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Original Article

Effect of Climate Change on Diarrhoea Diseases among Under-Five Children: A Scoping Review

Iddi Mapande[1], Oscar Punguti[2], Amelia Chebyala[1], Edson Protas[1], Novatus Tesha[1], Jovine Bachwenkizi[1] & January G. Msemakweli[1]*

[1] Muhimbili University of Health and Allied Sciences, P. O. Box 65015, Upanga West, Dar es Salaam, Tanzania.
[2] Mbeya University of Science and Technology, P. O. Box 131, Mbeya, Tanzania.
*Author for Correspondence Email: mapandeiddi@gmail.com

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Climate Change, Climatic Factors, Diarrhoea Diseases, Under-Five Children.

ABSTRACT

Background/ objective: Diarrhoea diseases continue to pose a serious threat to worldwide public health, especially among under-five children. This review paper aims to pool together the accessible evidence regarding the impacts of climate change on diarrhoea disease among under-five children. Methods: This review paper utilises PubMed, Scopus, and Web of Science to collect data from original articles published globally between 2010 and 2024. Initially, 150 articles were downloaded, and after screening using Rayyan software, 29 articles were selected based on eligibility criteria. The study follows the PRISMA statement as its protocol and conducts qualitative data analysis. Results: Maximum temperature and extreme rainfall were significantly associated with increased incidences of diarrhoea among those under five in 69% of the articles reviewed. Meanwhile, 31% of the publications also addressed the effects of seasonal changes and extreme events such as heat waves, droughts, and flooding on diarrhoea episodes in this age group. The reported incidence of diarrhoea among children under five ranged from 0.19% to 74.2% across different regions. Conclusions: There is a strong positive correlation between under-five diarrhoea and various meteorological factors, such as temperature and heavy rainfall, as well as extreme events (drought, flooding, cyclones, and heat waves). The findings demonstrate the urgent need for public health interventions.

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INTRODUCTION

Diarrhoea illnesses continue to be a severe global public health burden, especially for children under five years of age, posing substantial burdens on morbidity and mortality worldwide (WHO, 2014). Globally, the World Health Organization (WHO) estimated approximately 1.7 billion cases of diarrhoea illness in under-five children yearly (World Health Organization, 2023). Currently, it is the third largest cause of death in children 1–59 months of age, each year killing approximately 443,832 children under five and an additional 50,851 children aged five to nine years (WHO, 2023).

The burden is disproportionately distributed in regions with limited sanitary facilities and services, clean and safe water, and sufficient medical resources (Checkley et al., 2000). Lower- and Middle-Income countries (LMICs) bear the brunt of this burden, where socioeconomic disparities exacerbate the susceptibility of young children to diarrhoea illnesses, and deaths caused by diarrhoea among children are highest in South Asia and sub-Saharan Africa (UNICEF, 2021). Within this context, emerging data suggests that climate change is increasingly linked to the prevalence and severity of diarrhoea diseases, aggravating the issues encountered by vulnerable groups (Prüss-Ustün et al., 2014).

While numerous factors contribute to the incidence of diarrhoea, including poor sanitation, inadequate hygiene practices, and limited access to healthcare, the effects of climate change on diarrhoea diseases remain a growing concern (Watts et al., 2021). Additionally, temperature variations, precipitation regimes, and extreme weather episodes can manipulate the transmission dynamics of diarrhoea pathogens, water quality, and food security, exacerbating the risk of diarrhoea outbreaks and related health consequences (Andhikaputra et al., 2023a).

Changing climate conditions significantly exacerbate diarrhoea diseases in children, primarily through impacts on water quality and sanitation (Lee et al., 2022). The IPCC synthesis report 2023 highlights that climate-driven waterborne diseases, including diarrhoea illnesses, are projected to increase with warming, particularly in areas where temperatures rise by 1.5°C to 2°C. Furthermore, the report estimates that for every 1°C increase in ambient temperature, there is an estimated 8-11% increase in diarrhoea cases in children under five (IPCC, 2023). During the 1997–98 *El Niño* episode, the mean ambient temperature in Lima increased up to 5ºC above normal, and the number of daily admissions for diarrhoea increased to 200% of the previous rate, and the study found 57 331 children under 10 years old admitted (Checkley et al., 2000).

Although climate change is recognised as a potential factor contributing to diarrhoea diseases, a comprehensive scoping literature review has not explored the relationship between climatic variables and diarrhoea patterns in children under five. Addressing this gap is essential for shaping targeted interventions and policies to mitigate the adverse health effects of climate change on young children.

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This scoping review aims to enhance understanding of the connection between climate change and diarrhoea diseases in children under five. By thoroughly analysing existing literature, the study seeks to consolidate current knowledge on how climate variability influences diarrhoea, thereby supporting evidence-based interventions and the development of adaptive strategies to reduce its impact on child health.

