

## Literature Review

# Climate Change and Its Emerging Impact on Pediatric Gastrointestinal Infections in Indonesia – A Review Article

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e-ISSN: 2830-5442

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**Published:**

31<sup>st</sup> August 2025

**DOI:**

<https://doi.org/10.58427/apghn.4.3.2025.151-157>

**Citation:**

Yanni DAP, Akbar RR. Climate change and its emerging impact on pediatric gastrointestinal infections in Indonesia. *Arch Pediatr Gastr Hepatol Nutr*. 2025;4(3): 151-157

**Abstract:**

**Background:** Pediatric gastrointestinal (GI) infections remain a major public health issue in Indonesia, particularly among children under five. These infections are closely linked to poor sanitation, unsafe water, malnutrition, and inadequate healthcare access. Climate change has intensified these challenges, with rising temperatures, floods, and droughts increasingly influencing disease patterns. Despite this growing threat, limited research has explored how environmental changes specifically impact pediatric GI infections in Indonesia.

**Discussion:** Climate change acts as a multiplier of risk for GI infections by disrupting water and sanitation systems, affecting food safety, and limiting hygiene practices. Floods often contaminate drinking water, while extreme heat enhances pathogen survival in food and water. Droughts reduce water availability, limiting handwashing and sanitation. These environmental stressors disproportionately affect vulnerable populations, especially children living in poverty or disaster-prone areas. In addition, climate-related events often disrupt healthcare services and contribute to malnutrition, further increasing children's susceptibility to infections. However, Indonesia's health and climate policies remain fragmented. There is a lack of integrated research, limited disease surveillance, and insufficient public health preparedness that specifically addresses pediatric needs in a changing climate.

**Conclusion:** To address the growing threat of climate-sensitive pediatric GI infections, Indonesia must strengthen its surveillance systems, invest in climate-resilient health infrastructure, and integrate environmental risks into child health strategies. A coordinated, multisectoral response that prioritizes vulnerable children is essential to reduce disease burden and improve health outcomes in the face of climate change.

**Keywords:** climate change, gastrointestinal infection, indonesia, surveillance

## Introduction

Pediatric GI infections, including diarrhea, typhoid fever, cholera, and hepatitis A, remain leading causes of morbidity and mortality among children in Indonesia, particularly in children under five.<sup>1, 2</sup> These infections are closely linked to poor sanitation, unsafe water, and limited access to healthcare, conditions that are prevalent in many parts of the country.<sup>3, 4</sup> According to the Indonesian Ministry of Health, diarrhea accounts for a significant proportion of childhood hospitalizations and deaths, up to 3.9% under one and 5.2% under four.<sup>5</sup> Importantly, the prevalence of these diseases tends to rise following extreme weather events, such as floods and prolonged droughts, or other natural hazards,<sup>6</sup> suggesting a potential link between climate variability and infectious disease outbreaks.<sup>3</sup>

Indonesia is one of the world's most climate-vulnerable countries, with its extensive coastline, high population density, and diverse ecosystems making it particularly susceptible to the effects of climate change.<sup>7</sup> In recent years, the country has experienced an increase in the frequency and intensity of natural disasters, including floods, droughts, and tropical storms.<sup>6</sup> These events can directly impact water quality, sanitation infrastructure, and food security, conditions that are strongly associated with increased risk of GI infections in children. For example, flooding often leads to contamination of drinking water sources,<sup>8</sup> while drought limits water availability for hygiene practices, both of which can elevate disease transmission in pediatric populations.<sup>9</sup>

Understanding how climate change affects pediatric gastrointestinal infections is crucial for informing health policy, enhancing healthcare systems, and developing early warning strategies in Indonesia. Children are especially vulnerable due to their developing immune systems and reliance on adults for care and hygiene.<sup>10</sup> This literature review aims to explore the emerging connections between climate change and the burden of pediatric GI infections in Indonesia, identify knowledge gaps, and highlight opportunities for targeted interventions in public health and climate adaptation planning.

