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Household Water Microbiological Screening by Toddler Stunting Status and Immediate Changes in Caregiver Knowledge in South Cimahi, Indonesia

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ABSTRACT

Household water quality and caregiver knowledge are relevant to environmental-health programs addressing childhood stunting, but their relationship requires cautious interpretation. This study aimed to compare presumptive coliform detection and selected physicochemical water parameters between households with stunted and non-stunted toddlers, and to describe immediate changes in caregiver knowledge after a single educational session. Two linked components were conducted in South Cimahi, Indonesia, in 2026: an exploratory cross-sectional comparison of 30 households selected from child health records (15 per stunting group) and a one-group immediate pretest–posttest assessment of 30 caregivers. Household water samples were cultured on MacConkey agar for presumptive coliform-like growth and examined for pH and dissolved iron (Fe), while caregiver knowledge was measured with the same 10-item questionnaire before and after education. Presumptive coliform-like growth was found in 12 of 15 (80.0%) households with a stunted toddler and 5 of 15 (33.3%) households with a non-stunted toddler (unadjusted OR 8.00; 95% CI 1.52–42.04; Fisher's exact $p = 0.025$). All pH values were within 6.5–8.5, and one Fe value exceeded 0.2 mg/L. Mean knowledge scores increased from 55.33 ± 9.73 to 86.33 ± 6.15 immediately after the session (median paired increase 30 points; Wilcoxon $p < 0.001$), and all caregivers scored ≥80 afterward. Presumptive coliform-like growth was more common in households with stunted toddlers; however, the small sample and the lack of organism confirmation preclude causal or regulatory-compliance conclusions, and the immediate score gains do not demonstrate sustained learning, behavior change, or safer water.

Keywords: Caregiver knowledge; Cross-sectional study; Household water; Presumptive coliform; Stunting; Water hygiene

INTRODUCTION

Stunting arises through interacting dietary, infectious, socioeconomic, and environmental determinants (Danaei et al., 2016; Vaivada et al., 2020). Reducing stunting remains a global and national priority (World Health Organization et al., 2023; Pemerintah Republik Indonesia, 2021). Inadequate sanitation and unsafe water may contribute to enteric exposure, but environmental enteric dysfunction and growth impairment cannot be inferred from household water screening alone (Mbuya & Humphrey, 2016; Budge et al., 2019). Water, sanitation, and hygiene form part of broader strategies alongside nutrition-specific actions (Cumming & Cairncross, 2016).

Household water can become microbiologically contaminated at its source, during distribution, or in storage (Wright et al., 2004; Bain et al., 2014; Genter et al., 2021). The intended use of water is important when selecting regulatory comparison values. Indonesia's Ministry of Health Regulation No. 2 of 2023, Annex, section "Water for Hygiene and Sanitation," Table 3, specifies zero *E. coli* and total coliform CFU/100 mL, pH 6.5–8.5, and dissolved Fe ≤0.2 mg/L for that water category (Kementerian Kesehatan Republik Indonesia, 2023; World Health Organization, 2017). However, direct MacConkey agar colony counts without species/indicator confirmation cannot establish compliance with the standard's prescribed total-coliform and *E. coli* indicators.

Relevant Indonesian evidence links environmental sanitation and water-related practices to child health (Khairunnisa et al., 2024; Oktaviana et al., 2025; Paundanan et al., 2025), and recent local assessments have documented variable water quality in community and household supplies (Rif'atunnisa et al., 2026; Yasin et al., 2026). These associations motivate local screening, but neither detection of presumptive colonies nor a cross-

sectional comparison is sufficient to infer pathogen-specific exposure, temporality, or causation.

This study in South Cimahi District addresses two distinct research questions: (1) how frequently were presumptive coliform-like colonies detected, and how did pH and dissolved Fe differ, in water sampled from households with stunted versus non-stunted toddlers; and (2) how did caregivers' scores on a 10-item knowledge questionnaire change immediately after an educational session? The first component is observational and exploratory; the second is an uncontrolled before–after description, not an efficacy trial.