METHODOLOGY

Protocol

This research study adhered to a protocol created by the PRISMA guideline, which offers criteria and recommendations for reporting systematic reviews (Page et al., 2021) to ensure that the methods and results were executed and documented systematically.

Eligibility Criteria

Inclusions

The eligibility criteria for this study were all original articles in a full text released globally from 2010 to 2024 written in English, addressing the influence of climate change and diarrhoea diseases among under-five children.

Exclusions

The research excluded all original articles that lacked any information or component related to climate change, diarrhoea disease, or under-five children. Additionally, guidelines, review articles, dissertations, observational and field reports, editorials, case studies, theoretical reflections, and conference proceedings abstracts were excluded.

Information Sources

Data sources used in this study include PubMed, Web of Science, Scopus, and through snowballing of references from fully screened pieces of literature.

Search Strategy.

The query formulation for this study encompassed labels of Medical Subject Headings (MeSH-terms) and keywords such as semi-arid, dryland, wetland, climate change, diarrhoea, acute diarrhoea, diarrhoea*, under-five children, under-five, infant, babies, and neonatal*. The Boolean AND operator was used to combine these keywords and descriptors of different concepts and OR for synonyms.

Parentheses were employed to group synonymous terms connected by the OR operator. Quotation marks were utilised for multi-word phrases, and the asterisk (*) served as a wildcard sign to expand and widen searches by capturing words starting with the same letters and variations of a keyword with minimal typing. The combination of keywords and descriptors led to the development of the following information retrieval plan :(semi-arid OR dryland OR wetland OR “climate change”)) AND (diarrhoea OR acute diarrhea OR diarrh*)) AND (under-five children OR under-five OR infant OR babies OR neonat*). The identical search strategy was applied to all information sources.

Four authors, IM, AA, EP, and OP, reviewed the citations and references of all chosen original articles to increase the review's breadth and incorporate pertinent research. The PRISMA flowchart meticulously documented the phases of identifying, screening, determining eligibility, and analysing the articles.

Data Extraction Process

Seven authors conducted the literature search, and 150 articles were downloaded, screened, and uploaded to the Rayyan software for systematic reviews. Each author read the title and abstract and was involved in the literature review. Each member independently assessed the allocated articles' titles and abstracts for eligibility during screening.

Four authors (IM, AA, EP, and OP) extracted data from the selected publications. Meanwhile, the fifth, sixth, and seventh authors (NV, JB, and JM) reviewed the discrepancies in the evaluations of the

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data and the articles. The Rayyan software helped eliminate 68 duplicate articles, and conflicts were resolved by the authors meeting and discussing the matter. The remaining articles were transferred into an electronic Google form created using Microsoft Excel, so all seven authors could read them on full screen.

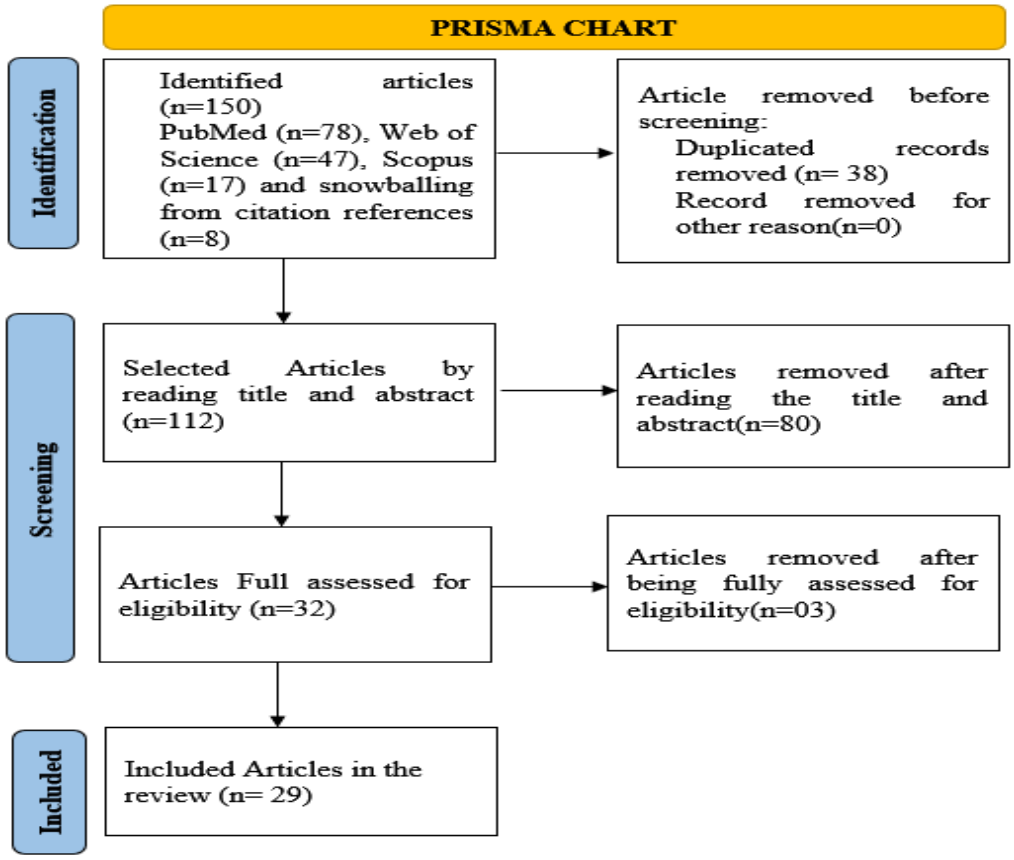
The Google Excel sheet is composed of different variables, including the research title, year of publication, journal name, authors, the country where the study was conducted, doi, the main objective of the study, study design, study population, type of study or approach used either quantitative or qualitative or both, period, study setting or place, data sources used (e.g. DHS or hospital data or Meteorological or both), statistical test used (such as a t-test, regression, etc.), the sample size used, findings reported and the research gap or conclusion from the study.

