October – December, 2025
Original Article
DOI: http://dx.doi.org/10.30867/action.v10i4.2901

AcTion: Aceh Nutrition Journal
Pages: 1046 – 1057 | p-issn 2527-3310; e-issn 2548-5741

Determinants of environmental health factors associated with the risk of stunting among children under five in North Aceh District

Determinasi faktor kesehatan lingkungan terhadap risiko stunting pada balita di Kabupaten Aceh Utara

Ibrahim[1*], Safwan[2], Safridha Kemala Putri[3], T. Khairul Fadjri[4]

[1] Department of Environmental Health, Poltekkes Kemenkes Aceh, Aceh, Indonesia.
E-mail: Ibrahimbram29@gmail.com
[2] Department of Medical Laboratory Technology, Poltekkes Kemenkes Aceh, Aceh, Indonesia.
E-mail: safwankumbang@gmail.com
[3] Department of Medical Laboratory Technology, Poltekkes Kemenkes Aceh, Aceh, Indonesia.
E-mail: safridhakputri@gmail.com
[4] Department of Nutrition, Poltekkes Kemenkes Aceh, Aceh, Indonesia.
E-mail: teukufadjri@gmail.com

***Correspondence Author:**
Department of Environmental Health, Poltekkes Kemenkes Aceh, Soekarno-Hatta Street, Kampus Terpadu Poltekkes Aceh, Lagang, Lampeuneurut Subdistrict, Aceh Besar 23352, Aceh, Indonesia.
Email: Ibrahimbram29@gmail.com

Article History:
Received: October 01, 2025; Revised: November 02, 2025; Accepted: November 18, 2025; Published: December 14, 2025.

Publisher:
Politeknik Kesehatan Aceh
Kementerian Kesehatan RI

Abstract

Stunting among children under five years of age remains a major public health concern and reflects long-term nutritional deficiencies, often linked to poor environmental health conditions. The North Aceh District reports a stunting prevalence higher than the provincial and national averages, indicating a critical research gap regarding the environmental determinants contributing to this burden in the region. This study aimed to analyze the association between environmental health factors and the risk of stunting among children under five years of age in North Aceh District. This quantitative cross-sectional study was conducted from April to August 2025 in the working areas of the Simpang Keramat and Kuta Makmur Public Health Centers. A total of 90 children under five were selected through purposive sampling. Data were collected using structured questionnaires and through direct observations. Instrument validity and reliability were assessed prior to data collection. Statistical analyses were performed using the chi-square test. The prevalence of stunting among children under five years of age was 54.4%. Significant associations were found between stunting and clean water availability (OR = 4.8; $p < 0.001$), latrine availability (OR = 5.1; $p = 0.002$), waste management practices (OR = 8.5; $p < 0.001$), household waste disposal (OR = 4.9; $p < 0.001$), and the presence of helminth eggs in feces (OR = 5.0; $p = 0.001$). Overall, inadequate household waste management was the strongest environmental determinant of child stunting. In conclusion, environmental sanitation conditions, particularly household waste management, play a substantial role in the risk of stunting in children under five years of age. Strengthening community-based sanitation interventions and improving household waste management practices may effectively reduce infection-related risks and lower the prevalence of stunting in North Aceh District.

Keywords: Environmental Health, Growth Disorders, Child, Preschool, Sanitation, Risk Factors

Abstrak

Stunting pada anak balita masih menjadi masalah kesehatan masyarakat yang serius dan mencerminkan kondisi kekurangan gizi kronis yang sering berkaitan dengan lingkungan kesehatan yang kurang memadai. Kabupaten Aceh Utara dilaporkan memiliki prevalensi stunting yang lebih tinggi dibandingkan rata-rata provinsi maupun nasional, menunjukkan adanya kesenjangan penelitian penting mengenai faktor-faktor lingkungan yang berkontribusi terhadap tingginya angka stunting tersebut. Penelitian ini bertujuan untuk menganalisis hubungan antara faktor-faktor kesehatan lingkungan dan risiko stunting pada anak balita di Kabupaten Aceh Utara. Penelitian kuantitatif dengan desain potong lintang ini dilaksanakan pada April hingga Agustus 2025 di wilayah kerja Puskesmas Simpang Keramat dan Kuta Makmur. Sebanyak 90 anak balita

dipilih melalui teknik purposive sampling. Pengumpulan data dilakukan menggunakan kuesioner terstruktur dan observasi langsung, dengan uji validitas serta reliabilitas instrumen dilakukan sebelum pengambilan data. Analisis statistik menggunakan uji chi-square. Hasil penelitian menunjukkan prevalensi stunting sebesar 54.4%. Terdapat hubungan bermakna antara stunting dengan ketersediaan air bersih (OR = 4.8; p < 0.001), kepemilikan jamban (OR = 5.1; p = 0.002), pengelolaan sampah (OR = 8.5; p < 0.001), pembuangan sampah rumah tangga (OR = 4.9; p < 0.001), serta keberadaan telur cacing dalam feses (OR = 5.0; p = 0.001). Secara keseluruhan, pengelolaan sampah rumah tangga yang tidak memadai menjadi faktor lingkungan paling kuat terkait stunting. Kesimpulan, sanitasi lingkungan khususnya pengelolaan sampah rumah tangga berperan besar dalam meningkatkan risiko stunting pada balita. Penguatan intervensi sanitasi berbasis masyarakat dan perbaikan praktik pengelolaan sampah rumah tangga berpotensi menurunkan risiko infeksi serta membantu menekan angka stunting di Aceh Utara.

