Distribution Pattern Environmental Sanitation Analysis and Diarrhea with Stunting Incidence in Toddlers in Karo Regency North Sumatra Province

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Abstract

Stunting is a national problem because its increasing prevalence and impact can increase less competitive human resources, affect work productivity, increase the risk of overweight and obesity, and trigger metabolic syndrome. Environmental factors such as sanitation and hygiene, drinking water sources, drinking water quality, and toilet ownership are indirect factors causing stunting. This study aims to analyze the distribution of stunting incidence and environmental sanitation factors causing stunting in Karo Regency, North Sumatra, Indonesia. A case-control design was conducted on 246 toddlers with a 1:1 ratio. The distribution pattern of stunting incidence and the relationship between patient characteristics and environmental risk factors were studied using a Geographic Information System. Data on clean and healthy living behavior were collected using a questionnaire, and microbiological laboratory tests measured water quality. Spatial analysis used an average nearest-neighbor overlay. The relationship between characteristics and risk factors with stunting incidence was analyzed using chi-square and logistic regression. The average nearest neighbor analysis showed a nearest neighbor index of 0.19 (<1) (Z score -16.72, p-value 0.01). Regression analysis was carried out using GeoDa software (p-value 0.76). There was a relationship between clean water quality, clean and healthy lifestyles (PHBS), and diarrhea (p-value <0.05) and stunting. Family latrines, waste disposal facilities, and wastewater drainage (p-value >0.05) were not associated with stunting. Case distribution tended to be clustered, and no association was found between population density and stunting. This study's findings provide new insights that health promotion to prevent stunting should not only focus on nutritional fulfillment but also on clean and healthy living behaviors and water quality

Keywords: Stunting, sanitation, diarrhea, Karo regency, clean water, waste

INTRODUCTION

Stunting happens when children do not grow as they should, leaving them shorter than the standard height for their age. It’s not just a medical issue, it’s a major public health challenge, especially in poorer and developing countries. The World Health Organization (WHO) reported that in 2020, around 149.2 million children under five worldwide were affected by stunting (Gabain et al., 2023). In Southeast Asia, Indonesia ranks third (Kementerian Kesehatan, 2022), with an average prevalence of 36.4%.

Stunting affects more than just a child’s height; it can influence physical health, mental well-being, brain development, and even future achievement. Although governments and organizations have worked hard to tackle this issue over the past two decades, it continues to be a tough challenge (Aswi et al., 2024). Still, Indonesia has shown encouraging progress: in

2024, the national stunting rate dropped to 19.8%, according to the 2024 SSGI released in May 2025. This figure is even better than Bappenas' projection (Kementerian Kesehatan, 2025) of 20.1% for the same year.

Research on stunting shows that several factors play a role, including child malnutrition, parental education, and socioeconomic conditions (Agri et al., 2024; Wulandari & Arianti, 2023). Problems during pregnancy also matter, malnutrition and anemia in mothers can slow fetal growth, while poor sanitation raises the risk of infection and reduces the body's ability to absorb nutrients (Fardiani et al., 2025). Yet many studies overlook spatial effects, even though stunting rates in one area can be influenced by neighboring regions. Communities that are close to each other often share similar socioeconomic conditions, environments, and access to health services, which in turn can shape stunting patterns.

According to the Indonesian Nutritional Status Survey (SSGI), North Sumatra recorded a stunting rate of 22% in 2024, higher than the national average of 19.8%. In Karo Regency, local government data shows the prevalence dropped slightly from 24.9% in 2022 to 24.7% in 2023, with further declines expected in 2024–2025. Despite this progress, Karo remains a priority area for stunting reduction in the province. This highlights the urgent need to strengthen evidence-based interventions (SSGI, 2024), not only at the district and city level but also down to sub-districts and villages.

