European Environment Agency

30 YEARS

Responding to climate change impacts on human health in Europe: focus on floods, droughts and water quality

EEA Report 3/2024

European Environment Agency

European Environment Agency
Kongens Nytorv 6
1050 Copenhagen K
Denmark

Tel.: +45 33 36 71 00
Web: eea.europa.eu
Contact us: eea.europa.eu/en/about/contact-us

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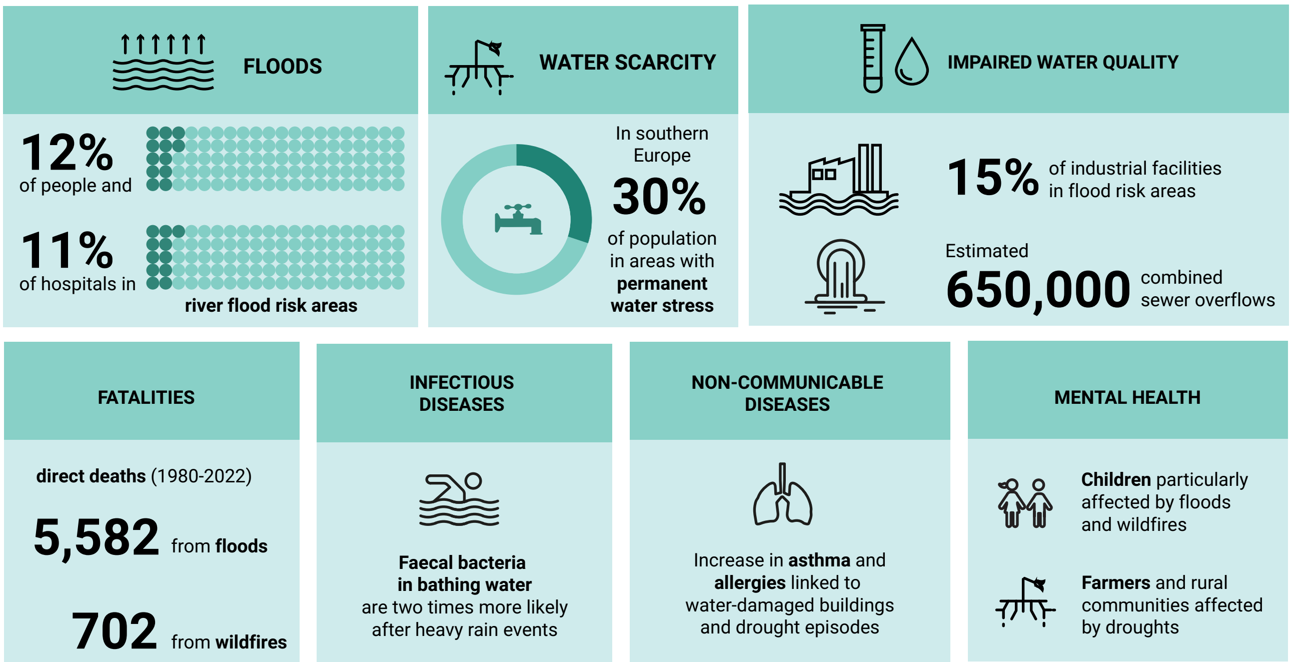
Executive summary

Protecting human lives and health from the impacts of droughts, floods and worsened water quality under climate change is of the utmost importance and urgency.

In recent years, Europe has seen devastating floods following record rainfall, droughts of magnitudes not experienced in hundreds of years, continuing sea level rise, and increasing lake and sea temperatures. While the effects of some of those changes on human health are painfully clear (e.g. deaths caused by flooding), others — such as droughts affecting farmers' mental health or diseases caused by pathogens and toxins — are not yet widely recognised (Figure ES.1). The European Climate Risk Assessment (EEA, 2024a) clearly shows that climate change will exacerbate threats to society in the future, highlighting health as one of the at-risk sectors.

Figure ES.1 Current exposure to water-related risks of climate change and selected health impacts



Source: EEA.

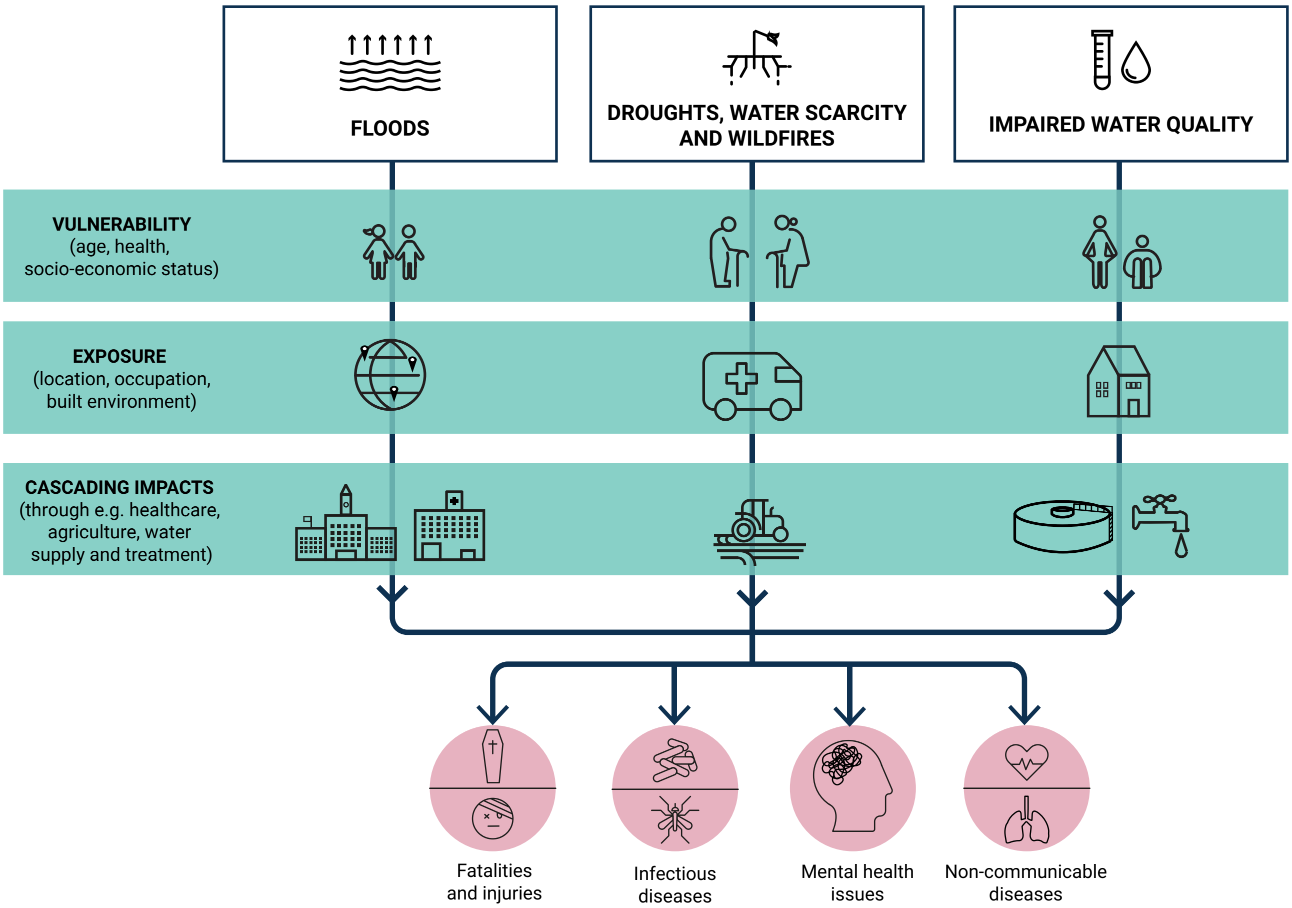
Better understanding, anticipating and preventing the health impacts of climate change is a key priority for the European Union, as highlighted in the EU adaptation strategy, EU Climate Law and the communication 'Managing climate risks — protecting people and prosperity' (EC, 2021c; EU, 2021; EC, 2024). It is vital to urgently implement actions across sectors and governance levels to protect lives, prevent adverse health outcomes and increase well-being.

This report aims to raise awareness about the range of risks to human health associated with changes in water quantity and quality under the changing climate. It assesses our preparedness for ongoing and future impacts by examining the current policy landscape in Europe. At the same time, it seeks to inspire action by showing examples of practical measures implemented across various sectors and on various scales in the EEA member and collaborating countries.

Without fast and systemic action to increase societal resilience, the health impacts of the changing climate through floods, droughts and impaired water quality will worsen. The impacts are not evenly distributed across geographic regions and populations, affecting already disadvantaged or vulnerable groups the most.

Ongoing and accelerating climate change is already leading to deaths, injuries, the exacerbation of non-communicable diseases, outbreaks of infectious diseases and mental health consequences (Figure ES.2).

Figure ES.2 Pathways of impacts on health via floods, water scarcity and wildfires, and impaired water and quality under the changing climate



Source: EEA.

One in eight Europeans currently live in areas potentially prone to river flooding. While many of those areas have flood defences, the level of security they offer varies. Further, the current patterns of development in risk areas put more and more people in harm's way. The growing risk of large-scale flooding from rivers, sea and heavy rainfall under the changing climate across most of Europe will multiply the number of people exposed and challenge our current protective infrastructure, requiring concerted action to prevent loss of life and damage to health.

At the same time, permanent water stress already affects 30% of people in southern Europe. Water restrictions and rationing — already in place in some regions — and inevitable price increases as the supplies run dry may affect poorer or larger households' ability to meet their hygiene needs. In addition, prolonged spells of dry and hot weather facilitate the spread of wildfires; again, mainly in southern Europe, but increasingly in other regions. Wildfires not only pose the direct health risk of flames; being exposed to the harmful chemicals in wildfire smoke has both acute and long-lasting health implications. Both droughts and wildfire risk will increase in the future in most of Europe, with southern Europe a particular hotspot.

The quality of water we drink or swim in, while overall very good, is also at risk. Rising air and water temperatures facilitate pathogen growth, increasing the risk of waterborne diseases. In low-lying areas, sea level rise causes intrusion of saline water into groundwater and surface water aquifers, with spillover effects on crops. Low flows during dry periods result in higher concentrations of pollutants and pharmaceuticals, requiring costly wastewater treatment. Further, during dry and hot periods, cyanobacterial blooms in nutrient-rich waters can jeopardise water quality. More floods and extreme rainfall can threaten the delivery of zero pollution ambitions in Europe, as combined sewer overflows, damage to industrial facilities and run-off from fields and streets affect our water quality.

In addition, not all in society are affected equally. Senior citizens, children, those in poor health and economically disadvantaged groups, as well as emergency services teams and clean-up professionals, are consistently the groups most affected by floods, wildfires or water- and vector-borne diseases. These groups tend to suffer physically and mentally the most, either immediately after extreme weather events or in the long term. A key group prone to cascading health impacts from droughts and floods are farmers and broader rural communities, whose livelihoods depend on suitable weather. The differences in vulnerability of various groups and the ongoing trends in ageing, disease prevalence and economic inequalities necessitate an equity-based, targeted approach to preventing health impacts under the changing climate.

The European climate, water and health policy framework offers a solid foundation for action but it needs to be better implemented. At the national level, health policies need to integrate a stronger focus on climate; locally (e.g. at city level), increasing funding and competencies for climate change adaptation with a focus on health can better protect human lives and well-being.

The EU already has a comprehensive and constantly improving policy landscape in relation to climate, water and health. The Floods Directive and the recast Urban Waste Water Treatment Directive already explicitly consider climate impacts on health. A solid foundation of other policies tackle climate resilience, water management and health. The recently-published communication of the European Commission 'Managing climate risks — protecting people and prosperity' (EC, 2024), building on the results of the first European Climate Risk Assessment (EEA, 2024a), calls for further improved and more consistent implementation of legislation relating to climate risks.

At the national level, health is consistently highlighted as the sector most vulnerable to climate change (EEA, 2023g). Currently, risks to health from floods, droughts and other water-related hazards are addressed to a greater extent in climate adaptation strategies than in health strategies. Ensuring further engagement of the health sector on climate adaptation is therefore crucial for an adequate response to the impacts. In addition, ensuring that policy and legislation related to water management, spatial planning or the built environment recognise and prevent climate impacts on health is essential, as many levers to reduce climate-related health risks lie outside traditional health policies (EEA, 2024a). Further, the growing impacts of persistent water scarcity on society require the EU and national policies to give droughts the same level of attention as floods.

Due to the local character of climate hazards and population characteristics, the sub-national administrative level is key for implementing adaptation actions. Many local authorities across Europe, in particular cities, have climate adaptation plans; water management is a definite focus for many sub-national authorities. However, in local climate adaptation plans, health is a much lower priority than it is at the national level, often due to limited competences of sub-national authorities on the issue. Bringing together climate and health is essential across governance levels. For cities and other local authorities, this may require additional funding, expertise and capacity building, and close collaboration with healthcare providers.

The health sector must be better prepared to deal with climate-related problems in the future. At the same time, addressing health impacts from floods, water scarcity and changes in water quality requires responses across sectors, actors and spatial scales. Quick wins include raising awareness about the risks; longer-term actions, including infrastructure improvements, require systematic planning and investment.

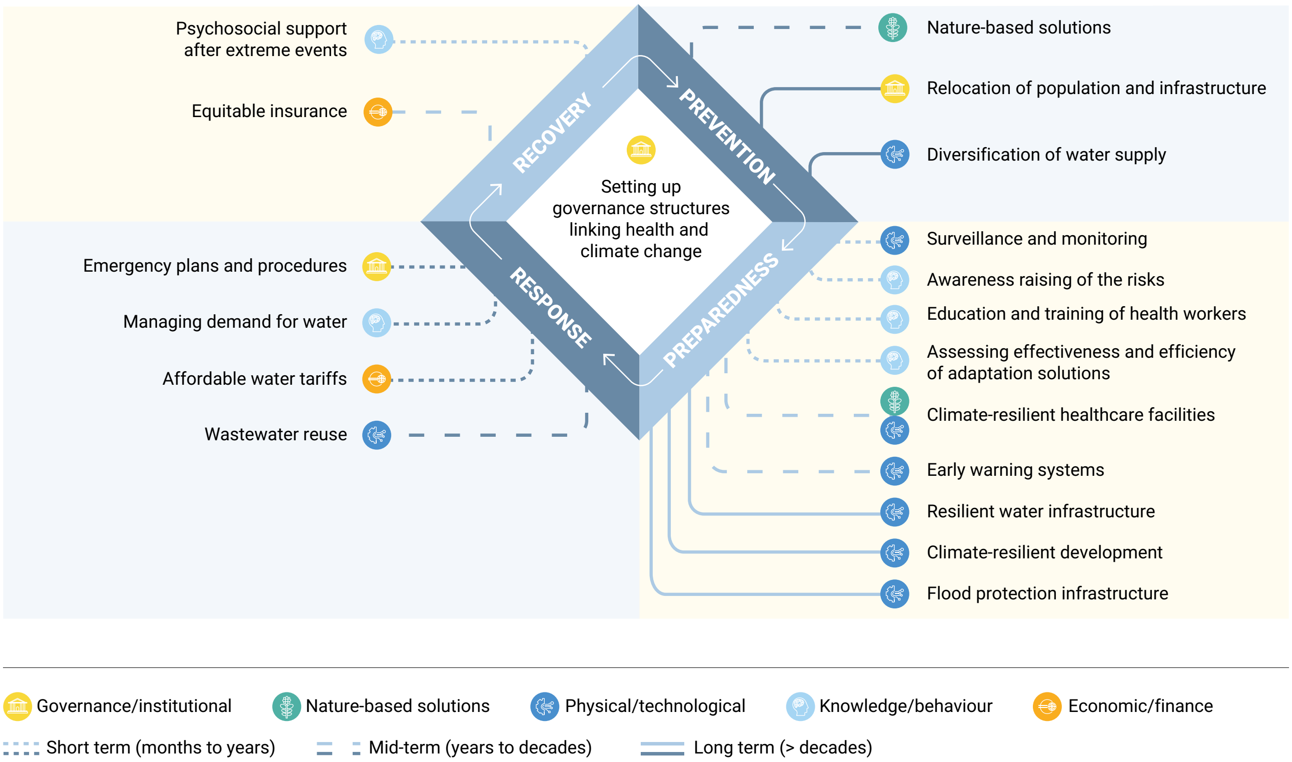
While various measures to build society's resilience to climate change are already being implemented, Europe must make rapid progress on the systemic and large-scale roll-out of on-the-ground solutions. Effectively preventing health risks from floods, water scarcity and worsened water quality under the changing climate requires prevention, preparedness, response and recovery actions (Figure ES.3). These should be implemented by stakeholders in and beyond the health sector, including those involved in water management, spatial planning, building design, occupational health, insurance and education.

Immediately, greater recognition across sectors of the seriousness of the impacts of climate change on human health is needed. Setting up governance structures or collaboration networks across institutions ensures clarity on the responsibilities for to the actions with a focus on climate, water and health.

To immediately reduce health risks, the public needs greater awareness of the health risks associated with floods, droughts, algal blooms or infectious diseases. Public health institutions at the national and sub-national level and healthcare practitioners can play a key role in this. Effective emergency plans — often developed by public health institutes in cooperation with meteorological organisations and other actors — are crucial in minimising the health impacts of extreme weather, pollution events or disease outbreaks under the changing climate.

Making health systems better prepared to respond to extreme weather events is urgent, including the need to develop procedures to deal with a greater demand for healthcare due to injuries, increased incidence of infectious diseases or mental health problems. Further, medical diagnostics to emerging health problems may need to be developed and raising awareness among healthcare staff on dealing

Figure ES.3 **Examples of actions preventing water-related climate change impacts on health**



Source: EEA.

with the impacts of climate change is crucial. In the medium term, developing comprehensive national health adaptation plans and boosting the current provisions for health in national climate adaptation strategies are an important aspect of a systematic response. Incorporating education and training of health professionals and students on climate change can build their capacity to anticipate, recognise and deal with the consequences. Investment in research on medical countermeasures, such as vaccines for infectious diseases that may spread under the changing climate, is another medium-term action. In the long term, investing in the resilience of healthcare facilities to floods and droughts, or relocating hospitals away from risk areas, can offer safety to patients and staff during extreme weather events.

In the water management sector, possible short-term actions include awareness-raising campaigns to reduce demand in water-scarce areas and periods. Implementing affordable tariffs would protect the well-being of low-income and vulnerable groups against price increases. In the medium term, managing water losses from the distribution network, improving the operational surveillance and monitoring of drinking, bathing and wastewater quantity and quality, and developing associated early warning systems are key to prevent health impacts from poor water quality or sewage overspills. Diversifying water supplies to ensure a sustainable provision of water while not negatively affecting other locations, and investing in wastewater infrastructure to reduce the risk of sewage overflows and improve treatment levels, would help minimise the health risks further.

Climate-aware spatial planning and resilient built environments are key to reducing people's exposure to water-related risks. Among the most important preventative medium-term measures are avoiding new or further development in risk areas through adjustments and adherence to spatial planning rules; implementing nature-based solutions such as constructed wetlands or sustainable drainage systems supporting the natural water cycle; and designing buildings to ensure their resilience to floods, fires and droughts. In the long term, further reducing development in high-risk areas and relocation away from floodplains, wildfire-prone areas and water-scarce locations can reduce people's exposure to climate-related health threats.

In the insurance sector, closing the protection gap and ensuring insurance affordability can ease the mental load for those at risk of large uninsured losses, such as farmers or low-income groups.

Crucially, in research and innovation, investment in assessing the effectiveness, co-benefits and trade-offs of various adaptation solutions would also play a role.

To conclude, Europe is well-equipped to act due to sufficient evidence of impacts, a solid policy framework, and examples of actions implemented across the continent. We have a unique opportunity to do more to protect health and well-being of European residents from one of the world's biggest health threats – climate change.

1 Introduction

Climate change directly affects the water cycle by altering precipitation patterns, leading to flooding, droughts and water scarcity. It also causes sea level rise and alters water temperature, chemistry and biota. As water is key to all our daily activities, climate-related changes in water quantity and quality have various severe implications for human health.

In Europe, the climate is changing quickly and the extreme events that have taken place over the last years are a foretaste of what is to come under future global warming. Devastating floods caused by extremely heavy rainfall in Belgium, Germany, Luxembourg and the Netherlands in July 2021 cost more than 230 lives and injured more than 750 people. In 2023, flooding affected southern and eastern Europe — Italy and central Europe in May, Slovenia in August, and Bulgaria, Greece and Türkiye in September. In October 2023, Denmark was hit by the worst storm surges in decades. In that year alone, flooding affected 1.6 million people (C3S and WMO, 2024).

At the same time, since 2018, more than half of Europe has been impacted by extreme drought conditions, affecting agricultural production, the availability and price of fruit and vegetables and drinking water. The dry and hot weather in recent years has led to large-scale wildfires (JRC, 2023) and contributed to ecological disasters, such as the pollution-caused ecosystem die-out in the Oder river in 2022 (Free et al., 2023). Furthermore, more frequent and intense flooding and drought events, combined with higher temperatures, exacerbate infectious diseases such as cryptosporidiosis or West Nile fever. Rising sea temperatures increase the load of *Vibrio* spp. in low-salinity waters, increasing the risk of infections. Emerging risks include ciguatera poisoning though fish consumption or pollution and microbial threats linked to permafrost thaw.

Managing climate risks and achieving climate resilience is a key concern for decision-makers in Europe, at all levels of governance, from European and national to regional and local (EC, 2024). This report aims to raise awareness about the various risks to human health posed by floods, droughts and changes in water quality under the changing climate. It assesses our preparedness for ongoing and future impacts by examining the policy landscape in Europe. At the same time, it seeks to inspire action by showing practical measures implemented in various sectors, largely provided by the EEA member and collaborating countries. The report is published as part of activities of the European Climate and Health Observatory initiative, building on and complementing the observatory's work.

Chapter 2 presents an overview of the health impacts of flooding in the context of past trends and projected changes in flooding hazards and population and facility exposure to them. In Chapter 3, the threats to human health associated with droughts and water scarcity, including indirect effects such as more frequent and severe wildfires, are explored. Chapter 4 summarises the key risks to human health associated with altering water chemistry and biology under the changing climate. Chapter 5 outlines the policy response to the impacts of changing water quality and quantity on human health, from EU policy to national and sub-national level. Chapter 6 presents examples of actions addressing climate change impacts on human health, due to poor water quality, floods or droughts and water scarcity. The opportunities for action are presented in Chapter 7.

2 Flooding and health

Key messages

- Currently, around 12% of the European population live in areas potentially prone to river flooding, although in many cases with flood defences in place. Between 2011 and 2021, there was an increase of over 935,000 people in Europe (1.8%) living in potential riverine flood-prone areas. In addition, 11% of healthcare facilities across Europe are located in such areas.
- Between 1980 and 2022, 5,582 flood-related deaths were recorded in Europe. In addition to fatalities and injuries, those affected by flooding suffer mental health consequences. The elderly, children, those in poor health, disadvantaged groups, rescue teams and clean-up professionals tend to suffer the most from flooding, while men and people travelling in vehicles are the most frequent casualties.
- Flooding can increase pollution risks: nearly 15% of industrial facilities in Europe are sited in potential riverine flood-prone areas; for urban wastewater treatment plants this percentage is 36%. An estimated 650,000 combined sewer overflows across Europe worsen water quality following heavy rainfall events.
- Heavy rainfalls raise the concentrations of the bacteria *E. coli* and *enterococci* in bathing waters to dangerous levels and floods are related to outbreaks of infectious diseases, such as leptospirosis, campylobacteriosis, norovirus, acute gastroenteritis and respiratory infections. Disruption of medical treatments, use of buildings affected by flooding and economic difficulties due to loss of property and livelihoods may cause acute and long-lasting health effects and an increase in all-cause mortality.
- According to the Joint Research Centre, under the high emissions climate scenario, more frequent and extreme flooding events may expose as many as 484,000 people to river flooding and up to 2.2 million to coastal flooding in Europe on an annual basis by the end of the century. The increased exposure may cause up to 340 flood-related fatalities a year unless adaptation actions are taken.

2.1 Flooding in Europe

Flooding in Europe occurs from natural watercourses, such as rivers, streams or lakes (fluvial flooding); directly from rainwater falling on or flowing over the land (pluvial flooding); from groundwater rising above the land surface; seawater flooding linked to extreme tidal levels or storm surges; or flooding from artificial water-bearing infrastructure (CIS WFD, 2013). Between 1870 and 2020, almost 49% of floods with significant socio-economic impact across Europe were caused by short but intense rainfall. These events caused 56% of all flood-related fatalities (Paprotny et al., 2023). Extreme downpours, in some cases preceded by dry spells reducing infiltration into the soil, have caused catastrophic events in recent years (see Box 2.1).

2.1.1 Heavy precipitation events and flooding

Extreme precipitation has increased since the 1950s, especially in northern and central Europe. Projections suggest that there will be large increases in extreme precipitation in northern Europe and somewhat smaller increases in central Europe throughout this century. No significant changes have been observed in or projected for southern Europe (EEA, 2021e; Map 2.1). Without adaptation, increased intensity of rainfall may lead to more flooding, mainly in northern and central Europe.

Box 2.1

Heavy precipitation as a cause of recent catastrophic flooding events (examples)

Western Germany and eastern Belgium, July 2021

In mid-July 2021, extreme precipitation occurred in parts of Belgium, Germany and the Netherlands. As much as 87mm of rain fell over a 2-hour period at some meteorological stations in western Germany. In eastern Belgium, one station recorded over 271mm of rain in 48 hours. The likelihood of such intense rainfall was increased by up to nine times in current climatic conditions compared to a 1.2°C cooler climate (World Weather Attribution, 2021). The downpours caused record-breaking river levels in the Meuse and Rhine catchments and devastating floods resulting in more than 240 deaths and nearly EUR 50 billion of damage (EEA, 2023e; Koks et al., 2021).

Emilia-Romagna, Italy, May 2023

In the Italian region of Emilia-Romagna, in mid-May 2023, 6 months' worth of rain fell in just 1.5 days, leading to 23 rivers bursting their banks. Within Emilia-Romagna, 42 municipalities were flooded and 400 landslides occurred, displacing 30,000 people and causing 14 deaths (Barnes et al., 2023; CEMS, 2023). The flooding was exacerbated by the previous months of drought conditions, which dried out soils and reduced their capacity to store water (JBA, 2023).

Slovenia, August 2023

In August 2023, parts of Slovenia received more than 100mm of rain within 24 hours — a month's worth. The Pasja Ravan weather station, north-west of Ljubljana, recorded 182.7mm over 12 hours. This resulted in exceptionally high levels of the Sava, Mura and Drava rivers. The flooding that affected two thirds of the country and caused seven deaths was the worst disaster to hit the country in more than 30 years, with reconstruction costs estimated at EUR 6.7 billion (STA, 2023; EBRD, 2023).

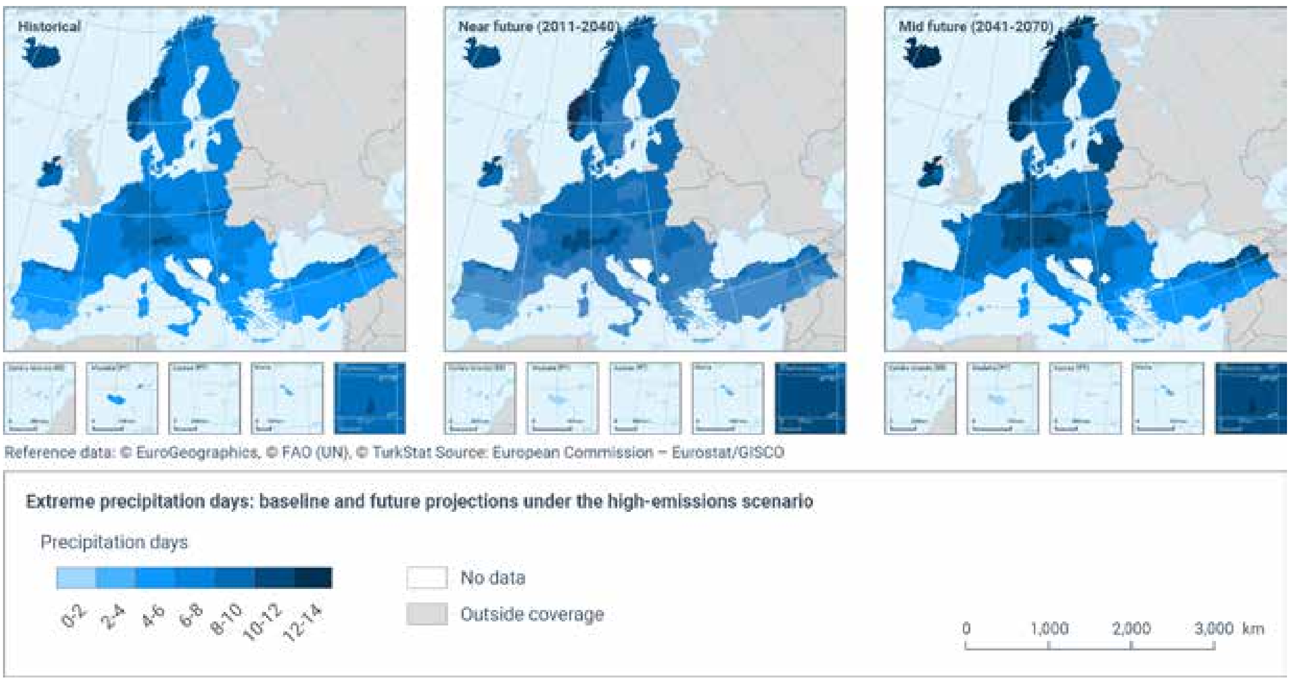
Greece, Bulgaria and Türkiye, September 2023

In September 2023, Storm Daniel brought an unprecedented volume of rain to Bulgaria, Greece and Türkiye. In Greece alone, 17 fatalities were linked to the storm (Naftemporiki, 2023). The heaviest rainfall was recorded in the village of Zagora, where 754mm fell in less than 24 hours, severely damaging infrastructure, residential buildings and businesses. In Türkiye, flash floods left several people stranded and an extensive search and rescue operation was deployed. In Bulgaria, the floods affected about 4,000 people (Davies, 2023).

Due to changes in precipitation, the risk of flooding under the changing climate is likely to increase for many regions across Europe. The annual maximum daily river discharge ([1]), which can be treated as a proxy for rarer and more extreme floods, will increase in north-western Europe and parts of central Europe but decrease in southern and north-eastern Europe. A similar geographical pattern was found for floods with an annual probability of occurring of 1%. The more likely and less extreme flood levels (annual probability of occurring of 2%) are projected to increase in most areas in Europe, particularly in central and central-eastern Europe. In some areas, a doubling of discharge levels is possible by the end of the century under the high emissions scenario (representative concentration pathway (RCP) 8.5). While decreasing precipitation and river flood levels are projected for some regions in southern Europe — such as the south of the Iberian Peninsula and Türkiye — floods are still projected to increase (EEA, 2021e; European Climate Data Explorer, 2023a).

Increased extreme precipitation events in the future can also lead to surface water (pluvial) flooding. This is especially pronounced in highly impermeable urban areas, where the drainage system cannot cope with the excess water (EEA, 2024c). Urban pluvial flooding often entails street flooding and/or flooding of combined sewerage systems, where rainwater mixes with sewage, raising health risks (Mulder et al., 2019) (see Section 2.2.5). European-scale assessments are currently lacking for pluvial flooding (EEA, 2024a).

Map 2.1 Extreme precipitation days — baseline and future projections under the high emissions scenario



Notes: The index gives the number of days in a year with daily total precipitation exceeding the 95th percentile threshold of rainy days of a reference period 1981-2010. Projections are made under the RCP 8.5 scenario. Interactive maps and additional information can be found in the source.

Source: European Climate Data Explorer (2023b) delivered by the Copernicus Climate Change Service.

([1]) River discharge is the volume of water flowing through a river channel, measured at any given point in cubic metres per second (C3S, 2022).

There is currently no coherent understanding of how climate change will impact the occurrence of precipitation-triggered landslides in Europe (Arias et al., 2021). However, landslides accompany some flood events (e.g. in Emilia-Romagna, May 2023) and have health implications (Box 2.2). Over the 1995-2014 period, deadly landslides were reported in 27 countries on the European continent. In some countries, e.g. Italy and Türkiye, an increasing number of landslides were observed, consistent with increases in extreme rainfall events (Haque et al., 2016).

Box 2.2

Impacts of landslides on human health

Landslides are gravitational ground movements — mud flows, rockslides and rockfalls — predominantly in mountainous areas. Their direct effects include fatalities and injuries. The rapidity of a landslide is one of the factors that determines the magnitude of direct impacts on people, as it leaves little time for warning and emergency procedure activation. Across Europe, the largest number of deaths between 1995 and 2014 were caused by the most rapid landslide phenomena such as rockfalls and debris flows.

Indirectly, landslides may cause disease outbreaks due to destruction of sanitation and water supply systems, or hinder emergency or medical treatment due to damage to healthcare and other infrastructure. Landslides also lead to stress, anxiety, depression and post-traumatic stress disorder due to displacement, social disruption or loss of livelihood (European Climate and Health Observatory, 2024a).

2.1.2 Sea level rise, coastal flooding and coastal erosion

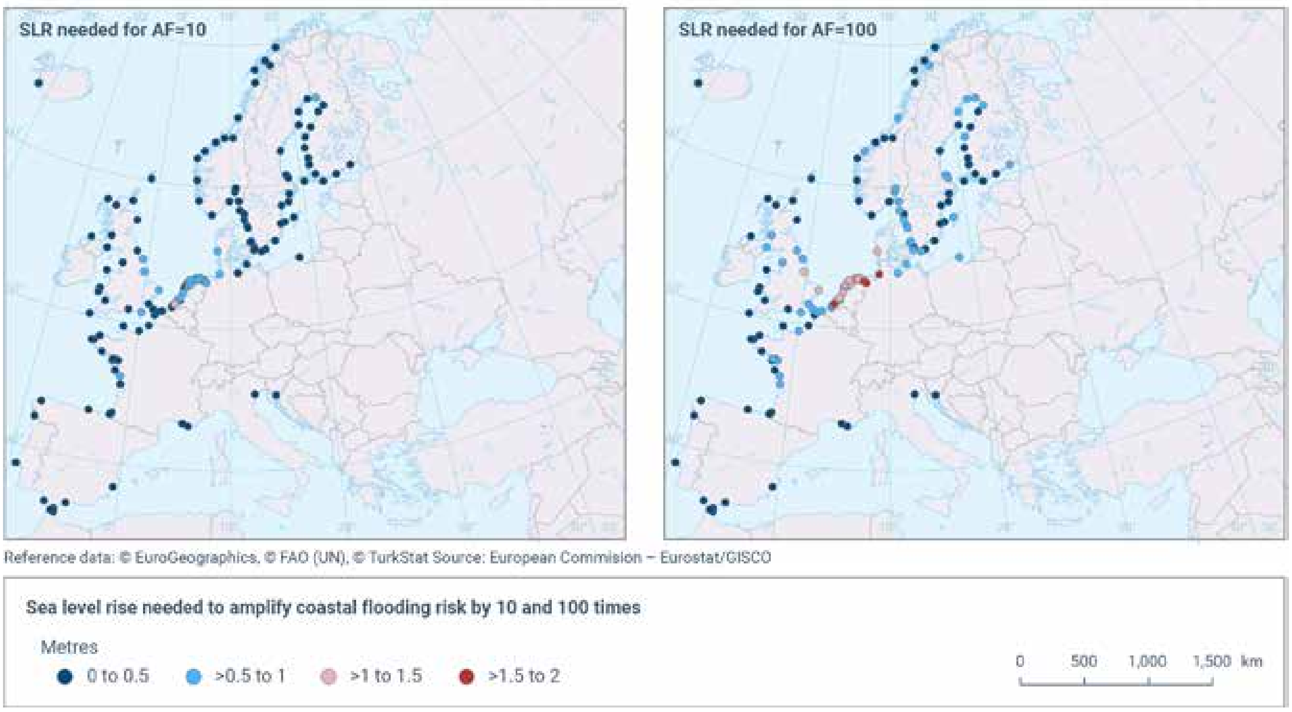
Global mean sea level rose faster in the 20th century than in any prior century over the last three millennia, with a 0.20m rise over the 1901-2018 period, and the rise has accelerated since the late 1960s. Since 1900, most coastal regions in Europe have experienced an increase in sea level relative to land, except for the northern Baltic Sea coast (EEA, 2024b).

The relative level of Europe's seas, as measured by tide gauges, is projected to continue to rise throughout this century under all emissions scenarios, driving more frequent coastal floods along most European coastlines. By 2100, the median increase of relative sea level from current levels along most of the European coastline is projected to be 0.28-0.55m under a very low emissions scenario and 0.63-1.02m under the high emissions scenario. The main exceptions are the northern Baltic Sea coast and the northern Norwegian coast, where sea level relative to land is expected to rise more slowly than elsewhere or even to decrease (EEA, 2021a).

On top of increasing sea levels, storm surges and tidal changes, particularly along the northern European coastline, can lead to coastal flooding if sufficient protection is absent, as was the case in Denmark in October 2023. A 10cm rise in sea level typically increases the frequency of flooding to a given height by a factor of approximately three. In the absence of better coastal protection, the sea level rise projected for 2100 will increase the frequency of extreme coastal flooding events by a factor of 10 along most European coastlines prior to 2050, depending on the location and the emissions scenario (Map 2.2) (EEA, 2024b). The impact of waves from more severe storms may exacerbate the effects of coastal flooding. In addition, sea level rise has implications for drinking water aquifers through saline water intrusion (see Section 4.2).

Between 27% and 40% of European sandy coastline is today affected by erosion, with the Mediterranean and North Sea shorelines retreating by 0.5-1m between 1984 and 2015 (IPCC, 2022a). Coastal erosion is likely to increase because of increases in sea levels, storms and wave height. By 2050, approximately 3,000-3,500km^2 of the European coastal zone could erode considering RCP 4.5 and RCP 8.5 scenarios, respectively (Paprotny et al., 2021). For more information, see the European Climate Risk Assessment (EEA, 2024a).

Map 2.2 Sea level rise needed to amplify coastal flooding risk by 10 and 100 times



Note: AF = amplification factor.

Source: EEA, 2024b.

2.2 Exposure of population to flooding and related health risks

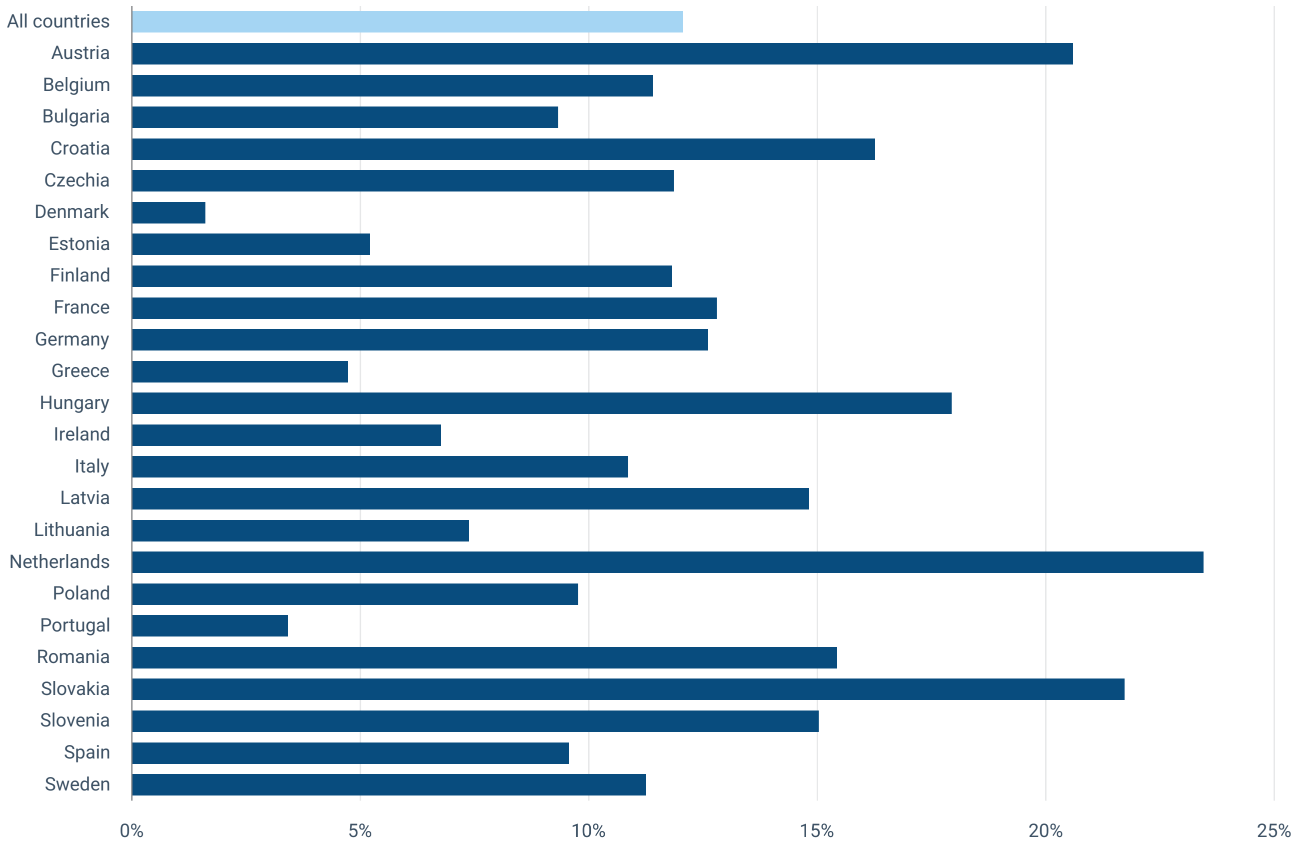
2.2.1 Population exposure to flooding

Under the Floods Directive (EU, 2007), the EU countries are required to assess all areas where significant floods could occur, map the flood extent and the assets and humans at risk in these areas, and take adequate and coordinated measures to reduce flood risk (see also Section 5.1). According to the European Commission's map viewer, which brings together the information reported by the countries under the Floods Directive, over 14,000 areas in the EU are at significant risk of flooding (EC, 2023a).

Trends in population exposure

According to an unpublished EEA analysis, in 2021, 52.5 million Europeans (²) (12.1% of the population) lived in potential riverine flood-prone areas (³), with the highest percentage in the Netherlands (23.4%), Slovakia (21.7%) and Austria (20.6%) (Figure 2.1). This is driven by the location of large cities near rivers, where high density of population coincides with potential flood risk (EEA, 2024c). On an annual basis, 172,000 people in the EU-27 and the UK are exposed to river flooding (Dottori et al., 2020).

Figure 2.1 Percentage of population living in potential riverine flood-prone areas in European countries



Note: The analysis covers EU-27 countries excluding Cyprus, Luxembourg and Malta.

Sources: EEA analysis based on EEA potential flood-prone areas and Eurostat data on population in 2021 (census) based on 1-km grid.

(²) Across EU-27 countries, excluding Cyprus, Luxembourg and Malta.
(³) Potential river flood-prone areas capture the area that could be flooded from rivers during a flood event with a return period of 1 in 100 years (under the current climate), as well as the river area. If flood defence structures are present, the floodplain is reduced to the flood hazard area inside those structures (see EEA, 2019c).

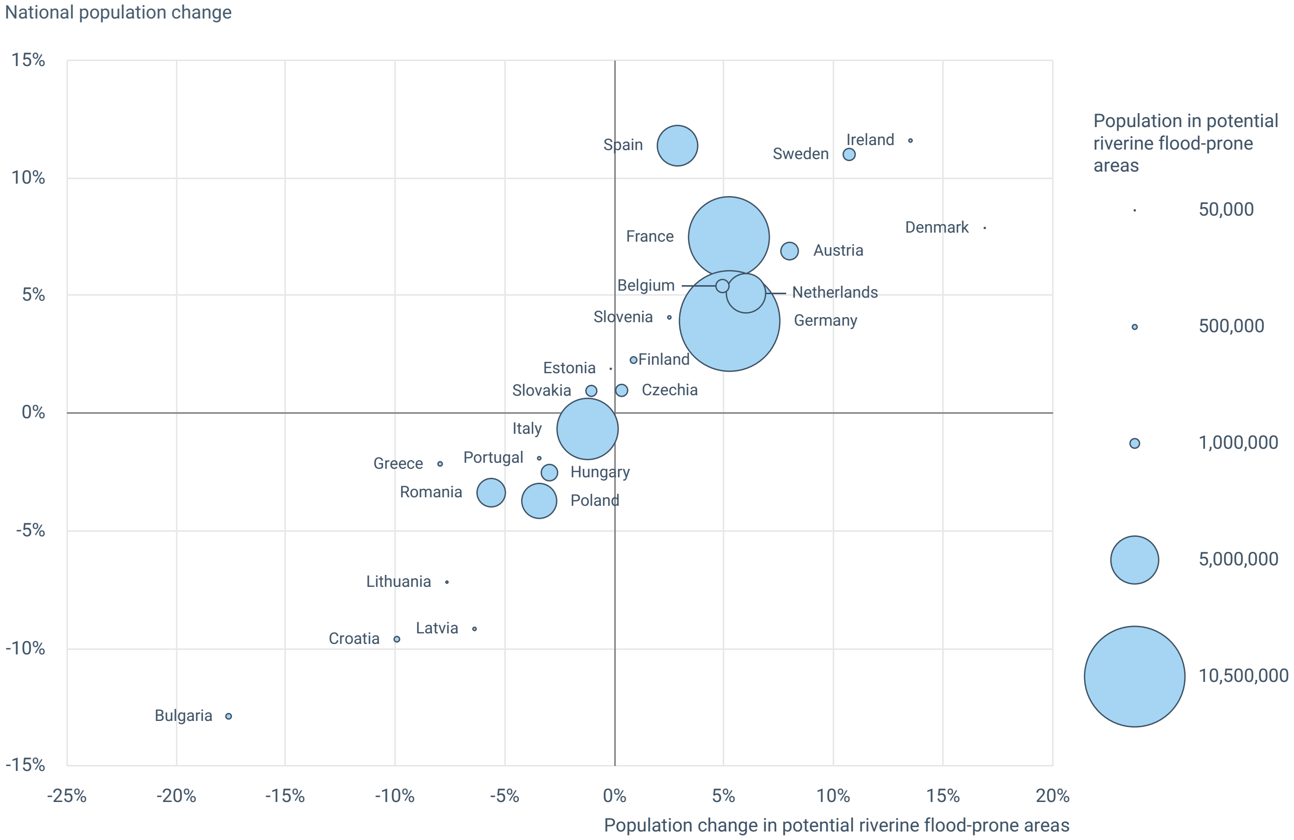
In 2013, approximately 42% of the total population of 26 European coastal countries (including the UK) lived in coastal regions (Iglesias-Campos et al., 2015). Around 100,000 people in the EU-27 and the UK may be exposed to coastal flooding every year (Vousdoukas et al., 2020). Unless additional adaptation measures are taken, exposure to flooding will increase across the continent's low-lying coastal areas and estuaries (Bednar-Friedl et al., 2022).