METHODS

Study Design and Setting

A community-based program in 2026 covered Cibeber, Leuwigajah, Utama, Melong, and Cibeureum in South Cimahi District, West Java, where households rely on a mix of bore wells, dug wells, and piped supply (Dinas Perumahan dan Kawasan Permukiman Kota Cimahi, 2021). Two analytically distinct components used the same participating households: (i) an exploratory cross-sectional comparison of water-screening results by toddler stunting classification and (ii) a single-group, immediate pretest–posttest assessment of caregiver knowledge. Neither component was designed to estimate a causal effect.

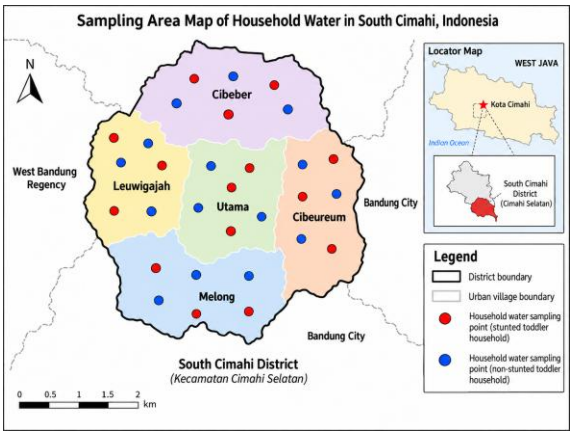


Figure 1. Schematic distribution of household water-sampling points across the five urban villages of South Cimahi District

Participants and Household Characteristics

The study included 30 households, comprising 15 with stunted toddlers and 15 with non-stunted toddlers, randomly selected within each group from existing child health records across five urban villages in South Cimahi District, with equal allocation (15 per group) rather than probability sampling of the district population. Households were excluded if no caregiver was willing to participate in the interview or provide a household water sample. Eligible children were aged 0–59 months.

Stunting status was confirmed through anthropometric measurements conducted by final-year students of Politeknik Kesehatan Kementerian Kesehatan Bandung under faculty supervision during July 2026. Recumbent length was measured using an infantometer for children younger than 24 months, while standing height was measured using a stadiometer for children aged 24–59 months. Classification followed the WHO Child Growth Standards using length-for-age or height-for-age Z-scores (LAZ/HAZ), with stunting defined as a Z-score below −2 standard deviations.

Anthropometric measurements and classifications were repeatedly cross-checked against original health records by three research team members to ensure data accuracy and consistency. Although households were randomly selected within groups from existing records, the small sample size and predetermined equal group allocation limit population representativeness. Therefore, the findings should be interpreted as exploratory and should not be generalized to all households in South Cimahi District.

The map in Figure 1 illustrates the geographic coverage of 30 participating households, comprising 15 households with stunted toddlers and 15 with non-stunted toddlers, across five urban villages in South Cimahi District. All sampling points represent household water collected for hygiene and sanitation purposes and subsequently examined in the laboratory. The sampling locations are presented schematically rather than as exact geographic coordinates. Therefore, the map does not imply geographic representativeness of the study population.

Table 1 summarizes the baseline characteristics of the 30 participating households, equally divided between the stunted and non-stunted toddler groups. Female children accounted for 53.3% and 73.3% of the respective groups, while children aged 0–24 months represented 53.3% and 33.3%. A history of diarrhea during the preceding year was reported for 46.7% of stunted toddlers and 40.0% of non-stunted toddlers. Bore wells were the predominant household water source in both groups (66.7% and 60.0%, respectively). Notably, water sources located less than 10 m from a septic tank were more frequently reported among households with stunted toddlers (80.0%) than those with non-stunted toddlers (60.0%). These descriptive differences suggest potential variation in demographic and environmental characteristics between groups. Given the small sample size and absence of multivariable adjustment, residual confounding cannot be excluded when interpreting the observed association between household water quality and toddler stunting status.

