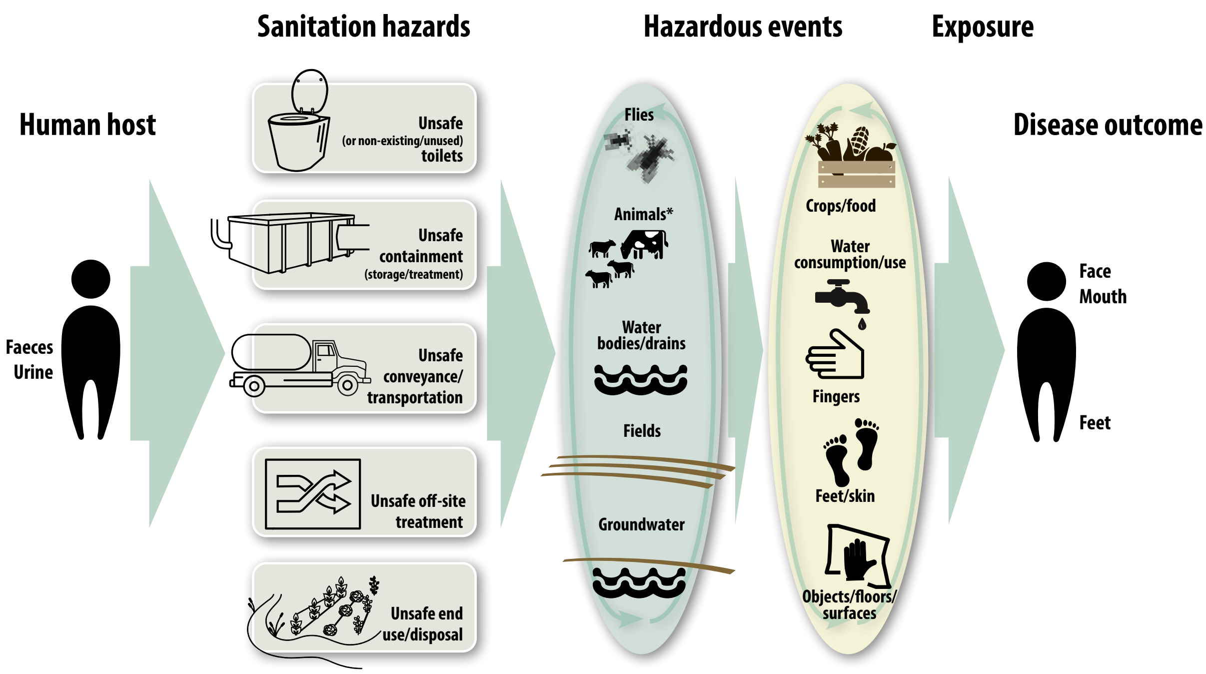

Source: Global health estimates: leading causes of death – cause-specific mortality, 2000–2019. Geneva: World Health Organization; 2019.

## Causes of diarrhoeal diseases

Diarrhoeal diseases are caused by the spread of infection through contaminated food and water or person-to-person contact. The spread of infection is more likely with inadequate sanitation and hygiene and where safe water for drinking, cooking and cleaning is unavailable. Children with underlying malnutrition are more vulnerable to diarrhoeal diseases, and in turn diarrhoeal diseases exacerbate malnutrition *(3)*.

Transmission pathways of excreta-related infections are illustrated in Figure 3. The figure shows the pathways from left to right, with excreta beginning the sanitation chain. It demonstrates the translation of sanitation hazards into hazardous events resulting in exposure and disease outcomes. The figure shows a range of potential transmission pathways, with vertical and horizontal interactions between the elements.

**Figure 3.** Transmission of excreta-related pathogens




Source: Guidelines on sanitation and health. Geneva: World Health Organization; 2018 (https://apps.who.int/iris/handle/10665/274939).

A study based on data from 2016 found that 60% of diarrhoea-related deaths in low- and middle-income countries are attributable to unsafe water, inadequate sanitation or insufficient hygiene *(7)*. Despite progress, the risk of disease due to inadequate water, sanitation and hygiene (WASH) remains high for many people. In 2020, an estimated 1.7 billion people worldwide still lacked basic sanitation services, 494 million people practised open defaecation, and 2 billion people lacked safely managed drinking water services *(8)*. Globally, almost 2 billion people rely on drinking water sources potentially contaminated with faeces *(9)*.

Diarrhoeal diseases are a concern in both developed and developing countries, but they are a serious concern in the developing world where a lack of safe drinking water, sanitation and hygiene and poor overall health and nutritional status drive transmission *(3)*.

Severe diarrhoea can be caused by viruses (e.g. rotavirus, norovirus), bacteria (e.g. *Escherichia coli, Shigella* spp., *Campylobacter* spp., *Salmonella* spp.), parasites (e.g. *Giardia lamblia, Entamoeba histolytica, Cryptosporidium* spp.) and marine toxins (e.g. ciguatera) (Table 1). In low-income countries, two pathogens (rotavirus, *E. coli*) cause the most moderate to severe cases of diarrhoea *(4)*. Four additional pathogens also contribute significantly to diarrhoea burden (*Shigella* spp., adenovirus 40/41, *Cryptosporidium* spp., *Campylobacter* spp.) *(10, 11)*. Other pathogens (e.g. *Vibrio cholerae, Aeromonas* spp.) are regionally important *(10)*.

Among these highly infectious pathogens, rotavirus is the most common cause of severe and fatal diarrhoea. It causes an estimated 37% of diarrhoea-related deaths in children aged under 5 years globally *(12)*.

*Shigella* spp. and enterotoxigenic *E. coli* (ETEC) are major causes of morbidity and mortality among older children, adolescents and adults *(13)*. In 2016, *Shigella* spp. was the second leading cause of diarrhoea-related mortality among all ages *(14)*. The highest burdens of *Shigella* spp. and ETEC infections are in Africa, where *Shigella* spp. caused 30.4 million episodes and ETEC 15 million episodes of diarrhoea in 2010. In South-East Asia in 2010, *Shigella* spp. caused 58.1 million episodes and ETEC 28.7 million episodes of diarrhoea *(15)*.

*Cryptosporidium* spp. is one of the most widespread intestinal parasites. It is highly persistent in the environment, can be present in "improved" water systems due to its resistance to chemical disinfection, and is a prevailing cause of severe diarrhoea in immunocompromised people and children *(13, 16, 17)*.

Cholera outbreaks and epidemics remain a risk for populations where access to safe drinking water and adequate sanitation cannot be guaranteed. Cholera is endemic in 69 countries *(18)*. Untreated cholera can cause death within hours. There are an estimated 21 000–143 000 cholera deaths annually worldwide *(4, 19)*.

A range of significant water-related diseases do not cause diarrhoea but result in malnutrition, skin infections or organ damage. These important water-related diseases may have part of their lifecycle in water (e.g. schistosomiasis, Buruli ulcer, dracunculiasis (guinea-worm disease)) or may result from inadequate personal hygiene, particularly in areas and health-care facilities lacking adequate water and sanitation and impacted by water stress or scarcity (e.g. hepatitis A and E, soil-transmitted helminths, lymphatic filariasis, trachoma) *(4, 20)*. Depending on the prevalence and priority of these diseases in the country, they may be considered in the assessment.

Soil-transmitted helminths are intestinal worms infecting humans that are transmitted through contaminated soil. Approximately 1.5 billion people worldwide are currently infected with soil-transmitted helminths *(21)*. The transmission of soil-transmitted helminths is mainly through the deposition of eggs from human faecal contamination of soil. Subsequent infection results from ingestion of eggs through inadequate preparation of vegetables, or through the penetration of larvae through the skin after contact with the contaminated soil. *Trichuris trichiura* particularly can cause diarrhoea and dysentery. Soil-transmitted helminth infections often cause impaired nutritional status *(22)*.

Diarrhoeal diseases and malnutrition form a vicious cycle. Malnutrition is an underlying risk factor for transmission of diarrhoeal diseases and increases the burden of disease *(3)*. The mortality risk from diarrhoeal diseases is increased in children with acute malnutrition *(23, 24)*. Repeated diarrhoeal episodes, symptoms of which include loss of appetite, malabsorption of nutrients and increased metabolism, can cause or worsen malnutrition. As such, diarrhoea is a leading cause of malnutrition among children aged under 5 years *(3)*. This guide can be used in conjunction with the technical guide for conducting a V&A assessment for undernutrition *(2)*.

## Prevention of diarrhoeal diseases

Figure 3 shows the many opportunities to prevent transmission of infectious pathogens. The first line of prevention is the isolation of human and animal faecal matter. This includes safe sanitation systems and practices, and measures that prevent animal faeces from contaminating water sources, agricultural production, and workers and vectors.

The second line of defence ensures water for domestic purposes is available, safe, and free from infectious pathogens. This includes the use of improved and protected water sources with risk assessment and risk management to ensure the systems remain safe. Household water treatment and safe storage can provide an interim solution in places where adequate infrastructure and management systems are not in place.

Hygiene and handwashing prevent person-to-person contact and consumption of infectious pathogens that may pass to foods via vectors (e.g. flies), surfaces, dirty hands or food preparation.

Diarrhoeal diseases occur where these prevention measures are not adequate and the transmission of pathogens occurs, such as under conditions of poor hygiene and sanitation, inadequate and unsafe water supplies, agricultural practices that compromise water and food safety, and underlying urban or rural poverty. Table 2 summarizes key interventions to mitigate these risks.

**Table 1.** Climate-sensitive diarrhoeal disease pathogens of concern, of highest public health significance and regionally significant

| Type | Disease | Pathogen | Non-human reservoir host | Transmission | Clinical features |
|---|---|---|---|---|---|
| Protozoa | Giardiasis | *G. duodenalis* | Cattle, cats, dogs | Person-to-person contact<br>Food- and waterborne<br>Vector-transported | Diarrhoea, abdominal pain, weight loss, failure to thrive |
| | Cryptosporidiosis | *Cryptosporidium* parvum | Cattle, sheep, domesticated animals | Person-to-person contact<br>Food- and waterborne (including recreational contact)<br>Vector-transported | Diarrhoea, often prolonged |
| | Cyclosporiasis | *Cyclospora cayetanensis* | Humans<br>No known zoonotic reservoirs | Faecal–oral<br>Food- and waterborne | Diarrhoea, abdominal pain, weight loss, failure to thrive |
| | Amoebiasis | *E. histolytica* | Humans<br>No-zoonotic reservoirs | Person-to-person contact<br>Food-, water- and fomite-borne | Diarrhoea (may be severe), dysentery |

| Type | Disease | Pathogen | Non-human reservoir host | Transmission | Clinical features |
|---|---|---|---|---|---|
| Bacteria | Watery diarrhoea | ETEC | Cattle, ruminants | Food- and waterborne (including recreational contact)<br>Person-to-person contact<br>Vector-transported | Watery diarrhoea |
| | Campylobacteriosis | *Campylobacter spp.* | Poultry | | Diarrhoea (frequently with blood loss) |
| | Bloody diarrhoea | Enterohaemorrhagic *E. coli* | Cattle, ruminants | | Bloody diarrhoea<br>Haemolytic–uraemic syndrome in children |
| | Shigellosis (bacillary dysentery) | *Shigella* spp. | Humans<br>No zoonotic reservoirs<br>Flies can transmit | | Diarrhoea (frequently with blood loss) |
| | Aeromonas | *A. hydrophila, A. caviae, A. veronii* | Fish, shellfish, reptiles, amphibians (host role undetermined) | | Resembles shigellosis (with blood and leukocytes in stool) |
| | Cholera | *V. cholerae* | Shellfish, fish | | Watery diarrhoea (may be severe) |
| | Salmonellosis | *Salmonella* spp. | Poultry, pigs | | Diarrhoea, colicky abdominal pain, fever |
| | Typhoid | *Salmonella typhi* | Humans<br>No zoonotic reservoirs | | Fever, malaise, abdominal pain<br>High mortality |
| | Yersiniosis | *Yersinia* spp. | Pigs, birds, rodents (regional variation) | | Fever, diarrhoea, abdominal pain |

| Type | Disease | Pathogen | Non-human reservoir host | Transmission | Clinical features |
|---|---|---|---|---|---|
| Viruses | Viral gastroenteritis | Adenoviruses (particularly 40/41) | Human | Person-to-person contact<br>Food- and waterborne likely | Watery diarrhoea, vomiting, abdominal pain |
| | | Rotaviruses | Humans (principle reservoir)<br>Also occur in animals | Person-to-person contact<br>Food-, water- and fomite-borne (including recreational water contact) | Vomiting, watery diarrhoea |
| | | Noroviruses | Range of domestic and wild animals may serve as reservoirs (unconfirmed role) | Food-, water- and fomite-borne | Vomiting, watery diarrhoea |
| Nematodes | Trichuriasis, whipworm infestation | *T. trichiura* | Non-human primates | Soil-transmitted, foodborne | Diarrhoea, abdominal pain |
| | | *Ancylostoma duodenale* and *Necator americanus* | Humans<br>No-zoonotic reservoirs | Soil-transmitted<br>Oral ingestion possible (only *A. duodenale*) | Rash, abdominal pain, diarrhoea, fatigue, anaemia |

| Type | Disease | Pathogen | Non-human reservoir host | Transmission | Clinical features |
|---|---|---|---|---|---|
| Toxin-producing harmful algal species | Cyanobacteria poisoning | Cyanobacteria (blue–green algae) | Seawater, fish | Waterborne<br>Toxins in contaminated drinking water or direct contact with harmful algal blooms<br>Foodborne – some toxins can accumulate in fish and shellfish | Dermatitis, hepatitis, diarrhoea, respiratory symptoms<br>Potentially fatal |
| | Shellfish poisoning | Various algae producing okadaic acid | Seawater, shellfish | Foodborne<br>Bioaccumulated toxins in fish | Nausea, vomiting, diarrhoea, neurological effects |
| | Ciguatera | *Gambierdiscus toxicus* | Seawater, fish | | |

**Table 2.** Key measures to prevent diarrhoeal diseases

| |
|---|
| Access to safe drinking water |
| Use of improved sanitation |
| Handwashing with soap |
| Exclusive breastfeeding for first 6 months of life |
| Good personal and food hygiene |
| Health education about how infections spread |
| Rotavirus vaccination |

Source: Diarrhoeal disease. Geneva: World Health Organization; 2017 (https://www.who.int/news-room/fact-sheets/detail/diarrhoeal-disease).

# 4 Climate change and diarrhoeal diseases

The Intergovernmental Panel on Climate Change (IPCC) has concluded that the risks of food- and waterborne diseases will increase (very high confidence) if climate change continues as projected across the representative concentration pathways (RCP) scenarios until the middle of the twenty-first century without effective adaptation *(25)*.

At current emission rates, global warming will surpass 1.5 °C and then 2 °C above pre-industrial levels during the twenty-first century. This will lead to more frequent and intense climate and weather extremes, varying by region, including heatwaves, heavy precipitation events, agricultural and ecological droughts, and intense tropical cyclones *(26)*. The IPCC Sixth Assessment Report found that increased temperatures (very high confidence), heavy rainfall (high confidence), flooding (medium confidence) and droughts (low confidence) are linked to increased incidence of diarrhoeal diseases *(25)*. Increased temperatures, rainfall and flooding have already resulted in increased incidence of cholera (very high confidence) and other gastrointestinal infections (high confidence) *(27)*. The evidence also shows that high air and water temperatures and a longer summer season are associated with increases in incidence of foodborne diseases (very high confidence) *(25)*.

Climate variables such as temperature, rainfall, humidity and extreme events have been shown to influence the transmission and geographical and seasonal ranges of diarrhoeal diseases *(28, 29)*. Climate change is expected to magnify the transmission of food- and water-related diseases in various ways, depending on the pathogen and on the ecological (e.g. water availability), agricultural (e.g. livestock and irrigation) and social (e.g. hygiene practices) conditions *(28)*. It is projected that climate change will cause an increase in the annual number of diarrhoea-related deaths in children aged under 15 years by approximately 48 000 in 2030 and 33 000 in 2050 *(29)*.

Figure 4 highlights how climate change is expected to directly or indirectly influence transmission of diarrhoeal diseases. Climate change will increase favourable conditions for the growth, survival, persistence, transmission and/or virulence of food- and water-related pathogens, increasing the infection hazard of human exposure to infected food, water or other people.

Indirectly, climate change is expected to alter or disrupt socioeconomic, environmental and behavioural determinants of transmission and human exposure. For example, extreme rainfall is known to increase agricultural runoff, which may result in more significant faecal contamination of water sources *(30)*. Conversely, extended dry periods may allow pathogens to grow and concentrate in surface water and groundwater or may reduce the water available for hygiene, further contributing to the dissemination of diarrhoeal diseases *(31)*.

Examples of these impacts from the scientific literature are summarized in Table 3 and described further in this section. These recognized influences serve as ideas of the mechanisms that can be investigated in a V&A assessment.

**Figure 4.** Direct and indirect influences of climate on transmission pathways for diarrhoeal diseases

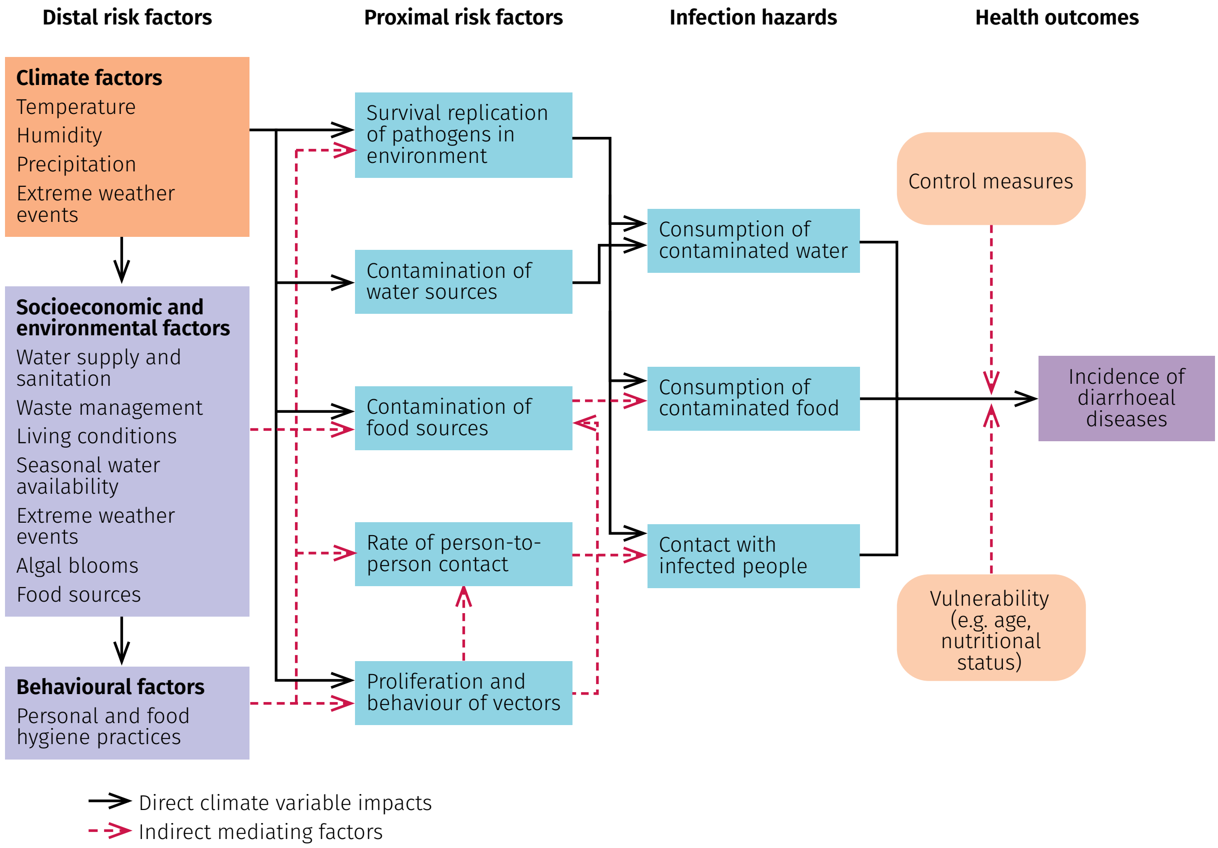



**Table 3.** Summary of impacts of climate change on risks of diarrhoeal diseases

| Effects of climate change | Influence on underlying risk factors | Influence on proximal risk factors |
|---|---|---|
| Increased mean global temperatures | Faster growth rates and survival of microorganisms in food and water<br>Altered vector behaviour and favourable conditions for proliferation<br>Increased expression of bacterial virulence genes<br>Melting permafrost<br>Acceleration of food spoiling at higher temperatures<br>Decreased stability of chlorine residuals | Increased microbiological contamination of foodstuffs<br>Increased microbiological contamination of coastal, recreational and surface waters<br>Longer favourable periods for vector-borne transmission<br>Increased or altered geographical distribution of vectors<br>Increased water consumption rates<br>Decreased effectiveness of water treatment |

| Effects of climate change | Influence on underlying risk factors | Influence on proximal risk factors |
|---|---|---|
| More intense rainfall and flooding | Increased agricultural and solid-waste runoff and wastewater overflows<br>Mobilization and transportation of pathogens<br>Flood damage to water and sanitation infrastructure<br>Increased loading of pathogens and chemicals<br>Decreased efficiency of natural water purification processes | Increased contamination of drinking and recreational water sources<br>Reduced water quality<br>Reduced access to improved water supplies<br>Reduced handwashing and personal hygiene<br>Reduced food hygiene |
| Increased frequency or duration of droughts | Decreased quantity and quality of available surface water and groundwater<br>Concentration of pathogenic, chemical and radiological contaminants<br>Increased proliferation of household flies<br>Increased vector breeding by slowing river flows<br>Decreased food security | Reduced access to safe drinking water<br>Reduced access to safe water for irrigation and food processing and preparation<br>Increased pathogen-loaded surface waters, leading to increased infection hazards<br>Increased person-to-person contact and food contamination<br>Reduced handwashing and personal hygiene<br>Reduced food hygiene<br>Increased levels of acute or chronic malnutrition |
| Extreme weather events | Temporary or long-term damage, destruction or disruption of water and sanitation and solid-waste management services<br>Increased sanitation and agricultural runoff<br>Decreased food security | Reduced water quality<br>Reduced access to improved water supplies<br>Reduced handwashing and personal hygiene<br>Reduced food hygiene<br>Increased harmful algal blooms<br>Increased levels of acute or chronic malnutrition |
| Increased sea-surface temperatures | Increased harmful algal blooms and favourable *Vibrio* spp. growth conditions | Increased risks of cholera, cyanobacteria and ciguatera outbreaks in some areas |

Climate change is likely to result in increased incidence of water- and food-related diarrhoeal diseases. The impact of temperature, rainfall and other climate changes on transmission of diarrhoeal diseases strongly depends on the pathogens involved and other climatic, environmental and behavioural factors *(32–34)*.