In the past 150 years, due to population growth, the population exposed to flooding in 42 European countries has increased by more than 130% (Paprotny and Mengel, 2023). Between 2012 and 2018, residential urban areas expanded on nearly 234km² of floodplains across the EU-27 and the UK, and nearly 1,128km² of floodplains saw development of economic sites and infrastructure (EEA, 2019b).

Between 2011 and 2021, there was an increase of more than 935,000 people living in potential riverine flood-prone areas — an increase of 1.8% — according to an unpublished EEA analysis of 24 European countries. This is smaller than the increase in population outside of the riverine flood-prone areas, which was around 2.9% ([4]). In most of the countries, the change in population potentially exposed to riverine flooding is thus slightly lower than the change in general population (Figure 2.2). However, in Denmark, the population growth in potential riverine flood-prone areas was more than double the general population growth, although overall affecting a very small number of people. In contrast, in Spain, the population increase in potential riverine flood-prone areas was substantially smaller than that of the general population. Further, in Bulgaria and Greece, two countries with a decreasing population, the decrease of the population in potential riverine flood-prone areas was much higher than the decrease in the general population.

([4]) The analysis did not take into account the existence of flood protection due to data unavailability, thus it is unclear whether the observed patterns in population growth actually put an increasing number of people at risk.

Figure 2.2 **Population change between 2011 and 2021 in European countries, considering potential riverine flood-prone areas**



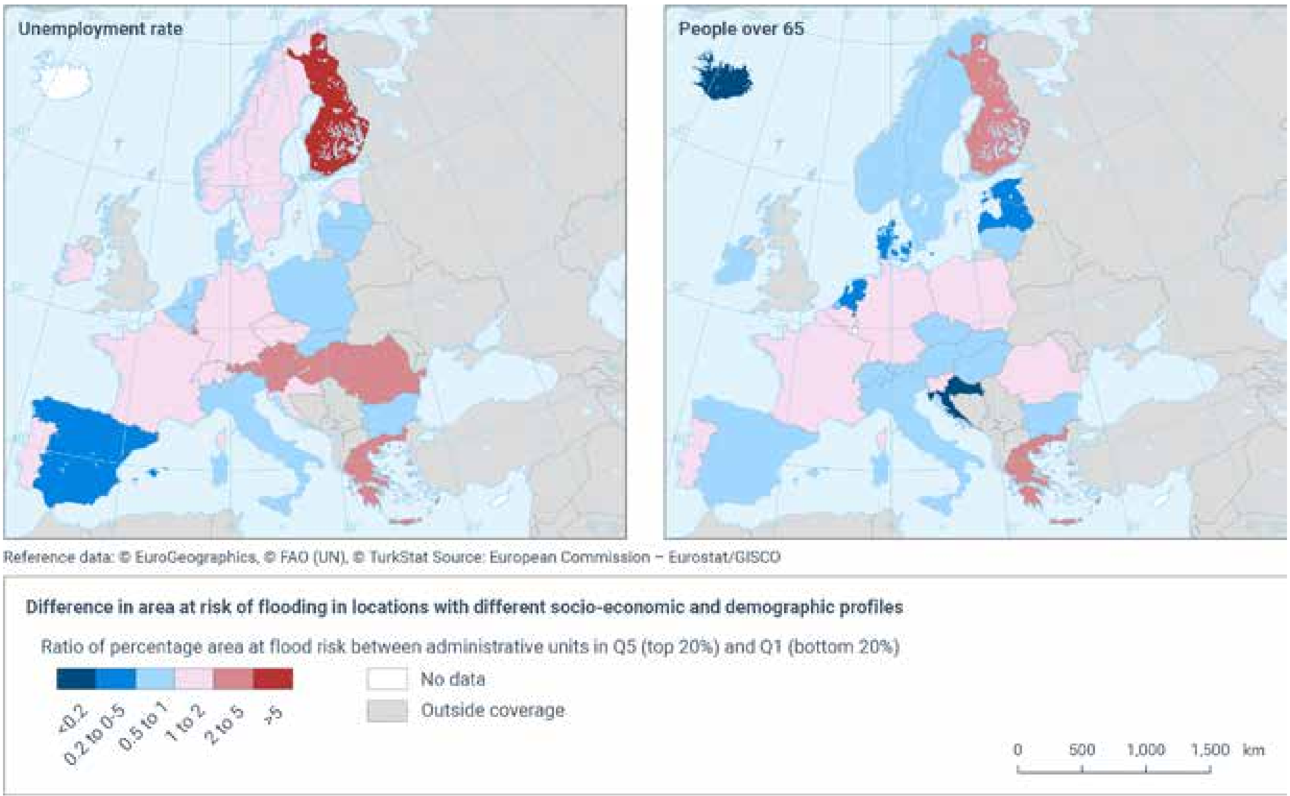
Note: The analysis covers EU-27 countries excluding Malta (no population in potential riverine flood-prone areas), Cyprus and Luxembourg (no Eurostat population data available for one of the years).

Sources: EEA analysis based on EEA potential flood-prone areas and Eurostat data on population in 2011 and 2021 (census) based on 1-km grid.

Inequalities in exposure to flooding

Some population groups tend to be more exposed to flooding due to factors such as the availability of cheaper housing in flood risk areas or an unwillingness to move. In some European countries, areas with a higher proportion of elderly people or higher unemployment rates tend to be more exposed to river floods. For example, in Greece and Finland, areas with the highest proportion of senior citizens in 2020 contained on average double the percentage of potential riverine flood risk areas compared to areas with the lowest proportion of elderly people. In Finland, Luxembourg and Slovenia, the proportion of area potentially at flood risk was three to five times larger for areas with the highest unemployment rate compared to areas with the lowest unemployment rate (Map 2.3).

Map 2.3 **Difference in areas at risk of flooding in locations with different socio-economic and demographic profiles**



Notes: The difference in area is expressed as a ratio. Higher ratio values (>1) indicate that locations with the highest unemployment rate or the highest share of over-65s (top 20% of local administrative units in a given country) tend to have more potential riverine flood-prone areas than locations with the lowest unemployment rate and the highest share of over-65s (bottom 20% of local administrative units in a given country). See the map viewer in the European Climate and Health Observatory.

Source: European Climate and Health Observatory, 2022a.

Whether people own or rent their homes, as well as their occupations, may also affect their exposure to flooding. For example, in the Ahr Valley, Germany, which was affected by the 2021 floods, significantly more renters lived inside the legally defined floodplain of July 2021, whereas more owners lived outside this area (Truedinger et al., 2023). People who commute to work may be more exposed through their travels (Petrucci et al., 2019) and various occupational groups may come in contact with floods (Box 2.3).

Box 2.3

Increased exposure of certain occupations to floods and their health impacts

The groups at highest risk from flooding are emergency and ambulance service workers, firefighters and professionals involved in flood response and clean-up. They may come into contact with contaminated flood water, debris and mud, which increases the likelihood of exposure to chemical hazards or infectious diseases (ECDC, 2021b) (see Section 2.3.3). For example, a fourfold increase in diarrhoea was found for people involved in flood clean-ups in 2002 in Germany (Schnitzler et al., 2007). In Copenhagen, in 2011, among those involved in the response to flash flooding and the clean-up (insurance agents, cleaners, engineers, maintenance workers, garbage workers, pest controllers, fire and rescue workers and police officers), 22% reported symptoms such as diarrhoea, colds or sore throats, headaches, allergic reactions (runny nose, red eyes, difficulty breathing), abdominal pain, nausea and severe muscle pains (Wójcik et al., 2013).

For more information about climate change risks in occupational settings see the European Climate and Health Observatory and EU-OSHA.

Projections

By the end of the century, the number of people exposed to annual riverine flooding in Europe is projected to be 252,000 under a 1.5°C global warming scenario; 338,000 under a 2°C scenario; and 484,000 — more than three times the current numbers — under a 3°C scenario. However, with adaptation measures, the population exposed can be limited to 100,000 or less under all scenarios (Dottori et al., 2020).

Forzieri et al. (2017) estimate that, by 2050, the number of people residing in coastal flood zones in the EU-27 and the UK (not considering protection measures) will increase by 24% compared with current values, with large variation between countries. Considering population growth and sea level rise, up to 2.2 million people are projected to be exposed to coastal flooding by 2100 under a high emissions scenario and 1.4 million under a moderate mitigation scenario, in the absence of additional adaptation measures. With adaptation measures, these numbers are expected to be reduced to 0.8 million and 0.6 million, respectively (Vousdoukas et al., 2020). With higher population growth and different climate mitigation scenarios, an even higher increase in exposure is expected, with 1.5-3.7 million people exposed to coastal flooding by 2100 (Vousdoukas et al., 2018; McEvoy et al., 2021). The European population exposed to the threat of a 100-year flood event will increase rapidly after 2040; by 2100, under a high emissions scenario (RPC 8.5) it is estimated that 10 million people would be exposed, if population size remains constant and no additional protective measures are taken (Bednar-Friedl et al., 2022).

2.2.2 Vulnerability of different population groups to flooding

Different groups of people experiencing the same flooding event may be affected by it in various ways. Populations seen as particularly vulnerable to adverse health effects from flooding include the elderly, children (see Box 2.4), people with chronic illnesses or physical impairments and pregnant women (WHO Europe, 2017). Other characteristics increasing vulnerability in the event of flooding are low socio-economic status, being an undocumented migrant, homelessness, living in a mobile home or living in a rural community. People without awareness or experience of climate-related hazards, those not speaking a country's official language/s and those with no technical measures against the hazard tend to be most vulnerable (Fekete and Rufat, 2023).

Young children, the elderly and people with weak immune systems are the most likely to suffer from severe disease course after contracting an infectious disease through contact with floodwater (see Section 2.3.3) (WHO Europe, 2017). People accommodated in temporary shelters are more susceptible to infectious diseases due to exposure to pathogens in communal accommodation and disruption of their regular healthcare provision (ECDC, 2021a).

In the aftermath of flooding, older people may face substantial mental and physical health problems due to, for example, living in a damp home. Financial constraints may make it more difficult for lower-income groups to prepare for and recover from extreme weather events (Breil et al., 2018). Women, the elderly, children, people with previous psychiatric illnesses and those experiencing social isolation, as well as indigenous and native communities, also have increased probability of developing psychopathologies after floods (Cianconi et al., 2020).

Box 2.4

Vulnerability of children to floods and their health impacts

While fewer children than adults in Europe die in floods, they face health risks during and after them. Waterborne diseases (see Section 2.3.3) and chemical contamination of floodwater (see Section 2.2.5) can affect children more due to their higher water intake compared to body weight, more frequent outdoor activities, greater likelihood of swallowing water and immature immune systems. According to data reported by European countries to the European Centre for Disease Prevention and Control between 2014 and 2021, campylobacteriosis and toxin-producing *E. coli* infections that may be affected by flooding had the highest incidence among children under five. Children were at higher risk than adults from heavy metal pollution in floodplain soils across the Elbe river (Rinklebe et al., 2019), indicating that the health risks persist long after the floodwaters have receded.

Climate-related disasters, including floods, have a profound negative impact on children's mental health. Various physiological, cognitive and emotional development factors make children more vulnerable to traumatic incidents like loss of loved ones, damage to possessions or displacement. They process traumatic events differently from adults and often lack appropriate coping strategies. Their dependency on adults can lead to psychosocial consequences of flooding impacts on their family or school. Children face a higher risk of developing mental health issues if they encounter community violence or trauma after a disaster, are exposed to multiple disaster events or stressors in the post-flooding recovery period, such as moving house or changing schools, or perceive their lives as being in danger.

Children affected by climate-related disasters may have difficulties sleeping. Behavioural changes, such as aggression, withdrawal, regressive behaviours and developmental setbacks, are also noted in children following flood events. Moreover, exposure to life-threatening emergencies and situations involving parental danger can result in depression symptoms, pessimism and sadness. The long-term consequences of flooding include heightened risk of post-traumatic stress disorder (PTSD) and an elevated risk of suicidal thoughts and substance use. Flood experience can also make children more susceptible to other stressors and adverse mental health outcomes in later life. Exposure to trauma can cause changes in brain anatomy and function, impeding the processes of learning and memory. Children with symptoms of PTSD often express difficulties concentrating, which can impede their ability to learn effectively at school.

For more information see European Climate and Health Observatory (2024b).

2.2.3 Exposure of healthcare facilities to flooding

Flooding of healthcare facilities disrupts care for existing patients, in some cases requiring evacuation (see Box 2.5). This also puts pressure on neighbouring hospitals, clinics and healthcare centres that need to take over the healthcare of the flooded facilities on top of their usual duties. According to the European Climate Risk Assessment (EEA, 2024a), healthcare buildings have a moderate susceptibility to various extreme weather events, with a heightened risk of river and coastal floods. As an example of the impact on health systems, in the Netherlands, 3% of internal hospital crises and disasters in the 2000-2020 period were related to hydrometeorological disasters, including impacts of pluvial and coastal floods (Klokman et al., 2021). In Finland, large-scale stormwater floods may have adverse effects on pre-hospital emergency medical services, according to the country reporting on adaptation under the Governance Regulation (EEA, 2023h).

Of more than 15,000 healthcare facilities in 28 European countries ([5]), 11% are in potential riverine flood-prone areas. The highest proportion of healthcare facilities potentially at risk of flooding from rivers are in Finland and the Netherlands (Figure 2.3).

Box 2.5

Examples of flooding impacts on healthcare facilities

Surface flooding in Copenhagen, Denmark, July 2011

During 2011 flash flooding in Copenhagen associated with a cloudburst event, the trauma centre at the main Rigshospitalet had to be moved to Herlev Hospital after mud and water entered the facility and damaged equipment. At Hvidovre Hospital, patients in the emergency department were sent home and management considered evacuating the entire hospital, including 450 bed-bound patients (B.T., 2012).

River flooding in Saint-Affrique, France, 2014

In 2014, the Centre Hospitalier de Saint-Affrique in the south of France was flooded by the Sorgue river after heavy rainfall. The long-term care unit, the retirement home within the hospital and the kitchen were badly affected and the residents and patients had to be evacuated and transferred to other hospitals. Parts of the hospital remained closed for nearly 6 months. The costs to the hospital were estimated at about EUR 1 million. The hospital is taking part in the LIFE RESYSTAL project, whereby green and blue adaptation measures will be planned and implemented by pilot hospitals to improve their resilience to climate change (personal communication with Sebastien Coquelin, former Director of Financial Affairs — Millau and St Affrique Hospitals, 7 February 2023).

River flooding in Germany, Belgium and the Netherlands, July 2021

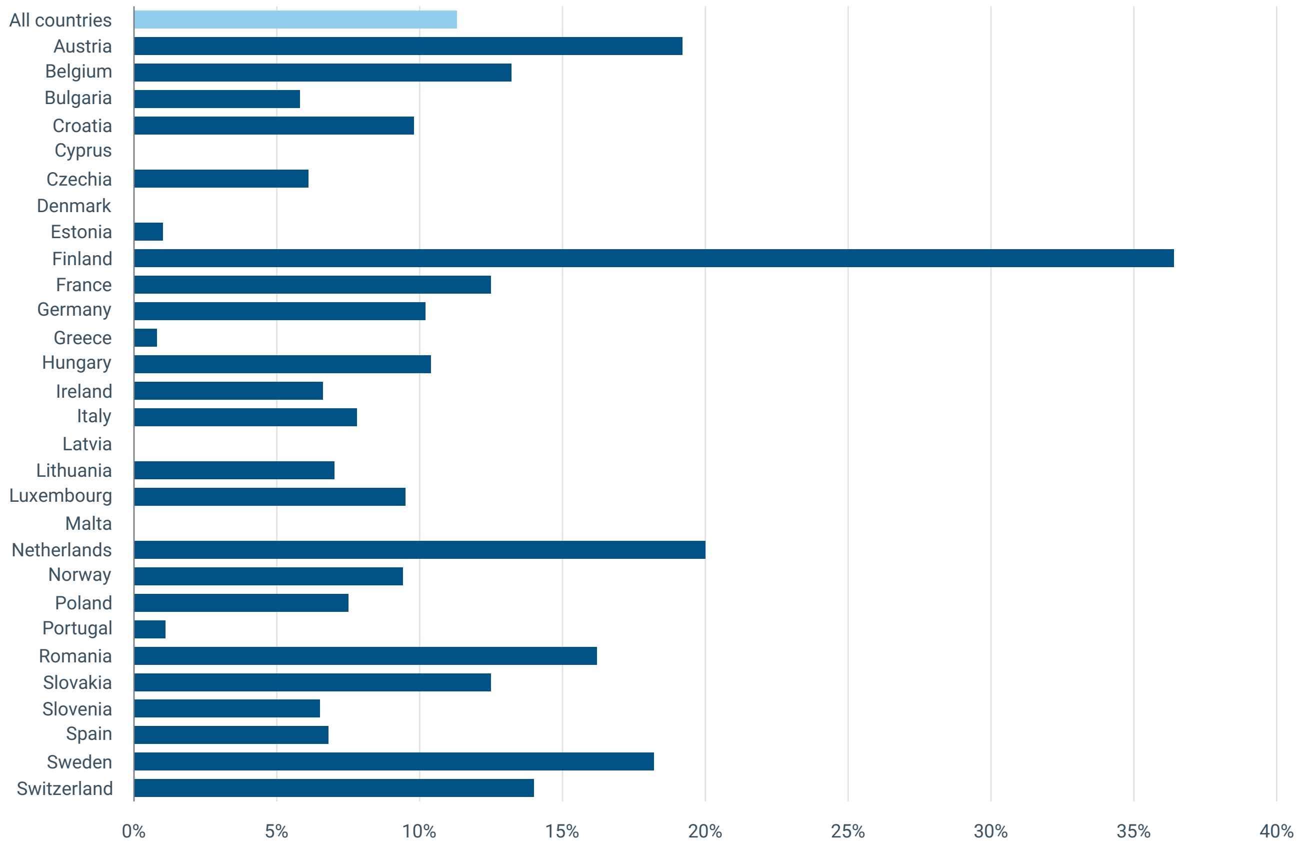
More than 100 general practitioner surgeries in western Germany were affected by the 2021 floods; some were destroyed and others were unable to operate due to a lack of running water and electricity. After 1.5 months, medical care was restored in the most affected regions in Rhineland-Palatinate. In the town of Eschweiler, the basement, outbuildings and the entire outdoor area of the hospital were flooded. The power supply collapsed, the building technology was destroyed and some 300 patients had to be evacuated by helicopter. Property damage was expected to be around EUR 50 million, with several millions in damage due to the operational downtime. The hospital became partially operational within 3.5 weeks and fully operational within 3 months. In Belgium, various rural clinics were affected and some destroyed. In the Netherlands, a nursing home was flooded and one hospital was evacuated as a precautionary measure (Manandhar et al., 2023; Koks et al., 2021).

River floods in Slovenia, August 2023

Water from rivers swollen by extreme rainfall flooded the entire area outside the Begunje Psychiatric Hospital, as well as the basement and ground floor rooms, where the hospital's functional, outpatient and emergency rooms are located. Access to the hospital was blocked. Problems also arose in Trbovlje General Hospital, where closed roads were the biggest problem (RTV SLO, 2023).

([5]) EU-27, excluding Estonia, plus Norway and Switzerland.

Figure 2.3 **Percentage of healthcare facilities located in potential riverine flood-prone areas per European country**



Notes: Figure covers EU-27, Switzerland and Norway. For Estonia, the data on location of healthcare facilities were made available by the Estonian Land Board (Ministry of Climate). Cyprus, Denmark, Latvia and Malta have no hospitals located in potential riverine flood-prone areas. See map viewer for interactive maps at NUTS 2 level in European Climate and Health Observatory.

Source: European Climate and Health Observatory, 2022a.

One factor determining the adaptive capacity of the health sector, i.e. how well it copes with climate change, is population access to services (Melica et al., 2022), which can be affected by flooding. In 2020, an estimated 82.5% of the EU population lived within 15 minutes by car of their nearest hospital (Eurostat, 2023a). However, excluding the hospitals located in potential riverine flood-prone areas extends the average travel time per NUTS 3 region from 22 minutes to nearly 24 minutes. While most of the regions did not have a substantial extension in travel time, in 21 regions, the average travel time became more than 10 minutes longer (European Climate and Health Observatory, 2022b).

For health facilities, structural damage from flooding, both river and coastal, and windstorms is expected to increase, with expected annual damage rising from EUR 250 million per year in the 2000s to EUR 520 million per year in the 2080s (Forzieri et al., 2018). Adaptation of these facilities to the changing climate is urgently needed (EEA, 2024a). However, local government flood protection efforts tend to prioritise technical infrastructure such as transport and electricity systems over social infrastructure like hospitals, nurseries and elderly care facilities (Sweco, 2023).

WHO (2020) provides guidance on water supply and sanitation in extreme weather events.

2.3.4 Exposure of water supply systems to flooding

Flooding of water supply areas can affect the quality of drinking water and severely limit its availability. Following the July 2021 floods in Germany, drinking water supply was disrupted for days or even weeks, depending on the location. The Rhineland-Palatinate region's supply was restored within 2 months. However, in Altenahr and Lind, emergency water supplies continued until October 2021 (Koks et al., 2021). As an example of the potential scale of the problem, an assessment of the impact of large-scale coastal and fluvial floods on drinking water supply in the Netherlands suggests that if the coastal or river districts were completely flooded, the drinking water supply of approximately 3.5 million people would be compromised. In a scenario where rivers overflow their banks when coastal defences were closed (transitional zone scenario), 1.7 million people would not have access to drinking water (van Leerdam et al., 2019). In addition, flooding of private wells has been found to increase risk of infections with waterborne diseases (see Box 2.6).

Box 2.6

Health impacts of contaminated private water supply in Ireland

Ireland has the highest notification rates for infections with toxin-producing *E. coli* (STEC) and cryptosporidiosis in Europe (ECDC, 2023b; see Section 2.3.3 for disease descriptions). About 720,000 people (15% of the population), particularly in rural areas, rely for drinking water on private wells, which are exempt from regulation and very vulnerable to contamination (Public Health Medicine Environment and Health Group, 2021). Nearly 83% of primary cases of STEC reported to the public health system were associated with drinking water. Heavier precipitation and more frequent and intense flood events increase the contamination risks of these wells with STEC and *Cryptosporidium* parasites that originate from the faeces of animals (personal communication with Ina Kelly, Health Protection Surveillance Centre, Ireland, 22 March 2023).

WHO (2011a) offers guidance on water supply and sanitation in extreme weather events.

2.2.5 Pollution risks associated with heavy precipitation and floods

Contaminated sites

Floods affecting critical infrastructure, industrial installations and contaminated sites may lead to soil, surface water and groundwater pollution with heavy metals and chemicals (Arrighi et al., 2018). Historically, landfill sites were often located in areas with cheap land, such as floodplains. Around 10,000 of Europe's historic landfill sites are on coasts at risk of flooding or erosion, with the potential to release their contaminant load directly to the marine environment (Ford and Spencer, 2021). In addition, Europe has a large legacy of abandoned mines, which constitute some of the highest environmental risks in Europe (EEA, 2023k). Tailing dams — earth-filled embankment dams used to store byproducts of mining operations — are particularly prone to failure due to heavy rainfall events, causing landslide and pollution risks (Rico et al., 2008).

Moreover, many previously flooded areas are hotspots for toxic pollutants, which can be released again to the environment. For example, floodplains of the Elbe river and its tributaries contain arsenic, chromium, vanadium and lead at levels harmful to human health (Rinklebe et al., 2019) (EEA, 2022f); floodplains of the Mulde, Bode and Saale in Germany have accumulated chlorinated dioxins (a byproduct of magnesium production) and pesticides produced in their catchments in the past, and during major flood events these become mobilised and contaminate the river waters and the fish living in them (Steinhäuser et al., 2022).

Industrial installations in potential riverine flood-prone areas

Floods are among the most frequent natural hazards triggering technological accidents. Water dispersion and reactions of released chemicals with water are the main causes for the health impacts experienced in such accidents (Cozzani et al., 2010). Factors that increase the risks of chemical release and adverse effects on human health include the following (WHO, 2018a):

- Location of industrial facilities in flood-prone areas; high population density around industrial sites; land with little capacity of absorbing rain due to erosion, deforestation or high proportion of sealed surfaces;

- Structures that are not flood resilient, including due to inadequate building and planning regulations. Storage tanks and pipeworks are the weakest points for chemical releases during floods; this has been the case for industrial accidents related to flooding in recent years (Box 2.7);

- Inadequate warning systems, safety measures or emergency planning; lack of public awareness about flood risks.

The general public, rescuers and those involved in clean-up operations may be exposed to a range of hazards, including burns, respiratory tract injuries and poisoning from exposure to spilled toxic chemicals, as well as hazards linked to flooding in general (WHO, 2018a).

Box 2.7

Examples of industrial accidents triggered by flooding

Flooding of chemicals factory in Neratovice, Czechia, 2002

In August 2002, heavy rains caused flooding of the Elbe and other rivers in Czechia, affecting 3.2 million people. The floods also caused several accidents associated with the release of hazardous substances, including serious contamination from a chemicals factory in Neratovice, north of Prague. In addition to oil, mercury and dioxins, 80 tonnes of chlorine was released into the air and into floodwaters. In one of the affected districts, almost half of the population reported impaired health during the flood and more than a third in the 6 weeks afterwards (WHO, 2018b).

Livorno refinery, Italy, 2017

On 9 and 10 September 2017, heavy rainfall — up to 260mm in 2 hours — hit the Livorno area, causing flash flooding exceeding 45km^2. Water from the Ugione creek flooded the Livorno refinery site, and the residual oil in the stormwater catchment network, as well as on the industrial site, was washed away and spread on the floodwater. Detection of the oil spill was delayed by the evacuation procedure. The containment wall around the site was breached, allowing the water polluted with oil to exit, enter the creek and reach the nearby sea. After the clean-up operation, additional safety measures were implemented, including improved spill detection, maintenance of the Ugione banks and installation of early warning system networks in the area (Necci and Krausmann, 2018; Ricci et al., 2022).

Oil spill on the Evalude river, Morbier, France, 2019

On 24 May 2019, a violent rainstorm caused water to enter a metal waste recovery centre's hydrocarbon separator, which was almost full due to a fuel spillage a few days earlier. The water carried some of the hydrocarbons in the separator to the river, causing iridescence and odour over a 1-km stretch. The preventive measures implemented after the incident included a weekly check of the condition of the oil separators, visual monitoring two to three times a week of the river at and downstream from the stormwater discharges and annual monitoring of discharges (ARIA, 2019).

Across Europe, nearly 15% of industrial facilities — as reported to the EEA under the Industrial Emissions Directive (Directive 2010/75/EU) and the European Pollutant Release and Transfer Register Regulation (Regulation (EC) No 166/2006) — are located in potential riverine flood-prone areas, with facilities in sectors such as paper and wood production and processing, hazardous waste and animal waste disposal particularly exposed (Table 2.1).

Table 2.1 **Location of industrial facilities in potential riverine flood-prone areas in Europe**

Sector: activity	Percentage in potential riverine flood-prone areas	Number in potential riverine flood-prone areas
Animal and vegetable products from the food and beverage sector	14.7	499
Chemical industry	19.7	683
Energy sector	15.9	358
Intensive livestock production and aquaculture	8.2	1,529
Mineral industry	12.9	505
Paper and wood production and processing	37.9	385
Production and processing of metals	19.6	987
Waste and wastewater management: installations for the disposal or recovery of hazardous waste	20.1	742
Waste and wastewater management: installations for the disposal or recycling of animal carcasses and animal waste	21.8	71
Waste and wastewater management: landfills	6.0	180

Note: The analysis was carried out for the EU-27 and Switzerland.

Sources: EEA analysis based on potential riverine flood-prone areas and industrial facilities data reported to the EEA under the European Pollutant Release and Transfer Register.

Exposure of urban wastewater treatment plants to flooding

While the downstream location of urban wastewater treatment plants (UWWTPs) allows gravitational movement of wastewater, it may increase the risk of flood damage to the plants, resulting in the pollution of floodwater and the spread of pollution downstream. For example, following the 2021 summer flooding in the German region of Rhineland-Palatinate, several sewage treatment plants in Altenahr, Mayschoss and Sinzig were damaged or destroyed (Koks et al., 2021). In Belgium, 15 water treatment plants were affected (Wallonie Environment SPW, 2021). Closure of plants due to floods can have longer-lasting implications for water quality (see Box 2.8).

Box 2.8

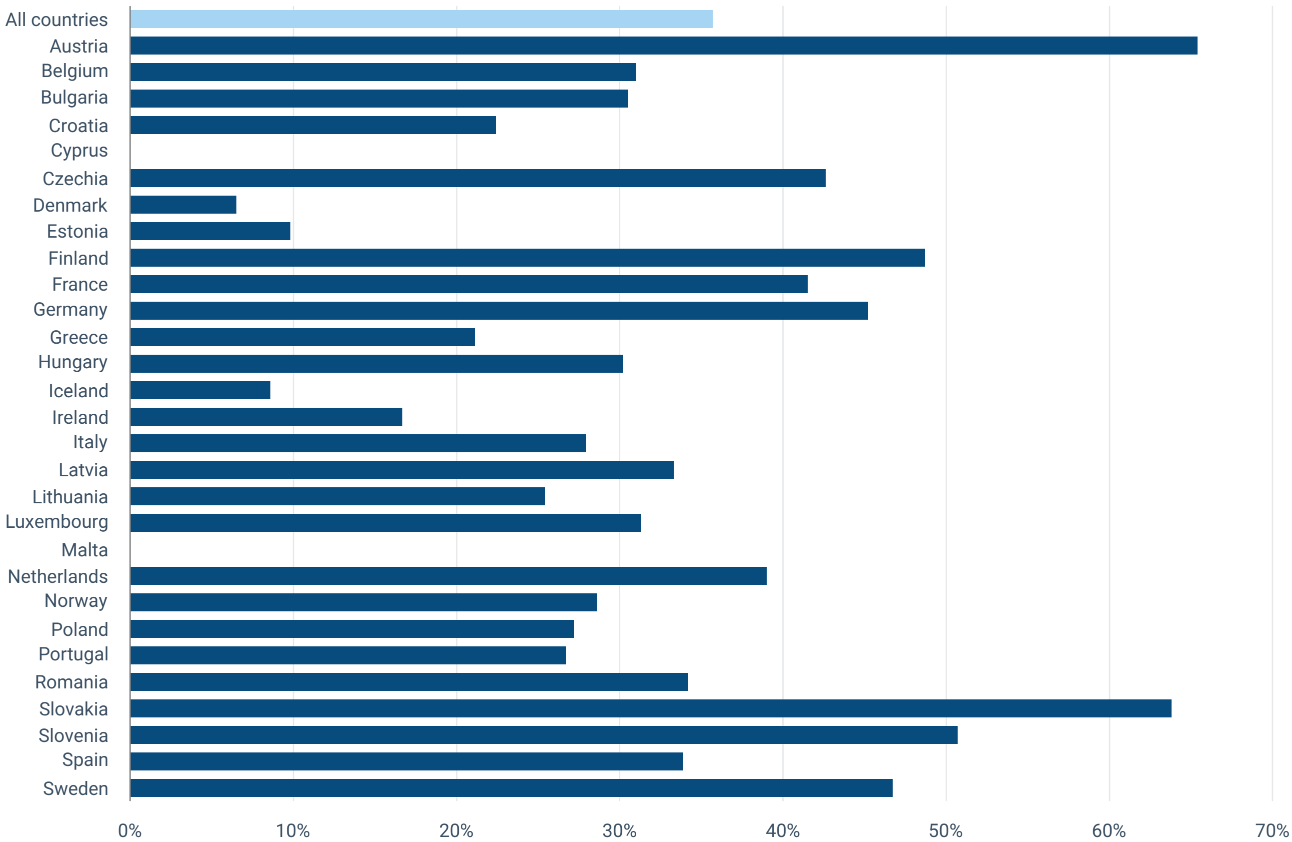
Reconstruction of UWWTP after flooding in Tarnobrzeg, Poland

In May and June 2010, a wastewater treatment plant serving 50,000 people as well as a sewerage system within five housing estates in Tarnobrzeg were flooded by the Vistula river, which broke through the flood embankment. The flood destroyed buildings at the wastewater treatment plant as well as facilities for mechanical and biological wastewater treatment. For several days, raw sewage from nearby housing entered the Vistula; following that, for several weeks only preliminary treatment was applied while reconstruction was carried out.

A total of PLN 17 million was committed to the reconstruction of the treatment plant and the sewerage system by the National Fund for Environmental Protection and Water Management. Storm overflow on the combined sewer and storm rainwater pre-treatment facilities and storm rainwater pumping station were added to protect the plant from future flooding. The main pumping station, the biological part of the plant, the grit chamber and temporary sludge storage yard were modernised (Skanska, 2023; NFOŚGW, 2011).

Analysis of the location of UWWTPs across Europe identified that 36% of the 24,074 plants are located in potential riverine flood-prone areas. The highest proportion of plants potentially exposed to riverine floods — nearly two thirds — are in Austria and Slovakia (Figure 2.4).

Figure 2.4 Percentage of UWWTPs in potential riverine flood-prone areas per country (2022)



Note: Figure includes the EU-27, Iceland and Norway. No UWWTPs were located in potential riverine flood-prone areas in Cyprus and Malta.

Sources: EEA, based on the 2022 UWTTP dataset (public version) and potential flood-prone areas dataset.

Combined sewer overflows

In addition to flooding from rivers, lakes or the sea, wastewater treatment plants can be affected by heavy rainstorms that overload combined sewerage systems and can cause overflows at treatment plants (EEA, 2019e), impacting their performance (WHO, 2011a). To prevent spills and flooding at undesirable locations or overloading of wastewater treatment plants during heavy rainfall events, combined sewerage systems — i.e. single pipeline systems that carry wastewater from homes, offices and industries with the stormwater from surface run-off ([6]) — incorporate combined sewer overflows. These ensure that the excess water, which is polluted with sewage, is discharged into a receiving water body at a designated location. There are an estimated 650,000 combined sewer overflows in Europe, supporting the functioning of more than 3 million km of sewer systems (EurEau, 2020a). Information about the proportion of combined versus separate sewage systems is not consistently available across Europe (EurEau, 2021).

Stormwater overflows affect the quality of the receiving water bodies locally and in the short term (EurEau, 2020a). The area of impervious land connected to combined sewer systems, proportion of combined sewer systems, storage capacity in the systems and their operational parameters affect the occurrence of polluting events. Stormwater overflows, due to the presence of sewage, contain chemical pollutants such as cleaning agents, personal care products and pharmaceuticals, diverse intestinal and soil-inhabiting bacteria, e.g. coliforms, streptococci and clostridia, and protozoa, viruses, fungi, worms and microalgae. As a result, discharge of untreated sewage can create serious public health risks (EEA, 2022b). Such events are often short — up to 72 hours (EEA, 2020a) — but have the potential to worsen water quality far from the point of release (Schernewski et al., 2014).

The European Commission's evaluation of the Urban Waste Water Treatment Directive notes that with more heavy rainfall events expected due to climate change (see Section 2.1.1), stormwater overflows will be an increasingly important source of pollution in surface water bodies (EC, 2019e). In the second reporting under the Water Framework Directive, 4% of surface water bodies were reported to be affected by pollution from storm overflows (from 18 Member States), although the actual proportion of bodies affected may be higher, as there are few data enabling quantification of the impacts of discharges on water bodies (EEA, 2022b). For example, in Poland in 2013-2019, the discharge from overflow of storm sewers of the combined sewerage system of Warsaw's left bank was 45 times the legal limit. In the city of Łódź, 50 discharges per year occur while 10 discharges per year are allowed, and other Polish cities are similarly affected. The situation may be similar in all of Europe (Suchowska-Kisielewicz and Nowogoński, 2021).

Diffuse pollution sources

In Europe, more progress has been made on addressing point source pollution problems than diffuse sources of pollution ([7]), e.g. those stemming from urban areas and agriculture. Diffuse pollution sources are estimated to affect 38% of all surface water bodies in Europe, while point source pollution accounts for 18% of degraded waters. Diffuse pollution from agriculture is the major pressure on groundwater quality, affecting 29% of groundwater bodies by area (EEA, 2018a).

([6]) Run-off is surface water flow of water from precipitation and outdoor water use that drains from roofs, paved areas and other surfaces.
([7]) Point source is a stationary location or fixed facility from which pollutants are discharged; any single identifiable source of pollution. Diffuse pollution comes from widespread activities with no one discrete source (EEA Glossary).

Heavy precipitation affects the application of pesticides and reduces the efficacy of some herbicides, enhancing their dilution and leaching into groundwater and run-off from the soil, leading to a greater contamination of water bodies in surrounding areas. To compensate for this loss of concentration, farmers sometimes apply more herbicide (FAO, 2020). Increases in the intensity and frequency of rain and storm events also promote the wet deposition of pesticides and other chemicals from the atmosphere to terrestrial and aquatic systems, exposing humans and wildlife to these chemicals (Noyes et al., 2009). Alongside the negative impacts on ecosystems, human exposure to certain chemical pesticides is linked to chronic illnesses such as cancer and heart, respiratory and neurological diseases (EEA, 2023f). EU regulations ([8]) set criteria for the approval of substances to be placed on the market and encourage environmentally friendly systems of pest control and restricted use of pesticides in sensitive areas, such as urban green areas and protected areas.

Run-off from agricultural land can also facilitate the spread of zoonotic pathogens from grazing animals that end up in watersheds and deteriorate the water quality. Floods can affect bioavailability and mobilisation of contaminants and faecal matter from soils and sediments, and therefore cause an increase in transport of pathogens and chemicals onto agricultural land, posing risk of food contamination (see Box 4.5). Further, the intensified nutrient run-off from agricultural areas can cause higher frequency of cyanobacterial blooms (see Section 4.3).

The annual pollution conveyed by urban run-off across the EU-27 and the UK has been estimated as an equivalent of untreated wastewater of about 31 million population equivalents for biochemical oxygen demand, about 18.5 million population equivalents for nitrogen and phosphorus and about 280 million population equivalents for total suspended solids. The projected increase in the total volume of precipitation in the north of Europe and longer dry spells and more intense storms in the south are expected to worsen urban water pollution across Europe. Reducing run-off volume from urban areas through improved water infiltration and retention is thus key to pollution control (Pistocchi, 2020).

Both diffuse and point source pollution following heavy rainfall worsen water quality (Box 2.9).

([8]) Including Regulation (EU) No 528/2012 concerning the making available on the market and use of biocidal products; Regulation (EC) No 1107/2009 concerning the placing of plant protection products on the market; Regulation (EU) 2016/2031 on protective measures against pests of plants.

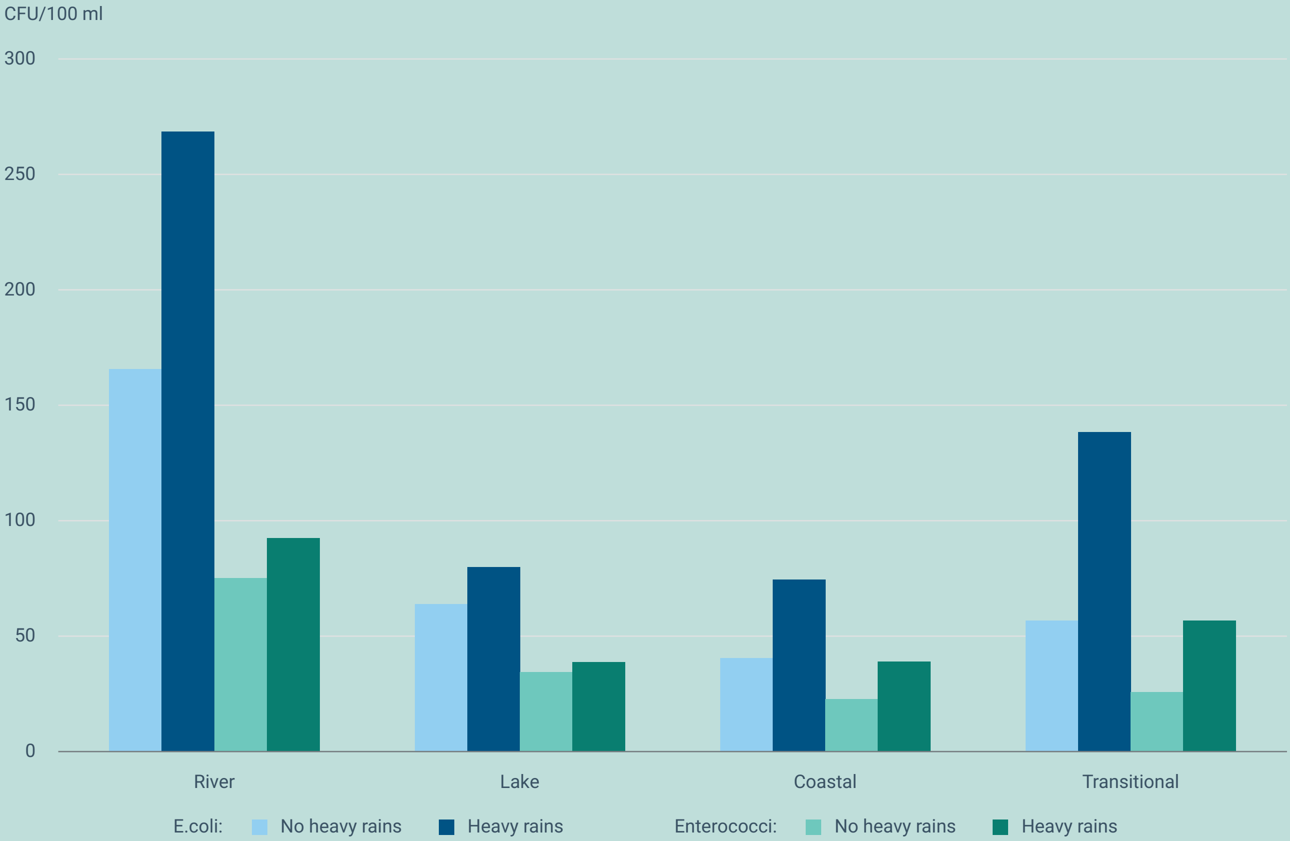
Box 2.9

Impact of heavy rainfall on bathing water quality in Europe

In 2022, 89% of the EU's coastal and 79% of its inland bathing waters were classified as being of excellent quality, based on monitoring of *E. coli* and *enterococci* under the Bathing Water Directive (EEA, 2023c).

Unpublished EEA analysis of bathing water quality data between 2008 and 2022 from 25,680 sites across Europe and rainfall data showed that concentrations of both *E. coli* and *enterococci* that can be hazardous to human health ([9]) were more likely when heavy rainfall (>20mm in a day) occurred within 3 days before sampling (Figure 2.5). This pattern is consistent across European regions and for different types of bathing waters (riverine, lake, coastal). The odds of finding hazardous concentrations of *E. coli* or *enterococci* in the sampled waters were at least two times higher after heavy rain events.

Figure 2.5 Mean concentration of *E. coli* and *enterococci* (CFU/100ml) in sampled European bathing water with and without prior heavy rains



Note: *E. coli* and *enterococci* concentration is in colony forming units (CFU)/100ml.

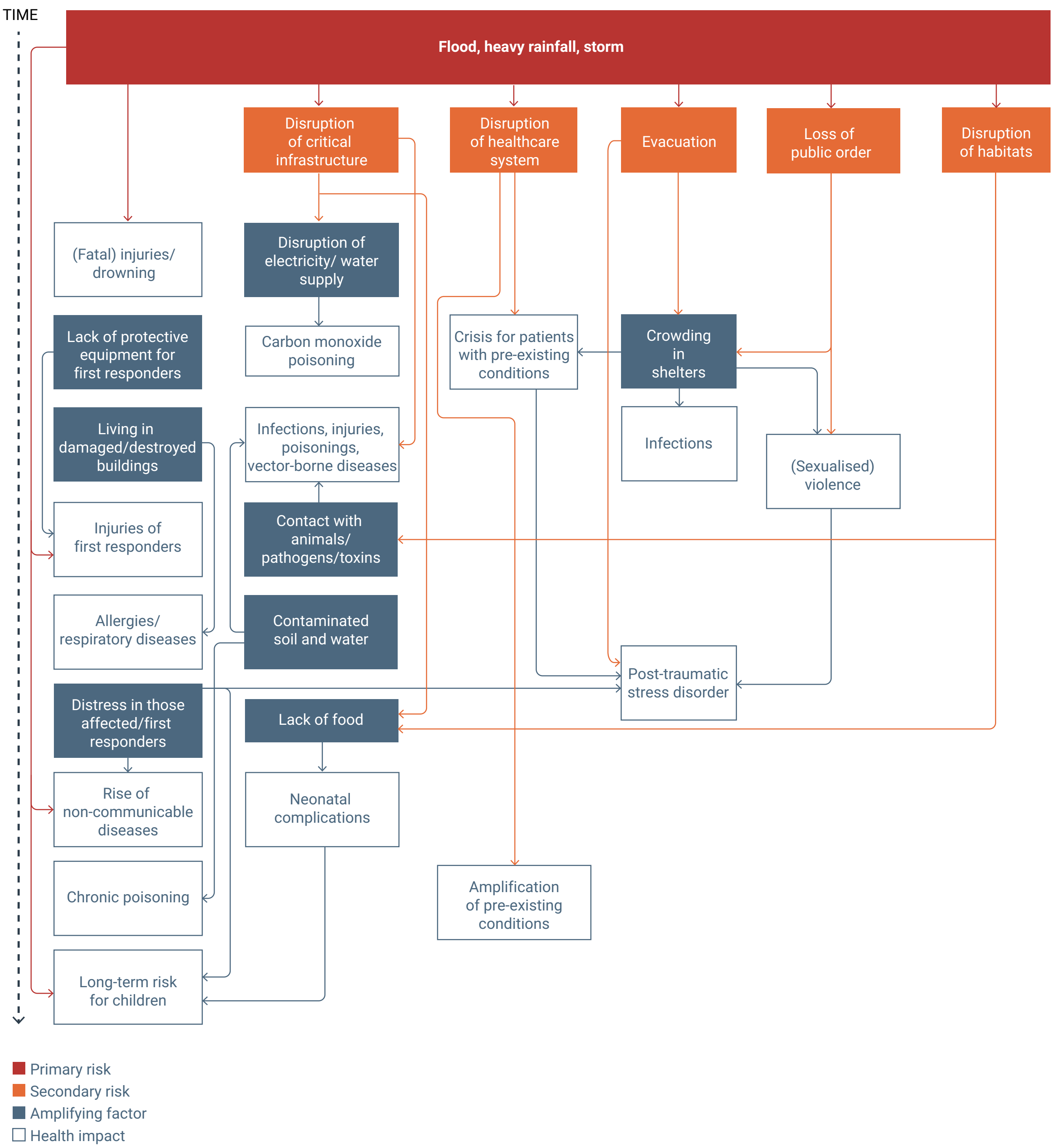
Source: EEA, based on analysis of Bathing Water Directive water quality samples (taken between 2008 and 2022 once a month during the bathing season, i.e. March-October, depending on the bathing site) and Copernicus ERA5-Land hourly precipitation reanalysis data.