## Methodology

This narrative review synthesized literature published between 2020 and 2025 on the impact of climate change on pediatric GI infections in Indonesia. Relevant articles were identified through searches in PubMed, Scopus, Google Scholar, and direct searches via Google, as well as national data sources such as Ministry of Health reports, WHO publications, and disaster databases. Eligible sources included studies or reports focusing on pediatric populations in Indonesia that addressed GI infections in relation to climate variability or environmental change. Articles unrelated to Indonesia, focusing solely on adults, or lacking relevant epidemiological or

environmental context were excluded. The selected literature was narratively synthesized to describe epidemiological patterns, climate-related transmission pathways, and research and policy gaps.

## Pediatric Gastrointestinal Infections in Indonesia

In the Indonesian context, pediatric GI infections exhibit marked seasonal and geographic variation, with higher incidence rates commonly observed during the rainy season and in flood-prone or low-income regions. For example, a study in South Kalimantan found statistically significant associations between rainfall, temperature, and diarrhea incidence in children under five.<sup>11</sup> Surveillance data show a consistent rise in outpatient visits and hospitalizations for acute diarrhea, particularly in provinces with limited access to piped water and poor sanitation coverage.<sup>12,13</sup> Urban slums and rural communities face overlapping risk factors, including unsafe drinking water, poor food hygiene, and overcrowded living conditions, which facilitate the transmission of GI pathogens.<sup>2</sup>

Rotavirus remains one of the most frequently detected viruses in stool specimens from children with diarrhea, despite the availability of a vaccine.<sup>14,15</sup> Meanwhile, bacterial infections caused by *Enterotoxigenic E. coli* (ETEC), *Shigella*, and *Salmonella* continue to be reported across healthcare facilities.<sup>15</sup> A study by Puspendari et al. found that around 68% diarrhea cases are viral infection, with 54% cases are due to Rotavirus, followed by less than 10% cases caused by ETEC, *Shigella*, and *Campylobacter jejuni*.<sup>15</sup> In some coastal areas, outbreaks of cholera and hepatitis A have been linked to contaminated water following extreme weather events, highlighting the environmental sensitivity of these diseases.<sup>16</sup>

Socio-economic determinants also shape the persistence of these infections. Household-level practices such as improper food handling, inadequate handwashing, and reliance on non-treated water sources remain prevalent.<sup>17,18</sup> Moreover, fragmented health service delivery, vaccine hesitancy, and limited laboratory capacity for pathogen-specific diagnostics pose significant barriers to timely diagnosis and treatment.<sup>19</sup> Malnutrition, particularly among children under five, further complicates disease management by increasing susceptibility and prolonging recovery.<sup>18</sup>

When considered alongside the intensifying effects of climate change, these conditions reinforce the need for a targeted, multisectoral approach to control and prevent pediatric GI infections across Indonesia's diverse regions.

## Climate-Driven Pathways of Infection

Climate change is increasingly influencing the transmission patterns of pediatric GI infections in Indonesia. Rising temperatures, unpredictable rainfall, floods, and prolonged droughts directly impact water quality, sanitation, and hygiene, critical

factors in the spread of GI diseases. Children are especially vulnerable due to their developing immune systems and frequent contact with contaminated environments such as floodwater, unclean food, or poor sanitation facilities.<sup>3, 8, 9</sup> A study by Dharmayanti et al. found that climate variables play a significant role in children's diarrhea incidence.<sup>11</sup>

Flooding, which has become more frequent in lowland and urban areas, often overwhelms sanitation systems and contaminates drinking water supplies. This leads to increased exposure to pathogens such as *E. coli*, *Shigella*, and *Salmonella*, especially in children who are more likely to play in or consume unsafe water. In coastal and island communities, saltwater intrusion caused by rising sea levels also compromises freshwater sources, pushing families to rely on unsafe alternatives.<sup>2, 15, 16</sup>

Meanwhile, extreme heat can increase the survival and replication of bacteria and viruses in food and water, particularly in households lacking refrigeration or safe storage. Droughts, on the other hand, limit water availability, reducing hygiene practices like handwashing and food rinsing. These environmental stressors worsen in areas already struggling with poor infrastructure, high poverty, and limited public health services.<sup>3, 17, 18</sup>