Kata Kunci: Kesehatan Lingkungan, Gangguan Pertumbuhan,Anak Pra-sekolah,Sanitasi, Faktor Risiko

Introduction

Child undernutrition remains a major global health concern, with stunting disproportionately affecting children in low- and middle-income countries. In 2023, approximately 148 million children under the age of five were stunted, 45 million were wasted, and 37 million were overweight (UNICEF/WHO/World Bank 2023). Despite overall progress, disparities persist across regions, especially in low- and middle-income countries (LMICs). Although global progress has been made, the persistent burden in countries such as Indonesia highlights the need to understand the contextual determinants of stunting. Nationally, stunting among children under five years of age declined from 24.4% in 2022 to 21.6% in 2023, and further to 19.8%, according to the 2024 Indonesian Nutritional Status Survey (Kemenkes RI, 2023)(Kemenkes RI, 2024). However, these figures remain above the national target of 14% and indicate that substantial challenges persist in achieving optimal child growth. Indonesia's geographic and socio-environmental diversity contributes to variations in nutritional status, making certain provinces a priority for targeted interventions.

Aceh is a priority region because of its consistently higher stunting prevalence than the national level. The prevalence of stunting in Aceh declined from 44.6% in 2007 to 34.1% in 2019; however, the reduction between 2019 and 2023 was slow, only about 2–3% within four years (Kemenkes RI, 2023). North Aceh District continues to rank among the districts with the highest stunting prevalence in Sumatra, at 33.9% in 2022 and 32.8% in 2023 (Aceh Provincial Health Office, 2023). This trend suggests enduring environmental and health-related constraints, emphasizing the importance of investigating the local determinants that hinder child growth.

Stunting is a multifactorial condition arising from inadequate nutrient intake, recurrent infections, poor environmental sanitation, and poor hygiene (Palmer et al., 2024; Saaka et al., 2021). Environmental infections, such as helminthiasis, tuberculosis (TB), and acute respiratory infections (ARI), are strongly linked to sanitation quality and hygiene behavior (Cumming & Cairncross, 2016; Hasyim et al., 2025). Soil-transmitted helminths, such as *Ascaris lumbricoides* and *Trichuris trichiura*, are still common among Indonesian children, with a prevalence varying between 5% and 62%, depending on environmental conditions (Agustina et al., 2022). Similarly, childhood TB contributes to approximately 10% of the national TB cases (WHO, 2023). These infections disrupt nutrient absorption and metabolism, leading to growth failure and anemia (Vilcins et al., 2018; Junita et al., 2024).

Existing studies in Indonesia and comparable settings have demonstrated associations between sanitation conditions, infectious disease exposure, and stunting in children (Butzin-Dozier et al., 2025; Rah et al., 2015). However, most prior investigations have focused on isolated variables, leaving a gap in understanding the combined influence of multiple environmental health determinants, particularly in the Aceh Province. Addressing this

gap is essential for developing comprehensive intervention strategies tailored to local contexts.

This study aimed to analyze the relationships between environmental health determinants including sanitation quality, hygiene behavior, and infectious disease exposure and stunting among children under five years of age in North Aceh District. The novelty of this study lies in its integrative approach, which simultaneously examines the environmental, behavioral, and infectious dimensions. By addressing these interconnected factors, this study provides evidence that may guide region-specific policies and accelerate stunting reduction efforts in Aceh and other high-burden areas.

Methods

This study employed a mixed-method design consisting of a quantitative case–control component followed by qualitative validation through Focus Group Discussions (FGDs). A mixed-method approach was used in a sequential explanatory design, in which quantitative findings on environmental health determinants of stunting were first identified, and qualitative discussions with cross-sector stakeholders were subsequently conducted to contextualize, validate, and strengthen the interpretation of results for policy formulation. This integration allowed for methodological triangulation and enhanced the depth and applicability of the findings.

The research was conducted in eight villages within the Simpang Keuramat and Kuta Makmur sub-districts of North Aceh Regency, Aceh Province from April to August 2025. The study population comprised children aged 0–59 months and their families residing in the study area. A case group (children with stunting, LAZ/HAZ < −2 SD) and a control group (children with normal growth, LAZ/HAZ ≥ −2 SD) were selected for the study.

This study employed an observational analytical design with a case–control approach. The study population included all children under five years of age (0–59 months) and their families residing in the villages within the study area. The sample consisted of two groups: a case group (children under five years with stunting, defined as a length-for-age or height-for-age z-score [LAZ/HAZ] < −2 SD) and a control group (children under five years with normal growth, defined as LAZ/HAZ ≥ −2 SD).

The sample size was determined using a case–control sample size formula with a 95% confidence level ($\alpha = 0.05$) and a precision level (d) of 10%. Participants were selected using purposive sampling, and matching was performed based on age and sex to minimize the potential confounding factors. The inclusion criteria were as follows: (1) children aged 0–59 months; (2) stunted or normal nutritional status according to the WHO growth standards; and (3) absence of severe illness during data collection. Children with acute illnesses, congenital disorders affecting growth, or whose caregivers declined to participate were excluded.

Nutritional status was determined through anthropometric measurements conducted by trained health workers using standardized instruments certified by the Indonesian Ministry of Health. Body length (for children <24 months) and height (for children ≥24 months) were measured to the nearest 0.1 cm using a stadiometer. The Length-for-Age Z-score (LAZ) and Height-for-Age Z-score (HAZ) were calculated using the PSG Balita software, following the Ministry of Health guidelines. Children with z-scores below −2 SD were categorized as stunted, while those with z-scores equal to or above −2 SD were classified as having a normal nutritional status, in accordance with the World Health Organization (WHO) Child Growth Standards commonly applied in pediatric nutritional epidemiology (Al Rahmad et al., 2023; 2024).