Table 1. Baseline characteristics of participating toddlers and households by stunting status (n = 30)

Characteristic	Stunted toddlers (n = 15)	Non-stunted toddlers (n = 15)	Total (n = 30)
Child sex			
Male	7 (46.7)	4 (26.7)	11 (36.7)
Female	8 (53.3)	11 (73.3)	19 (63.3)
Child age			
0–24 months	8 (53.3)	5 (33.3)	13 (43.3)
25–59 months	7 (46.7)	10 (66.7)	17 (56.7)
Diarrhea during the preceding year			
Yes	7 (46.7)	6 (40.0)	13 (43.3)
No	8 (53.3)	9 (60.0)	17 (56.7)
Household water source			
Bore well	10 (66.7)	9 (60.0)	19 (63.3)
Dug well	2 (13.3)	2 (13.3)	4 (13.3)
Piped water supply (PDAM)	3 (20.0)	4 (26.7)	7 (23.3)
Water source–septic tank distance			
<10 m	12 (80.0)	9 (60.0)	21 (70.0)
≥10 m	2 (13.3)	5 (33.3)	7 (23.3)
Unknown	1 (6.7)	1 (6.7)	2 (6.7)

Note: Values are n (%). Source: primary program data, 2026.

Water Sampling and Laboratory Examination

Household water samples intended for hygiene and sanitation were collected from domestic water sources or outlets in South Cimahi District in early July 2026, between 08:00 and 12:00 Western Indonesian Time. Before sampling, outlets were disinfected using alcohol-soaked cotton for heat-sensitive materials or flame sterilization for heat-resistant materials, followed by flushing for 1–2 minutes. Approximately 200 mL of water was collected in sterile, tightly capped 250-mL glass bottles with appropriate sample identification. Samples were transported to the Medical Laboratory Technology laboratories in a cool box maintained at 4–8°C, and microbiological examination was initiated approximately two hours after collection. No chemical disinfectant neutralizer was added.

Microbiological analysis was performed using serial dilutions (10^{0}–10^{-3}) prepared in sterile physiological saline. A 10-µL aliquot from each dilution was inoculated onto MacConkey agar using a calibrated loop, with duplicate examinations performed for each sample. Plates were incubated at 35–37°C for 24–48 hours. Colony counts within 30–300 colonies were used for quantitative estimation, while counts below this range were estimated from the lowest available dilution. Bacterial concentrations were calculated as CFU/100 mL by accounting for the inoculated volume and dilution factor. For example, two colonies recovered from 10 µL of undiluted water corresponded to an estimated 2×10^{4} CFU/100 mL. Quality control included visual inspection of unexpired culture media, sterile MacConkey agar and physiological saline as negative-control materials, and an *Escherichia coli* positive control exhibiting characteristic pink lactose-fermenting colonies. As confirmatory identification of environmental isolates was not performed, results were interpreted as presumptive coliform-like bacterial growth rather than confirmed total coliform or *E. coli* contamination. Counts below the established countable range were considered approximate estimates, while the absence of visible growth did not establish microbiological sterility.

Physicochemical analysis included pH measurement using a calibrated digital pH meter and dissolved iron (Fe) determination by spectrophotometry. Results were compared with the reference values for water intended for hygiene and sanitation specified in Indonesian Ministry of Health Regulation No. 2 of 2023 (pH 6.5–8.5; Fe ≤0.2 mg/L). A descriptive screening classification incorporating presumptive bacterial growth, pH, and Fe was applied to characterize household water quality. This classification was intended for exploratory assessment rather than formal regulatory compliance determination, as microbiological identification was not confirmed using a validated reference method.

Educational Intervention and Knowledge Assessment

Caregiver knowledge was assessed using a 10-item multiple-choice questionnaire developed collaboratively by the research team with expertise in microbiology, water chemistry, and public health. The instrument covered stunting prevention, waterborne health risks, microbiological and physicochemical water-quality indicators, handwashing with soap, and safe household water management. Each correct response was assigned 10 points, yielding a total score of 0–100, categorized descriptively as poor (<60), moderate (60–79), or good (≥80). These categories were established for program evaluation rather than derived from validated thresholds. No independent formal content-validity assessment was conducted, and psychometric reliability estimates were not available.