Data Analyses

Due to the high heterogeneity of data from the screened articles in terms of variety in methodological designs, a narrative technique was used to compare and evaluate the findings. This review focused on climate change issues and diarrhoea illnesses among children. Data were arranged in a table with the key results correlated with the study question and categorised into thematic areas.

150 published articles were downloaded (78 from PubMed, 47 from Web of Science, 17 from Scopus, and 8 from citation references), 68 duplicates were removed, and 112 articles were selected using Rayyan software after screening by reading the title and abstract. Thereafter, the study used 29 original articles obtained after completing the selected articles and omitted all unrelated articles based on the eligibility criteria (PRISMA Fig.1).

Figure 1: PRISMA Chart of Articles Included in the Scoping Review



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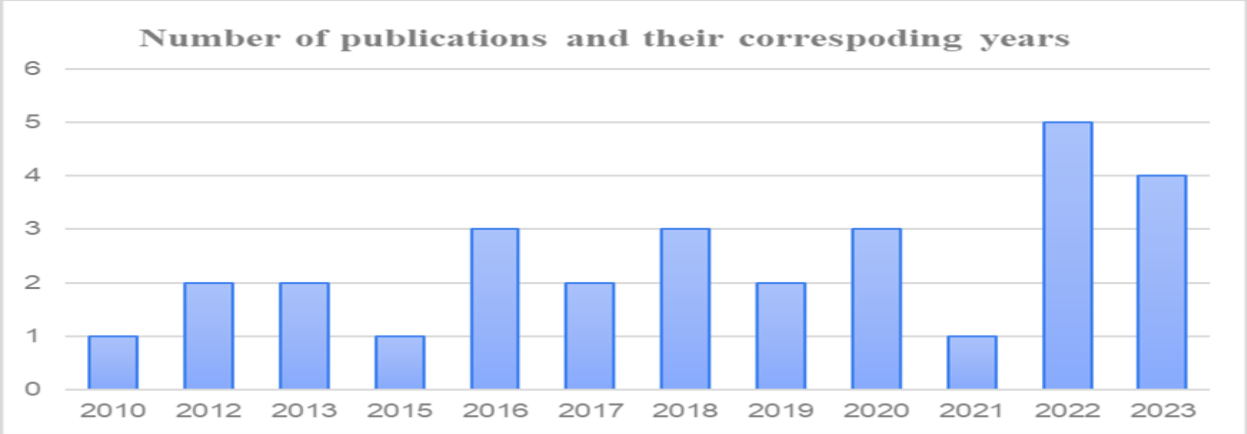
RESULTS

Number of Published Papers

The number of publications fluctuates over the years, with some having more than others. For instance, there were fewer publications in 2010, 2015, and 2021 than in other years. However, in 2022, there was a notable increase in publications. In addition, most research was undertaken in lower-middle-income countries. (See Fig2)

