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Water Resources Availability and Quality, and Waterborne Diseases

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Abstract:
Climate change is altering both freshwater availability and quality, with consequences for waterborne illness. This paper reviews evidence from IPCC and WHO assessments, peer-reviewed studies, and outbreak investigations. It examines changes in water supply, water quality, and disease outcomes, including cholera, typhoid, cryptosporidiosis, and diarrhoea. Warming intensifies water-cycle variability, raises flood and drought risks, can accelerate pathogen growth, and may promote harmful algal blooms. Children and communities with inadequate sanitation face the greatest risks. Climate-resilient water and sanitation systems, water safety planning, and early-warning surveillance are key responses.

Keywords: climate change, water availability, water quality, waterborne diseases, cholera, adaptation

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I. INTRODUCTION

Fresh water makes up only about 2.5% of Earth's water, and most of it is stored in ice or deep groundwater. Population growth, urbanisation, and agriculture already strain this limited supply. Climate change adds pressure: average global surface temperature in 2011-2020 was about 1.1 deg C above the 1850-1900 average, a change caused by human influence [1].

Meanwhile, billions of people still lack safely managed drinking water and sanitation, and unsafe water, sanitation and hygiene remain major causes of diarrhoeal deaths among children under five [2]. Climate change threatens to reverse recent gains.

The IPCC describes climate-related health risk as the result of three interacting factors: a hazard such as flooding, drought, or warming; the people and assets exposed to it; and their vulnerability and capacity to respond [3]. This helps explain why the same hazard can trigger a cholera outbreak in one place and little illness in another. Infrastructure, governance, and living conditions shape the outcome alongside weather.

This review examines how warming affects water availability and quality, how those changes relate to waterborne disease, and which adaptation measures can reduce risk. It is a narrative review drawing on IPCC and WHO assessments, systematic reviews, and key epidemiological studies.

II. METHODOLOGY

The review draws on three source types: IPCC and WHO assessments of climate, water, and health; systematic reviews and epidemiological studies that measure links between climate variables and waterborne disease; and documented outbreak investigations. Sources were chosen for scientific credibility, relevance to the paper's themes, and coverage of different regions.

The evidence is organised as a causal sequence: a climate hazard changes water quantity or quality; this changes exposure to pathogens or toxins; and the resulting health effects depend in part on sanitation, infrastructure, and social vulnerability.

This narrative review is not a formal meta-analysis. The included studies differ in design, location, and pathogen, so their effect sizes cannot be compared

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directly. Most disease findings are observational and show associations rather than proving causation.

III. WARMING AND WATER AVAILABILITY

A warmer atmosphere holds about 7% more water vapour per 1 deg C, which intensifies the water cycle. Wet regions and seasons tend to get heavier rain, while dry regions lose more water to evaporation. The main result is greater variability, not a uniform change in supply.

Glaciers and snowmelt. Millions of people in South Asia, Central Asia and the Andes depend on meltwater. Glacier retreat first raises river flow, then reduces dry-season flow once ice reserves shrink, and earlier snowmelt shifts peak flow away from the crop season.

Drought and water stress. Higher evaporation increases the frequency and severity of droughts in the Mediterranean, southern Africa, parts of South Asia and south-western North America [3].

Groundwater. Intense rain runs off instead of recharging aquifers, heavy pumping lowers water tables during droughts, and sea-level rise brings saltwater into coastal aquifers, as in the Ganges-Brahmaputra delta.

Floods. Heavy rain, cyclones and sea-level rise damage water and sanitation infrastructure and displace people into crowded shelters.

Warming also raises demand. Crops need more irrigation, cities use more water for cooling and domestic needs during heat, and energy production competes with agriculture and households because thermal power and hydropower both depend on water. Where supply falls while demand rises, rationing and intermittent supply become common, and households store water in containers where it can be recontaminated, so scarcity itself degrades quality at the point of use.

Projections of water availability remain uncertain at regional scale, because climate models agree far more on the direction of temperature change than on changes in rainfall. Planning should therefore favour robust measures that perform well under a range of futures rather than depend on a single forecast [3].

IV. WARMING AND WATER QUALITY

Warmer water holds less dissolved oxygen and speeds microbial and chemical processes, which weakens the self-purification capacity of rivers and lakes [4]. Four pathways are most important.