The intervention followed a structured sequence comprising informed consent, verification of toddler stunting status through anthropometric assessment, household interviews, pretesting, education, immediate posttesting, household water sampling, and subsequent laboratory examination. A single 60-minute educational session was delivered by faculty researchers with postgraduate qualifications in microbiology, public health, and chemistry. Educational activities incorporated presentations, interactive discussions, and practical demonstrations supported by a pocketbook and two educational posters distributed to participants. The session aimed to strengthen caregivers' understanding of stunting and its prevention, the potential relationship between contaminated water, recurrent diarrhea, and impaired child growth, basic water-quality indicators, proper handwashing practices, and safe household water treatment and storage. The same questionnaire was administered immediately before and after education to assess short-term changes in knowledge scores. Given the absence of a comparison group and delayed follow-up, potential testing and recall effects could not be excluded, and the findings were interpreted as immediate changes in test performance rather than evidence of sustained knowledge retention or behavioral improvement.

Statistical Analysis

Categorical variables were summarized as frequencies and percentages, while continuous variables were expressed as means, standard deviations, medians, and ranges. The association between presumptive coliform-like bacterial growth and toddler stunting status was assessed using a two-sided Fisher's exact test, with the Yates-corrected chi-square test retained for comparison. Unadjusted odds ratios (ORs) and 95% confidence intervals (CIs) were calculated without multivariable adjustment because of the small sample size and potential instability of estimates. Caregiver knowledge scores were analyzed using the Shapiro–Wilk test for normality of paired differences, followed by the Wilcoxon signed-rank test with average ranks assigned to tied absolute differences. The matched-pairs rank-biserial correlation was calculated to determine the magnitude and direction of score changes. Statistical significance was set at a two-sided p-value <0.05, with all findings interpreted as exploratory rather than causal.

RESULTS AND DISCUSSION

Household Water Quality

In the 30-household program sample, presumptive coliform-like growth was recorded in 12/15 (80.0%) households with a stunted toddler and 5/15 (33.3%) with a non-stunted toddler. Corresponding counts without recorded growth were 3 and 10, respectively. The unadjusted odds ratio for detected growth by stunting-group status was 8.00 (95% CI 1.52–42.04; Fisher's exact two-sided p = 0.025; Yates-corrected p = 0.027). The confidence interval is wide, and the observed association must not be described as a causal or independently adjusted relationship.

All measured pH values fell within the 6.5–8.5 reference interval. Dissolved Fe exceeded 0.2 mg/L in one sample in the stunted-toddler group. The group means for pH were 7.33 and 7.43, and mean Fe values were 0.062 and 0.038 mg/L, respectively. Presumptive growth, rather than pH or Fe exceedance, accounted for most positive screening flags. Neither water-use categories nor organisms were adequately confirmed for a formal statement that samples "failed" Indonesian regulatory standards.

The exact 2×2 distribution is presented in Table 2. The contrast applies only to these 30 program households, which were not a probability sample of the district, and is not an estimate of district prevalence or the independent influence of water quality on stunting.

Table 2. Household water screening results by toddler stunting status (n = 30)

Parameter	Stunted toddlers (n = 15)	Non-stunted toddlers (n = 15)
Presumptive coliform detected, n (%)	12 (80.0)	5 (33.3)
pH, mean ± SD	7.33 ± 0.21	7.43 ± 0.46
pH range	6.94–7.77	6.76–8.43
Fe (mg/L), mean ± SD	0.062 ± 0.076	0.038 ± 0.019
Fe range (mg/L)	0.02–0.32	0.02–0.09
pH outside 6.5–8.5, n (%)	0 (0.0)	0 (0.0)
Fe >0.2 mg/L, n (%)	1 (6.7)	0 (0.0)
Composite screening flag[a], n (%)	12 (80.0)	5 (33.3)

Note: Reference values follow Ministry of Health Regulation No. 2 of 2023 for water for hygiene and sanitation (pH 6.5–8.5; Fe ≤0.2 mg/L). [a]Presumptive growth, pH outside the reference range, or Fe >0.2 mg/L; descriptive screening only, not validated regulatory compliance.