Helminth infection was determined through stool examination using the direct/native smear method performed by qualified laboratory technicians at local Primary Health Centers (PHCs). Stool samples were collected from each participating child under hygienic conditions. The examination results were classified as positive (presence of helminth eggs) or negative (absence of helminth eggs) according to the standard procedures for clinical parasitological diagnostics (Garcia & Procop, 2016).

Environmental health conditions were evaluated through structured interviews with caregivers and field observations. The variables included the availability of clean water, toilet facilities, and solid and wastewater management. Data were collected using a validated

questionnaire developed based on the 2020 Indonesian Ministry of Health's Environmental Health Minimum Service Standards (Arbiana et al., 2020). Each variable was scored and categorized as meeting the standard (≥70%) or not meeting the standard (<70%), consistent with national environmental health benchmarks.

Data analysis was performed in three steps. The univariate analysis summarized the variable distributions. Bivariate associations were examined using the chi-square test with significance set at $\alpha = 0.05$. Because matching was applied, conditional logistic regression was used in the multivariate analysis to identify the independent predictors of stunting. Variables with $p < 0.25$ in the bivariate analysis were included in the final model. Results are presented as Odds Ratios (OR) with 95% Confidence Intervals (CI). Analyses were conducted using IBM SPSS Statistics Version 30. Ethical clearance for the study was obtained from the institutional ethics committee, and informed consent was obtained from all caregivers.

Result and Discussion

Characteristics of Children Under Five

Table 1. Characteristics of children under five

Characteristics	n	%
Age of Children		
12–36 months	21	23.3
37–60 months	69	76.7
Sex		
Male	44	48.9
Female	46	51.1
Stunting		
Yes	49	54.4
No	41	45.6

The majority of children under five years were aged 37–60 months (76.7%) and were female (51.1%). The prevalence of stunting was 54.4%, indicating that more than half of the children experienced growth retardation. This finding reflects that stunting remains a major public health problem in the study area, emphasizing the need for targeted interventions focusing on preschool age groups, who are particularly vulnerable to chronic malnutrition.

Most of the children in this study were aged 37–60 months, indicating that most were in the preschool period, a critical stage of growth and cognitive development that remains highly susceptible to nutritional deficiency. The prevalence of stunting (54.4%) was considerably higher than the national average and the WHO threshold of 20%, confirming that it continues to pose a severe public health issue in the region. Similar findings have been reported in other low- and middle-income settings, where inadequate dietary intake and recurrent infections during early childhood contribute to impaired growth (Fufa, 2022; UNICEF, 2023). The nearly equal distribution between boys and girls suggests that sex differences may play a minor role, and environmental or household factors are likely to be stronger determinants of the risk of stunting (Thurstans et al., 2020).

Household Environmental Conditions

Table 2. Household sanitation and stool examination of children under five

Variable	n	%
Clean Water Supply		
Meets standards	39	43.3
Does not meet standards	51	56.7
Toilet Facilities		
Meets standards	23	25.6
Does not meet standards	67	74.4
Waste Management		
Meets standards	43	47.8
Does not meet standards	47	52.2
Wastewater Management		
Meets standards	55	61.1
Does not meet standards	35	38.9
Stool Examination (Helminth Eggs)		
Positive	6	6.7
Negative	84	93.3

In this study, more than half of the households did not meet the national standards for clean water supply (56.7%) and toilet facilities (74.4%), while 52.2% did not meet the standards for solid waste management. In contrast, 61.1% of households met wastewater management standards, and only 6.7% of children had positive stool samples for helminth eggs. These findings indicate that in North Aceh, gaps in basic environmental health services—especially access to safe water, improved sanitation, and organized solid waste management—remain widespread and affect a large proportion of children under five years of age. These deficiencies in water, sanitation, and hygiene (WASH) are concerning as they foster conditions conducive to fecal–oral pathogen

transmission and recurrent enteric infections, both of which are critical contributors to environmental enteric dysfunction (EED) (Ntshebe et al., 2019; Yani et al., 2023). EED is characterized by chronic inflammation of the intestinal mucosa, which can lead to diminished nutrient absorption and hinder healthy linear growth in children (Sari et al., 2023; Yani et al., 2023). Previous studies support these findings, emphasizing the role of effective WASH services as a determinant of nutritional outcomes among children under five years of age owing to their direct impact on health and developmental trajectories (Al Rahmad et al., 2020; Humphrey et al., 2019; Striessnig & Bora, 2020).

Despite compliance with the minimum health benchmarks for wastewater management (61.1% of households), inadequate solid waste management practices (52.2%) raise concerns about persistent microbial exposure in domestic settings (Agho et al., 2019; Humphrey et al., 2019). The relatively low occurrence of helminth infections (6.7%) could imply some success attributed to periodic deworming programs or enhanced hygiene practices among the population. However, poor sanitation exacerbates the risk of subclinical infections, leading to micronutrient deficits and systemic inflammation that complicate stunting in children (Agho et al., 2019; Ciptanurani & Chen, 2021).

The implications of these environmental factors are critical for developing effective interventions to combat stunting in vulnerable populations. While family and household characteristics, such as wealth and food security, markedly influence children's nutritional status, addressing the foundational issues of WASH infrastructure and sanitation remains paramount (Al Rahmad et al., 2020; Humphrey et al., 2019; Nkhoma et al., 2021; Striessnig & Bora, 2020; Yani et al., 2023). Ensuring access to clean water and safe sanitation facilities is an integral component of stunting prevention strategies, particularly in rural, low-resource settings. Programs that holistically integrate improvements in environmental sanitation alongside nutrition-focused interventions present a valuable pathway for mitigating childhood stunting and promoting overall health (Sari et al., 2023; Striessnig & Bora, 2020).

