学 位 論 文

The Impact of Water, Sanitation, Hygiene and Nutrition on Children's Health Outcomes in an Urban Slum in Bandung, Indonesia

（インドネシア・バンドンの都市スラムにおける水、衛生、栄養が子どもの健康に及ぼす影響）

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２０２３年度

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ABSTRACT

Diarrhea and malnutrition remain significant global health concerns, posing a substantial risk to children. This health burden is particularly pronounced in low and middle-income countries, including Indonesia. Basic health survey reported that around 12.3% and 28.7% of Indonesian children are at risk of diarrhea and stunting, respectively. This situation may arise due to inadequate water, sanitation, and hygiene (WASH) facilities, unhygienic behavior, and lack of knowledge. During the COVID-19 pandemic, there was an expectation that this condition would improve as households followed health protocols. However, the connection between WASH levels and their impact on child health was not fully revealed, especially in urban slums. The objectives of this research were to: 1) investigate the effect of handwashing techniques on reducing *E. coli* on children's hands, 2) assess handwashing behavior and facilities during the COVID-19 pandemic and their correlation with diarrhea incidence among children, and 3) explore factors and perspectives about malnutrition related to WASH among children and mothers.

The research was conducted in Bandung, West Java, Indonesia, comprised three studies: Study 1 observed 137 primary school students, focusing on handwashing practices and *E. coli*. Study 2 included 238 mother-student pairs, observing WASH facilities, handwashing behavior and diarrhea. Study 3 used a mixed-methods approach with 273 students and mothers for quantitative analysis and 47 mothers for qualitative study. Methods included questionnaires,

anthropometric measurements, food recall, interviews, and focus group discussions. Data processing for all studies used JMP SAS version 17 and MAXQDA software.

A school-based study revealed that children's handwashing techniques were effective but insufficient in fully removing *E. coli* contamination. Key factors for reducing *E. coli* included cleaning between fingers, using soap, and drying hands with a single-use tissue. However, children tended to overlook specific steps, highlighting the need for improvement. These findings align with a study on handwashing behavior, which observed a significant increase in handwashing frequency but not followed by improvement in technique during the COVID-19 pandemic. Additionally, families were also struggling with access to water and soap, contributing to a higher incidence of diarrhea. Malnutrition was also an emerging issue, with around 13.1% and 19.7% of children experiencing stunting and wasting, respectively. Malnutrition was associated with dietary intake and the WASH Index. Additionally, food insecurity was prevalent, posing a significant barrier to food access.

This study highlights that handwashing and WASH practices of children were insufficient in minimizing contamination. The results emphasize the role of WASH behavior and facilities in addressing child health issues, especially among younger children as the crucial age group. Therefore, we need to design specific educational media and messages tailored to this age group to enhance their motivation and awareness. Additionally, we need to emphasize parental involvement in child education to create a home environment that encourages healthy practices.

CHAPTER I

Effect of handwashing on the reduction of *Escherichia coli* on children's hands in an urban slum Indonesia

(Rifqi, M.A., Hamidah, U., Sintawardani, N., Harada, H., Nyambe, S., Sai, A & Yamauchi, T. (2023). Effect of handwashing on the reduction of *Escherichia coli* on children's hands in an urban slum Indonesia. *Journal of Water and Health*, 21(11), 1651. DOI: 10.2166/wh.2023.121)

1.1 ABSTRACT

Poor hand hygiene practice has been linked to an increase in the number of infections among children in urban slums. Hands are considered an intersection for bacterial transmission, but it is unclear whether handwashing technique affects bacteria elimination. This study investigated the effect of handwashing on the concentration of *Escherichia coli (E. coli)* and factors related to its reduction among children in an urban slum in Bandung, Indonesia. We observed handwashing and conducted repeated hand swabs before and after handwashing among 137 participants. The mean *E. coli* concentration on the hands decreased after handwashing, with a higher reduction in *E. coli* count among students who used soap and had soap contact for more than 10 s during handwashing. Cleaning in-between fingers, using soap, soap contact for more than 10 s, and drying hands with a single-use towel were effective factors for reducing *E. coli* concentration after handwashing ($p < 0.05$). More than half of the swab samples (59%) tested positive for *E. coli* after handwashing, indicating that the children's handwashing technique was not effective in completely removing *E. coli* from the hands. Moreover, sustained and consistent