Algal blooms. Warm, nutrient-rich, stratified water favours cyanobacteria, some of which produce toxins such as microcystins that harm the liver and nervous system [5].

Storm runoff. Heavy rain washes animal waste, fertiliser and urban pollutants into water bodies, and combined sewers can overflow. Higher turbidity also reduces the effectiveness of chlorination and filtration.

Drought concentration. Low river flows dilute pollutants less, so salts, nutrients and pathogens become more concentrated, and people turn to unsafe sources.

Salinity. Sea-level rise and storm surges raise salinity in coastal drinking water, which has been linked to hypertension and pregnancy complications in places such as coastal Bangladesh.

Chemical quality is also at risk. Floods and storms can mobilise pesticides, heavy metals and industrial chemicals from soils, landfills and storage sites, and warmer, low-oxygen water can release metals and phosphorus from sediments [4].

Each pathway raises the cost and complexity of treatment. Algal blooms clog filters and require extra processes to remove toxins, and turbid water needs higher coagulant and disinfectant doses. Utilities in low-income settings often lack redundancy and are the least able to adapt, so the same hazard leaves their consumers more exposed.

V. WATERBORNE DISEASES AND CLIMATE

Waterborne diseases are caused by bacteria, viruses and protozoa transmitted mainly through contaminated water. Their climate sensitivity differs by pathogen (Table 1).

TABLE I. CLIMATE SENSITIVITY OF SELECTED WATERBORNE AND WATER-RELATED DISEASES

Disease	**Pathogen**	**Main climate sensitivity**
Cholera	Vibrio cholerae	Warm water, plankton blooms, floods
Typhoid	Salmonella Typhi	Flooding, sewage contamination
Diarrhoeal disease	E. coli, rotavirus	Temperature, heavy rain, drought
Cryptosporidiosis	Protozoan	Heavy rain, livestock runoff
Hepatitis A and E	Viruses	Flooding, poor sanitation
Leptospirosis	Bacterium	Floodwater, rodent exposure

Five mechanisms link warming to disease: faster pathogen growth in warm water [6], [7]; contamination spread by heavy rainfall and floods; reduced water for

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hygiene during drought; crowding and displacement after disasters; and ecological change in coastal and aquatic hosts. Curriero et al. [8] found that a large share of waterborne outbreaks in the United States from 1948 to 1994 followed extreme rainfall.

Systematic reviews support these links. Levy et al. [9] concluded that higher temperature, heavy rainfall, flooding and drought were each associated with more diarrhoeal disease in many settings, though effects vary with pathogen and infrastructure. Carlton et al. [10] found that heavy rainfall raised diarrhoea incidence, with the effect shaped by water source and sanitation. Baker-Austin et al. [11] showed that rising sea temperatures were expanding conditions suitable for Vibrio infections in the Baltic region. Cholera outbreaks after cyclones and floods in Mozambique, Haiti and Yemen, and post-flood surges of diarrhoea, typhoid and hepatitis in South Asia, show the same pattern where systems are weak.

A. A. Seasonality

Diarrhoeal pathogens show distinct seasonal patterns. Bacterial infections generally peak in warm and rainy periods, while some viral infections such as rotavirus peak in cooler or drier months in many regions. Seasonal patterns matter for surveillance because they show when risk is highest and why a single climate variable cannot explain all disease trends.

B. B. Water-Related Vector-Borne Diseases

Malaria and dengue are not waterborne in the strict sense, but their mosquito vectors breed in standing water, and temperature affects vector development speed and parasite incubation. Warming and altered rainfall can therefore change where and when these diseases are transmitted, adding to the burden on communities already coping with unsafe water [12].

VI. REGIONAL CASE STUDIES

The interaction of climate hazards and weak systems is clearest in regional examples.

C. A. South Asia

South Asia combines heavy dependence on glacier and monsoon water with dense populations and large sanitation gaps. Cholera in the Bay of Bengal region shows strong seasonal cycles linked to sea surface temperature, plankton blooms and flooding [6], [7]. The 2022 floods in Pakistan affected tens of millions of people and were followed, according to WHO and national reports, by increases in diarrhoea, malaria and skin infections. In coastal Bangladesh, saltwater intrusion forces households to rely on distant or unsafe sources.