Stunting in toddlers is influenced by many factors, and one important cause is the environment. Challenges such as limited access to safe drinking water, poor sanitation, and inadequate hygiene practices (WASH) play a major role (Syahruddin et al., 2023). Data from the Ministry of Health's 2020 SKAMRT survey shows that about 70% of households in Indonesia still depend on drinking water contaminated with E. coli. Even more concerning, only 11.9% of the population has access to water that is truly safe to drink (Munthe et al., 2024). These water-related issues, restricted access, unsafe sources, and improper treatment, are believed to contribute to the high rates of stunting among toddlers. Consuming contaminated water can lead to illnesses (Putri et al., 2024) such as diarrhea and pneumonia, which weaken a child's nutritional status and increase their vulnerability to stunting.

Evidence from Indonesia and other middle-income countries shows that WASH (water, sanitation, and hygiene) and digestive infectious diseases are key factors behind stunting, alongside socio-economic conditions, nutrition, and maternal-child health services (Harahap et al., 2024). National studies reveal that children living in households with poor toilet facilities and untreated drinking water face a higher risk of stunting compared to those with better WASH conditions (Girma et al., 2024). More recent research also highlights the role of environmental enteric dysfunction (EED), a condition linked to gut dysbiosis and subclinical inflammation caused by exposure to fecal pathogens. These disruptions can reduce micronutrient absorption and hinder growth. However, findings remain mixed on how much WASH interventions alone (Rizaldi et al., 2025) can improve child growth outcomes.

This article seeks to provide a comprehensive analysis of how environmental factors, sanitation, and infectious diseases contribute to stunting among toddlers in Karo Regency. The central focus is on mapping the distribution of stunting cases to identify areas most at risk. By doing so, the study aims to offer a clearer picture of how local environmental conditions shape children's nutritional status. More specifically, the objectives are to: Describe the distribution patterns of stunting cases in toddlers across Karo Regency; Assess the risk of stunting in relation to access to clean water; Examine how toilet ownership and usage are linked to stunting; Evaluate the impact of household waste disposal systems on stunting incidence; Explore the role of handwashing with soap in preventing stunting; Investigate the relationship between wastewater drainage conditions and stunting. And analyze how recurrent diarrhea affects child nutrition and contributes to stunting.

This study is designed to build a stronger evidence base for understanding how sanitation and environmental health factors contribute to stunting at the local level. The findings are expected not only deepen academic insights into the causes of stunting in mountainous and agrarian regions like Karo Regency, but also offer practical guidance for local governments and public health stakeholders. With this knowledge, they can design more targeted and effective strategies to prevent and manage stunting.

METHODS

This study applied a quantitative case-control design, comparing toddlers who were stunted (cases) with those who were not (controls) to examine sanitation and WASH-related risk factors. The study population included all toddlers living within the service areas of 19 Community Health Centers in Karo Regency (38,284 children). From this population, a sample of 246 toddlers, 123 cases and 123 controls, was selected using the Lemeshow formula and simple random sampling. Data collection involved direct observations of sanitation facilities (such as drinking water sources, latrines, waste disposal systems, and wastewater treatment facilities) and structured interviews guided by a questionnaire based on WHO's 2014 WASH indicators.

The instrument was rigorously tested: content validity was confirmed through expert review, construct validity through item-total correlation, and reliability through Cronbach's

Alpha, which met the threshold of ≥0.70. Data analysis was carried out using SPSS v.26, which included descriptive tests, bivariate tests (Chi-square, α=0.05), and multiple logistic regression to identify the main factors contributing to stunting. Spatial analysis was also conducted: SaTScan was used to detect clusters, while GeoDa and QGIS were applied to map case distribution using the Average Nearest Neighbor method. The findings are presented in the form of frequencies, odds ratios (OR), relative risks (RR), 95% confidence intervals (CI), p-values, and visual maps of case distribution. This study received ethical approval from the Ethics Commission of the Medan Ministry of Health Polytechnic (No. 01.26504/KEPK/Poltekkes Kemenkes Medan/2024). Informed consent was obtained from parents of the toddlers, and confidentiality of respondent data was strictly maintained.

