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BINARY LOGISTIC REGRESSION ANALYSIS OF ENVIRONMENTAL AND SOCIODEMOGRAPHIC DETERMINANTS FOR CHILDHOOD STUNTING

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ABSTRACT

This study analyzed the influence of regional disparities, environmental factors, and sociodemographic characteristics on stunting risk among children under five in Central Java. A cross-sectional design utilized secondary data from 73,358 children, which were evaluated through binary logistic regression to identify multiple risk factors. The results revealed that children residing in urban areas exhibited 1.73 times higher odds of stunting (95% CI: 1.27–2.36, $p < 0.001$). Unsafe non-drinking water access emerged as the most significant predictor, increasing stunting odds by 2.30 times (95% CI:1.56–3.37, $p < 0.001$). Conversely, parental education, employment status, and toilet availability showed no statistically significant associations with the outcome in this cohort. The study concluded that structural environmental challenges in urbanized settings outweighed individual sociodemographic factors. These findings highlight the necessity for targeted urban-specific sanitation strategies and improved water quality for daily household hygiene to effectively mitigate stunting prevalence and support regional health development targets.

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1. INTRODUCTION

Childhood stunting remains a critical indicator of global public health, reflecting chronic systemic nutritional and developmental deficits. Beyond physical growth retardation, stunting impairs cognitive development and diminishes long-term economic productivity, thereby perpetuating the cycle of poverty in low- and middle-income countries [1]. In Indonesia, despite a steady decline in national prevalence, current progress exhibits a substantial discrepancy relative to the strategic national milestones. As illustrated in Figure 1, the divergence between the observed prevalence and the ambitious national target of 14% by 2024 necessitates a steep, non-linear reduction trajectory that has yet to be fully realized [2]. This gap underscores the inadequacy of business-as-usual approaches in meeting national health milestones.

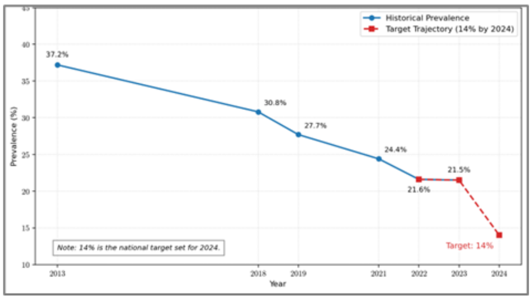

Figure 1: Trend of Stunting Prevalence in Indonesia Relative to the 2024 National Target.

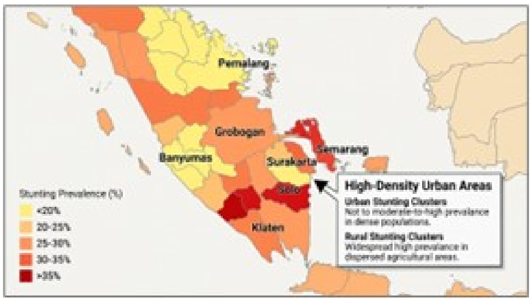

Figure 2: Spatial Disparity of Stunting Prevalence Across Districts in Central Java

Central Java, one of the nation's most densely populated provinces, serves as a critical focal point for this challenge. However, a generalized national approach often overlooks the substantial spatial heterogeneity within the province. As visualized in the choropleth map in Figure 2, stunting prevalence varies significantly across districts, with high-risk clusters appearing in both agricultural rural zones and dense urban centers. This localized persistence underscores the necessity for targeted, context-specific interventions that account for regional heterogeneity. The etiology of stunting extends far beyond inadequate dietary intake, as it is increasingly recognized as a multifaceted syndrome driven by complex socio-environmental determinants. The interaction between Water, Sanitation, and Hygiene (WASH) infrastructure and biological outcomes is fundamental to this syndrome. As noted by Beal et al. [3] [4], poor sanitation and reliance on unsafe water sources precipitate Environmental Enteric Dysfunction (EED). This pathophysiological pathway, detailed in the conceptual framework in Figure 3, illustrates how chronic exposure to fecal pathogens leads to subclinical intestinal inflammation and nutrient malabsorption. Consequently, growth faltering occurs even in the presence of adequate caloric intake, highlighting the critical role of environmental quality [5].