([9]) The threshold values for 'hazardous' concentrations of *E. coli* and *enterococci* correspond with values for bacteria concentrations in the Bathing Water Directive that classify bathing water quality as 'poor', applied to the quality of a single bathing water sample in relation to the occurrence of heavy rainfall.

2.3 How floods and extreme precipitation events impact human health

Health effects of flood events arise directly through contact with floodwaters or indirectly from damage to health facilities, infrastructure, ecosystems, food and water supplies or social support systems. They can be immediate or may appear days, weeks or months after the floods have receded (WHO Regional Office for Europe, 2017; Figure 2.6).

Figure 2.6 Cascading risks triggered by floods, heavy rainfall and storms



Note: Arrows indicate possible causal relationships between risks, amplifying factors and health consequences.

Source: Reproduced from Butsch et al., 2023, licensed under CC BY 4.0.

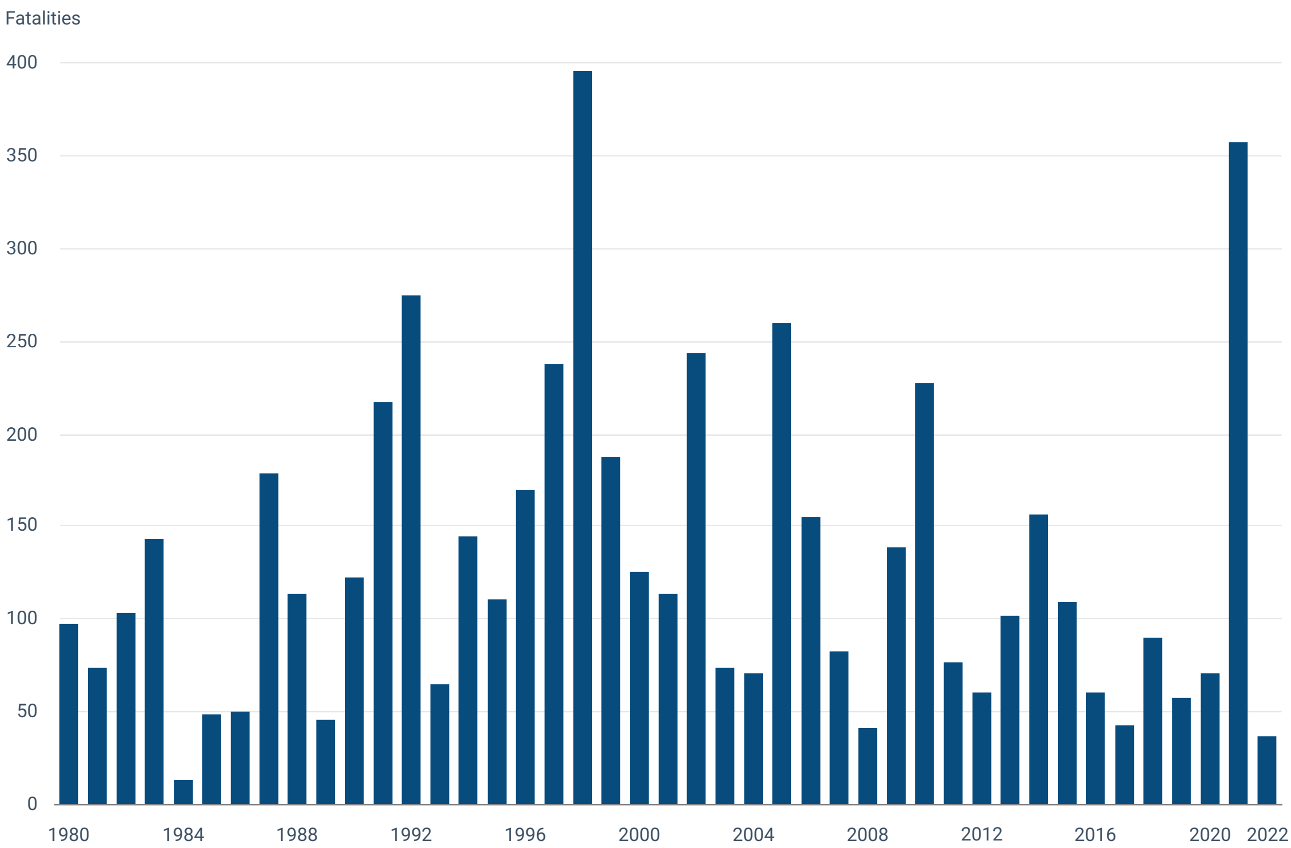
2.3.1 Fatalities and physical injuries

Between 1980 and 2022, a total of 5,582 deaths were directly caused by flooding in the 32 EEA member countries (EEA, 2023l). In that period, the highest number of fatalities was recorded in 1998, followed by 2021. There is no clear temporal trend in the number of flood-related fatalities in Europe over the past 4 decades (Figure 2.7).

Looking at longer trends, since 1870 the number of fatalities linked to large floods has decreased (by 1.4% per year since 1870 and 4.3% since 1950), despite an increase in the area flooded annually and the number of people exposed (Paprotny et al., 2018). This decline may be attributed to improved flood prevention, emergency management and protection (see Chapter 6), following the policy requirements in place (Chapter 5).

However, ongoing climate change may reverse this decreasing trend. In the 2071-2100 period, river floods are projected to cause on average 106 deaths every year and coastal floods 233 deaths, the latter compared with only six a year during the reference period (Forzieri et al., 2017).

Figure 2.7 Fatalities associated with hydrological events in the EEA-32 in 1980-2022



Note: For a detailed breakdown of fatalities per year and per country in map format, see Flooding in the European Climate and Health Observatory.

Source: Based on EEA, 2023l.

The primary cause of death linked to floods is drowning (often while in motor vehicles), followed by heart attack (Petrucci et al., 2019). Other causes include physical trauma, electrocution, carbon monoxide poisoning and fire (WHO Europe, 2017). In Europe, children and teenage girls are less frequently direct victims of flooding, presumably due to the care taken to protect them (Salvati et al., 2018). Among adults, men are more likely to die during floods than women. Most flood casualties occur outdoors and are adults of working age, which can be explained by their exposure to floods while commuting (Petrucci et al., 2019; Salvati et al., 2018) ([10]). Elderly people are more frequently trapped in their homes by floods than working-age adults. While fatalities in adults over 65 constituted less than 2% of the total number of 2,466 flood fatalities analysed by Petrucci et al. (2019), the toll of the 2021 flood in Germany suggests that advanced age and disability play a significant role in deaths due to flooding (Box 2.10).

Box 2.10

Casualties of the 2021 floods in Germany

Among the 184 people who died in Rhineland-Palatinate and North Rhine-Westphalia, 138 (75%) were older than 60, while the population share of people over 60 in North Rhine-Westphalia was 27%. Three victims (1.6%) were under 14 (population share in North Rhine-Westphalia, 13%). The ratio of men (65 deaths) to women (70) among fatalities was balanced in Rhineland-Palatinate, while in North Rhine-Westphalia about twice as many men (31) as women (18) died (Butsch et al., 2023). In Sinzig, where 13 people died during the night of the floods, 12 had been living in a facility for people with intellectual disabilities (Schmid-Johannsen et al., 2023).

Injuries occur as people walk and drive through floodwater, when contact with floating debris or unseen obstacles causes strains, lacerations, fractures and punctures. The most common injuries leading to hospitalisation following the 2021 floods in Germany were leg fractures and soft tissue wounds, predominantly in men (Gathen et al., 2022). Due to contamination of floodwaters, there is a high risk of infection to wounds, e.g. with tetanus (ECDC, 2021a; WHO Europe, 2017).

In addition, hypothermia can be caused by standing in water colder than 20°C. Power lines and electrical appliances pose a risk of electrocution when they are wet or in contact with water. Injuries may be caused by bites or stings of animals displaced by floodwater. People's behaviour and decisions can influence the likelihood of injury and even fatalities, particularly when they do not comply with evacuation orders. After a flood subsides, injuries remain a concern for those involved in the clean-up (see Box 2.3) and for children living and playing in areas with debris (see Box 2.4; WHO Europe, 2017).

([10]) In developing countries, being female is linked to higher mortality due to floods (see e.g. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3644291).

2.3.2 Mental health impacts

People affected by flooding may suffer from mental health problems: trauma and mental distress in the short term, often followed by post-traumatic stress disorder (PTSD), anxiety, insomnia, psychosis and depression (European Climate and Health Observatory, 2022c). Experiencing flooding can increase the chance of facing mental health problems by 50% (Thiebes et al., 2022; Weilnhammer et al., 2021). Flood-related displacement, especially without warning, increases the likelihood of mental health effects (Tong, 2017). During the 2021 floods in the Netherlands, almost all evacuees experienced some degree of stress and 28% experienced a great amount of stress while evacuating (Endendijk et al., 2023; see also Box 2.12).

The number of people affected by flooding and reporting mental health effects in Europe between 1998 and 2018 has been estimated to be in the range of 1.7-10.6 million (Devadason and Jackson, 2019). Projections estimate that coastal flooding in the EU could potentially cause 5 million additional cases of mild depression annually by the end of the 21st century under a high sea level rise scenario in the absence of adaptation (Bosello et al., 2012).

The mental health effects can be long-lasting (Weilnhammer et al., 2021). More than a third of people affected by the 2021 floods in the Netherlands continued to suffer significant stress for several months (Endendijk et al., 2023). Depression, anxiety and PTSD may persist for years after a flooding event for those whose houses were flooded (Mulchandani et al., 2020). The processes of compensation and reconstruction, if continuing over a long time, negatively affect mental health (Bubeck and Thieken, 2018; Endendijk et al., 2023). Lack of flood insurance, common in some parts of Europe (see Section 6.5.2), has also been linked to poorer mental health (European Climate and Health Observatory, 2022c; Mulchandani et al., 2019).

Various factors — personal, health-related, social and others — mediate the development of mental-health disorders caused by exposure to flooding (Fernández et al., 2015). Children and adolescents show increased vulnerability to the effects of extreme weather (see Box 2.4), while evidence for the influence of age and gender is not consistent. The depth of flooding has been found to be associated with the probability of developing PTSD symptoms (Waite et al., 2017). Those who suffer financial losses because of a flood, experience significant disruption to daily routines — including temporary or permanent loss of employment or loss of services — and those who face disputes with insurers or construction companies present higher levels of mental health problems (Fernández et al., 2015). Personality traits (e.g. higher self-esteem), meaning-focused coping and successful emotion regulation strategies, as well as support from family in the wider social environment, increase individual resilience to flood events (Gebhardt et al., 2023).

2.3.3 Water-, food- and vector-borne diseases

Changing precipitation patterns and extreme weather events can directly impact the distribution, transmission and persistence of pathogens in the environment, influencing the incidence and spread of climate-sensitive infectious diseases (EEA, 2024a). Diseases can be transmitted by ingestion of contaminated water or food, skin contact, inhalation of water droplets or contact with pathogen-carrying vectors or animals. The likelihood of disease outbreaks after floods rises, particularly via contaminated food and water, and can lead to mortality rates increasing by up to 50% during the first year following a flood (Weilnhammer et al., 2021).

Waterborne and foodborne diseases

Floodwaters can contain pathogens originating from animal faeces or carcasses, sewage and surface run-off. More frequent and intense flood events may increase exposure to pathogens via direct contact with contaminated water or debris. Vast areas of standing water following flooding can create new areas for potential pathogen exposure, which may contaminate crops (Weilnhammer et al., 2021). Flood-related disruption to power plants or water supply networks can affect food storage and preparation and increase the risk of foodborne diseases, especially during high temperatures.

Disruption or contamination of potable water supplies may result in improper hygienic practices and contribute to the transmission of diseases. Infection risk is also raised in temporary shelters for people displaced by floods, where the density of people may facilitate the spread of infectious gastrointestinal and respiratory diseases (see also Box 2.12). Further, stress caused by flooding (see Section 2.3.2) may reduce the body's capacity to deal with pathogens, leading to more severe disease courses (Mora et al., 2022).

Infection risks are highest for viruses such as norovirus — mainly via exposure to contaminated water but also through consumption of sewage-contaminated seafood like oysters (EFSA et al., 2020) — rotavirus and hepatitis A; bacteria including pathogenic *E. coli*, *Salmonella* spp. and *Campylobacter* spp.; and *Cryptosporidium* spp., causing parasitic infections. Sporadically, leptospirosis, shigellosis, *Giardia* and Legionnaires' disease infections can be expected after flooding (ECDC, 2021a) (Box 2.11). Investments in water and sanitation infrastructure have largely led to the elimination of cholera in Europe (WHO, 2022b).

Box 2.11

Examples of flood and extreme weather events causing infectious diseases

Norovirus outbreak among tourists and rescue workers in Salzburg, Austria, 2005

In 2005, Austria reported a norovirus outbreak among tourists and firefighters. It resulted from their exposure to sewage water during clean-up activities in a hotel after a flood (Schmid et al., 2005).

Leptospirosis cases linked to cloudburst event in Copenhagen, 2011

Two leptospirosis cases were notified after a cloudburst event in Copenhagen on 2 July 2011. Both cases were previously healthy, middle-aged men who had spent many hours in knee-high water without protective clothing, emptying cellars of water following the rainstorm. One experienced an intense headache, high fever, dry cough, vomiting and right-sided abdominal pain 1 week after contact with flood water. He was admitted to hospital and died due to pulmonary haemorrhage and heart failure. The other had influenza-like symptoms, was admitted to hospital and made a full recovery (Müller et al., 2011).

Gastrointestinal and respiratory diseases after pluvial flooding in the Netherlands, 2015

In the Netherlands, in the weeks following pluvial flooding, more urban residents than normally reported acute gastroenteritis and respiratory infections. Dermal contact with floodwater that surrounded many houses, post-flooding cleaning operations and cycling through floodwater were the risk factors for the diseases (Mulder et al., 2019).

Cryptosporidiosis outbreak among children weeks after flooding in Germany, 2013

In Halle, children were affected by an outbreak of cryptosporidiosis in 2013 after a river flooded the city centre and damaged the sewerage system. Recreational activities in the dried-out floodplain within the city led to infection among some children several weeks after the floods. The authorities recommended avoiding playing, swimming and picnicking in the flood-affected area to avoid contact with long-surviving parasites. The sites were cleaned and then reopened (Gertler et al., 2015).

Campylobacteriosis is the most widespread bacterial gastrointestinal disease and zoonosis in the EU, with 46.9 cases per 100,000 people in 2022 (ECDC, 2022c). It is spread by consumption of contaminated food and consumption of or direct contact with contaminated water. Infections occur throughout the year but peak between June and September (European Climate and Health Observatory, 2023e). More frequent and intense flood events in the future could increase *Campylobacter* transmission; Scandinavia can expect the incidence of campylobacteriosis to double by 2080 due to the expected increase in mean temperatures and more heavy rainfall (Kuhn et al., 2020).

Salmonellosis, caused by *Salmonella* bacteria, is one of the most common foodborne diseases in Europe, with 15.5 cases per 100,000 people in 2022 (ECDC, 2023b). Salmonellosis is 11 times more common in children aged up to four than in adults (ECDC, 2022). Infections peak in August and September (European Climate and Health Observatory, 2023d). Temperature rises and extreme weather events have been linked to increased *Salmonella* infections (Kovats et al., 2004). *Salmonella* spp. from sewage, animal waste and soil can be carried by floodwaters and contaminate crops, which, if not properly washed or cooked before consumption, can increase the risk of infections. By the end of the 21st century, climate change could increase the number of temperature-related *Salmonella* cases in Europe by up to 40,000 a year (Watkiss and Hunt, 2012).

Shiga toxin-producing *E. coli* bacteria (STEC) ([11]) can cause diarrhoea and other severe diseases through contaminated food or water or contact with infected animals or their faeces. With 2.5 cases per 100,000 people in 2022 (ECDC, 2024), infections with toxin-producing *E. coli* are common, especially between June and September (European Climate and Health Observatory, 2023f). More frequent heavy rainfall events, flooding and increased temperature in the future create optimal conditions for bacterial growth, survival and spread and increase the STEC-related infection risk, including via ingress of pathogens to both surface and groundwater sources (Watkiss and Hunt, 2012; Andrade et al., 2018).

Shigellosis is a gastrointestinal bacterial disease. Infections occur through faecal contamination and spread via dirty hands, contaminated food and water and sexual contact. Outbreaks can happen in crowded places and in poor sanitation conditions (ECDC, 2022a). According to data reported to ECDC, children under five and young adult men are most prone to infection. In Europe, infections peak in late summer and autumn. Higher temperatures, increased rainfall and humidity driven by climate change accelerate bacterial survival and spread and the contamination of water and soils, raising infection risks (European Climate and Health Observatory, 2023c).

Leptospirosis is a widespread bacterial disease globally but is currently relatively uncommon in Europe, with 0.2 cases per 100,000 people in 2022 (ECDC, 2023a). *Leptospira* spp. spread through contaminated soil or water or contact with infected animals or their urine. In Europe, infections peak in August and September due to increased outdoor activities, heavy rainfall and high temperatures. Higher temperatures, increased rainfall and more flooding under the changing climate enhance bacterial growth, prolong the infectious season and expand bacterial distribution, leading to an increased risk of transmission to humans (European Climate and Health Observatory, 2023g).

([11]) Also known as verocytotoxin-producing or enterohemorrhagic *E. coli (VTEC/EHEC).*

Giardiasis, caused by the parasite *Giardia lamblia*, is a prevalent infectious diarrhoeal disease in Europe, with 3.9 cases per 100,000 population in 2022 (ECDC, 2023b). It is often transmitted through contaminated water, food, soil or surfaces. The disease is more common among children and individuals in areas with poor sanitation or those working in day-care centres. Intensified and more frequent extreme precipitation events are expected to increase giardiasis incidence (Rupasinghe et al., 2022) by increasing *Giardia* cyst-infested run-off from pastures and fields and increasing likelihood of sewage overflows (Young et al., 2015).

Cryptosporidiosis is an infectious diarrhoeal disease caused by the parasite *Cryptosporidium,* which is more prevalent in countries with limited access to clean water and poor sanitation. The disease tends to be under-diagnosed and underreported in Europe; in 2022 there were 2.3 cases per 100,000 people (ECDC, 2023b). The parasite is transmitted through ingestion of contaminated water or food or contact with infected humans or animals. Infections typically result in gastrointestinal symptoms, but more severe cases also occur. Intensified and more frequent extreme precipitation events are expected to increase cryptosporidiosis incidence if cysts from contaminated sources are washed into water bodies (Rupasinghe et al., 2022).

Vector-borne diseases

Flooding can also impact diseases transmitted to humans by vectors such as mosquitos, flies and ticks through their bites. While flooding initially sweeps away vector habitats and reduces populations, after 7-10 days, stagnant water resulting from increased rainfall or flooding (e.g. in basements, gardens, parks, fields and artificial containers) can become suitable breeding sites for mosquitoes carrying diseases such as malaria (*Anopheles* mosquitoes), West Nile virus (*Culex* mosquitoes), dengue, chikungunya and Zika (*Aedes* mosquitoes). Both *Anopheles* and *Aedes* mosquitoes thrive in high precipitation and high humidity (Marini et al., 2020; Benali et al., 2014).

Overall, wetter and particularly warmer climates favour tick distribution, activity and survival, and hence increase infection risks for tick-borne diseases (Gilbert, 2021). However, extensive flooding may reduce the risk of tick-borne diseases such as tick-borne encephalitis or Lyme disease. A study on the impact of a 200-year flood event in 2013 on tick abundance along the banks of the Danube in Austria found that tick activity and abundance were significantly reduced after the floods due to being drowned or covered in sediment (Weiler et al., 2017).

ECDC's Surveillance Atlas of Infectious Diseases and Annual Epidemiological Reports are key sources of epidemiological data. Information about water- and foodborne diseases and vector-borne diseases under the changing climate can also be found at the European Climate and Health Observatory.

2.3.4 *Indirect and delayed impacts of floods*

Indirect health effects during and after flooding include a rupture in medical treatment due to disruption of healthcare facilities; physical workload associated with clean-up and reconstruction; or shortages of medical aid, electricity or safe food and water (Paterson et al., 2018; Butsch et al., 2023). Flooding can also lead to loss of employment and livelihoods (e.g. for farmers), lack of access to childcare and school services and increased domestic violence (Mason et al., 2021).

Property damage can lead to displacement and overcrowding in shelters. Living in housing affected by flooding can lead to pulmonary and systemic fungal infections (e.g. from airborne and dust-borne *Aspergillus*) and mycotoxin exposure (Butsch et al., 2023). Under the changing climate, the risk of flooding to residential buildings in Europe is estimated to increase seven-fold (under RCP 4.5) or even 10-fold (under RCP 8.5). Germany, France, Italy and Spain have the highest flood risk for residential buildings in monetary terms. Urban areas emerge as hotspots of flood risk due to the high concentration of exposed residential buildings vulnerable to damage (Steinhausen et al., 2022).

Analysis of the July 2021 floods' impacts in western Europe shows that at least 71,859 buildings were affected by the flooding: 37,662 in Germany, 26,371 in Belgium, 3,053 in Luxembourg, more than 2,500 in the Netherlands (see also Box 2.12) and 866 in France (ICEYE, 2021, in Moll et al., 2021; Evans, 2021). Of the approximately 56,000 people living along the Ahr river in 2021, at least 17,000 were left with almost nothing after the disaster, and more than 9,000 buildings were completely destroyed or severely damaged (Truedinger et al., 2023).

Indirect impacts on health from flood-affected buildings may be prolonged if owners lack insurance for renovations. It is estimated that only 37-47% of houses in Germany have flood insurance (Munich RE, 2022; Mohr et al., 2022). In Belgium, insurance penetration is higher, as weather-related damage is part of standard insurance policies (Nienaber and Thomasson, 2021). See also Section 6.5.2 on flood insurance as one of the measures to reduce health and well-being risks from flooding.

Box 2.12

Health impacts of the 2021 floods in the Netherlands

Despite good performance of the main flood defences along the Meuse river in the Netherlands, and only occasional erosion and overflow of embankments and breaches of local flood defences, the 2021 floods led to severe economic damage and losses in the affected area in the Netherlands. More than 2,500 houses and 5,000 inhabitants were directly affected, and the total physical damage to houses, infrastructure, crops and businesses was estimated at EUR 350-600 million.

No fatalities were reported, but around 50,000 people were evacuated before and during the flood. About two thirds of healthcare workers reported an increase in patients with psychological complaints in the aftermath of the floods; psychological symptoms were the main cause of absence from work for people in the flood area. In addition, some healthcare workers reported an increase of patients with gastroenteritis, respiratory complaints and skin infections. Increased SARS-CoV-2 cases in affected municipalities suggest that the flooding events and evacuations contributed to increased disease transmission locally.

The floods also caused a temporary closure of the drinking water wells of the Meuse and Eyserbeek due to chemical and microbiological contamination. The reserve capacity was sufficient to prevent shortages of drinking water supplies, thanks to the wet and mild summer (ENW, 2021).

3 Droughts, water scarcity, wildfires and health

Key messages

- In southern Europe, approximately 30% of the population live in areas with permanent water stress and up to 70% in areas with seasonal water stress during summer. Under the changing climate, the number of people living in water-scarce conditions in southern and central Europe will increase.
- Groups particularly vulnerable to health impacts of droughts and water scarcity are farmers, through impacts on their livelihoods and mental health, and private well users, via water quality.
- Dry periods increase the likelihood of West Nile virus infections and some water- and foodborne diseases.
- Low water levels increase concentrations of chemicals and pharmaceuticals in water bodies receiving effluent from wastewater treatment plants, which calls for improved wastewater treatment.
- Protracted droughts increase the risk of wildfires, which have directly caused the deaths of more than 700 people over the last 4 decades and indirectly affect human health via smoke. Southern Europe is projected to experience a marked increase in the number of days with high fire danger.

3.1 Drought, water scarcity and wildfires under the changing climate

Drought — a climate extreme characterised by unusually persistent dry weather that affects hydrology — can be divided into three types: meteorological (rainfall deficit), agricultural/ecological (soil moisture deficit) and hydrological (surface and sub-surface water deficit) (EDO, 2023). While meteorological droughts are a causal factor for the other types, and thus occur more frequently, agricultural/ecological and hydrological droughts can last longer — from weeks to years — and have more severe consequences (UCP, 2023). When droughts cause socio-economic effects, i.e. when the available water resources cannot match the demand, the term 'water scarcity' is used (EDO, 2023).

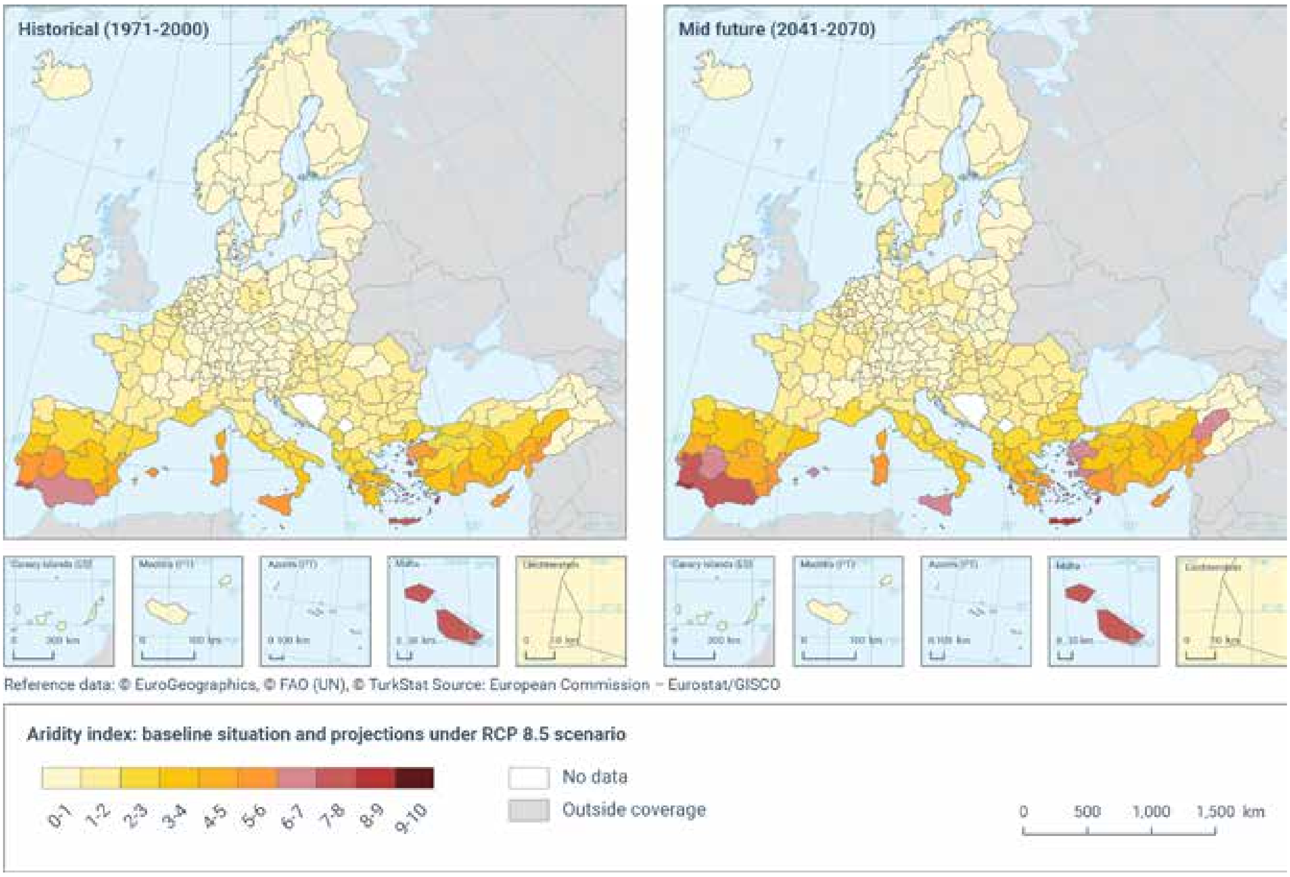
Under the changing climate, northern Europe is becoming wetter in general, but drier in summer. Southern Europe is becoming drier, especially in winter. For central-eastern and western Europe, the trend is less clear (Bednar-Friedl et al., 2022). In addition to those precipitation trends, temperature rise has increased evapotranspiration rates and accelerated a drying trend in Europe, which is most pronounced in southern and central-eastern Europe. However, all European regions are affected by droughts, with severe meteorological droughts including large economic losses occurring in 2018 and 2023 (EEA, 2024a).

Agricultural and ecological droughts in Europe have been increasing since around 2000; 10 out of 12 years since 2011 have seen below-average soil moisture. 2022 was the sixth consecutive year of below-average soil moisture and saw the second-lowest average soil moisture content since the 1960s (C3S, 2023). Hydrological droughts have increased in southern Europe and in spring and summer in western and northern Europe. Since 2015, 7 out of 8 years have seen below-average river flow for Europe as a whole, with only 2016 seeing slightly above-average river flow. 2022 was the sixth consecutive year of below-average flows, with the second-lowest average river flow in a record dating back to 1991 (C3S, 2022).

Large parts of Europe have experienced a combination of meteorological, agricultural/ecological and hydrological drought conditions in recent years. In 2022, a persistent lack of precipitation from winter to summer, with higher-than-average temperatures, triggered a severe to extreme drought affecting over one third of Europe at its peak. Previously, in 2021, large parts of the central Mediterranean region were affected by exceptional droughts. In 2018, northern Europe experienced drought conditions that at the time were the most severe since 1976, while in 2017 drought conditions in some areas of south-western Europe persisted for up to a year (C3S, 2023; Toreti et al., 2023).

Drought risks and water scarcity are expected to increase in the next decades due to climate change throughout Europe, except in some regions in Scandinavia and the Baltic area. While southern Europe will continue to be most affected by increasing water scarcity, western and central Europe will also increasingly face drought and water scarcity, especially in summer and autumn (Bednar-Friedl et al., 2022). Projections show increases in the aridity index, i.e. the ratio between daily precipitation and evapotranspiration, mainly in parts of southern Europe (Map 3.1). According to the European Climate Risk Assessment (EEA, 2024a), groundwater-related scarcity will expand to nearly all basins.

Map 3.1 **Aridity index, annual: baseline situation and projections under RCP 8.5 scenario**

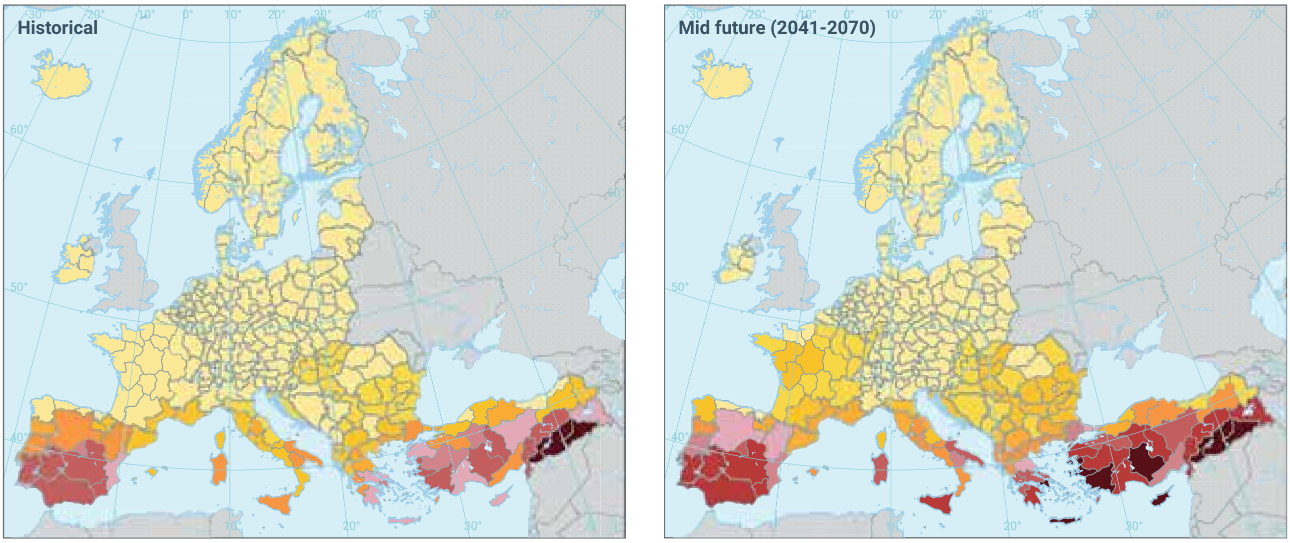


Notes: The aridity index is based on daily precipitation and evapotranspiration according to E-HYPE model median ensemble. A higher/lower value indicates reduced/increased soil water availability.

Source: European Climate Data Explorer (2023c) delivered by the Copernicus Climate Change Service.

Protracted drought conditions also increase the risk of wildfires. While most wildfires in Europe are started by human activities, dry and hot periods with strong winds increase their intensity and impact. The above-average temperatures and drought conditions in 2021 and 2022 led to extreme fire danger and the spread of wildfires, with 2022 seeing the second-largest burnt area on record across the EU, of 748,426 hectares (JRC, 2023). Currently, forest fires largely affect southern Europe but increasingly happen in central and even northern Europe. Under the high emissions climate change scenario, southern Europe, in particular the Iberian Peninsula and Türkiye, will experience a marked increase in the number of days with high fire danger (European Climate Data Explorer, 2023d; Map 3.2).

Map 3.2 **Number of high fire danger days in summer in the baseline period (1981-2010) and in 2041-2070 under RCP 8.5 scenario**



Reference data: © EuroGeographics, © FAO (UN), © TurkStat Source: European Commission – Eurostat/GISCO

Number of high fire danger days in summer in the baseline period (1981-2010) and in 2041-2070 under RCP8.5 scenario

Index

<5, 5-10, 10-20, 20-30, 30-40, 40-50, 50-60, 60-70, 70-80, >80

Outside coverage

0 500 1,000 1,500 km

Source: European Climate Data Explorer (2023d) delivered by the Copernicus Climate Change Service.

3.2 Population exposure to droughts and water scarcity

3.2.3 Geographical distribution of water scarcity

Between 2000 and 2019, the area in the EU affected by water scarcity was stable or increasing (EEA, 2023i). This is despite declines in total water abstraction by about 15% over that period (EEA, 2022h). At the same time, population growth over the past 50 years has contributed to an overall decrease in renewable water resources per capita by 24%. This decrease is particularly evident in southern Europe (EEA, 2018c).

As a result, some regions face problems associated with water scarcity; in parts of southern Europe approximately 30% of the population live in areas with permanent water stress ([12]) and up to 70% in areas with seasonal water stress during summer (EEA, 2023i). For the 1990-2019 period, recurrent water stress conditions were present in specific river sub-basins in, for example, Poland, Italy and the Netherlands (Map 3.3). Regions associated with low rainfall, high population density or intensive agricultural or industrial activity across Europe may face water availability issues in the near future, exacerbated by climate change and water management practices (Eurostat, 2023b) (Box 3.1).

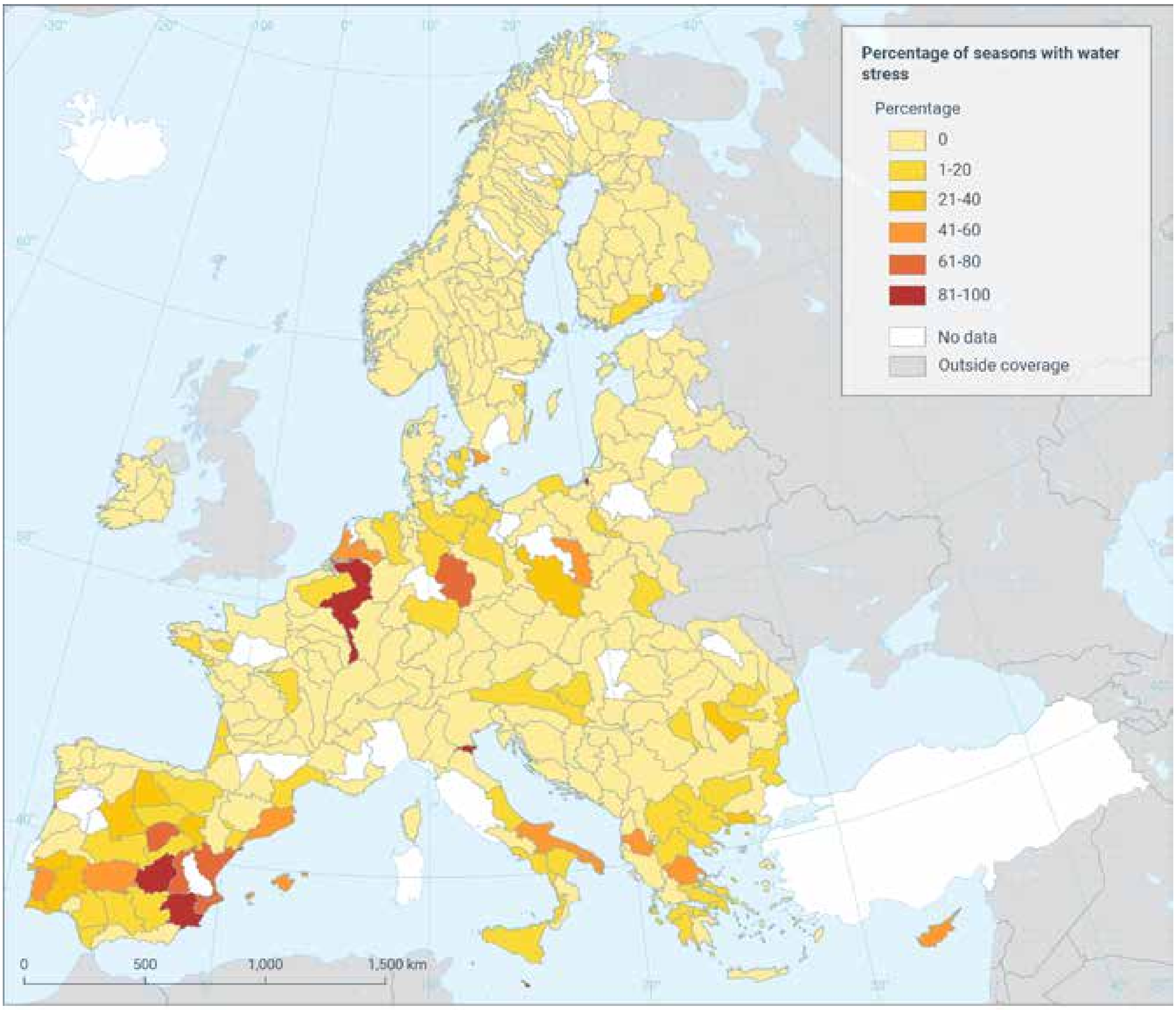
([12]) Water stress occurs when demand for water exceeds the amount available in a certain period or when poor quality restricts its use (EEA glossary).

Box 3.1

Challenges to meeting future drinking water demand in the Netherlands

In the Netherlands, climate change, economic growth and population pressure are expected to increase the demand for drinking water by 2030 to a level that current supplies may not be sufficient to respond to. Today, in certain provinces — Gelderland, Overijssel, Groningen and the western part of South Holland — reserves are not always immediately available to respond to demand, which could escalate. In other provinces, drinking water companies need to find additional sources for drinking water to continue meeting demand in or even before 2030. This is a challenge, as suppliers are often operating at full licence extraction capacity or their water extraction is limited by nature protection measures (Van Leerdam et al., 2023).

Map 3.3 Water stress conditions in river sub-basins in Europe 1990-2019



Reference data: © EuroGeographics, © FAO (UN), © TurkStat Source: European Commission – Eurostat/GISCO

Notes: The map presents the percentage of seasons that experienced water stress, i.e. recorded a water exploitation index + (WEI+) over 40% from 1990 to 2019. WEI+ is estimated as the ratio of water use to renewable freshwater resources for a given spatial unit, e.g. river basin or country level in a defined time period, i.e. seasonal (quarter) (EEA, 2023i).

Source: EEA, based on WEI+ indicator dataset.

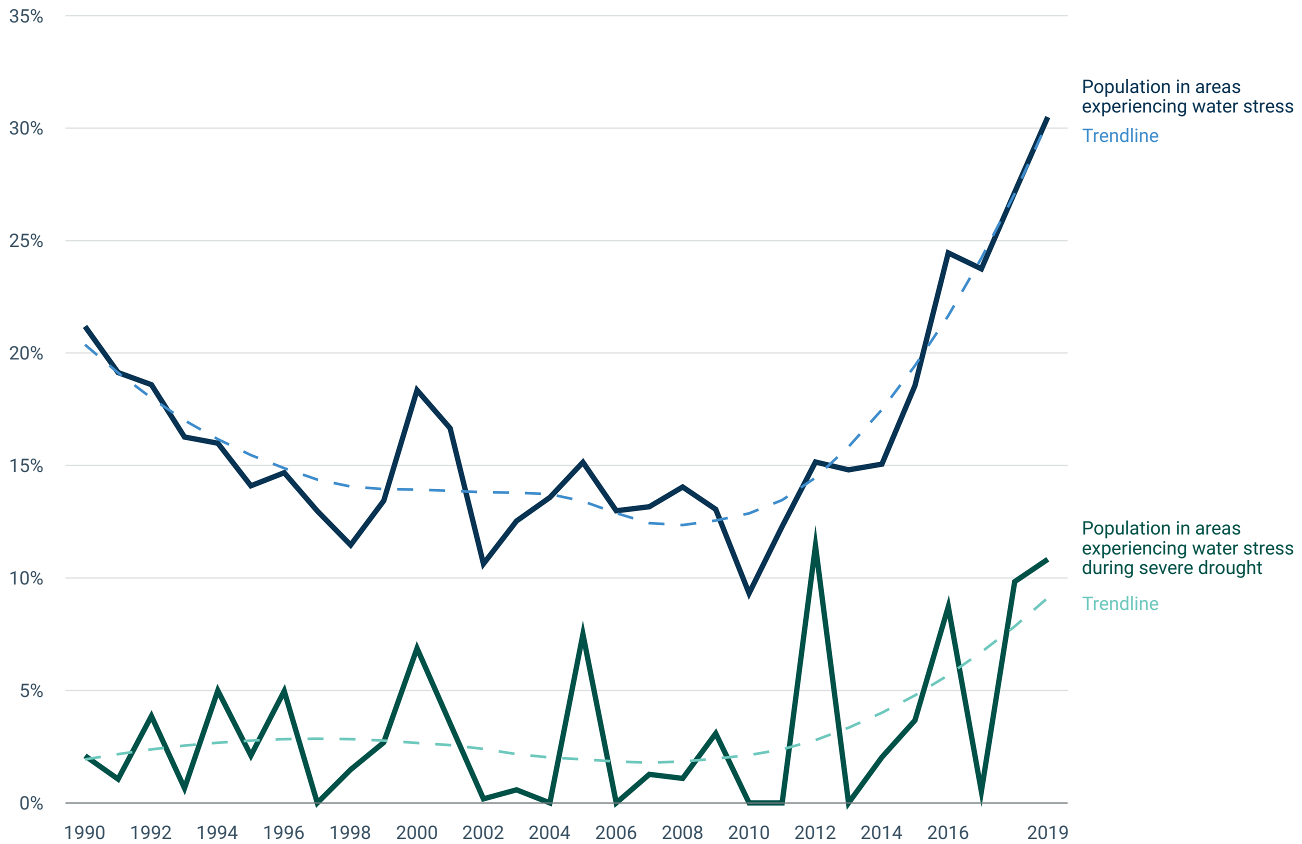
3.2.2 *Population exposure and groups affected by droughts, water scarcity and wildfires*

Trends and projections in population exposure

The number of people exposed to water stress conditions decreased in the 1990-2010 period due to reduced water abstraction (EEA, 2018b). However, the hot and dry years (2003, 2012, the 2015-2022 period) mean that population exposure to water stress has again been increasing (Figure 3.1).

The number of Europeans living in areas that are water scarce for at least 1 month every year could rise by a quarter in a 3°C warming scenario (Feyen et al., 2020). The IPCC expects more than a third of the population in southern Europe to be exposed to water scarcity at 2°C global warming level, and twice as many under 3°C global warming level. In western and central Europe, 16% of the population could experience at least moderate water scarcity under 2°C warming (Bednar-Friedl et al., 2022).

Figure 3.1 Population exposed to drought conditions and water scarcity in Europe in summer



Notes: For EU, excluding Italy, during summer. Water stress conditions refer to Water Exploitation Index + values > 40. Severe drought condition refers to Standardised Precipitation-Evapotranspiration Index for September < -1.3.