RESULTS

The characteristics of the respondents in this case are mothers of toddlers, including age, education, and occupation, which can be seen in Table 1.

Table 1. Distribution of Mothers of Toddlers Based on Characteristics

Characteristics	N	%
Age		
<20 years	33	13,4
21-25 years	16	6,5
26-30 years	69	28,0
31-35 years	43	17,5
36-40 years	65	26,4
41-45 years	20	8,1
Education		
Elementary School	3	1,2
Elementary School (Elementary/Junior High School)	80	32,5
Completed High School/Vocational High School	146	59,3
Diploma/Bachelor's Degree	17	6,9
Occupation		
Housewife	46	18,7
Farmer	138	56,1
Civil Servant	2	0,8
Self-Employed	44	17,9
Other	16	6,5
Income		
< Rp. 2.500.000,-	131	53,3
>= Rp. 2.500.000,-	115	46,7
Total	**246**	**100**

Based on Table 1, it can be seen that the distribution of maternal ages is mostly at the age of 26-30 years at 28%, followed by the age of 36-40 years at 26.4% and the age of 31-35 years at 17.5%. When viewed in terms of maternal education level, it is known that the majority of mothers with secondary education (SMA/SMK) as much as 59.3% and followed by elementary education (SD/SMP) as much as 32.5%. This shows that the level of maternal education is still in the secondary education category, this will affect the type of work and the mother's ability to receive the education provided (Nisa et al., 2023) The most common occupation for mothers was farming, at 56.1%, followed by housewives at 18.7%. The high number of mothers in both categories likely stems from their limited educational attainment, resulting in limited job opportunities. Meanwhile, the dominant family income, at 53.3%, was Rp. 2,500,000.

Table 2. Distribution of Children Based on Characteristics

Characteristics	n	%
Age		
6-12 Months	97	39,4
13-24 Months	127	51,6
25-36 Months	22	8,9
Total	**246**	**100**

From Table 2, it can be seen that the ages of the children who were the research samples were 13-24 months at 51.6%, followed by 6-12 months at 39.4% and 25-36 months at 8.9%.

Distribution Pattern of Stunting in Karo Regency

Stunting is a characteristic that indicates recurring and long-term nutritional problems. Karo Regency is one of the regencies with a relatively high stunting rate. The distribution of stunting cases in Karo Regency can be seen in Figure 1.