## Increasing temperatures

Increasing temperatures caused by climate change are likely to exacerbate the risk of transmission of diarrhoeal diseases. Various studies have demonstrated an increase in incidence of diarrhoeal diseases with incremental increases in temperature *(31, 33, 35–39)*. Two systematic reviews found significant positive associations between all-cause and bacterial diarrhoea and ambient temperature *(32, 33)*. In Nepal, researchers found that for every 1 °C increase in temperature, there was an accompanying 8.1% increase in the number of cases of diarrhoeal diseases, and 7.5% of the diarrhoeal burden in children could be attributed to temperature *(40)*. In Cape Town, South Africa, 5 °C increases in the minimum and maximum temperatures were associated with 39% and 31% increases, respectively, in the number of cases of diarrhoeal diseases in children aged under 5 years *(31)*.

Several other studies have demonstrated a relationship between temperature and incidence of diarrhoeal diseases, including increases in childhood diarrhoea related to both temperature increases and decreases and heatwaves in Brisbane, Australia *(38)*; high temperatures and increased incidence of diarrhoeal diseases in the Mekong Delta *(41)*; and an increase in the rate of reported cases of adult diarrhoeal diseases with increased annual average temperatures in the Pacific *(37)*.

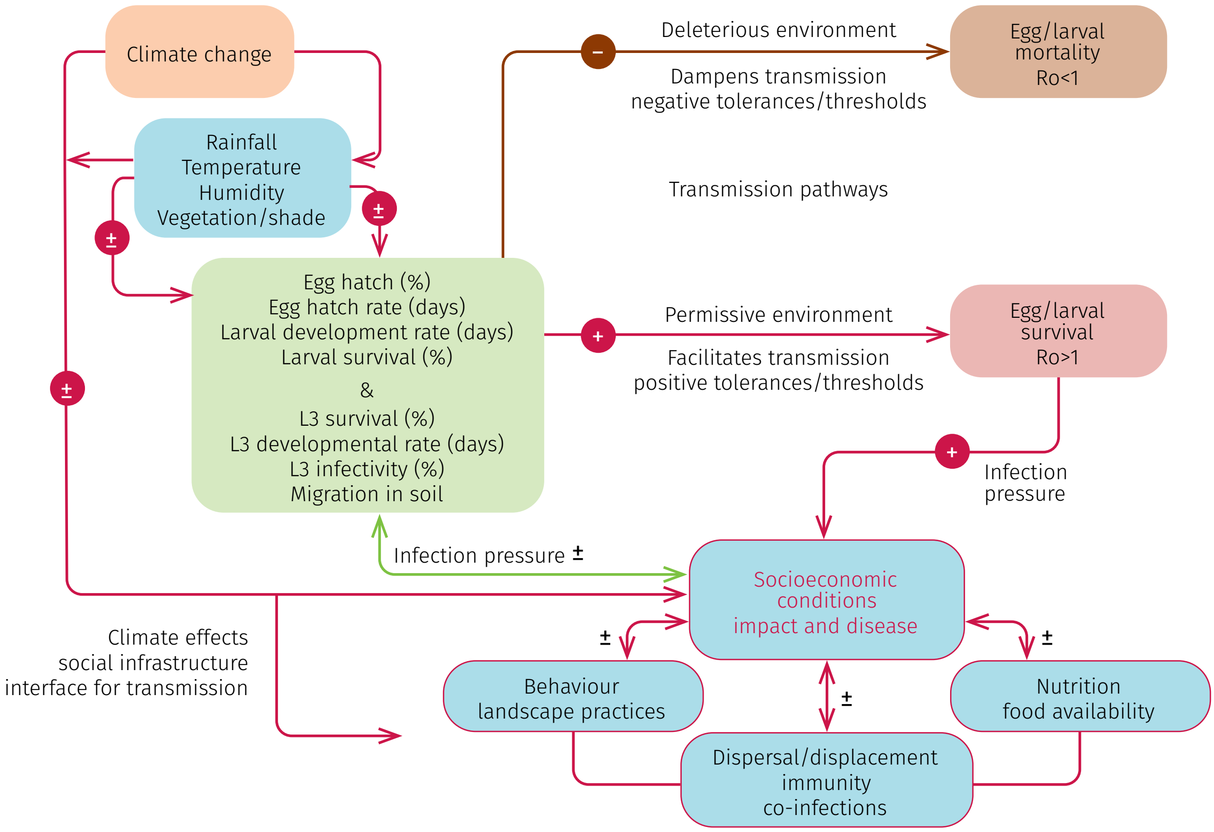
Increases in temperature are associated with a higher incidence of diarrhoeal diseases resulting from increased pathogen growth and survival of bacterial pathogens in drinking and recreational water sources and water pipes *(32)*, and other non-climatic and behavioural factors such as bathing habits *(42)*. Increasing temperatures may precipitate an increase in vector populations, which can consequently cause increases in diarrhoea-producing pathogens *(39)*. Plankton are known to harbour faecal indicators such as *E. coli*, enterococci and *Clostridium perfringens* and pathogens such as *Campylobacter* spp., *Pseudomonas aeruginosa, Legionella* spp. and *Aeromonas* spp. *(43–45)*. At higher temperatures, the stability of chlorine residuals is reduced and the effectiveness of water treatment decreases *(46)*.

Increased temperatures are more favourable for the growth and survival of *Campylobacter* spp., *E. coli*, *Vibri* spp., *Salmonella* spp. and *Shigella* spp., some of the most virulent foodborne bacteria *(47, 48)*. Warmer and more variable conditions affect agroecosystems, altering the behaviour and geographical distribution of host reservoirs, pests and vectors, which can result in agricultural contamination and post-production spoilage, including increased formation of diarrhoea-causing mycotoxins *(49)*.

Increasing average temperatures, longer periods with higher temperatures and heatwaves will increase the risk of foodborne outbreaks, particularly in areas without adequate refrigeration, safe water and hygiene. It is conceivable that increasing temperatures will accelerate food expiration in households and facilities where appropriate frigid food storage conditions are not available. Opportunities for compromised food safety present at higher ambient temperatures throughout the food cycle, including primary production, storage, transport, handling and preparation.

Soil-transmitted helminth infections are found mainly in areas with warm and moist climates where sanitation and hygiene are poor, including in temperate zones during warmer months. Increasing temperatures and extreme fluctuations in temperature and precipitation will influence, often favourably, parasite ecology and transmission (Figure 5) *(50)*.

**Figure 5.** Soil-transmitted helminths and climate




Source: Weaver HJ, Hawdon JM, Hoberg EP. Soil-transmitted helminthiases: implications of climate change and human behavior. Trends Parasitol. 2010;26(12):574–581.

## More intense rainfall and flooding

Precipitation and flooding events have been associated with increased incidence of diarrhoeal diseases *(33, 35, 40, 41)*. A systematic review found moderate evidence of associations between increased incidence of diarrhoeal diseases and heavy rainfall events, heavy rainfall following dry periods, and flooding *(33)*. A study in Ecuador found that extreme rainfall events following dry periods were associated with increased incidence of diarrhoeal diseases, but decreased incidence following wet periods *(35)*.

Several other studies have found links between incidence of diarrhoeal diseases and rainfall. In Nepal, cases of diarrhoeal diseases increased by 0.9% for every 10 mm increase in rainfall *(40)*. There were associations between high cumulative rainfall and increased incidence of diarrhoeal diseases in the Mekong Delta *(41)*. In Mozambique, an additional rainy day per week was associated with a 0.63–2.09% (varying regionally) increase in incidence of diarrhoeal diseases *(51)*.

Increased extreme precipitation and flooding increase agricultural and solid-waste runoff and cause wastewater overflows that can contaminate drinking and recreational water sources *(46, 52)*. Heavy rainfalls after dry periods mobilize and transport pathogens that have accumulated in the environment from human and animal excreta *(33, 35, 53, 54)*. This can occur through two causal pathways. Directly, rainfall through runoff can flush pathogens into surface-water stores. Indirectly, rainwater can lead to contamination of water stores through the mobilization of bacteria within various soil compartments *(35)*.

Of note, heavy rainfalls after wet periods are observed to dilute pathogenic concentrations in the environment, decreasing transmission *(35)*. This is in contrast to heavy rainfalls after dry periods, where pathogen concentrations are known to increase and subsequent rainfall fosters transmission.

Within vulnerable communities that have experienced heavy rainfalls, protective measures that have decreased the association between rainfall and incidence of diarrhoeal diseases include the use of treated water and improved sanitation facilities *(55)*.

Extreme weather events such as heavy flooding, landslides, cyclones and storms are known to overwhelm, damage, disrupt and destroy sanitation and water infrastructure, including wastewater treatment plants, electrical substations, water pipes and household latrines, leading to leakages of pathogens into drinking-water sources, recreational waters and irrigation *(33, 46, 56)*. Risks of outbreaks of diarrhoeal diseases increase significantly if emergency water supplies and sanitation facilities are not available to affected populations.

## Increasing frequency or duration of droughts

Worldwide, prevalence of diarrhoeal diseases is often highest during dry seasons *(57, 58)*. At times of water scarcity, households tend to reduce the use of water for hygiene purposes, such as handwashing after defaecation and before food preparation *(57, 59, 60)*. Increased drought is a risk factor for diarrhoeal diseases as it is associated with longer-term impaired water quality *(46)*. Droughts can negatively affect the quality of surface water and groundwater sources through increased eutrophication, turbidity, concentration of pathogens and pollutants. Reduced water availability can result in increased infection hazards as less water is available for personal hygiene, improved sanitation systems are unreliable, water sources are shared with animals, and unsafe alternative water sources may be used *(33, 34, 46)*.

## Increasing sea-surface temperatures

Warmer sea-surface temperatures accelerate the growth of bacteria such as *V. vulnificus, V. cholerae* (non-O1 and non-O139) and cyanobacteria in the sea and brackish waters *(61)*.

Increasing sea-surface temperatures accelerate the formation of harmful algal blooms, which cultivate a range of poisonous toxins in diatoms and dinoflagellates, and *Vibrio* spp., which are absorbed in fish and shellfish and become a significant foodborne threat *(62)*. Ciguatera poisoning occurs due to the ingestion of reef fish and shellfish in tropical and subtropical regions with accumulated toxins and results in a range of gastrointestinal, cardiovascular and neurological symptoms, including diarrhoea. Climate change is likely to affect the spread and growth of these toxins *(63)*.

### *Additional resources*

Campbell-Lendrum D, Woodruff R. Climate change: quantifying the health impact at national and local levels. In: Prüss-Üstün A, Corvalán C, editors. Geneva: World Health Organization; 2007 (https://apps.who.int/iris/handle/10665/43708, accessed 29 June 2022).

Climate change: implications for food safety. Rome: Food and Agriculture Organization; 2008 (https://www.fao.org/publications/card/en/c/fb2e21c6-0c8a-564d-b208-611d2e27754e/, accessed 29 June 2022).

Climate change 2022: impacts, adaptation and vulnerability. Geneva: Intergovernmental Panel on Climate Change; 2022 (https://www.ipcc.ch/report/ar6/wg2/, accessed 29 June 2022). *(See Chapter 4 Water and Chapter 7 Health, wellbeing and the changing structure of communities.)*

Climate change 2021: the physical science basis. Geneva: Working Group 1, Intergovernmental Panel on Climate Change; 2021 (https://www.ipcc.ch/report/ar6/wg1/, accessed 29 June 2022). *(See Chapter 8 Water cycle changes and Chapter 11 Weather and climate extreme events in a changing climate.)*

AR5 climate change 2014: impacts, adaptation, and vulnerability. Geneva: Working Group II, Intergovernmental Panel on Climate Change; 2014 (http://ipcc.ch/report/ar5/wg2/, accessed 29 June 2022). *(See Chapter 3 Freshwater resources and Chapter 11 Human health: impacts, adaptation, and co-benefits.)*

Climate change and water. Geneva: Intergovernmental Panel on Climate Change; 2008 (https://www.ipcc.ch/publication/climate-change-and-water-2/, accessed 29 June 2022).

United Nations world water development report 2020: water and climate change. Paris: United Nations Educational, Scientific and Cultural Organization; 2020 (https://www.unwater.org/publications/world-water-development-report-2020, accessed 29 June 2022).

Discussion paper: climate, sanitation and health. Geneva: World Health Organization; 2019 (https://www.who.int/publications/m/item/discussion-paper-climate-sanitation-and-health, accessed 29 June 2022).

Climate-resilient water safety plans: managing health risks associated with climate variability and change. Geneva: World Health Organization; 2017 (https://apps.who.int/iris/handle/10665/258722, accessed 29 June 2022).

Human health and climate change in Pacific Island countries. Geneva: World Health Organization; 2015 (https://apps.who.int/iris/handle/10665/208253, accessed 29 June 2022).

Atlas of health and climate. Geneva: World Health Organization; 2012 (https://apps.who.int/iris/handle/10665/76224, accessed 29 June 2022).

Health and climate change country profiles. Geneva: World Health Organization (https://www.who.int/teams/environment-climate-change-and-health/climate-change-and-health/evidence-monitoring/country-profiles, accessed 12 December 2022).

# 5 V&A assessment steps

## Step 1. Getting started: plan the assessment

A V&A assessment is a participatory process and an evaluation tool that allows countries to assess which populations and geographical locations are most vulnerable to increased risk of diarrhoeal diseases as a result of climate change. The assessment helps to identify the weaknesses in the systems that should protect people and to specify the interventions to prevent climate-sensitive diseases – in this case, diarrhoeal diseases.

Stakeholder engagement is essential for the process to address local climate sensitivity and to develop sustainable interventions.

Before undertaking a V&A assessment on diarrhoeal diseases, framing and scoping key aspects of the assessment process is necessary. The following four steps should be considered:

- Determine how the assessment will be managed.
- Define the scale of the assessment (e.g. national, subnational, state, provincial).
- Identify the target diseases to assess (e.g. inclusion of malnutrition or other water-related diseases).
- Establish a workplan that includes a timeframe, key information sources, context-specific adaptation needs, participation of stakeholders, and a communication plan for informing stakeholders.

A V&A assessment for diarrhoeal diseases can take from a few months to several months. It may involve a handful of experts or a large group of scientists and stakeholders in various areas, including climatology, meteorology, public health, WASH, medicine, information technology and other related areas. The size of the budget varies.

A well-prepared plan will make a significant difference in the effective and efficient management of the project by taking the realities of time and resources into account.

Step-by-step guidance on planning a V&A assessment can be found in *Climate change and health: vulnerability and adaptation assessment (1).*

## Step 2. Vulnerability assessment: describe the current burden of diarrhoeal diseases and vulnerabilities to climate variability and recent climate change

In this step, the V&A assessment describes the current burden of climate-sensitive diarrhoeal diseases and current vulnerabilities and then works towards establishing a baseline for further analyses and assessments. This description can be a qualitative or quantitative summary of the current distribution and burden of diarrhoeal diseases by vulnerable population or geographical area and can establish the vulnerability baseline.

### Step 2A. Describe the current burden of diarrhoeal diseases

Basic research questions to answer in this step:

- What are the current distribution and burden of diarrhoeal diseases?
- What are the current programmes and policies that protect humans from diarrhoeal diseases?
- In what ways do communities and institutions prepare for diarrhoeal diseases?

Documents and data collected in Step 1 should be analysed and synthesized to describe the current distribution and burden of diarrhoeal disease. The synthesis can include experiences and insights from departments within the ministry of health.

Data sources for further analyses should be identified. The synthesis should take into account knowledge about the burden of diarrhoeal diseases in neighbouring countries and regions, such as increasing or decreasing outbreaks along a border. If the information available is insufficient for further quantitative assessment of diarrhoeal diseases or to understand their sensitivities to climate variables, interviews with subject matter experts can help fill knowledge gaps and inform future analyses of vulnerabilities.

The synthesis is needed to establish a baseline for further analyses and assessments. This synthesis can be a qualitative, quantitative or mixed-methods summary.

#### *Additional resources*

Existing national health surveillance systems in your country should be primary sources for national and subnational epidemiological data. The WHO Global Health Observatory also provides disease burden estimates *(64)*.

### Step 2B. Analyse the relationships between diarrhoeal diseases and current and past weather and climate conditions

Basic research questions to answer in this step:

- How do average, seasonal and extreme climatic conditions influence the burden of diarrhoeal diseases?
- How can we measure the relationships between diarrhoeal diseases and climate variables?
- What are the environmental factors affected by weather and climate conditions and causing diarrhoeal diseases?

This step examines the climate sensitivity of diarrhoeal diseases, or the degree to which climate determines the occurrence and spatial distribution of diarrhoeal diseases. The degree to which diarrhoeal diseases respond to exposure to diverse climatic conditions depends on many complex non-climatic factors. The relationships between transmission of diarrhoeal diseases and core weather variables, such as average temperature, precipitation and extreme weather events, can be explored.

Diarrhoeal diseases are highly climate-sensitive. Although transmission dynamics are complex and often not fully understood, it is well known that survival and replication of pathogens are particularly influenced by changes in ambient conditions *(65)*. Careful analysis and judgement are needed, however, and caution should be exercised when interpreting correlations of causality, particularly from low-resolution data.

Sensitivity studies are ecological studies (in the epidemiological sense) that investigate population-scale relationships through spatial or temporal variation in exposure and outcome. Empirical studies of climate and health impacts have made important insights about calculating these relationships and caution that simplistic models may be misleading.

General considerations for conducting sensitivity studies are that they should:

- be based on local meteorological data at high temporal and spatial resolution (e.g. daily or weekly data from local meteorological stations);
- use anthropometric and health data based on standardized diagnostic criteria that are comparable over time and be representative of the study population (e.g. national health surveillance services for countries or large areas, or from specific sites such as hospitals);
- have a control for the effects of non-climatic seasonal variations *(66)*.