Source: Adapted from van Daalen et al., 2024.

Groups affected by droughts and water scarcity

While the EU enjoys very good access to high quality drinking water ([13]), some groups continue to have limited access to safe water. Significant parts of the Roma population, the largest ethnic minority in the EU, live in settlements without access to tap water (FRA, 2016; ERRC, 2017). Migrants and asylum seekers in Europe also suffer from limited access to drinking water, with specific concerns about Europe's formal and informal refugee camps being raised by the United Nations High Commission for Refugees (UNHCR, 2020).

Large cities tend to have preparedness plans and contingencies for water scarcity and drinking water is usually prioritised (EurEau, 2020b). However, smaller municipalities and households that depend on their own wells may be affected more immediately. While in most European countries nearly all the population is connected to a drinking water network, in some countries many people use private sources: 30% in Romania, 15% in Sweden (EurEau, 2021) and Ireland (see Box 2.6) and 13% in Estonia ([14]). Private sources often have limited redundancies and are not subject to the same quality regulations as public supplies, and are thus vulnerable during scarcity periods (Bryan et al., 2020).

Farmers are a group particularly exposed to health and well-being risks associated with droughts and water scarcity, including through economic losses. The EEA (2019a) reported that farms in Italy, Greece, Portugal, the south of France and Spain could suffer value losses up to 9% under a 1°C rise in global temperatures. According to these projections, the farmland value in regions in southern Europe is projected to decrease by more than 80% by 2100. The majority of the loss in land values in the EU could be concentrated in Italy, where the revenues of farms are very sensitive to seasonal changes in climate parameters. Such impacts on farm and land values would have implications for farmers' livelihoods and potentially their mental health (see also Section 3.3.5). In addition, farmers would be increasingly exposed to dust from cultivating agricultural land in drought periods, which could lead to respiratory problems (ANSES, 2018).

The healthcare sector could also be affected by water scarcity due to heavy consumption of water by hospitals, estimated in Germany at 300-600 litres per bed per day (Braun et al., 2015). This could be lowered with water use auditing, checking and fixing leaks, installing flow restrictors and dual-flush toilets and reclaiming water from dialysis units and sterilisers (Seppänen and Or, 2023). Use of reclaimed water for systems where potable water is not essential is another way of reducing use (Box 3.2). For health and education facilities, the expected annual damage due to drought-induced subsidence is projected to rise from EUR 10 million per year in the 2000s to EUR 460 million per year in the 2080s (Forzieri et al., 2018).

([13]) https://environment.ec.europa.eu/topics/water/drinking-water_en
([14]) Information provided by the Estonian Ministry of Climate.

Box 3.2

Rainwater reuse in the Centro Hospitalario Universitario de Ourense, Spain

One of the buildings of the Centro Hospitalario Universitario de Ourense, built in 2017, contains a rainwater collection system with a storage capacity of 850m^3 (167m^2 of surface, 5m high). The stored rainwater is used for toilet flushing and watering 1,925m^2 of lawns. Data for July shows an estimated 65.6m^3 of water is used per day for toilet flushing and 9.5m^3 for watering lawns. Rainwater reuse results in an estimated 60% reduction of water used for flushing and lawn watering. As part of the LIFE RESYSTAL project, an underground rainwater storage tank is planned, with 75m^3 capacity, with the primary aim of watering the vegetation around the hospital (personal communication with Miguel Díaz-Cacho Dafonte, Sustainable Projects Manager at Área Sanitaria de Ourense, SERGAS (Spain)).

Exposure to wildfires

Wildfires affect not only the people living in burnt areas but also the adjacent population, through smoke, evacuations and road or school closures. C3S and WMO (2024) estimate that 36,000 people were affected by wildfires in Europe in 2023. Between 2010 and 2012, on average annually nearly 50,000 people in the EEA member and cooperating countries and the UK lived in areas assessed as burned by wildfires. The average population living within 5km of burnt areas was nearly 7.08 million people each year. Between 2017 and 2019, these numbers were on average almost 119,000 and nearly 10.83 million, respectively. The highest proportions of the population living within 5km of burnt areas were in regions of Portugal, Spain, Italy and Albania (EEA, 2023e).

The number of people living near wildland and exposed to high-to-extreme fire danger levels for at least 10 days per year is projected to grow by 15 million (an increase of 24%) with 3°C of warming (JRC, 2020). The current rate of population exposure to wildfire smoke (less than 10 per 1,000 people exposed from 1981 to 2010) is projected to increase to between 12 and 20 per 1,000 people across Europe in the years 2071-2100 (Forzieri et al., 2017).

3.3 How droughts and water scarcity impact human health

The impacts on health of drought and water scarcity in Europe are predominantly indirect (Figure 3.2). Among them are health impacts due to shortages of drinking water, including limited water for sanitation and hygiene, worsened water and air quality, food insecurity and malnutrition through crop loss, and loss of income and unemployment with subsequent mental health impacts among, for example, farmers and seasonal agricultural workers. Droughts can affect populations' health and well-being far from the source — such as through increased prices of imported food products — and long after a drought has ended, e.g. through changed livelihoods.

Dry soils inhibit water infiltration, increasing flash flood hazards and associated health impacts when heavy rainfall events occur during a drought. In addition, the entry of pollutants or germs from surface water run-off following a dry period can lead to a deterioration of water quality (Butsch et al., 2023). Outbreaks of infectious diseases like campylobacteriosis (see Section 2.3.3) are often triggered by heavy rain events preceded by periods of drought (Semenza et al., 2012).

According to Vos et al. (2021), the greatest public health concerns in drought-prone high-income countries until recently were the mental health impacts of drought in rural and farming populations (see Section 3.3.5) and outbreaks of West Nile virus in places that harbour the transmitting vector (see Section 3.3.3).

See also the drought and water scarcity webpage in the European Climate and Health Observatory (2024c).

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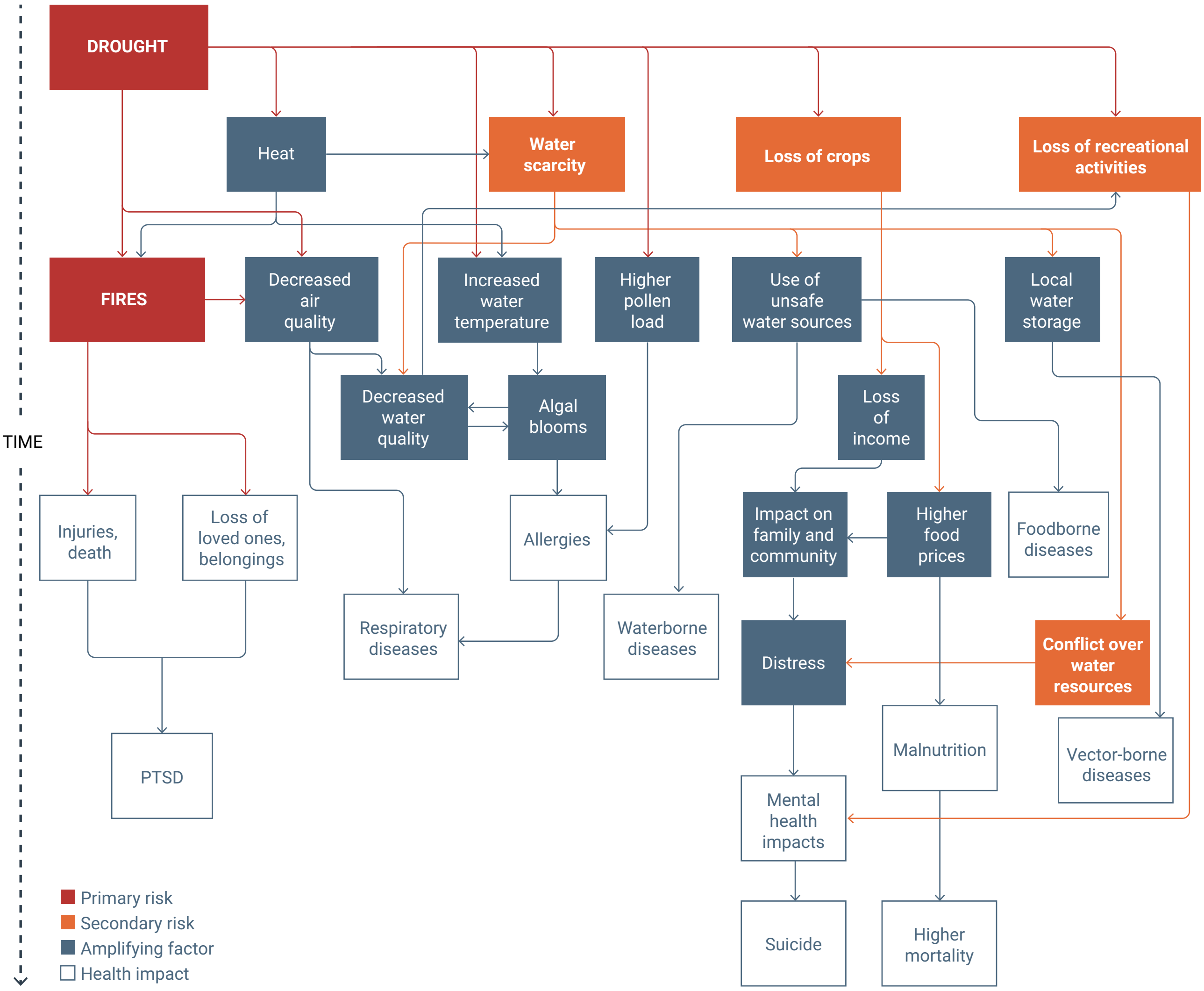
Figure 3.2 **Main cascading risks that can be triggered by droughts and fires**



Source: Adapted from Butsch et al., 2023, licensed under CC BY 4.0.

3.3.1 *Decreased water availability*

The complete unavailability of potable water for households has been rare in recent years in Europe, but it has occurred. In 2022 in France, more than 100 municipalities had water supply issues and drinking water was delivered by truck (Toreti et al., 2022). In Italy, about 50% of the population was affected by emergency water restrictions, especially in the north of the country (Faranda et al., 2023). In January 2024, 70 towns in the metropolitan areas of Barcelona and Girona used wells and tankers to guarantee water availability for residents, who were storing water at home (Velasco and Coll, 2024). In general, competition for water is growing between domestic uses and other needs, especially in western-central and southern Europe. The first European Climate Risk Assessment does not rule out severe water scarcity and prolonged droughts leading to conflicts not only among different water-using sectors but also among countries that share water resources (EEA, 2024a).

Reduced water supply, either as limited volume or restricted to certain hours a day, can lead to water-related diseases caused by reduced hygiene. Recurring droughts can negatively affect groundwater levels and quality (Lapworth et al., 2023), exacerbating the problem of falling levels due to abstraction (EEA, 2022h). Health risks can also arise indirectly from reduced water availability when people seek alternative supplies (e.g. private wells) that are not controlled or regulated. The need to boil poor-quality water before use has been linked to scalding injuries at home, especially in children (Bryan et al., 2020).

Drought has a mixed impact on recreational activities and sport. While some activities such as field sports and canoeing or kayaking on inland waters may suffer, other activities associated with dry and warm weather, like hiking, biking and sea swimming, may increase (Bryan et al., 2020).

3.3.2 Decreased water quality

While pollutant transport from agricultural and urban surface run-off is reduced during droughts, surface water quality deteriorates due to lower dissolved oxygen and higher river temperature, salinity and concentrations of pollutants such as pharmaceuticals from point sources owing to lower dilution (van Vliet et al., 2023). Discharge from wastewater treatment plants in Europe in general worsens the ecological status of water. During dry periods, water quality can be further compromised, especially for smaller streams and in other water bodies where the proportion of effluent exceeds several percent of the receiving water volume (Büttner et al., 2022).

The risk of harmful concentrations of chemicals increases during droughts. In 2015-2018, droughts contributed to elevated concentrations of chloride and sulphate, heavy metals, arsenic and pharmaceuticals such as metoprolol and ibuprofen in the Elbe, Rhine and Meuse rivers (Belz et al., 2021; Wolff and van Vliet, 2021; Delpla et al., 2009). Increased temperatures and nutrient concentrations in surface waters may also increase the likelihood and extent of algal and cyanobacterial blooms (see also Section 4.3). An extreme example was the pollution-caused ecosystem die-out in the Oder river in 2022, further fuelled by dry and hot weather (Free et al., 2023). In addition, antimicrobial resistance may be facilitated by droughts, as the proportion of effluent from urban wastewater plants, which often contains high levels of antibiotic resistance genes if effective treatment is not applied, become higher in the receiving water bodies during low flow periods (Schwermer and Uhl, 2021). Reduced water flows projected for large parts of Europe under the changing climate highlight the increasing need for additional wastewater treatment.

3.3.3 Water-, food- and vector-borne diseases

How droughts affect infectious diseases depends on their severity, the density of the human population, socio-economic factors and the presence of wild and farmed animals that play a role in transmission.

Low water levels result in elevated pathogen concentrations (e.g. harmful *E. coli* bacteria) in the surface and groundwater due to less dilution and lower filtration capacity of the soil. This can lead to higher risks of water- and foodborne diseases (Lapworth et al., 2023). In most European countries, well-regulated and quality-controlled public drinking water and sanitation systems mean that waterborne disease outbreaks linked to drought are rare. However, outbreaks of infectious diseases associated with private water supplies have been described for England and Wales (Stanke et al., 2013) and Ireland (PHMEHG, 2021). Low water availability may lead to use of untreated water for irrigation of crops, raising the risk of foodborne disease outbreaks (Box 3.3).

Box 3.3

Drought leading to foodborne disease outbreak in Ireland

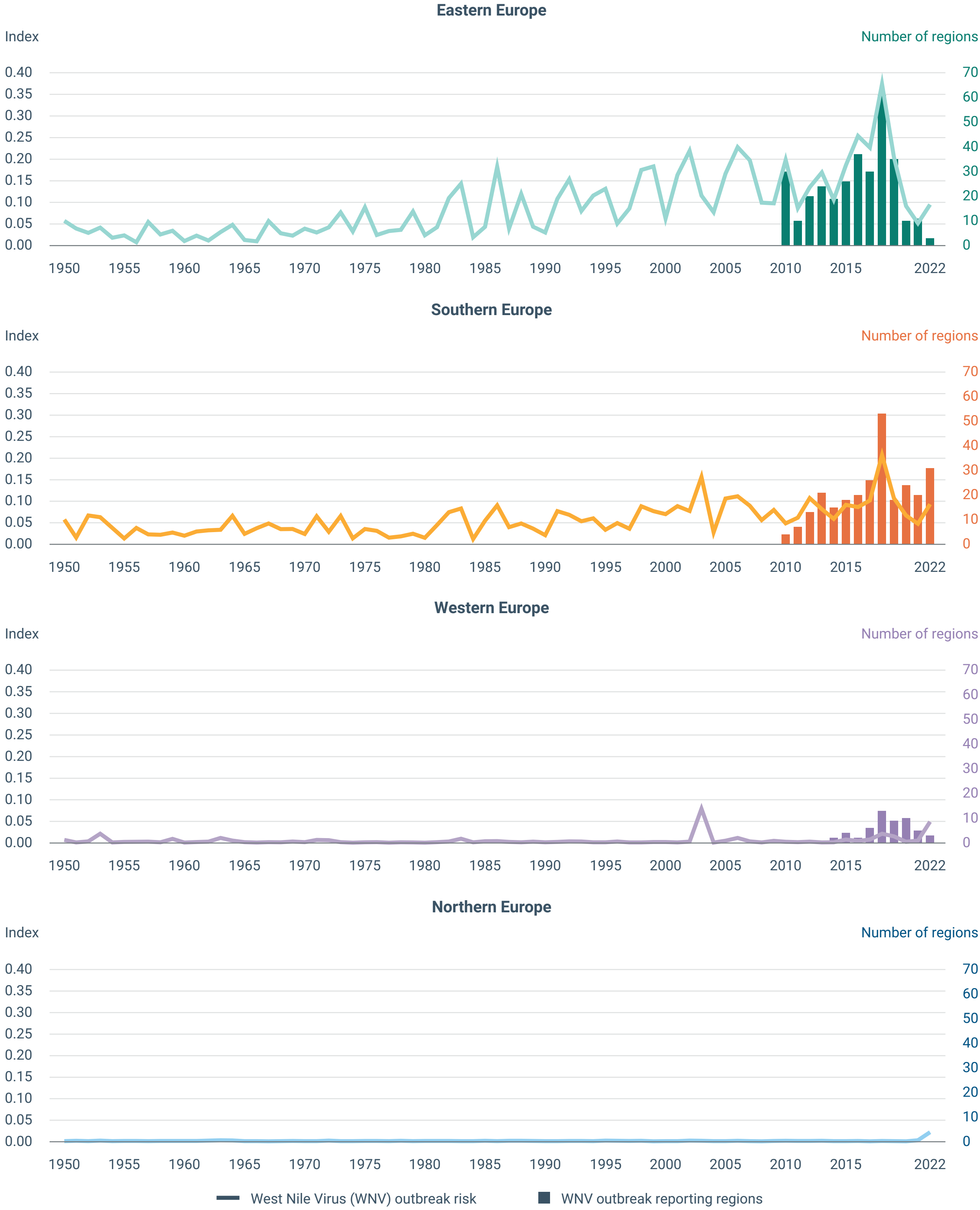
In the summer of 2018, Ireland experienced one of its largest foodborne disease outbreaks. Almost 200 people were infected by toxin-producing *E. coli bacteria* (STEC), some requiring hospitalisation. The outbreak originated from a common food source on the Irish market, probably lettuce. A long spell of warm and dry weather during the summer and associated water use restrictions are thought to incite the use of untreated water, contaminated with *E. coli*, for the irrigation of vegetables. This could have contributed to the presence of bacteria in food (personal communication with Ina Kelly, Health Protection Surveillance Centre, Ireland, 22 March 2023).

Droughts may increase *Giardia or Cryptosporidium* parasite concentrations to harmful levels in water treatment plant effluent, and subsequently water bodies (Semenza and Menne, 2009), or cause low flows, leading the pathogen to settle in the sediments (Patz et al., 2000). Dry and warm periods also stimulate recreational activities like swimming and bathing, increasing people's contact with water that may be contaminated with pathogens such as *Leptospira* spp., *E. coli, enterococci*, or parasites causing cercarial dermatitis (see also Section 4.6.3). Low flow rates in drought periods can increase bacterial growth, including of *Legionella* spp. (see also Section 4.4), in both natural water bodies and artificial systems such as cooling towers, reservoirs, humidifiers, fountains and hot tubs. Inhaling an aerosol contaminated with *Legionella* spp. increases the risk of developing infectious diseases such as Legionnaires' disease (Han, 2021).

Droughts exacerbate the risk of West Nile virus infections (EEA, 2022c). Key predictors for outbreaks include high summer temperatures, high precipitation in late winter or early spring, summer droughts, the presence of irrigated croplands and highly fragmented forests (Marcantonio et al., 2015). In 2018, the increase of West Nile virus infections in Europe was linked to a wet spring followed by drought (Semenza and Paz, 2021; ECDC, 2018). Pools of stagnant water in dry periods have higher organic material content, which favours larval development and mosquito population growth, and lack of regular heavy rainfall reduces the flushing of juvenile mosquito stages (Ferraccioli et al., 2023). Droughts also cause birds — reservoir hosts for the virus — and *Culex* mosquitoes to cluster around remaining water sources and human settlements, which can enhance the transmission of pathogens among them and increase the risk of outbreak among humans (Paz, 2019; Cotar et al., 2016; Wang et al., 2010). In habitats rewetted after a dry period, mosquitoes can thrive with fewer competitors and predators (Stanke et al., 2013; Chase and Knight, 2003). With changing climatic conditions, the risk of West Nile virus transmission has been steadily increasing across Europe in the past few decades. The relative increase in risk in 2013-2022 compared to the 1951-1960 baseline was 256%, with the highest relative risk increase seen in eastern Europe (516%) and southern Europe (203%) (Figure 3.3; van Daalen et al., 2024).

On the other hand, the expected rise in summer droughts in southern European countries that currently provide suitable habitats for tiger mosquito populations (*Aedes albopictus*), such as northern Italy, will probably create less suitable conditions for the mosquito and decrease the transmission risks of diseases like chikungunya or dengue (Tjaden et al., 2017). Extreme droughts are also likely to have a mitigating effect on tick abundance and activity, as they are sensitive to desiccation (Ogden et al., 2021). Nevertheless, combined with increasing temperatures, tick-borne infections are expected to increase overall (Gilbert, 2021).

Figure 3.3 West Nile virus outbreak risk trends by European sub-region from 1950 to 2022



Note: The outbreak risk was calculated at the NUTS 3 level. Bars represent the number of NUTS 3 regions reporting transmission for each sub-region (2010-2022).
Eastern Europe: Bulgaria, Czechia, Hungary, Poland, Romania, Slovakia; Northern Europe: Denmark, Estonia, Finland, Iceland, Ireland, Latvia, Lithuania, Norway, Sweden; Southern Europe: Albania, Bosnia and Herzegovina, Cyprus, Croatia, Greece, Italy, Kosovo*, Malta, Montenegro, North Macedonia, Portugal, Serbia, Slovenia, Spain, Türkiye; Western Europe: Austria, Belgium, France, Germany, Liechtenstein, Luxembourg, Netherlands, Switzerland.

Source: van Daalen et al., 2024.

2.3.4 Decreased air quality

While overall air quality and its impacts on health are improving in Europe (EEA, 2023b), the increased intensity and frequency of drought and wildfire events may slow down this improvement (CAMS, 2023). For example, droughts may lead to higher concentrations of dust in the air from dried-up soil, thus increasing particulate matter (PM) pollution. A study in Czechia found that PM_{10} ([15]) concentrations were 26.7-46.7% higher during dry periods (Šmejkalová and Brzezina, 2022).

Soil particles raised by winds may be polluted with microorganisms, pesticides, fertilisers, wastewater and sewage sludge in agricultural areas, as well as with heavy metals and hazardous materials, depending on industrial and mining activities or the proximity of waste management facilities. People, in particular children playing on the ground, may be exposed to those pollutants through direct skin contact or by breathing in dust (EEA, 2022f).

In addition to local dust, Saharan dust storms affect air quality in southern Europe, causing significant increases in mortality, especially among older people (Pérez et al., 2008; Zauli Sajani et al., 2011; Samoli et al., 2011). However, the intensity of dust transport from Sahara to Europe may decline under the changing climate (Evan et al., 2016).

Dust not only worsens air quality but may also decrease visibility or result in soil/dust from bare fields being blown into roads, increasing the risk of accidents. The dust events may also result in people staying indoors to limit their exposure, thus sacrificing the physical and mental benefits of being outdoors (Bryan et al., 2020).

In addition, during drier periods, pollen concentrations in the air may be higher. The respiratory conditions worsened by droughts include asthma and allergies. A correlation has been identified between fluctuations in dryness and the incidence of asthma in Italy (Bonomo et al., 2023).

Drought conditions also lead to decreased uptake of herbicides due to changes in the leaf morphology of plants and increased movement of herbicide vapours through the air. Alongside other impacts of climate change on plant health and crop yields, this may lead to changes in pesticide use (FAO, 2020; EFSA et al., 2020). In the EU, concerns about the impacts of human exposure to pesticides have led to efforts to reduce overall pesticide use and risk (EEA, 2023f).

3.3.5 Mental health impacts

Droughts and water scarcity can affect mental health through stress, anxiety and emotional and psychological distress, in some cases leading to illnesses such as depression (Figure 3.2). Rural or remote communities, agriculture-dependent populations and indigenous populations emerged as particularly vulnerable to the mental health impacts (Vins et al., 2015).

The impacts of droughts and water scarcity on agricultural production (see Box 3.4) for farmers may translate into economic difficulties. Additional workload affects family and social life and uncertainty about the future causes stress, anxiety and depression (Vins et al., 2015; see also Box 3.5). The economic uncertainties caused by droughts can also affect the mental health of people working in forestry, although the evidence from Europe is limited (Butsch et al., 2023).

([15]) Particles with aerodynamic diameter below 10μm.

Box 3.4

Impacts of droughts on agricultural production

Between 2000 and 2021, on average 76,873km² of cropland — nearly the area of Czechia — were affected by drought each year across the 38 EEA member and cooperating countries. In the record-breaking year of 2012, more than 202,000km² of cropland were affected (EEA, 2021c). In 2018 alone, agricultural damage amounted to some EUR 2 billion in France, EUR 1.4 billion in the Netherlands and EUR 770 million in Germany (EC, 2021c). In Serbia, yield reductions of up to 35% for grasses, 60% for maize and 55% for soy and sugar beets were recorded due to droughts between 2010 and 2015 (Ministry of Agriculture and Environmental Protection, 2015) and farmers include drought among the most damaging factors under the changing climate (Stricevic et al., 2020).

In summer 2022, Europe experienced its worst drought of the last 500 years. Across the EU, the 2022 maize yield was around 75% of the 2017-2021 average and the 2022 soybean yield was nearly 10% lower than the 2017-2021 average. In Italy, drought and water shortages led to a 45% drop in corn and animal feed yields, and a 30% reduction in wheat and rice production. The olive yield in Spain, which exports almost half of the world's olive oil, was the worst in a century and was half the yield of 2021 (EEA, 2023e).

Box 3.5

Addressing mental health issues among farmers in Ireland

Male Irish farmers experience some of the highest levels of adverse health outcomes relative to other occupations, particularly in relation to heart disease, cancers and mental health. According to Teagasc, (2022), the Irish Agriculture and Food Development Authority, 27% of farmers assess their well-being as 'poor' or 'below average'. The most frequently reported source of stress was poor weather, listed by 47% of respondents to a recent survey (two thirds in the case of dairy farmers; Brennan et al., 2022). Many farmers view seeking help as an admission of failure and they tend to prioritise farm work and the health of their animals over their own well-being (Hammersley et al., 2021).

In 2018, Ireland saw exceptional rainfall in the spring, resulting in the exhaustion of winter fodder. This was followed by unprecedented dry summer, causing severe fodder deficit and additional expenditure for farmers (Nolan et al., 2021). Samaritans Ireland, a volunteer organisation operating a helpline for people feeling suicidal or depressed, noted that in 2018 farmers were contacting them more frequently (Samaritans Ireland, 2018). Weather events similar to that of 2018 may increase in frequency and severity by the mid-21st century due to seasonal shifts in precipitation (Nolan et al., 2021).

In recognition of the stress and anxiety among farmers, a number of initiatives have been created, such as On Feirm Ground, which involves training agricultural advisors to engage with farmers on their health and well-being. Mental Health Ireland launched the Farming Resilience initiative, which provides resources to help farmers deal with uncertainties. The Irish Farmers' Association has created the 'Dealing with Stress' leaflet and, with non-governmental organisations SeeChange and Mental Health Ireland and the semi-state forestry company Coillte, it hosts an annual community walk throughout the country. The campaign aims to bring rural communities together and create a space to talk about mental health to increase awareness and reduce stigma (Euractiv, 2022).

3.3.6 Food, nutrition and healthy diets

Compared to the Global South, a lack of safe food is not a widespread risk in Europe. However, extreme weather events such as droughts affect the availability and affordability of fresh and healthy food (EEA, 2023a). Droughts, in combination with heat stress, have already decreased European crop production substantially, especially in southern Europe (see Box 3.4). In addition, severe droughts have the potential to reduce food quality, for example through affecting nutrient and mineral contents (Stagnari et al., 2016).

Droughts, in addition to factors such as energy and fertiliser prices, can increase the cost of food to consumers (EEA, 2024a). For example, in the summer of 2023, prices for Spanish tomatoes, broccoli and oranges increased by 25-35% due to drought-related crop losses (Campbell, 2023). Higher prices of fresh produce may cause dietary shifts towards cheaper but less healthy products, as well as reduced food intake among parts of the population (UN, 2021; Bryan et al., 2020). People who skip meals because of costs suffer from more mental stress (Friel et al., 2014). Those most at risk from poor diets are people with lower socio-economic status, as well as pregnant women and children under five (Black et al., 2008), and people with pre-existing health conditions. These consequences increase healthcare costs and reduce productivity, which can perpetuate a cycle of poverty and health issues (WHO, 2021b).

Among the countries reporting on adaptation under the Governance Regulation, only Slovakia explicitly mentions the risk of droughts to food security (EEA, 2023h). However, the problem is likely to be widespread across Europe. The Lancet Countdown in Europe estimates that nearly 60 million people experienced moderate or severe food insecurity in 37 European countries in 2021. Around 12 million of these can be attributed to an increase in heatwave days and drought months, compared with the average across 1981-2010. Increasing frequency of droughts resulted in food insecurity being 0.47 percentage points (equivalent to 3.5 million people) higher in 2021 than the 1981-2010 average. Low-income people have a statistically significantly higher risk of food insecurity compared to median-income people (Dasgupta and Robinson, 2022; van Daalen et al., 2024).

Drought stress can also cause food safety problems, as stressed plants become more vulnerable to pests. Maize, for example, is more sensitive to fungal infections and subsequent mycotoxin contamination during extreme dry growing conditions. In 2003-2004, unusual drought conditions in Italy led to aflatoxin contamination above legal food safety limits in feed maize (Giorni et al., 2007). Future heat and droughts are highly likely to pose further issues to plant health, with moderate to large impacts (EFSA et al., 2020).

In addition, water stress intensifying pollution in some river basins in Europe may have implications for recreational and commercial fisheries. This was, for instance, observed in the Oder river, where the drought and resulting low water levels in August 2022 were seen as a contributing factor in the death of approximately 360 tonnes of fish caused by industrial wastewater discharges with a high salt content (Free et al., 2023).

See also Box 4.5 for impacts of water quality on food production systems and the European Climate Risk Assessment (EEA, 2024a) for further information on food security under the changing climate.

3.3.7 Health impacts of wildfires

Direct exposure to flames or heat can cause burns, injuries or death and heat-related problems such as dehydration and heatstroke. It also harms people's respiratory systems (via, e.g. coughing, bronchitis, reduced lung function, asthma exacerbation) and cardiovascular functioning (e.g. heart failure, heart attack, stroke). Between 1980 and 2022, there were 702 fatalities directly caused by wildfires recorded in the 32 EEA member countries. Over that period, the highest numbers of wildfire-related deaths were recorded in Greece (216), Portugal (210) and Spain (80). The worst years for wildfire-related deaths were 2017 (117 deaths), 2018 (102) and 2007 (101) (EEA, 2023l; European Climate and Health Observatory, 2023a). Under the high emissions climate change scenario, a substantial increase in deaths caused by wildfires is expected by 2071-2100 (138%); on average, 57 lives a year are projected to be lost (Forzieri et al., 2017).

Wildfire smoke contains several components known to be harmful to human health, such as high levels of fine particulate matter ($PM_{2.5}$) ([16]), carbon monoxide and nitrogen oxides. Wildfire-related $PM_{2.5}$ has stronger effects on mortality than urban $PM_{2.5}$ due to a higher proportion of small particles, greater toxicity and more oxidative and proinflammatory components. Wildfire smoke contains toxic combustion products (e.g. polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), mercury, hexavalent chromium and persistent organic pollutants (POPs)) and increases their mobility in the environment (Hung et al., 2022). A 14% increase in global emissions of mercury due to wildfires is expected between 2000 and 2050 (FAO, 2020). Toxicants derived from burnt plastic, such as benzene, or industrial leachates, such as mercury or arsenic, can also accumulate in ash and end up in surface waters via run-off (UNEP, 2022).

Wildfire smoke can affect a large part of the population, as it can travel thousands of kilometres from the fire source (Xu et al., 2020). Exposure to heavy smoke in areas surrounding a wildfire can cause eye and skin irritation or lead to the onset or exacerbation of acute and chronic respiratory diseases. An increase of premature deaths, respiratory diseases and pneumonia cases in populations exposed to smoke has been reported after wildfires (Kollanus et al., 2017). Exposure to $PM_{2.5}$ and chemicals in wildfire smoke was found to be correlated with an increased risk of all types of cancer (Grant and Runkle, 2022).

A study of 27 European countries estimated that, in 2005 and 2008, there were respectively 1,483 and 1,080 premature deaths attributable to vegetation fire-originated $PM_{2.5}$, with greater impacts in southern and eastern Europe (Kollanus et al., 2017b). In 2021, 376 premature deaths were estimated in the eastern and central Mediterranean basin due to short-term exposure to wildfire-caused changes in ozone and $PM_{2.5}$ (Zhou and Knote, 2023).

Analyses of trends in population exposure in Europe to wildfire smoke over the last two decades differ. Van Daalen et al. (2024) state that $PM_{2.5}$ smoke exposure shows no clear positive or negative patterns over 2003-2022. However, according to ENBEL (2024), population exposure to wildfire particulate matter in Europe over the last two decades has increased by 40%. As a result, the contribution of wildfires to deaths associated with exposure to $PM_{2.5}$ is increasing — from 2 out of 1,000 excess deaths from ambient $PM_{2.5}$ exposure associated with fire $PM_{2.5}$ in 1990 to 13 in 2019 (Chowdhury et al., 2024). As emissions from wildfires can be up to 10 times more toxic than other sources of $PM_{2.5}$, wildfires may contribute to more than 13% of total excess deaths in Europe attributed to $PM_{2.5}$ pollution (ENBEL, 2024).

([16]) Particles with aerodynamic diameter ≤2.5µm.

People affected by traumatic experiences, such as loss of loved ones, damage to property or destruction of essential infrastructure in their area, are at increased risk of PTSD, depression and insomnia (European Climate Health Observatory, 2022c, 2023a).

Populations particularly vulnerable to adverse effects of wildfire smoke include the elderly, children, people with pre-existing cardiovascular or respiratory conditions and pregnant women. The 2023 death toll included 19 undocumented migrants who lost their lives in fires in the Alexandroupolis region of Greece (Roush, 2023). In addition, healthcare facilities can be threatened by quickly spreading wildfires, necessitating evacuations and putting patients at risk (Box 3.6).

Box 3.6

Examples of impacts of wildfires on healthcare facilities and healthcare provision

More than 200 patients were evacuated from a small hospital in Madeira, Portugal, in 2016 as a precautionary measure due to approaching fire (NBC News, 2016). In 2021, the Greek health service was burdened by people having difficulties with breathing due to smoke from the wildfires. Athens had one of the worst air pollution levels among world cities on some days, and in one night there were 77 calls for ambulance assistance from people with breathing issues (Stamouli and Weise, 2021). In 2022, due to widespread wildfires in the region, the general hospital of Alexandroupolis, Greece, had to evacuate its patients as fire had almost reached the hospital (Avramidis, 2023).

Outdoor and rescue workers are also at high risk through occupational exposure (Ioannou et al., 2022). One of the highest fatality rates from forest fires occurred in August 2007 in Croatia, where 12 firefighters died and one was seriously injured (Stipaničev et al., 2008). Among firefighters, cardiovascular disease is the leading cause of death, with higher risks for older workers with physically strenuous tasks (EU-OSHA, 2023). In the longer term, occupational exposure to smoke may increase the risk of hypertension and PTSD symptoms (Groot et al., 2019).

4 Health impacts of changed water temperature, chemistry and ecology

Key messages

- Water quality is at risk under the changing climate due to rising temperatures influencing pathogen growth. Rising infectious diseases driven by high temperatures include Legionnaires' disease and vibriosis, contracted through contact with *Vibrio* bacteria in warm, low-salinity waters.
- There is a risk to drinking water supplies from saline intrusions into groundwater aquifers, caused by sea level rise combined with groundwater abstraction, and into estuaries during low flow periods.
- During dry and hot periods, higher temperatures and nutrient concentrations can stimulate cyanobacterial and algal blooms, affecting the quality of both bathing and drinking water.
- Emerging risks to human health include mobilisation of chemicals and potentially pathogens due to permafrost thaw in northern Europe and ciguatera poisoning in Macaronesia and in the Mediterranean.

4.1 Increased temperatures of drinking water supply

Water temperatures in major European lakes and rivers have risen by about 1-3°C over the past century and accelerated river water warming is expected, aggravated by declining summer flows (EEA, 2024a). According to the reporting of the 2nd river basin management plans by EU Member States under the Water Framework Directive, 1,644 surface water bodies in 13 countries have significant impacts of elevated temperatures (WISE, 2023). For example, Denmark, in reporting on adaptation under the EU's Governance Regulation, highlights that some Danish waterworks are already struggling to comply with recommended requirements for the temperature of drinking water (max. 12°C at the tap) (EEA, 2023h). Higher water temperatures may pose risks, particularly for countries that rely on surface water as the public water supply, such as Finland or Sweden. In the latter, surface water currently accounts for approximately 50% of water production**.** Higher temperatures create better growing conditions for cyanobacteria, pathogens such as the *Cryptosporidium* parasite (see Box 4.1) and biofilms in treatment systems. This raises the need to cool surface water through artificial infiltration to lower the risk of infections via the water (personal communication with Karin Lundgren Kownacki, SMHI, 16 March 2023). Higher temperatures can also facilitate the production of disinfection byproducts, such as conditionally carcinogenic trihalomethanes (Valdivia-Garcia et al., 2019).

Box 4.1

Improving drinking water quality after *Cryptosporidium* outbreak in Östersund, Sweden

In the winter of 2010/2011, 27,000 (45%) of the inhabitants of Östersund municipality became ill with diarrhoea, abdominal pain, vomiting and/or fever after drinking tap water infected with the *Cryptosporidium* parasite (Robertson and Huang, 2012). Ten years after the outbreak, those originally infected were still three times more likely to experience symptoms of the disease compared to those who had not been infected (Boks et al., 2023).

The pathogen was present in the Storsjön lake that supplies drinking water in Östersund. Increased winter precipitation and higher temperatures led to the parasite's presence in the water. Immediately after the outbreak was recognised, the municipality instructed residents to boil all water, an order that remained in place from November to February. To cope with increasing concentrations of pathogens, the municipality altered its water and sewage treatment processes and started to replace existing water purification facilities using inactivating barriers — which make pathogens harmless via ozonisation — with filter barriers that separate pathogens physically. The new facilities are expected to be finalised in 2026 (Swedish Portal for Climate Change Adaptation, 2018; personal communication with Karin Lundgren Kownacki, SMHI, 16 March 2023).

4.2 Saline intrusions

Saline drinking water may increase the risks of high blood pressure, preeclampsia in pregnant women and infant mortality, especially in communities using untreated water (NCCEH, 2022). It may also cause the release of heavy metals from pipes into the water, causing further negative health impacts (Lassiter, 2021).

Rising sea levels contribute to saltwater intrusion into groundwater and surface water aquifers in coastal areas, which can make the groundwater unusable for decades and increase the cost of treatment (EEA, 2022a). The projected sea level rise combined with abstraction of groundwater resources will increase the problem (EEA, 2024a), for example for the karst aquifers in Croatia, Greece, France, Italy, Malta and Spain (EEA, 2022a).

Saline intrusions in freshwater systems can be particularly challenging in periods of droughts. In 2022, ascent of salt water in Italy's Po Delta was recorded up to 38km from the coast (Navarra and Bruno, 2022). Rising sea levels triggered by climate change increase seepage of saltwater into agricultural soils, with potential negative effects for food production (see Box 4.5). In addition, increasing inland salinity levels could result in expanded Vibrio spp. distribution (NCCEH, 2022); see also Section 4.5. Future rising sea levels and consequent seawater intrusion into estuaries will cause further salinisation (EEA, 2024a).

According to the Member States' 2nd river basin management plans under the Water Framework Directive, 281 groundwater bodies across 16 EU Member States failed to achieve good chemical status as a result of saline or other intrusion. In total, 950 surface water bodies across 13 countries are under significant saline or other intrusion impacts (WISE, 2023). Belgium, Poland and Sweden explicitly include sea level rise as a threat to drinking water supply in the 2023 reporting on national adaptation under the Governance Regulation (EEA, 2023h). This may require development of new infrastructure (see Box 4.2).

Box 4.2

Reconstruction of city locks in Stockholm, Sweden

Lake Mälaren, a source of drinking water for 2 million people in Sweden, meets the Baltic Sea in Stockholm. While the lake is around 70cm above current sea levels, to protect it from saltwater intrusion from the Baltic Sea in the future, Stockholm is reconstructing one of the city's locks. The new lock, due to be completed in 2025, is designed to withstand up to a 2-m seawater rise (Doyle, 2022; CDP, 2021).

4.3 Harmful cyanobacterial and algal blooms

Harmful algal or cyanobacterial blooms are extensive, often colourful, overgrowths of algae or cyanobacteria in nutrient-rich and warm water (EEA, 2022i), causing detrimental effects on human and animal health, local ecosystems and the economy. True algae dominate marine waters, while cyanobacteria — commonly known as blue-green algae — are most often responsible for blooms in freshwater (Wurtsbaugh et al., 2019).

4.3.1 Cyanobacterial blooms

Cyanobacteria produce toxins harmful to human and animal life (Lad et al., 2022; Neves et al., 2021). Exposure to cyanotoxins and harmful cyanobacterial blooms occurs mostly via accidental ingestion of contaminated bathing water, skin contact (Nielsen and Jiang, 2020), consumption of contaminated and improperly treated drinking water (Steffen et al., 2017) and, to a lesser extent, inhalation of water droplets (Plaas and Paerl, 2021). Direct contact with certain cyanobacterial blooms can cause skin and eye irritation and allergy-like symptoms; inhaling toxins causes airway inflammation; and ingestion of cyanotoxins may lead to gastrointestinal diseases, liver and kidney damage, neurological disorders and cancer (Melaram et al., 2022).

Cyanobacteria pose a particular public health threat when they enter the drinking water supply (see Box 4.3). The EU Drinking Water Directive requires that microcystin-LR, a common and widespread cyanotoxin, is measured when a cyanobacterial bloom is detected in a drinking water reservoir (EU, 2020b). The EU Bathing Water Directive (EU, 2006) states that in the event of potential blooms (increasing cyanobacterial cell density or bloom-forming potential), appropriate monitoring is to be carried out to enable timely identification of health risks. When cyanobacterial proliferation occurs and a health risk has been identified or presumed, adequate management measures must be taken immediately to prevent exposure, including providing information to the public.

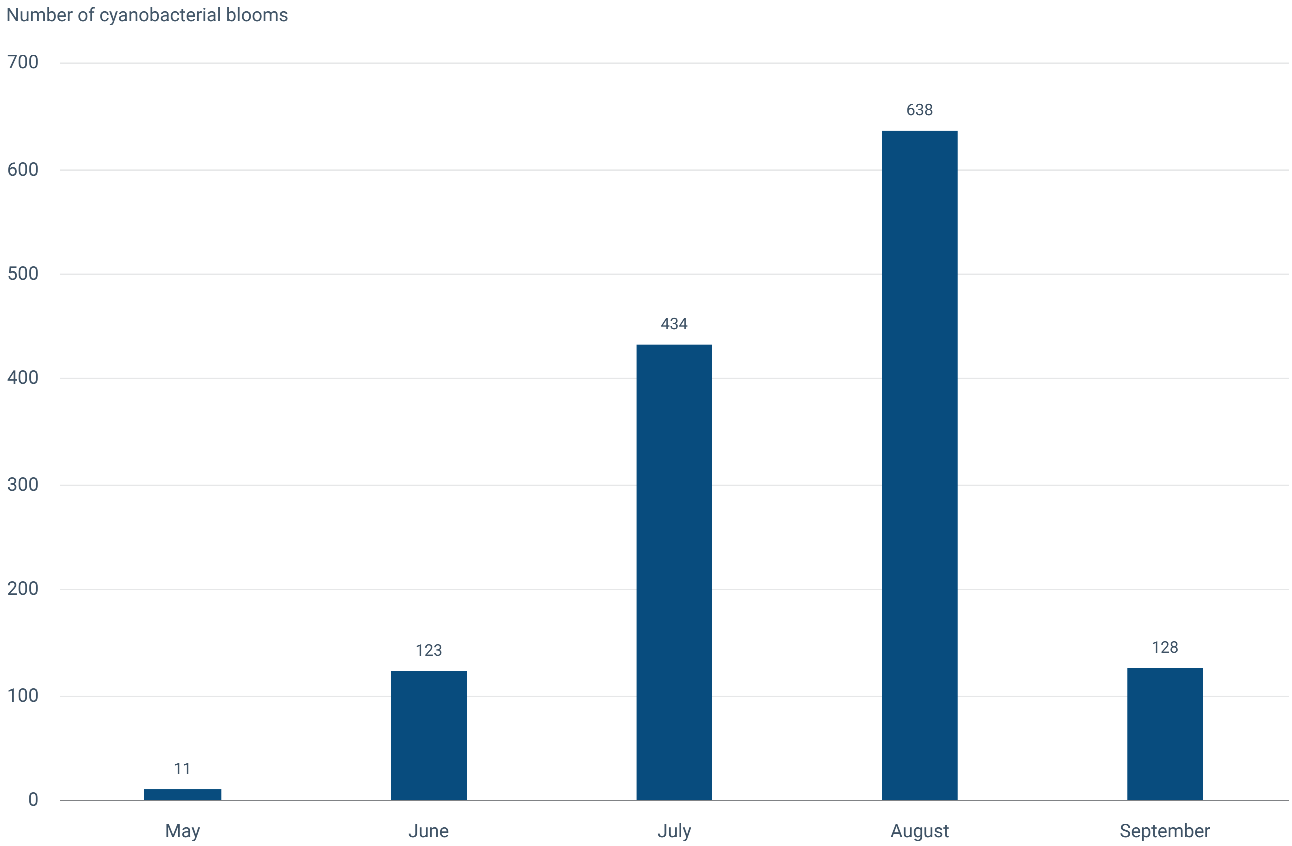
Box 4.3

Management of cyanobacterial risks to drinking water in the Occhito basin, Italy

In 2009, an extraordinary bloom of the cyanobacterium *Planktothrix rubescens* occurred in the Occhito basin, an artificial reservoir supplying around 800,000 people with water. Microcystin occurred in raw water used for human consumption. To manage the risk, screening and confirmation protocols were evaluated, the drinking water supply chain was monitored, operators were trained and a dedicated website for risk communication was developed. The water was treated by peroxidation with chlorine dioxide followed by flocculation and settling, which ensured continuous water supply to the population (Bogialli et al., 2013). Direct costs relating to the treatment plants were estimated at about EUR 700,000 for the first emergency actions, which consisted of the removal of a 0.5-m layer of sand from the standard filtration systems and its replacement with a 0.5-m layer of granulated activated carbon (WHO, 2011a).