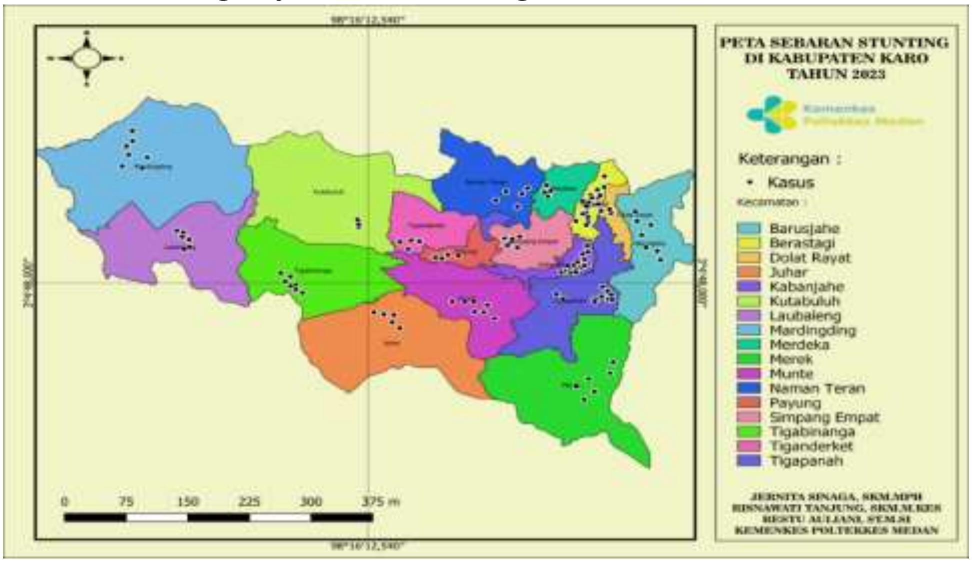

Figure 1. Distribution of Stunting Cases in Karo Regency

Stunting cases in Karo Regency are distributed across all villages. Based on the research, the highest number of cases occurred in Berastagi District, with 23 cases. Meanwhile, the villages with the lowest number of cases were Dolat Rayat and Kutabuluh Districts, with 3 cases.

The distribution of cases was then analyzed using the average nearest neighbor analysis method to determine the distribution pattern. The indicator used was the nearest neighbor index, taking into account the average distance from each case coordinate point. there are 5 clusters, namely : 33 cases, p-value <0.0001; RR: 4.51; radius: 31.68 km. This indicates a cluster of cases at highest risk, with a 4.51-fold increase in the risk of stunting for those within the cluster compared to those outside the cluster, with a radius of 31.68 km; 20 cases, p-value <0.0001; RR: 8.13; radius: 18.7 km, indicating a cluster of cases at highest risk, with an 8.13-fold risk of stunting for those within the cluster compared to those outside the cluster, with a radius of 18.7 km; There were 17 cases, p-value <0.0001; RR: 3.35; radius: 10.02 km, indicating a cluster of cases at highest risk, with a 3.35-fold risk of stunting for those within the cluster compared to those outside the cluster, with a radius of 10.02 km; There were 15 cases, p-value <0.0001; RR: 3.45; radius: 8.19 km, which means there is a cluster of cases at the highest risk, with a risk level of 3.45 times that of stunting for sufferers within the cluster compared to sufferers outside the cluster with a cluster radius of 8.19 km. And there are 10 cases, p-value <0.0001; RR: 6.73; radius: 5.54 km, which means there is a cluster of cases at the highest risk, with a risk level of 6.73 times that of stunting for sufferers within the cluster compared to sufferers outside the cluster with a cluster radius of 5.54 km.

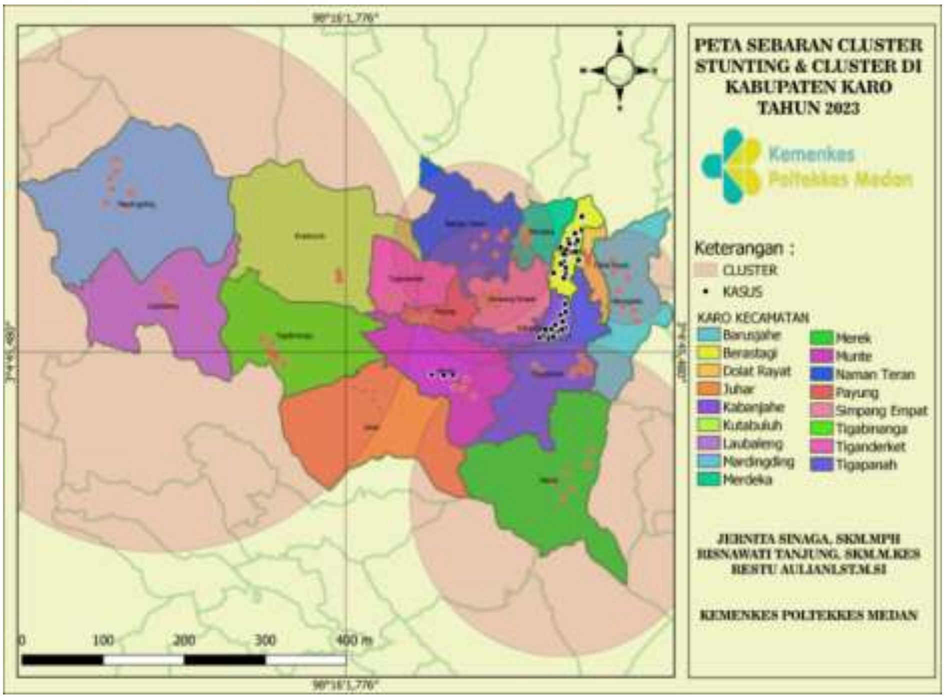

Figure 2. Nearest Neighbor Analysis and Distribution of Stunting Cases in Karo Regency