The interconnection between household environmental conditions and child nutrition elucidated in this study underscores the need for targeted public health strategies: by enhancing WASH infrastructure and food security, we can substantially reduce the prevalence of stunting and improve the growth and development of children in at-risk communities. Sustainable initiatives that incorporate multifaceted approaches are likely to have the most significant impact on child health.

Association Between Environmental Health Factors and Stunting

Bivariate chi-square analysis showed statistically significant associations between all environmental variables and stunting ($p < 0.05$). As summarized in Table 3, children from households with a clean water supply that did not meet the standards had almost five times higher odds of being stunted than children from households that met the national standards (OR = 4.8; 95% CI: 1.96–11.78). Similarly, children in households where toilet facilities did not meet standards had more than five times higher odds of stunting compared with those with adequate toilets (OR: 5.1; 95% CI: 1.76–14.59). Poor household solid waste management was associated with more than eight-fold higher odds of stunting (OR = 8.5; 95% CI: 3.00–23.85), and inadequate wastewater management increased the odds by nearly five-fold (OR = 4.9; 95% CI: 1.99–11.95). The presence of helminth eggs in the stool was also significantly associated with stunting (OR = 5.0; 95% CI: 1.75–14.33). In all instances, the confidence intervals did not cross 1.0, supporting the interpretation that these associations were statistically and clinically meaningful.

Table 3. Association between environmental health variables and stunting among children under five

Environmental Health Variable	Category	Stunting; n (%)	Normal; n (%)	p-value	OR (95% CI)
Clean Water Supply	Meets standards	13 (33.3)	26 (66.7)	<0.001	4.8
	Does not meet standards	36 (70.6)	15 (29.4)		(1.96–11.78)
Toilet Facilities	Meets standards	6 (26.1)	17 (73.9)	0.002	5.1
	Does not meet standards	43 (64.2)	24 (35.8)		(1.76–14.59)

Household Solid Waste Management	Meets standards	15 (34.9)	28 (65.1)	<0.001	8.5 (3.00–23.85)
	Does not meet standards	34 (72.3)	13 (27.7)		
Household Wastewater Management	Meets standards	20 (36.4)	35 (63.6)	<0.001	4.9 (1.99–11.95)
	Does not meet standards	29 (82.9)	6 (17.1)		
Helminth Eggs in Stool Samples	Positive (eggs found)	5 (83.3)	1 (16.7)	0.001	5.0 (1.75–14.33)
	Negative (no eggs found)	44 (52.4)	40 (47.6)		

These results underline that children living in households that do not meet the national environmental health standards are substantially more vulnerable to chronic growth faltering. In North Aceh, where many households still lack access to safe water and improved sanitation, environmental exposure pathways likely play a central role in sustaining the high burden of short stature. The associations observed in this study can be explained by biologically plausible causal mechanisms. Inadequate sanitation and contamination from unsafe water sources increase exposure to enteric pathogens, culminating in recurrent infections and environmental enteric dysfunction (EED) (Ciptanurani & Chen, 2021; Sari et al., 2023). EED, characterized by chronic inflammation and villous atrophy in the intestines, restricts nutrient absorption, thereby impeding growth in children, even in the absence of overt diarrhea (Khan et al., 2019). Recent literature corroborates that suboptimal WASH conditions substantially contribute to linear growth failure through persistent intestinal inflammation and reduced nutrient uptake (Anastasia et al., 2023; Pun et al., 2021). Furthermore, infections caused by soil-transmitted helminths adversely affect nutrient absorption and can induce anemia, reduce appetite, and cause chronic inflammation, all of which aggravate the risk of stunting (Fauziah et al., 2022).

These findings appear consistent with broader trends observed in Indonesia and various other low- and middle-income countries, where similar studies have documented that poor sanitation and inadequate water supply are strong predictors of the prevalence of stunting (Anastasia et al., 2023; Gassara et al., 2023). In particular, comprehensive reviews and analyses emphasize how factors related to WASH critically influence child growth (Gassara et al., 2023; Yani et al., 2023). However, the effectiveness of these interventions varies based on their scope and intensity. Randomized controlled trials indicate that isolated household-level interventions often yield insufficient improvements in child height-for-age, whereas community-wide programs integrating sanitation infrastructure, hygiene promotion, and nutritional education result in more significant overall improvements (Blankenship et al., 2020; Morales et al., 2024).

This underscores the necessity of integrating environmental health into strategies aimed at combating stunting. Solely relying on nutritional interventions, such as dietary supplementation and growth monitoring, will prove inadequate if children continue to experience adverse environmental conditions (Yani et al., 2023). Consequently, stakeholders should implement multisectoral approaches encompassing WASH infrastructure development, solid waste management, hygiene behavior promotion (CHLB), and parasitic infection control measures. Community-level sanitation programs, unimpeded access to safe drinking water, and regular deworming campaigns must be prioritized, alongside fostering community engagement in behavior change interventions, such as handwashing with soap and proper disposal of child feces, to ensure the sustained adoption of healthy practices (Fauziah et al., 2022; Gassara et al., 2023; Raj et al., 2022).

The results of this study offer compelling evidence that inadequate household environmental conditions significantly influence the prevalence of stunting in children. Effective stunting prevention requires holistic interventions that address both the nutritional and environmental health determinants of stunting. By prioritizing these integrated strategies, public health initiatives can create healthier environments conducive to the growth and development of children, ultimately reducing the prevalence of stunted growth in childhood.