Table 4 outlines key climatic variables and climate-sensitive risk factors that can be analysed, and known associations that can be explored at the subnational level.

**Table 4.** Sensitivity of risk factors for diarrhoeal diseases to climate

| Environmental change | Outcome | Key risk factors | | | | |
|---|---|---|---|---|---|---|
| | Incidence of diarrhoeal diseases | Pathogen survival | Water quantity and quality | Host-reservoir ecology and behaviour | Hygiene | Exposure to harmful algal blooms |
| Daily temperature (maximum/minimum) | X | X | X | X | X | X |
| Extreme temperature/ temperature threshold | X | X | X | X | X | |
| Daily Precipitation (maximum/minimum) | X | X | X | X | X | |
| Extreme precipitation (flooding, droughts, storms) | X | X | X | X | X | X |
| Relative humidity or air pressure | X | X | | | | |
| Sea-surface temperatures | X | X | X | X | | X |

Different approaches can be used to identify statistically significant associations between incidence of diarrhoeal diseases and sudden, periodic or long-term changes in climatic conditions such as temperature, rainfall or relative humidity *(65)*. At a minimum, time-series regression analyses should be conducted of the relationships between diarrhoeal diseases (daily, weekly or monthly admission of cases or mortality rates) and core weather variables such as average maximum and minimum daily temperatures, precipitation, relative humidity, vapour pressure and extreme weather events. Spatial analysis using geographical information systems (GIS) can be helpful.

It is advisable to examine associations beyond averages. Investigation of relationships between incidence of diseases, extreme values of key variables (e.g. extreme weather events), or the observation of seasonal and geographical variations is highly indicative of climate sensitivity, particularly the following:

- **Extreme weather events** (also known as weather anomalies or interannual variability) can promote or inhibit transmission of diseases, disrupt water and sanitation systems, trigger outbreaks, and cause a temporal change in data. These events can be isolated in time; may last days, weeks or months; and represent a marked set of environmental conditions. For example, both high and low rainfall can exacerbate transmission of cholera through different mechanisms *(67)*. In Haiti, rainfall played a role in the 2010–2013 cholera epidemic, and heavy rainfall was associated with an increased cholera risk 4–7 days later *(68)*.
- **The El Niño Southern Oscillation** (ENSO) is a climate event that originates in the Pacific Ocean on a quasi-periodic basis (every 3–8 years) with wide-ranging consequences for weather around the world. ENSO affects regional rainfall patterns and alters the intensity of floods and droughts. ENSO affects the transmission of diarrhoeal, vector-borne and rodent-borne diseases, affects the incidence of seafood poisoning, and may provoke the disruption of health services *(69)*. Historic ENSO years are listed in Annex 1 and should be accounted for appropriately in sensitivity analyses.
- **Seasonal trends** are expected in climate-sensitive health conditions, especially those with short development periods such as diarrhoeal diseases *(70)*. This may result in periods of high risk and low risk. Local people and medical personnel should be aware of the seasonal patterns. Temporal analysis can help identify the timing of peak incidence of diarrhoeal diseases during the wet season, when higher rates of diarrhoea transmission may be observed. For example, in arid northern Kenya, the wet season in March to June results in increased incidence of diarrhoeal diseases after the rain peaks in April *(71)*. In Botswana, a biannual peak in incidence of diarrhoeal diseases is observed during the wet and dry seasons *(57)*. In Thailand, a consistent reduction in relative incidence of diarrhoeal diseases is observed during July or August after the rains have begun *(72)*.

  Pathogen specificity is particularly important when determining seasonality. Incidence of bacterial diarrhoeal diseases may peak in the warmer season, whereas incidence of viral diarrhoeal diseases may peak in the winter (suggesting food is a more likely vehicle than water) *(59)*. Seasonal disease trends may vary regionally and may be mediated by non-climatic social or environmental factors. For example, rotavirus is observed in the cooler and drier times of the year in tropical regions *(54, 73)*, but recent research suggests seasonality may be due to factors intrinsic to the population such as birth and vaccination rates, in addition to environmental conditions *(42)*. Additionally, periodic human behaviour or activities may result in increased exposure (e.g. harvesting, husbandry practices), or migratory birds may play a role in seasonal transmission patterns *(74, 75)*.
- **Geographical variation** is expected in key climate and outcome indicators where local microclimates, changes in altitude or place-based vulnerabilities (e.g. urban slums) may significantly affect local exposure to climate hazards, water access, population dynamics and onset of seasons. Spatial analysis can reveal important associations between environment, climate and incidence of diarrhoeal diseases.

Further considerations include the following:

- The extent of influence of climate variables is highly dependent on the pathogen type *(76)*. It is advisable to discern the aetiology of diarrhoea if possible (e.g. rotavirus, *Shigella* spp., *E. coli*, *Cryptosporidium* spp., cholera). This will improve the quality of analysis, since viruses, bacteria, protozoa and oocysts respond differently to diverse ambient conditions. The type of vector that carries the pathogen is also a consideration, because the influence of climate variables can affect the spatial distribution of various species.

- Taking into account non-climatic factors and controlling for confounders are paramount. Failure to incorporate non-climatic factors can lead to incorrect attribution of disease to climate or poor predictive accuracy. Notably, rotavirus vaccination is expected to significantly alter incidence of diarrhoeal diseases in some places and may increase the degree of seasonal variation in the incidence of rotavirus *(12, 42)*. HIV infection, immunity and long-term nutritional status (using average weight for height z-scores) may play an important role in promoting transmission of diarrhoeal diseases in certain populations *(57)*.
- A constant correlation coefficient of the temperature–diarrhoea relationship has been sought in several studies *(76–80)*. A meta-analysis consisting of 26 studies found an increase of 7% for incidence of all-cause diarrhoea and 7% for bacterial diarrhoea, but this increase was not found for viral diarrhoea *(32)*. It is not likely that a universal value of sensitivity exists, even within the taxa. Studies have found important nonlinear responses in the temperature–diarrhoea relationship. The replication rate of rotavirus has been observed to increase at a significantly higher rate (20–60%) above a 29 °C temperature threshold *(81)*, and cholera admissions have been observed to double when temperatures were up to 5 °C above normal *(82)*. Rates of diarrhoeagenic *E. coli* increase by 8% for each 1 °C increase in temperature *(83)*. In the United Kingdom of Great Britain and Northern Ireland, it was determined that for every 1 °C increase in average weekly temperature, there is an increase of 0.73% in the mean number of cases of *Campylobacter* spp. *(84)*. A study in Australia found that a 5 °C in mean temperature was associated with a 45.4% increase in cases of salmonellosis *(85)*.
- The relationship between diarrhoea and precipitation is less clear than that with temperature because it is highly dependent on the pathogens and local sanitation facilities, is often indirect, and may be mediated by local environmental conditions *(76)*. Positive associations have been found between the number of extreme rainfall days and incidence of diarrhoeal diseases in Canada *(86)*, Taiwan, China *(87)* and the United States of America *(52)*, and associated with low levels of rainfall in the Pacific *(37)*. This may be due to factors such as timing of the events and existing local conditions. For example, research indicates that when a heavy rain follows a dry spell, the incidence of diarrhoeal diseases can increase by as much as 39%; but when heavy rainfall is preceded by a wet period, the incidence of diarrhoeal diseases may drop by more than 25% *(35)*. The protective mechanism of heavy rainfall is mediated by the flushing of enteric pathogens from the local environment. Accordingly, the relationship between rainfall and diarrhoeal diseases is highly dependent on the type of sanitation facilities. For example, in a recent study in Ecuador, it was inferred that after more than 5 days of heavy rainfall, pathogens may be flushed out of unimproved sanitation facilities *(55)*.
- A time lag is often expected between precipitation and incidence of diarrhoeal diseases *(57, 73, 87, 88)*. Lagging is pathogen-dependent. It may range from 0 to 2 months and should be calculated based on the known incubation and transmission of pathogens.

Understanding the spatial and temporal patterns in disease occurrence, and the degree to which climate may play a role in these patterns, is highly valuable. This information can be used immediately to improve the effectiveness of disease control programmes and give insight into how diseases are likely to respond to increasing variability as part of longer-term climate change trends.

## Additional resources

Existing national climate assessments and national meteorological services should be primary sources for national and subnational climate data. Annexes 1–3 include additional sources of current and historical meteorological data, including ENSO years, and national hazard calendars indicating harvest and lean season relations to climate events.

See also the WHO *Atlas of health and climate* for an overview of the geographical relationship between diarrhoeal diseases and climate variables and an overview for emergencies such as floods, cyclones and droughts *(89)*.

## Step 2C. Describe the risk distribution and identify trends in upstream determinants

Basic research questions to answer in this step:

- How are diarrhoeal diseases distributed spatially?
- How can we use GIS in protection from diarrhoeal diseases?
- Are there vulnerable populations based on their geographical locations?

Spatial mapping is a useful approach for describing the geographical distribution of current or projected future vulnerabilities and hazards. Spatial mapping permits the analysis and visualization of health and environmental data and provides effective and efficient risk communication of the health impact. A geographical perspective and the use of GIS offer opportunities to understand distribution patterns of populations and the spatial relationship to diseases, river basins prone to flooding, health-care facilities, and other important variables of interest, pinpointing the issues and describing the intensity or extent of the cause or effect.

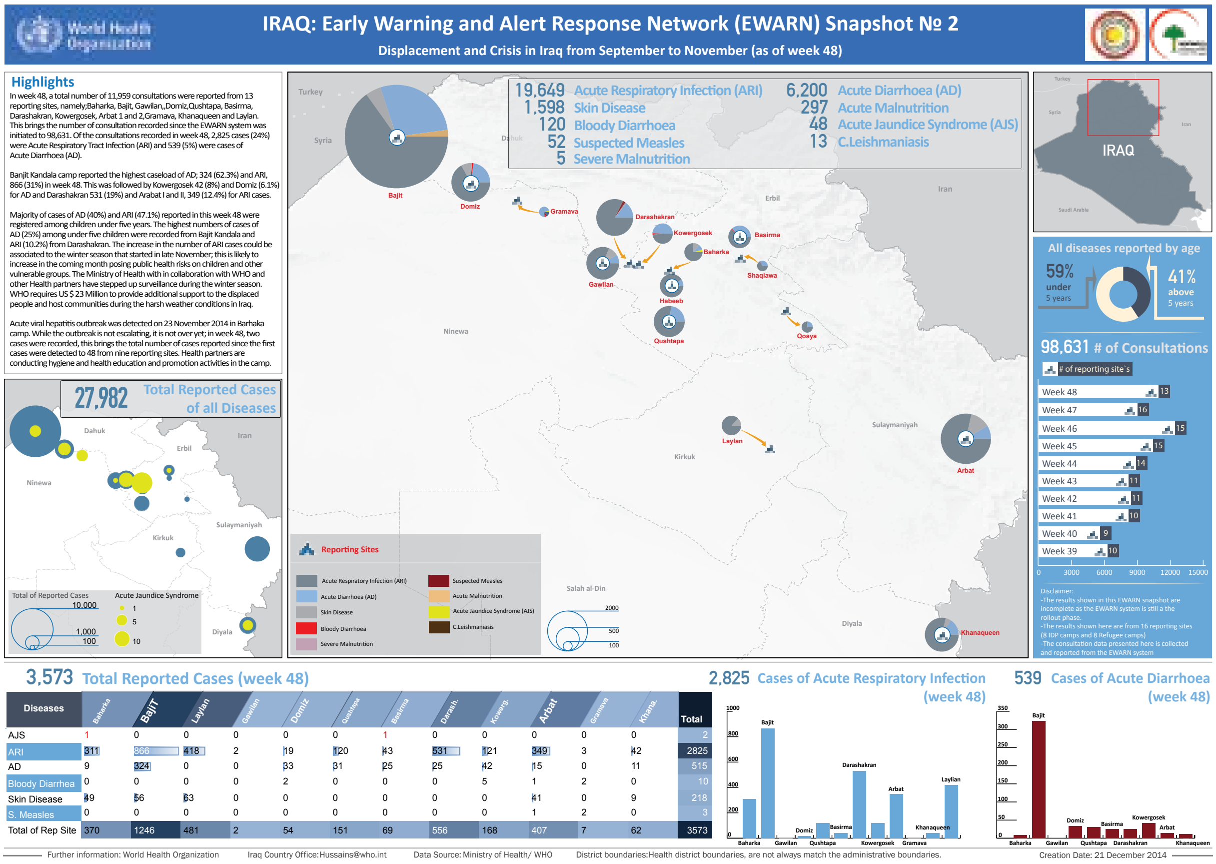
GIS can highlight localized problems (e.g. lack of basic sanitation in a particular hotspot) and more diffuse problems (e.g. seasonal water availability). The spatial resolution of the mapping is influenced by data availability. Grids, natural areas or administrative units usually serve as spatial resolution.

Mapping diseases with meteorological and other environmental information can be used for climate-informed early warning systems for health outcomes sensitive to climate variation and change. Mapping environmental indicators for prevalence of diarrhoeal diseases may provide insights into areas where these occur but are not well observed due to underreporting. In addition, mapping helps in understanding pattern changes in the distribution of diseases under an altered climate.

It is essential to understand the extent to which exposures not related to climate change do or could affect human health. Assessments should consider how key indicators such as poverty, the availability and quality of water and food, and population density and dynamics (e.g. displacement or migration to urban or coastal areas or other countries) could affect relationships between weather patterns and climate-sensitive diseases. Analyses should focus on understanding these trends scaled to the area of interest.

Figure 6 shows a report from the Early Warning and Alert Response Network in Iraq in 2014. This system monitors health outcomes with population displacement and crisis. Among the reported health outcomes, acute respiratory infection ($n$ = 19 679) and acute diarrhoea ($n$ = 6200) were the most prevalent. This demonstrates that dynamic population displacement with changes in the environment can trigger acute outbreaks of diarrhoeal diseases.

# Figure 6. Monitoring of health outcomes in conjunction with population displacement and crisis information




| Diseases | Baharka | BajiT | Laylan | Gawilan | Domiz | Qushtapa | Basirma | Darash. | Kowerg. | Arbat | Gramava | Khana. | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AJS | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 2 |
| ARI | 311 | 866 | 418 | 2 | 19 | 120 | 43 | 531 | 121 | 349 | 3 | 42 | 2825 |
| AD | 9 | 324 | 0 | 0 | 33 | 31 | 25 | 25 | 42 | 15 | 0 | 11 | 515 |
| Bloody Diarrhea | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 5 | 1 | 2 | 0 | 10 |
| Skin Disease | 49 | 56 | 63 | 0 | 0 | 0 | 0 | 0 | 0 | 41 | 0 | 9 | 218 |
| S. Measles | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 0 | 3 |
| Total of Rep Site | 370 | 1246 | 481 | 2 | 54 | 151 | 69 | 556 | 168 | 407 | 7 | 62 | 3573 |

Source: Iraq: Early Warning and Alert Response Network (EWARN) snapshot no 2 – displacement and crisis in Iraq from September to November (as of week 48). Geneva: World Health Organization (https://reliefweb.int/report/iraq/iraq-early-warning-and-alert-response-network-ewarn-snapshot-2-displacement-and-crisis).

To assess the associations in the temporal trends of climate hazards and diarrhoeal diseases, time series of 10 years of data are recommended. Risk mapping is helpful as an initial step for identifying geographical patterns, especially if only limited time-series data are available.

It is important to consider factors that could influence any observed trends, such as changes in disease interventions, disease case definitions and land use (e.g. forestation, deforestation), and mediating factors such as access to improved water and sanitation systems.

## Additional resources

Several GIS software packages are publicly available. A variety of potentially relevant environmental, climate and sociodemographic data are available through web-based sources, such as ArcGIS Online,[1] the Centers for Disease Control and Prevention Map feature in Epi Info,[2] QGIS[3] and the R Project.[4]

Further information and resources on spatial mapping are outlined in *Climate change and health: vulnerability and adaptation assessment (1).*

[1] https://www.arcgis.com/index.html
[2] https://www.cdc.gov/epiinfo/user-guide/maps/mapsintro.html
[3] https://www.qgis.org/en/site/
[4] https://cran.r-project.org/web/views/Spatial.html

## Step 2D. Identify population groups and geographical regions in situations of increased vulnerability

Basic research questions to answer in this step:

- Which populations are most vulnerable to climate-exacerbated risk of diarrhoeal diseases?
- What are the main conditions that make these populations vulnerable?
- Are there particular regions or areas with high concentrations of vulnerability?
- What are the major trends that may change population vulnerability in the future?

This step identifies subpopulations that are vulnerable to diarrhoeal diseases associated with weather, current climate variability and recent climate change, and examines factors that create their vulnerability. The step is fundamental to understanding who may be most affected by future climate change, why they may be affected, and how to appropriately target preventive measures.

Populations highly vulnerable to diarrhoeal diseases include children aged 5 years and younger, older people, people with chronic illness, people with malnutrition, urban populations, people living in poverty, and people living in countries at high risk of extreme weather events.

The data should be disaggregated by district, climatic or agroecological zone or rural/urban to identify the geographical distribution of demographic and health-based vulnerability. Mapping tools can be useful.

It is important to identify the non-physiological, non-demographic reasons for vulnerability, which may be behavioural or due to social, economic, environmental or political conditions. For example, the following questions can be explored:

- Why do some regions or populations have inadequate WASH services?
- Are there hotspots of highly vulnerable populations?

Table 5 outlines relevant factors that may determine vulnerability to climate-related diarrhoeal diseases. These factors manifest at various levels of society, including individual, household, community and subnational levels. This analysis serves as the foundation for further steps in the assessment and can be relatively simple to implement using expert opinion, problem trees, conceptual and geographical mapping, and population data analysis (clustering or multivariate). It will be refined with quantitative data in later steps.

Ranking populations by high, medium and low risk, or the relative importance of risk factors, can identify priorities.

Men, women, boys and girls may have different levels of vulnerability due to varied water and hygiene needs (e.g. menstrual hygiene management), gender differences in vulnerability to diarrhoeal diseases and related risk factors (e.g. undernutrition), and culturally defined gender roles that affect exposure, incidence and health outcomes for risks related to diarrhoeal diseases *(90)*. Gender analysis is of particular relevance for climate, WASH and diarrhoeal diseases.

Current vulnerability is a strong indicator for future vulnerability. Over time, however, the geographical distribution of risk and vulnerability is likely to shift. Changing trends in population growth, urbanization, migration and socioeconomic growth will influence livelihoods, access to water and sanitation services, and social protection mechanisms. Current trends relevant for future vulnerability should be noted.

**Table 5.** Populations vulnerable to diarrhoeal diseases

| Category | Vulnerability factor | Reasons for vulnerability |
|---|---|---|
| Demographic factors | Age (young, old)<br>Gender | Immunological susceptibility to diarrhoeal diseases and undernutrition in elderly people and children<br>Increased exposure, incidence and health outcomes for women and girls due to gender roles |
| Biological and health factors | Seasonal or chronic malnutrition<br>Infectious diseases and parasitic infections<br>Immunocompromised people and people living with HIV<br>People with mental or physical disabilities | Underlying medical conditions:<br>· predispose to infection<br>· hinder treatment<br>· exacerbate existing episodes of infection |
| Behavioural and cultural factors | Poor food preparation<br>Poor hygiene habits and knowledge<br>Unsafe defaecation practices<br>Strongly rooted or longstanding cultural practices | Lack of basic knowledge on transmission of infectious diseases and germs:<br>· increases risk of food contamination and spoilage<br>· decreases lack of acceptance of sanitary practices<br>· increases lack of awareness of infection<br>· increases transmission of infectious diseases<br>Firm acceptance of longstanding cultural practices prevents progression towards improved practices |
| Socioeconomic factors | Poverty<br>Inadequate access to or use of health care<br>Inadequate access to and use of safe water and sanitation<br>Poor education<br>Political, racial, ethnic or cultural instability<br>Discrimination and prejudice<br>Crowding and dense populations (urban slums)<br>Displaced populations<br>Marginalized populations (e.g. ethnic minorities, nomadic and semi-nomadic peoples) | Limited access to basic assets such as health care, food, water and sanitation<br>Diminished access to prevention, diagnosis and treatment<br>Groups that may be discriminated against for ethnic, caste, gender or socioeconomic vulnerabilities<br>Fragile or unsafe water and sanitation infrastructure may be damaged or destroyed<br>Displaced populations at risk of outbreaks due to limited resources, disrupted access to water, sanitation and health care, and crowding |

| Category | Vulnerability factor | Reasons for vulnerability |
| --- | --- | --- |
| Environmental and sociopolitical factors | Exposure to livestock and agricultural wastewater<br>Fragile ecosystems: dry lands, coastal areas, floodplains, mountains, Arctic<br>Climate variation in temperature and precipitation patterns<br>Poor or unplanned urban and peri-urban settlements and worker settlements<br>Conflict and post-conflict zones | Increasing water scarcity may increase water-related costs leading to:<br>· consumption patterns at fewer safe sources<br>· decreased allocation of water to hygiene and sanitation<br>· increased exposure to pathogens and tropical enteropathy<br>Areas highly susceptible to environmental effects of climate change may result in diminishment of livelihood assets and ecological change<br>Decreased water availability will strain resources and increase transmission of diseases<br>Diminished or limited infrastructure and adaptive capacity |

## *Additional resources*

Romanello M, McGushin A, Di Napoli C, Drummond P, Hughes N, Jamart L et al. The 2021 report of the Lancet Countdown on health and climate change: code red for a healthy future. Lancet. 2021;398(10 311):1619–1662.