Figure 2: Number of Publications per Year

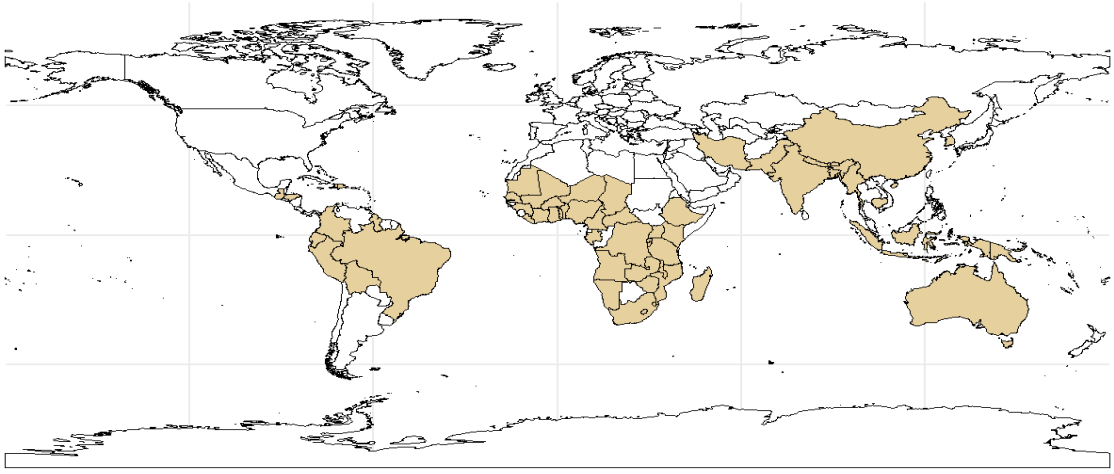


(Source: Authors own construction)

Study Setting

The study used original articles reported from countries with different income levels, from which six (n=6) studies were reported from low-income countries including Ethiopia, Rwanda, and Sub-Saharan African countries [9, 10, 11, 12, 13, 14], furthermore, eleven (n=11) studies from lower and middle-income countries including some countries in Sub-Saharan Africa, Nepal, Bangladesh, India, Solomon Island, Iran, Mauritania, and Bhutan [12, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24], while seven (n=7) studies were reported from upper-middle-income countries which were Botswana, South Africa, Brazil, China, and Ecuador [25, 26, 27, 28, 29, 30, 31] and four articles were reported from high-income countries including Korea, Australia, Taiwan, and China [32, 33, 34, 35]. (See Fig 3)

Figure 3: A Map Highlighting Countries Covered in the Literature Included in this Review



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Climatic Factors and Diarrhoea

The study revealed that the prevalence of diarrhoea among children under five ranged from 0.19% to 74.2%. Table 1 describes the included studies and follows with a narrative data synthesis. Moreover, we uncovered a significant association between rainfall, temperature, and diarrhoea cases. Approximately 69% of the reviewed articles highlighted maximum and extreme rainfall linked to increased diarrhoea cases. However, only one study indicates humidity has no relationship with diarrhoea incidences (Azage et al., 2017).

Overall, all studies indicated that every 1mm increase in rainfall and every 1 degree Celsius temperature can significantly increase diarrhoea cases. Furthermore, both developed and developing countries have been impacted by increased cases of diarrhoea due to changes in rainfall and temperature patterns. For example, in China, heavy precipitation and high temperatures are significantly reported to affect the elevated risk of viral diarrhoea infection in children, with a reported 2794 cases (Lu et al., 2021). Furthermore, Southwestern Ethiopia reported a 9.26% prevalence of diarrhoea due to rainfall and temperature being a significant risk factor of cumulative degree days (CDD) per rise in 1mm and 1°C, respectively (Alemayehu et al., 2020).

Extreme Events, Seasonal Changes and Diarrhoea

Climate change results in extreme events and changes in season; the review indicates that about 31% of the articles discussed the impact of climate change in terms of extreme events and changes in season, such as droughts, flooding, heat waves, and seasonal variations, which influencing diarrhoea cases in under-five children. In addition, many of the studies were conducted in developing countries due to the disproportionate impact of climate change. For instance, severe or mild drought exposure was significantly associated with an increased likelihood of diarrhoea of 8% or 5% (5–11%), respectively, with a prevalence of 14.40% in low- and middle-income countries (Wang et al., 2022).

Table 1: A Summarised Table of Key Findings

Descriptions	Year and Location	Key Findings	References
Climatic factors (Temperature, Rainfall , and humidity)	2016 Cape Town, South Africa	A 5℃ increase in lowest and maximum temperatures leads to a 40% and 32% increase in diarrhoea cases, respectively, with a prevalence rate of 8.60%. (IRR 1.39 and 1.31 for Min and max temp, respectively)	(Musengimana et al., 2016)
	2022 Sub Saharan Africa (SSA)	Prevalence was 6.7%, and Residents of a region exhibiting frequent episodes of diarrhoea were 1.567 times more likely to experience diarrhoea, while average temperature increase and rainfall had more influence on cases of diarrhoea (IRR 1.067 for 1>℃ and 1.006 for 1mm increase)	(Kemajou, 2022)
	2023 North, Chumiao, Central, Yunchianan,	Extreme heat and precipitation were the related risks of morbidity of all diarrhoea cases among those under-fives with 2266	(Andhikaputra et al., 2023b)