Water can meet selected pH and Fe comparison values yet yield presumptive growth on selective agar. However, this study did not use confirmatory *E. coli* or total-coliform identification on every sample; the finding is a screening signal rather than verified fecal contamination. In addition, the presence of presumptive colonies in sampled household water does not demonstrate that toddlers drank it or how often exposure occurred.

Recurrent enteric infection and environmental enteric dysfunction are biologically plausible pathways discussed in the literature (Mbuya & Humphrey, 2016; Budge et al., 2019), not outcomes measured here. No pathogen-specific confirmation, intestinal biomarkers, nutritional intake, or longitudinal exposure data were collected. The temporal direction between a one-time water result and the chronic development of stunting is unknown.

Related observational studies have reported associations involving WASH conditions and child growth (Fink et al., 2011; Spears et al., 2013; Gizaw et al., 2022; Paundanan et al., 2025), while large randomized interventions illustrate the complexity of achieving linear-growth improvements (Luby et al., 2018). Potential confounding includes child age, nutritional adequacy, socioeconomic position, maternal education, diarrhea history, source characteristics, sanitation, and hygiene. These factors were not adequately measured or jointly analyzed in this small sample. Accordingly, no adjusted effect, biological mediation, or causal effect should be inferred.

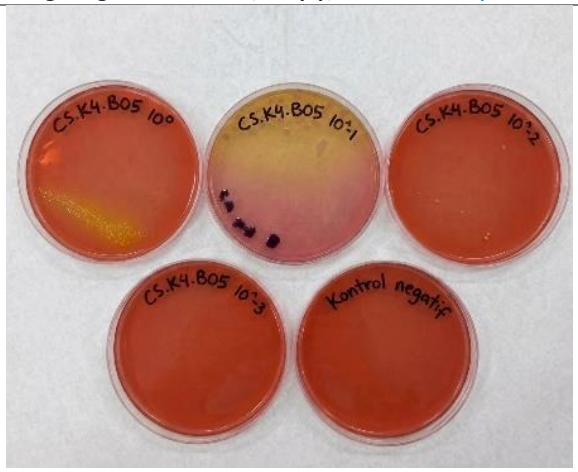


Figure 2. Representative presumptive colony growth on MacConkey agar from a household water sample at serial dilutions, with a negative control

Figure 2 provides a visual representation of viable bacterial growth recovered from selected water samples. MacConkey agar is selective for many Gram-negative enteric organisms and differentiates colonies according to lactose-fermentation characteristics; therefore, visible growth supports the presence of presumptive enteric bacteria but does not, by itself, establish species identity. The negative control was included to assess procedural contamination. This conservative interpretation is important because water-quality surveillance literature distinguishes screening indicators from confirmed organism identification and emphasizes the need for standardized quality control and confirmatory testing when species-level conclusions are intended (Bain et al., 2014; Bain et al., 2021). Because complete biochemical or molecular confirmation was not documented for every isolate, the findings are appropriately reported as presumptive coliform colony counts rather than confirmed *Escherichia coli*.

The group contrast was concentrated in the microbiological screening outcome (12/15 versus 5/15), whereas pH remained within the selected reference interval in all 30 samples, and Fe exceeded its contextual reference level in one. Because indicator-organism confirmation and water use were incompletely documented, microbiological screening and physicochemical comparisons are reported separately rather than combined into a formal compliance endpoint.

The OR is unadjusted and imprecise; its wide CI reflects the small 2×2 table. Baseline differences between groups (Table 1) were described but not adjusted for. No causal or generalizable interpretation is warranted.

Figure 3 illustrates the descriptive counts of the three-parameter screening flag (12 vs 5); it is not a regulatory compliance chart. The single Fe exceedance occurred in the stunted-toddler group, in which most samples were already flagged on the basis of presumptive growth.