Roy J, Tschakert P, Waisman H, Halim SA, Antwi-Agyei P, Dasgupta P et al. Sustainable development, poverty eradication and reducing inequalities. In: Masson-Delmotte V, Zhai P, Pörtner H-O, Roberts D, Skea J, Shukla PR et al., editors. Global warming of 1.5 °C: an IPCC special report on the impacts of global warming of 1.5 °C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty. Geneva: World Meteorological Organization; 2018 (https://www.ipcc.ch/site/assets/uploads/sites/2/2019/02/SR15_Chapter5_Low_Res.pdf, accessed 7 December 2021).

Progress on household drinking water, sanitation and hygiene 2000–2017: special focus on inequalities. New York: United Nations Children's Fund and World Health Organization; 2019 (https://apps.who.int/iris/handle/10665/329370, accessed 29 June 2022).

Climate change and health: vulnerability and adaptation assessment. Geneva: World Health Organization; 2021 (https://apps.who.int/iris/handle/10665/345968, accessed 29 June 2022).

A guide to equitable water safety planning: ensuring no one is left behind. Geneva: World Health Organization; 2019 (https://apps.who.int/iris/handle/10665/311148, accessed 7 December 2021).

The social dimensions of climate change. Geneva: World Health Organization; 2011 (https://www.afro.who.int/publications/social-dimensions-climate-change, accessed 7 December 2021).

### Step 2E. Document baseline information for monitoring changes in future vulnerability and evaluating adaptation options

Basic research questions to answer in this step:

- What conditions persist that determine this situation?
- What are the average and extreme climatic conditions?
- What are the current programmes and policies that control diarrhoeal diseases?
- In what ways do communities and institutions prepare for and cope with water stress, compromised water quality and outbreaks?

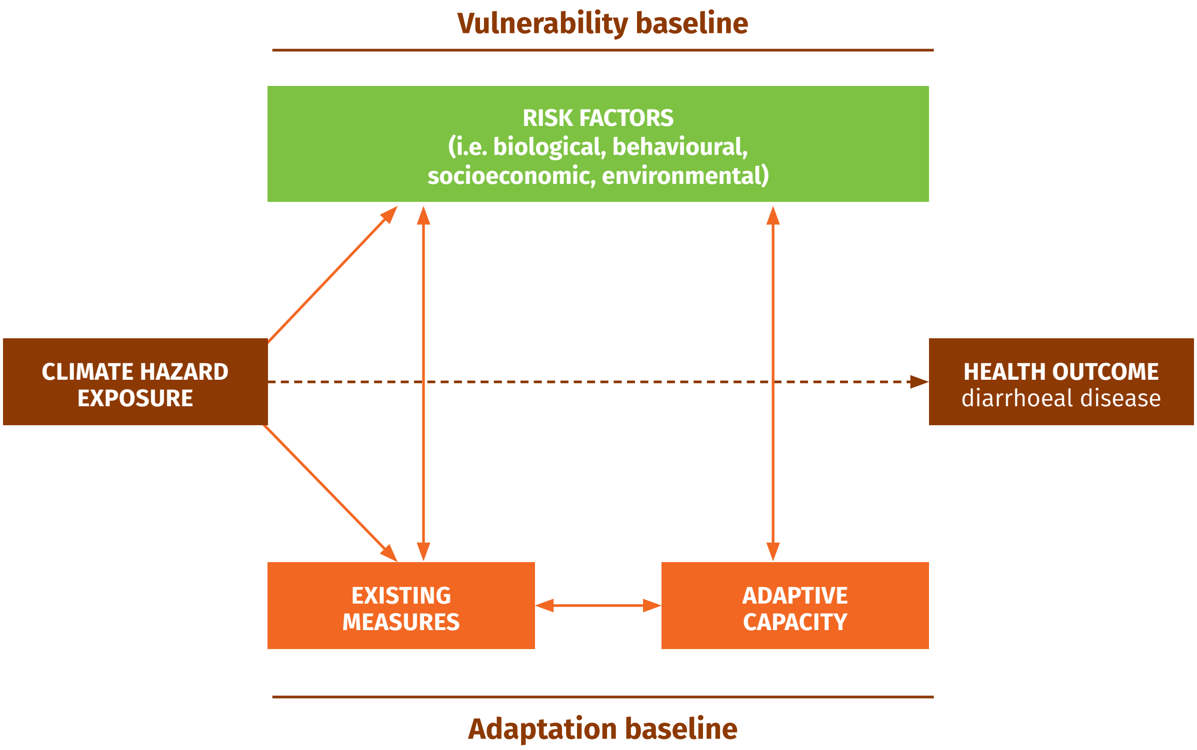
The baseline is a situation analysis, or a snapshot of the current conditions that determine the diarrhoeal disease status of the population using qualitative descriptions and quantitative metrics. The baseline helps examine why diarrhoeal diseases occur, and the relative importance of different conditions in causing and reducing transmission of the diseases. As multiple factors drive transmission, the best baselines will be constructed using a range of indicators and information from a variety of sectors through a multidisciplinary approach.

A comprehensive baseline should reflect current disease burden realities. It should be structured to allow for monitoring changes in principle risk conditions (e.g. water and sanitation) and response capacity over time. The baseline is essential for later steps of the V&A assessment where predictive models and scenarios of future conditions are created, based on local information (assuming known exposure–response relationships remain constant).

A baseline aims to capture "normal" conditions. Data that may reflect abnormal or crisis conditions must be noted (e.g. baseline set in an ENSO year or post-crisis situation) so that future monitoring and research can appropriately recognize these biases. Including too many indicators in the baseline may complicate future monitoring, so it may be better to select only some key indicators.

Relevant statistics and qualitative information could be gathered to describe the categories shown in Figure 7. These include climatic conditions that the population is exposed to, risk factors that determine vulnerability and may be modified by climate and interventions, existing policies and measures that modify outcomes, adaptive capacity to cope with future risks, and the health outcome (diarrhoeal diseases).

**Figure 7.** Key categories of information to be included in the climate and diarrhoeal diseases baseline




For a climate and diarrhoeal diseases baseline, it is important to obtain a good understanding of the following:

i. **Exposure to climate hazards:** capture historical averages and extreme climate conditions affecting the study area (e.g. temperature and precipitation patterns; type, frequency and magnitude of extreme weather events that affect the population; sanitary conditions). Climate conditions should be described in the context of local hydrology, noting other relevant environmental conditions (e.g. agriculture, coastal location). Descriptions of past extreme events and the type of impacts observed on diarrhoeal diseases and water and sanitation infrastructure can be helpful.

ii. **Risk factors:**

(a) **WASH and food:** capture key socioeconomic and environmental elements determining WASH and food safety, including local water resources (e.g. surface water and groundwater availability, glacial fed, arid zone, coastal aquifers); WASH conditions (e.g. types and distribution of major water and sanitation infrastructure, services, drinking water, piped systems, protected wells or springs); access to and use of safe water and improved sanitation stratified by rural/urban or socioeconomic status; types of handwashing; food preparation knowledge and behaviour; and description of known causes for endemic and epidemic diarrhoeal diseases.

(b) **Care and feeding practices:** capture relevant socioeconomic and behavioural determinants of diarrhoeal diseases (e.g. infant and young child feeding practices; child health-care-seeking behaviours; levels of knowledge of nutrition, food safety and hygiene).

(c) **Access to health services and healthy environments:** capture access to and use of good-quality health services, including rotavirus and cholera vaccine rates.

iv. **Existing measures:** capture effectiveness of current disease control, vaccination and WASH efforts (e.g. coverage rates), health services, national childhood disease priorities, food safety regulations, preparedness measures to address food- and water-related outbreaks, economic and social protection resources, and local customs and coping mechanisms for preventing outbreaks or maintaining hygiene during floods or droughts.

v. **Adaptive capacity:** capture community and health system capacity to respond to changes (e.g. possible increases in incidence of diarrhoeal diseases) and adapt in ways that will counter and manage increasing vulnerability to diarrhoeal diseases. This may include preparedness for outbreaks or increases in incidence of diarrhoeal diseases; capacity to anticipate and mitigate crises; institutional, legal and policy contexts (e.g. food safety and water policies) that enhance community resilience and community engagement; and humanitarian contexts.

vi. **Health and diarrhoeal disease status:** capture the ultimate outcome of interest (diarrhoeal diseases) and immediate causes of diarrhoeal diseases related to WASH. Data should be stratified by pathogen pathway (if possible), age and gender, and should describe seasonal calendars of when and why seasonal variations in incidence of diarrhoeal diseases may occur. Indicators for other health conditions exacerbated by or increasing vulnerability to diarrhoeal diseases (e.g. HIV, malnutrition) should be reflected.

Sex-disaggregated anthropometric data of infants and children aged under 5 years should be among the first data collected. It is recommended that baseline data for at least 10 years be used for longitudinal analyses in later steps of the V&A assessment.

This principle step of the assessment collects a vast amount of secondary data. An indicator framework can be useful to organize, understand and monitor these conditions over time. It is recommended that three to six key metrics (principle indicators) are selected to summarize the baseline information categories and provide a quantitative snapshot of current vulnerability of diarrhoeal diseases to climate change at the desired scale (e.g. national, provincial, district).

Selection criteria for indicators will vary, but ideally these metrics are easily measured through existing mechanisms such as Demographic and Health Surveys (DHS), Multiple Indicator Cluster Surveys (MICS), the UN-Water Global Analysis and Assessment of Sanitation and Drinking-Water (GLAAS) *(91)* and the WHO/UNICEF Joint Monitoring Programme for Water Supply, Sanitation and Hygiene (JMP) *(92)*. These indicators could be presented in conjunction with descriptive contextual information about behavioural, social and environmental factors that drive the observed geographical and spatial distribution of disease transmission within the population.

It is not necessary to analyse all these outcomes. Some examples of common indicators to represent these categories and potential sources are included in Table 6 and in the additional resources for this section.

The completed baseline should be analysed and refined to answer key questions such as:

- How many, and which, subpopulations are affected by and vulnerable to different types of diarrhoeal disease?
- What are the main causes of their vulnerability?

- What is the magnitude of climate stress and shocks currently experienced?
- How would decisions in other sectors influence these outcomes?

Cross-tabulations, regressions and multivariate analyses can provide insights about local determinants of diarrhoeal diseases and reduce uncertainty related to transmission dynamics.

**Table 6.** Metrics for understanding and monitoring the effects of climate on diarrhoeal diseases

| Vulnerability factor | Metrics | Data sources to consult |
|---|---|---|
| i. Climate hazard exposure | Average monthly precipitation for past 10 years (longer if available)<br>Frequency of precipitation anomalies: number and magnitude of extreme weather events that damaged water and wastewater treatment facilities, drainage and water sources (e.g. flooding, droughts, high temperatures, windstorms)<br>Type and number of algal blooms, cyclones or floods that reduced water quality or quantity<br>Annual freshwater withdrawals, total (billion cubic metres)<br>Mean annual surface temperature increase rate/ time period | WHO/United Nations Framework Convention on Climate Change (UNFCCC) Climate and Health Country Profiles<br>UNDP Country Climate Change Profiles<br>World Bank Climate Portal<br>Pacific Climate Change Science Country Brochures<br>Caribbean Health – Climatic Bulletin<br>World Weather Records<br>Global Precipitation Climatology Project (GPCP) |
| ii. Risk factors | | |
| (a) WASH and food | **Water**<br>Proportion of population with sustainable access to improved drinking-water sources[a]<br>Proportion of population with availability of at least 20 L of water per person per day from a source within 1 km of user's dwelling<br>Percentage of households with availability of improved infrastructure for small-scale water capture, storage and use<br>Proportion of population using piped water on premises for past 12 months<br>Proportion of water sources that are perennial versus seasonal<br>Proportion of population dependent on seasonal or surface waters | WHO/UNICEF Joint Monitoring Programme Data<br>WHO – Water, sanitation and hygiene: Exposure by country<br>UN - Water Global Analysis and Assessment of Sanitation and Drinking-water (GLAAS)<br>WHO Guidelines for drinking-water quality<br>UN Sustainable Development Goals Indicator Database<br>WHO Nutrition Landscape Information System (NLiS)<br>World Bank Data<br>UN World Water Development Report<br>WHO estimates of the global burden of foodborne diseases |

| Vulnerability factor | Metrics | Data sources to consult |
|---|---|---|
| | To measure inequality[b] in safe water access between users of same source type:<br>• percentage of population using tube wells by wealth quintile<br>• percentage of population using piped water by wealth quintile<br>• percentage of users of piped water with detectable free residual chlorine by wealth quintile<br>To measure inequality in safe water access between users of different source types:<br>• percentage of population with access to safe drinking water in poorest wealth quintile based on use of improved sources only<br>• percentage of population with access to safe drinking water in richest wealth quintile based on use of improved sources only<br>• percentage of population with access to safe drinking water in poorest wealth quintile based on use of improved water sources<br>• percentage of population with access to safe drinking water in richest wealth quintile based on use of improved source water sources<br>Extent to which, in frequency and level of involvement, service users participate in planning of WASH services<br>Existence of public complaint and feedback mechanism for service users to contribute to facility improvement<br>**Sanitation**<br>Proportion of population with sustainable access to improved sanitation<br>Proportion of population practising open defaecation<br>Percentage coverage of basic, safely managed and limited sanitation across communities<br>**Hygiene and food safety**<br>Availability of wastewater for agricultural purposes<br>Number of households with specific place for handwashing where water and soap are present<br>Prevalence of foodborne diseases and incidence of foodborne disease outbreaks | |

| Vulnerability factor | Metrics | Data sources to consult |
| --- | --- | --- |
| (b) Care and feeding practices | **Infant and young child feeding practices**<br>Proportion of infants aged under 6 months who are exclusively breastfed<br>Proportion of infants aged 6–8 months who receive solid, semisolid or soft food<br>Proportion of children aged 6–23 months who receive minimal acceptable diet (including foods from four or more food groups)<br>Percentage of women aged 15–19 years who are mothers or pregnant with their first child<br>**Health-care access and seeking behaviours**<br>Percentage of births attended by skilled health personnel<br>Percentage of children aged 1 year immunized against measles<br>Percentage of children with diarrhoea who receive zinc<br>Percentage of women receiving daily iron (60 mg) and folate (400 µg) supplements during pregnancy<br>Percentage of children aged 6–59 months who received at least 1 high-dose vitamin A (and percentage receiving dose 2) | UN Sustainable Development Goals Indicator Database<br>WHO Nutrition Landscape Information System (NLiS) |
| (c) Access to health services and healthy environments | **Health service capacity and access**<br>Density of hospital beds (per 10 000 population)<br>Density of physicians (total number per 1000 population)<br>Access to essential medicines<br>Coverage of rotavirus and cholera vaccination<br>**Environmental conditions**<br>Type and number of algal blooms, cyclones or floods that reduce aquaculture yields or available species<br>Proportion of agricultural land that is rain-fed versus irrigated<br>Annual freshwater withdrawals, total (billion cubic metres)<br>Agricultural irrigated land (percentage of total agricultural land) | WHO – Universal Health Coverage Data (GHO)<br>UN Sustainable Development Goals Indicator Database<br>WHO Nutrition Landscape Information System (NLiS)<br>WHO/UNICEF Joint Monitoring Programme Data<br>World Bank Data |

| Vulnerability factor | Metrics | Data sources to consult |
|---|---|---|
| iii. Existing measures | National coverage of water quality monitoring systems for microbiological or chemical contamination following floods or droughts<br>Integration of climate and weather data in health surveillance and early warning systems<br>Food safety and water safety monitoring and regulation in place<br>Irrigation and wastewater safety consider a range of climate conditions<br>Number of health workers trained in management of acute diarrhoeal diseases<br>Monitoring and public restrictions for recreational water use<br>Duration of time since last national assessment for sanitation by WHO and UN-Water<br>Data available and used for resource allocation for drinking water and sanitation<br>Sources of funding (e.g. tariffs, taxes, transfers), financial allocation for water and sanitation services, and respective adequacy to sustain WASH services<br>Vaccination programme coverage for rotavirus and cholera | UN World Water Development Report<br>WHO/United Nations Framework Convention on Climate Change (UNFCCC) Climate and Health Country Profiles |
| iv. Adaptive capacity | **Enabling environment**<br>Strength of water governance:<br>• national legislation and adaptation strategies for climate and health or water and agricultural sector includes diarrhoeal disease protection<br>• health and WASH services have assessed future performance in light of projected climate change<br>• performance information collected and analysed, and lessons learnt are incorporated into policy and programming<br>**Community coping mechanisms**<br>Availability of early warning systems for epidemic potential diseases at community level<br>Multiple options available for delivering or accessing safe water and sanitation services to reduce dependency on single sources<br>Mechanisms in place for community-based organizations and services to coordinate and communicate adequately with formal health services<br>Mechanisms in place to counter supply failures in pharmaceuticals and water supplies | UN World Water Development Report<br>WHO/UNFCCC Health and Climate Change Country Profiles |

| Vulnerability factor | Metrics | Data sources to consult |
|---|---|---|
| v. Health and diarrhoeal disease status | Number of children aged under 5 years with diarrhoea in previous 2 weeks who received oral rehydration therapy (packet or recommended homemade fluid or increased fluids) and continued feeding during episode of diarrhoea<br>Percentage of children aged under 5 years with diarrhoea receiving oral rehydration therapy[c]<br>Percentage of mothers of children aged 0–23 months who sought advice treatment from service providers for episodes of diarrhoea, by district<br>All-cause child mortality rate (children aged under 5 years)<br>Mortality and burden of disease attributable to WASH – number of deaths, death rate, number or rate of disability-adjusted life-years (DALYs):<br>• diarrhoea-attributable deaths (1000s) in children aged under 5 years<br>• diarrhoea-attributable DALYs per 100 000 children aged under 5 years<br>• diarrhoea-attributable DALYs per 100 000 people<br>Intestinal helminthic infection rates<br>Seasonal incidence of diarrhoeal diseases<br>Infection rates (asymptomatic or symptomatic) by rotavirus, norovirus, *E. coli*, *Shigella* spp., *Campylobacter* spp., *Salmonella* spp., *G. lamblia, E. histolytica* and *Cryptosporidium* spp.<br>Foodborne disease outbreaks reported<br>Coinfection rates: HIV prevalence<br>Undernutrition:<br>• percentage of children underweight (weight for age below 2 standard deviations of WHO child growth standards median)[d]<br>• percentage of stunted children (height for age below 2 standard deviations of WHO child growth standard median)<br>• percentage of child wasting (weight for height below 2 standard deviations of WHO child growth standard median) | WHO - Water, sanitation and hygiene: Burden of disease by country<br>WHO – NLIS<br>WHO/UNICEF Joint Monitoring Programme Data<br>WHO Nutrition Landscape Information System (NLiS)<br>Demographic and Health Surveys |

[a] Use of an improved drinking water source is a proxy for the use of safe drinking water.

[b] Inequality assessment is based on use of an improved source as per the JMP methodology, and compares this with an approach that combines use of an improved source with measured chemical and microbial water quality parameters. It also assesses safe water access in relation to quintiles based on household socioeconomic status, which is based on durable asset ownership, access to services, and educational level of the head of the household *(93)*.