The primary factor influencing the presence of cyanobacterial blooms is nutrient availability, mainly nitrogen and phosphorus coming from agricultural fields with run-off (see Section 2.2.4). To a lesser extent, increased water temperatures can affect the occurrence of harmful cyanobacterial blooms (West et al., 2021; Huisman et al., 2018). Higher temperatures and low flows cause stratification in the water, which further favours algal blooms in nutrient-rich water (Mosley, 2015; Richardson et al., 2018). Increasing water temperatures influence the presence and distribution of some toxin-producing cyanobacteria species of tropical origin in Europe, such as *Cylindrospermopsis raciborskii.* Lake surface water temperatures across Europe have been warming since the 1990s, at a rate of 0.33°C per decade (C3S, 2023). Across the year, the number of cyanobacterial blooms in sampled EU bathing waters peaks in August (Figure 4.1).

Figure 4.1 **Number of cyanobacterial blooms in bathing water samples per month in Europe (2008-2022)**



Note: Based on data from 25,680 bathing water sites across EU-27 countries, Switzerland, Albania, Montenegro and the UK.

Source: EEA, based on Bathing Water Directive - Status of bathing water dataset.

An unpublished EEA analysis of data on 25,680 bathing waters across Europe between 2008 and 2022 and air temperature anomaly data suggests that water samples taken during periods of reported cyanobacterial blooms are more frequently associated with unusually warm conditions, relative to the long-term average of the 1981-2010 period, compared to water samples without blooms (Table 4.1).

Table 4.1 Cyanobacteria blooms and heat anomalies

Cyanobacteria bloom	Air temperature anomaly (°C): mean and standard deviation	Sample size (n)
Yes	1.42 (1.48)	1,330
No	0.69 (1.00)	4,938,828

Note: Cyanobacteria monitoring is not performed routinely in all European bathing waters but follows a risk-based approach, thus it varies across countries and over time.

Sources: EEA analysis, based on Bathing Water Directive - Status of bathing water dataset and monthly temperature anomalies of Copernicus' Essential Climate Variables dataset.

Although the measures taken under the Urban Waste Water Treatment Directive, the Water Framework Directive and the Nitrates Directive (see also Section 5.1) have reduced phosphorus and nitrogen discharge into water bodies, persistent high loads combined with increasing temperature may increase algal and cyanobacterial bloom occurrence in some water bodies (Chorus and Welker, 2021). To protect people's health from cyanotoxins under the changing climate conditions (increased run-off and longer periods of high air temperatures), reducing anthropogenic nutrient inputs in agriculture should be the primary focus for mitigating cyanobacteria in surface waters (EEA, 2022d, 2022i). According to EFSA et al. (2020), it is necessary to revisit and expand the present regulatory framework and design and implement appropriate monitoring and surveillance systems for early detection, prevention, mitigation, analysis and control of cyanobacterial and algal blooms and their negative health and economic effects.

4.3.2 Algal blooms

Marine dinoflagellate algae produce phytotoxins that easily accumulate in fish and shellfish, which, when consumed by people, can cause nausea, vomiting and diarrhoea (ClimaHealth.info, no date). Less frequently, they can cause more serious neurological disorders and acute toxicity (Etheridge, 2010). In the south of Europe, warming sea temperatures cause a proliferation of dinoflagellates and the phytotoxins they produce (Dickey and Plakas, 2010). Neurotoxins are commonly found in European coastal shellfish in the English Channel and Atlantic coastal region of Brittany (Belin et al., 2021). In addition, cases of seafood poisoning from locally caught fish due to ciguatoxins have been documented in the Canary Islands and Madeira (see Section 4.6.2). In addition to the direct health impacts, harmful algal and cyanobacterial blooms cause disruptions and damage to economic activities such as aquaculture, fisheries and tourism (Unesco, 2021).

Harmful algal blooms increased in marine waters in Europe and the Mediterranean region between 1985 and 2000, which was followed by a decrease in such events in the Mediterranean and fluctuations in the rest of Europe. Globally, no significant link with climatic changes could be found (Unesco, 2021). Nonetheless, observed trends in the proliferation of harmful algal blooms can be linked in part to ocean warming, marine heatwaves and depletion of oxygen, as well as strong non-climatic drivers such as increased riverine nutrients run-off and pollution. As a result, climate change may fuel the exacerbation of harmful algal blooms in response to eutrophication (Gobler, 2020).

4.2 *Legionella*

Legionnaires' disease, caused by *Legionella* spp. bacteria, is primarily contracted through inhalation of aerosols or small water droplets from natural water bodies and artificial aquatic systems and can lead to serious lung infections and respiratory diseases. Under climate change, intensified precipitation creates waterborne pathways for the bacteria, and droughts and warm temperatures can increase bacterial growth, leading to higher infection risks (Pampaka et al., 2022).

Outbreaks occur when the water systems of residential buildings, cooling towers or air conditioning systems are infected with the bacteria, yet in Europe it is mainly a sporadic respiratory infection. The disease is underdiagnosed and underreported. It is fatal in 7-9% of reported cases (ECDC, 2023a).

The highest annual notification rate of Legionnaires' disease to date in the EU/EEA was observed in 2021, with more than 10,700 cases reported and 704 known fatalities. Italy, France, Spain and Germany accounted for 75% of notified cases (ECDC, 2023a). Infections peak between June and October, correlating with higher temperatures (European Climate and Health Observatory, 2023h). For example, in August 2023, an increased number of cases was recorded in Germany. The increase was considered to be related to the meteorological conditions of the preceding weeks — relatively high humidity in summer temperatures (RKI, 2023).

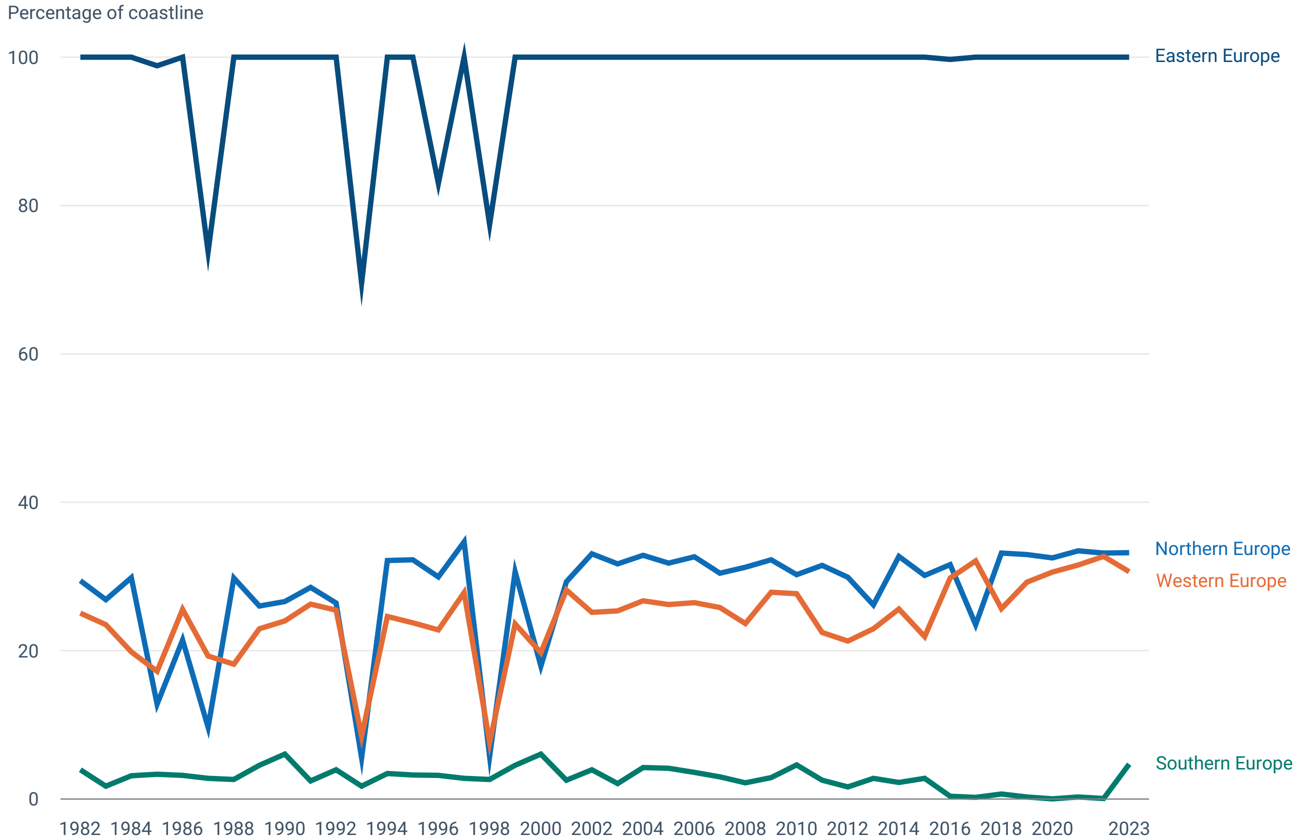
4.3 *Vibrio*

Vibrio spp. are common bacteria occurring naturally in aquatic environments. *Vibrio parahaemolyticus*, *V. vulnificus* and *V. cholerae* are important pathogens for humans. *Vibrio* spp. loads and densities in aquatic environments are affected by water temperature and salinity; they thrive in warm water (>15°C) and low to moderate salinity. In coastal areas, they survive well on marine shells and plankton. Consumption of contaminated, raw seafood containing *Vibrio* spp. can cause gastroenteritis (Box 4.5). Direct exposure to *Vibrio* spp. in coastal water may cause wounds and skin and ear infections, as well as more severe outcomes including necrotising fasciitis, sepsis and death. People suffering from liver disease or immune deficiency and those with skin lesions or wounds are the most vulnerable (European Climate and Health Observatory, 2021).

All five European seas have warmed considerably since 1870, particularly since the late 1970s (EEA, 2024a). The Baltic Sea has warmed by 0.6°C per decade over the last 30 years (EEA, 2023d) and its shallow, low salinity and nutrient-rich waters make it particularly suitable for *Vibrio spp.* Warming of the Baltic Sea is regarded as the main driver for the substantial increase in *Vibrio* spp. infections in recent decades (European Climate and Health Observatory, 2021). According to van Daalen et al. (2024), 18 countries showed suitable areas for *Vibrio* spp. in Europe in 2022, with a total of 1,654 cumulative days with high risk of exposure. The length of the coastline affected in these countries (23,011km in 2022) shows a consistent increase between 1982 and 2022, in particular in western Europe (Figure 4.2).

While infections associated with marine environments are dominated by *Vibrio* infections, the risk of infection with the less common *Shewanella* spp. is also increasing with rising seawater temperatures in Europe (e.g. Naseer et al., 2019; Hounmanou et al., 2023).

Figure 4.2 **Percentage of coastline showing suitable conditions for *Vibrio* spp. at any time of the year (1982-2023).**



Source: van Daalen et al., 2024.

Clear associations can be observed between hot summers and the number of reported vibriosis cases (Box 4.4). Rising temperatures are expected to further increase the climatic suitability for *Vibrio* spp., leading to a northward spread of the bacteria, higher concentrations and a longer infective season. For example, in Germany, the number of months in a year with warm enough seawater in the North and Baltic Seas for the potential presence of human pathogenic *Vibrio* spp. is projected to increase from 2-3 in the baseline period of 1970-1999 to 3.5-4.5 in the near future (2021-2050 under SRES scenario A1B) (Wolf et al., 2021). According to EFSA et al. (2020), *Vibrio spp.* are the biological hazard to human health with the highest likelihood of being exacerbated under climate change and having almost the highest impact on human health. Despite an increase in vibriosis cases and future projections for growth, it is not yet a notifiable disease in the EU.

Box 4.4

Cases of vibriosis in selected European countries

The number of *Vibrio* infection cases in Sweden between 2009 and 2023 ranged from fewer than 10 up to 135 cases; the record year was 2018, with a very hot summer, when an unusual number of people suffered wound and blood *Vibrio* infections in July and August. This was followed by 66 cases in 2021 and 56 in 2014, both years with exceptionally warm summers (Folkhälsomyndigheten, 2023).

In France, the average number of clinical cases of *Vibrio* infections reported between 1995 and 2015 was 10, but it has increased in recent years, with a total of 26 cases in 2017, 60 in 2018 and 69 in 2019. In over 70% of the cases, a link to marine water was established, with ingestion of seafood being the main route of contamination and gastroenteritis the main consequence (Centre national de référence, 2021).

In Germany, several *Vibrio* spp. have been detected in coastal bathing waters of the North and Baltic Seas as well as the estuarine areas of the Elbe, Weser and Ems rivers. The first case was recorded in 1994. Between 2003 and 2019, there were 120 cases and 15 deaths associated with *Vibrio,* mainly through wound infections. 2018 and 2019, the years characterised by summer heatwaves, saw more recorded infections than other years. Since 1 March 2020, vibriosis has been a notifiable disease in Germany according to the Federal Law on the Prevention of Infectious Diseases in Humans (Brehm et al., 2021).

Box 4.5

Impacts of water temperature and chemical and biological characteristics on food systems

Higher water temperatures have implications for the availability of certain species for fishing. For example, in the upper Adriatic, most catches previously consisted of species preferring cold or temperate water, which are the most sensitive to thermal variations. Under the changing climate, the water temperature in the area is expected to grow beyond the optimal levels of those species, potentially leading to population collapse. Even some of the invasive thermophilic species that are increasing in presence and could potentially be used as a replacement will not withstand the projected temperature increase (Piattaforma Nazionale Adattamento Cambiamenti Climatici, 2023). In Sweden, fish production in the great lakes — Vänern, Vättern and Mälaren — may be affected by the changing hydrological cycle (EEA, 2023h).

Climate change is expected to increase mercury bioaccumulation in the marine food chain due to rising ocean temperatures, ocean acidification and permafrost thawing in Arctic ecosystems, as well as the deposition of inorganic mercury from the atmosphere (e.g. from coal-fired power plant emissions) with increased precipitation (FAO, 2020), with potential health implications for consumers. In addition, warmer temperatures in sea-and brackish waters are increasing the occurrence of *Vibrio* spp. in fish and shellfish. In Europe, an increase in seafood-related vibriosis outbreaks has been observed (Swedish Food Agency, 2021).

Saline water intrusion into soils, partially driven by rising sea levels and droughts, may affect crop production and reduce land productivity, in turn affecting food quality and pricing and human diets. Soil salinity already affects an estimated 1 million ha in the EU, predominantly in the Mediterranean. In north-western Europe, pockets of soil salinisation are mainly caused by sea level rise and surface seawater seepage (Tzemi et al., 2023a). For example, projected yield losses in Groningen, the Netherlands, assuming irrigation with groundwater contaminated with seawater, were 3,118 tonnes for maize, 1,134 tonnes for wheat, 20,650,094 tonnes for sugar beet, 1,871,424 tonnes for barley and 9,120,207 tonnes for potatoes (Tzemi et al., 2023b).

Droughts can result in food safety risks if food processing plants need to reuse wastewater or change standard hygiene procedures as the presence of pathogens in water poses a risk. For example, *Cryptosporidium* in drinking water in Östersund, Sweden (Box 4.1), may have affected a supplier of cured meat products. The process of curing uses tap water and the products could have become contaminated with *Cryptosporidium* oocysts during their water contact, potentially acting as vehicles for further transmission of the parasite to consumers (Robertson and Huang, 2012). Indirectly, climate change impacts that change the nutritional content or preservability of food products may require current food processing methods to be redesigned (FAO, 2020).

4.6 Emerging risks

4.6.1 Permafrost thaw

Thawing of permafrost — in Europe found in high-latitude Arctic regions (Fennoscandia and Iceland) and high-altitude mountainous areas (the Alps) — affects human health through the following main pathways (European Climate and Health Observatory, 2024d):

- Deteriorated water and food quality: increased run-off causes pollution and the release of trace elements (e.g. metal contaminants) and major ions, previously stored in the permafrost, into water sources (Lamontagne-Hallé et al., 2018) can lead to cancers, developmental and reproductive disorders, cardiovascular and skeletal diseases, and neurotoxicity (WHO, 2022a). Northern permafrost soils are the largest reservoir of mercury on Earth, which when released can contaminate drinking water and accumulate in fish and sea mammals, posing risks of kidney toxicity and neurological disorders if eaten (AMAP, 2021). Permafrost thaw impacts the ability of some communities in Greenland to obtain food and spring water (Jungsberg et al., 2022) and, for those relying on natural refrigeration, it increases the risks of foodborne diseases and food insecurity (Parkinson and Evengård, 2009).

- Rockfall and subsidence: in July 2022, the Marmolada glacier in the northern Italian Alps collapsed due to thawing permafrost and melting snow, killing 11 people and injuring seven (Bondesan and Francese, 2023). In the Arctic, permafrost thaw damages infrastructure, affecting communities' access to essential services and negatively affecting mental health (Bell et al., 2010).

- Exposure to pathogens: permafrost thaw can release previously contained pathogens, including antibiotic-resistant bacteria and unknown viruses. The risk of preserved pathogens being active after thawing is low, yet the consequences of their release are difficult to predict (Wu et al., 2022). Indirectly, the warmer and wetter conditions linked to permafrost thaw can also lead to increased disease transmission. Increased risk of anthrax outbreaks decimating reindeer poses a serious threat for Arctic herding communities through reduced source of food and income (Stella et al., 2020).

- Hazardous waste release: chemical and radioactive waste is stored in several industrial sites currently located on degrading permafrost across the Northern Hemisphere (Langer et al., 2023). Its release can lead to radiation sickness and cancer or physiological impairments, depending on the material and the level of exposure (Miner et al., 2021).

4.6.2 Ciguatera fish poisoning

Ciguatera poisoning (CP) is caused by eating fish that have accumulated ciguatoxins due to feeding on toxic microalgae *(Gambierdiscus* spp. and *Fukuyoa* spp.). Ciguatoxin is responsible for most seafood-related poisonings around the world (Chinain et al., 2021). Traditional endemic regions for ciguatoxic fish (e.g. barracuda, grouper, amberjack, red snapper, moray eel, hogfish, mackerel, surgeonfish and parrotfish) include areas in the Caribbean Sea and the Pacific and Indian Oceans. In Europe, *Gambierdiscus* and *Fukuyoa* spp. are found in the Spanish and Portuguese Atlantic islands as well as in several Mediterranean islands including Crete, Cyprus and the Balearics. In the Canary Islands, 14% of the 746 fish caught and checked within the EuroCigua project (2016-2021) tested positive for ciguatoxins (Diogène et al., 2021).

Ciguatoxins are not destroyed by cooking or by freezing the fish and the toxins cannot be detected by sight, taste or smell. Symptoms of CP include nausea, vomiting, diarrhoea, abdominal cramps, burning sensation of lips, tongue and extremities, a metallic taste in the mouth, joint and muscle pain, skin itching, muscle weakness, blurred vision, low blood pressure and slow heart rate. Neurological symptoms usually resolve within weeks, although some symptoms can last for months. CP is rarely fatal, but death can occur in severe cases (ECDC, 2021).

While in mainland European countries outbreaks of CP have been associated with the consumption of imported fish, autochthonous outbreaks been reported in the Canary Islands and Madeira. In the Canary Islands, 22 autochthonous outbreaks occurred in 2008-2023, with 129 people suffering from CP, including one hospitalised case. In the event of CP outbreaks, the EU Rapid Alert System for Food and Feed provides alerts to food safety agencies and consumers. See also Box 6.23 on CP control measures introduced in the Canary Islands.

The projected increase of sea surface temperatures by 0.4-1.4°C by the mid-21st century is likely to spur toxic microalgae growth, resulting in higher population densities. Range extensions of several degrees of latitude also are anticipated, where species-specific habitat requirements are met (e.g. temperature, suitable substrate, low turbulence, light, salinity, pH) (Tester et al., 2020). The increasing densities and range of the toxic microalgae may mean that CP becomes more widespread in Europe in the future. EFSA et al. (2020) ranks ciguatoxins among the contaminants with the highest likelihood of emergence under the changing climate.

4.6.3 Swimmer's itch

Swimmer's itch (cercarial dermatitis) is a skin condition caused by a parasite that lives in waterfowl and snails which results in an intensely itching rash and sometimes fever, swelling of local lymph nodes and oedema, raised bumps and tenderness of the skin. It may become more common in parts of Europe due to increasing water temperatures creating optimal conditions for the parasite (Al-Jubury et al., 2020) and higher recreational use of bathing sites during hot summers.

5 Responding to water-related health risks in policy: an overview

Key messages

- The EU has a comprehensive policy landscape in relation to climate and water. The Floods Directive, the recast Drinking Water Directive and the recast Urban Waste Water Treatment Directive already consider how climate change could harm human health. Improved policy implementation would further facilitate health protection from the changing climate.
- Health is reported by European countries as the sector most vulnerable to climate change. Currently, measures addressing health risks from climate change are included in national adaptation strategies to a greater extent than in national health strategies. Therefore, ensuring the health sector is further engaged in climate adaptation is crucial to planning and implementing appropriate actions.
- Given their broad societal implications, droughts deserve more attention in the EU and national policy landscape. While in 19 of the EU Member States drought management is regulated by legislation, only 13 countries have non-compulsory drought risk adaptation plans, with little focus on human well-being.
- The local authorities that have adaptation plans tend to plan actions related to water management, and most local adaptation plans contain some measures linked to public health. Yet, in contrast to the national level, health is a lower priority for adaptive actions in cities. To ensure more health-oriented adaptation planning and implementation at the local level, it is vital to address local authorities' constraints in financing, expertise and technical capacity.

5.1 International and European policy framework

5.1.1 International frameworks

The activities of EU and individual European countries on addressing climate change impacts on health via water are guided by international frameworks and agreements. For example, the EU has a wide range of legislation, strategies, policies, initiatives and tools in place to contribute to the implementation of Sustainable Development Goal 6 — Ensure availability and sustainable management of water and sanitation for all — under the 2030 Agenda for Sustainable Development (EESC, 2019). This includes the Water Framework Directive, the new Drinking Water Directive, the Regulation on minimum requirements for water reuse for agricultural irrigation, the revised Urban Waste Water Treatment Directive, the Groundwater Directive, the Zero Pollution Action Plan and the Bathing Water Directive (EC, 2023h).

Among the EEA member and cooperating countries, 24 have ratified the Protocol on Water and Health, an international, legally binding agreement for countries in the pan-European region to protect human health and well-being through sustainable water management and by preventing and controlling water-related diseases.

Increasing resilience to climate change is one of the technical areas under the protocol's programme of work (UNECE, 2022). The 2022 Background Note on Increasing Resilience to Climate Change through the Protocol on Water and Health provides examples of how climate considerations could be addressed under the framework of the Protocol. The six technical areas of work under the Protocol where climate change could be addressed include governance, prevention and reduction of disease, institutional water and sanitation, small water supplies and sanitation, safe and efficient management, and equitable access to water and sanitation, plus a dedicated programme of work on climate resilience.

The countries in the WHO European region made a commitment to action on the environment and health, including climate, by signing the Budapest Declaration in July 2023 (WHO Europe, 2023a). With regard to the climate risks to health, the countries commit, among other things, to:

- make health systems and facilities climate resilient;
- develop, update and implement Health National Adaptation Plans;
- establish and update regulatory requirements to ensure the climate resilience of water and sanitation services (including water reuse where appropriate);
- strengthen natural disaster risk reduction policies and climate-informed health early warning and surveillance systems for extreme weather events and climate-sensitive disease outbreaks;
- strengthen the climate literacy of health professionals.

The United Arab Emirates (UAE) Framework for Global Climate Resilience (UNFCCC, 2023), adopted at the COP28 summit in December 2023, uniquely positions climate change adaptation as a top priority for all nations. It urges countries to achieve, among other things, the following targets by 2030:

- significantly reducing climate-induced water scarcity and enhancing climate resilience to water-related hazards towards a climate-resilient water supply, climate-resilient sanitation and access to safe and affordable potable water for all;
- attaining resilience against climate change-related health impacts, promoting climate-resilient health services, and significantly reducing climate-related morbidity and mortality, particularly in the most vulnerable communities.

The UNFCCC 2-year UAE — Belém work programme was launched at COP28 and endorsed formally by the European Commission. It focuses on identifying and developing indicators for measuring progress towards the targets of the Global Goal on Adaptation, including on water resilience and climate-related health impacts (UNFCCC, 2023). Working towards defining those indicators at the European level by 2025 can help in developing a shared understanding of resilience to climate change in the context of both water and health, and give a concrete direction for Member States' activities.

By 1 February 2024, the COP28 Declaration on Climate and Health had been signed by both the EU and 35 of the EEA member and cooperating countries. The signatories commit to developing and implementing adaptation policies and policies across sectors that deliver positive health outcomes, and to boosting the health sector's preparedness to climate impacts (COP28 UAE, 2023).

5.1.2 European policy framework

Health impacts of water quality and quantity under the changing climate are considered in the EU policy framework, but more integration of the topics would benefit overall coherence.

The European Green Deal is a package of policy initiatives aiming to set the EU on the path to a green transition. It aspires to improve the well-being and health of citizens and future generations by ensuring clean, pollutant-free water (EC, 2019b). The 8th Environment Action Programme (8th EAP) agenda builds on the Green Deal to ensure that EU climate and environment laws are effectively implemented, including climate change adaptation as one of the six priority objectives up to 2030 (EU, 2022a). Water is an integral part of these objectives, particularly the circular economy and zero pollution. The 8th EAP references the One Health approach as an enabling condition to attain the priority objectives, to contribute to better human, animal, plant and environmental health, and improved water and food safety.

Key EU climate adaptation and resilience policies

The European Climate Law formulates a legal duty on adaptation for Member States, with progress to be assessed every five years, including information submitted and reported under the Governance Regulation (Regulation (EU) 2018/1999) as one of the inputs. The Climate Law also defines the role of the European Climate and Health Observatory 'to better understand, anticipate and minimise the health threats caused by climate change' (EU, 2021).

The EU strategy on adaptation to climate change (EC, 2021c), in response to the effect of water shortages on people's health and well-being due to climate change, includes commitments for the European Commission to 'improve coordination of thematic plans and other mechanisms such as water resource allocation and water permits' and 'help guarantee a stable and secure supply of drinking water by encouraging the incorporation of the risks of climate change in risk analyses of water management'. However, the European Environment Bureau observes that concrete targets and deadlines for these aspirations are lacking (EEB, 2021).

The EU communication 'Managing climate risks — protecting people and prosperity' (EC, 2024), building on the first European Climate Risk Assessment (EEA, 2024a), highlights the importance of safeguarding good quality, affordable and accessible freshwater supplies for all to ensure a water-resilient Europe. It commits the European Commission to comprehensively taking stock of water issues. With regard to health, it states that the European Commission will strengthen surveillance and response mechanisms for climate-related health threats, strengthen cross-border mobilisation of medical personnel and patient transfer, secure access to and development of critical medical countermeasures, and enhance the European Climate and Health Observatory.

The Critical Entities Resilience Directive aims to increase the resilience of bodies that provide services to maintain essential societal functions, ensure public health and safety, and protect health facilities, drinking water and wastewater infrastructure against risks including natural disasters and climate change. By 17 July 2026, Member States must compile lists of their critical entities, which will inform risk assessments and actions to strengthen their resilience. The European Commission has also published technical guidance on the climate-proofing of infrastructure projects (EC, 2021b), which is relevant to water infrastructure (e.g. water supply pipelines, reservoirs, wastewater treatment facilities), and on enhancing the climate resilience of buildings, which is relevant to healthcare facilities (EC, 2023f).

Key EU health policies

Under Article 168 of the Treaty of the Functioning of the EU, the primary responsibility for organising and providing health services and medical care lies with Member States. EU health policy serves to complement national policies and ensure health protection in all EU policies. The EU regulation on serious cross-border threats to health (EU, 2022b) aims to strengthen prevention, preparedness and response planning to a variety of threats, including those of environmental and climatic origin. It creates a more robust mandate for the EU and its Member States on coordination and cooperation for a more effective response to serious cross-border health threats, including notifications, public health risk assessments and interventions. Recognition of environmental threats, including those of climate origin, can help to ensure collaborative response to large-scale floods or disease outbreaks. The European Commission is building a strong European Health Union to further improve coordination of such serious cross-border threats. One element is a comprehensive approach to mental health, whereby climate anxiety and other mental health effects are recognised (EC, 2023c).

The first European Climate Risk Assessment (EEA, 2024a) recognises the EU4Health programme among the policies with high adaptation potential, providing a potential funding source for actions on climate change and health, including those under the Healthier Together initiative. The European Health Emergency Preparedness and Response Authority, established in 2021, is another important resource for improved preparedness for crises linked to climate extremes.

The EU pharmaceutical strategy (EC, 2020c) aims to revise pharmaceutical legislation to strengthen environmental risk assessment requirements and conditions of use for medicines and take stock of the results of research under the Innovative Medicines initiative. This is relevant to mitigating increased pollution risks during dry periods (see also Section 3.3.2) or due to flooding of wastewater treatment plants (see Section 2.2.5). The Council Recommendation on stepping up EU actions to combat antimicrobial resistance in a One Health approach (Council of the European Union, 2023), which recognises that residues of medicinal products are widely found in groundwater and surface water, including coastal waters and soils, aims to strengthen the environmental monitoring of antimicrobial resistance in groundwater and surface water.

Key EU water policies

The EU water policy framework has significantly improved water quality over the past 4 decades; its overarching objective is protection of human health and the environment (EC, 2019d). The link between a policy topic and climate change or human health is often established in EU water policies. Yet, in the older policies, the impact of climate change on water quantity or quality — and the way it affects human health — is not extensively developed. The ongoing policy revisions tend to bring in the topics of water, climate and health closer together.

The Water Framework Directive (WFD) (EU, 2000) aims to ensure quality water sufficient to support ecosystems and human needs, by requiring that pollutant concentrations do not exceed levels safe for human health and the environment and by requiring surface water levels and flows to support ecological needs and groundwater levels not to be compromised by rates of abstraction. While the directive does not explicitly consider future changes in the risk of flooding or drought due to climate change, it refers to the need to identify all 'significant pressures' affecting water bodies. The 2019 fitness check of water legislation concluded that the WFD, its daughter directives and the Floods Directive are largely fit for purpose and that they allow climate change, droughts and water scarcity to be taken into account as necessary in implementation by Member States (EC, 2019a).

The Floods Directive (EU, 2007) aims to reduce and manage the risks from floods to human health and life, alongside the environment, cultural heritage, economic activity and infrastructure. It requires Member States to create and update flood hazard maps (where significant floods could take place) and flood risk maps (showing the potential flood extent and the assets and people at risk in these areas), which serve as the basis for drafting flood risk management plans. These plans must be periodically reviewed and updated, taking into account the likely impacts of climate change on the occurrence of floods. In the context of the Directive, the European Court of Auditors (ECA, 2019) emphasised the need to improve the knowledge and modelling of the impact of climate change on all sources of floods.

The European Commission works closely with Member States through the common implementation strategy for the Water Framework and Floods Directives. Climate-resilient water management across sectors and borders is well incorporated in the strategy's workplan for 2022-2024, with actions targeting water resource allocation, water permitting systems and cost recovery through water pricing. In addition, the European Commission and Member States are revising the strategy guidance document No 24 on river basin management in a changing climate (EC, 2023b). According to the EEB (2021, 2023), enforcement of Water Framework Directive implementation is essential to ensure the EU adaptation strategy's aims on water are achieved.

The Urban Waste Water Treatment Directive, originally adopted in 1991, does not extensively cover many urban discharges to receiving waters, including urban stormwater run-off, combined sewer overflows and unplanned discharges, which thus remain largely unregulated. In January 2024, the European Parliament and the Council agreed on the recast of the Directive based on the European Commission proposal (EC, 2022c) that acknowledges climate change as a factor influencing hydrological regimes and strengthens the aim to enhance access to sanitation, especially for the most vulnerable and marginalised groups. The recast of the directive requires Member States to assess the vulnerability of urban wastewater treatment plants and collecting systems at design, construction and operation phases; systematically promote the reuse of treated wastewater from all urban wastewater treatment plants (see also Section 6.3.4) and prioritise green and blue infrastructure solutions, to control flows and reduce pollution from stormwater overflows and run-off (see also Section 6.2) (EC, 2023f).

The Regulation on minimum requirements for water reuse (EU, 2020c), applied from 26 June 2023, aims to encourage and facilitate the safe reuse of treated urban wastewater for agricultural irrigation, in response to water scarcity and deterioration in quality due in part to climate change. It sets minimum water quality and monitoring requirements, risk management rules to assess and address potential additional health risks and environmental risks, permitting obligations and rules on transparency. Guidelines (EC, 2022a) support the regulation's application.

The recast Drinking Water Directive (EU, 2020a) includes updated safety standards and a methodology to identify and manage quality risks in the water supply chain, taking climate change into consideration, and establishes a watch list of emerging substances. It addresses leakages in the distribution system and includes new provisions that require Member States to improve and maintain access to drinking water for all, especially vulnerable and marginalised groups. The directive includes a risk-based approach throughout the entire drinking water supply chain, requiring risk assessment and risk management of catchment areas for abstraction points of drinking water sources, reviewed at least every 6 years (EC, 2023f).

The Bathing Water Directive (EU, 2006), currently under review by the European Commission, requires Member States to monitor and assess bathing water quality to protect public health. It ensures timely information is given to the public during the bathing season. Climate change is not currently referenced.

5.2 Selected national policy responses

To achieve a policy that supports the transformation of health systems to climate resilience and neutrality, the WHO advocates for developing specific national strategies on health and climate change (WHO, 2023a). As of 2021, only a few countries in Europe had such strategies: Finland, Ireland, Sweden and North Macedonia (European Climate and Health Observatory, 2022d). However, most countries had a strong focus on health in their national adaptation policies, in many cases directly referring to water-related health impacts.

5.2.1 National adaptation policies and national health strategies

In 2021, the EEA carried out an analysis of the 38 member and cooperating countries' policies on climate change adaptation and national health strategies. Heavy precipitation and flooding were recognised as hazards to human health in nearly all national adaptation policies and in two thirds of national health strategies (European Climate and Health Observatory, 2022d). The health impacts that related to water quality and quantity were included to a greater extent in the national adaptation policies than in health strategies (see Table 5.1).

Both types of national policies emphasise monitoring and surveillance, including early warning systems (see Section 6.3.2), awareness raising campaigns for the public (see Section 6.4.1), and continued research into climate change impacts on health (European Climate and Health Observatory, 2022d). The specific measures targeting various water-related risks in both types of policies relate to increasing the resilience of physical infrastructure, raising awareness among the public and health professionals and green solutions and nature-based solutions (Table 5.2).

Table 5.1 Coverage of health impacts of altered water quantity and quality in national adaptation policies and national health strategies of the 38 EEA member and cooperating countries (2021)

	Number of national adaptation strategies (total: 37)	Number of national health strategies (total: 34)
Infectious and vector-borne diseases	31	21
Injuries from extreme weather events	19	13
Disease due to post-disaster water contamination	16	12
Disease from bacteria and algae in bathing water	14	10
Mental trauma linked to extreme weather events	13	7
Mental trauma linked to economic impacts	6	5

Source: European Climate and Health Observatory, 2022d.

Table 5.2 Examples of measures planned in national adaptation policies and national health strategies

Country	Measures
National adaptation policies	
Luxembourg	Drinking water monitoring and warning system, including increased surveillance of microbiological conditions in critical periods, accompanied by development of a catalogue of measures to protect drinking water against the impacts of climate change
	Increased surface permeability, greening and shading of both private and public land
	Development of areas with fast-moving water (whitewater)
	Designation of drinking water protection zones
	Communication and awareness raising on possible drinking water quality decrease
	Integrated regional drinking water supply plans, including long-term quality assurance
Slovakia	Infrastructure protection and use of nature-based solutions
	Adequate standards of healthcare facilities and housing
	Strengthened energy security to reduce vulnerability of hospitals in case of energy supply disruptions or natural disasters
National health strategies	
Estonia	Mitigation of parasite risk, particularly in supply sources using surface water (especially during flood periods)
	Identification of risk of cyanobacterial toxins
France	Support measures for people affected by natural disasters, particularly to manage post-traumatic stress
North Macedonia	Resilience of health system infrastructure to extreme events
	Training for health professionals to understand climate change threats
Belgium (Flanders)	Flemish adaptation plan 2030: research and awareness raising on health risks of effects of climate change, including creation of knowledge hub on environment and health

Source: EEA (unpublished analysis supporting European Climate and Health Observatory, 2022d).

5.2.2 Adaptation reporting under Governance Regulation

Among the 29 countries reporting under the Governance Regulation (EU, 2018) ([17]) in 2023, 26 highlighted health as the key affected sector. The water management sector was reported as affected by 22 countries (EEA, 2023g). The section below summarises an unpublished analysis of the coverage of links between climate, water and health in the 2023 reporting on national adaptation actions.

The links between hazards and responses to them, and the implications for populations' health and well-being, are seldomly made explicit, which may be due to the more general focus of reporting. When addressed, flooding, also associated with precipitation or storms, is the water-related hazard most frequently linked to health impacts, followed by droughts and — in some cases — sea level rise.

([17]) The EU-27, Iceland and Switzerland.

Several countries reported generally that flooding and drought affect physical and mental health. Death, injury and disease were listed as direct impacts of flooding, whereas changes in the availability of drinking water are an indirect impact of floods, droughts and sea level rise. Additional indirect impacts of flooding and drought include loss of food, worsened water quality and damage to houses. Flooding was also reported to indirectly impact health and well-being via food insecurity, damage to property and livelihoods, bathing water prohibitions, challenges for pre-hospital emergency medical services, hindering the mobility of people using assistive devices, and by affecting cultural heritage and cultural environments. In many other cases, information was reported on the impacts of climate hazards on water quantity and quality, water systems and wastewater infrastructure, albeit without explicit reference to impacts on human health.

Adaptation responses to improve human health and well-being reported by the countries vary. Czechia's national adaptation plan addresses droughts, floods and heavy rainfall with one objective focused on the resilience of human settlements, including vulnerable groups, and another on early warning systems and appropriate reactions. In Portugal, Decree-Law No 119/2019 controls reuse of treated wastewater, taking an approach similar to EU regulation on minimum requirements for water reuse (EU, 2020c; see Section 5.1.2), i.e. fit-for-purpose quality standards and risk management on health and the environment. Activities and plans under the Estonian Emergency Act (see also Box 6.1) and Water Act aim to manage the potential damaging consequences arising from floods for human health and cultural heritage, while flood risk management plans must be considered in development plans, planning decisions and crisis management plans of both national and local governments. Czechia's drought plan proposes measures to ensure a sufficient amount of water to meet basic social needs, and the Netherlands' Delta programme for spatial adaptation covers the protection of vital and vulnerable functions, including drinking water and sewage.

Several countries refer to their flood risk management plans prepared under the Floods Directive and river basin management plans drawn up under the Water Framework Directive (see also Section 5.2.3), yet the benefits of these plans for the population's health and well-being are not discussed. Likewise, flood warning systems are mentioned by multiple countries in the reporting on adaptation actions; however, only one country makes the link to those systems saving human lives.

Numerous measures and projects that address water-related hazards capable of impacting human health were reported. These include: utilising information, monitoring and support systems and surveillance programmes (see also Section 6.3.2); increasing preparedness, including emergency provisions and the rapid restoration of vital and vulnerable infrastructure (see Section 6.1.1); developing action plans; improving prevention, alert and crisis management tools; undertaking infrastructure projects (see Section 6.3); carrying out vulnerability assessments; and evaluating the design of policy instruments, local governance and implementation status.

For more information, see the climate and health country profiles in the European Climate and Health Observatory. The country reporting can be found in Climate-ADAPT.

5.2.3 Flood risk management plans

Climate change was considered in most flood risk management plans (FRMPs) for 2010-2015 produced by Member States under the Floods Directive. In that first cycle of reporting, of 23 countries assessed, 17 considered climate change in their preliminary flood risk assessments. Sixteen out of 27 (including the UK at the time) took climate change into account in their flood risk and flood hazard maps. Fourteen of 27 considered at least some aspects of climate change in the first cycle of FRMPs, while 10 provided strong evidence that climate change was taken into account. In 15 out of 26 countries, FRMPs contained some discussion of climate change influencing flooding events (see Box 5.1). In eight countries, all FRMPs assessed referred to national adaptation strategies; in a further six, some but not all FRMPs did so (EC, 2019d).

Box 5.1

Consideration of climate change in flood risk management plans

Germany

By late 2015, all German river basins had flood risk management plans developed in line with the EU Floods Directive. Every 6 years, these plans are subject to revision and updating, taking into account the anticipated impacts of climate change, by *Länder*, which have responsibility for flood protection. The plans include measures to cope with climate change-induced risks, such as flood infrastructure, restoration of retention areas and rehabilitation of water bodies. Additional measures such as delineation of flood risk areas and preliminary work on the implementation of operational measures for floodwater protection are embedded in the *Wasserhaushaltsgesetz* (Water Resources Act).

For the state of Hesse alone, the cumulative expenditure for such planning measures amounted to EUR 6.85 million over 10 years. These efforts are complemented with behavioural measures; preventive technical and nature-based solutions implemented in other sectors (buildings, development planning); improved flood forecasting; crisis management; and risk-adapted reconstruction. Some *Länder* such as Baden-Württemberg and Bavaria already take climate change into account when designing their flood protection defences, e.g. using a 100-year flood event as a baseline, to ensure protection in the future (German Interministerial Working Group on Adaptation to Climate Change, 2019).

Sweden

In Sweden, all general flood inundation maps incorporate projections of climate adapted discharges (for the end of the century. They are published in the Flood Portal. These maps are used in the preliminary flood risk assessment and include data for the four objectives of protecting human health, environment, cultural heritage and economic activity. The detailed flood risk and flood hazard maps also include climate change-related discharges. Risk management plans are in line with climate change adaptation plans and other legislation and plans, including the Water Framework Directive river basin management plans, crisis management plans, Civil Protection Act and Planning and Building Act (Näslund-Landenmark, 2021).

The European Commission's recommendations, following assessment of Member States' first flood risk management plans (for the 2016-2021 period), included that Member States should factor in the likely impacts of climate change on the occurrence of flooding and adapt measures accordingly, in consideration and coordination with national adaptation strategies. In their subsequent preliminary flood risk assessments, 14 out of 27 countries provided strong evidence for a clear methodology to consider climate change; another 11 provided some evidence, and one country provided none. However, only four Member States explicitly referred to their national adaptation strategies (Kavvadas, 2022).

5.2.4 Drought legislation and drought management plans

In 2020, 24 Member States considered droughts and water scarcity to be key emerging or climate-related disaster risks, compared to only 11 in 2015, indicating growing recognition of the problem. As of October 2023, drought management is regulated by legislation in 19 out of 27 EU Member States. No legislation was yet in place in Austria, Estonia, Finland, Croatia, Ireland, Luxembourg, Slovenia or Slovakia. Thirteen Member States make an explicit link between droughts and climate change in their legislation, referring to the expected increase in frequency and intensity of droughts (EC, 2023g).

The European Commission recommends establishing specific drought management plans where relevant. In 2019, only eight Member States had developed drought management plans for their river basin districts (EC, 2019c); by 2023, this had increased to 13. In Cyprus, Ireland, the Netherlands, Portugal and Romania, plans covers the whole territory; in Belgium, Germany and Sweden, one or several regions are covered; Greece, Spain, France, Hungary and Italy plan for droughts on a river basin district, local administrative area or other territorial unit basis (EC, 2023g).

Whilst most Member States' plans identify drinking water as the use to be prioritised during droughts, one of the weaknesses of the management systems identified is the lack of focus on people and their livelihoods, including the most vulnerable and marginalised (EC, 2023g). This suggests that the impacts of droughts on human health (see Section 3.3) are not sufficiently addressed through the legislation and drought management plans. In addition to the national plans, cooperation is needed on transboundary river basins to assess and prevent escalation of potential tensions over scarce water resources (EEA, 2024a).

The tools published by the European Commission to enhance the EU's preparedness for droughts include the European Drought Impact Database and the European Drought Risk Atlas. The database includes a compilation of data on the impact of droughts between 1977 and 2022. The atlas uses machine learning to simulate the impact that an increase of temperature could have in the future.

5.3 Sub-national climate adaptation planning

There is no comprehensive overview of climate adaptation planning and actions at sub-national level (EEA, 2020c). To understand how the impacts on health via altered water quality and quantity under the changing climate are addressed at local level, this sub-section draws on the following sources:

- Assessment of the signatories to the Covenant of Mayors for Climate and Energy (Melica et al., 2022), which offers information about the vulnerability assessments and adaptation actions planned by 4,560 ([18]) local authorities committed to adaptation action under this initiative.

- Database of cities reporting to CDP (formerly the Carbon Disclosure Project), 2022 Full Cities Dataset (CDP, 2022) covering 105 cities from 27 countries ([19]), 2021 Cities Water Adaptation Actions and 2021 Cities Water Security Risks (CDP, 2021) (149 cities and municipalities in 25 countries) ([20]). This data was collected by CDP and ICLEI — Local Governments for Sustainability.

- Analysis of 136 European cities that are included in City Statistics (previously Urban Audit; sample of cities with over 50,000 inhabitants) and had developed local adaptation action plans by 2020 (Reckien et al., 2022).

([18]) Among those, 4,044 signatories are from the EU-27, 384 from the Eastern Partnership countries, 127 from non-EU European countries and five from the rest of the world (Melica et al., 2022).