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Descriptions	Year and Location	Key Findings	References
	Kaoping, and Huatung Regions Taiwan.	cases per week (RR=1.44, 1.07, 2.77, and 1.08 for extremely low temperature (15.30°C), high temperature (30.18°C), high precipitation (290mm) and low precipitation (0mm) respectively.	
	2013 Brisbane, Australia	Diurnal temperature ranges were statistically significant with childhood diarrhoea, with a 3.00% prevalence.	(Xu et al., 2013)
	2022 Iran	Temperature showed a consistent positive association with seasonal under-five acute watery diarrhoea (U5AWD), with the prevalence ranging from 0.4761% to 1.9184% (IRR=1.0497)	(Masinaei, 2022)
	2010 Subtropical Taiwan	1,212,621 cases were reported, while the maximum temperature and extreme rainfall days strongly related to diarrhoea-associated morbidity	(Chou et al., 2010)
	2018 Korea	The yearly rate of incidence was 7.9 cases/million people, and it is projected to rise with a 1°C increase in temperatures and a 1 mm increase in indicated precipitation.	(Song et al., 2018)
	2023 Bangladesh	1°C rise in maximum temperature increased diarrhoea hospitalisations by 4.6%, with 0.19% prevalence (IRR=1.046).	(Rahaman et al., 2023)
	2017 Zones of Amhara, Ethiopia	CDD was prevalent at 1.14%, and the incidence rate was significantly associated with monthly typical rainfall and temperature but negatively with humidity.	(Azage et al., 2017)
	2020 Bench Maji Zone-Southwestern Ethiopia	9.26% prevalence was reported, with rainfall and temperature being a significant risk factor of Cumulative degree days (CDD) per rise in 1mm and 1°C respectively (RR=1.1666; 95% CI: per rise in 1°C and 1.00167; 95% CI: per rise in 1 mm	(Alemayehu et al., 2020)
	2020 Kathmandu, Nepal	7.5% and 1286 cases per month were reported, while the monthly count of diarrhoea cases was raised by 8.1% (RR=1.081; 95% CI: per increase in 1°C	(Bhandari et al., 2020)

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Descriptions	Year and Location	Key Findings	References
		temperature and 1.009; 95% CI) for every 10mm increase in rainfall.	
	2021 Jilin Province, China	Heavy precipitation and high temperatures are significantly reported to affect the elevated risk of viral diarrhoea infection in children, with 2794 cases reported.	(Lu et al., 2021)
	2017 Bhutan	A 74.20% prevalence rate was reported, with an incidence increase for every degree increase in maximum temperature and for a 1mm increase in rainfall.	(Wangdi & Clements, 2017)
	2022 Kersa, Ethiopia	Diarrhoea was prevalent at 17.2%, while average rainfall was an associated factor. (IRR range from 1.49 to 1.77)-	(Mengistie et al., 2022)
	2019 Rural Tamil Nadu, India	Diarrhoea prevalence was 11.10%, and incidences were much higher during torrential rainfall periods following a 60-day drought stretch.	(Mertens et al., 2019)
	2013 Villages of Matlab, Bangladesh	16,551 cases were reported, and the rise in the number of hot and heavy-rain days was an associated factor for an increase in the risk of CDD by 1–3% and 1.3–5.3%, respectively	(Wu et al., 2014)
Extreme events (Drought, Flooding, Heat waves, and Cyclones)	2022 Low and middle-income countries	Severe or mild drought exposure was significantly associated with an increased likelihood of diarrhoea of 8% or 5% (5–11%), respectively, with a prevalence of 14.40% (RR 1.11 (95% CI: 1.08–1.14) and 1.07 (95% (CI): 1.05–1.09), respectively.	(Wang et al., 2022)
	2018 Matlab, Bangladesh	Heat waves increase the chances of cholera while being influenced by rain and tree cover. (OR=l.53, 95% CI: 1.07-2.19) on wet days and for houses with fewer medium-dense tree cover (OR=1.80, 95% CI: 1.01-3.22).	(Wu et al., 2014)
	2015 Guangdong Province, China	Diarrhoea infections, instead of typhoid, cholera, dysentery, and paratyphoid, significantly spiked following tropical cyclones (HRs = 1.95, 95% CI = 1.22, 3.12).	(Kang et al., 2015)
	2016	Diarrhoea outbreaks occurred in both flood-affected and provinces unaffected	(Jones et al., 2016)