[c] Proportion of children aged 0–59 months who had diarrhoea in the past 2 weeks and were treated with oral rehydration salts or an appropriate household solution.

[d] The percentage can be substituted by absolute numbers (× 1000 children).

## *Additional resources*

Relevant global datasets such as the GLAAS, UNICEF, WHO and World Bank databases that provide useful country profiles allow for a range of aggregated variables related to climate-related health risks, water and sanitation and diarrhoeal diseases to be gathered quickly and identify the types of data to be sourced elsewhere. WHO has aggregated key national WASH data from the United Nations and partner organizations in the Global Health Observatory.

National household surveys (e.g. DHS, MICS) and other instruments should be sourced through national statistics agencies, development agencies and research institutes for disaggregated subnational data. Community-level surveys and other qualitative instruments may be necessary to compile the baseline data.


The CARIWIG portal [website]. Caribbean Weather Impacts Group (http://cariwig.caribbeanclimate.bz, accessed 29 June 2022).

DHIS2 Google Earth Engine app and data importer App v1.1.0 [website] (https://github.com/EyeSeeTea/dhis2-gee-app-blessed/releases/tag/1.1.0, accessed 29 June 2022).

Explore a world of health data. In: Global Health Observatory [website] (http://www.who.int/gho/en/, accessed 29 June 2022).

Number of reported cases of cholera. In: Global Health Observatory [website] (https://www.who.int/data/gho/data/indicators/indicator-details/GHO/number-of-reported-cases-of-cholera, accessed 29 June 2022).

Water, sanitation and hygiene: burden of disease. In: Global Health Observatory [website] (https://www.who.int/data/gho/data/themes/topics/topic-details/GHO/water-sanitation-and-hygiene-burden-of-disease, accessed 29 June 2022).

UNDP climate change country profiles. In: Oxford University Centre for the Environment [website] (https://www.geog.ox.ac.uk/research/climate/projects/undp-cp/, accessed 29 June 2022).

Pacific climate change data [website]. Pacific Climate Change Science (https://www.pacificclimatechangescience.org/climate-tools/pacific-climate-change-data-portal/, accessed 29 June 2022).

Sustainable Development Goals global database [website]. United Nations (https://unstats.un.org/sdgs/indicators/database/, accessed 29 June 2022).

Multiple indicator cluster surveys [website]. United Nations Children's Fund (http://mics.unicef.org/surveys, accessed 30 November 2021).

National communication submissions from Non-Annex I parties. Bonn: United Nations Framework Convention on Climate Change (http://unfccc.int/national_reports/non-annex_i_natcom/items/2979.php, accessed 29 June 2022).

Demographic and health surveys. Washington, DC: United States Agency for International Development (http://dhsprogram.com/data/available-datasets.cfm, accessed 30 November 2021).

Climate change knowledge portal [website]. World Bank (https://climateknowledgeportal.worldbank.org/, accessed 29 June 2022).

Data[website]. World Bank (http://data.worldbank.org/indicator?tab=all, accessed 29 June 2022).

Health and climate change country profiles. Geneva: World Health Organization (https://www.who.int/teams/environment-climate-change-and-health/climate-change-and-health/evidence-monitoring/country-profiles, accessed 29 June 2022).

Nutrition Landscape Information System [website]. World Health Organization (https://www.who.int/teams/nutrition-and-food-safety/databases/nutrition-landscape-information-system, accessed 30 November 2021).

UN-Water Global Analysis and Assessment of Sanitation and Drinking-water (GLAAS) [website]. World Health Organization (https://www.who.int/teams/environment-climate-change-and-health/water-sanitation-and-health/monitoring-and-evidence/wash-systems-monitoring/un-water-global-analysis-and-assessment-of-sanitation-and-drinking-water, accessed 29 June 2022).

Joint Monitoring Programme (JMP) for Water Supply, Sanitation and Hygiene [website]. World Health Organization and United Nations Children's Fund (https://washdata.org/, accessed 29 June 2022).

National services [website]. World Meteorological Organization (https://public.wmo.int/en/about-us/members/national-services, accessed 29 June 2022).

## Step 3. Capacity assessment: assess the capacities of health and WASH systems

Basic research questions to answer in this step:

- What conditions persist that determine this situation?
- What are the average and extreme climatic conditions?
- What are the current programmes and policies that control diarrhoeal diseases?
- In what ways do communities and institutions prepare for and cope with water stress, compromised water quality and outbreaks?

Climate-sensitive health outcomes, including diarrhoeal diseases, are among the leading causes of global morbidity and mortality. A wide range of policies and plans exist to control these health burdens, but many countries are still ill-equipped to tackle the health impacts caused by current and future climate variability and change. Moreover, they may experience health and health-relevant systems damage and setbacks when disease burdens exceed the capacity of health systems. It is important to assess the capacity of national health systems, including their effectiveness, strengths and weaknesses under current and future conditions of climate variability and change.

This step proposes possible improvement measures for existing programmes and actions to build the capacity of health systems to mitigate and prevent the risks caused by climate change. The following should be considered:

- Identify the policies, programmes and infrastructure designed to manage current and future burden of diarrhoeal diseases.
- Assess the current capacity of health systems to address the risks of increased burden of diarrhoeal diseases as a result of climate change.
- Assess the current actions of other sectors that affect the risks of diarrhoeal diseases.

Table 7 outlines key components to strengthen capacity in health programmes and health-care facilities to manage the increased risk of diarrhoeal diseases posed by climate change.

**Table 7.** Key components to strengthen capacity to manage climate change-induced risk of diarrhoeal diseases

| | |
|---|---|
| Diarrhoeal diseases programme | Climate-resilient water safety plans and sanitation safety plans<br>Regulations to control water- and foodborne diseases and contaminants<br>Programmes to increase access to and use of safe water in sufficient quantities and improved sanitation<br>Surveillance and monitoring programmes for diarrhoeal diseases<br>Educational programmes on food handling and safety<br>Water quality regulations<br>Maternal and child health programmes, including vaccination campaigns |
| Nutrition programme | Monitoring programmes for malnutrition in vulnerable populations<br>Programmes to support local food production and sustainable food sources<br>Emergency response plans to increase food and nutrition security<br>Nutrition education for individuals and communities |
| Health-care facilities | Health workforce<br>Reliability of water, sanitation and waste management systems<br>Reliability of energy sources<br>Safety and reliability of infrastructure, technology, products and services |
| Extreme weather events | Early warning systems and emergency response plans<br>Programmes to monitor outbreaks of diarrhoeal diseases during and after extreme weather events<br>Educational programmes for individuals, communities, responders and health-care workers on risks of and appropriate responses to extreme weather events<br>Cross-sectoral management of disaster risk reduction activities |

## *Additional resources*

Climate-resilient water safety plans: managing health risks associated with climate variability and change. Geneva: World Health Organization; 2017 (https://apps.who.int/iris/handle/10665/258722, accessed 29 June 2022).

WHO guidance for climate resilient and environmentally sustainable health care facilities. Geneva: World Health Organization; 2020 (https://apps.who.int/iris/handle/10665/335909, accessed 29 June 2022).

## Step 4. Future risk assessment: qualitatively or quantitatively project climate change-related risk of diarrhoeal diseases

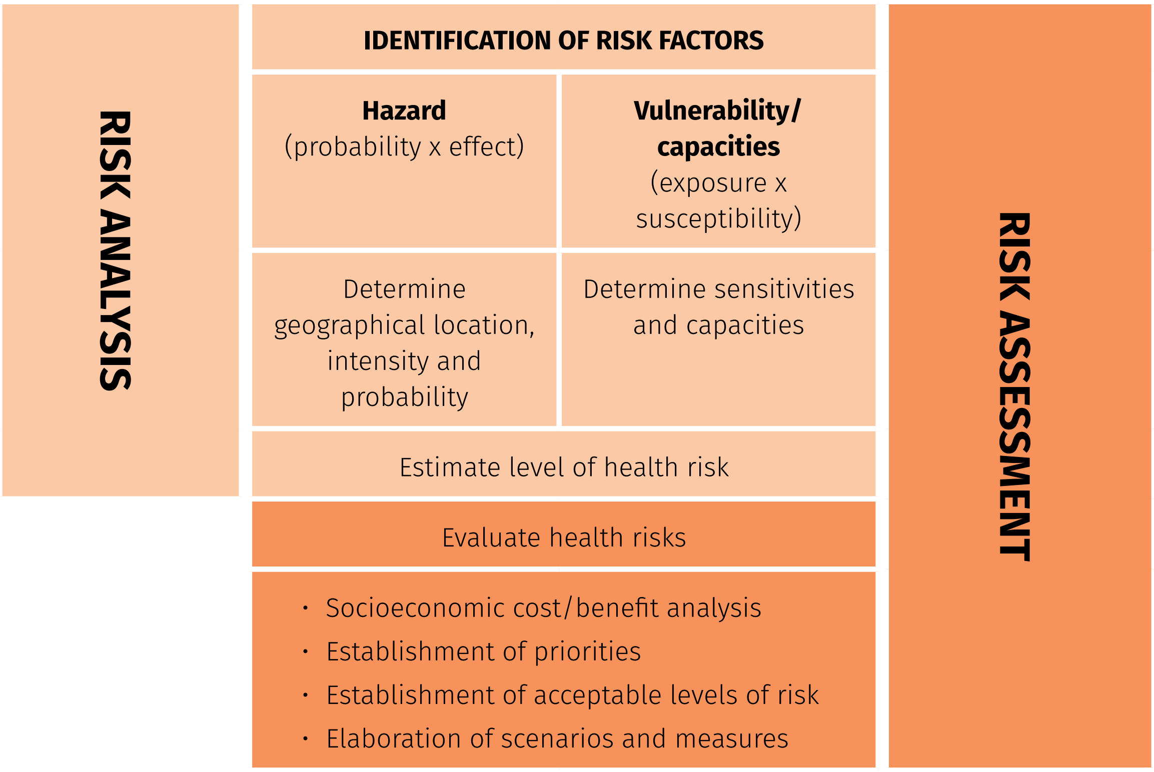
Basic research questions to answer in this step:

- How will the predicted changes in climate and other factors affect future health status and risk of diarrhoeal diseases in the study area?
- How far into the future are these changes expected?

One of the main goals of a V&A assessment is to understand the current climate risk and the risks of health outcomes, including diarrhoeal diseases, and to predict the future change of climate and the corresponding risks of health outcomes. Future prediction is critical to strengthen the core functions of health systems against upcoming health threats and improve the current risk management actions on climate-sensitive health outcomes.

The magnitude and geospatial patterns of health impacts depend on the actual exposure to climate hazards (e.g. heatwaves, floods, storms) and the vulnerability and capacity of the population or community. Assessing their impact on health is the risk assessment (Figure 8).

**Figure 8.** Risk assessment process




Source: Modified from Living with risk: a global review of disaster reduction initiatives – preliminary version. Geneva: United Nations Inter-Agency Secretariat International Strategy for Disaster Reduction; 2002.

Risk assessment is a process to determine the nature and extent of risk by analysing potential hazards and evaluating existing conditions of vulnerability and capacities that could potentially impact human health and the environment on which they depend. As a process, it is recommended to include the following steps:

- Describe how current risks of diarrhoeal diseases could change under diverse scenarios of climate change and development.
- Estimate the possible additional diarrhoeal diseases due to climate change.

Projected risks may present some degree of uncertainty due to the inherent nature of future prediction. Therefore, it is necessary to describe the potential biases and conduct bias sensitivity analysis by considering a range of uncertainties and the consequent risk estimation.

The impacts of climate change on diarrhoeal diseases that may occur in a particular location will depend on the actual climate change experienced, the future socioeconomic development of the area that is driving the true vulnerability of the community and region, and the actions in place to control transmission of diseases. Constructing future scenarios for diarrhoeal diseases is a complex task – the qualitative and quantitative approaches used will depend on the data and resources available to the study, and the decision needs for understanding future risks.

The assessment should aim to cover the timeframe of decision needs and position these decisions within long-term climate and water, hygiene and food safety conditions. For example, operational planning needs may require short-term projections (e.g. seasonal and intra-annual influences of climate variability) to inform early warning systems or emergency planning. Long-term adaptation planning and research may require long-term (20–100 years) projections to understand systemic changes in the food system, landscape and society. A single time value (e.g. the year 2020 or 2050) is adequate if the aim is to show what can happen in different parts of the country over time, but three time periods (e.g. 2015–2025, 2026–2050 and 2051–2080) should be chosen if the aim is to show at what time and to what degree various adaptive measures need to be implemented *(94)*.

When trying to understand how the climate may change at the national or subnational level, it is advised to consult the national climate authorities and use the same climate scenarios and timeframes as used for UNFCCC national climate communications or other studies to encourage compatibility. Trade-offs are to be expected between the kinds of information available from climate models (which are better at predicting interdecadal trends rather than year-to-year variations); projections of socioeconomics, water and agriculture (which tend to be more accurate in the short rather than the long term); and the time horizon of decision-makers (which is often only a few years into the future).

Both quantitative and qualitative methods can be used. As the impacts of climate on diarrhoeal diseases are indirect and complex, however, qualitative scenarios may be the most useful way to begin identifying how risk factors may evolve over time. For quantitative modelling, long-term projections often use baseline data to model how diarrhoea transmission may evolve in the absence of climate change, accounting for factors such as economic growth rates, future investments in programming, water availability, population dynamics and current levels of disruption from extreme events. Then, assuming that exposure–response relationships remain constant, new information on how the climate is likely to change the principle risk factors in the study area (e.g. increased frequency of flooding or warmer daytime temperatures) and the sensitivity analysis factors (e.g. flooding or warmer temperatures are observed to increase relative risk of diarrhoea by *x*%) can be applied to extrapolate future conditions.

For both approaches, existing projections should be used for reference, noting that current long-term predictions of the effect climate change will have on diarrhoeal diseases are based predominantly on projected temperature models and do not account for social and economic growth, precipitation or the role of rotavirus vaccination. The study should aim to further refine the resolution of such projections, using similar or diverse methods, for the study area.

A 2016 estimate of the impact of warming temperatures on incidence of diarrhoeal diseases found a 7% increase for a 1 °C change in ambient temperature *(32)*. A comprehensive regional projection was constructed in 2011 *(76)*. Table 8 describes the regional distribution of these projected increases in the relative risk of diarrhoea over three time periods. A range of additional considerations may be relevant and should be explored, such as population displacement or migration, regional changes that may have cross-border consequences on local disease transmission, changes in agriculture and water security, and population growth and dynamics.

**Table 8.** Projected relative risk of diarrhoea between 2010 and 2099 relative to a 1961–1990 baseline

| Region | Projected relative risk (standard deviation) | | |
|---|---|---|---|
| | 2010–2039 | 2040–2069 | 2070–2099 |
| South America | 1.09 (0.04) | 1.17 (0.07) | 1.25 (0.11) |
| North America | 1.10 (0.04) | 1.19 (0.08) | 1.27 (0.11) |
| Middle East | 1.11 (0.05) | 1.20 (0.08) | 1.29 (0.12) |
| Equatorial Africa | 1.08 (0.04) | 1.15 (0.06) | 1.23 (0.10) |
| Southern Africa | 1.09 (0.04) | 1.18 (0.07) | 1.26 (0.11) |
| South-East Asia | 1.08 (0.03) | 1.15 (0.06) | 1.22 (0.09) |

Source: Kolstad EW, Johansson KA. Uncertainties associated with quantifying climate change impacts on human health: a case study for diarrhea. Environ Health Perspect. 2011;119(3):299–305.

### Communicating uncertainty in predictive models

The credibility and validity of predictive statistical models depends on the quality and quantity of data and the analytical capacity and availability of useful models to test the desirable associations. Realistically, causal models of climate and disease impacts may be difficult or impossible to establish *(95)*. The associations between climate change and disease are complex due to the social and mediated factors of disease transmission and exposure. Robust models can be very insightful but require clear descriptions of model uncertainty and the parameters measured. This is particularly essential in V&A assessments, which may not be fully peer-reviewed before making recommendations to policy-makers. False predictions based on unfounded data or methods may have undesirable consequences for policy and programming. Thus, the use of robust decision-making tools based on available data may be more appropriate than predictive modelling in some cases.

## *Additional resources*

See Annex 4 for existing futures studies of diarrhoeal diseases associated with climate, and Annex 5 for datasets and tools for creating climate-based projections of diarrhoeal diseases.

Campbell-Lendrum D, Woodruff R. Climate change: quantifying the health impact at national and local levels. In: Prüss-Üstün A, Corvalán C, editors. Geneva: World Health Organization; 2007 (https://apps.who.int/iris/handle/10665/43708, accessed 29 June 2022).

Climate Prediction Center – international desks. In: Climate Prediction Center [website] (http://www.cpc.ncep.noaa.gov/products/international/index.shtml, accessed 29 June 2022).

El Niño/La Niña Home [website]. Climate Prediction Center (http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/lanina/, accessed 29 June 2022).

Humanitarian Early Warning System [website]. Eldis (http://www.eldis.org/go/home&id=7288&type=Organisation#.WVPAVeuGOUk, accessed 29 June 2022).

Semenza JC, Suk JE, Estevez V Ebi KL, Lindgren E. Mapping climate change vulnerabilities to infectious diseases in Europe. Environ Health Perspect. 2012;120(3):385–392.

Quality criteria for the evaluation of climate-informed early warning systems for infectious diseases. Geneva: World Health Organization; 2021 (https://apps.who.int/iris/handle/10665/345530, accessed 29 June 2022).

Operational guide using the web-based dashboard: Early Warning and Response System (EWARS) for dengue outbreaks. Geneva: World Health Organization; 2020 (https://apps.who.int/iris/handle/10665/332323, accessed 29 June 2022).

Strengthening surveillance of and response to foodborne diseases. Geneva: World Health Organization; 2017 (https://www.who.int/publications/i/item/strengthening-surveillance-of-and-response-to-foodborne-diseases/, accessed 30 November 2021).

Integrated surveillance and climate-informed health early warning systems. Geneva: World Health Organization (https://www.who.int/teams/environment-climate-change-and-health/climate-change-and-health/country-support/integrated-surveillance-and-climate-informed-health-early-warning-systems, accessed 29 June 2022).

## Step 5. Adaptation assessment: identify and prioritize policies, programmes and actions to address current and projected risks of diarrhoeal diseases

Basic research questions to answer in this step:

- What adaptation measures can be implemented to mitigate the impacts of climate variability and change on the burden of diarrhoeal diseases?
- Which adaptation options should be prioritized?

The identification of adaptation options is based on judgements about whether current and planned policies and programming would be adequate to manage the identified potential shocks and pressures on nutrition.

Standard approaches for policy analysis and measuring programme coverage and efficacy can be used to answer questions such as:

- Do coverage gaps and vulnerabilities exist in certain geographical areas?
- How will health, water and sanitation services and infrastructure perform under diverse climate shocks and stresses?
- In what contexts could failures be expected?
- Are specific vulnerable populations underserved or unprotected from the impacts of extreme events?
- Are there specific times of year that require additional programmatic support or more intensive monitoring?
- Up to what point will current capacities and approaches be sufficient to manage the magnitude of projected climate impacts on diarrhoeal diseases?

This step is most effective if it involves decision-makers and practitioners familiar with available and current interventions.

Once impacts have been identified at appropriate spatial and temporal scales (e.g. now, in 5 years, in 10 years, in 20 years), all possible adaptation policies and programmes should be identified, screened for feasibility and prioritized. Some of the most important protective measures may be general (e.g. poverty reduction), and many may occur in other sectors. Specific interventions should be evidence-based and adhere to international and national standards. Interventions can be selected from recommended control interventions for diarrhoeal diseases *(96, 97)*.

Identifying adaptation options is not simply about implementing "more of the same". To address the issues presented by climate change, these interventions should be designed to be future-looking and proactive; responsive to new knowledge about climate-sensitivity and vulnerability of diarrhoeal diseases generated from the study; informed by trends and information about the climate, society and environment; and increasingly flexible to respond to changes and unexpected challenges *(98)*. Understanding how gender dynamics determine WASH and health outcomes will also be critical to the design of effective interventions *(99)*.

WASH and disease control programming can become more climate-responsive by strengthening climate considerations in areas of leadership and governance, workforce, vulnerability, capacity and adaptation assessments, integrated risk monitoring and early warning, research, management of environmental determinants of health and nutrition, emergency preparedness and management, and finance *(100)*.