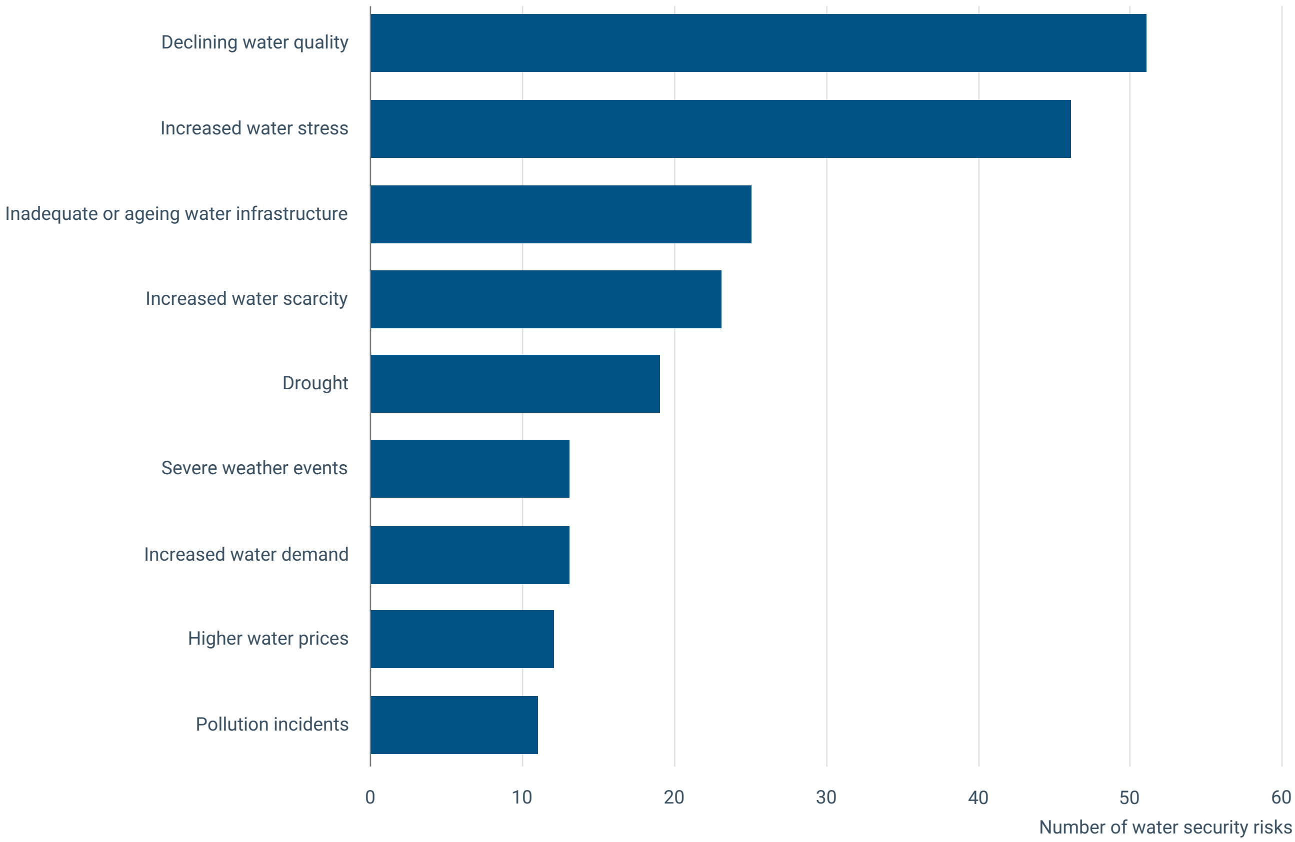
([19]) Albania, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Czechia, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Montenegro, the Netherlands, Norway, Poland, Portugal, Slovenia, Spain, Sweden, Switzerland and Türkiye.

([20]) Belgium, Bulgaria, Croatia, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Latvia, Lithuania, Montenegro, the Netherlands, Norway, Poland, Portugal, Romania, Serbia, Slovenia, Spain, Sweden, Switzerland and Türkiye.

Recognition of water-related climate hazards and related actions

Three types of water-related climate hazards were among the most frequently reported by the Covenant of Mayors signatories in their risk and vulnerability assessments, after extreme heat (15%): droughts and water scarcity (14%), heavy precipitation (14%) and floods and sea level rise (14%). Most signatories anticipated an increase in the frequency and intensity of these hazards (Melica et al., 2022). The risks to water security most frequently listed by the cities reporting to CDP (2021) were declining water quality and increased water stress (Figure 5.1).

Figure 5.1 **The most frequently addressed types of water security risks via urban water management actions**



Note: Only the risks that were addressed by more than 10 actions are included in the figure. Based on 240 answers from 82 cities in 22 European countries (Belgium, Bulgaria, Denmark, Finland, France, Germany, Iceland, Ireland, Italy, Latvia, Lithuania, Montenegro, the Netherlands, Norway, Poland, Portugal, Serbia, Slovenia, Spain, Sweden, Switzerland and Türkiye).

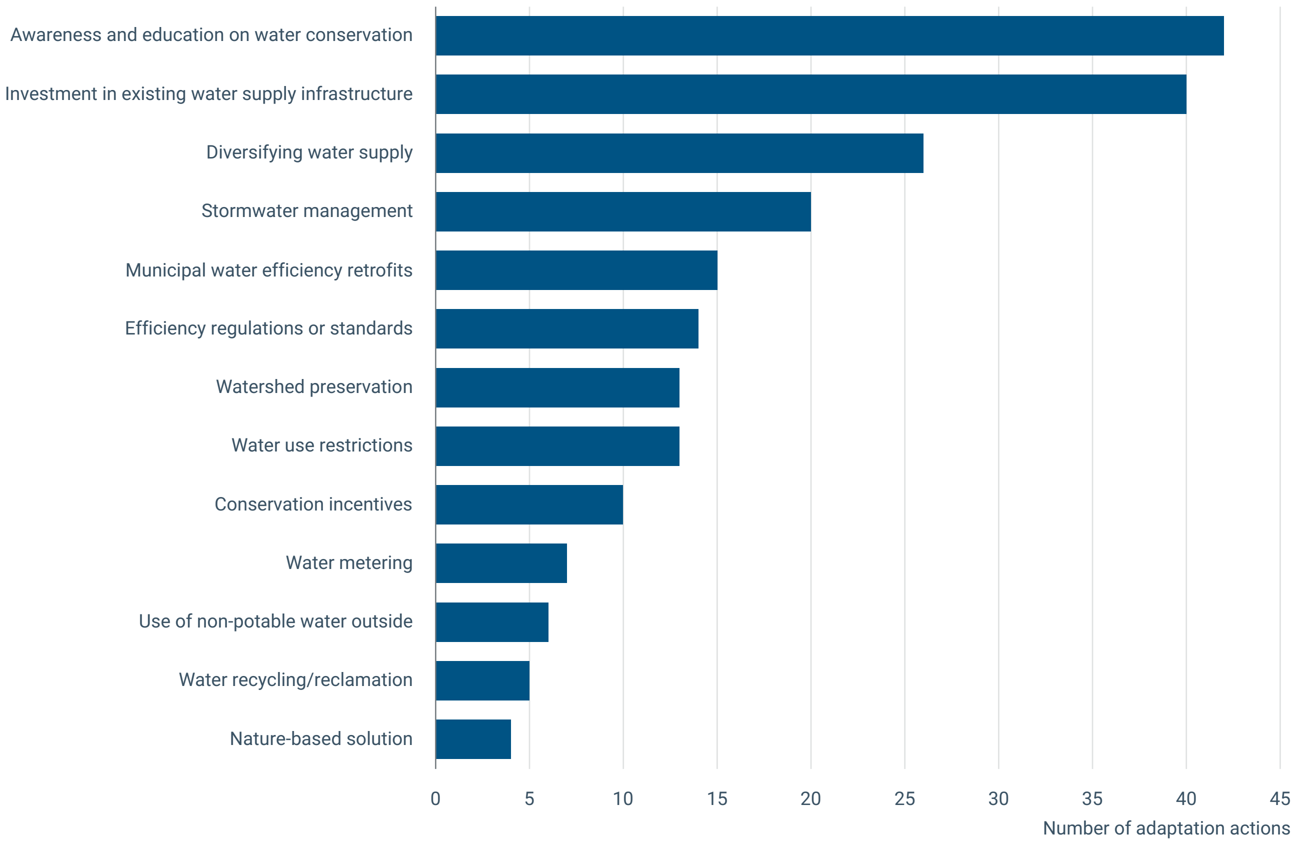
Source: EEA, based on CDP, 2021.

For Covenant of Mayors signatories, extreme heat is addressed by the highest number of actions (3,091), followed by droughts and water scarcity (2,566), heavy precipitation (2,518), and floods and sea level rise (1,905).

Among the 136 cities with local adaptation plans analysed by Reckien et al. (2022), 89% included at least one planned adaptation measure related to water management. For 71%, these were related to infrastructure improvements, such as increased drainage system capacity (see also Section 6.3.3). In 45% of plans, measures related to water conservation (water metering, greywater use, water restrictions and rationing) were included.

Actions reported by cities to CDP (2022) regarding water security include mainly awareness raising and education on conservation (see also Section 6.4.2), investment in existing water supply infrastructure and diversifying supply (see also Section 6.3.4), and stormwater management (Figure 5.2).

Figure 5.2 Adaptation actions taken to reduce the risks to cities' water security



Note: Based on 216 actions reported by 79 cities from 22 European countries (Belgium, Bulgaria, Denmark, Finland, France, Germany, Iceland, Ireland, Italy, Latvia, Lithuania, Montenegro, the Netherlands, Norway, Poland, Portugal, Serbia, Slovenia, Spain, Sweden, Switzerland and Türkiye).

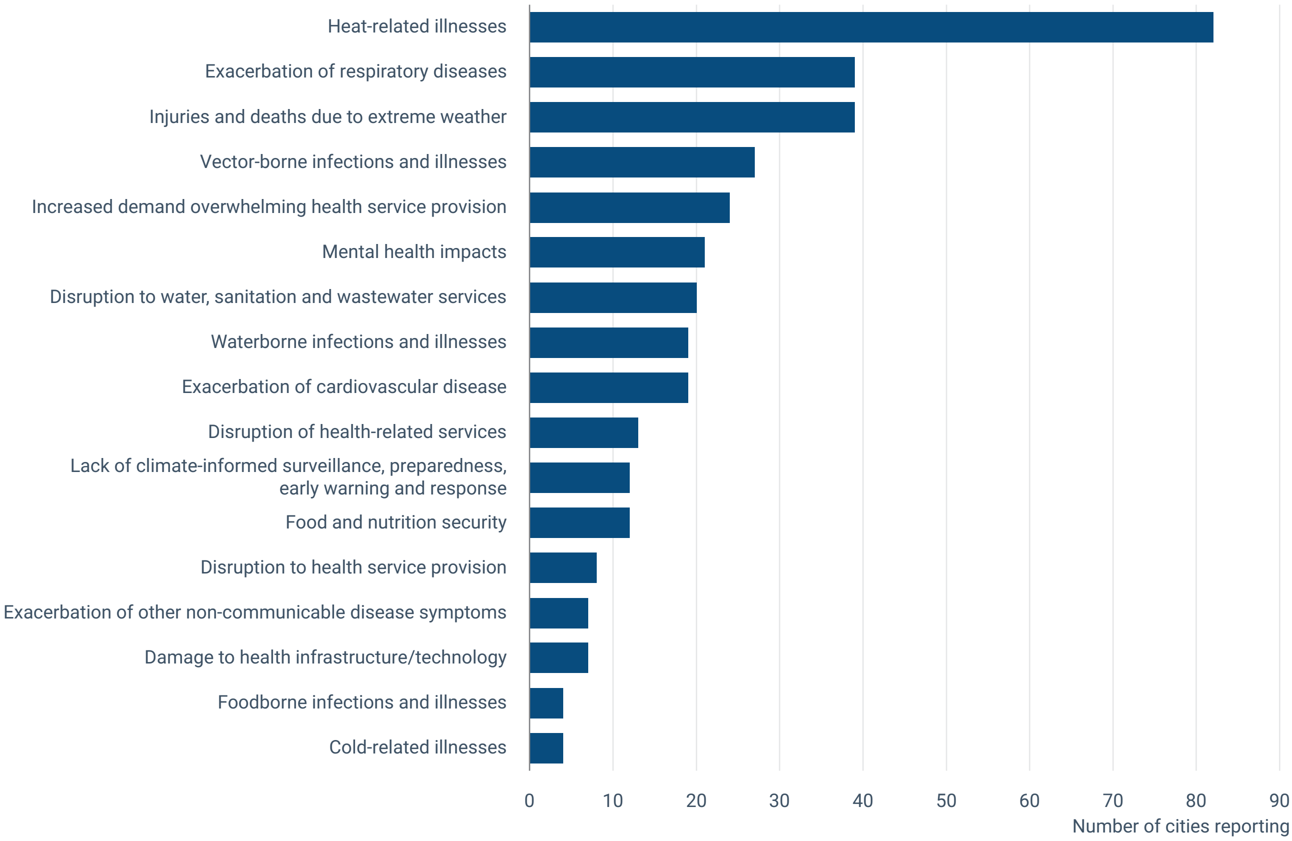
Source: EEA based on CDP, 2022.

Impacts on health: recognised but potentially underestimated

Health is reported as the most vulnerable sector by only 11% of the Covenant of Mayors signatories, following agriculture and forestry, environment and biodiversity, and civil protection and emergency (Melica et al., 2022). This is in contrast with the national level, where health was the sector most frequently reported as affected by climate change in 2023 (see also Section 5.2.2). The relatively low recognition of impacts on the health sector at sub-national level could lead to actions that overlook them. This is particularly concerning as most of the national adaptation strategies emphasise that implementation of adaptation actions should mainly happen at sub-national level (EEA, 2024c).

Health issues driven by the climate hazards identified by cities are dominated by heat-related impacts. However, direct physical injuries and deaths due to extreme weather events are recognised by one third of the cities reporting to CDP (2022). About one fifth also note mental health effects, disruption to water, sanitation and wastewater services, and waterborne diseases (Figure 5.3).

Figure 5.3 Health issues driven by climate hazards



Note: Based on 365 answers from 104 cities in 27 EEA member and cooperating countries (Albania, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Czechia, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Montenegro, the Netherlands, Norway, Poland, Portugal, Slovenia, Spain, Sweden, Switzerland and Türkiye).

Source: EEA, based on CDP, 2022.

Among the 136 local adaptation plans analysed by Reckien et al. (2022), 69% included at least one measure relating to health systems, while 43% contained actions related to healthcare centres, hospitals and warning systems. Other measures included monitoring new infectious diseases and actions targeting vulnerable populations (e.g. to identify these groups, raise their awareness about and protect them from climate change impacts).

Among the Covenant of Mayors signatories, health ranks as the fifth sector in terms of the number of adaptation actions planned, after water, environment and biodiversity, buildings, and land use planning (Melica et al., 2022). This relatively low position may be related to adaptation being predominantly driven by local authorities' urban planning, environment and civil engineering departments, with limited engagement of health and social care departments or external stakeholders, especially in the case of small local authorities (EEA, 2020c).

Some cities reporting to CDP (2022) ([21]) highlighted the factors reducing their ability to act on the public health impacts of climate change. The list was dominated by lack of financing and expertise or technical capacity. This mirrors the barriers faced by local authorities in their adaptation efforts in general (EEA, 2024c). Second was a lack of political priority, followed by not having direct responsibility for healthcare. For locations where the health sector is more the responsibility of regions, initiatives such as the EU Mission on adaptation to climate change can boost adaptation actions in the health sector at sub-national level (EC, 2021a).

Recognition of vulnerable groups

The Covenant of Mayors signatories report on groups vulnerable to specific hazards. For water-related climate hazards, these include people living in sub-standard housing (most frequently reported as vulnerable to heavy precipitation), marginalised groups (floods and sea level rise) and unemployed people (droughts and water scarcity). Children and the elderly are the main vulnerable groups that are the explicit focus of adaptation actions planned by signatories (Melica et al., 2022).

Among the 137 local adaptation plans analysed by Reckien et al. (2022), 46% included measures targeting vulnerable people. The groups most often targeted were the elderly (in 32% of plans), children and youth (23%), and people with poor health and in hospital or care institutions (17%). The relatively good recognition of vulnerable groups at risk can be seen as the first step towards minimising the impacts on them, as long as they are then covered by and included in adaptive actions.

([21]) 42 cities in 20 countries: Bulgaria, Croatia, Czechia, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Lithuania, the Netherlands, Norway, Poland, Portugal, Slovenia, Spain, Sweden, Switzerland and Türkiye.

6 Actions to prevent or reduce health risks from climate-related water hazards

Key messages

- Effectively preventing water-related risks to health under the changing climate requires acting at prevention, preparedness, response and recovery stages. Actions are needed by stakeholders both in and beyond the health sector, including those involved in water management, spatial planning, building design, insurance or education.
- Across Europe, numerous examples of actions, from nature-based solutions to behavioural change, are present. More systematic implementation and assessment of their effectiveness, equity, co-benefits and trade-offs is needed to better protect people from the negative health effects of climate change.
- Preventative measures reducing the exposure of people to climate risks, such as avoidance of development in risk areas, should be prioritised. In addition, surveillance and monitoring of water quantity and quality, associated early warning systems and emergency plans are crucial to minimise health impacts in the case of extreme weather, pollution events or disease outbreaks.
- Training and capacity building on climate change for healthcare and public health professionals and students, as well as awareness raising of the risks, can further reduce health risks to the general public.
- Equitable solutions, for example for flood insurance and water pricing, should be prioritised to ensure that the livelihoods, health and mental well-being of the most vulnerable groups are also protected.

A variety of measures can prevent or mitigate the loss of human life and damage to health and well-being due to floods, water scarcity or altered water quality under the changing climate. The WHO Regional Office for Europe (2017) divides efforts to protect population health from flooding into measures linked to prevention, preparedness, response and recovery. We can similarly categorise measures addressing the health impacts of water scarcity or water quality.

Prevention and preparedness initiatives facilitate adaptation and ultimately mitigate evolving risks, including the effects of climate change (CIRCABC, 2021b). Examples of prevention measures are increasing the permeability of surfaces to reduce the risk of flooding and allow recharging of groundwater aquifers; removing human activities from areas at risk of floods, acute water scarcity or wildfires; using flood protection infrastructure; and avoiding pollution to reduce risks to drinking water. Figure 6.1 summarises the effectiveness and feasibility of adaptation options for flood-related climate impacts in Europe.

Preparedness measures include early warning systems; climate-resilient water supply and sanitation systems; and increasing awareness of the risks among the public, healthcare workers and decision-makers.

The response stage includes having a flood-health preparedness plan in place; trained and aware emergency, healthcare and public health professionals; procedures for when vectors capable of spreading diseases are detected; and contingency plans for healthcare facilities (WHO Europe, 2017). Measures in the recovery stage, after floods, drought or wildfires, include providing mental health support (see Box 6.3) and economic help, e.g. through equitable and efficient insurance systems (see Section 6.5.2).

Figure 6.1 Effectiveness and feasibility of water-related adaptation options to achieve objectives under increasing climate hazards

	Focus	Effectiveness	Feasibility: Economic	Technological	Institutional	Socio-cultural	Ecological	Geographical
Flooding: coastal/river								
Flood defenses	Prevent	High	Medium	Medium	Medium	No or limited evidence	Low	High (a)
Preparedness and early warnings	Prepare	Medium (b)	High	High	High	No or limited evidence	High	No or limited evidence
Planned relocation	Prevent	High	High	High	High	Low	High	High
No development in risk areas	Prevent	Medium	High	High	Medium	No or limited evidence	No or limited evidence	No or limited evidence
Flood insurance	Recover	Low	Medium	High	High	High	Medium	No or limited evidence
Coastal flooding								
NBS (e.g. wetlands)	Prevent	Medium	High	High	No or limited evidence	No or limited evidence	High	Low (a)
Sediment-based (e.g. nourishment)	Prevent	Medium	Medium	Medium	High	No or limited evidence	Medium	Medium (c)
Property-level flood resilience	Prepare	Low	Medium	No or limited evidence	High	High		
River flooding								
NBS (e.g. floodplain restoration)	Prevent	High	Medium	Medium	No or limited evidence	No or limited evidence	High	Medium
Retention and diversion	Prepare	Medium	High	High	No or limited evidence	No or limited evidence	No or limited evidence	No or limited evidence
Property-level flood resilience	Prepare	Medium	Medium	Medium	High	High	No or limited evidence	No or limited evidence
Pluvial flooding								
Retention: green roofs	Prevent	Low	No or limited evidence	No or limited evidence	No or limited evidence	No or limited evidence	High	Medium
Retention: parks	Prevent	High	No or limited evidence	Medium	No or limited evidence	No or limited evidence	High	Medium
Update drainage systems	Prepare	No or limited evidence	Low	No or limited evidence	No or limited evidence	No or limited evidence	No or limited evidence	Medium
Water scarcity								
Storage: reservoirs	Supply management	Medium	Low	Medium	Medium	Medium	Low	Medium
Water diversion and transfer	Supply management	Low (d)	Low	Medium	High	Medium	Medium	No or limited evidence
Desalination	Supply management	High (e)	Low	High	High	High	Low	High
Water reuse	Supply management	Medium	Medium	Medium	Medium	Low	Medium	No or limited evidence
Water saving and efficiency	Demand management	Low	Medium	Medium	High	Medium	Medium	Medium
Regulate distribution	Demand management	Medium	High	Medium	Medium	No or limited evidence	No or limited evidence	No or limited evidence
Economic instruments	Demand management	Medium	High	Medium	High	Medium	No or limited evidence	No or limited evidence
Land management	Demand management	Medium	High	Medium	High	No or limited evidence	Medium	Medium
Monitoring and early warnings	—	Low	High	Medium	High	No or limited evidence	High	No or limited evidence

LEGEND:
- Low
- Medium
- High
- No or limited evidence

- Prevent
- Prepare
- Recover
- Supply management
- Demand management

a: Physically hampered in highly urbanised regions
b: Low on preventing damages; medium on preventing fatalities
c: Availability of sand can hamper feasibility in southern Europe
d: In southern Europe, no evidence for other parts of Europe
e: Medium in southern Europe, and high in western and central Europe/northern Europe

Source: Adapted from Figure 13.6 in Bednar-Friedl et al., 2022.

Protecting human health from the impacts of floods, droughts or altered water quality under the changing climate requires actions before, during and after the event. The possible impact-reducing measures go far beyond the healthcare and water sectors and span spatial planning, building design, economic and market tools, education, social care, employment and others. The impacts of climate change are cross-sectoral and solutions require climate and health-proofing to be integrated into decision-making across all sectors and levels of government (WHO Europe, 2023b). In this report, the actions are grouped under the headings of governance and institutional measures; nature-based solutions; physical and technological measures; knowledge and behavioural change options; and economic and finance measures.

6.1 Governance and institutional measures

These include policy instruments at various spatial levels (see Chapter 5); planning and management (e.g. spatial planning measures or emergency procedures); new and revised regulations; and coordination and networking activities.

6.1.1 Emergency and response plans and procedures

Appropriate preparation, including crisis and operational plans, alerts and communications, is essential to guide decisions, inform the public and reduce harm to health (CIRCABC, 2021b). At EU level, the EU Civil Protection Mechanism is in place to help countries affected by disasters. It can mobilise emergency aid such as satellite images, firefighters, pumping equipment and financial support. According to the European Court of Auditors (ECA, 2023), this mechanism has been timely and has helped coordinate participating countries' team efforts. At national level, countries have disaster risk reduction plans, which can in some cases promote longer-term adaptation to climate change that can affect health (see Box 6.1).

Box 6.1

Addressing climate-related risks through the Emergency Act in Estonia

In Estonia, responding to and preparing for extreme weather and climate events is mostly covered by the Emergency Act. This governs the performance of risk analysis, development of response plans, emergency-related training, notification of emergencies, management of emergency responses and declaration of emergency situations and the measures applied in them.

The act states that, in case of a rescue event (e.g. floods in densely populated areas or extensive wildfires), the Estonian Rescue Board is the lead authority preparing the emergency risk analysis and, for a healthcare event (e.g. disease outbreak), the Health Board is the lead. Risk analyses enable systematic assessment of which events may develop into an emergency. Although climate adaptation is not the explicit subject of such analysis, the emergency measures help manage climate-related risks. Examples include modernising stormwater drainage systems, dam maintenance, developing more accurate risk maps, preparing risk management plans and training local governments on issues related to emergencies.

The act also stipulates the continuity of vital services such as electricity, gas and water supply, ambulance service and the sewerage network, which may be affected by more frequent extreme weather in the future. The focus of measures related to the act is to increase awareness among the public and providers of vital services, inform groups at risk and promote cooperation, to make weather forecasts more effective and establish weatherproof infrastructure (EEA, 2023h).

At health system level, the WHO (2023a) highlights examples of measurable outputs and indicators under climate-related emergency preparedness and management responses (Table 6.1). It also outlines examples of responses to water-related health outcomes and hazards to ensure resilience during extreme weather events and disease outbreaks (Table 6.2).

Table 6.1 Sample of measurable outputs and indicators under climate-related emergency preparedness and management

Objective	Action
Policies and protocols	• Policies, protocols, plans and strategies for Health Emergency and Disaster Risk Management (H-EDRM) reviewed and improved through integrating climate-sensitive health risks and weather and climate information. • Health sector contingency plans for extreme weather events developed and implemented. • Gender sensitivity and equity approaches included in H-EDRM, considering vulnerable populations and regions at risk from climate-related hazards. • Health sector contingency plans for extreme weather events, including risk reduction, preparedness and response, are aligned with the WHO H-EDRM or a local health emergency and disaster risk management framework. • Protocols for H-EDRM integrate low-carbon and environmentally sustainable practices for logistics, supply chains, procurement and storage of medicines and equipment, and transport
Risk management	• Risk assessments for current and projected future exposure to extreme weather events routinely used to inform health sector strategic development plans • Climate change-related emergency and disaster response plans for individual health facilities developed and implemented. • Geographical and seasonal distribution of climate health risks and outcomes used to inform emergency and disaster response plans. • Early warning systems for extreme weather events and climate-sensitive diseases used to inform roles and responsibilities of all actors in H-EDRM planning.
Community empowerment	• Capacity development programmes implemented to support the roles of local communities to identify risks, prevent exposure to hazards and act to save lives in extreme weather events. • Stakeholder mechanism established to support participation, dialogue and information exchange, and to empower civil society and community groups as primary actors in emergency preparedness and response. • Mechanisms in place to ensure information on health risks from extreme weather events reaches communities in a way that triggers preventive action by them.

Source: WHO, 2023a.

Table 6.2 Examples of responses in the health sector to water-related health outcomes and hazards to ensure resilience during extreme weather events and disease outbreaks

Health outcome/hazard	Responses
Waterborne and foodborne diseases	• Equip health facilities with Water and Sanitation for Health Facility Improvement Tool (WASH FIT). • Enhance monitoring systems and water- and foodborne disease surveillance systems during high-risk periods (drought, flood, extreme heat). • Strengthen food and water quality control (e.g. management of drinking water quality and food safety policies and regulations). • Improve sanitation, hygiene and waste management practices. • Ensure availability of sufficient water for drinking, environmental cleaning, hand hygiene, food preparation, personal hygiene and other needs.
Zoonotic and vector-borne diseases	• Establish environmentally sustainable vector/pest control policies and action plans. • Expand the scope of monitored diseases and monitor at the margins of current geographic distributions to detect their spread. • Establish EWS where appropriate. • Enhance diagnostic and treatment options in high-risk regions and periods. • Ensure adequate animal and human vaccination coverage.
Storms and floods	• Include climate risk in siting, designing and retrofitting health infrastructure. • Establish safe procedures for procuring, storing, dispensing and disposing of pharmaceuticals and medical products.
Droughts	• Implement water conservation strategies in health systems. • Establish disease surveillance systems to track drought-related health outcomes.
Wildfires	• Provide clear messages on actions to reduce exposure to smoke, ash and elevated temperatures (e.g. reducing outdoor activities, avoiding the use of exhaust fans, providing cleaner air spaces, setting air conditioners to recirculation mode where safe). • Protect chemicals and fuel (e.g. store away from excessive heat). • Protect water tanks from excessive heat and contamination by fire particles.

Source: WHO, 2023a.

WHO (2021a) provides checklists to assess vulnerabilities in healthcare facilities in the context of climate change, including vulnerability to floods, droughts, sea-level rise and wildfires.

WHO Europe describes in detail the emergency planning for water suppliers and wastewater managers in the case of extreme weather events (WHO, 2011a).

The immediate government responses to extreme weather can include arrangements to support citizens with humanitarian aid. This helps businesses to stay afloat, which can reduce the mental health implications (Eurofound, 2023; see examples in Box 6.2). Alongside economic support, psychosocial aid offered to those affected by flooding also helps reduce the mental health impacts of floods (see Box 6.3). Farmers' mental health may be particularly affected by the weather (see Section 3.3.5). Detecting poor mental health is central to preventing serious consequences, such as suicides. Helplines for farmers have been set up, for example in Ireland (Box 3.5).

Box 6.2

Examples of government responses to floods in Europe

Ordinance following catastrophic flooding in Emilia-Romagna

The ordinance was issued in response to severe weather conditions that struck various provinces in Italy from 1 May 2023. It was intended to provide immediate financial assistance and recovery support to the affected people and areas. People with primary residences damaged by these events were eligible for a contribution of up to EUR 5,000. This was intended for the partial restoration of homes, ancillary buildings and access areas, including cleaning and debris removal. Additionally, the ordinance provided for the replacement or repair of destroyed or damaged essential household items. A further EUR 750 was allotted as a flat-rate contribution towards expert assessments.

Compensation for uninsured flood victims in Limburg and North Brabant, the Netherlands

Because of the scale of the floods in July 2021 and the extent of the damage and suffering caused, the government provided one-off compensation for damage that was, in principle, reasonably insurable. The scheme ensured that people who were not insured for flood damage or insufficiently insured (e.g. insured for damage to the building but not the contents) were compensated in the same way as people who did not suffer reasonably insurable damage.

Source: Eurofound Policy Watch.

Box 6.3

Psychosocial support for affected people after the floods

Schleiden, Germany

Immediately after the July 2021 floods, the town of Schleiden, together with district authorities and charitable and aid organisations, established a psychosocial crisis management centre to complement the crisis intervention centres set up for people affected by the floods and emergency service providers. In the first two weeks, ad hoc support was offered in the form of around 1,500 conversations in person or via a hotline. In the following months and years, specialists at the Schleidener Tal Aid Centre continued to provide free psychosocial support and counselling to those affected by the flood, including emergency service providers. This involved active identification and support of people in need of social services, accessible outreach social work, grief and loss counselling, general psychological advice, long-term psychotherapy in addition to standard care, trauma therapy and treatment of trauma-related disorders such as depression, specialised support to specific groups (e.g. children and adolescents), and lectures on trauma, stress and loss (Climate-ADAPT, 2024a).

Emilia-Romagna, Italy

Following the catastrophic floods and landslides in May 2021, the Regional Health Centre set up a team of psychologists to provide support to people in the affected areas. Six hubs were organised within shelters for displaced people to provide assistance. Psychologists were also reachable through a dedicated call centre, where trained staff addressed and prioritised requests according to the severity, referring callers to specialists. The most vulnerable, i.e. the elderly, children, people with disabilities and people with psychiatric disorders, were given priority. The objectives of the psychological support included management of the acute phase, stress mitigation and prevention of the onset of psychopathological stress disorders (Climate-ADAPT, 2024b).

6.1.2 Governance structures

Climate change impacts on human health, including those caused by floods, droughts or altered water quality, are a complex problem and require collaboration with various partners. At the EU level, the European Climate and Health Observatory is a partnership between the European Commission, the EEA and several other organisations. It aims to support Europe in preparing for and adapting to the impacts of climate change on human health by providing access to relevant information and tools. It also fosters information exchange and cooperation between relevant international, European, national, sub-national and non-governmental actors.

The Budapest Declaration on environment and health signed by the member countries in the WHO European region emphasises the need for transformative governance for environment and health (WHO Europe, 2023a). The Guidelines on Member States' adaptation strategies and plans from the European Commission (EC, 2023e) recommend setting up a national interdepartmental adaptation workforce to ensure a high-level political process for adaptation to climate change. This workforce should include ministries concerned with climate change, environment/nature, public health, civil protection/interior affairs, infrastructure, energy, economic affairs/finance, agriculture, forestry, fisheries, water management, and employment and social affairs. Similarly, WHO Europe (2023) recommends establishing an interministerial group on climate change and health to help key health-determining sectors strengthen their adaptation and mitigation policies. It also recommends creating broader, multisectoral governance and coordination mechanisms to support climate resilience and decarbonisation in the health system. For example, in Croatia, a national working group was established to develop a document linking climate change and human health (EEA, 2023h).

WHO (2023a) provides the following examples of joint actions between ministries of health and other sectors to manage the environmental determinants of health, with relevance to water resilience:

- Water/municipal services: integration of health in water resource management policy; promotion of adequate safe municipal water supply and water and wastewater treatment facilities (see also Sections 6.3.3 and 6.3.4); implementation of climate-resilient water safety plans; definition and monitoring of water quality standards;
- Spatial planning: zoning and building regulations for health and other infrastructure taking account of flood and storm risks (see also Section 6.1.3);
- Disaster management and meteorological services: health and public safety plans and training for early warnings of extreme weather events.

To achieve climate-transformative leadership and governance, it is recommended to designate climate change and health focal points within the health ministries with a specific programme of action and budget (WHO, 2023). This is starting to happen in Europe. Ireland has established a Climate Change Unit in its Department of Health, which seeks to align climate action across the health sector with national efforts to tackle the climate challenge. In Romania, the President established a department of climate and sustainability in 2020, recognising climate change as a public health crisis. Germany's Minister of Health established a health protection and sustainability division that focuses on environment, climate change and health to define and fulfil the sector's role in tackling climate change. The division helps to connect and mobilise relevant stakeholders to make climate change-related issues an integral part of the health system (WHO Europe, 2021).

Section 5.3 highlights that health issues in climate change adaptation are of relatively low importance at local level compared to the weight given at national level. The EC (2023) Guidelines on Member States' adaptation strategies and plans recommend involving local and regional levels of governance in adaptation planning, as well as identifying and involving vulnerable stakeholders. National public health institutes play a key role in monitoring and addressing the health impacts of climate change, from vector-borne diseases to the social determinants of health to emergency response. In 2020, the International Association of National Public Health Institutes (IANPHI), a network of 110 public health institutes from around the world, created a climate change committee to help its members develop capacities in climate change and health (WHO Europe, 2021).

The EC (2023) guidelines also recommend involving cross-border actors to ensure coordinated actions among neighbouring countries in border regions. Such collaboration is already happening in the transnational regions; for example, in the Danube area or in the Balkans (Box 6.4).

Box 6.4

Toolbox for transboundary water contingency management in the Sava river basin to mitigate environmental and health risks

The Sava river crosses multiple countries — Albania, Bosnia and Herzegovina, Croatia, Montenegro, Serbia and Slovenia. Its management and the response to extreme flooding and pollution events that may pose harm to human health and the environment are therefore a transboundary issue. To facilitate a coordinated response, an operational system featuring several tools was developed by stakeholders from the countries that form the basin.

The toolbox includes:

- a real-time platform that enables efficient and effective communication and knowledge-sharing between those involved in mitigating a flooding or pollution incident, via a single database of incident reports submitted by all stakeholders and additional background information;
- a GIS-based mapping tool, which offers 'nowcasting' of flood and pollution risks based on real-time data on river discharges, as well as forecasting of flooding and accidental pollution spread, thus assisting the emergency management of risks;
- a catalogue of best practices and strategy guidelines on how to use the tools and manage hazards such as floods and pollution (Climate-ADAPT, 2024c).

6.1.3 New or revised regulations

In addition to the policies in Section 5, adjustment of existing regulations can reduce health risks.

Avoiding development in risk areas

Avoiding further development in areas at risk of climate-related hazards can reduce the health risks and people's exposure. Residential sites have continued to be developed in areas potentially at risk of flooding (see Section 2.2.1), requiring mechanisms to be put in place to prevent this. The German Strategy for Adaptation to Climate Change recommends avoiding settlement development in areas with climate hazards (Truedinger et al., 2023); however, it is non-binding, and decisions made in this regard are mainly the competence of sub-national governments.

Limiting new developments in flood-prone areas may be a cost-effective alternative to traditional coastal defence measures in reducing population and asset exposure. In southern Europe, for example, an integrated coastal zone management protocol has been introduced that mandates a setback zone of 100m from the coastline in areas without protection. Such zones are projected to substantially mitigate impacts, particularly in urbanised zones (Bednar-Friedl et al., 2022).

Restricting development can also be a measure against water scarcity. Following the droughts of 2022, nine municipalities in the south of France have placed a 4-year moratorium on issuing of new building permits, due to low groundwater levels and prioritising adequate access to water for current residents (The Local France, 2023).

Land use planning that reduces urban sprawl into forest and brush areas is also an important measure to limit the impacts of forest fires on human settlements. For example, the municipality of Esteribar in the Basque Country, Spain, considered classifying land based on the presence of forests near urban centres; creating firebreaks following recommendations by Civil Protection; duplicating access ways to vulnerable populations; and regulating uses of undeveloped land to avoid activities that could cause fires (Climate-ADAPT, 2023a).

Water restrictions

In dry regions or regions that face water scarcity, restrictions and rationing are commonly applied. Restrictions limit certain uses of water, for example irrigation of lawns, car washing, filling swimming pools or hosing down pavement areas. Rationing includes a temporary suspension of supply or a reduction of pressure, to ensure that critically limited supplies are distributed in a way that protects public health and safety.

While the local and regional authorities in the Mediterranean have been forced to implement water restrictions due to persistent water scarcity (Box 6.5), this is also practised in countries not traditionally associated with droughts. For example, in Sweden, Västervik municipality has prohibited the watering of gardens using drinking water every summer in recent years (CDP, 2021).

Box 6.5

Restrictions in water use in the Mediterranean in early 2024 due to record drought

Persistent high temperatures and below-average precipitation caused severe drought conditions in early 2024 in parts of the Mediterranean. Several water reservoirs in northern Catalonia and southern Andalusia in Spain have fallen below 16% of their capacity. People living in villages and smaller towns that rely on wells for drinking water saw many of their sources running dry. In Catalonia, the regional authorities declared a drought emergency on 1 February 2024, bringing restrictions in the amount of water municipalities can use and people can consume at home. In southern Spain, bans on certain non-vital water uses (e.g. filling of swimming pools) were issued and the water pressure in taps was reduced at certain hours of the day. In Sicily, Italy, and the Algarve, southern Portugal, water use restrictions were ordered in response to low levels of water in the reservoirs (Toreti et al., 2024).

See Climate-ADAPT for more information about water restrictions and water rationing as an adaptation option.

6.1.4 Relocation (managed retreat)

Relocation involves moving populations and infrastructure from present locations to new lower-risk areas, either individually or as communities, with the objective of long-term sustainability (Quinn et al., 2023a). The Sendai Framework recommends relocating public facilities and infrastructures from the risk-prone area in the reconstruction process (Truedinger et al., 2023). Planned relocation will likely become a more important flood and coastal risk management strategy in response to sea level rise or increasing risk of flooding (Mayr et al., 2020), as it can yield more favourable cost-benefit outcomes compared to protective measures, particularly in less densely populated areas (Bednar-Friedl et al., 2022). So far, relocation from areas at risk is a relatively uncommon adaptive measure, mainly done at a small scale (Truedinger et al., 2023; Mayr et al., 2020) (Box 6.6).

Box 6.6

Examples of relocation from flood risk areas

Relocation from Noordwaard polder in the Netherlands

In the Netherlands, the 'making room for water' initiative enables rivers to flood into their natural floodplains, reducing the risk of flooding. In 2020, Rijkswaterstaat, the Dutch body responsible for national public works, completed restructuring the 4,450 ha Noordwaard polder so it can flood. Originally, the polder contained about 75 households, which were offered the opportunity to sell their homes at market value; farmers were helped to find new farmland. Those who wanted to remain in Noordwaard could receive compensation for moving to higher ground or for installing high water-protection measures. Of the 25 farmers who participated in the decision-making, 15 had to leave the area because there would not be enough agricultural land for them in the newly designed Noordwaard. Of the remaining 50 households, about half had to move, because their homes would be in danger of flooding (Dutch Water Sector, 2015; van Alphen, 2020).

Managed retreat from Danube flood risk areas

Since the 1970s, the Austrian national, regional and local authorities have organised a managed retreat process for private households and businesses along the Danube river. More than 500 households have been moved. Compensation covering 80% of the value of the building as well as 80% of the demolition costs was offered to the affected householders. The majority of residents who accepted the relocation offer returned to previous levels of personal well-being within five years after moving. In the Eferdinger Becken area, which included more than 150 houses that flooded regularly, relocation emerged as the most effective measure to reduce flood impacts. The residents who decided to move were supported in obtaining substitute plots of land in the region at an affordable price. By January 2016, 149 households had requested and 146 had received relocation compensation offers; 80 decided to move (Schindelegger et al., 2021; Climate-ADAPT, 2017).

Small-scale household relocation in Simbach, Germany

After extreme flooding in June 2016 in Simbach, Bavaria, the decision was taken to plan structural flood defence measures and relocate 11 households. The adaptive planning process started immediately after the floods and was executed with authorities and stakeholders at various levels and from different sectors, while including citizens. Residents were informed early, and the personalised communication, as well as trust in actors, enhanced the acceptance of decisions (Mayr et al., 2020).

Willingness to move is key to successful relocation. In the Ahr Valley, Germany, more than 40% of residents had to leave their homes after the July 2021 flooding, according to a survey. However, a large proportion left only temporarily. One year later, almost three quarters of people were still — or again — living in the same house or apartment as in July 2021. Only around one fifth had moved or were planning to do so. Slightly more renters were willing to move than homeowners (Truedinger et al., 2023).

Forced relocations can result in adverse well-being outcomes through the loss of land, housing and employment opportunities and economic marginalisation. The health effects for both displaced and host communities include the impacts associated with poverty and overcrowding; increases in substance misuse and gender-based violence; and higher rates of depression, social isolation and loneliness. Relocation processes that lack transparency can increase distrust and reduce participation. However, supported relocation can be beneficial from a health perspective, as rebuilding in high-risk areas can lead to higher levels of stress compared to receiving financial support to move elsewhere. Access to personal counselling, central contact points for legal and practical support and support for those who choose to stay behind in voluntary schemes can reduce mental health implications (IDMC, 2021; Quinn et al., 2023b).

See Climate-ADAPT for more information about managed retreat as an adaptation option.

6.2 Nature-based solutions

6.2.1 Synergies in achieving climate adaptation and health goals

Nature-based solutions — actions inspired by, supported by or copied from nature — are intended to help societies address a variety of environmental, social and economic challenges in sustainable ways (EC, 2015). They use existing, restored or new ecosystems and natural environments to reduce climate change impacts with potential environmental, economic and societal benefits. They can lower the risk of flooding by making space for water and creating permeable surfaces for water to infiltrate, which at the same time can help recharge groundwater resources. In particular in cities, greening streets, rooftops, building facades or tram tracks reduces the pressure that extreme precipitation puts on drainage systems (EEA, 2024c). According to Quaranta et al. (2021), greening 35% of the EU's urban surface (i.e. more than 26,000km^2) would reduce run-off by 17.5% (10km^3/year), thus reducing the risk of combined sewer overflows and urban run-off entering the water bodies without prior treatment.

Beyond urban greening, actions such as the restoration and management of wetlands, floodplains and rivers (Box 6.7) and re-meandering rivers or creating riparian woodland can reduce the risk of flooding downstream (Grow Green, 2020). Nature-based solutions can also help reduce the risk of coastal flooding through the restoration and management of coastal wetlands, sand dune construction and strengthening, and shore and beach nourishment (Table 6.3).

Box 6.7

Examples of river restoration efforts reducing the risk of flooding

In the Ruhr region, after mining activities were finished, an 85km stretch of the central Emscher river and its tributaries were restored into nature-like waterways. The project also included developing an underground wastewater network, flood protection measures and sustainable rainwater management, and developing recreation areas. The cross-sectoral approach involved a broad range of stakeholders, including emergency services and health sector representatives (Climate-ADAPT, 2020a).

The rivers in Łódź, Poland were culverted in the 19th century; combined with the high level of surface sealing in the city, this has increased the risk of flooding and reduced water retention in soil. The restoration of Sokołówka river has amplified its retention capacity and improved the local microclimate, thus mitigating potential impacts from both flooding and heat on the residents (Climate-ADAPT, 2020b).

The once wild alpine Isar river with a constantly changing riverbed was canalised within Munich, Germany in the 19th century. In 2000, the re-naturalisation of the 8km stretch of the river was initiated to improve both flood security and recreational opportunities through enhanced infrastructural flood defences. The resulting attractive green and blue space in the city centre is a popular recreational spot (Climate-ADAPT, 2020c).

Table 6.3 Water-related climate hazards that can be addressed by nature-based solutions (examples)

Nature-based solution	Floods			Droughts and water scarcity	Water quality	Health/ quality of life
	Fluvial	Pluvial	Coastal			
Green roofs		x				M
Urban parks, gardens and green spaces		x				H
Greening of transport infrastructure		x				M
Wetland restoration/management	x			x	x	M
Restoration/management of floodplains	x					
River restoration for flood control	x					M
Oxbow lakes re-meandering/reconnection	x					
Re-naturalisation of polder areas	x		x			
Lake restoration	x	x		x	x	M
Floodplain and riparian wood creation	x				x	L
Managed realignment			x			
Coastal wetlands restoration/management			x			M
Sand dune construction/strengthening			x			L
Shore and beach nourishment			x			L
Sustainable drainage systems		x		x	x	M
Rainwater harvesting		x		x		
Pervious surfaces		x			x	
Infiltration basins, trenches, rain gardens		x		x	x	
Detention/retention ponds		x		x	x	
Blue roofs		x		x		
Constructed wetlands					x	
Filter strips					x	M

Notes: Health and quality of life: H = high, M = medium, L = low provision of co-benefits.
Based on literature and expert judgement within the Grow Green Horizon Europe project.

Source: Grow Green, 2020.

In addition, accessible and high-quality urban green and blue spaces (parks, urban forests, tree-lined streets, allotments, riverbanks and coastlines) provide significant health benefits, including reduced mortality and morbidity from chronic diseases, improving mental health and pregnancy outcomes, and reducing obesity (EEA, 2020b). Therefore, access to green space can reduce people's vulnerability to negative health outcomes from climate change.

Thus, to ensure that green spaces provide the greatest health benefits, they should be located where they can mitigate water-related hazards and improve the health of the most vulnerable groups. Regeneration of the relatively deprived Augustenborg neighbourhood in Malmö, Sweden (Climate-ADAPT, 2020d; Box 6.10) shows that sustainable urban drainage systems — with the right design and location — can play a positive and significant role in improving well-being.