Despite growing academic and governmental attention, previous studies in Indonesia have mostly emphasized isolated socioeconomic determinants [6],[7],[8],[9], often relying on univariate analyses that fail to account for complex confounding variables. Specifically, fewer studies have jointly examined the interaction between urban-rural contexts, WASH conditions, and sociodemographic factors within a unified multivariate framework. Moreover,

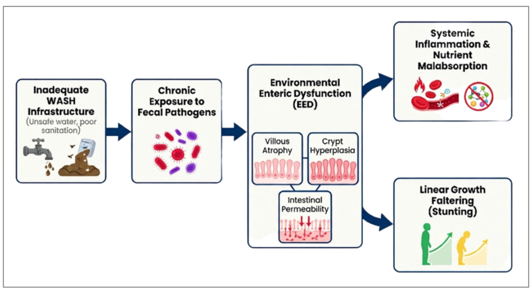

Figure 3: Pathophysiological Pathway of the Fecal-Oral Route and EED in the Etiology of Childhood Stunting

the role of unsafe non-drinking water as a potential risk factor for stunting in Central Java remains insufficiently studied. While extensive research addresses rural stunting, the emerging challenge of 'urban stunting' driven by high-density, poor-sanitation environments requires deeper empirical scrutiny [10]. Given the persistent burden of stunting in Indonesia and the spatial disparities across Central Java, identifying context-specific environmental and sociodemographic risk factors is essential for developing more effective interventions.

To address these unresolved problems, this study employs a binary logistic regression model to evaluate the cumulative risk of multidimensional determinants. By analyzing a large-scale dataset from the Indonesian Nutritional Status Survey (SSGI 2021), this approach provides a robust probabilistic framework to isolate the adjusted odds ratios (OR) of specific risk factors, offering actionable insights for targeted policy formulation. The ultimate objective is to analyze the multivariate influence of regional urban-rural disparities and household environmental factors on the risk of child stunting in Central Java, thereby providing a more nuanced evidence base for public health interventions.

2. RESEARCH METHOD

2.1 Study Design and Data Source

This study employed a quantitative research design with a cross-sectional approach, adhering to the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines [11] to ensure methodological transparency. The analysis utilized secondary data from the 2021 Indonesian Nutritional Status Survey (Studi Status Gizi Indonesia - SSGI) [2]. The dataset focused on households in Central Java Province, Indonesia, capturing a critical snapshot of child health during a period of significant demographic transition. This design was specifically chosen to evaluate the prevalence of stunting and to identify its environmental and sociodemographic predictors within a large-scale population [12].

2.2 Population and Sampling Procedure

The study population consisted of children under five years of age residing in Central Java. To ensure a representative sample across both urban and rural landscapes, the SSGI 2021 utilized a multi-stage stratified cluster sampling method. This rigorous sampling frame included all districts in the province, yielding a final analytical cohort of 73,358 children. During the data cleaning phase, observations with missing or biologically implausible anthropometric values (outliers in Height-for-Age Z-scores) were systematically excluded to maintain the integrity of the statistical estimation.

2.3 Operational Definition of Variables

The primary dependent variable was stunting status, modeled as a binary outcome. Following the World Health Organization (WHO) Growth Standards, children were classified as "stunted" (coded as 1) if their Height-for-Age Z-score (HAZ) was less than -2 standard deviations (-2 SD) from the median reference population. Conversely, children with a HAZ ≥ -2 SD were classified as "normal" (coded as 0). The independent variables were categorized into environmental and sociodemographic domains, as detailed in Table 1. The variable classifications followed the standardized protocols of the SSGI 2021 survey, which categorized water safety based on source type rather than microbial parameters.

Table 1: Operational Definition and Coding of Research Variables

Variable Category	**Predictor Variable**	**Symbol**	**Coding / Reference Category**
Dependent	Stunting Status	Y	0: Normal; 1: Stunted
Environmental	Residence Area	X_1	0: Rural; 1: Urban
	Drinking Water Access	X_2	0: Safe; 1: Unsafe
	Non-Drinking Water	X_3	0: Safe; 1: Unsafe
	Toilet Avai\lability	X_4	0: Available; 1: Unavailable
	Defecation Location	X_5	0: Inside; 1: Outside
Sociodemographic	Child's Sex	X_6	0: Female; 1: Male
	Mother's Education	X_7	0: Low; 1: Medium; 2: High
	Employment Status	X_8	0: Unemployed; 1: Employed