WHO guidance on protecting health from climate change through health adaptation planning provides further information on integrating WASH adaptation into the national adaptation plan process *(101)*.

Table 9 list some examples of options to be considered in an adaptation plan. These options have been structured using the categories included in the WHO *Operational framework for building climate resilient health systems*, which provides further information and guidance on developing a comprehensive health adaptation plan *(100)*.

For solutions to be locally and culturally appropriate and effective, communities must be involved in the design and implementation. Women in particular should be consulted to understand household water and sanitation behaviours, feeding habits, nutritional needs, and food preparation and hygiene habits. It is important to remember that urban and rural areas differ in the available options at the household level, and that adequate and environmentally sustainable energy and water are necessary requirements for food preparation and hygiene.

**Table 9.** Adaptation options to enhance resilience to climate-driven diarrhoeal diseases

| Building blocks and resilience components | Examples |
|---|---|
| **Leadership and governance** | |
| | National health adaptation plans include risks of food- and water-related diseases |
| | Climate change and WASH focal point designated within health or other relevant ministry with specific programme of action and budget allocation |
| | Agreements established between ministries of health, agriculture and environment to increase policy coherence and multidisciplinary collaboration at national level to increase and maintain access to safe water and improved sanitation |
| | Climate variability and change considerations mainstreamed into WASH policies |
| | National strategy on climate change and WASH |
| | Multisectoral policies, integrated plans and programmes for climate change adaptation developed or revised to include health and the health sector |
| | Water policies and regulations account for and are adjusted adequately to remain protective of human health |
| **Health workforce** | |
| | Health personnel trained in use of climate information |
| | Human resources allocated to respond to increased needs during outbreaks of diarrhoeal diseases |
| | Community training to identify and mitigate risks of diarrhoeal diseases during droughts and floods |

| Building blocks and resilience components | Examples |
| --- | --- |
| **Health information systems** | |
| Vulnerability, capacity and adaptation assessment | Understanding of high-risk population areas and seasonal disease risks refined<br>Climate sensitivity of diarrhoeal diseases assessed for local context |
| Integrated risk monitoring and early warning | Climate data integrated in health early warning and surveillance systems<br>Surveillance of foodborne outbreaks<br>Early warning systems for cholera, cryptosporidium and other diarrhoeal diseases of national priority<br>Water quality monitoring<br>Community surveillance of water sources<br>Water availability monitoring<br>Agriculture and health monitoring of irrigation water safety and wastewater use<br>Communication strategy for different target audiences |
| Health and climate research | Sensitivity of diarrhoeal diseases to rainfall variability, extreme events and other climate variables assessed<br>Foodborne disease climate-related risks and communication needs identified<br>National stratification of diarrhoeal aetiology by region<br>Community water security assessments include climate-related risks |
| **Climate-resilient and sustainable technologies and infrastructure** | |
| | Sanitation against extreme precipitation events strengthened<br>Structures for water control and processing improved<br>Water resource planning at sub-watershed levels<br>New WASH infrastructure built to withstand climate extremes |
| **Service delivery** | |
| Management of environmental determinants of health | Community mobilization for waste management and vector control activities<br>Universal access to clean potable water and improved sanitation ensured<br>Integrated water quality management and monitoring<br>Climate-resilient water and sanitation safety plans |
| Climate-informed health programmes | Seasonal campaigns for prevention (handwashing, vector control, food storage, preparation) and health-seeking behaviours<br>Rotavirus and cholera vaccination in high-risk areas<br>Outbreak management<br>Risk mapping and sentinel surveillance during high-risk periods |

| Building blocks and resilience components | Examples |
|---|---|
| Emergency preparedness and management | Water utilities and health facilities informed of flood and cyclone forecasts and activate emergency protocols<br>Emergency planning and supplies in place for outbreaks of diarrhoeal diseases<br>Community and clinic flood preparedness to ensure emergency and regular life-saving services are available during flood events<br>Temporary measures to reduce pathogen concentration in drinking water during extreme weather events and outbreaks of diarrhoeal diseases<br>Community training to identify and mitigate risks of diarrhoeal diseases during droughts or floods |
| **Climate and health financing** | |
| | National adaptation plans include adequate budgetary allocations and incorporate appropriate actions to decrease risk of diarrhoeal diseases<br>Screening for climate variability, climate change risks and health protection included as criteria for selecting investments in water and sanitation sector<br>Resources mobilized from international climate change funding mechanisms for climate adaptation for WASH infrastructure |

## *Additional resources*


Batchelor C, Smits S, James AJ. Adaptation of WASH services delivery to climate change and other sources of risk and uncertainty. The Hague: IRC International Water and Sanitation Centre; 2011 (https://www.ircwash.org/sites/default/files/Batchelor-2011-Adaptation.pdf, accessed 29 June 2022).

Guidance on water and adaptation to climate change. Geneva: Economic Commission for Europe; 2009 (http://www.unece.org/fileadmin/DAM/env/water/publications/documents/Guidance_water_climate.pdf, accessed 29 June 2022).

PROVIA: Programme of Research on Climate Change Vulnerability, Impacts and Adaptation. In: Global Climate Forum [website] (https://globalclimateforum.org/portfolio-item/provia/, accessed 29 June 2022).

How to integrate climate change adaptation into national-level policy and planning in the water sector: a practical guide for developing country governments. Teddington: Tearfund; 2010 (http://tilz.tearfund.org/~/media/files/tilz/topics/watsan/water_adaptation_guide_web.pdf, accessed 29 June 2022).

Tirado MC, Clarke R, Jaykus LA, McQuatters-Gollopd A, Franke JM. Food safety and climate change: a review. Food Res Int. 2010;43(7):1745–1765.

Multi-criteria analysis. In: Assessing the costs and benefits of adaptation options: an overview of approaches. Bonn: United Nations Framework Convention on Climate Change; 2010 (https://unfccc.int/resource/docs/publications/pub_nwp_costs_benefits_adaptation.pdf, accessed 29 June 2022).

Checklists to assess vulnerabilities in health care facilities in the context of climate change. Geneva: World Health Organization; 2021 (https://apps.who.int/iris/handle/10665/340656, accessed 29 June 2022).

New cost-effectiveness updates from WHO-CHOICE. Geneva: World Health Organization; 2021 (https://www.who.int/news-room/feature-stories/detail/new-cost-effectiveness-updates-from-who-choice, accessed 29 June 2022).

Quality criteria for the evaluation of climate-informed early warning systems for infectious diseases. Geneva: World Health Organization; 2021 (https://apps.who.int/iris/handle/10665/345530, accessed 29 June 2022).

Quality criteria for health national adaptation plans. Geneva: World Health Organization; 2021 (https://apps.who.int/iris/handle/10665/339454, accessed 29 June 2022).

WHO guidance for climate resilient and environmentally sustainable health care facilities. Geneva: World Health Organization; 2020 (https://apps.who.int/iris/handle/10665/335909, accessed 29 June 2022).

Discussion paper: climate, sanitation and health. Geneva: World Health Organization; 2019 (https://www.who.int/publications/m/item/discussion-paper-climate-sanitation-and-health, accessed 29 June 2022).

Climate-resilient water safety plans: managing health risks associated with climate variability and change. Geneva: World Health Organization; 2017 (https://apps.who.int/iris/handle/10665/258722, accessed 29 June 2022).

Lessons learned on health adaptation to climate variability and change: experiences across low- and middle-income countries. Geneva: World Health Organization; 2015 (https://apps.who.int/iris/handle/10665/176009, accessed 29 June 2022).

Gender, climate change and health. Geneva: World Health Organization; 2014 (https://apps.who.int/iris/handle/10665/144781, accessed 29 June 2022).

Mainstreaming gender in health adaptation to climate change programmes. Geneva: World Health Organization; 2012 (https://www.who.int/westernpacific/publications-detail/mainstreaming-gender-in-health-adaptation-to-climate-change-programmes, accessed 29 June 2022).

Operational framework for building climate resilient health systems. Geneva: World Health Organization; 2014 (https://apps.who.int/iris/handle/10665/189951, accessed 29 June 2022).

WHO guidance to protect health from climate change through health adaptation planning. Geneva: World Health Organization; 2014 (https://apps.who.int/iris/handle/10665/137383, accessed 29 June 2022).

## Step 6. Inform policies and plans and iterative monitoring

### Synthesizing the knowledge and understanding gained as input into a health adaptation plan

As part of the V&A process, a policy brief with a synthesis of key messages should be prepared to inform decision-makers and stakeholders overseeing the implementation of recommendations. It is important to ensure the results of the V&A assessment are included in the key climate change policies and action plans, such as nationally determined contributions (NDCs), national communications and national adaptation plans (NAPs). The V&A results provide the key content to inform the development of a comprehensive health national adaptation plan (HNAP), as part of the national adaptation plan process.

### An iterative process for managing and monitoring diarrhoeal disease risks

Effective monitoring should aim to ensure recognized risks of diarrhoeal diseases are being appropriately managed, population vulnerabilities do not worsen, and identified gaps in coverage or increasing vulnerability are countered.

Management of climate-related risks will evolve as climatic environments, economies and populations change, and as more is understood about the relationships between weather, climate and diarrhoeal diseases. Adaptation is a process that is often planned amid uncertainty, with incomplete knowledge, and requiring substantial learning, capacity-building and institutional change.

Monitoring of baselines and adaptation plans plays a critical role in this process. Plans and resources for monitoring should be included in the adaptation plan. To identify needs and inform adjustments in interventions, it is essential to track changing risk conditions in the short, medium and long term, and to track the degree of desired impact from policy, programme or project output adaptation.

The variables to be monitored are the same as those included in the baseline and should cover all categories affecting vulnerability (e.g. climate hazard exposure, risk factors, existing measures, adaptive capacity, health and diarrhoeal disease status). The suite of indicators to be monitored will vary according to the timeframe of the likely response, requiring more frequent review of some indicators and only occasional monitoring of others:

- Immediate and short-term decisions for outbreak response planning to respond to potential climate-triggered outbreaks may use indicators such as seasonal incidence rates, vaccine coverage rates, and proportion of water sources at risk of seasonal contamination or failure in droughts or floods.
- Medium-term decisions for programmatic modifications and WASH strategy re-evaluations to prepare for climate shocks and stresses may use metrics similar to those included in the JMP *(92)*.
- Longer-term decisions for policy changes and investment to address system-wide implications of climate change may include indicators such as prevalence of diarrhoeal diseases, proportion of the population accessing improved water and sanitation, and national sectoral policies informed by local climate risks. Metrics similar to those proposed in the JMP *(92)*, GLAAS *(91)*, SDG 6 *(102)* and World Water Development *(103)* monitoring reports may be useful.

All variables should undergo long-term monitoring and be synchronized where possible with indicators collected through existing national and global WASH and health surveillance systems (e.g. DHS, GLAAS, JMP, MICS) *(91, 92, 104)*.

## *Additional resources*


Long-term strategies portal [website]. United Nations Framework Convention on Climate Change (https://unfccc.int/process/the-paris-agreement/long-term-strategies, accessed 29 June 2022).

Guidelines for national adaptation plans (NAPs) [website]. United Nations Framework Convention on Climate Change (https://unfccc.int/topics/adaptation-and-resilience/workstreams/national-adaptation-plans-naps/guidelines-for-national-adaptation-plans-naps, accessed 29 June 2022).

National adaptation plans: NAPs from developing countries [website]. United Nations Framework Convention on Climate Change (https://www4.unfccc.int/sites/NAPC/Pages/national-adaptation-plans.aspx, accessed 29 June 2022).

National communication submissions from Non-Annex I parties [website]. United Nations Framework Convention on Climate Change (http://unfccc.int/national_reports/non-annex_i_natcom/items/2979.php, accessed 29 June 2022).

NDC registry [website]. United Nations Framework Convention on Climate Change (https://www4.unfccc.int/sites/NDCStaging/Pages/All.aspx, accessed 29 June 2022).

Quality criteria for health national adaptation plans. Geneva: World Health Organization; 2021 (https://apps.who.int/iris/handle/10665/339454, accessed 29 June 2022).

WHO guidance to protect health from climate change through health adaptation planning. Geneva: World Health Organization; 2014 (https://apps.who.int/iris/handle/10665/137383, accessed 29 June 2022).

# 6 Conclusions

Managing the health and diarrhoeal disease-related risks of climate change involves an iterative management process that starts with:

- assessing the current and likely future vulnerability of the target community or region;
- estimating the extent of the future burden of diarrhoeal diseases due to climate change;
- designing and implementing policies and programmes to reduce current and future transmission of diarrhoeal diseases;
- improving maternal and child care and feeding practices;
- increasing the climate resilience of health systems;
- minimizing health risks due to climate change;
- monitoring and evaluating these policies and programmes to identify necessary modifications.

This process should go hand in hand with overall strengthening of the six building blocks of the health system – leadership and governance, service delivery, health workforce, financing, essential medical products and technologies, and health information systems.

Through new technologies, research and development and stakeholder advocacy, the potential adverse consequences for diarrhoeal diseases can be minimized or managed. This work may include improved technologies (e.g. sanitation and water infrastructure strengthened against extreme events); improvements in early warning systems for cholera, cryptosporidium and other diarrhoeal diseases (e.g. integrating climate data); and addressing the underlying and basic determinants of transmission of diarrhoeal diseases (e.g. ensuring universal access to clean potable water and improved sanitation).

It is important to ensure there are adequate health services alongside a sanitary environment. Strengthening and increasing the climate resilience of health systems and improving access to health services are fundamental to decreasing overall vulnerability and managing diarrhoeal diseases.

Stakeholder engagement is integral to understanding and protecting the health of vulnerable populations. At each step of the V&A assessment, opportunities should be sought to involve all relevant stakeholders in the process and communicate findings to stakeholders, decision-makers, researchers and the public for dialogue about local risks and available options to protect community health from the threats of climate change.

Coordination of the assessment should ensure consistency and scientific integrity across thematic assessments. This study can be an important complement to existing studies on climate change and water, and fill knowledge gaps about human and social impacts of climate change.

# References


1. Climate change and health: vulnerability and adaptation assessment. Geneva: World Health Organization; 2021 (https://apps.who.int/iris/handle/10665/345968, accessed 29 June 2022).
2. Adapting to climate sensitive health impacts: undernutrition. Geneva: World Health Organization; 2019 (https://www.who.int/publications/i/item/9789241515566, accessed 29 June 2022).
3. Diarrhoeal disease. Geneva: World Health Organization; 2017 (https://www.who.int/news-room/fact-sheets/detail/diarrhoeal-disease, accessed 29 June 2022).
4. Global health estimates: leading causes of death – cause-specific mortality, 2000–2019. Geneva: World Health Organization; 2019 (https://www.who.int/data/gho/data/themes/mortality-and-global-health-estimates/ghe-leading-causes-of-death, accessed 29 June 2022).
5. Vos T, Allen C, Arora M, et al. Global, regional, and national incidence, prevalence, and years lived with disability for 310 diseases and injuries, 1990–2015: a systematic analysis for the Global Burden of Disease Study 2015. Lancet. 2016;388(10 053):1545–1602.
6. Walker CLF, Rudan I, Liu L, et al. Global burden of childhood pneumonia and diarrhoea. Lancet. 2013;381(9875):1405–1416.
7. Prüss-Ustün A, Wolf J, Bartram J, et al. Burden of disease from inadequate water, sanitation and hygiene for selected adverse health outcomes: an updated analysis with a focus on low- and middle-income countries. Int J Hyg Environ Health. 2019;222(5):765–777.
8. Progress on household drinking water, sanitation and hygiene 2000–2020: five years into the SDGs. Geneva: World Health Organization and United Nations Children's Fund; 2021 (https://apps.who.int/iris/handle/10665/345081, accessed 29 June 2022).
9. Drinking-water. Geneva: World Health Organization; 2019 (https://www.who.int/news-room/fact-sheets/detail/drinking-water, accessed 29 June 2022).
10. Kotloff KL, Nataro JP, Blackwelder WC, et al. Burden and aetiology of diarrhoeal disease in infants and young children in developing countries (the Global Enteric Multicenter Study, GEMS): a prospective, case-control study. Lancet. 2013;382(9888):209–222.
11. Liu J, Platts-Mills JA, Juma J, et al. Use of quantitative molecular diagnostic methods to identify causes of diarrhoea in children: a reanalysis of the GEMS case-control study. Lancet. 2016;388(10 051):1291–1301.
12. Tate JE, Panozzo CA, Payne DC, et al. Decline and change in seasonality of US rotavirus activity after the introduction of rotavirus vaccine. Pediatrics. 2009;124(2):465–471.
13. Lamberti LM, Bourgeois AL, Fischer Walker CL, et al. Estimating diarrheal illness and deaths attributable to *Shigellae* and enterotoxigenic *Escherichia coli* among older children, adolescents, and adults in South Asia and Africa. PloS Negl Trop Dis. 2014;8(2):e2705.
14. Khalil IA, Troeger C, Blacker BF, et al. Morbidity and mortality due to shigella and enterotoxigenic *Escherichia coli* diarrhoea: the global burden of disease study 1990–2016. Lancet Infect Dis. 2018;18(11):1229–1240.
15. Anderson JD, Bagamian KH, Muhib F, et al. Potential impact and cost-effectiveness of future ETEC and *Shigella* vaccines in 79 low- and lower middle-income countries. Vaccine. 2019;2:100 024.
16. Lal A, Baker MG, Hales S, French NP. Potential effects of global environmental changes on cryptosporidiosis and giardiasis transmission. Trends Parasitol. 2013;29(2):83–90.

17. Peletz R, Mahin T, Elliott M, et al. Preventing cryptosporidiosis: the need for safe drinking water. Bull World Health Organ. 2013;91(4):238–238A.
18. Weekly epidemiological record, 2016, vol. 91, 38. Geneva: World Health Organization; 2016 (https://apps.who.int/iris/handle/10665/250142, accessed 29 June 2022).
19. Cholera. Geneva: World Health Organization; 2022 (https://www.who.int/news-room/fact-sheets/detail/cholera, accessed 29 June 2022).
20. Water, sanitation, hygiene and health: a primer for health professionals. Geneva: World Health Organization; 2019 (https://apps.who.int/iris/handle/10665/330100, accessed 29 June 2022).
21. Soil-transmitted helminth infections. Geneva: World Health Organization; 202 (https://www.who.int/news-room/fact-sheets/detail/soil-transmitted-helminth-infections#:~:text=Approximately%201.5%20billion%20people%20are,soil%20contamination%20with%20infective%20eggs, accessed 29 June 2022).
22. Soil-transmitted helminth infections. Geneva: World Health Organization; 2022 (https://www.who.int/news-room/fact-sheets/detail/soil-transmitted-helminth-infections, accessed 29 June 2022).
23. Black RE, Allen LH, Bhutta ZA, et al. Maternal and child undernutrition: global and regional exposures and health consequences. Lancet. 2008;371(9608):243–260.
24. Tickell KD, Sharmin R, Deichsel EL, et al. The effect of acute malnutrition on enteric pathogens, moderate-to-severe diarrhoea, and associated mortality in the Global Enteric Multicenter Study cohort: a post-hoc analysis. Lancet Glob Health. 2020;8(2):e215–e224.
25. Cissé G, McLeman R, Adams H, et al. Health, wellbeing, and the changing structure of communities. In: Climate change 2022: impacts, adaptation, and vulnerability. Cambridge: Cambridge University Press; 2022 (https://www.ipcc.ch/report/ar6/wg2/, accessed 29 June 2022).
26. Summary for policymakers. In: Climate change 2021: the physical science basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge and New York: Cambridge University Press; 2021.
27. Summary for policymakers. In: Climate change 2022: mitigation of climate change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press; 2022 (https://www.ipcc.ch/report/ar6/wg3/downloads/report/IPCC_AR6_WGIII_SPM.pdf, accessed 29 June 2022).
28. Climate change 2022: impacts, adaptation and vulnerability. Contribution of Working Group II to the sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press; 2022 (https://www.ipcc.ch/report/sixth-assessment-report-working-group-ii/, accessed 29 June 2022).
29. Quantitative risk assessment of the effects of climate change on selected causes of death, 2030s and 2050s. Geneva: World Health Organization; 2014 (https://apps.who.int/iris/handle/10665/134014, accessed 29 June 2022).
30. Kistemann T, Classen T, Koch C, et al. 2002 Microbial load of drinking water reservoir tributaries during extreme rainfall and runoff. Appl Environ Microbiol. 2002;68(5):2188–2197.
31. Musengimana G, Mukinda FK, Machekano R, Mahomed H. Temperature variability and occurrence of diarrhoea in children under five-years-old in Cape Town metropolitan sub-districts. Int J Environ Res Public Health. 2016;13(9):859.
32. Carlton EJ, Woster AP, DeWitt P, et al. A systematic review and meta-analysis of ambient temperature and diarrhoeal diseases. Int J Epidemiol. 2016;45(1):117–130.
33. Levy K, Woster AP, Goldstein RS, Carlton EJ. Untangling the impacts of climate change on waterborne diseases: a systematic review of relationships between diarrheal diseases and temperature, rainfall, flooding, and drought. Environ Sci Technol. 2016;50(10):4905–4922.