Similarly, the RESILIO project in relatively deprived Amsterdam neighbourhoods provides smart blue-green roofs, designed to store more rainwater than standard green roofs, for social housing complexes.

Greening social facilities can help reduce the risks of flooding and heatwaves for users. However, while on average 42% of a European city area is covered by vegetation (EEA, 2022e), under 16% of the area within a 300m radius of healthcare facilities is green. The greenest school and hospital surroundings are in northern Europe (European Climate and Health Observatory, 2022e). See Box 6.8 for examples of nature-based solutions within healthcare facilities.

Box 6.8

Use of nature-based solutions in healthcare facilities to reduce risk of flooding

The design of the New North Zealand Hospital in Hillerød, Denmark enhances its resilience against future climate-related impacts. The low elevation of the site, coupled with high groundwater level and municipality restrictions on the volume of rainwater that can be discharged off the site, has necessitated detailed analysis of the ground's response to rainfall absorption, taking into account climate change projections. Ponds and streams were created to provide storage and to move water away from the access road and hospital building. Car park trenches and vegetated areas around the complex provide further rainwater attenuation (Climate-ADAPT, 2022c).

A roof garden measuring 370m^2 was built on the new building of the Diakonissen hospital in Augsburg, Germany during renovation in 2013. The green roof retains about 60-70% of annual rainfall, reducing incidents caused by heavy rains by 50-100% and delaying water discharge to the sewer system. In addition, the retained rainwater evaporates and cools the surroundings (Urban Nature Atlas, 2021a).

The Ospedale dell'Angelo Mestre in Venice, Italy is surrounded by an extensive garden that offers opportunities for relaxation as well as stormwater management and storage. It also has various roof gardens, including an area called 'the meadow', a large roof garden linking the hospital block with the supplies department building (Urban Nature Atlas, 2021c).

Nature-based solutions, due to the range of benefits they provide and generally high social acceptance, are one of the most popular adaptation measures in cities. According to Reckien et al. (2022), 114 of the 137 local adaptation action plans aimed at an increase in quality, quantity or protection of green spaces; 66 aimed to improve watersheds, lakes or streams; and 60 aimed to improve flood marshes, floodplains or salt marshes. Yet the implementation of nature-based solutions is carried out at a small scale. In most European cities, the trend of building on green spaces prevails, and the scale of built-up areas being turned into green space is miniscule (EEA, 2019d). This is associated with land pressures in many European cities — for example, housing needs — or a lack of long-term political vision for urban greening (Buffam et al., 2022). Embedding requirements for nature-based solutions in regulations and providing guidelines for urban planners can increase take-up of those measures (Box 6.9).

Box 6.9

Applying sponge city principles in Switzerland

Under the Swiss Water Protection Act, the local water cycle should be maintained or restored by unsealing surfaces and promoting infiltration, evaporation and retention to reduce rainwater run-off. Local storage of rainwater — known as the sponge city principle — not only lowers discharge into water bodies but also reduces local heat stress and improves biodiversity. In addition, rainwater can be used as a design element or for irrigation, cleaning or cooling buildings.

The Swiss Association of Municipal Infrastructure published guidance for urban planners to include rainwater management in development projects. It documents planned and already realised practical examples in Swiss cities, with tools that can be used to promote sponge city measures. The guidance aims to foster exchanges between municipalities and allow learning by highlighting successful projects and the challenges encountered. One example of a completed project is the greening of the courtyard in the retirement home Der Burgerspittel in Bern, to ensure rainwater infiltration and respite from heat (SKVI, 2022).

See Climate-ADAPT for general information about nature-based solutions as an adaptation option.

6.2.2 Examples of solutions

Sustainable drainage systems: reducing flooding risk

Sustainable drainage systems — solutions designed to manage stormwater locally, through permeable surfaces and retention basins such as bioswales and rain gardens — can intercept, evaporate and infiltrate stormwater before it reaches sewerage systems, decreasing the volume of water needing treatment. They can also reduce diffuse pollution and contribute to human well-being and quality of life (Box 6.10). These systems, combined with the use of permeable surfaces in urban areas (e.g. through de-paving front gardens and greening car parks), properly planned and designed rainwater, and stormwater management systems (see Section 6.3.3) can reduce combined sewer overflows (EurEau, 2020a) (see Section 2.2.4). Integrating nature-based solutions such as green roofs into stormwater management systems can outperform hard infrastructure storage tanks in terms of combined sewer overflow reductions (EC, 2020b).

Box 6.10

Examples of sustainable drainage systems providing health co-benefits

In the 1980s and 1990s, the low-income neighbourhood of Augustenborg in Malmö, Sweden, was frequently flooded by an overflowing drainage system. Between 1998 and 2002, alongside refurbishment of buildings, a sustainable urban drainage system was provided, comprising channels, ditches, ponds and wetlands. Green roofs were installed on new developments and retrofitted on over 11,000m^2 of existing rooftops. As a result, problems with flooding have ceased and both the environmental quality and image of the area have significantly improved (Climate-ADAPT, 2020d).

During heavy rainfall, surface water run-off from the Gomeznarro park in Madrid, Spain, was causing flash flooding in surrounding residential areas. The park refurbishment in 2003 included development of an underground rainwater collection system, reduction of impermeable surfaces and revegetation. The improved drainage resolved flooding issues and reduced the long-term health impacts from damp and mould on ground floors. The increased humidity of the soil sustains the vegetation and reduces heat-related impacts for the residents (Climate-ADAPT, 2020e).

Nature-based solutions in improving water quality

Nature-based solutions can contribute to urban water pollution control alongside the predominant 'end of pipe' measures (Oral et al., 2020). Most sustainable urban drainage-type solutions are effective at removing metals such as copper and reducing concentrations of total suspended solids and oils. However, their effectiveness for removal of bacteria, nutrients and dissolved lead and arsenic varies (EC, 2020b).

Constructed wetlands are the most common and widely accepted nature-based solution for pollution control. They are usually regarded as a cost-effective option for reducing the impacts of combined sewer overflows (Quaranta et al., 2022). The slow water flow in constructed wetlands facilitates deposition of pollutants, which are then absorbed by plants, locked up in the soil or transformed into non-toxic substances (Grow Green, 2020). Thus, constructed wetlands can be used for combined sewer overflow treatment, polishing of the outflow from existing wastewater treatment plants or greywater treatment (Oral et al., 2020) (see Box 6.11).

Box 6.11

Use of constructed wetlands to improve water quality

Water quality improvement in Arvika, Sweden
Water quality in lake Kyrkviken, next to the city of Arvika, is affected by the more frequent heavy rainfall under the changing climate, as the stormwater run-off washes nutrients and pollution from the city and adjacent land use into the lake. Within the North Sea Region project CATCH (water sensitive Cities: the Answer To Challenges of extreme weather events), Arvika worked on improving lake water quality by, first, installing floating screens in 2019. They capture part of the sediment as well as diverting the run-off into vegetation. Constructed wetlands were added in 2020, which provide a curtain of roots that absorb dissolved pollution and reduce water velocity, and contribute to the appearance of landscape (CATCH, 2023b).

Constructed wetlands at Gorla Maggiore water park, Lombardy, Italy
The Gorla Maggiore water park, opened in 2013, was funded by the Lombardy regional government and Fondazione Cariplo to test the feasibility of constructed wetlands for treating combined sewer overflows. The 9ha park includes:

- a pollutant removal area composed of a grid, sedimentation tank and four vertical sub-surface flow constructed wetlands;
- a constructed wetland that provides pollution retention and flood water storage;
- a recreational green space.

The system purifies water and reduces flood risk equally well to alternative grey infrastructure. At a similar cost, the solution also provides wildlife habitat and recreational opportunities (Liquete et al., 2016; Urban Nature Atlas, 2021b).

Protecting surface water quality in Lappeenranta, Finland
The city of Lappeenranta lies on the shore of lake Saimaa in south-eastern Finland. The lake is a source of drinking water for the city, but water quality is deteriorating due to increased rainfall, extreme weather and flood events, which lead to higher run-off bringing in contaminants and nutrients. Eight wetlands designed to cope with stormwater management have been constructed in urban areas, and the urban run-off system is getting an improved design and a new monitoring system (Climate-ADAPT, 2024d).

In rural areas, providing vegetated strips can reduce nutrient and pesticide run-off to rivers and streams, thus reducing the risk of cyanobacterial blooms or pesticide pollution (Rizzo et al., 2023). For example, in Germany, to limit the discharge of pollutants from agricultural sources into groundwater, creation of vegetated riparian buffer strips along water bodies in areas with an incline of >5% is stipulated in the 2020 Fertiliser Application Ordinance and in the Federal Water Act. The amendment to the Use of Pesticides Ordinance in 2021 stipulates a ban on the use of pesticides along water bodies at a distance of 10m and for vegetated buffer strips of 5m (BMUV, 2023).

Daylighting, or opening rivers and streams that were in culverts and in the same systems as wastewater, can also improve quality. In Denmark, the Aarhus river, which had been culverted in the 1950s to give space to a road, was opened between 1992 and 2015. The benefits of resulting water quality improvements were calculated at EUR 120 million. Opening the river has also reduced the risk of flooding from extreme weather events (EC, 2020b). Similarly, in Porto, Portugal, investing in improving the quality of streams has reduced flood risk and improved water quality (Box 6.12).

Box 6.12

The Porto Streams project: improvement of water quality under the changing climate

Porto has four rivers and 12 streams with a total length of 66km, of which 75% were culverted to allow construction of buildings, leading to degradation of the water resource. Through the Ribeiras do Porto (Porto Streams) project, between 2007 and 2020, the city rehabilitated six watercourse stretches with the aim of reducing erosion of stream banks, retaining stormwater in the landscape to reduce flood risk, planting new trees on the banks and improving accessibility of the riparian corridors to the public through the adjoining open space. This stream rehabilitation, alongside enhancing wastewater drainage and treatment systems and increasing permeable areas, has resulted in water quality improvements. As a result, all nine beaches alongside the 3.4km Porto coastline have a Blue Flag, awarded in recognition of the municipality's investment in improving the quality of the water in the streams and rivers (Malheiro and Cunha, 2023; Porto Ambiente, 2020; CDP, 2021).

6.2.3 Ensuring safety and viability of nature-based solutions under the changing climate

While nature-based solutions are recommended by many EU policies, including the EU adaptation strategy (EEA, 2021d; EEA, 2024a), and are beginning to be widely used, they are not without risks or trade-offs. These should be carefully managed to ensure benefits to human health.

Land use

Wetlands can play an important role in flood mitigation, groundwater recharge and water purification, but they are characterised by high land take and may cause conflicts between stakeholders, particularly in densely populated areas (Grow Green, 2020; Bednar-Friedl et al., 2022). Other green spaces may also cause space issues, as happened in Barcelona. The city invested in a network of trees; despite the benefits for climate change adaptation, this limited space for other uses and caused some health and safety risks due to pollen and the danger of falling trees or branches (Climate-ADAPT, 2022d).

Pollution risks

In urban settings, if no treatment is installed, there is a risk of groundwater contamination from infiltration of surface run-off via sustainable urban drainage. Water filtering can be achieved by using constructed wetlands with vertical water flows. Green facades — one of the measures applied in management of excess heat — may have negative impacts on run-off water quality if fertilisers or pesticides are used (Pérez-Urrestarazu et al., 2015).

Risk of infectious diseases

Nature-based solutions can provide a habitat for mosquitoes carrying infectious diseases (Grow Green, 2020). All nine local dengue transmission events in 2022 in the south of France were recorded in suburban residential areas, where relatively high population density is combined with the presence of gardens and green spaces providing suitable conditions for *Aedes albopictus* (Cochet et al., 2022). Further, mosquitoes breed in pools of water or in vessels for water storage in the absence of predators (Butsch et al., 2023). Therefore, the use of nature-based solutions in cities may necessitate additional measures to reduce mosquito populations and infection risk. In Paris, monitoring of tiger mosquitoes and actions to suppress larvae are already carried out. Innovations such as bioclimatic mosquito nets are also being tested and assessed in public buildings (CDP, 2022). In summer 2023, the health authorities fumigated areas of Paris for the first time as a prevention measure to stop dengue spread from a travel-related case (The Guardian, 2023). Incorporating entomological surveillance into nature-based solutions in high-risk areas for infectious diseases should be considered, as well as developing response plans in case of mosquito emergence.

Urban water features used in adaptation to high temperatures, such as water fountains, curtains and sprinklers, may also pose a risk of waterborne diseases or other hazards, which can also be mitigated by close surveillance (Box 6.13).

Box 6.13

Examples of tools ensuring the safety of urban water features under the changing climate

The Waterkwaliteitscheck tool, developed in the Netherlands, allows a microbiological risk inventory to be carried out for new or existing blue infrastructure such as fountains, water playgrounds or paddling pools. It consists of a questionnaire and calculation module to identify potential microbiological health risks and estimate infection risks. It also provides advice on how to reduce these risks. Simple and practical adjustments to the design, construction or management of the blue-green infrastructure can reduce health risks due to microbiological contamination of water. Targeted users include designers, local authorities or initiators, water boards, environmental services or regional authorities.

The BlueHealth project (2016-2020), funded under EU Horizon 2020, aimed to understand links between people's exposure to 'blue' spaces (sea, rivers, lakes, artificial ponds and water fountains) and their health. The BlueHealth Decision Support Tool was developed to facilitate the management of blue spaces' risks and benefits to health and well-being. It was piloted in the Appia Antica park in Rome, which covers about 190ha and has up to 30,000 visitors a day. It identified risks including hazardous litter in the waterfront area, inadequate disposal of food and beverage containers that can attract insects and animals, and inadequate maintenance of benches and pathways. Among the actions to enhance health benefits was the creation of more shaded areas for older people, children and active users (Personal communication with Camilla Puccinelli, Istituto Superiore di Sanità, Italy).

Allergenicity of plants

Pollen-producing trees, shrubs and grasses in cities can increase the health and well-being risks to allergy sufferers, and potentially sensitise further parts of the population to pollen allergies. This is particularly valid under the changing climate, as the increased pollen seasons, concentrations and allergenicity are expected to increase exposure to pollen and aeroallergens in the future (European Climate and Health Observatory, 2022f; Aerts et al., 2021).

The better adaptability of some species to urban environmental conditions, their greater tolerance to pruning and a variety of ecological conditions mean that certain species (*Platanus, Acer, Fraxinus, Betula, Carpinus, Celtis, Cupressus, Morus* and *Tilia* genus) are over-represented in European cities (Cariñanos and Marinangeli, 2021). The London plane tree (*Platanus* spp.) performs well in southern

European cities due to its rapid growth, resistance to drought and a wide crown providing shade (Aerts et al., 2021). However, a correlation between the growing number of plane trees and an increase in both the annual pollen index and the number of days on which allergy sufferers are at risk was found in central Spain (Lara et al., 2020). Four in 10 of the common Mediterranean tree species have moderate to very high allergenicity (Cariñanos and Marinangeli, 2021). Careful tree species selection in urban green space policy and planning is recommended (Aerts et al., 2021).

In Belgium, living in proximity to areas with high grass cover, such as residential gardens, was found to correlate with sales of medication for obstructed airways disease for children. As no such association was found with forest cover, lowering the dominance of grass in public and private green space might reduce the childhood asthma burden, while improving the ecological value of urban green space (Aerts et al., 2020). In general, monospecific stands of an allergenic ornamental species should be avoided. Increasing urban biodiversity appears to bring benefits for nature, health and adaptation to climate change (Jochner-Oette et al., 2018). Further, the widespread pollen allergies emphasise the importance of systems for monitoring pollen counts, sensitisation to pollen allergens and occurrence of allergy.

Drought, water scarcity and temperature impacts on urban vegetation

Urban vegetation is under considerable stress from water scarcity and high temperatures; heat and drought are major drivers of tree mortality in Europe (EEA, 2024a). In cities with scarce rainfall, the cost of irrigating green roofs can outweigh the savings from reduced energy demand for air-conditioning (Ascione et al., 2013). More efficient watering of urban green infrastructure is therefore needed. For example, Porto municipality uses an intelligent automatic watering control in its green spaces, which assesses meteorological conditions and calculates the water requirements for plants. A smart irrigation system has also been installed in Barcelona, which takes into account rainfall, evapotranspiration and plant requirements to determine watering needs (CDP, 2022).

In summary, under the changing climate, there is a growing need to combine urban planning, biodiversity targets and health concerns in applying nature-based solutions so that the benefits are maximised and the risks minimised. For example, *Climate Impact and Risk Assessment 2021 for Germany* (2021) planned the development of guidelines for selecting tree species and other vegetation, considering both the drought- and heat-resilience of the plants, and their low allergenicity (UBA, 2021).

6.3 Physical and technological measures

Various infrastructure and physical measures can be deployed to protect people from floods, reduce pollution risks and maintain quality of drinking and bathing water, or to reduce water scarcity (Table 6.4). Technological measures — including surveillance, monitoring and early warning systems — also play an important role in protecting human health from floods, droughts and poor water quality.

Table 6.4 Physical infrastructure solutions to water-related climate hazards (examples)

Physical infrastructure measures	Floods			Water scarcity
	Fluvial	Pluvial	Coastal	
Dykes	x			
Floodwalls	x			
Dams	x			
Temporary and demountable barriers	x		x	
High-water channel	x			
Compartmentalisation	x		x	
Storm surge barriers/gates			x	
Groynes, breakwaters and artificial reefs			x	
Higher quays			x	
Quay walls			x	
Sluices and pumping stations	x		x	
Dry flood-proofing	x		x	
Wet flood-proofing	x		x	
Floating and amphibious housing			x	
Floating or elevated roads	x	x	x	
Raising coastal land			x	
Upgrading drainage systems		x		
Flow regulators		x		
Smart regulation of the sewerage system		x		
Underground water storage		x		x
Backflow blocker		x		
Pump well with check valve		x		
Greywater recycling system				x
Desalination				x

Source: Grow Green, 2020.

6.3.1 Reducing exposure of people and facilities to climate extremes

Flood protection infrastructure

Physical infrastructure — dykes, levees, seawalls and similar — have been used for centuries to protect people and assets from flooding. According to FLOPROS, a global database of flood protection standards, European countries have some of the best flood protection standards in the world (Scussolini et al., 2016). An overview of European studies shows that dykes or dams tend to be a cost-effective measure, with a mean benefit-to-cost ratio of 3.7 (EEA, 2020c).

Flood defences need to be regularly checked and maintained (CIRCABC, 2021b). Hard flood defences are also subject to failure; for example, the Netherlands, in its reporting on adaptation actions under the Governance Regulation, includes floods due to collapsing of the secondary water defence system as a risk probable this century, potentially causing economic impact (EUR 10-100 million damage) and medium impact for people (10,000-100,000 people affected or up to 10 deaths) (EEA, 2023h).

Flood protection infrastructure can lead to increased exposure, as people and businesses move into protected areas, and result in more vulnerability, as those in areas protected by dykes and levees may be less well prepared if a flood occurs (EEA, 2024a). Existing flood defences may not be sufficient as the changing climate intensifies the frequency and magnitude of floods, and their enhancement may be necessary. For example, elevating dykes along around 30% of Europe's coastline could help to prevent at least 83% of coastal flood damage by 2100. Improving protection against coastal flooding is the most economically advantageous solution for densely inhabited regions; however, land availability and societal acceptance may be constraints (Bednar-Friedl et al., 2022). See example from Germany (Box 6.14).

Box 6.14

Investment in coastal protection infrastructure in Germany

In Germany, the federal government provides funds — with co-financing by the coastal *Länder* and the EU — for coastal protection measures against sea level rise and floods under climate change, as part of the implementation of the Floods Directive. These include heightening and reinforcement of dykes and structures such as barrages, groynes or breakwaters; extensive beach nourishment; essential land acquisition; and nature conservation actions and landscape maintenance. Since 2012, the total annual expenditure has been about EUR 150 million. In the state of Schleswig-Holstein, EUR 292 million was invested in coastal protection between 2012 and 2017, including dyke reinforcement along 93km of coast, which allows future heightening by 1-1.5m should the need arise (German Interministerial Working Group on Adaptation to Climate Change, 2019).

Decisions about where to invest in flood defences, or which areas to prioritise, are often based on cost-benefit analyses, which usually ignore the distribution of damage across populations and may expose more vulnerable populations to disproportionate impacts. This calls for the greater integration of social justice and consideration of health and well-being repercussions into the decision-making process (Hudson, 2020). For example, in Finland, the SOLARIS (Solidarity in climate change adaptation policies: towards more socio-spatial justice in the face of multiple risks) project evaluates the design of policy instruments, local governance and implementation of ongoing projects in terms of fairness in flood risk management. Events with local people facing significant flood risks help to develop an understanding of social vulnerabilities to floods and how to better address them. The results will provide guidance on how to improve the engagement of vulnerable groups in flood risk management (EEA, 2023h).

In addition, physical protection measures may pose risks to ecosystems and, indirectly, human health, for example, by interfering with sediment quality or quantity, impairing the ecological or chemical status of the water bodies. To avoid this, integrated sediment management planning should be applied as part of or in alignment with the preparation of river basin management plans (CIRCABC, 2022). Further, failure of dams — constructed to provide water supply, for irrigation, hydropower or flood control — can have catastrophic outcomes for people living downstream. In Europe, the common main or corresponding cause of dam failure is heavy precipitation (Li, 2015), as in August 2023 in Norway, where a dam partially burst after days of heavy rain (Olsen, 2023). Thus, maintaining infrastructure with climate change in mind is essential to reduce risks from dam failure.

See also Climate-ADAPT for more information on the following adaptation options:

- Seawalls and jetties
- Flood barriers
- Improved design of dikes and levees

Flood-resilient redevelopment

Where relocation of people living in risk areas is not possible (see Section 6.1.4), redevelopment in a flood-resilient manner, combining nature-based solutions with hard infrastructure, can reduce the risks to people to an extent (Box 6.15). Water-resilient and climate-proof planning can curb but not fully eliminate the damage caused by extreme weather situations, as recognised by the Dutch Delta programme. Since 2015, the Water and Evacuation programme in the Netherlands has been improving preparedness for the consequences of floods (EEA, 2023h). Authorities responsible for areas at risk of flooding need to ensure emergency provisions (see Section 6.1.1) and the rapid restoration of vital and vulnerable infrastructure.

Box 6.15

Redevelopment in flood-prone areas in Belgium

The city of Herentals in the Kleine Nete valley is vulnerable to flood events through increasing urbanisation in naturally flood-prone areas under the changing climate. By combining a 'room for water' approach and city expansion in the low-lying Olympiadelaan area, new development can happen in a climate adaptive way. After redevelopment, an extra buffer capacity of 39,000m³ is available to temporarily store water from the river. In addition, the redevelopment will create storage for pluvial water (4,500m³) from the town centre by using an old watercourse and creating ditches next to the city walls. Enlarging the water storage capacity will also create ecological corridors and provide ecosystem services (CATCH, 2023a).

On the banks of the Vesdre river and its tributaries, the Walloon government is working on resilient reconstruction after the devasting floods in July 2021. A total of EUR 453 million will be set aside for riverbank rehabilitation and resilient development as part of the regional recovery plan. The green and resilient structures on 46 reconstruction sites along the banks have been designed with the affected municipalities and river managers. More extensive permeable, unbuilt surfaces next to the river are provided and previously industrial land has been converted to recreational areas that can be temporarily flooded. The complete redesign of the riverbanks has consequences for existing buildings, which require demolition and relocation of the inhabitants (Personal communication with Natalia Bustos Sierra, Sciensano, Belgium, 15 March 2023; Service public de Wallonie, 2022; Vedia, 2022).

As one of the main causes of death during flooding is linked with driving through floodwaters (see Section 2.3.1), ensuring that transport infrastructure is flood-resilient is a key aspect in preventing injury and loss of life. See Box 6.16 for an example from Germany.

Box 6.16

Flood-resilient traffic management system in Oldenburg, Germany

To keep traffic out of a flooded area, traffic signs with changeable symbols have been installed at several locations in Oldenburg, Germany. Sensors connected to the signs were installed in the sewer system at two locations. When sewer capacity is reached, the signs are automatically activated to warn road users and divert traffic from streets that may be flooded. Simultaneously, warnings are sent to the city authorities, fire department, police, rescue services, public transport operator and the control centre of the Oldenburg wastewater treatment plant. As soon as the level falls below the threshold value, the traffic signs are automatically switched back to normal operation (CATCH, 2023c).

Property-level flood resilience measures

Under the changing climate, considering new construction standards focused on the safety and robustness of buildings is essential (EEA, 2024a). Hard defences will not protect everyone against flooding in the future, and flood-proofing individual properties is increasingly recognised as a cost-effective back-up solution (JRC, 2022). Property-level flood protection measures include mountable floodgates, anti-flooding valves and airbrick covers. According to Steinhausen et al. (2022), better implementation of such private precautionary measures in residential buildings could reduce flood risk in Europe by 15%.

In Germany, floods in the Elbe and Danube catchments in 2002 and 2013 resulted in average losses to flooded households of EUR 48,000, including the costs of repairing damaged building structures. Property-level flood protection measures, either permanent or temporary, have been found to reduce damage costs by 27% (Sairam et al., 2019). Based on experience from 2021 in the Netherlands, measures such as use of water-resistant materials in construction and evacuating valuable possessions reduced flood damage by 20-50%. People aware of flood risk were more likely to have resilience measures in place, which emphasises the importance of awareness raising (see Section 6.4.1) (Endendijk et al., 2023).

However, adaptation measures in individual buildings present potential trade-offs. Higher material use for resistance to storm, subsidence or flooding could potentially result in higher greenhouse gas emissions, unless changes are made to how these materials are produced (EC, 2023d). Flood-proofing is expensive and many households are not able or not willing to invest in it (Attems et al., 2020). The highest rates of flood-proofing unaffordability are found in eastern Europe, the Baltic States and parts of southern Europe. Equitable financing mechanisms and better integration of such solutions into zoning policies and existing welfare systems are needed to ensure that all at risk can benefit from property-level adaptation measures (Hudson, 2020).

More advanced flood resilience measures for individual properties include floating and amphibious housing.

Simple, property-level protection measures, such as using mosquito screens in windows and doors, can prevent transmission of vector-borne diseases. In a global review of effectiveness of measures against dengue, providing houses with screens was the most effective (Bowman et al., 2016).

6.3.2 Surveillance, monitoring and early warning systems

Surveillance and monitoring (i.e. the systematic collection, analysis, interpretation and dissemination of information for public health) are the most frequently planned types of actions in national adaptation policies and health strategies (see Section 5.2.1), as they not only underpin the development of early warning systems but also support the general understanding of the risks.

Surveillance and monitoring can happen in situ and be done manually, for example by sampling water according to the requirements of the Bathing Water Directive, but it is increasingly done using automatic sensors and remote sensing. In particular, satellite observations are being used for monitoring droughts (e.g. as a basis for maps provided in 10-day intervals by the European Drought Observatory); floods (e.g. European Flood Awareness System); or water quality (e.g. via Copernicus Marine Service). However, these data often remain inaccessible to public health experts, public authorities responsible for the health and well-being of the population and other decision-makers. Copernicus4Regions User Stories provide examples of the use of satellite data in monitoring water quantity in reservoirs, water quality or flooding in various locations across Europe.

Low-cost, portable sensors can provide real-time data on water quality, allowing for timely responses to pollution incidents. In addition, machine learning algorithms can analyse large datasets and identify patterns not easily detectable by humans. New technologies allow for monitoring of large areas, real-time data transmission and swift information flow to inform management decisions.

The main elements of the early warning chain, based on the monitored data, are:

- detecting and forecasting extreme events to formulate warnings on the basis of scientific knowledge and monitoring, and consideration of factors that affect disaster severity;
- disseminating warning information to the political authorities for wider communication, including appropriate recommendations for urgent action;
- responding to warnings by the local authorities, the population at risk, operators of utilities and others, with implementation of protective measures.

See Climate-ADAPT for more information about early warning systems as a climate adaptation option. The European Climate and Health Observatory includes information about early warning systems in place in Europe.

Extreme weather events: floods, landslides and wildfires

Forecasting and warning systems are designed to predict and warn against extreme events so that responsible agencies can activate emergency plans, and households and businesses can take action to protect themselves and their families, employees, pets, livestock, property and belongings. Such systems become more accurate as the event draws closer (WHO Europe, 2017). When functional, early warning systems have a very high cost-effectiveness, with benefit-to-cost ratio of up to 24 (EEA, 2020c). Early warning systems, combined with flood protection measures (see Section 6.3), have decreased the fatalities related to flooding in Europe (Bednar-Friedl et al., 2022).

However, flood-warning systems are effective only if they result in an appropriate response (WHO Europe, 2017). During the July 2021 flooding, translation of the early warnings into action had some deficiencies (Box 6.17). For example, in Luxembourg, people did not believe the magnitude of flooding predicted and the warnings were not treated with sufficient gravity (CIRCABC, 2021a). Lessons from those events emphasise the need to develop, test and review public communication strategies. Public warning systems need to provide timely, clear notifications and understandable information, and misinformation must be detected and addressed (Roncero, 2021).

Box 6.17

Flood warnings in July 2021: what went wrong?

On 9 and 10 July, the European Flood Awareness System (EFAS) forecast a high and increasing probability of flooding for the Rhine basin, affecting Switzerland and Germany. The following day, forecasts indicated a high risk of flooding for the Meuse basin, affecting Belgium. The first notifications were sent to the relevant national authorities on 10 July for the Rhine and on 12 July for the Meuse. Based on continuously updated forecasts, more than 25 notifications were sent for specific regions in both basins until 14 July (EFAS, 2021).

In Belgium, Germany and the Netherlands, the unprecedented nature of the extreme precipitation revealed several system limitations. Official weather radars in the Netherlands underestimated precipitation by a factor of three (Imhoff et al., 2021). In the communication to the public, it was not clear which information was meant only for major rivers and which was applicable elsewhere, leading to flooding of smaller rivers being unexpected by some communities (Flood Resilience Alliance, 2022).

The Ahr valley in Germany, where the floods cost 134 lives, witnessed systemic failure of its early warning and emergency management systems due to fragmentation of institutional responsibilities, data sharing constraints, limited information during the flood (in part due to the destruction of water level gauges and mobile network outages) and poor risk awareness and preparedness among the public (Apel et al., 2022; Thieken et al., 2022). A post-flood survey of residents in North Rhine-Westphalia and Rhineland-Palatinate found that around one third received no warnings. Of those who did, 85% did not expect very severe flooding and 46% were not sure how to respond (Thieken et al., 2023).

In Belgium and Germany, responders were also let down by the flood hazard and risk maps, which were designed for spatial planning rather than emergencies. In addition, the responders were ill-prepared to deal with a flood event of such magnitude (Flood Resilience Alliance, 2022).

Based on the above, the European early warning systems should be further promoted as a complementary tool to national systems, and awareness raising and training on its use are needed. Further translation of early information (including from awareness raising tools such as the flood risk areas viewer for the general public and forecasting systems for professionals such as EFAS) into early action should be ensured. The technical information (e.g. height of water at certain water gauges) or scientific knowledge needs to be translated into clear messages to support action, especially for decision-makers at local or regional level (CIRCABC, 2021b).

In many countries, warnings about extreme weather conditions can be sent directly to individual mobile phones. For example, in Germany, residents can subscribe to the federal government's warnings app, NINA (Emergency Information and News App), and the Hochwasserportal (floodwater portal) issues daily data on flood warnings for any water body at lower administrative level. For citizens close to the North Sea and Baltic Sea coasts, the Sturmflutwarndienst (storm surge warning service) communicates water levels at the coastal gauges. Several other information services are offered in the German Climate Preparedness Portal (German Interministerial Working Group on Adaptation to Climate Change, 2019). Similarly in Estonia, apps such as Ilm+ or Be prepared — Ole valmis offer warnings and advice during storms, floods or heatwaves (EEA, 2023h).

Early warnings may reduce the impacts of wildfires. For example, the Portuguese entity responsible for civil protection, following the disastrous forest fires in 2017, developed a national alert and warning system through text messages issued to mobile phones active in the area at risk of wildfires as well as floods or extreme weather (EEA, 2020c). In Germany, an automated early wildfire detection system is used to guide fire suppression activities in some states (Butsch et al., 2023).

Surveillance and early warning systems can also reduce the impacts from landslides. Identifying risk zones combined with landslide monitoring can save lives and prevent property losses. Monitoring can detect when hillslopes are primed for sliding and can provide early indications of rapid, catastrophic movement. The EU-funded GIMS project developed an advanced, low-cost system for monitoring landslides and subsidence.

Early warning systems across Europe use a variety of phrasing, number of alert levels or visualisation of risk levels. Following a consistent scheme across countries and hazards could improve understanding and pick-up of the warnings, including among visitors and minorities (Neußner, 2021).

Water supply and quality

Monitoring water supply can detect leakages or quality problems, allowing action to address the loss or public health problems (see also Section 6.3.4). In Lisbon, a monitoring programme identifies and locates potential leakages by comparing datasets of expected vs real-time use. The cumulative savings thanks to a reduction in non-revenue water for the public water company since 2005 amount to around EUR 68 million (Climate-ADAPT, 2023b). See also the example from Porto (Box 6.18). In Italy, the early warning system implemented in the wastewater reuse sector is able to identify the occurrence of a contamination or hazard event in real-time or even before during the production of reclaimed wastewater to improve safeguarding of public health and the environment (Box 6.19).

Box 6.18

Integrated management of the urban water cycle in Porto, Portugal

H2Porto is a technological platform to support integrated management of the urban water cycle in Porto, combining information from the water supply and urban drainage systems, streams and beaches in one tool. This allows remote monitoring and detection of anomalous situations, enabling real-time management of networks and teams. The tool integrates data from various sources: real-time sensors, household meters, geospatial information systems, automation signals in equipment, simulation models of hydraulic networks, remote management systems, weather forecasts and operating systems. It creates a digital twin that models water levels and flow to predict flooding, service interruptions or water quality problems. H2Porto reduced supply interruptions by 23% and sewer collapses by 54%. The volume of non-revenue water dropped by 3.6%. In addition, employee and customer satisfaction is reported to have increased (CDP, 2021).

Box 6.19

Early warning system ensuring high quality of reused water in Milan, Italy

The early warning system is based on a comprehensive network of in-situ sensors (including real-time *E. coli* measurements) automatically and continuously monitoring the contamination risk of water reuse in the Milan Peschiera Borromeo wastewater treatment plant. The monitoring and operational data are processed and machine learning algorithms are applied to detect outliers and predict contamination events at the outflow of the plant. This allows wastewater utilities to control, monitor and share with stakeholders and users data on quality of the treated water, which is reused in agriculture. The system is aligned with the WHO guidelines for Water Safety Plans (Digital Water City, 2023).

Bathing water quality

Monitoring bathing water quality by the Member States under the Bathing Water Directive (see Section 5.1) is required for *E. coli and enterococci* bacteria. While other pathogens present in bathing water (viruses, parasites) are not covered by mandatory monitoring under the directive, WHO (2018) concluded that evidence does not support including a viral indicator or pathogen as a regulatory parameter. At the same time, it is suggested that the bathing profiles of locations where swimmer's itch or wound infections caused by *Vibrio spp.* are likely or known to have occurred should provide the public with the necessary information and advice on hygiene measures.

Many EU Member States — e.g. Finland, France, Germany, Hungary, Italy, Malta, the Netherlands, Spain and Sweden — perform additional monitoring or warning activities on top of the directive's requirements. For example, in Finland, bathing water outbreaks are now a part of the early notification system that is also used for drinking water outbreaks. In Germany, public health officials should be warned of increased risk of infection from *Vibrio vulnificus* when bathing water temperatures on the coasts of the North and Baltic Seas are above 20°C. At the end of the bathing season, the Dutch National Institute of Public Health and the Environment compiles information from local health departments and provinces on health complaints related to bathing water. This information, compiled into an annual surveillance overview, improves the ability to detect, notify and survey the occurrence of common, mild health problems that may otherwise be underreported (Limaheluw et al., 2020).

In Latvia, since 2011, several municipalities have organised and financed water sampling in those bathing areas that are not officially included in the Cabinet of Ministers' regulations under the Bathing Water Directive. The results, including sampling locations, times, water quality indicator results and conclusions on bathing restrictions, are published on the Health Inspectorate's website. In case of inadequate results, short-term pollution events and other bathing area-related issues, the Health Inspectorate provides advice on required actions (personal communication with Jānis Ruško, Institute of Food Safety, Animal Health and Environment, 24 March 2023).

In Belgium, the Flemish Department of Care advises lifeguards and coastal municipalities about poor water quality (e.g. after heavy rainfall and associated sewer overflows) to guide issuance on banning swimming or other activities. Since 2022, this advice has been based on an operational prediction model, which is much faster than the previously applied water sampling and analysis for *E. coli* and *enterococci*, and allows for timely issuance and revoking of bans. The Flemish Environment Agency continues to take samples to monitor water quality and adjust the model if necessary (personal communication with Liesbet Van Rooy, Flemish Department of Care, Belgium, 22 September 2023).

Continuous monitoring of bacterial enzymes can speed up the detectability of incidents that impair microbiological water quality, e.g. after extreme weather events and potentially associated sewerage system overflows, allowing action to prevent disease outbreaks and adverse health effects (Box 6.20).

Box 6.20

Online monitoring and early warning system for bacterial contamination in open waters in Breda, the Netherlands

The city of Breda, the Netherlands, uses BACTcontrol, an enzymatic monitoring and early warning system, to monitor the quality of its open waters, which are frequently used by the public in warm periods. The system conducts continuous monitoring for *E. coli* and cyanobacteria in the public waters and analyses them within 1-2 hours. This allows much faster response measures, compared to traditional microbiological methods, which are labour-intensive and require cultivation of micro-organisms, taking up to 2 days to obtain reliable results. The system provides the city authorities with early warning notifications of bacterial contamination, which are shared with the public in clear language to diminish the risk of disease outbreaks and adverse health effects (Climate-ADAPT, 2024h).

Cyanobacterial and algal risk assessment and management are described in the Bathing Water Directive only in general terms, but most EU Member States have more detailed detection systems and regulations (Ibelings et al., 2014). Since 2012, the Netherlands has had in place the Cyanobacterial Protocol 2020 to comply with the requirements of the directive, which outlines a procedure for water inspection. Based on inspection outcomes, risk levels for bathing sites and associated measures are established, depending on the health risk. This may be a warning, advice against bathing or a swimming ban (Schets et al., 2020). In Italy, toxic algae (*Ostreopsis ovata*) blooms have been subject to national monitoring in coastal waters and shellfish farming since 2007 and in marine bathing waters since 2010. The surveillance system includes three levels of action (Routine, Alert, Emergency) according to detected algae concentrations. Toxic algae are found yearly in most of the 15 surveyed regions, with the highest concentrations between June and September. In some regions, the Alert threshold is regularly surpassed, while some regions reach the Emergency threshold. A general increase in the number of toxic microalgae was detected between 2010 and 2022 (ISPRA, 2023). Citizen involvement can be used to boost reporting of algal blooms in regions where less infrastructure for monitoring is available (EFSA et al., 2020), see Box 6.21.

Box 6.21

Engaging citizens in monitoring blue-green algae in Finland

In Finland, the results of official weekly monitoring of cyanobacteria at 300 predetermined sites are published by regional authorities in Järvi-meriwiki ('lake and sea wiki'). A weekly report summarises the national situation, including a map and a cyanobacterial barometer.

Järvi-meriwiki is an open, community-based web service of more than 55,000 Finnish lakes over 1ha in size and coastal marine areas, which is built and published online with the cooperation of citizens. Every Finnish lake and coastal area has its own mini-page, maintained by users. The content is not moderated and all changes made by users are published immediately. It is accompanied by the Observation Sender app, which allows users to save observations directly from the site. The Järvi-meriwiki discussion forum aims to develop a virtual meeting place where local residents, summer cottagers and other lake users monitor the water condition, organise voluntary activities and discuss restoration measures required.

Järvi-meriwiki is maintained by the Finnish Environment Institute (Syke) and received EU LIFE funding as part of the GisBloom project (2011-2013), which built a system for predicting and managing algae damage. The first version was published in March 2011 (SYKE, 2013; Järviwiki, 2021; Ibelings et al., 2014).

Infectious diseases

Monitoring of vector-, water- and foodborne diseases in Europe is done by EFSA and the ECDC based on data collected by EU Member States. The ECDC produces annual epidemiological reports for notifiable diseases and updates the Surveillance Atlas of Infectious Diseases. It also monitors West Nile fever outbreaks in birds, equids and humans every season from May to December on a weekly basis, as well as dengue cases. With VectorNet, the ECDC creates maps of the most important vectors in Europe. It also produces risk assessments as needed in the event of outbreaks and rapid outbreak assessments with EFSA for foodborne outbreaks. EFSA produces, with the ECDC, annual summary reports on zoonotic infections and foodborne outbreaks. Extending surveillance from people to animals is essential for identification of outbreak risk in humans and implementation of timely prevention and control measures, for example in the case of West Nile virus infections (Climate-ADAPT, 2021).

See Climate-ADAPT for the description of early warning systems for vector-borne diseases as an adaptation option.

In response to the rising presence of *Vibrio* spp. in coastal waters and associated infections, VibrioNet Europe was established, a network of research institutes across Europe that survey the prevalence of *Vibrio* spp. and vibriosis and develop an early warning system for bathers and doctors to enable early detection and treatment (Wolf et al., 2021). The ECDC also monitors the daily *Vibrio* risk in summer. There is surveillance in various countries, especially around the Baltic Sea (Box 6.22). Ciguatera fish poisoning is so far only monitored and controlled in the Canary Islands (Box 6.23).

Box 6.22

Surveillance system for *Vibrio* spp. in Estonia

In 2019, the Health Board of Estonia started a surveillance system for *Vibrio* spp. in coastal bathing waters, to map the prevalence of *Vibrio* spp. and associated disease outbreaks during the peak bathing period (July-August). *Vibrio* spp., the majority of which were pathogenic for humans, were detected in samples at several bathing sites in summer and their presence increased with rising temperatures. In the period 2020-2022, 24 cases of vibriosis were diagnosed (15 cases in 2022 alone). While the source, location and pathway of infection could not be formally identified, the occurrence of cases during the summer and the patients' residence close to the sea suggest bathing in seawater as an important risk factor for infection (personal communication with Liina Eek, Estonian Environment Agency, 21 August 2023).

Monitoring and reporting systems for the surveillance of infectious or vector-borne diseases are frequently identified in national adaptation and health strategies as vital elements of an effective health system (European Climate and Health Observatory, 2022d). In some cases, monitoring vectors that may spread diseases under the changing climate is done with the support of citizens. For example, in Germany, the Mückenatlas (mosquito atlas) allows citizens to submit mosquito samples, which are then identified and used for research by experts. The international Mosquito Alert, a non-profit cooperative citizen science project, aims to study, monitor and fight the spread of invasive mosquitoes capable of transmitting global diseases such as dengue, Zika or chikungunya. Surveillance is carried out with the Mosquito Alert app, which allows the public to provide photos of mosquitos and their locations to a team of entomologists, who validate the photos, identify the species where possible and provide feedback to senders, and include the result in the interactive map.

Box 6.23

Control of ciguatera fish poisoning in the Canary Islands, Spain

In the Canary Islands, 129 cases of ciguatera poisoning (CP) were recorded between 2008 and 2023. In recognition of the public health risk, several control methods have been introduced. First, certain species and sizes of fish caught are controlled for ciguatoxins before being approved for human consumption. Second, the Canary Islands Public Health Service has made CP a notifiable disease, which means diagnosed cases are recorded so their numbers can be monitored. Finally, the government is participating in the EuroCigua 2 project, which covers the epidemiology of CP in Europe, environmental modelling, ciguatoxin characterisation and training. The project is co-ordinated by the Spanish Ministry of Health and is co-funded by the European Food Safety Authority (Climate-ADAPT, 2024e).

6.3.3 *Wastewater management interventions*

Urban wastewater treatment in all of Europe has improved over the past decades and the majority of European countries collect and treat sewage effectively for most of their population. However, maintaining existing wastewater treatment infrastructure, including its adaptation to climate change, will require substantial investments. Every year, EUR 45 billion is invested in water and sewerage infrastructure in the EU (EurEau, 2021). Total cumulative additional expenditures for water supply and sanitation amounts for the EU-27 plus the UK between 2019 and 2030 was estimated at EUR 289 billion to meet the existing Drinking Water Directive and Urban Waste Water Treatment Directive requirements (OECD, 2020).

Reducing the risk of pollution from combined sewer overflows under the changing climate can be achieved by managing stormwater locally, e.g. with the use of nature-based solutions (see Section 6.2) or e.g. stormwater storage. For example, Madrid has designed a wide infrastructure of 37 stormwater storage tanks, with a combined capacity exceeding 1.37 million m^3 (CDP, 2021), and a similar solution is coming in Copenhagen (Box 6.24). As an alternative, increasing the capacity of urban drainage infrastructure, e.g. through implementing larger sewer pipes, can be a relatively cost-effective measure, with the average benefit-to-cost ratio of 2.2 (EEA, 2020c).

Box 6.24

Reducing combined sewer overflows linked to heavy rainfall in Copenhagen

The Copenhagen harbour and beaches, especially in the north of the city, are affected by combined sewer overflows after heavy rainfall. This leads to red-flag alerts and prohibition of bathing in the sea. In 2010, over 40% of athletes taking part in a triathlon in Copenhagen after heavy rain fell sick with gastroenteritis (Harder-Lauridsen et al., 2013). In August 2022, the Christiansborg Rundt swimming event was cancelled on the day due to heavy rainfall, as tests showed the water was not safe to swim in.

To reduce the frequency of short-term pollution events, Copenhagen is implementing projects within its Cloudburst Management Plan. For example, Kalvebod Brygge Skybrudstunnel (in construction, to be completed in 2026) is one of several main waterways to collect stormwater from parts of the city (Frederiksberg East and Vesterbro). The 1.3km tunnel can store 10,000m^3 of water until the treatment plant has the capacity to process it. In the event of very heavy downpours, the tunnel can also direct water into the harbour via a pumping station, avoiding the overload of combined sewerage systems. Initially, the tunnel is expected to be in operation on average three times a decade; in future, given the projected change in heavy rainfall events, it is expected to increase to seven times a decade (HOFOR, 2023). In addition, new built-up areas in Copenhagen tend to be equipped with green roofs and sustainable drainage systems, and sustainable drainage is retrofitted into residential streets across the city.