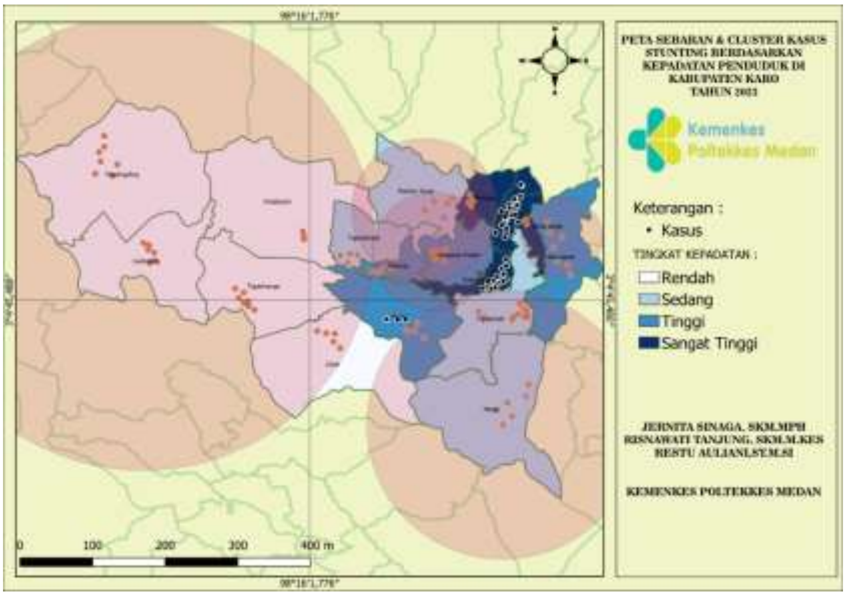

Figure 3. Map of Distribution of Stunting Cases Based on Population Density in Karo Regency

Based on the results of a regression analysis using GeoDa software, no relationship was found between population density and stunting in Karo Regency (p-value: 0.82). Stunting can occur due to both direct and indirect factors. The risk factors for stunting (clean water quality, toilet facilities, waste disposal facilities, handwashing habits with soap, wastewater drainage, and diarrhea) are shown in the table below.

Table 3. Relationship between Clean Water Quality, Clean and Healthy Living Behavior (PHBS), Toilet Facilities, Diarrhea Incidence, Waste Disposal Facilities, SPAL with Stunting Incidence

Variable	*Stunting*		*Not Stunting*		Total		*OR*	*p value*
	n	%	n	%	N	%		
Clean Water Quality								
Yes	93	75,6	47	38,2	140	56,9	5,01	0,000
No	30	24,4	76	61,8	106	43,1		
Clean and Healthy Living Behavior								
Good	58	47,2	82	66,7	140	56,9	2,24	0,003
Poor	65	52,8	41	33,3	106	43,1		
Family Toilet Facilities								
Qualify	63	51,2	77	62,6	140	56,9		
Not eligible	60	48,8	46	37,4	106	43,1	1,59	0,094
Diarrhea Incident								
No Diarrhea	43	35,0	61	54,6	104	42,3		
Diarrhea	80	65,0	62	50,4	142	57,7	1,83	0,028
Waste Disposal Facilities								
Qualify	54	43,9	67	54,5	121	49,2	1,52	0,126
Not eligible	69	56,1	56	45,5	125	50,8		
Wastewater Disposal Facilities (SPAL)								
Qualify	56	45,5	69	56,1	125	50,8	1,52	0,126
Not eligible	67	54,5	54	43,9	121	49,2		
Total	**123**	**100**	**123**	**100**	**246**	**100**		