Table 4. Analysis of environmental health determinants associated with stunting among children under five

Independent Variable	Adjusted Odds Ratio (AOR)	95% Confidence Interval (CI)	p-value
Clean Water Supply (does not meet standards)	2.91	1.12 – 7.56	0.028
Toilet Facilities (does not meet standards)	3.76	1.33 – 10.61	0.012
Household Solid Waste Management (does not meet standards)	5.84	2.03 – 16.81	0.001
Household Wastewater Management (does not meet standards)	2.64	1.05 – 6.63	0.039
Helminth Eggs in Stool (positive)	3.98	1.11 – 14.28	0.035

Nagelkerke $R^2 = 0.61$; Hosmer–Lemeshow Test: $\chi^2 = 5.27$, $p = 0.728$ (model fit); Overall model significance: $p < 0.001$

Multivariate logistic regression analysis (Table 4) revealed that several environmental health factors were significantly associated with stunting in children aged under five years. The overall model showed a good fit (Hosmer–Lemeshow p = 0.728) and explained approximately 61% of the variance in stunting (Nagelkerke R^2 = 0.61). Among the assessed variables, inadequate solid waste management emerged as the strongest risk factor, with an adjusted odds ratio (AOR) of 5.84 (95% CI: 2.03–16.81; p = 0.001). Children from households lacking proper waste disposal systems were nearly six times more likely to be stunted than their counterparts in households with adequate waste management (Utami et al., 2024). Similarly, insufficient toilet facilities and unsafe water sources also presented significant risks, with AORs of 3.76 and 2.91, respectively (Sahiledengle et al., 2022; Shrestha et al., 2020).

These results indicate that adverse environmental conditions not only act independently but may also interact synergistically to impair children's growth. Specifically, solid waste mismanagement likely leads to increased environmental contamination, fostering the proliferation of disease vectors such as flies, which can exacerbate the transmission of enteric pathogens (Prüss-Üstün et al., 2019). Research supports this hypothesis; Utami et al. (2024) found that children in households with poor waste disposal were over four times more likely to experience stunting, which corroborates the findings of this study. Moreover, inadequate sanitation facilities elevate exposure to enteric pathogens and contribute to environmental enteric dysfunction (EED), which is characterized by chronic intestinal inflammation and negatively impacts nutrient absorption (Sahiledengle et al., 2022).

Unsafe water sources further compound these risks by facilitating recurrent diarrheal and parasitic infections that hinder linear growth and increase vulnerability to stunting (Shrestha et al., 2020). The association between helminth infection (AOR = 3.98) and stunting aligns with the existing literature, indicating that soil-transmitted helminth infections can lead to nutritional deficiencies and inflammatory processes that directly undermine children's growth potential (Fauziah et al., 2022). A recent systematic review confirmed this association, linking helminth infections to a greater risk of undernutrition, particularly in settings with poor sanitation (Nuraini et al., 2022).

These findings highlight the interdependent nature of environmental risk factors affecting children's health. Cumulative exposure to suboptimal sanitation, unsafe water, and inadequate waste management amplifies the risk of exposure to fecal pathogens, contributing to higher stunting rates (Shrestha et al., 2020). Integrated community-wide water, sanitation, and hygiene (WASH) interventions have been found to be more effective than isolated household programs, as they address the complex interactions between these environmental factors (Zhu et al., 2021). The Global Nutrition Report (2024) advocates embedding environmental health improvements within multisectoral nutrition initiatives to effectively combat stunting (Siramaneerat et al., 2024).

From a public health policy perspective, these findings highlight the urgent need to reinforce environmental health systems as part of comprehensive strategies to reduce stunting. Improving solid waste management, ensuring universal access to safe sanitation, and securing reliable potable water supplies should be

prioritized alongside targeted nutritional interventions. Indonesia's National Action Plan on Stunting (2024–2030) emphasizes the integration of WASH with promotional health strategies as the key to achieving national stunting reduction goals (Siramaneerat et al., 2024). Furthermore, efforts to sustain community-based deworming initiatives and hygiene education must continue to disrupt helminth transmission and support healthy child development (Fauziah et al., 2022).

Overall, the multivariate findings strongly indicate that environmental determinants, particularly solid waste management, sanitation, water quality, and parasitic infections, are critical predictors of stunting in children. Addressing malnutrition thus requires robust integrated approaches that encompass both nutritional interventions and comprehensive environmental reforms to foster a clean, disease-free environment conducive to child growth. Such integrated WASH-nutrition policies, supported by active community engagement and ongoing monitoring, represent a promising pathway to significantly reduce stunting prevalence in Indonesia and similar contexts.

This study offers important insights into the environmental determinants of stunting in a high-burden rural area. This study has several limitations. First, the retrospective case–control design restricts causal inference and may be affected by temporal ambiguity between exposure and outcome. Second, residual confounding from socioeconomic status, maternal education, and other unmeasured variables may persist despite adjustments. Third, potential measurement bias may have arisen from the categorical scoring of environmental conditions and reliance on caregiver self-reports for some behaviors, which can introduce recall or social desirability bias. Finally, external validity is limited because the sample was drawn from eight villages in two rural sub-districts; therefore, the findings should be generalized with caution to other regions with different socio-environmental profiles. Nonetheless, the consistency of associations across multiple environmental indicators, their biological plausibility, and their alignment with national and international evidence strengthen the confidence in the conclusion that environmental sanitation, especially household solid waste management, is a critical determinant of stunting in North Aceh.