Moreover, climate-related disasters often disrupt healthcare access. Post-disaster periods frequently see spikes in diarrhea and other GI diseases, but health systems may be ill-prepared to handle such outbreaks. Temporary shelters often lack adequate sanitation, clean water, and child-specific care, creating hotspots for disease transmission. Surveillance systems may miss early signs due to weak coordination between the environmental and health sectors.<sup>2, 20</sup>

Additionally, climate change impacts food security, which in turn contributes to a higher risk of infection. Malnutrition compromises immune function, making children more susceptible to infections and slowing recovery. Studies in Indonesia have shown that undernourished children are more likely to suffer severe and prolonged bouts of diarrhea following exposure to waterborne pathogens.<sup>21</sup>

Despite the growing evidence, climate-health links in Indonesia are not yet fully incorporated into pediatric infection control programs. Most responses remain reactive rather than preventive. Understanding these pathways is crucial not just for responding to outbreaks but also for planning climate-resilient health systems that protect vulnerable children amid a changing environment.

## Research and Policy Gap

Indonesia still lacks integrated research and policy frameworks that connect environmental risks with child health outcomes. Most surveillance systems are

fragmented and reactive, making it difficult to predict or prevent outbreaks.<sup>22</sup> Few studies specifically examine how climate-related events, like floods or droughts, affect GI infection patterns in children.<sup>3, 8, 9, 20, 21</sup> Existing research often focuses on adults, overlooks regional disparities, or lacks long-term data. As a result, children's unique vulnerabilities—such as weaker immunity and high exposure to contaminated environments—remain underrepresented in national health strategies. On the policy side, health and climate programs are still treated as separate domains. Initiatives like the *Rencana Aksi Nasional Adaptasi Perubahan Iklim*/National Action Plan for Climate Change Adaptation (RAN-API) rarely address pediatric-specific health threats.<sup>23</sup> Meanwhile, public health measures such as rotavirus vaccination, clean water infrastructure, and hygiene promotion remain inconsistently implemented across provinces. Limited investment in laboratory diagnostics, behavior change programs, and early warning systems further hinders a timely response.

Addressing these gaps requires a coordinated approach that integrates health, environmental, and disaster management policies while placing children's needs at the center of climate adaptation and public health planning. Policy priorities should include incorporating pediatric-specific climate–health risk assessments into national adaptation strategies such as the RAN-API, mandating climate-resilient Water, Sanitation, and Hygiene (WASH) infrastructure in schools, health centers, and community shelters, and expanding rotavirus vaccination coverage with priority for flood-prone and high-incidence provinces. On the research front, longitudinal surveillance linking district-level climate variables with pediatric GI infection trends is essential to enable earlier detection and targeted interventions. Operational research on affordable, climate-resilient water purification and storage systems suitable for rural and peri-urban households, as well as the development of predictive models that combine meteorological forecasts with health surveillance data, will further strengthen the country's capacity to prevent climate-triggered outbreaks. These efforts, if implemented in a coordinated manner, can help reduce the burden of pediatric GI infections and build long-term resilience against the health impacts of climate change in Indonesia.

## Conclusion

Pediatric gastrointestinal infections in Indonesia remain a significant public health concern, increasingly shaped by climate-related factors such as floods, heat waves, and poor water quality. Children are especially vulnerable due to their biology, environment, and nutritional status. Yet, existing research and policy frameworks often overlook the intersection of climate change and child health. To reduce disease burden, Indonesia must strengthen surveillance systems, invest in climate-resilient infrastructure, and integrate health with environmental planning. A multisectoral

approach that prioritizes children's needs is essential to build long-term resilience and ensure healthier outcomes in an era of growing climate uncertainty.

## Acknowledgement

The authors have no acknowledgments to declare

## Conflict of Interest

None declared.

## Funding Statement

The authors received no specific grant from any funding agency in the public, commercial, or not-profit sectors.

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