34. Mellor JE, Levy K, Zimmerman J, et al. Planning for climate change: the need for mechanistic systems-based approaches to study climate change impacts on diarrheal diseases. Sci Total Environ. 2016;548–549:82–90.
35. Carlton EJ, Eisenberg JNS, Goldstick J, et al. Heavy rainfall events and diarrhea incidence: the role of social and environmental factors. Am J Epidemiol. 2014;179(3):344–352.
36. Dhimal M, Karki KB, Aryal KK, et al. Final report on assessment of effects of climate factors on diarrheal diseases at national and sub-national levels in Nepal. Kathmandu: Nepal Health Research Council and Word Health Organization Country Office for Nepal; 2016 (https://climate.mohp.gov.np/downloads/final-report-cc-and-Diarrhoea-study.pdf, accessed 29 June 2022).
37. Singh RB, Hales S, de Wet N, et al. The influence of climate variation and change on diarrheal disease in the Pacific Islands. Environ Health Perspect. 2001;109(2):155–159.
38. Xu Z, Liu Y, Ma Z, et al. Assessment of the temperature effect on childhood diarrhea using satellite imagery. Sci Rep. 2014;4:5389.
39. Zhou X, Zhou Y, Chen R, et al. High temperature as a risk factor for infectious diarrhea in Shanghai, China. J Epidemiol. 2013;23(6):418–423.
40. Bhandari D, Peng B, Sherchand JB, et al. Assessing the effect of climate factors on childhood diarrhoea burden in Kathmandu, Nepal. Int J Hyg Environ Health. 2020;223(1):199–206.
41. Phung D, Huang C, Rutherford S, et al. Association between climate factors and diarrhoea in a Mekong Delta area. Int J Biometeorol. 2015;59(9):1321–1331.
42. Pitzer VE, Patel MM, Lopman BA, et al. Modeling rotavirus strain dynamics in developed countries to understand the potential impact of vaccination on genotype distributions. Proc Natl Acad Sci. 2011;108(48):19 353–19 358.
43. Maugeri Tl, Carbone M, Fera MT, et al. Distribution of potentially pathogenic bacteria as free living and plankton associated in a marine coastal zone. J Appl Microbiol. 2004;97(2):354–361.
44. Mote BL, Turner JW, Lipp EK. Persistence and growth of the fecal indicator bacteria enterococci in detritus and natural estuarine plankton communities. Appl Environ Microbiol. 2012;78(8):2569–2577.
45. Tewes M. Association of hygienically relevant microorganisms with freshwater plankton. Dissertation. University of Duisburg-Essen; 2013 (https://doi.org/10.17185/duepublico/72203, accessed 29 June 2022).
46. Climate-resilient water safety plans: managing health risks associated with climate variability and change. Geneva: World Health Organization; 2017 (https://apps.who.int/iris/handle/10665/258722, accessed 29 June 2022).
47. Chua PLC, Huber V, Ng CFS, et al. Global projections of temperature: attributable mortality due to enteric infections – a modelling study. Lancet Planet Health. 2021;5(7):e436–e445.
48. Food safety climate change and the role of WHO. Geneva: World Health Organization; 2018 (https://cdn.who.int/media/docs/default-source/food-safety/climate-change.pdf?sfvrsn=59c632e7_2&download=true , accessed 29 June 2022).
49. Van der Fels-Klerx HJ, Olesen JE, Naustvoll LJ, et al. Climate change impacts on natural toxins in food production systems, exemplified by deoxynivalenol in wheat and diarrhetic shellfish toxins. Food Addit Contam Part A Chem Anal Control Expo Risk Assess. 2012;29(10):1647–1659.
50. Weaver HJ, Hawdon JM, Hoberg EP. Soil-transmitted helminthiases: implications of climate change and human behavior. Trends Parasitol. 2010;26(12):574–581.
51. Horn LM, Hajat A, Sheppard L, et al. Association between precipitation and diarrheal disease in Mozambique. Int J Environ Res Public Health. 2018;15(4):709.
52. Curriero FC, Patz JA, Rose JB, Lele S. The association between extreme precipitation and waterborne disease outbreaks in the United States, 1948–1994. Am J Public Health. 2001;91(8):1194–1199.

53. Effler E, Isaäcson M, Arntzen L, et al. Factors contributing to the emergence of *Escherichia coli* O157 in Africa. Emerg Infect Dis.2001;7(5):812.
54. Levy K, Hubbard AE, Nelson KL, Eisenberg JNS. Drivers of water quality variability in northern coastal Ecuador. Environ Sci Technol. 2009;43(6):1788–1797.
55. Bhavnani D, Goldstick JE, Cevallos W, et al. Impact of rainfall on diarrheal disease risk associated with unimproved water and sanitation. Am J Trop Med Hyg. 2014;90(4):705–711.
56. Bartram J, Howard G. Vision 2030: the resilience of water supply and sanitation in the face of climate change – technical report. Geneva: World Health Organization; 2010 (https://apps.who.int/iris/handle/10665/70462, accessed 29 June 2022).
57. Alexander KA, Carzolio M, Goodin D, Vance E. Climate change is likely to worsen the public health threat of diarrheal disease in Botswana. Int J Environ Res Public Health. 2013;10(4):1202–1230.
58. Oloukoi G, Bob U, Jaggernath J. Perception and trends of associated health risks with seasonal climate variation in Oke-Ogun Region, Nigeria. Health Place. 2014;25:47–55.
59. Cairncross S, Valdmanis V. Water supply, sanitation, and hygiene promotion. In: Jamison DT, Breman JG, Measham AR, et al., editors. Disease control priorities in developing countries. Washington, DC: World Bank; 2006.
60. Tucker J, MacDonald A, Coulter L, Calow RC. Household water use, poverty and seasonality: wealth effects, labour constraints, and minimal consumption in Ethiopia. Water Resour Rural Dev. 2014;3:27–47.
61. Merel S, Walker D, Chicana R, et al. State of knowledge and concerns on cyanobacterial blooms and cyanotoxins. Environ Int. 2013;59:303–327.
62. Das JK, Hadi YB, Salam RA, et al. Fly control to prevent diarrhoea in children. Cochrane Database Syst Rev. 2018;12(12):CD011654.
63. Report of the expert meeting on ciguatera poisoning: Rome, 19–23 November 2018. Rome: Food and Agriculture Organization and World Health Organization; 2018 (https://apps.who.int/iris/handle/10665/332640, accessed 29 June 2022).
64. Burden of disease from inadequate water, sanitation and hygiene in low- and middle-income countries. Geneva: World Health Organization (https://www.who.int/data/gho/data/themes/topics/indicator-groups/indicator-group-details/GHO/burden-of-disease-from-inadequate-water-sanitation-and-hygiene-in-low--and-middle-income-countries, accessed 29 June 2022).
65. Blaser MJ, Smith PD, Ravdin JI, et al. Infections of the gastrointestinal tract. New York: Raven Press; 1995.
66. Campbell-Lendrum D, Woodruff R. Climate change: quantifying the health impact at national and local levels. In: Prüss-Üstün A, Corvalán C, editors. Geneva: World Health Organization; 2007 (https://apps.who.int/iris/handle/10665/43708, accessed 29 June 2022).
67. Rebaudet S, Sudre B, Faucher B, Piarroux R. Environmental determinants of cholera outbreaks in inland Africa: a systematic review of main transmission foci and propagation routes. J Infect Dis. 2013;208(Suppl. 1):S46–S54.
68. Ahern M, Sari Kovats R, Wilkinson P, et al. Global health impacts of floods: epidemiologic evidence. Epidemiol Rev. 2005;27:36–46.
69. El Niño Southern Oscillation (ENSO) and health. Geneva: World Health Organization; 2015 (https://apps.who.int/iris/bitstream/handle/10665/65995/WHO_SDE_PHE_99.4.pdf?sequence=1&isAllowed=y, accessed 29 June 2022).
70. Kelly-Hope L, Thomson MC. Climate and infectious diseases. In: Thomson MC, Garcia-Herrera R, Beniston M, editors. Seasonal forecasts, climatic change and human health, advances in global change research. Dordrecht: Springer; 2008.

71. Grobler-Tanner C. Understanding nutrition data and the causes of malnutrition in Kenya: a special report by the Famine Early Warning Systems Network (FEWS NET). Washington, DC: United States Agency for International Development; 2006 (https://reliefweb.int/report/kenya/understanding-nutrition-data-and-causes-malnutrition-kenya, accessed 29 June 2022).
72. Pinfold JV, Horan NJ, Mara DD. Seasonal effects on the reported incidence of acute diarrhoeal disease in northeast Thailand. Int J Epidemiol. 1991;20(3):777–786.
73. Jagai JS, Sarkar R, Castronovo D, et al. Seasonality of rotavirus in South Asia: a meta-analysis approach assessing associations with temperature, precipitation, and vegetation index. PLoS One. 2012;7(5):e38168.
74. Bandelj P, Trilar T, Blagus R, et al. Prevalence and molecular characterization of Clostridium difficile isolated from European barn swallows (*Hirundo rustica*) during migration. BMC Vet Res. 2014;10:40.
75. Ryu H, Grond K, Verheijen B, et al. Intestinal microbiota and species diversity of *Campylobacter* and *Helicobacter* spp. in migrating shorebirds in Delaware Bay. Appl Environ Microbiol. 2014;80(6):1838–1847.
76. Kolstad EW, Johansson KA. Uncertainties associated with quantifying climate change impacts on human health: a case study for diarrhea. Environ Health Perspect. 2011;119(3):299–305.
77. Hashizume M, Armstrong B, Hajat S, et al. Association between climate variability and hospital visits for non-cholera diarrhoea in Bangladesh: effects and vulnerable groups. Int J Epidemiol. 2007;36(5):1030–1037.
78. Lama JR, Seas CR, León-Barúa R, et al. Environmental temperature, cholera, and acute diarrhoea in adults in Lima, Peru. J Health Pop Nutr. 2004;22(4):399–403.
79. McMichael A, Woodruff R, Whetton P, et al. Human health and climate change in Oceania: a risk assessment. Canberra: Commonwealth Department of Health and Ageing; 2003.
80. Onozuka D, Hashizume M, Hagihara A. Effects of weather variability on infectious gastroenteritis. Epidemiol Infect. 2010;138(2):236–243.
81. Hashizume M, Wagatsuma Y, Faruque ASG, et al. Factors determining vulnerability to diarrhoea during and after severe floods in Bangladesh. J Water Health. 2008;6(3):323–332.
82. Checkley W, Epstein LD, Gilman RH, et al. Effects of El Niño and ambient temperature on hospital admissions for diarrhoeal diseases in Peruvian children. Lancet. 2000;355(9202):442–450.
83. Philipsborn R, Ahmed SM, Brosi BJ, Levy K. Climatic drivers of diarrheagenic Escherichia coli incidence: a systematic review and meta-analysis. J Infect Dis. 2016;214(1):6–15.
84. Djennad A, Iacono GL, Sarran C, et al. Seasonality and the effects of weather on *Campylobacter* infections. BMC Infect Dis. 2019;19(1):255.
85. Stephen DM, Barnett AG. Effect of temperature and precipitation on salmonellosis cases in South-East Queensland, Australia: an observational study. BMJ Open. 2016;6(2):e010204.
86. Auld H, MacIver D, Klaassen J. Heavy rainfall and waterborne disease outbreaks: the Walkerton example. J Toxicol Environ Health A. 2004;67(20–22):1879–1887.
87. Chou W-C, Wu J-L, Wang Y-C, et al. Modeling the impact of climate variability on diarrhea-associated diseases in Taiwan (1996–2007). Sci Total Environ. 2010;409(1):43–51.
88. Bandyopadhyay S, Kanji S, Wang L. The impact of rainfall and temperature variation on diarrheal prevalence in sub-Saharan Africa. Appl Geogr. 2012;33:63–72.
89. Atlas of health and climate. Geneva: World Health Organization; 2012 (https://apps.who.int/iris/handle/10665/76224, accessed 29 June 2022).
90. Briefing note: strategy for integrating a gendered response in Haiti's cholera epidemic. Port-au-Prince: United Nations Children's Fund; 2010 (https://sites.unicef.org/cholera/Chapter_8_case_management/29_Haiti_UNICEF_Briefing_Note_Gender_Cholera.pdf, accessed 29 June 2022).

91. UN-water global analysis and assessment of sanitation and drinking-water (GLAAS) 2014 report: investing in water and sanitation – increasing access, reducing inequalities. Geneva: World Health Organization; 2020 (https://apps.who.int/iris/handle/10665/139735, accessed 29 June 2022).
92. WHO/UNICEF Joint Monitoring Programme (JMP) data. Geneva: United Nations Children's Fund and World Health Organization (https://washdata.org/data/, accessed 29 June 2022).
93. Yang H, Bain R, Bartram J, et al. Water safety and inequality in access to drinking-water between rich and poor households. Environ Sci Technol. 2013;47(3)1222–1230.
94. Climate change and communicable diseases in the EU Member States: handbook for national vulnerability, impact and adaptation assessments. Stockholm: European Centre for Disease Prevention and Control; 2010 (https://op.europa.eu/en/publication-detail/-/publication/4686802f-a819-417e-90bd-69c2eda7a5fe, accessed 29 June 2022).
95. Haines A, Kovats RS, Campbell-Lendrum D, Corvalan C. Climate change and human health: impacts, vulnerability and public health. Public Health. 2006;120(7):585–596.
96. Bhutta ZA, Das JK, Walker N, et al. Interventions to address deaths from childhood pneumonia and diarrhoea equitably: what works and at what cost? Lancet. 2013;381(9875):1417–1429.
97. Ending preventable deaths from pneumonia and diarrhoea by 2025. Geneva: World Health Organization; 2013 (https://apps.who.int/iris/bitstream/handle/10665/79207/WHO_FWC_MCA_13_01_eng.pdf, accessed 29 June 2022).
98. Smith KR, Woodward A, Campbell-Lendrum D, et al. Human health: impacts, adaptation, and co-benefits. In: Field CB, Barros VR, Dokken DJ, et al., editors. Climate change 2014: impacts, adaptation, and vulnerability. Part A: global and sectoral aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press; 2014: 709–754.
99. Gender, climate change and health. Geneva: World Health Organization; 2014 (https://apps.who.int/iris/bitstream/handle/10665/144781/9789241508186_eng.pdf, accessed 29 June 2022).
100. Operational framework for building climate resilient health systems. Geneva: World Health Organization; 2014 (https://apps.who.int/iris/handle/10665/189951, accessed 29 June 2022).
101. WHO guidance to protect health from climate change through health adaptation planning. Geneva: World Health Organization; 2014 (https://apps.who.int/iris/handle/10665/137383, accessed 29 June 2022).
102. Monitoring water and sanitation in the 2030 Agenda for Sustainable Development. Geneva: UN-Water; 2022 (https://www.sdg6monitoring.org, accessed 29 June 2022).
103. United Nations world water development report 2020: water and climate change. Paris: United Nations Educational, Scientific and Cultural Organization; 2020 (https://www.unwater.org/publications/world-water-development-report-2020, accessed 29 June 2022).
104. A toolkit for monitoring and evaluating household water treatment and safe storage. Geneva: World Health Organization and United Nations Children's Fund; 2012 (https://apps.who.int/iris/handle/10665/76568, accessed 29 June 2022).

# Annex 1. El Niño and La Niña years and intensities

| El Niño | | | | La Niña | | |
|---|---|---|---|---|---|---|
| Weak | Moderate | Strong | Very strong | Weak | Moderate | Strong |
| 1952–1953 | 1951–1952 | 1957–1958 | 1982–1983 | 1954–1955 | 1955–1956 | 1973–1974 |
| 1953–1954 | 1963–1964 | 1965–1966 | 1997–1998 | 1964–1965 | 1970–1971 | 1975–1976 |
| 1958–1959 | 1968–1969 | 1972–1973 | 2015–2016 | 1971–1972 | 1995–1996 | 1988–1989 |
| 1969–1970 | 1986–1987 | 1987–1988 | | 1974–1975 | 2011–2012 | 1998–1999 |
| 1976–1977 | 1994–1995 | 1991–1992 | | 1983–1984 | 2020–2021 | 1999–2000 |
| 1977–1978 | 2002–2003 | | | 1984–1985 | | 2007–2008 |
| 1979–1980 | 2009–2010 | | | 2000–2001 | | 2010–2011 |
| 2004–2005 | | | | 2005–2006 | | |
| 2006–2007 | | | | 2008–2009 | | |
| 2014–2015 | | | | 2016–2017 | | |
| 2018–2019 | | | | 2017–2018 | | |

Local influences should be accounted for appropriately in sensitivity analyses.

Source: El Niño and La Niña years and intensities. Half Moon Bay, CA: Golden Gate Weather Services (http://ggweather.com/enso/oni.htm, accessed 2 December 2021).