Conclusion

This study found that inadequate household environmental health conditions particularly poor solid waste management, lack of sanitary toilets, unsafe water sources, and helminth infections were significantly associated with a higher risk of stunting among children under five years of age in the North Aceh District. Multivariate analysis identified improper household solid waste management as the strongest environmental predictor of stunting (AOR = 5.84), indicating that children living in households that do not meet waste management standards are at a markedly greater risk of impaired linear growth. These findings highlight that efforts to prevent stunting must extend beyond nutrition-specific interventions to include sustained improvements in sanitation, water quality, and hygiene at the household and community levels in the long term.

To effectively reduce stunting, local governments and health authorities should strengthen community-based WASH programs by improving household solid waste management systems, expanding universal access to safe drinking water, and ensuring the availability and use of sanitary toilet. Regular deworming, hygiene promotion, and health education delivered through community health workers and integrated into existing primary health care and *Posyandu* services are essential for reducing infection-related risks. Cross-sectoral collaboration between the health sector, environmental and sanitation agencies, public works and infrastructure units, and village and education authorities is crucial for designing and implementing integrated interventions that combine environmental health improvements with nutrition programs. Continuous monitoring and behavior change strategies that promote clean and healthy living practices will be key to achieving sustainable reductions in childhood stunting in North Aceh and similar high-burden settings.

Acknowledgments

This study was supported by funding from the North Aceh District Health Office under the 2024 Community-Based Health Research Grant. The authors express their sincere appreciation to the Head of the North Aceh District Health Office, the

Heads of the Simpang Keramat and Kuta Makmur Primary Health Centers, and all staff members for their valuable cooperation and assistance during the fieldwork.

Special thanks are also extended to the enumerators, laboratory personnel, and nutrition officers for their dedicated contribution to data collection and analysis, as well as to all participating households for their willingness and trust throughout the study.

References

Aceh Provincial Health Office. (2023). *Aceh health profile 2023*. https://dinkes.acehprov.go.id/

Agho, K., Mukabutera, C., Mukazi, M., Ntambara, M., Mbugua, I., Dowling, M., & Kamara, J. K. (2019). Moderate and severe household food insecurity predicts stunting and severe stunting among Rwanda children aged 6–59 months residing in Gicumbi district. *Maternal and Child Nutrition, 15*(3), e12767. https://doi.org/10.1111/mcn.12767

Agustina, K. K., Wirawan, I. M. A., Sudarmaja, I. M., Subrata, M., & Dharmawan, N. S. (2022). The first report on the prevalence of soil-transmitted helminth infections and associated risk factors among traditional pig farmers in Bali Province, Indonesia. *Veterinary World, 15*(5), 1154–1162. https://doi.org/10.14202/vetworld.2022.1154-1162

Al Rahmad, A. H., Miko, A., Labatjo, R., Fajriansyah, F., Fitri, Y., & Suryana, S. (2020). Malnutrition prevalence among toddlers based on family characteristics: A cross-sectional study in the rural and urban areas of Aceh, Indonesia. *Sri Lanka Journal of Child Health, 49*(3), 263. https://doi.org/10.4038/sljch.v49i3.9145

Al Rahmad, A. H., Junaidi, J., Muliyani, N. S., & Emilda, E. (2023). The impact of integrating the ISO/IEC 25010 standard into the "PSG Balita" on the quality of the toddler nutritional status report data. *AcTion: Aceh Nutrition Journal, 8*(4), 653–659. https://doi.org/10.30867/action.v8i4.754

Al Rahmad, A. H., Sofyan, H., Usman, S., & Mudatsir. (2024). The accuracy data of the toddlers' nutritional status using the "PSG Balita" app. In T. Tahlil & P. Ardia (Eds.), *The 6th Aceh International Nursing Conference* (pp. 82–86). Journal of Liaquat University of Medical and Health Sciences. https://doi.org/10.22442/jlumhs.2024.01130

Anastasia, H., Hadju, V., Hartono, R., Samarang, Manjilala, Sirajuddin, Salam, A., & Atmarita. (2023). Determinants of stunting in children under five years old in South Sulawesi and West Sulawesi Province: 2013 and 2018 Indonesian Basic Health Survey. *PLOS ONE, 18*(5), e0281962. https://doi.org/10.1371/journal.pone.0281962

Arbiana, A., Tsaralatifah, R., & Nuraeni, N. (2020). Management of expired liquid chemicals in Gunung Batu's chemistry laboratory of Health Polytechnic of the Ministry of Health Bandung in 2018. *Jurnal Kesehatan Lingkungan, 12*(4), 270–275. https://doi.org/10.20473/jkl.v12i4.2020.270-275

Blankenship, J., Gwavuya, S., Palaniappan, U., Alfred, J., DeBrum, F., & Erasmus, W. (2020). High double burden of child stunting and maternal overweight in the Republic of the Marshall Islands. *Maternal and Child Nutrition, 16*(2), e12832. https://doi.org/10.1111/mcn.12832

Butzin-Dozier, Z., Ji, Y., Coyle, J., Malenica, I., Rogawski McQuade, E. T., Grembi, J. A., Platts-Mills, J. A., Houpt, E. R., Graham, J. P., Ali, S., Rahman, M. Z., Alauddin, M., Famida, S. L., Akther, S., Hossen, M. S., Mutsuddi, P., Shoab, A. K., Rahman, M., Islam, M. O., … Lin, A. (2025). Treatment heterogeneity of water, sanitation, hygiene, and nutrition interventions on child growth by environmental enteric dysfunction and pathogen status for young children in Bangladesh. *PLOS Neglected Tropical Diseases, 19*(2), e0012881. https://doi.org/10.1371/journal.pntd.0012881

Ciptanurani, C., & Chen, H. (2021). Household structure and concurrent stunting and overweight among young children in Indonesia. *Public Health Nutrition, 24*(9), 2629–2639.