Further, separation of stormwater at source to attenuate flow rates in the wastewater treatment system is urged to reduce both flooding and pollution-related health risks, alongside reduced costs for sewage treatment (EurEau, 2020a). For example, the city of Zurich is estimated to have reduced wastewater treatment costs by removing stream flows from sewer networks, such that each litre per second of flows diverted saved around CHF 5,000 a year in treatment costs (Wild, 2020). An example from Rimini shows the effectiveness of sewer separation for bathing water quality (Box 6.25).

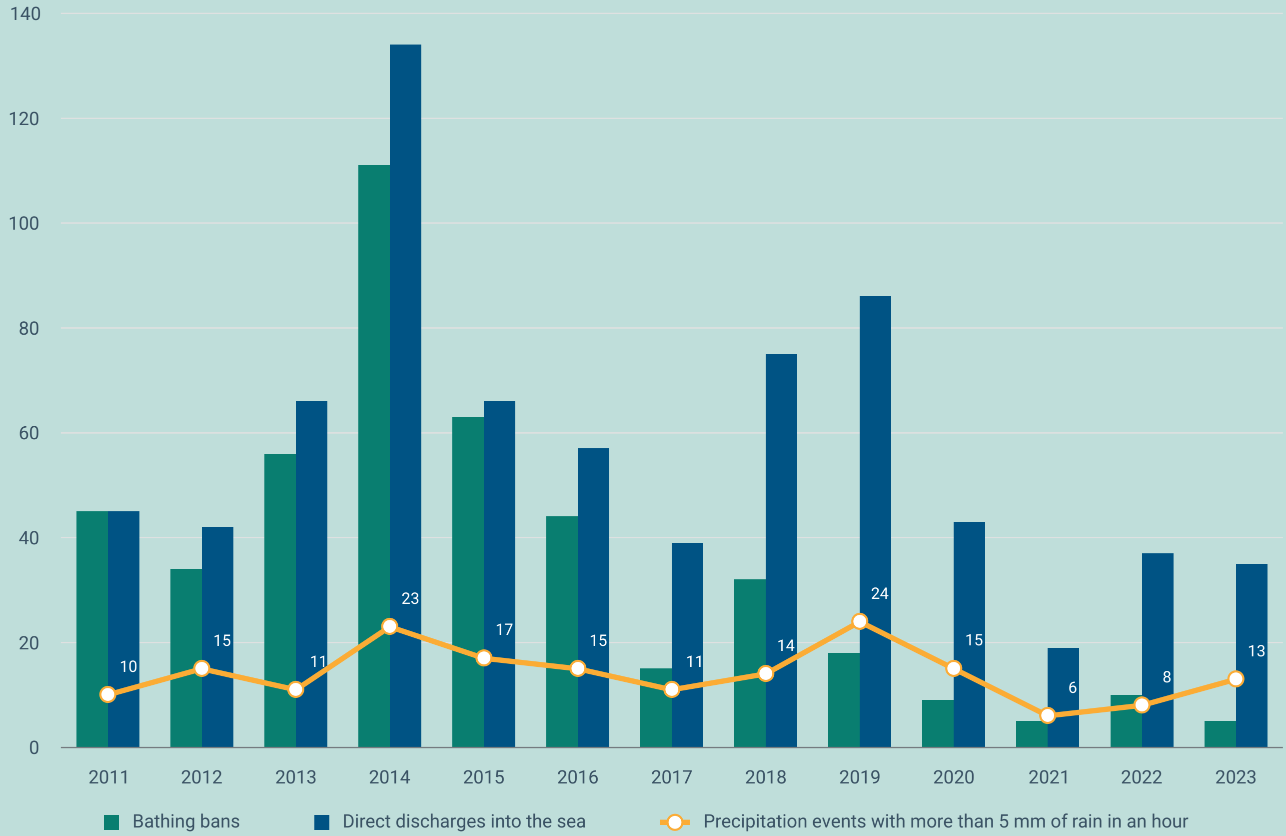
Box 6.25

Protecting bathing water quality in case of sewage overflows in Rimini, Italy

During heavy rainfall events, Rimini frequently experienced combined sewer overflows that caused local surface flooding in the city and direct discharge of untreated wastewater into the sea. The resulting contamination of seawater posed health risks and necessitated implementation of bathing bans on the city's beaches.

The municipality of Rimini is implementing a comprehensive plan of seawater protection, which includes creating a separated sewage collection system, improved sewage treatment and construction of storage tanks for overflows. The completion of sewerage improvements on Rimini's northern coast in 2020 resulted in drastic reduction in wastewater discharges into the sea. Despite heavy rainfall events, only a small number of bathing bans have been necessary in recent years (Figure 6.2; Climate-ADAPT, 2024f).

Figure 6.2 Heavy rainfall events, wastewater discharges and bathing bans for the Rimini North area, 2011-2023 (May-September)



Rainwater in separate sewerage can be reused (e.g. for irrigation) and thus alleviate water scarcity. However, urban run-off tends to be polluted with substances washed off from sealed surfaces; for example, metals, hydrocarbons or microplastics from tyre wear (see also Section 2.2.4). Thus, in addition to efforts to reduce pollution of the urban run-off (e.g. through traffic management), separation of sewage from surface run-off should be combined with downstream treatment using wetlands, ponds, filtration or other suitable systems. Germany and the Netherlands promote separation programmes only where suitable treatment for rainwater is provided (OECD, 2020).

Furthermore, separate systems cannot easily be retrofitted into urban areas with existing combined systems. In managing combined sewer overflows, nature-based solutions (see Section 6.2) may cost less than infrastructure retrofitting for the same effectiveness and show a much higher benefit-cost ratio (Quaranta et al., 2022). Rainwater harvesting and retention through e.g. constructed wetlands offers the additional advantage of allowing water to infiltrate or be reused, keeping it locally available to cope with the expected longer periods of drought (EurEau, 2020a).

See WHO (2011) guidance on water supply and sanitation in extreme weather events and the guidance on sanitation safety plans (WHO, 2022c).

In addition to sewer separation and rainwater retention, technological solutions to reduce pollution risks from combined sewer overflows can range from relatively simple (stormwater retention in sewers, screens and net bags) to advanced real-time management of stormwater flows in sewers (see also Section 6.3.2). Modelling of sewer networks and water quality at the local catchment scale can support decision-making in terms of efficient investment in sewer network infrastructure that delivers meaningful environmental and public health outcomes (EurEau, 2020a).

6.3.4 Ensuring adequate drinking water supply

Efficient use of water resources

Using existing drinking water resources effectively is a key measure to ensure availability of high-quality public water supply for all. Substantial savings can be achieved by managing leaks and other distribution losses in water supply networks, which on average in Europe constitute 25% of the drinking water supply, but in some countries (e.g. Bulgaria and Romania) are much higher (EurEau, 2021). For example, in Rome, water losses between 2017 and 2020 were reduced from 43% to 29%. The city of Porto achieved a historically low non-revenue water level of 17% in 2019 (against 54% in 2006) through loss control activities and quick and efficient intervention in the repair of bursts and leaks, high investment in the rehabilitation of the water supply network and renovation of the water meter park, and the active search for and correction of illegal connections. In Vitoria-Gasteiz, Spain, part of the supply network is renewed every year, and only 8% of water is lost due to leaks or unregistered or fraudulent intakes (CDP, 2021).

Other technological solutions can be applied at local level. For example, Barcelona installed water-saving taps in municipal buildings and Florence has promoted the use of various water-saving devices — such as dual-flush WC, tap aerators and water-efficient household appliances — and provided all drinking water consumers with a meter. Istanbul Metropolitan Municipality distributed a tap kit that prevented overconsumption in the pilot district of Besiktas (CDP, 2021).

Protection of groundwater aquifers

Some regions have secured prioritisation of drinking water supplies (Box 6.26), and others have adopted climate adaptation measures. For example, Porvoo Water, the public water supplier in the city of Porvoo, Finland, carried out a risk assessment in 2008 to guide emergency preparedness to extreme weather events and adaptation measures to long-term climate change, guaranteeing provision of services for about 43,000 people and 700 businesses (Jarva et al., 2014). Two main water intakes are equipped with emergency power supply systems in case of damage to the electricity supply and extra chlorination is available in case of flood events compromising water quality. An artificial groundwater infiltration system ensures availability in dry periods (personal communication with Karoliina Koho, Geological Survey of Finland, 22 March 2023).

Infiltration is one of the methods covered by the term 'managed aquifer recharge', which is increasingly used to replenish groundwater aquifers and secure groundwater availability. Managed aquifer recharge is done by directing excess surface water into the ground — by spreading it on the surface, through recharge wells or by altering natural conditions to increase infiltration, while maintaining high water quality. However, riverbank filtration sites are sensitive to extreme climatic conditions. Floods may cause poor river water quality and organic matter occurrence in underground aquifers; droughts clog riverbeds and reduce infiltration rates (DEEPWATER-CE, 2020).

Human responses to climate change bring new risks to groundwater. In Finland, a growing incidence of near-zero temperatures in winter results in increased use of road salt for de-icing, which causes elevated chloride concentrations in groundwaters. In Lahti, since 2017, the city's municipal services have been using potassium formate instead of sodium chloride to prevent water salinisation (Jarva et al., 2014; Geological Survey of Finland, 2022).

Box 6.26

Reserving groundwater aquifers for drinking water in the Loire-Bretagne basin in France

In the Loire-Bretagne basin in France, since 1996, authorities have been identifying groundwater bodies that should be prioritised for drinking water purposes. In 2022, the Regional Health Agency requested river basin authorities to extend protection to more groundwater resources with good status and reserve additional aquifers for drinking water. The 2022-2027 River Basin Management Plan recommends that new abstractions for other uses only be accepted under limited conditions and that relevant stakeholders be involved in deciding on permits and on ways to preserve water resources and reduce pollution risks (WWF, 2023; Agence de l'eau Loire-Bretagne, 2022).

Improvements in water supply and storage infrastructure

Water supply infrastructure in many European countries is ageing and requires maintenance or replacement. In Kalmar, Sweden, between 2008 and 2013 the local water company, Kalmar Vatten, increased the rate of renewal of the pipeline network to about 10km of pipeline each year. This has decreased leakages and addressed water shortages (Klimatanpassing, 2018). Under climate change, water scarcity may affect areas with hitherto sufficient supply. In the Netherlands, systems have not been routinely designed to withstand prolonged periods of drought (Bartholomeus et al., 2023).

To ensure continued water availability, some areas diversify supply and ensure storage. In Vitoria-Gasteiz, Spain, the existing storage tank at the Araka drinking water treatment plant was expanded and two new tanks constructed, bringing the capacity of the system to 105,000m^3 at a cost of EUR 8 million. This guarantees water for 2 days in winter and 1.5 days in summer. In Rome, part of the Tiber river water is planned to be withdrawn and treated to be mixed in the distribution network during drought (CDP, 2021). Paris combines those strategies with diversified water sources (Box 6.27). However, the use of sources far from the point of consumption brings a need for extensive infrastructure, energy use and potential conflicts with users closer to the source.

Box 6.27

Ensuring constant water supply in Paris.

Paris has a wide network of drinkable water supply (about 2,000km of pipes), which uses diverse sources (102 groundwater sources and two surface water sources). The most distant source is 173km from Paris. Half of the water consumed is from surface water, the other half from groundwater. Thanks to this diversity of supply, the risk of shortages is minimised. Moreover, there are five main water tanks within Paris that allow storage for the amount of water consumed in Paris in 3 days. Connections between the network in Paris and surrounding areas allow exchange of water from one network to another if needed (CDP, 2021).

WHO provides water safety plan manual with focus on resilience to climate change (WHO, 2023b).

Reuse of treated wastewater

Treated wastewater can be a reliable water supply able to cover peaks of water demand (European Commission, 2019), thus reducing pressure on drinking water supplies. It can also ensure that water is returned to the environment and plays a role in groundwater aquifer recharge. Wastewater reuse is usually a cost-efficient type of measure addressing drought, with a benefit-to-cost ratio exceeding 5 (EEA, 2020c) despite the need to ensure the highest standard of wastewater treatment (Ricardo

Energy & Environment, 2019). Wastewater reuse is increasingly applied in Mediterranean cities (see Box 6.28). However, reclaimed water for agriculture and food production might be contaminated with hazardous substances that usual treatments fail to eliminate, which may require future research and monitoring (EFSA et al., 2020).

Box 6.28

Reuse of wastewater in southern Europe

Madrid has deployed a wide network for the supply of recycled and treated wastewater. This water is used in municipal services, in parks, gardens and streets, allowing the city to save 6.2 cubic hectometres of drinking water in 2011. The annual saving is expected to reach 22.7 cubic hectometres when the network is complete.

Barcelona developed the Alternative Water Resources Master Plan in 2020 to promote the use of groundwater for purposes such as street cleaning or irrigation of green spaces. The city council is piloting the use of greywater for toilet flushing and watering of green spaces in municipal buildings.

The Portuguese government has established that the 52 largest wastewater treatment plants in the country must reuse 10% of the wastewater treated in those plants by 2025, increasing this target to 20% in 2030. A project in Porto aims to reuse 11,200m^3 of water per day within 10 years; the treated wastewater will be used for watering municipal gardens and washing waste transport vehicles (CDP, 2021).

Currently, across Europe, only approximately 2.4% of treated urban wastewater is reused. Depending on water availability, this rate can reach up to 70% (Digital Water City, 2023). To achieve higher reuse rates and improve public confidence that the reused water is of high quality, the EU Regulation on minimum requirements for water reuse came into force (EU, 2020c). Reuse is also included as a resource-saving and climate adaptation measure in several EU policies, including the circular economy action plan (EC, 2020a), EU climate adaptation strategy (EC, 2021c) and the Commission's proposal for a revised Industrial Emissions Directive (EC, 2022b).

With the developments in treatment technologies ensuring safety for human consumption, the reuse of wastewater can be extended to drinking. According to a survey of 2,500 participants in the Netherlands, Spain and the UK, between 67% and 75% of respondents supported or strongly supported the use of recycled water for drinking (Water Reuse Europe, 2021).

WHO provides guidelines for the safe use of wastewater, excreta and greywater in four volumes.

Desalination

In the EU, a small fraction of freshwater is obtained through seawater desalination. EU facilities can supply up to 2.89 billion m^3 of desalted water a year. 71% of the water produced is used for public water supply (2 billion m^3, 4.2% of total water employed in public supply). EU desalination plants are mainly in Mediterranean countries: about 1,200 plants provide a capacity of 2.37 billion m^3 (82% of total EU desalination capacity) (Adamovic et al., 2019). The Metropolitan Area of Barcelona has built a desalinisation plant to guarantee water supply for homes and avoid domestic water restrictions (CDP, 2022). This method of obtaining water is not without environmental impacts, however, as it is energy-intensive and the high-salinity waste with chemical residue can impact ecosystems when discharged into marine environments (Panagopoulos and Haralambous, 2020).

Drinking desalinated water without proper treatment may pose health risks. Desalination removes important minerals — iodine, magnesium, calcium — alongside the chlorides, with potential serious health implications in case of prolonged consumption. In Israel, associations have been found between drinking desalinated water and iodine deficiency leading to thyroid diseases, as well as a higher risk of heart diseases. In addition, the use of desalinated water for irrigation has led to lower magnesium and sodium content in produce, reducing the intake of those minerals via food (Environment+Energy Leader, 2019).

See Climate-ADAPT for more information about desalinisation as a water scarcity adaptation option.

WHO offers guidance on ensuring safe drinking water from desalination, with regards to chemicals, efficiency of pathogen removals and remineralisation (WHO, 2011b).

6.4 Knowledge and behavioural change

6.4.1 Raising awareness of risks and informing action

Awareness-raising is essential to ensure that citizens and professionals are prepared for extreme weather events and other emergencies under the changing climate. 77% of the EU public see climate change as a very serious problem and 37% already feel personally exposed to climate risks (EU, 2023), yet recent extreme events suggest low awareness levels. The 2021 flooding in Limburg, the Netherlands, showed that awareness of flood risk was relatively low (CIRCABC, 2021c). According to Flood Resilience Alliance (2022), the description of the 2021 flooding in Belgium by some media as a 'once in a century' event led some to believe that there would not be another occurrence for a century, and that no immediate action is needed to increase resilience to such events. Similarly, in the Ahr Valley in Germany, a year after the 2021 flooding, over half of people surveyed considered such an extreme flood very unlikely in the future and therefore would not want to move out of the flood risk area (Truedinger et al., 2023) (see also Box 6.17).

General public

National and regional web platforms that gather tailored information on climate change and ways to adapt to it are one channel for disseminating relevant information about its impacts on health. These platforms should relate to existing portals on sectoral policies such as disaster risk reduction, water and health to promote mainstreaming of climate action into those sectors (EC, 2023e). For example, the National Institute for Public Health and the Environment in the Netherlands has a set of webpages on the climate impacts on health, including via water. In Germany, people are informed about forest fire hazards and correct behaviour through the services of the German Meteorological Service (forest/ grassland fire hazard indices) between March and October every year, as well as information boards or flyers in relevant locations (Butsch et al., 2023).

See country profiles in Climate-ADAPT for further information about climate adaptation platforms in various European countries.

In 2023, the European Commission published a map viewer pooling the information reported by Member States under the Floods Directive to raise awareness about significant flood risks. Some countries produce risk maps, where citizens can check the risks in their vicinity, e.g. the Netherlands.

In Italy, guidelines to manage the presence of toxin-producing cyanobacterial blooms in bathing waters provide information for awareness-raising among the public, not only serving the need to protect citizens in the case of sudden events but also engaging people in tackling the problem (personal communication with Francesca De Maio, Italian Institute for Environmental Protection and Research, 24 March 2023).

In Sweden, increasing knowledge and understanding of transmission routes of pathogens — including those whose spread is facilitated by climate change, flooding and run-off from agricultural land — among professionals and the general public is one of the key activities of the Swedish National Veterinary Institute.

Education programmes in schools also play an important role. Disaster preparedness can start by educating children about extreme events and teaching them how to prepare and react (Seddighi et al., 2020). Education programmes in relation to flood risk have been designed in the Netherlands. Virtual reality and educational video games have proved to be effective tools for awareness raising (Feng et al., 2018); in France, students who tested the SPRITE game for management of coastal flood hazards improved their knowledge of risks and risk management (Taillandier and Adam, 2018).

Awareness raising can be particularly important in relation to the less recognised risks, such as water quality issues in private wells as a result of flooding. In Ireland, many private well users, in particular in rural areas, did not consider floods likely, and most of those who experienced flooding failed to take protective action (Musacchio et al., 2021).

Awareness raising, education and training of professionals in various fields

Italy's Water Safety Plans guidelines — addressed to water management system managers and operators, health authorities and other stakeholders involved in drinking water quality — aim to provide the criteria, methods and procedures for the implementation of safety plans in drinking water management systems. The guidelines advise on risk assessments for biological, chemical, physical and radiological agents in drinking water. A dedicated section describes risks linked with climate change (personal communication with Francesca De Maio, Italian Institute for Environmental Protection and Research, 24 March 2023). The Swedish National Food Agency has developed materials to support professionals in assessing emerging risks for drinking water, and food safety in general, related to climate change. A free national e-learning course for drinking water inspectors and responsible authorities aims to support them in assessing risks related to microbiological safety (personal communication with Melle Säve-Söderbergh, Swedish Food Agency, 21 March 2023).

It is equally important to raise awareness of climate risks across the various levels of public administration. In Germany, the 2050 National Water Strategy, published in 2023, targets different stakeholder levels — especially the federal government, federal states and municipalities — and contributes to raising awareness of the importance of water among them (personal communication with Inke Schauser, German Environment Agency, and Jan Praest, Federal Ministry of Health, Germany, 23 March 2023). In response to water scarcity in 2016 and 2017 in Sweden, the National Water Disaster Group and the Swedish National Food Agency shared knowledge and advice with affected regions and municipalities. In addition, a knowledge exchange programme with local authorities in southern Europe was organised to strengthen municipalities' ability to build resilience against future water shortages (Livsmedelsverket, 2017).

Regarding occupational groups particularly at risk from water-related climate threats to health, rescue services are a key group to address with awareness-raising (see also Box 2.3). For example, the German fire brigade association has published a recommendation on safety and tactics during vegetation fires to better prepare personnel for operations (Butsch et al., 2023).

Raising awareness of not only climate change and its impacts but also climate adaptation options is important for farmers (Howard et al., 2020). For example, nearly 84% of farmers responding to a survey in Serbia believed that climate change awareness-raising and training would be very useful (Stricevic et al., 2020). One example in Sweden is the project 'Building of a resilient water supply through preparedness and redundancy' financed by the Swedish Civil Contingencies Agency, which maps water users' needs and characteristics and provides tools and solutions. The Gradvis project, initiated by Hushållningssällskapet Halland — an advisory organisation in the agricultural sector — and supported by the National Association of Farmers and the EU's rural development programme, provides farmers with access to practical advice, based on available research outputs, on how to prepare for climate-related risks and benefit from the opportunities (personal communication with Johanna Dernfalk, National Veterinary Institute, 28 March 2023).

Serious gaming can be an effective instrument to support collaboration between stakeholders involved with disaster management. In the Netherlands, the game 'Dike Dilemmas Under Pressure' contributes to improving mutual understanding and collaboration between actors in flood defence asset management (Den Heijer et al., 2023).

Currently, climate change is not taught widely to medical students. The 2020 International Federation of Medical Students Associations survey on climate change education in 592 medical schools in the European region indicated that 153 medical schools provide formal climate change education and 118 informal or youth-led education (personal communication with Daniel Dîrul, Regional Director for Europe, 1 September 2023). The environmental determinants of health, including climate change, are more visible in the public health curricula; according to a 2021 survey, 29 out of 45 schools of public health in Europe provided climate and health education in 2020 (Orhan et al., 2021).

A survey among 150 doctors and nurses in France, Germany and the UK shows that nearly three quarters had no environmental literacy support. While many doctors and nurses wanted to educate patients about the impacts of climate change and sustainable lifestyles, they lacked the time, resources and education to do so (The Economist, 2022). In recognition of this gap, multiple actors are calling for or committing to more education and training of public health and wider healthcare professionals and students on climate change (see Box 6.29).

Box 6.29

Towards inclusion of climate change in public health and healthcare professionals' education and training

The joint statement by the EU Health Policy Platform's thematic network 'Climate action through public health education and training' led by ASPHER (2022) was endorsed by nearly 100 professional bodies, civil society organisations and universities in public health and healthcare. It emphasises that public health and healthcare professionals require core training and continuous professional development to improve their understanding of the links between climate and health and to make it a priority in their work. It calls for an update of curricula for undergraduate and postgraduate programmes and continuous professional development by including concepts such as One Health and Planetary Health. The Standing Committee of European Doctors (CPME), representing national medical associations across Europe, in its policy on climate change and health, called on the EU, its Member States and local policymakers to act, ensuring that medical students, doctors and other healthcare professionals are trained to inform people about the health impacts of climate change and treat patients affected by them (CPME, 2023). The International Association of National Public Health Institutes (IANPHI), in its roadmap for action on health and climate change, committed to enhancing capacity, competence and training through peer-to-peer support and knowledge sharing between institutes to support them in their development as key climate actors (IANPHI, 2021).

At ministerial level, in 2022, the G7 Health Ministers' Communiqué committed the member countries to addressing the health impacts of climate change and to building climate-resilient, sustainable and climate-neutral health systems. It includes the aim to incorporate climate change-related aspects into the education and training of healthcare and public health professionals (G7 Germany, 2022). In July 2023, the WHO European region member countries adopted the declaration of the Seventh Ministerial Conference on Environment and Health organised by WHO Europe in July 2023 in Budapest. The countries committed to, among other things, strengthen the climate-literacy of health professionals to empower them to respond to climate health impacts and engage meaningfully on climate change policy development in the health sector. The 148 parties that signed the COP28 UAE Declaration on Climate and Health (2023) by 1 February 2024 committed to improving the ability of health systems to anticipate and implement climate adaptation interventions by a climate-ready health workforce.

In particular, the increasing prevalence of climate-sensitive infectious diseases and emergence of health problems previously absent in Europe may necessitate further training in diagnosing and treatment. The scale of health impacts associated with extreme weather events may require learning more about their management and profile. Box 6.30 presents examples of training and engagement for health professionals on climate change.

WHO Europe provides a number of training materials relevant to the climate-water-health nexus, for example Introduction to water-related infectious diseases or Surveillance of water-related infectious diseases.

Box 6.30

Examples of continuous professional training and engagement initiatives for healthcare professionals

The German Climate Change and Health Alliance founded the first Planetary Health Academy lecture series in summer 2020. This is a free online lecture series on human-made issues such as the climate crisis, loss of biodiversity, pollution and change of land use, and solutions. The academy is aimed at all interested parties from the healthcare sector including physicians, trainees, students and employees of all health professions (Climate-ADAPT, 2022e).

The Nurses Climate Challenge Europe aims to support nurses who want to educate their colleagues and communities about the health impacts of climate change. Since January 2021, the initiative has provided knowledge on climate and health resources, education and advocacy material, and practical measures to integrate climate knowledge into nursing practice, tailored to nurses working in European healthcare. It also serves as a networking opportunity for participants to share their experiences. As of January 2024, 6,568 nurses have been trained, nearly double the original target of 3,500. Twenty European nursing schools and universities are participating in the Nursing School Commitment, empowering nursing students at all levels to become confident climate and health advocates and be leaders in resilient and sustainable healthcare (Climate-ADAPT, 2022f).

The ASPHER Climate and Health Working Group and the Global Consortium of Climate Change and Health Education (GCCHE) have developed a free online course on climate change and health. The course aims to engage public health staff, the wider health workforce and other professionals interested in climate change and health. It aims to facilitate their involvement in policy and advocacy related to climate adaptation and mitigation, as well as research that supports decision-making across sectors. The course aligns with the ASPHER Climate and Health Competencies for Public Health Professionals in Europe (ASPHER, 2021) and the updated GCCHE Climate & Health Core Concepts for Health Professionals (GCCHE et al., 2023).

6.4.2 Water demand management

The average consumption of residential drinking water in Europe is 124 litres per person per day, or 105m^3 per household per year, and decreased by 3% and 6% respectively between 2017 and 2021 (EurEau, 2021). Education and public awareness campaigns encouraging more rational use of water, as well as promotion of water-saving technologies, are among the most effective measures for reducing demand (Tortajada et al., 2019).

In several cities reporting to CDP (2021), water companies organised awareness-raising activities aimed at reducing water use. In Reykjavik, Iceland, the water company Veitur set up a website where it promotes ways for the public to save water. In Warsaw, Poland, the municipal water company MPWiK S.A. has been leading educational workshops for children since 2011. The municipality of Amarante in Portugal has collaborated with the local water and wastewater company and the health authority to carry out actions in schools to reduce consumption.

Florence, Italy, decreased the demand for drinkable water in recent years through information and awareness campaigns, including actions targeted at tourists. Podgorica, Montenegro, carried out a media campaign for rational use of water. Engagement of children and adults through educational activities has also been done in Porto, where Pavilhão da Água (Water House) educates around 52,000 visitors per year with interactive and multimedia exhibitions on the importance of preserving water resources. In Barcelona, actions including active involvement of the municipality in World Water Day, informative material, exhibitions and opening water cycle facilities to visitors have contributed to reducing consumption by about 20% in the last 15 years (CDP, 2021). In some regions, unconventional campaigns are used to raise awareness of the need to save water (Box 6.31).

Box 6.31

Ugly lawn competition in Gotland, Sweden

Water availability on the island of Gotland, Sweden, is expected to decrease by 13% by 2050, while demand could increase by 40% by 2045 (OECD, 2022). To raise awareness of shortages and to encourage rational use of increasingly scarce resources, the ugliest lawn contest was organised in 2022 by the Gotland region. Residents were encouraged not to water their lawns over summer, challenging the social convention of a well-kept lawn. In 2022, the competition, with other water-saving initiatives, resulted in a 5% reduction in consumption on the island compared to the previous summer (Gotland Region, 2024). The competition has now been taken up in other countries. The region's website provides guidance on setting up the contest.

Replacement of collective water meters with individual ones can substantially reduce per capita water consumption, according to a study in Spain (Tortajada et al., 2019). In Porto, the municipal water company replaced 56% (89,343) of water meters between 2015 and 2020, with the aim of replacing another 40,000 by 2022. At the beginning of 2021, more than 50% of the water meter park in the city of Porto was composed of automatic meters, which helps to calculate the water balance more rigorously and to obtain more accurate billing (CDP, 2022).

6.5 Economic and financial measures

At health system level, WHO (2023a) provides examples of measurable outputs and indicators of sustainable climate and health financing. With regard to climate resilience, this includes providing scaled-up public financing, as well as domestic or international funding for climate resilience, and inclusion of resources for climate change and health interventions in national or sub-national health investment plans, including resources for the climate resilience of individual health facilities. Access to health funding and financing should ideally be guided by health national adaptation plans. Funding and financing should also be available for health-determining sectors such as water, sanitation, food and agriculture, energy, transport and urban planning to screen for climate variability and change and to implement adaptation projects to limit the health impacts.

At the level of the individual and community, economic tools such as insurance, tariffs ensuring affordability of water, and subsidies and incentives are examples of approaches that can reduce the water-related impacts of climate change on health.

6.5.1 Ensuring affordability of water

Decreasing availability may necessitate transport of water, establishing new sources or additional treatment methods, the costs of which may be passed on to consumers. However, Target 6.1 of the Sustainable Development Goals says that by 2030, the UN member states should achieve universal and equitable access to safe and affordable drinking water for all (UN, 2024). Ensuring access to safe drinking water and sanitation is therefore a legal obligation for all UN member states (WHO Europe, 2022). According to Article 9 of the Water Framework Directive, by 2010, member states should have ensured that water-pricing policies provide adequate incentives for users to use resources efficiently and that economic analysis supporting the adequate contribution of different water uses, including households, considers the social, environmental and economic effects of the costs on users, alongside the geographic and climatic conditions.

However, water affordability is not a given for some households in the EU. The simulated impact of passing on the additional expenditures for water supply and sanitation to households shows that the 10% poorest households in countries such as Bulgaria, Greece, Italy, Lithuania, Poland and Romania will face affordability issues. Half of EU Member States face affordability issues for at least 5% of their population (OECD, 2020).

Where water is available but not affordable, people may limit the use of water below levels necessary for personal use and hygiene. They may turn to cheaper, unsafe sources or compromise on other essential goods and services, impacting their human rights and affecting health and well-being (WHO Europe, 2022).

WHO Europe (2022) provides policy options and good practices to ensure the affordability of safe drinking water and sanitation services, targeting vulnerable groups including those in poor health (see Box 6.32 for selected cases).

Box 6.32

Examples of measures ensuring affordability of drinking water to vulnerable households

The water social bonus in Italy

This measure, introduced by Prime Ministerial decree in October 2016, provides a free water allowance of 50 litres per capita per day to cover essential needs for households experiencing economic and social hardship. In 2021, the households entitled to the water social bonus included those with an income not exceeding EUR 8,265 per year, those with four or more dependent children and income below EUR 20,000 per year, and those in receipt of a citizens' income or citizens' pension.

Social tariffs in Belgrade, Serbia

Since 1995, the city of Belgrade has progressively developed and updated a system of social protection for its most vulnerable citizens, with the last reform in 2015. This includes a programme to subsidise the cost of utilities, including safe drinking water and treatment and disposal of rain- and wastewater. Discounts of up to 30% on the monthly bill are available to low-income households and low-income pensioners, households affected by war and households with members with disabilities or requiring care.

Flexible payment systems for special groups in Hungary

In its Water Utility Act of 2011, Hungary defined two population groups eligible for special treatment: protected consumers and consumers living with disabilities. Protected consumers — those on low incomes, people caring for people with disabilities or chronically ill family members, or foster parents — can apply for deferred payment of water bills by 60 or 90 days without a fee, or, if in arrears, for debt payment in instalments. Consumers with disabilities are eligible to have their water meter read monthly by the water operator and can pay their bill on site in cash (WHO Europe, 2022).

6.5.2 Equitable insurance approaches

Insurance covering extreme weather events allows repair to property and replacement of damaged belongings. Efficient processing of insurance claims after extreme weather events is among the factors lessening the mental health impact of floods (see Section 2.3.2). Having access to insurance can also help to bring a flooded house back to the living standard and avoid the health risks linked to living in a damp, cold and mould-infested dwelling, or living in a shelter or replacement housing. The scale of exposure of residential buildings to flooding (see Section 2.3.4) highlights how private insurance against flooding and extreme weather events can play a role in mediating the health impacts of the changing climate.

Insurance against flood damage is generally considered a viable option for compensating financial losses caused by flooding. However, returning to the status quo, which is the usual principle of flood insurance contracts, can result in maladaptation, as it prevents 'building back better' to adapt to future risks (EEA, 2020c).

Flood insurance systems can also help limit overall flood risk by differentiating insurance premiums according to risk level. This can encourage households to move away from — or avoid locating in — high-risk areas. However, if the market regulates the premium, the insurance in risk areas may be unaffordable for the poorest households, potentially resulting in huge flood damage. Flood insurance unaffordability is estimated to be highest in high-risk areas of Poland and Portugal, followed by several regions in Croatia, Germany and the Baltic States. With the changing climate, unaffordability is projected to rise and demand for flood insurance to decline towards 2080, mostly in eastern Europe and some regions in Italy, Portugal and Sweden (Tesselaar et al., 2020). This could disproportionately affect the poorest residents in those areas and requires transformative solutions in the insurance sector to avoid further health and well-being impacts (EEA, 2022g).

Flood insurance penetration rates vary considerably among European countries. EIOPA (2023) provides a breakdown of flood insurance penetration for residential buildings, which can be indicative of the magnitude of well-being impacts should flooding happen. Croatia, Greece, Italy, the Netherlands and Romania have the lowest rates of flood insurance penetration for residential buildings. Indeed, according to Romania's reporting under the Governance Regulation, the potential risks and damage from flooding and seismic events are rising due to climate change and ageing infrastructure. The government liability from losses in the event of a major disaster could exceed 0.4% of GDP, considering the vulnerability of residential building stock — estimated to account for more than 50% of potential losses — and of public assets (EEA, 2023h). Incentivising the take-up of insurance, through its affordability, can reduce the amount of emergency payouts made by governments to ease the impacts of extreme events on people (see Box 6.2).

Drought insurance, alongside national drought management plans (see Section 5.2.4), can be an effective option to reduce the impact on the livelihoods and mental health of farmers. However, drought is underrepresented in the insurance products available on the market across Europe, based on analysis of six countries (Bucheli et al., 2023). In Germany, while a large proportion of farmers are considering drought insurance, only 1% are already insured. Increasing premiums due to more frequent droughts, and the drought index of insurance products based on meteorological observations not matching conditions on their fields, reduce insurance demand by farmers. On the other hand, those previously affected by droughts are more likely to have insurance (Nordmeyer and Mußhoff, 2023).

From 2018, the common agricultural policy allowed premium subsidies of up to 70%, which has translated into different national levels of subsidies. Currently, Austria subsidises premiums by up to 55% (Box 6.33), France and Italy by up to 70% and Spain by about 40%. Insurers should continue efforts to establish a system that covers all relevant weather risks with products that are not prone to market failure and can be offered at low cost (Bucheli et al., 2023).

Box 6.33

Subsidised drought insurance for farmers in Austria

In Austria, the considerable impacts of droughts on agricultural production and crop losses led the government to adopt a subsidised drought insurance system for farmers in 2016. It replaces the traditional approach of providing ad hoc compensation for farmers' economic damage and has two key characteristics. First, it moves away from the traditional indemnity-based approach, based on proven loss of turnover or production, and offers index-based products that consider variations in weather variables. Compensation is paid if the number of wet days or total rainfall remain substantially below the 10-year average, irrespective of damage. These index-based products generally facilitate faster compensation payout, thereby releasing economic and mental pressure from farmers earlier.

Second, it is a public-private financed insurance system in which the government shares risk costs with farmers. The state finances 55% of the cost of premiums, with the aim of reducing the overall cost to the taxpayer from emergency payouts for uninsured farmers and at the same time supporting the take-up of insurance among farmers. More than three quarters of 500 surveyed Austrian farmers expressed their support for the system (Climate-ADAPT, 2024g).

See Climate-ADAPT for additional information on insurance as risk management tool.

6.5.3 Financial incentives

Rainwater collection to reduce pressure on stormwater systems can help reduce the risk of flooding or combined sewer overflows as well as provide water for e.g. watering plants during droughts. Many countries in Europe have been offering subsidies and incentives for homeowners to collect rainwater; see example from Poland in Box 6.34. Other examples are available in the EEA publications focused on adaptation to climate change in cities (EEA, 2020a, 2024c).

On the other hand, a financial disincentive such as raising water prices is not very effective in curbing individual household demand as it does not fall proportionally to the increase in price. A price increasing by 10% may reduce household water consumption by 1-5% (Reynaud, 2015). The wealthiest households tend to be the biggest consumers. In Italy, for example, water demand increases by a factor of 1.5 with increasing income (EEA, 2017). Establishing seasonal tariffs or providing discounts for low use may be more effective than raising prices (Tortajada et al., 2019).

Box 6.34

My Water programme of subsidies for home water retention systems in Poland

Since July 2020, the Polish Ministry of Climate and Environment has provided subsidies for home rainwater retention systems with the My Water programme, amounting to about EUR 50 million. The programme aims to protect resources and reduce the amount of water discharged into drainage systems by offering financial support to homeowners to install systems for retaining rainwater and snowmelt on private land. An individual applicant can receive a subsidy of up to 80% of eligible costs, up to PLN 5,000 for an investment with a minimum amount of PLN 2,000 and a minimum total size of tanks of 2m^3. Housing cooperatives can receive up to PLN 10,000. The programme aims to support the retention of more than 2 million m^3 of water per year. In parallel, the ministry supports local governments' investments in water storage and retention measures (personal communication with Patrycja Ciechańska, Ministry of Climate and Environment, Poland, 29 March 2023).

Some countries offer subsidies for municipalities as the main actors in implementing adaptation to climate change. For example, Swedish municipalities can apply for grants from the Swedish Civil Contingency Agency directed against disasters, including flooding, with the aim of protecting people's lives and health. Eligible measures that have a direct impact on human health include embankments, pumping stations, retention reservoirs, renaturation of watercourses and, in the long term, restoration of wetlands. Protecting potential pollution sources, such as contaminated land and wastewater treatment plants, against flooding is also eligible. The current grant level is SEK 500 million per year (personal communication with Cecilia Alfredsson, Swedish Civil Contingencies Agency, 24 March 2023).

Climate-ADAPT provides more information about the use of economic incentives for behavioural change in climate change adaptation

7 Opportunities for action

This report compiles unequivocal evidence that people's health in Europe is already threatened by floods, droughts and changes in water quality, and that more of those effects can be expected under the changing climate. The key risk assessments (EEA, 2024a; IPCC, 2022) leave no doubt that health risks will only become more pronounced in the future — unless action is taken. We therefore have to act now. The priorities for actions to reduce serious health impacts from the changing climate through water are as follows:

- Mitigating climate change. Minimising greenhouse gas emissions and phasing out fossil fuels at the global level are the most effective ways to minimise the magnitude and frequency of climate extremes and their impacts on human health.

- In parallel, lowering human exposure to existing hazards is essential to reducing health risks. This can happen through various actions, such as reducing development in areas of high flood risk, water scarcity, vulnerability to wildfire or coastal erosion, and by considering relocation from these areas. Using an effective balance of infrastructural measures (e.g. small-scale water retention, flood defence systems, advanced water treatment methods) and nature-based solutions — sustainable urban drainage systems or constructed wetlands — can reduce the scale of flooding and drought-related impacts and improve water quality. Improved information and public awareness about the health risks linked to flooding, climate-sensitive infectious diseases and harmful algal blooms are crucial for citizens to act responsibly in the face of increasing or new threats. Early warnings supported by accurate monitoring, effectively communicated to, understood and followed by responsible authorities and the public, can reduce health risks once an extreme weather event is approaching or a disease outbreak happens.

- Systematic implementation of preventative actions at scale. The examples of measures in this report protect the population against the health impacts of floods, water scarcity and worsened water quality under the changing climate and often bring wider benefits for health, including mitigation of heat stress, as well as improved environmental quality or economic benefits. However, the measures are often implemented at a small scale or ad hoc as a response to a harmful event. Europe would benefit from a more coherent and systematic implementation of measures that protect human health (Bednar-Friedl et al., 2022). A stronger focus on water safety to avoid overexploitation or pollution of water resources in agriculture and tourism could protect public health. In addition, more investments should be made in gaining knowledge on the long-term effectiveness of measures. This includes an economic cost-benefit analysis, assessment of social justice and comprehensive evaluation of co-benefits and potential trade-offs.

- Specifically in the health sector, adaptation to climate change needs to accelerate. Our health systems need to become resilient to the impacts of climate change. Ensuring that healthcare infrastructure — hospitals, clinics and supply chains — can withstand extreme weather threats is urgent and necessary to prevent cascading risks of interrupted or unavailable healthcare. A climate-savvy health workforce is the second key aspect to building climate resilience in health systems (WHO, 2023a). Developing, updating and implementing national health adaptation plans, supported by integration of health-related targets in other policies, in line with the Budapest Declaration, is advocated. Awareness-raising, education, training and capacity building activities on the links between climate change and health, accompanied by appropriate procedures in prevention, diagnosis and treatment of climate-sensitive ailments ensure that healthcare professionals can respond to climate impacts on human health as well as act as an information source for patients and decision-makers. Promoting exchange of experience and knowledge in managing crises related to climate change among health professionals from national health systems, public health, academia and other organisations would ensure better preparedness and resilience of health systems. In addition, healthcare professionals such as doctors, nurses and pharmacists are highly trusted and thus can raise awareness of the risks and solutions related to the health impacts of climate change among the public (in particular vulnerable individuals) and decision-makers.

- Making mental health a focus of policy and action. As the numbers of people whose mental health is impacted by floods or water scarcity tend to exceed those affected physically, addressing the impacts of climate extremes on mental health is urgently needed. In the aftermath of extreme weather events, providing psychosocial support can help prevent long-lasting health impacts. Mental health advice is particularly important for farmers, rural communities and people with low socio-economic status. For emergency service teams and healthcare workers, who bear the brunt of responding to the health impacts caused by extreme weather events, the mental health implications require adequate consideration. The mental health of children and young people, impacted both directly by the climate extremes they encounter and by anxiety about an uncertain future, requires adequate recognition and specific support mechanisms to prevent adverse outcomes.

- Justice in adapting to climate change and in managing increasingly scarce, unpredictable or polluted water resources must be ensured. Some groups are particularly prone to the health impacts of changed water quantity and quality under the changing climate: children, the elderly, those with existing health conditions, those on lower incomes and indigenous and rural communities. Prioritising the protection of the most vulnerable — for example by ensuring flood resilience of schools, adequate water tariffs for large households or pensioners or equitable approaches to insurance from extreme weather events — can bring substantial health and well-being gains for those directly affected and the whole of society. In addition, policy and action should focus on the occupations that emerge as particularly affected by the climate-related water risks: farmers, rescue workers and those involved in flood response and clean-up. In parallel to systematic and large-scale realisation of measures by policymakers, motivating action by citizens — water-use reduction in social solidarity actions to protect the vulnerable, moving away from risk areas — while recognising their needs and concerns empowers people and makes them part of the solution.

Both the EU and its Member States must become substantially better at preparing for and effectively addressing climate risks. At EU level, climate risks should be better considered in the governance aspects of policies, legislation and financial instruments, and in seeking synergies between EU policies and measures and their implementation (EC, 2024). While flood preparedness and water quality issues are heavily regulated by the EU, Member States are responsible for organising and delivering health services and medical care and for other topics with influence on health under the changing climate, such as spatial planning.

The first European Climate Risk Assessment (EEA, 2024a) assigns risk ownership to both EU and Member States in most areas, including health. It advocates that the EU should design financial instruments and provide additional resources to shore up climate resilience and capacity in the healthcare sector at the national level, as overall investment in many Member States' public healthcare systems is failing to keep up with the growing pressures from climate change. The EU can also exert considerable influence on spatial planning through other sectoral competences (e.g. environment) and funding instruments (e.g. Cohesion Fund) (EEA, 2024a). Finally, the EU plays a strong role via its continuing support for knowledge development and exchange — under the Horizon Europe programme, through European Missions and the LIFE programme. In addition, the European Climate and Health Observatory extending its activities from knowledge collection to capacity building among healthcare and public health communities and other stakeholders can further support sharing of knowledge.

Within Member States, clear governance structures for managing climate risks should ensure vertical and horizontal coordination between national, regional and local levels (EC, 2024a). Following up on the commitments of the Budapest Declaration (see Section 5.1) can address climate change impacts on health. These activities can be usefully complemented by revising national and sub-national laws and regulations on siting of housing, schools and hospitals, or industrial facilities in areas at risk of floods, water scarcity or wildfires, to reduce the exposure of the population to extreme weather events or pollution risks. In addition, establishing and updating regulatory requirements to ensure the climate resilience of water and sanitation services is key (EEA, 2024a). To secure drinking water supplies, development of water safety plans is advocated by WHO (2023b). This can help ensure the development of sustainable drainage systems, green roofs, rainwater retention and storage, and sewer separation. In addition, strengthening disaster risk reduction policies and early warning and surveillance systems can help prevent risks to health (EEA, 2024a). Generally, the application of the Health in All policies concept and use of Health Impact Assessment is encouraged by WHO (2024) to judge the potential health effects of any policy, programme or project on a population, particularly vulnerable or disadvantaged groups. Identifying the health impacts of various water management or climate adaptation developments can be integrated in other impact assessment procedures such as environmental impact assessments (Cave et al., 2020).

The sub-national governance level is seen as the most appropriate for the implementation of many adaptation actions, by both the EU (EC, 2021c) and the countries (EEA, 2023g). However, health is currently not a priority sector for adaptation activities at local level. At the same time, local and regional authorities tend to be responsible for spatial planning, housing, water management and other health-determining sectors, as well as being familiar with the local risks and vulnerabilities of the population (see Section 5.3). Therefore, decision-makers at sub-national level need to be urgently made aware of the health risks and provided with the appropriate technical knowledge and funding to re-centre the scope of climate adaptation to health.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Kongens Nytorv 6
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