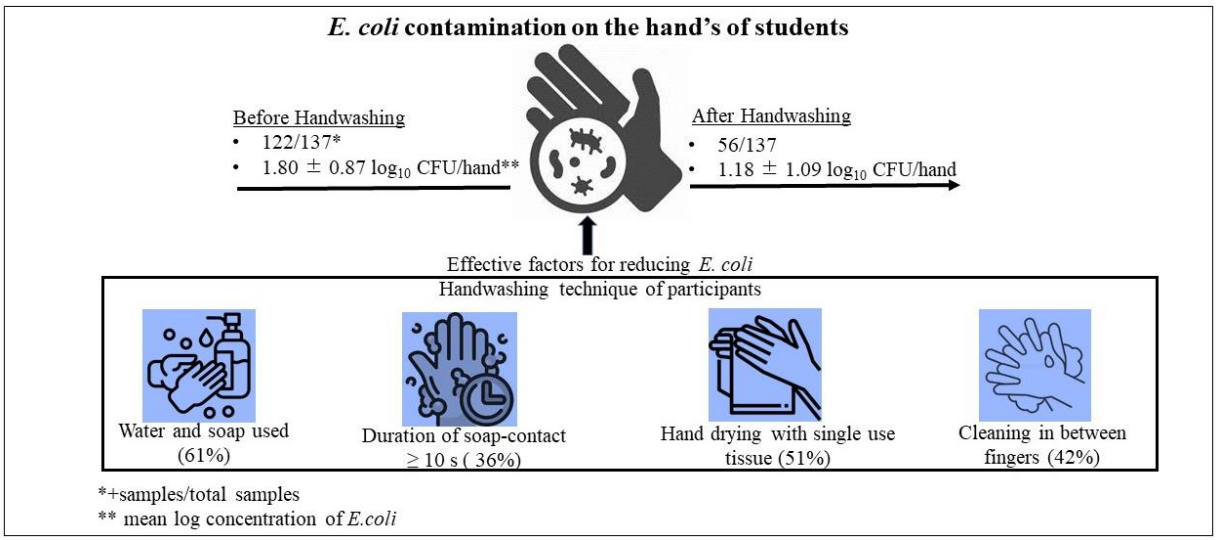
handwashing practice as a daily behavior in children would maximize the effect.

Key words: child, *E. coli*, handwashing technique, hand hygiene, urban slum

Highlights:

- Fecal contamination (*E. coli*) was detected on the hands of some students before and after handwashing
- The children's handwashing practice falls short of the standard, which affect the level of reduction of fecal contamination on their hands
- The short duration of soap contact with hand (<10 s) is not enough to reduce the number of *E. coli* on the hands
- The results imply the need to focus on specific critical points on handwashing education of young children

Graphical Abstract



1.2 INTRODUCTION

Diarrhea is a leading cause of mortality in children worldwide, with an estimated 1,438 deaths per day (Levine *et al.* 2020). Pathogens, including *E. coli*, are often associated with diarrhea, and hands can serve as a vehicle for pathogen transmission through the fecal-oral route (Abba *et al.* 2009). Handwashing with soap and water has been shown to eliminate bacteria from the hands (Curtis *et al.* 2005; Burton *et al.* 2011) and reduce the risk of diarrhea by 40% (Freeman *et al.* 2014). However, the impact of hand hygiene on reducing fecal contamination remains unclear, particularly in resource-limited settings (Saboori *et al.* 2013; Aihara *et al.* 2014).