2.4 Statistical Analysis and Model Diagnostics

Data analysis was conducted using a structured quantitative approach with a cross-sectional study design to ensure the accuracy and robustness of the predictors for childhood stunting. The analytical process commenced with bivariate analysis using the Chi-Square (χ^2) test to evaluate the initial association between independent variables, comprising environmental and sociodemographic factors and the stunting status. The test was calculated using the following Equation (1).

$$\chi^2 = \sum \frac{(f_o - f_e)^2}{f_e} \tag{1}$$

where f_o represents the observed frequency and f_e denotes the expected frequency. To prevent the premature exclusion of potentially significant variables, all predictors with a p-value < 0.25 in the bivariate stage were progressed to the multivariate modeling phase.

Subsequently, Binary Logistic Regression was employed as the primary multivariate framework, given the dichotomous nature of the dependent variable. The model estimates the probability (P) of stunting occurrence through the logit link function, defined as Equation (2).

$$ln = \left(\frac{P}{1-P}\right) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_k X_k \tag{2}$$

where $ln = \left(\frac{P}{1-P}\right)$ represents the log-odds (logit), β_0 is the intercept, β_i denotes the regression coefficients for each predictor, and X_i represents the independent variables such as regional setting and water access.

To ensure the statistical validity of the derived model, the Hosmer-Lemeshow test was applied as a goodness-of-fit measure. This test follows a Chi-Square distribution, formulated as:

$$H = \sum_{g-1}^{G} \frac{(O_g - E_g)^2}{E_g\,(1 - E_g/n_g)} \tag{3}$$

where O_g and E_g are the observed and expected events in the $g-th$ group, respectively, and n_g is the number of observations . A p-value > 0.05 was utilized as the threshold to indicate that the model's predictions are consistent with the observed data. Furthermore, potential multicollinearity among independent variables was scrutinized using the Variance Inflation Factor (VIF), calculated as Equation (4).

$$VIF = \frac{1}{1 - R_j^2} \tag{4}$$

where R_j^2 is the coefficient of determination when regressing variable j against all other predictors. A conservative threshold of VIF < 10 was strictly maintained to ensure no significant redundancy within the model.

Finally, the strength and direction of the associations were interpreted using the Adjusted Odds Ratio (AOR), derived from the antilogarithm of the regression coefficients:

$$AOR = e^{\beta} \tag{5}$$

An AOR ¿ 1 indicated that the variable is a significant risk factor, increasing the probability of stunting within the population, while the precision of these estimates was confirmed via 95% Confidence Intervals (CI). All statistical analyses and model diagnostics were performed using R version 4.2.2 with the anthro package for anthropometric Z-score calculations. Spatial mapping for regional disparities was generated using QGIS v3.22, while the conceptual framework was illustrated using draw.io.

2.5 Ethical Considerations

As this study analyzed anonymized secondary data from a public national survey (SSGI), it was exempt from formal ethical review. However, the researchers maintained full compliance with ethical standards for data handling, ensuring that the confidentiality of the households was preserved throughout the analysis.

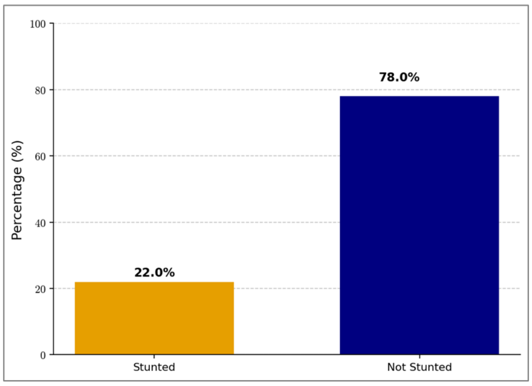

Figure 4: Distribution of Stunting Status in Central Java

3. RESULT AND ANALYSIS

3.1 Descriptive Statistics and Stunting Prevalence

The analysis included a total of 73,358 children, providing a high-powered dataset to examine the determinants of growth faltering in Central Java. Table 2 presents the socio-environmental characteristics of the cohort. A notable demographic feature is the high degree of urbanization, with 74.34% of respondents residing in urban areas. Despite the relatively high coverage of basic infrastructure evidenced by nearly universal access to toilet facilities (98.42%) significant vulnerabilities remain in the quality of water used for domestic purposes. As illustrated in Figure 4, the prevalence of stunting within this cohort remains a significant public health concern. While the majority of children are classified as "Not Stunted," the affected sub-population represents a critical mass that requires targeted intervention. The descriptive data suggest a "water quality loophole": while 72.26% have safe drinking water, a subset of the population (6.80%) relies on unsafe water for non-drinking activities (bathing, cleaning, etc.), which may serve as a hidden vector for pathogen transmission.