# Annex 2. Cited studies for example sensitivity analyses, variables and statistical approaches

| Study | Methods detailed in study |
|---|---|
| Alexander KA, Carzolio M, Goodin D, Vance E. Climate change is likely to worsen the public health threat of diarrheal disease in Botswana. Int J Environ Res Public Health. 2013;10(4):1202–1230 | Monthly report reported cases of diarrhoeal disease for 30-year period (1974–2003) compared with climatic variables<br>All statistical analyses conducted using R and MASS library<br>Model selection used forward–backward stepwise variable selection to minimize Bayesian information criterion |
| Azage M, Kumie A, Worku A, et al. Effect of climatic variability on childhood diarrhea and its high risk periods in northwestern parts of Ethiopia. PLoS One. 2017;12(10):e0186933 | Spearman's correlation coefficient, bivariate and multivariable negative binomial regressions used to examine relationship between climatic factors and childhood diarrhoea |
| Britton E, Hales S, Venugopal K, Baker MG. Positive association between ambient temperature and salmonellosis notifications in New Zealand, 1965–2006. Aust New Z J Public Health. 2010;34(2):126–129 | Negative binomial regression model used to analyse monthly average ambient temperature and salmonellosis notifications in New Zealand between 1965 and 2006 |
| Carlton EJ, Eisenberg JNS, Goldstick J, et al. Heavy rainfall events and diarrhea incidence: the role of social and environmental factors. Am J Epidemiol. 2014;179(3):344–352 | Mixed-effects Poisson regression used to explore effects of rainfall in previous 8 weeks, water and sanitation conditions, and social cohesion on relationship between heavy rainfall events and incidence of diarrhoeal diseases in Ecuador |
| Carlton EJ, Woster AP, DeWitt P, et al. A systematic review and meta-analysis of ambient temperature and diarrhoeal diseases. Int J Epidemiol. 2016;45(1):117–130 | Global: evaluated sources of heterogeneity by pathogen taxon, exposure measure, study quality, country income level and regional climate<br>Meta-analysis methods used to estimate pooled effects |
| Checkley W, Epstein LD, Gilman RH, et al. Effects of El Niño and ambient temperature on hospital admissions for diarrhoeal diseases in Peruvian children. Lancet. 2000;355(9202):442–450 | Daily data on hospital admissions from oral rehydration unit, and meteorological data from Peruvian Weather Service<br>Time-series linear regression models used to assess effects of 1997–1998 El Niño event on admissions for diarrhoeal disease |

| Study | Methods detailed in study |
|---|---|
| Chou W-C, Wu J-L, Wang Y-C, et al. Modeling the impact of climate variability on diarrhea-associated diseases in Taiwan (1996–2007). Sci Total Environ. 2010;409(1):43–51 | Sensitivity study applied climate variation-guided Poisson regression model to predict dynamics of diarrhoea-associated morbidity<br>Model allows relative humidity, maximum temperature and numbers of extreme rainfall events, autoregression, long-term trends and seasonality, and lag-time effect |
| Dhimal M, Karki KB, Aryal KK, et al. Final report on assessment of effects of climate factors on diarrheal diseases at national and sub-national levels in Nepal. Kathmandu: Nepal Health Research Council and Word Health Organization Country Office for Nepal; 2016 (https://climate.mohp.gov.np/downloads/final-report-cc-and-Diarrhoea-study.pdf, accessed 29 June 2022) | Statistical modelling using negative binomial model to associate weather-related variables with cases of diarrhoeal diseases |
| Djennad A, Iacono GL, Sarran C, et al. Seasonality and the effects of weather on *Campylobacter* infections. BMC Infect Dis. 2019;19(1):255 | Comparative conditional incidence, wavelet, clustering and time-series analyses used to explore impacts of temperature and rainfall on *Campylobacter* spp. infections in England and Wales |
| Lloyd SJ, Kovats RS, Armstrong BG. Global diarrhoea morbidity, weather and climate. Clim Res. 2007;34(2):119–127 | Cross-sectional study of incidence of diarrhoeal diseases in children aged under 5 years, drawing on studies published in past 50 years<br>Association with climate variables assessed<br>Log-linear regression used to quantify any association, controlling for age, socioeconomic conditions, and access to improved water and sanitation |
| Jagai JS, Castronovo DA, Monchak J, Naumova EN. Seasonality of cryptosporidiosis: a meta-analysis approach. Environ Res. 2009;109(4):465–478 | Novel meta-analysis technique identifies increases in temperature and precipitation to predict increase in cryptosporidiosis<br>Strengths of relationship vary by climate subcategory |
| Lal A, Ikeda T, French N, et al. Climate variability, weather and enteric disease incidence in New Zealand: time series analysis. PLoS One. 2013;8(12):e83484 | Associations between monthly climate and enteric diseases (campylobacteriosis, salmonellosis, cryptosporidiosis, giardiasis) investigated using seasonal auto-regressive integrated moving average models |
| Lal A, Baker MG, Hales S, French NP. Potential effects of global environmental changes on cryptosporidiosis and giardiasis transmission. Trends Parasitol. 2013;29(2):83–90 | Summarizes published studies examining influence of climate variability and agricultural land-use patterns on incidence of cryptosporidiosis and giardiasis<br>Presents conceptual framework |

| Study | Methods detailed in study |
|---|---|
| Musengimana G, Mukinda FK, Machekano R, Mahomed H. Temperature variability and occurrence of diarrhoea in children under five-years-old in Cape Town metropolitan sub-districts. Int J Environ Res Public Health. 2016;13(9):859 | Poisson regression model and lagged Poisson model with autocorrelation used to test relationship between minimum and maximum temperature and incidence of diarrhoeal diseases |
| Naumova EN, Jagai JS, Matyas B, et al. Seasonality in six enterically transmitted diseases and ambient temperature. Epidemiol Infect. 2007;135(2):281–292 | Analytical and conceptual framework for systematic and comprehensive assessment of disease seasonality to detect changes and quantify and compare temporal patterns |
| Philipsborn R, Ahmed SM, Brosi BJ, Levy K. Climatic drivers of diarrheagenic *Escherichia coli* incidence: a systematic review and meta-analysis. J Infect Dis. 2016;214(1):6–15 | Global: climate drivers of incidence of diarrhoeagenic *E. coli* explored using univariate Poisson models for single studies and meta-analysis (generalized estimating equation model) on full dataset |
| Singh RB, Hales S, de Wet N, et al. The influence of climate variation and change on diarrheal disease in the Pacific Islands. Environ Health Perspect. 2001;109(2):155–159 | Cross-sectional and time-series of diarrhoeal rates from 1986 to 1994 for 18 Pacific Island countries |
| Stephen DM, Barnett AG. Effect of temperature and precipitation on salmonellosis cases in South-East Queensland, Australia: an observational study. BMJ Open. 2016;6(2):e010204 | Two common regression models and switching model used to analyse weather and salmonellosis in Australia |
| Zhou X, Zhou Y, Chen R, et al. High temperature as a risk factor for infectious diarrhea in Shanghai, China. J Epidemiol. 2013;23(6):418–423 | Two sensitivity analyses conducted, including daily mean temperature and daily minimum and maximum temperatures |

# Annex 3. Sources of national and regional climate data

| Source | Description |
| --- | --- |
| World Bank Climate Variability Tool (http://iridl.ldeo.columbia.edu/maproom/Global/World_Bank/Climate_Variability/index.html) | Historical variability of precipitation and temperature at various timescales (interannual, decades, long-term linear trends) over twentieth century near a user-selected location |
| Columbia Climate School International Research Institute for Climate and Society climate data library (http://iridl.ldeo.columbia.edu/) | Climatologies give monthly or seasonal behaviour in average year for temperature, precipitation and wind |
| Columbia Climate School International Research Institute for Climate and Society climate and health resource room (http://iridl.ldeo.columbia.edu/maproom/Health/index.html) | Climate and health resource room |
| United States National Oceanic and Atmospheric Administration (https://www.noaa.gov/education/resource-collections/weather-atmosphere/el-nino)<br>Golden Gate Weather Services (http://ggweather.com/enso/oni.htm)<br>United States National Weather Service Climate Prediction Center (http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ensoyears.shtml) | El Niño and La Niña years |
| United States National Weather Service Climate Prediction Center (http://www.cpc.ncep.noaa.gov/) | Climate prediction centre |
| World Meteorological Organization World Climate Services Programme (https://public.wmo.int/en/programmes/world-climate-services-programme) | World Climate Applications and Services Programme |
| African Center of Meteorological Applications for Development (http://www.acmad.net/new/) | Regional climate centre – western and central Africa |
| Intergovernmental Authority on Development (IGAD) Climate Prediction and Applications Centre (http://www.icpac.net/) | Regional climate centre – eastern and southern Africa |
| Pacific Climate Change Science (https://www.pacificclimatechangescience.org/climate-tools/pacific-climate-change-data-portal/) | Regional climate centre – western Pacific |

| Source | Description |
|---|---|
| Global Atmosphere Watch Programme (https://community.wmo.int/activity-areas/gaw) | Observational data of humidity, precipitation, temperature, wind speed, wind direction, ozone, persistent organic pollutants, etc. for selected global and regional locations |
| World Weather Records (https://www.ncdc.noaa.gov/wdcmet/data-access-search-viewer-tools/world-weather-records-wwr-clearinghouse) | 1927 to present: monthly mean values of pressure, temperature, precipitation and (where available) station metadata notes documenting observation practices and station configurations |
| DHIS2 Google Earth Engine App and Data importer App v1.1.0 (https://github.com/EyeSeeTea/dhis2-gee-app-blessed/releases/tag/1.1.0) | Two web apps enabling users and administrators to easily inject Google Earth Engine data into DHIS2 instances |

# Annex 4. Existing futures studies of diarrhoeal diseases associated with climate

| Study | Projections |
|---|---|
| Bambrick H, Dear K, Woodruff R, et al. The impacts of climate change on three health outcomes: temperature-related mortality and hospitalisations, salmonellosis and other bacterial gastroenteritis, and population at risk from dengue. In: Garnaut R, editor. Garnaut climate change review. Canberra: Australian National University; 2008 (https://eprints.qut.edu.au/103231/1/103231.pdf, accessed 29 June 2022) | Australia: *Salmonella* spp. and bacterial gastroenteritis |
| Fleury M, Charron DF, Holt JD, et al. A time series analysis of the relationship of ambient temperature and common bacterial enteric infections in two Canadian provinces. Int J Biometeorol. 2006;50(6):385–391 | Generalized linear models and generalized additive models used to estimate effect of seasonal adjustments on estimated models of 3 enteric infections using threshold models of future relative risks |
| Kolstad EW, Johansson KA. Uncertainties associated with quantifying climate change impacts on human health: a case study for diarrhea. Environ Health Perspect. 2011;119(3):299–305 | 6 geographical regions: combined range of linear regression coefficients used to compute projections of future climate change-induced increases in diarrhoeal diseases using results from 5 empirical studies and a 19-member climate model ensemble |
| McMichael A, Woodruff R, Whetton P, et al. Human health and climate change in Oceania: a risk assessment. Canberra: Commonwealth Department of Health and Ageing; 2003 | Considerations in calculating dose–response of climate and diarrhoeal diseases<br>Relative risk calculated by multiplying projected increase in temperature by common dose–response value<br>Increase in relative risk multiplied by baseline annual estimate of admissions for diarrhoeal diseases to estimate possible future numbers of admissions for diarrhoeal diseases among aboriginal populations for 2020 and 2050<br>Increasing temperatures and incidence of all-cause diarrhoea only |
| Onozuka D, Gasparrini A, Sera F, et al. Modeling future projections of temperature-related excess morbidity due to infectious gastroenteritis under climate change conditions in Japan. Environ Health Perspect. 2019;127(7):077 006 | Japan: projections of future temperature-related infectious gastroenteritis under 4 climate change scenarios |

| Study | Projections |
| --- | --- |
| Quantitative risk assessment of the effects of climate change on selected causes of death, 2030s and 2050s. Geneva: World Health Organization; 2014 (https://apps.who.int/iris/handle/10665/134014, accessed 29 June 2022) | Global and regional: projections for disease risks associated with climate change for 2030 and 2050 |

# Annex 5. Datasets and tools for creating climate-based projections of diarrhoeal diseases

| Source | Description |
|---|---|
| Columbia Climate School International Research Institute for Climate and Society map room (http://iridl.ldeo.columbia.edu/maproom/) | Maps and analyses of seasonal statistics of historical temperature and precipitation, seasonal temperature and precipitation forecasts, and general circulation model skill maps for regions of Asia and South America<br>Map of African farming systems |
| Intergovernmental Panel on Climate Change data distribution centre (http://www.ipcc-data.org/) | Climate, socioeconomic and environmental data from past and future scenarios |
| Intergovernmental Panel on Climate Change sixth assessment report: Working Group 1 (https://www.ipcc.ch/report/ar6/wg1/) | Regional climate scenario maps |
| DHIS2 Google Earth Engine App and Data importer App v1.1.0 (https://github.com/EyeSeeTea/dhis2-gee-app-blessed/releases/tag/1.1.0) | Two web apps enabling end-users and administrators to easily inject Google Earth Engine data into DHIS2 instances |
| United Nations Department of Economic and Social Affairs population dynamics (https://esa.un.org/unpd/wpp/) | National-level demographic projections to 2050 for all countries |
| Columbia Climate School International Research Institute for Climate and Society climate analysis, monitoring and forecasts (http://iridl.ldeo.columbia.edu/maproom/Global/index.html) | Historical, current and future climate conditions around the globe |
| Food and Agriculture Organization modelling system for agricultural impacts of climate change (https://www.fao.org/in-action/mosaicc/en) | Statistical downscaling method for processing global circulation model output data<br>Hydrological model for estimating water resources for irrigation<br>Crop growth model to simulate future crop yields and effect of changing yields on national economies |

| Source | Description |
| --- | --- |
| World Climate Research Programme Group on Regional Climate Coordinated Regional Climate Downscaling Experiment (CORDEX) (http://www.cordex.org/) | Global coordination of regional climate downscaling for improved regional climate change adaptation and impact assessment |
| Caribbean Weather Impacts Group (CARIWIG) (http://cariwig.caribbeanclimate.bz/#info) | Information and datasets on:<br>• observed climate<br>• regional climate model projections of future climate<br>• future scenarios of weather downscaled from regional climate model projections<br>• scenarios of weather derived from hypothetical tropical cyclone events |

# Annex 6. Glossary

**Adaptation** Includes actions taken by nations, communities and ecosystems to moderate, cope with or take advantage of actual or expected changes in climate conditions.

**Aetiology** Scientific study of the causes of disease.

**Climate** Measure of the expected atmospheric conditions at a particular location over a particular period (e.g. month or season) based on statistics built up from observations over many years (it is distinct from *weather* – see below). Also defined as the weather averaged over time, typically 30 years.

**Climate change** Shifts in the mean state of the climate or in its variability, persisting for an extended period of decades or longer. Climate change may be due to natural changes or to persistent anthropogenic changes in the composition of the atmosphere or in land use.

**Climate-sensitive disease** Disease that is sensitive to weather or climate factors, with the current spatial distribution and seasonal transmission being affected.

**Climate variability** Variations in the mean state of climate on all temporal and spatial scales beyond that of individual weather events, as opposed to long-term climate change trends. Examples of climate variability include extended droughts, floods and conditions that result from periodic El Niño and La Niña events.

**Diarrhoea** Defined as the passage of three or more loose or liquid stools per day, or more frequent passage than is normal for the individual.

**Disability-adjusted life-year (DALY)** One DALY is considered one lost year of "healthy" life. The sum of these DALYs across the population, or the burden of disease, can be thought of as a measurement of the gap between current health status and an ideal health situation where the entire population lives to an advanced age, free from disease and disability.

**Disaster risk reduction** Concept and practice of reducing disaster risks through systematic efforts to analyse and manage the causal factors of disasters, including through reduced exposure to hazards, reduced vulnerability of people and property, wise management of land and the environment, and improved preparedness for adverse events.

**Drought** Temporary reduction in water or moisture availability significantly below the normal or expected amount for a specified period. The key assumptions of such a definition are that:

- the reduction is temporary (if the reduction is permanent, then terms such as "dry" and "arid" are more appropriate);
- the reduction is significant;
- the reduction is defined in relation to a norm (i.e. normal expectation);
- the period taken as the basis for the norm is specified.

**Early detection** Detection of changes in disease transmission, usually based on data from an active or passive disease surveillance system. Early detection systems usually include a set of predefined rules, such as thresholds of case numbers that must be exceeded for an epidemic to be declared and responses to be initiated. Early detection systems include consideration of operational conditions and responses.

**Early warning** Warning based on biologically and statistically important predictor of changes in disease transmission. This can be measurements of these factors (e.g. rainfall data) or predictions in advance of their occurrence (e.g. seasonal forecasts of temperature and rainfall based on the El Niño Southern Oscillation). Early warning systems include consideration of operational conditions and responses.

**Early warning system** Information collection, analysis and use aimed at predicting, preventing and mitigating the effects of future hazards and risks.

**Ecosystem** Area within the natural environment in which physical factors of the environment, such as rocks and soil, function together along with interdependent organisms, such as plants and animals, within the same habitat.

**El Niño Southern Oscillation (ENSO)** Periodic appearance of warm and cool sea surface water in the central and eastern Pacific Ocean. It is the most prominent known source of interannual variability in weather and climate around the world. ENSO events are associated with increased probability of drought in some areas and excess rainfall in others, together with temperature increases in many regions. The ENSO occurs on a quasi-periodic (about 3–8 years) timescale.

**Endemic** Constant presence or usual prevalence of a disease or infectious agent in a population within a geographical area. The term "hyperendemic" refers to persistent high levels of disease occurrence.

**Environmental enteropathy (tropical enteropathy)** Subclinical condition caused by constant faecal–oral contamination, resulting in blunting of intestinal villi and intestinal inflammation. It contributes to poor response to nutritional therapy.

**Epidemic** Increase, often sudden, in the number of cases of a disease above what is normally expected in that population in that area. The term "outbreak" is synonymous with "epidemic" but often used for a more limited geographical area. An epidemic may result from:

- a recent increase in the amount or virulence of the agent;
- the recent introduction of the agent into a setting where it has not been before;
- an enhanced mode of transmission so that more susceptible people are exposed;
- a change in the susceptibility of the host response to the agent;
- factors that increase host exposure or involve introduction through new portals of entry.

**Fomite** Any object or substance capable of carrying infectious organisms, such as germs or parasites, and hence transferring them from one individual to another. Skin cells, hair, clothing and bedding are common hospital sources of contamination.

**Foodborne diseases** Encompass a wide spectrum of illnesses that result from the ingestion of foodstuffs contaminated with microorganisms or chemicals. Symptoms of foodborne illness generally include diarrhoea and vomiting; fever may or may not be present. Onset of disease varies greatly with the particular cause of disease. Symptoms can be due to toxins that are present following the growth of pathogens in the food, or to an infection that occurs in the intestinal tract after eating food contaminated with live pathogens.

**Gastroenteritis or infectious diarrhoea** Inflammation of the gastrointestinal tract, including the stomach and small and large intestines, which results in a combination of diarrhoea, vomiting, abdominal pain and cramping. Causes include rotavirus and campylobacter.

**Hazard** Potential occurrence of a natural or human-induced physical event or trend that may cause loss of life, injury or other health impact, and damage to or loss of property, infrastructure, livelihood, service provision, ecosystems and environmental resources.

**Incidence** Number of times an event (e.g. an infection) occurs in a given period of time. Usually expressed as numbers of cases per year per capita of a defined population.

**Outbreak** Epidemic limited to a localized increase in the incidence of a disease, such as in a village, town or closed institution.

**Pandemic** Widespread epidemic occurring throughout a country or geographical area or worldwide.

**Prevalence** The number of occurrences of a disease or event in a given population, usually expressed as the number of events occurring per the number of units in the population at risk for the occurrence.

**Relative risk or risk ratio (RR)** Ratio of the risk of disease or death among exposed people to the risk among unexposed people.

**Representative concentration pathways (RCPs)** Four greenhouse gas concentration (not emission) trajectories adopted by the Intergovernmental Panel on Climate Change for its fifth assessment report. The pathways are used for climate modelling and research. They describe four possible climate futures, all of which are considered possible depending on how much greenhouse gas is emitted in the years to come.

**Transmission (direct)** An infectious agent is transferred from a reservoir to a susceptible host by direct contact or droplet spread. Indirect transmission refers to the transfer of an infectious agent from a reservoir to a host by suspended air particles, food, water, blood, fomites (e.g. bedding, medical or household instrument), or animate intermediaries (vectors, e.g. flies, mosquitos, fleas).

**Vulnerability** Susceptibility to harm defined in terms of a population or location. Vulnerability to climate change is the degree to which a system is susceptible to or unable to cope with the adverse effects of climate variability and change. Vulnerability is dynamic and may itself be influenced by climate change (e.g. extreme weather events affecting health infrastructure). From a health perspective, vulnerability can be defined as the summation of all risk and protective factors that ultimately determine whether a subpopulation or region experiences adverse health outcomes due to climate change. Characteristics of a region, such as baseline climate, abundance of natural resources (e.g. access to fresh water), elevation, infrastructure and other factors, can alter vulnerability.

**Water, sanitation and hygiene (WASH)** Comprehensive package of interventions to address public health risks related to:

- a medium that can serve to transmit pathogens and toxic chemicals (drinking water);
- services (drinking water, sanitation, solid waste management, irrigation water management) that contribute to disease prevention and, conversely, the lack of which increases the risk of several diseases;
- behaviours such as personal and domestic hygiene and unsafe use of built environments;
- natural resources and ecosystems, the development and management of which may increase or decrease disease risks.

**Waterborne diseases** Spectrum of illnesses resulting from ingestion of infectious agents carried or spread by water.

**Water-related diseases** Spectrum of illnesses linked with water, including waterborne diseases, water-washed diseases and water-based diseases.

**Water scarcity** Imbalance between supply and demand of fresh water in a specified domain (e.g. country, region, catchment, river basin) as a result of a high rate of demand compared with available supply, under prevailing institutional arrangements (including price) and infrastructural conditions. Symptoms are unsatisfied demand, tensions between users, competition for water, overextraction of groundwater and insufficient flows to the natural environment. Artificial or constructed water scarcity refers to the situation resulting from overdevelopment of hydraulic infrastructure relative to available supply, leading to a situation of increasing water shortage.

**Water shortage** Shortage of water supply of an acceptable quality; low levels of water supply, at a given place and a given time, relative to design supply levels. The shortage may arise from climatic factors or other causes of insufficient water resources; a lack of, or poorly maintained, infrastructure; or a range of other hydrological or hydrogeological factors.

**Water stress** Situation where the availability of water is a major constraint on human activity. It includes symptoms of water scarcity or shortage, including widespread, frequent and serious restrictions on use; growing conflict between users and competition for water; declining standards of reliability and service; and harvest failures and food insecurity.

**Water supply** Amount of water available or made available for use.

**Weather** Atmospheric conditions at a particular place in terms of air temperature, pressure, humidity, wind speed and precipitation (it is distinct from *climate* – see above).

**Zoonosis** Disease or infection that is naturally transmissible from vertebrate animals to humans, and vice versa.

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