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Descriptions	Year and Location	Key Findings	References
	Honiara, Solomon Islands	by tropical depression and flooding with a reported 32% prevalence (RR 2.90, (95% CI 2.13–3.96)	
Seasons (Dry, Wet, Summer, Rain, Spring, and winter)	2018 Chobe, Botswana	The overall prevalence of diarrhoea occurrence was 1022, with greater rates recorded during dry and rainy seasons. Moreover, a 10-mm rise in rainfall was related to an estimated 6.5% increase in instances.	(Alexander et al., 2018)
	2020 Esmeraldas Province, Ecuador	61.40% prevalence of diarrhoea was reported, while preceding dry conditions emerged as the predominant risk factor, contrasting with wet conditions.	(Deshpande et al., 2020)
	2012 Kaédi, southern Mauritania	Diarrhoea was highly prevalent during dry seasons, with a 35% prevalence.	(Touray et al., 2012)
	2012 Sub Saharan Africa (SSA)	The risk of under-five diarrhoea increases due to the shortage of rainfall during the dry season, with a prevalence of 22.9%.	(Bandyopadhyay et al., 2012)
	2019 Mopani, South Africa	8885 Under-five diarrhoea cases were reported, greatly attributed to extremely dry, hot, and wetter conditions than usual.	(Ikeda et al., 2019)
	2022 Nepal	11.63% increase in diarrhoea cases during summer seasons and 14.5% decrease during spring compared to the winter season); meanwhile, the repercussions of rainfall and temperature were most substantial in the mountain zone compared to other geographical areas.	(Dhimal et al., 2022)
Others (Runoff and Sanitation)	2023 Teresina, Brazil	The average under-five diarrhoea hospitalisation rate was higher in the semi-arid macro-region, with a 3.66% prevalence.	(da Costa et al., 2023)
	2016 Rwanda	Elevated runoff levels were associated with lower rates of diarrhoea than reduced runoff, with a reported prevalence of 13.20% (OR = 0.54).	(Mukabutera et al., 2016)
	2023 Fragile states	Essential water services and safely managed water services were moderators on under-five diarrhoea mortality with a 0.05% death rate.	(Al Wazni et al., 2023)

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DISCUSSION

The study found that the global prevalence of under-five diarrhoea ranges from 0.19% to 74.2%. This indicates that diarrhoea in children is significantly variable depending on multiple factors, while climate change is a triggering factor. The wide range in prevalence reflects the significant differences in climate impacts across various regions. However, areas heavily affected by climate change experience more extreme weather events, which exacerbate conditions, leading to higher rates of under-five diarrhoea.

Perhaps not surprisingly, all seasons of the year, ranging from summer, winter, and spring (dry and wet seasons), were significantly revealed to be associated with a more significant global incidence of under-five diarrhoea diseases [25, 26, 31]. Furthermore, regions with frequent flooding and extreme drought were reported to be risk factors for increasing diarrhoea incidences in under-five children (Jones et al., 2016). Similar to the study by Karen Levy in 2016, positive correlations between under-five diarrhoea diseases and ambient temperature were reported. Except for diarrhoea caused by viral agents and an increase in diarrhoea disease after flooding and substantial rainfall events, there is insufficient proof for evaluating the effect of drought on under-five diarrhoea (Levy et al., 2017).

Under-five diarrhoea is ubiquitous, including in developed countries (Bandyopadhyay et al., 2012); however, not only in climatic regions perceived as high risk for diarrhoea, such as sub-Saharan countries. Under-five diarrhoea is a problem even in developed countries with good WASH services due to the variation in current global climatic conditions [32, 33]. However, most cases have been reported from developing countries leading to under-five morbidity and mortality, caused by less resilience to climate impacts due to inadequate infrastructure and resources [10, 11, 14, 26]. Similar findings were reported by (Idham Malik, 2021), which identified all countries in the world as being at risk of the effects of climate change among under-five children. Developing countries must prepare and take steps to prevent seasonal diarrhoea due to climate change and health information to lessen the incidence of diarrhoea worldwide.

Several articles [12, 27, 34] document that elevated or any seasonal change of temperatures can accelerate and promote the incubation period, growth, development, and spread of microorganisms (pathogens). Furthermore, it was reported that infective parasites, protozoa, bacteria, and viruses in water and food increase the risk of diarrhoea transmission, which is fast and widespread, with under-five children being the most susceptible group. Also, prolonged heat can deteriorate food and water quality, facilitating transmission of diarrhoea disease (Wang et al., 2022). Consistent with the study by (Idham Malik, 2021), environmental factors, including prolonged temperature, can influence the survival of resistant microorganisms like *Shigella species* and *Escherichia coli*, increasing diarrhoea disease burden. Reviewed articles reported increased flooding in most areas due to extreme weather events contaminating water supplies with pathogens, leading to higher rates of under-five diarrhoea diseases. Consistent with the findings by (Jones et al., 2016), reported flooding invented a national epidemic of diarrhoea that subsequently spread to areas unaffected by floods causing over 6,000 under-five cases of diarrhoea with 27 fatalities, while rotavirus was identified in 38% of case-patients examined in the city.