https://doi.org/10.1017/S1368980021001385

Cumming, O., & Cairncross, S. (2016). Can water, sanitation and hygiene help eliminate stunting? Current evidence and policy implications. *Maternal & Child Nutrition, 12*(S1), 91–105. https://doi.org/10.1111/mcn.12258

Fauziah, N., Ar-Rizqi, M. A., Hana, S., Patahuddin, N. M., & Diptyanusa, A. (2022). Stunting as a risk factor of soil-transmitted helminthiasis in children: A literature review. *Interdisciplinary Perspectives on Infectious Diseases, 2022*, 1–14. https://doi.org/10.1155/2022/8929025

Fufa, D. A. (2022). Determinants of stunting in children under five years in Dibate district of Ethiopia: A case-control study. *Human Nutrition & Metabolism, 30*, 200162. https://doi.org/10.1016/j.hnm.2022.200162

Garcia, L. S., & Procop, G. W. (2016). Diagnostic medical parasitology. In *Manual of commercial methods in clinical microbiology: International edition* (pp. 284–308). [data tidak tersedia penerbit]. https://doi.org/10.1002/9781119021872.ch15

Gassara, G., Lin, Q., Deng, J., Zhang, Y., Wei, J., & Chen, J. (2023). Dietary diversity, household food insecurity and stunting among children aged 12 to 59 months in N'Djamena—Chad. *Nutrients, 15*(3), 573. https://doi.org/10.3390/nu15030573

Hasyim, H., Kusuma Aerosta, D., Budiastuti, A., Razak, R., Yeni, Y., Misnaniarti, M., Alam Fajar, N., Febry, F., Etrawati, F., Lionita, W., Rahmawaty, A., Amin Arigo Saci, M., Yuliana, I., Indah Fajar Ningsih, W., Pratiwi, L., Yasyfi Nur Alfaini, N., Putri, N., Wahyuni, N., Murniati, N., … Fadhilah Eka Maharani. (2025). Environmental factors' determinant of childhood stunting in Indonesia: A systematic review and meta-analysis. *Malaysian Journal of Public Health Medicine, 25*(2), 11–19. https://www.mjphm.org/index.php/mjphm/article/view/2538

Humphrey, J. H., Jones, A. D., Manges, A. R., Mangwadu, G., Maluccio, J. A., Mbuya, M. N. N., Moulton, L. H., Ntozini, R., Prendergast, A. J., Stoltzfus, R. J., Tielsch, J. M., Chasokela, C., Chigumira, A., Heylar, W., Hwena, P., Kembo, G., Majo, F. D., Mutasa, B., Mutasa, K., … Makoni, T. (2019). Independent and combined effects of improved water, sanitation, and hygiene, and improved complementary feeding, on child stunting and anaemia in rural Zimbabwe: A cluster-randomised trial. *The Lancet Global Health, 7*(1), e132–e147. https://doi.org/10.1016/S2214-109X(18)30374-7

Junita, D., Al Rahmad, A. H., & Fajarna, F. (2024). Health status of adolescence girls based on nutritional status assessment and cardiorespiratory endurance (VO2max). *National Nutrition Journal/Media Gizi Indonesia, 19*(3), 275–281. https://doi.org/10.20473/mgi.v19i3.275–281

Kemenkes RI. (2023). *Survei Kesehatan Indonesia (SKI) 2023*. https://www.badankebijakan.kemkes.go.id/ski-2023-dalam-angka/

Kemenkes RI. (2024). *Survei Status Gizi Indonesia (SSGI) 2024: Hasil utama nasional dan provinsi*. https://www.badankebijakan.kemkes.go.id/survei-status-gizi-indonesia-ssgi-2024/

Khan, S., Zaheer, S., & Safdar, N. F. (2019). Determinants of stunting, underweight and wasting among children < 5 years of age: Evidence from 2012–2013 Pakistan Demographic and Health Survey. *BMC Public Health, 19*(1), 358. https://doi.org/10.1186/s12889-019-6688-2

Morales, S., Bowers, M. E., Shuffrey, L. C., Ziegler, K., Troller-Renfree, S. V., Hernández, A., Leach, S. C., McGrath, M., Ola, C., Leve, L. D., Nozadi, S. S., Swingler, M. M., Lai, J., Schweitzer, J. B., Fifer, W. P., Camargo, C. A., Hershey, G. K. K., Shapiro, A., Keating, D. P., … Elliott, A. J. (2024). Maternal education prospectively predicts child neurocognitive function: An environmental influences on child health outcomes study. *Developmental Psychology, 60*(6), 1028–1040. https://doi.org/10.1037/dev0001642

Nkhoma, B., Ng'ambi, W., Chipimo, P. J., & Zambwe, M. (2021). Determinants of stunting among children < 5 years of age: Evidence from 2018–2019 Zambia Demographic and Health Survey. *[data*

tidak tersedia nama jurnal/preprint server]. https://doi.org/10.1101/2021.05.19.21257389

Ntshebe, O., Channon, A. A., & Hosegood, V. (2019). Household composition and child health in Botswana. *BMC Public Health, 19*(1), 1621. https://doi.org/10.1186/s12889-019-7963-y

Nuraini, I., Iswati, R. S., & Aisyah, A. (2022). Intervention of stunting aged 0–59 months reviewing from nutrition. *Journal of Pharmaceutical Negative Results, 13*(4), 700–705. https://doi.org/10.47750/pnr.2022.13.04.094

Palmer, S., Burton-Obanla, A., Goon, S., Allison, T., Bogdonas, K., Fombelle, M., Hoffman, A., Smith, J., McCaffrey, J., & Prescott, M. P. (2024). Policy, systems, and environmental changes in child nutrition programs: A systematic literature review. *Advances in Nutrition, 15*(1), 100116. https://doi.org/10.1016/j.advnut.2023.09.004