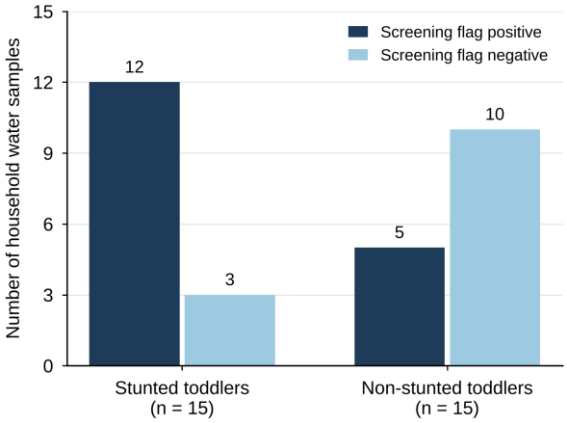


Figure 3. Descriptive screening flags by toddler stunting status

Change in Caregiver Knowledge

The mean knowledge score increased from 55.33 ± 9.73 immediately before to 86.33 ± 6.15 immediately after the educational session (Table 3); the median paired gain was 30 points (Wilcoxon $p < 0.001$). All 30 caregivers scored in the program-defined ≥80 band afterward. This apparent ceiling effect constrains measurement at the upper end of the scale. The before–after contrast reflects immediate test performance and does not demonstrate durable learning or a causal effect of the education session.

Table 3. The mean knowledge score increased

Measure	Pretest	Posttest	Change
Mean ± SD	55.33 ± 9.73	86.33 ± 6.15	31.00 ± 5.48
Median	60	90	30
Range	40–70	80–100	20–40
Poor knowledge, n (%)	14 (46.7)	0 (0.0)	–
Moderate knowledge, n (%)	16 (53.3)	0 (0.0)	–
Good knowledge, n (%)	0 (0.0)	30 (100.0)	–

Note: Shapiro–Wilk test for paired differences: $p < 0.001$; Wilcoxon signed-rank test: $W = 0$, $p < 0.001$.

Figure 4 illustrates paired caregiver knowledge scores obtained immediately before and after the educational intervention, rather than longitudinal follow-up measurements. The mean score increased from 55.33 ± 9.73 to 86.33 ± 6.15, with an average paired increase of 31.00 ± 5.48 points. All 30 participants demonstrated higher posttest scores, reaching the program-defined good-knowledge category (≥80). The Wilcoxon signed-rank test indicated a statistically significant difference ($W = 0$, $p < 0.001$), with a matched-pairs rank-biserial correlation of 1.00, reflecting consistently positive score changes. However, these findings represent immediate improvements in test performance rather than evidence of sustained knowledge retention or behavioral change.

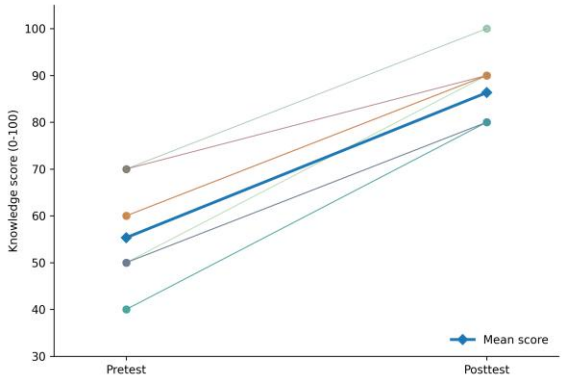


Figure 4. Individual and mean caregiver knowledge scores immediately before and after the single educational session (no delayed follow-up)

The 60-minute educational session was facilitated by faculty researchers specializing in microbiology, public health, and chemistry. Educational activities combined verbal explanations, interactive discussions, practical demonstrations, a pocketbook, and two educational posters distributed to participants. This multimodal approach was intended to strengthen understanding of stunting prevention, water-related health risks, household water-quality indicators, handwashing, and safe water management. Such educational strategies may support health literacy by presenting scientific information in accessible formats (Nutbeam, 2000), although knowledge gains alone rarely translate into sustained hygiene behavior without addressing contextual and habitual determinants (Dreibelbis et al., 2013; Kelly & Barker, 2016). Nevertheless, the contribution of individual educational components could not be determined. Furthermore, the questionnaire was developed by the research team without documented formal psychometric validation, and its knowledge categories were defined for program evaluation. Repeated administration of identical questions may have introduced testing and recall effects, while the concentration of posttest scores between 80 and 100 suggests a potential ceiling effect.