Heavy rains from various regions due to climate change are reported to overwhelm sanitation systems (Lu et al., 2021), leading to sewage overflow and drinking water contamination. Heavy rainfall can introduce disease pathogens brought by surface running water from poor sanitation, contaminating water sources and supplies (Alemayehu et al., 2020). Irregular or unpredictable rainfall patterns sometimes disrupt agricultural practices, affecting food security and nutrition,

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crucial for preventing diarrhoea diseases (Bandyopadhyay et al., 2012). Similarly, the study by (Deshpande et al., 2020) reported high under-five diarrhoea incidence in rural areas, especially during heavy rainfall seasons triggered by faecal accumulation and contamination during dry seasons, followed by flushing effects during heavy rainfall events.

On the other hand, people displaced by climate-related events, including floods and drought, often move to overcrowded areas with inadequate sanitation facilities, increasing the risk of under-five diarrhoea diseases. Similar to the study reported by (Wang et al., 2022), identified long-term exposure to severe droughts was significantly linked with an increased under-five diarrhoea risk. However, the association was much stronger among children living in a household that needed more time to collect water or had no access to water or detergent for hand washing—suggesting that the risk could be minimised through improved sanitation, water, and hygiene practices, which are made more crucial and urgent by a likely spike in droughts attributed to a change in climatic conditions.

Further environmental causes like increased rainfall cause floods, which may lead to a rise in viral or bacterial contamination from unfavourable conditions combined with flooding. Similar to the findings by (Alum et al., 2014), the impact of environmental factors on the survival of parasites that cause diarrhoea disease was reported. The movement of disease-transmitting organisms can be influenced by fluctuations in rainfall seasons, which can contaminate water supplies by allowing human and animal waste to seep into groundwater. *Giardia lamblia*, *Cryptosporidium, Shigella, and Escherichia coli* are among the microbes that can cause illnesses like diarrhoea found in faeces (Alum et al., 2014).

Evidence from the reviewed articles reported that there would be less rain or perhaps none during dry conditions, which can affect the availability of safe and clean water and increase the risk of illnesses linked to hygiene-like diarrhoea. People's behaviour, particularly when it comes to washing hands before eating or using clean utensils, will also be lessened, reducing the chance of microorganisms that cause diarrhoea to contaminate their bodies and cause diseases. In most cases, extreme drought conditions reduce water availability, which forces the populations to use unsafe water sources which can sometimes be contaminated, leading to higher rates of diarrhoea diseases, especially in children, consistent with the data reported by B. Mengistie where he identified the high diarrhoea prevalence among children under five years of age while diarrhoea was also predicted by lower daily per capita water use and consumption, sharing sources of water with animals, and domestic water treatment practices among people living in the mid-and lowlands (Mengistie et al., 2022).

Contrary to the study conducted by R. Moreira, which identified temperature as the primary weather factor, also reported that, even though studies demonstrated that certain climate conditions appear more promising for the incidences of respiratory and vector-borne illnesses, little is known about how seasonal patterns affect the onset, progression, and end of CSDs, particularly gastrointestinal disorders. In addition, little is known about how droughts affect CSDs (Moreira & Costa, 2020).

The primary anticipated health effects of climate change are projected impacts on hydrological systems and waterborne enteric illnesses. It is crucial to comprehend how meteorological phenomena affect enteric and diarrhoea diseases because even small corresponding increases in risk for diarrhoea can significantly impact the global under-five disease burden. In addition, according to research by F. Jones, diarrhoea may interfere with children under five years old's growth and intellectual development and make them more susceptible to subsequent chronic and infectious diseases. It can also make people more vulnerable to the effects of climate change on an individual and community level (Jones et al., 2016).

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Therefore, the impact of meteorological conditions on diarrhoea diseases is determined by social and biophysical phenomena, as the scoping review of the literature clarifies. Furthermore, the extent to which a child under-five experiences health effects from meteorological conditions relies not merely on the graveness of the meteorological exposure but also on variables, including access to healthcare, infrastructure for water and sanitation, and the availability of resources for intervention to prevent increased disease burden. This study additionally reveals that high temperatures, intense rainfall, and flooding can affect the incidence of under-five diarrhoea infections, even in affluent nations with upgraded water and sanitation systems [22, 29, 32, 33]

Theoretical Implications of the Study

Theoretical implications of this review include improved comprehension of disease dynamics. This will deepen the understanding of how climate change influences the incidence and distribution of under-five diarrhoea diseases, potentially improving the accuracy of disease outbreak prediction models for more reliable forecasting and early warning systems. Additionally, understanding the interactions between climate change variables and the pathogens causing diarrhoea could improve the theoretical frameworks for disease transmission.