Prüss-Üstün, A., Wolf, J., Bartram, J., Clasen, T., Cumming, O., Freeman, M. C., Gordon, B., Hunter, P., Medlicott, K., & Johnston, R. B. (2019). Burden of disease from inadequate water, sanitation and hygiene for selected adverse health outcomes: An updated analysis with a focus on low- and middle-income countries. *International Journal of Hygiene and Environmental Health, 222*(5), 765–777. https://doi.org/10.1016/j.ijheh.2019.05.004

Pun, V. C., Dowling, R., & Mehta, S. (2021). Ambient and household air pollution on early-life determinants of stunting: A systematic review and meta-analysis. *Environmental Science and Pollution Research, 28*(21), 26404–26412. https://doi.org/10.1007/s11356-021-13719-7

Rah, J. H., Cronin, A. A., Badgaiyan, B., Aguayo, V. M., Coates, S., & Ahmed, S. (2015). Household sanitation and personal hygiene practices are associated with child stunting in rural India: A cross-sectional analysis of surveys. *BMJ Open, 5*(2), e005180. https://doi.org/10.1136/bmjopen-2014-005180

Raj, E., Calvo-Urbano, B., Heffernan, C., Halder, J. B., & Webster, J. P. (2022). Systematic review to evaluate a potential association between helminth infection and physical stunting in children. *Parasites & Vectors, 15*(1), 135. https://doi.org/10.1186/s13071-022-05235-5

Saaka, M., Saapiire, F. N., & Dogoli, R. N. (2021). Independent and joint contribution of inappropriate complementary feeding and poor water, sanitation and hygiene (WASH) practices to stunted child growth. *Journal of Nutritional Science, 10*, e109. https://doi.org/10.1017/jns.2021.103

Sahiledengle, B., Petrucka, P., Kumie, A., Mwanri, L., Beressa, G., Atlaw, D., Tekalegn, Y., Zenbaba, D., Desta, F., & Agho, K. (2022). Association between water, sanitation and hygiene (WASH) and child undernutrition in Ethiopia: A hierarchical approach. *BMC Public Health, 22*(1), 1943. https://doi.org/10.1186/s12889-022-14309-z

Sari, I. P., Ningsih, W. I. F., & Sari, D. M. (2023). The correlation between the household food security and the incidence of stunting in toddlers 6–59 months in Seberang Ulu I Palembang. *Jurnal Ilmu Kesehatan Masyarakat, 14*(2), 198–209. https://doi.org/10.26553/jikm.2023.14.2.198-209

Shrestha, A., Six, J., Dahal, D., Marks, S., & Meierhofer, R. (2020). Association of nutrition, water, sanitation and hygiene practices with children's nutritional status, intestinal parasitic infections and diarrhoea in rural Nepal: A cross. *BMC Public Health, 20*(1), 1241. https://doi.org/10.1186/s12889-020-09302-3

Siramaneerat, I., Astutik, E., Agushybana, F., Bhumkittipich, P., & Lamprom, W. (2024). Examining determinants of stunting in urban and rural Indonesian: A multilevel analysis using the population-based Indonesian Family Life Survey (IFLS). *BMC Public Health, 24*(1), 1371. https://doi.org/10.1186/s12889-024-

18824-z

Striessnig, E., & Bora, J. K. (2020). Under-five child growth and nutrition status: Spatial clustering of Indian districts. *Spatial Demography, 8*(1), 63–84. https://doi.org/10.1007/s40980-020-00058-3

Thurstans, S., Opondo, C., Seal, A., Wells, J., Khara, T., Dolan, C., Briend, A., Myatt, M., Garenne, M., Sear, R., & Kerac, M. (2020). Boys are more likely to be undernourished than girls: A systematic review and meta-analysis of sex differences in undernutrition. *BMJ Global Health, 5*(12), e004030. https://doi.org/10.1136/bmjgh-2020-004030

UNICEF. (2023). *The state of the world's children 2023*. https://www.unicef.org/reports/state-worlds-children-2023

UNICEF/WHO/World Bank. (2023). *Levels and trends in child malnutrition: 2023 edition*. World Health Organization. https://www.who.int/publications/i/item/9789240073791

Utami, W. S., Armiyanti, Y., & Amrina, A. P. Y. (2024). Analysis of determinants of tuberculosis in stunted toddlers in Rambipuji, Jember. *Journal of Agromedicine and Medical Sciences, 10*(1), 34–40. https://doi.org/10.19184/ams.v10i1.46500

Vilcins, D., Sly, P. D., & Jagals, P. (2018). Environmental risk factors associated with child stunting: A systematic review of the literature. *Annals of Global Health, 84*(4), 551–562. https://doi.org/10.9204/aogh.2361

WHO. (2023). *Global tuberculosis report 2023*. https://www.who.int/teams/global-programme-on-tuberculosis-and-lung-health/tb-reports/global-tuberculosis-report-2023

Yani, D. I., Rahayuwati, L., Sari, C. W. M., Komariah, M., & Fauziah, S. R. (2023). Family household characteristics and stunting: An update scoping review. *Nutrients, 15*(1), 233. https://doi.org/10.3390/nu15010233

Zhu, W., Zhu, S., Sunguya, B., & Huang, J. (2021). Urban–rural disparities in the magnitude and determinants of stunting among children under five in Tanzania: Based on Tanzania Demographic and Health Surveys 1991–2016. *International Journal of Environmental Research and Public Health, 18*(10), 5184. https://doi.org/10.3390/ijerph18105184