These findings should be interpreted cautiously because the one-group pretest–posttest design lacked a concurrent comparison group and delayed follow-up. Consequently, the observed score increases cannot establish the independent effectiveness of the educational intervention or demonstrate sustained improvements in household hygiene practices, water treatment, storage behavior, microbiological water quality, or child health outcomes. Future studies should employ validated knowledge instruments, comparison groups, delayed assessments, direct observations of household practices, and repeated microbiological examinations to evaluate whether immediate knowledge gains translate into sustained behavioral and environmental-health improvements.

Program Implications and Limitations

The principal empirical findings are the unequal distribution of presumptive growth between two groups and an immediate increase in repeated-questionnaire scores. In practice, these observations may guide risk communication and more rigorous follow-up; they should not be described as demonstrated reductions in toddler exposure or stunting. Potential program actions, which were not tested as intervention outcomes here, include sanitary inspections, source-protection review, context-appropriate water treatment, safer storage, and confirmatory repeat sampling. Their usefulness should be evaluated separately with appropriate follow-up.

The study is limited by nonprobability selection (n = 30), single-time-point sampling, uncertain intended use of the sampled water, limited covariate data, lack of adjusted analysis, incomplete microbial confirmation and laboratory protocol reporting, and no direct measurement of child exposure. Limited variation, sparse cell counts, and the broad OR confidence interval restrict precision and generalizability. One-time sampling cannot account for seasonal variation or establish the temporal order of contamination and stunting.

The educational component additionally lacks questionnaire validation details, a contemporaneous control group, and delayed outcomes, while using the same questions immediately after the lesson. Future research should enroll a larger probability-based sample, obtain longitudinal water samples in different seasons, use standardized confirmatory *E. coli*/total-coliform methods, record water consumption and hygiene practices, collect relevant confounders for multivariable analysis, and assess educational retention and behavior change with validated instruments.

CONCLUSION

In this nonrepresentative sample of 30 South Cimahi households, presumptive coliform-like growth on MacConkey agar was detected more frequently in sampled household water where a toddler was classified as stunted (12/15) than where a toddler was classified as non-stunted (5/15). The unadjusted association was imprecise and cannot establish microbial species identity, toddler exposure, temporality, independent association, or causation. Measured pH values were within the contextual hygiene-and-sanitation reference range, and one Fe value exceeded its reference threshold, but formal microbiological regulatory compliance could not be assessed using the available culture identification. Caregiver questionnaire scores increased immediately after education; the uncontrolled repeated-test design does not demonstrate sustained knowledge retention, behavior change, or safer water. Confirmatory microbiology and better-controlled longitudinal evaluation are needed.

DECLARATIONS

Ethical Approval and Consent to Participate. The study protocol was approved by the Health Research Ethics Committee of Politeknik Kesehatan Kementerian Kesehatan Bandung (approval No. 1074/KEPK/EC/VII/2026). Written informed consent was obtained from each parent or guardian before the household interview, anthropometric measurement, and water collection.

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Conflict of Interest Disclosures. The authors declare no conflict of interest.

Author Contributions. Hafizah Ilmi Sufa: Conceptualization, Methodology, Investigation, Formal analysis, Project administration, Writing – original draft. Dhini Annisa Rahmasari Kanto: Methodology, Investigation, Data curation, Writing – review & editing. Asep Dermawan: Conceptualization, Supervision, Funding acquisition, Writing – review & editing. Oos Fatimah Rosyati: Investigation, Resources, Validation, Writing – review & editing. Febri Sembiring: Formal analysis, Validation, Writing – review & editing. Nur Farida Ulfah: Investigation, Visualization, Writing – review & editing. Ghaisani Fitri Sajidah and Najla' Naimah Qonita: Investigation, Data curation. All authors read and approved the final manuscript.

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Data Availability. De-identified aggregate data are presented in this manuscript. Access to de-identified sample-level data may be requested from the corresponding author, subject to institutional and participant-protection requirements.

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