Table 2: Socio-Environmental and Demographic Characteristics of the Study Populations (N=73,358)

Variable	**Category**	**Frequency** (n)	**Percentage** (%)
Regional Setting	Urban	54,534	74.34
	Rural	18,824	25.66
Child's Sex	Male	34,669	47.26
	Female	38,689	52.74
Parental Education	High	5,186	7.07
	Medium	27,289	37.20
	Low	40,883	55.73
Employment Status	Employed	45,900	62.57
	Unemployed	27,458	37.43
Drinking Water Access	Safe	53,009	72.26
	Unsafe	20,349	27.74
Non-Drinking Water	Safe	68,370	93.20
	Unsafe	4,988	6.80
Sanitation (Toilet)	Available	72,199	98.42
	Unavailable	1,159	1.58
Defecation Site	Private/Inside	70,878	96.62
	Public/Outside	2,480	3.38

3.2 Multivariate Determinants and Model Rigor

To determine the independent effect of each variable while adjusting for potential confounders, a Binary Logistic Regression was employed. The model demonstrated excellent fit, as indicated by the Hosmer-Lemeshow test ($\chi^2 = 5.14, p = 0.642$), suggesting that the model's predictions are consistent with the observed data. Diagnostic tests for multicollinearity revealed Variance Inflation Factor (VIF) values ranging from 1.02 to 1.28, well below the conservative threshold of 2.5, confirming the stability of the coefficient estimates.

Table 3: Adjusted Odds Ratios (AOR) for Factors Associated with Childhood Stunting

Predictor Variable	β	**AOR**	95% **CI**	$p - value$
(Intercept)	6.094	0.002	[0.001, 0.003]	< 0.001
Region (Urban)	0.551	1.73	[1.27, 2.36]	< 0.001
Child's Sex (Female)	0.126	1.13	[0.89, 1.44]	0.296
Education (Medium)	0.157	0.85	[0.60, 1.21]	0.371
Education (Low)	0.073	1.08	[0.84, 1.38]	0.572
Employment (Unemployed)	0.029	0.97	[0.75, 1.25]	0.823
Drinking Water (Unsafe)	0.170	0.84	[0.63, 1.12]	0.240
Non-Drinking Water (Unsafe)	0.832	2.30	[1.56, 3.37]	< 0.001
Toilet (Unavailable)	0.628	1.87	[0.54, 6.44]	0.318
Defecation (Outside)	0.305	0.74	[0.27, 1.98]	0.546

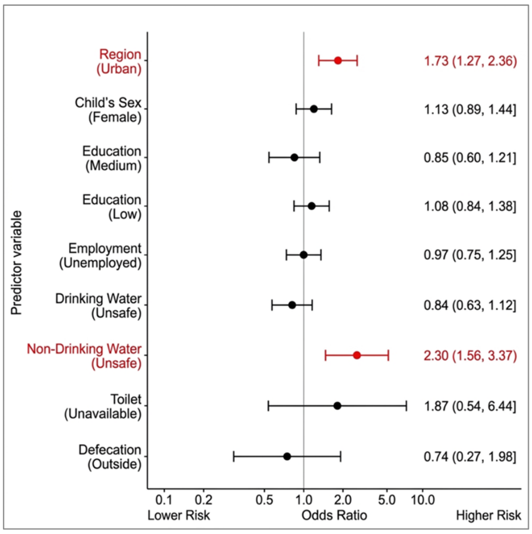

Figure 5: Forest Plot of Adjusted Odds Ratios (AOR) for Stunting Risk Factors

The Forest Plot in Figure 5 visually summarizes the magnitude of risk for each predictor variable after controlling for confounders. The analysis identifies two primary drivers of stunting with high statistical precision: regional setting and the quality of non-drinking water. Specifically, children residing in urban areas exhibit 1.73 times higher odds of being stunted compared to those in rural regions (AOR=1.73; 95% CI:$1.27 - 2.36$). Notably, the use of unsafe water for non-drinking purposes emerged as the most potent predictor, increasing the odds of stunting by 130% (AOR=2.30;95%CI:1.56-3.37). To assess the public health significance, we estimated the Population Attributable Fraction (PAF), finding that approximately 8.1% of stunting cases in the population could be averted if unsafe non-drinking water exposures were eliminated. For urban residency, the PAF was estimated at 35.1%, highlighting the heavy burden imposed by the urban environment.