This study found that clean water quality, PHBS, and diarrhea incidence were significantly associated with stunting. Toddlers who used clean water containing E. coli had a

5.01 times greater risk of stunting (p = 0.00), toddlers from families with poor PHBS had a 2.24 times greater risk (p = 0.01), and toddlers who had experienced diarrhea had a 1.83 times greater risk (p = 0.04). Meanwhile, family toilet facilities (OR = 1.59; p = 0.09), waste disposal facilities (OR = 1.52; p = 0.126), and wastewater drainage channels (OR = 1.52; p > 0.05) did not show a significant association with stunting, although they still have potential risks.

DISCUSSION

Geographic Information Systems (GIS) are map-based epidemiological visualizations that depict the distribution of health conditions according to regional analysis (Santoso et al., 2025). GIS is useful for observing the distribution pattern of stunting and its relationship to risk factors through a spatial perspective. The results of the average nearest neighbor analysis show a clustered distribution pattern of stunting cases. Analysis using SaTScan identified 5 significant clusters (p < 0.0001), namely: (1) 33 cases, RR = 4.51, radius 31.68 km; (2) 20 cases, RR = 8.13, radius 18.7 km; (3) 17 cases, RR = 3.35, radius 10.02 km; (4) 15 cases, RR = 3.45, radius 8.19 km; and (5) 10 cases, RR = 6.73, radius 5.54 km. These findings indicate that there are areas with a higher risk of stunting compared to areas outside the cluster.

This research is in line with research (García Cruz et al., 2017) which states that there is a relationship between the rural-urban status of an area and the incidence of stunting in that area. Children living in urban areas have a lower risk of experiencing stunting than children living in rural areas. Research (Rachmi et al., 2016) said the prevalence of stunting is increasing in densely populated and rural areas with a positive Moran I index value of 0.71 (p=0.0001) for stunting incidents in densely populated areas, 0.6 (p=0.0002) in rural areas and 0.45 (p=0.0001) in highland areas.

The quality of drinking water, particularly contamination with E. coli, has been shown to have a strong link with stunting (p = 0.000; OR = 5.01). Children exposed to unsafe water face a five-fold higher risk of becoming stunted. Access to clean water is essential, because without it, children are more likely to suffer from repeated diarrhea and worm infections. These illnesses interfere with nutrient absorption, deplete key micronutrients like zinc, and ultimately hinder growth (Kwami et al., 2019). In this study, 75.6% of stunted toddlers were found to be exposed to E. coli-contaminated water, compared to 38.2% of non-stunted toddlers. Multivariate analysis further confirmed that water quality was the dominant risk factor, with Exp B = 22.5 (p = 0.000). This finding underscores how limited access to clean water, still affecting one in three households, (Torlesse et al., 2016) contributes to higher rates of infectious disease and stunted growth in children.

The study found that Clean and Healthy Living Behavior (PHBS) was significantly linked to stunting, with a p-value of 0.003 and an odds ratio (OR) of 2.24. In other words, families with poor PHBS were more than twice as likely to have stunted children compared to families with good PHBS. Because stunting is driven by many factors, tackling it requires a multidisciplinary approach. Nutritional programs alone are not enough, lifestyle, sanitation, and environmental hygiene also play a crucial role (Aprizah, 2021). Poor sanitation and hygiene, in fact, are key indicators of PHBS.

Clean and Healthy Living Behavior (PHBS) is a preventive health effort that contributes about 30–35% to overall health. In this study, most stunted children came from families with poor PHBS (67.4%), while most non-stunted children came from families with good PHBS (66.7%). These findings are consistent with (Uliyanti et al., 2017), who also reported a significant relationship between PHBS and child health outcomes.