D. B. Sub-Saharan Africa

Sub-Saharan Africa has the lowest coverage of safely managed drinking water of any world region [2], so climate shocks fall on a thin margin of protection. Cyclone Idai (2019) devastated central Mozambique and was followed within weeks by a cholera outbreak that required emergency vaccination. In drought-affected areas such as the Horn of Africa, scarcity pushes people toward unprotected sources and increases outbreak risk.

E. C. Europe and North America

High-income countries are not immune. In 1993 a rainfall-linked cryptosporidiosis outbreak in Milwaukee, transmitted through the public water supply, made an estimated 400,000 people ill [13]. In 2000, heavy rainfall carried livestock waste into a well in Walkerton, Ontario, causing seven deaths and about 2,300 illnesses [14]. In northern Europe, warming Baltic waters are increasing Vibrio infections [11]. These cases show that strong systems reduce risk but need to be designed for extremes.

F. D. Small Islands and Coastal Deltas

Small island states often depend on thin freshwater lenses and rainwater collection. Sea-level rise, storm surge and drought contaminate or salinise these supplies, and cyclones damage storage and sanitation. Cholera cases in Haiti rose again after Hurricane Matthew in 2016, illustrating how storms can reignite transmission where systems are fragile.

VII. VULNERABILITY AND EQUITY

Impacts are uneven. Children under five face the highest risk of dehydration and death, and repeated infections cause malnutrition and stunting. Informal settlements often lack piped water and drainage and sit on floodplains. Rural households relying on unprotected wells and ponds face high exposure, and women and girls carry most of the burden of fetching water. Coastal and small island populations face salinity and sea-level rise. Without targeted adaptation, climate change may widen existing health inequalities.

Waterborne illness also carries an economic burden. It reduces school attendance and work productivity, treatment costs push poor households further into poverty, and the time spent collecting water in scarce periods is time lost to education and income. Conflict and forced displacement compound the problem, because camps and informal settlements often have the least capacity to deliver safe water and sanitation.

VIII. ADAPTATION AND MITIGATION

Resilient WASH infrastructure. Universal safely managed water, sanitation and hygiene (Sustainable

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Development Goal 6) is the strongest buffer. Wells, latrines and treatment plants in flood-prone areas should be raised and protected.

Water safety plans. The WHO recommends risk-based planning from catchment to tap that includes climate hazards [15].

Surveillance and early warning. Linking rainfall, temperature and sea-surface data with health surveillance can trigger early action, such as stocking chlorine and oral rehydration salts.

Water resource management. Rainwater harvesting, managed aquifer recharge, watershed protection, treated wastewater reuse and efficient irrigation reduce shortages and protect quality.

Household measures and vaccines. Boiling, chlorination, safe storage and handwashing are low-cost and effective, and cholera and typhoid vaccines complement but do not replace safe water.

Mitigation. Cutting greenhouse gas emissions limits the scale of future hydrological extremes.

IX. POLICY, GOVERNANCE AND RESEARCH GAPS

Technical measures succeed only when supported by governance and finance. Climate adaptation plans should include water and health explicitly, and water, health, environment and disaster agencies need to share data and responsibilities. Investment in low-income countries remains far below what universal water and sanitation access requires, and adaptation finance should prioritise the most exposed communities. Tracking indicators over time, as the Lancet Countdown does for health and climate change, helps governments see whether protection is keeping pace with risk [16].

Several research gaps remain:

- Limited long-term surveillance data on waterborne disease in many low-income countries.
- Difficulty separating climate effects from other drivers such as population growth, land use and sanitation coverage.
- Uncertainty in regional rainfall projections, which complicates infrastructure planning.
- Too few studies of compound events, such as a heat wave followed by floods.
- Limited evidence on which adaptation measures are most cost-effective under different conditions.

X. CONCLUSION

Climate change is altering when and how much water is available, as well as its quality, through glacier loss, heavier rainfall, longer droughts, rising seas, and warmer water bodies. These shifts can increase disease risk by supporting pathogen growth, spreading contamination during floods, limiting water for hygiene in droughts, and damaging infrastructure. Children and low-income communities face the greatest burden. Priorities include reducing greenhouse-gas emissions, strengthening climate-resilient water and sanitation services, using water safety plans, and linking climate data with health surveillance. Protecting water is a direct way to protect health.

Future studies should combine local climate, hydrology, and health data, evaluate adaptation measures rigorously, and focus on the communities facing the highest risks.

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