Practical Implications

The findings of this study clarify the effects of climate change, which can help develop focused public health interventions and strategies. Examples include increasing sanitation efforts during high-risk periods and more efficiently allocating resources, focusing on times and areas where diarrhoea diseases are more likely to occur. However, legislators can create health policies that are perceptive to climate change, preparing for and reducing the effects of climate variability and the severe burden of diarrhoea illnesses in under-fives.

Unexpected Results

In some high-income countries, including Korea, Australia, Taiwan, and China, unexpected under-five diarrhoea cases are reported as associated with climatic factors despite well-improved WASH services, practices, and infrastructures (Andhikaputra et al., 2023b; Chou et al., 2010; Song et al., 2018). Some studies revealed non-linear relationships where diarrhoea disease incidence only increased beyond specific climatic thresholds, including extreme heat waves or heavy rainfall, suggesting that moderate changes in climate might not significantly impact disease rates (Chou et al., 2010; Lu et al., 2021; Wu et al., 2014).

Study Strength

A review study focused solely on under-five children, as this demographic is particularly vulnerable to diarrhoea diseases compared to other age groups. This targeted approach is essential for developing interventions to protect children, mainly due to climate variables such as rainfall, drought, temperature, and flooding. By considering these factors, interventions can be tailored to mitigate the effects of environmental changes during both wet and dry seasons.

Moreover, employing multiple approaches in studying the relationship between climate change and diarrhoea disease in under-five children allows for a broader range of scientific findings. This comprehensive approach enhances the grasp of the multifaceted relationships between climate variables and diarrhoea diseases, thereby facilitating the development of more effective preventive measures and interventions. In addition, these results support the development of early warning systems by scientists and researchers that can identify changes in climate factors associated with diarrhoea illness.

Study Limitations

The review was restricted to articles written in English, which may have reduced the breadth of the reports we could gather on these exposures. In addition, out of 150 articles, only 29 were included

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because the titles and abstracts revealed that the association between climatic exposure and diarrhoea for children under five was not investigated. Second, no qualitative research was gathered or considered; only quantitative studies were used and published from 2010 up to 2024. Last, most of the research in Africa has been generalised to regions such as Sub-Saharan Africa (SSA), which comprises several countries. Since the results of these studies are frequently extrapolated to the entire region, this wider reach may impact the veracity of data unique to individual countries.

Future Directions

The assessment of the relationships between climatic factors and under-five children's diarrhoea diseases suggests intricate causal chains. While more studies evaluating climatic exposure to disease associations serve as an indispensable preliminary step, cohort studies of under-five children in different climatic regions should be established to assess the long-term health impacts and resilience factors. Meanwhile, there is a need to investigate the specific mechanisms by which different diarrhoea pathogens (e.g. rotavirus, *E. coli*) respond to climatic variables by providing a detailed understanding of pathogens' ecology. Nevertheless, there is also a need to invest in sustainable water, sanitation, and hygiene (WASH) infrastructures that can withstand climatic extremes and reduce the risk of under-five diarrhoea diseases, as studies reported incidence of Under-five diarrhoea even in developed countries with good WASH services.

CONCLUSION

This review underscores the considerable effects of climate change on diarrhoea diseases for children under five years old. Examining 29 rigorously selected studies reveals a notable connection between climatic variables, especially extreme temperature and rainfall, with diarrhoea cases in this susceptible population. These findings highlight the critical demand and need for public health strategies considering climatic factors contributing to diarrhoea diseases. By combining climate adaptation initiatives with health interventions, policymakers can more effectively protect young children from the worsening impacts of climate change on diarrhoea illness and death rates. Future studies should concentrate on region-specific effects and the development of effective mitigation strategies to improve resilience against climate-related health challenges for young children.

Ethics Statement

This scoping review used publicly available data and did not involve human participants; thus, ethical approval was not required.

Author Contributions

Iddi Mapande: Conceptualization, Data curation, writing-original draft, Review & Editing. **Oscar Punguti**: Data curation and Methodology - Review & Editing. **Amelia Alfred**: Conceptualization and Data curation. **Edson Protas**: Data curation, Formal analysis and visualisation. **Novatus Tesha**: Conceptualization and writing-original draft **Jovine Bachwenkizi** provided supervision and reviewed the final draft. **January Msemakweli**: Formal analysis and visualisation.

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Not Applicable.

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During the preparation of this work, the author(s) used Grammarly in order to improve grammar and clarity. After using this tool/service, the author(s)

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