According to the Regulation of the Minister of Health of the Republic of Indonesia No. 2269/MENKES/PER/XI/2011, the guidelines for fostering Clean and Healthy Living Behavior (PHBS) include simple daily practices such as washing hands with soap, drinking boiled water, keeping eating utensils clean, covering food, trimming children's nails, and using proper latrines. To help reduce stunting rates, PHBS is promoted through integrated household-based programs that empower individuals, families, and communities. These efforts are carried out via village and sub-district forums, health cadres, Integrated Health Posts (Posyandu), home visits, and family support initiatives, all aimed at strengthening PHBS practices (Ministry of Health of Indonesia, 2011).

The study found that diarrhea was significantly linked to stunting ($p = 0.02$), with toddlers who experienced diarrhea facing a 1.83 times higher risk compared to those who did not. This reflects the vicious cycle between infection and nutrition: chronic infections worsen nutritional status, while malnutrition weakens immunity, making children more vulnerable to further infections. Each episode of diarrhea disrupts nutrient absorption, and when repeated or prolonged, it can hinder a child's growth. Diarrhea remains a major contributor to childhood illness and death, accounting for 15–34% of toddler mortality, around 300 cases annually. The risk is higher among children with poor hand and nail hygiene or those who do not wash their hands before eating, as these habits allow bacteria to enter the body. With their immune systems still developing, toddlers are especially susceptible. Diarrhea damages the intestinal villi, reducing nutrient absorption, and if persistent, contributes to stunting (Darmawan et al., 2025). In addition, unsanitary latrines (Zahrawani et al., 2022) can contaminate the environment, including clean water sources, and become another source of infection.

The study found that family toilet facilities were not significantly associated with stunting (p = 0.09), although toddlers from households with toilets that did not meet health standards faced a 1.59 times higher risk compared to those with healthy toilets. Ownership of sanitary toilets was fairly similar between groups: 51.2% in the stunting group and 62.6% in the non-stunting group. Most households in Karo Regency already use sanitary toilets equipped with gooseneck designs and septic tanks. Even so, unhealthy toilets can still trigger infectious diseases due to poor hygiene and sanitation, which in turn disrupt nutrient absorption in toddlers. This finding is consistent with the Decree of the Minister of Health No. 852/MENKES/SK/IX/2008, which emphasizes healthy toilets as effective facilities for breaking the chain of disease transmission. The results also align with Sanjaya et al., (2024), who reported no significant link between toilet ownership and stunting, and with Ihsan et al., (2020), who found that toilet quality had no direct effect but did have an indirect effect. Their study showed that unsanitary toilet conditions did not significantly affect stunting directly (β = 0.172), but indirectly contributed through other pathways (β = 0.556).

The study found that waste disposal facilities were not significantly associated with stunting (p = 0.126), although toddlers living in households with facilities that did not meet health standards faced a 1.26 times higher risk. In the stunting group, 43.9% of households had proper waste disposal facilities, compared to 54.5% in the non-stunting group. This result is consistent with Gea et al., (2023), who also reported no significant link, but differs from Mujahidin et al., (2025), who found an association. Proper household waste management remains important to prevent breeding grounds for disease vectors. However, in this study, most respondents managed their waste adequately, which explains why waste disposal did not have a direct impact on stunting.

The study found that 54.5% of households had inadequate wastewater drainage systems (SPAL), while 45.5% had adequate systems. Statistical tests showed no significant relationship between SPAL and stunting (p = 0.126), though toddlers living in homes with poor drainage faced a 1.52 times higher risk compared to those with proper systems. Many households without SPAL dispose of wastewater behind the house, leading to puddles, foul odors, and breeding grounds for diseases such as diarrhea, acute respiratory infections (ARI), and worms, all of which can weaken children's nutritional status (Kanan et al., 2024). Interestingly, some toddlers in homes with inadequate SPAL did not experience stunting, suggesting that other factors also play a role. One of these is Clean and Healthy Living Behavior (PHBS), whichAprizah (2021), highlights as closely linked to toddler nutrition and stunting prevention.

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