In contrast, traditional socioeconomic proxies, including parental education and employment status, did not reach statistical significance within this multivariate framework ($p > 0.05$), with confidence intervals crossing the null value of 1.0. Furthermore, while the lack of toilet facilities showed a high point estimate (AOR=1.87), its extremely wide confidence interval (95% CI:0.54-6.44) indicates substantial variability, likely due to the low frequency of households without sanitation in the dataset.

3.3 Discussion

The findings of this study provide a compelling multivariate perspective on the structural and environmental loopholes that perpetuate stunting in Central Java. Primarily, the identification of urban residence as a significant risk factor (AOR=1.73; $p < 0.001$) confirms the existence of an "urban paradox" in the region. While urban environments are traditionally associated with superior healthcare access and infrastructure, our data suggest that rapid, high-density urbanization has created localized pockets of vulnerability. In these dense urban centers, the "neighborhood effect" often negates individual household improvements; even households with safe practices are compromised by the collective burden of poor waste management and environmental contamination in surrounding slums [10,13]. This erosion of the urban advantage indicates that proximity to health facilities is insufficient when the immediate physical environment remains a high-risk vector for infection. While we propose a 'neighborhood effect' as a driver for this risk, where localized crowding and shared waste systems compromise hygiene, we acknowledge that this remains a conceptual interpretation. Future studies employing spatial regression or mediation analysis are needed to empirically unpack these granular urban risk mechanisms.

The most potent predictor identified in this framework is the quality of non-drinking water, which increases stunting odds by 130% (AOR=2.30;$p < 0.001$). This result provides critical empirical support for the Environmental Enteric Dysfunction (EED) hypothesis. To further validate the robustness of this association against unmeasured confounding (such as dietary diversity or maternal height), we calculated an E-value of 4.03 for the non-drinking water effect. This high E-value suggests that any unmeasured confounder would need to possess a substantial association with both the exposure and the outcome to negate our findings, thereby reinforcing the stability of our model estimates. Unlike acute diarrheal diseases, EED is a subclinical intestinal inflammation caused by chronic ingestion of fecal pathogens, which leads to chronic malabsorption of nutrients [5]. As illustrated in the biological pathway of fecal-oral transmission, even when households invest in safe bottled water for consumption, the reliance on contaminated well or river water for secondary activities such as bathing, dishwashing, or laundry facilitates a "silent" ingestion of pathogens.

As illustrated in the biological pathway of fecal-oral transmission can be seen in Figure 5, even when households invest in safe bottled water for consumption, the reliance on contaminated water for secondary activities, such as bathing and cleaning, facilitates a 'silent' ingestion of pathogens. This chronic exposure triggers intestinal inflammation, leading to nutrient malabsorption and eventual growth faltering.

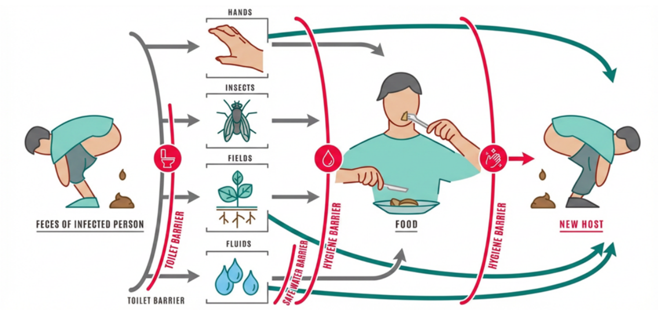

Figure 6: Conceptual Pathway of Stunting via Fecal-Oral Transmission and Environmental Enteric Dysfunction (EED)

This mechanism explains why current interventions that focus narrowly on "clean drinking water" have failed to reach the national target of 14%. Without safeguarding all domestic water sources, the biological tax of a contaminated environment will continue to override other nutritional gains [13].

Furthermore, the lack of statistical significance for parental education and employment status ($p > 0.05$) represents a critical shift in the stunting landscape. This "socioeconomic neutrality" suggests that the environmental burden in Central Java is so pervasive that it overrides the protective benefits typically provided by a parent's social standing. A parent's education cannot compensate for a child's constant exposure to structural environmental deficits. Similarly, while the lack of toilet facilities showed a high point estimate for risk ($AOR = 1.87$), its non-significance due to a wide confidence interval (0.54–6.44) likely reflects the success of basic sanitation coverage in the region (98.42% availability), but also highlights that the existence of a toilet is less important than the safety of the water used within it. These findings underscore a necessary shift from "nutrition-specific" policies toward "nutrition-sensitive" structural reforms, specifically focusing on urban water infrastructure and groundwater protection [3].

Despite the high power of this 73,358 child dataset, certain limitations must be acknowledged. The cross-sectional nature of the SSGI 2021 data allows for the identification of associations but precludes the establishment of definitive causality. Additionally, the secondary nature of the database meant that critical confounding variables such as breastfeeding duration, dietary diversity, and household income could not be integrated into the model. Future research should leverage Geographic Information Systems (GIS) to map specific "EED hotspots" within urban slums to allow for micro-targeted interventions. Nevertheless, this study's strength lies in exposing the hidden risk of non-drinking water, providing a robust empirical foundation for a more holistic WASH strategy in Indonesia's stunting eradication programs. However, as this study is focused on Central Java, the findings' external validity may be primarily limited to similar high-density provinces in Indonesia. The transferability to regions with different ecological or governance contexts, such as the less-populated outer islands, should be approached with caution and requires further comparative research.

3.4 Limitations

Despite its robust sample size, this study has several limitations that warrant consideration. First, the reliance on secondary data from SSGI 2021 meant that key confounders, including breastfeeding duration, dietary diversity, household income, and maternal height were unavailable for adjustment. This absence introduces the potential for residual confounding, where the observed effect of water quality might be partially influenced by unmeasured socioeconomic or nutritional factors. Second, the classification of water as 'safe' or 'unsafe' was based on source categories rather than microbial testing or E. coli counts, which may mask underlying heterogeneity in pathogen exposure. Third, the use of a binary urban-rural residence variable oversimplifies the complex peri-urban gradients where infrastructure deficits are often most acute. Future research should consider utilizing population density or infrastructure indices to better capture these spatial nuances. Finally, as the data were collected in 2021, the findings reflect a specific post-pandemic context that may not fully capture subsequent shifts in WASH access or economic stressors. These factors should be considered when generalizing the results to current policy frameworks.

4. CONCLUSION

This research successfully achieves its objective of elucidating the multivariate determinants of stunting in Central Java identifying that growth faltering is significantly associated with systemic environmental stressors rather than personal sociodemographic standing. Through a robust logistic regression framework, the study reveals a significant geographical disparity where children in urbanized settings and those exposed to unsafe non-drinking water face substantially higher odds of stunting. This evidence suggests a potential link between the challenges of rapid urbanization and the development of essential sanitation infrastructure, creating "urban pockets of vulnerability." The lack of significant association between parental socioeconomic proxies, such as education and employment, and nutritional outcomes further reinforces the observation that household-level social standing cannot may not sufficiently buffer children against the pervasive biological tax imposed by a contaminated physical environment.

Theoretically, these findings provide critical empirical weight to the Environmental Enteric Dysfunction (EED) hypothesis, identifying proposing unsafe water for hygiene as a "silent vector" that may be linked to subclinical intestinal inflammation and nutrient malabsorption. From a policy perspective, the identified risk factors highlight the importance of nutrition-sensitive structural reforms. In light of these specific findings, enhancing urban-specific sanitation upgrades and the stringent regulation of groundwater quality for all domestic uses to emerge as relevant considerations for breaking the cycle of stunting. While this high-powered cross-sectional analysis provides a clear snapshot of environmental risk associations, its reliance on secondary data precludes the establishment of temporal causality. Future research should therefore transition toward longitudinal designs and the integration of spatial "hotspot" mapping to further validate these findings and refine the precision of public health interventions in rapidly developing regions.

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