Proper handwashing remains a challenge for children in low- and middle-income countries (LMICs), and young children often demonstrate poor handwashing practice (Xuan *et al.* 2011). Several studies have found that a common problem in urban slum communities is the lack of access to soap and clean water, which can affect handwashing technique and bacterial count (Pickering 2011; Paraduth *et al.* 2015). Some experimental trials (laboratory and field studies) confirmed this by manipulating some steps (use of soap, length of time, or hand-drying method) to measure the effect of various methods on bacteria elimination (Burton *et al.* 2011; Kim *et al.* 2019; Gizaw *et al.* 2022). However, these studies did not reflect the natural, daily handwashing behavior of participants in their community. In addition, some of the studies were limited to clinical settings (Seid *et al*. 2022), and comprehensive assessments of the slum

community are scarce.

In urban slum settings, child hygiene is often compromised (Kundu *et al*. 2018). Our recent study in Indonesia found that young children in urban slums had poor handwashing techniques, which was significantly associated with *E. coli* detection on their hands. Similarly, awareness and knowledge of handwashing with soap (HWWS) was inadequate (Otsuka *et.al* 2019). Previous studies in Indonesia have primarily focused on public perception, behavioral intervention, and determinants of handwashing among people (Hirai *et al*. 2016; Karon *et al*. 2017; Dwipayanti *et al*. 2021). However, no study has examined the effect of handwashing technique on reducing *E. coli* on children's hands in this setting, particularly during the Covid-19 pandemic.

Therefore, this observational study investigated the effect of handwashing technique on the reduction of *E. coli* on children's hands in urban slum. Our study focuses on analyzing which steps are practicable within the community's target population**.** We also assessed the relationship between *E. coli* reduction and several key handwashing variables, including duration, soap and water contact, handwashing steps, water used, and hand-drying methods.

1.3 MATERIALS AND METHODS

1.3.1 Study areas and participants

This cross-sectional study was conducted among pre-school and primary school students in Kiaracondong, an urban slum in Bandung, Indonesia, between August and

September 2022. Bandung is the third most populous city, experiencing rapid urbanization and overcrowding, particularly in the slums. Bandung's slum settlements still suffer from poor sanitation and water access (Tarigan *et al*. 2015). Kiaracondong is one of Bandung's most populous urban slum communities, with a high population density (22,426/km^2) and poor water and sanitation infrastructure (BPS 2022). After explaining the purpose and content of the study, 137 students provided written consent and participated. We included students from preschool, grades 2, 4 and 6 with mean age of 8.9 ± 2.4 years old.

1.3.2 Data collection

1.3.2.1 Handwashing technique

The participants were asked to perform their daily handwashing practice individually in a detached space, while an observer observed the entire handwashing process. They were provided with all the needed materials, such as tap water, soap, tissue paper, and hand towel. Schools and households in developing countries (Kim *et al*. 2019), including Indonesia, provide hand towels as a common practice. The handwashing process was video recorded using two cameras (front and side views), and the evaluation was based on both recorded video and direct observation. A single observer determined the process and was supported by one research assistant who ensured the recording, use of water, and management of each student's turn. Five main points were assessed in this process: (1) handwashing steps (10 steps) (Otsuka *et al*. 2019), (2) the use of soap, (3) the volume of water, (4) length of time (total duration, water contact,

and soap contact), and (5) the hand-drying method. The volume of water used for handwashing was measured using a modified jerrycan equipped with a volume scale, while the length of time was measured using stopwatch and video observation.

1.3.2.2 Hand swabs and microbial test

The hand swab test was used to determine the level of *E. coli* on the children's hands before and after handwashing. The researcher performed the swab test using a swab test kit (Pro Media ST-25 PBS; Series: 64-8070-68, ELMEX, Japan) containing a wiping swab in 10 ml Phosphate Buffer Saline (PBS). Pre-test with four samples was performed before the school assessment. To minimize bias due to tap water contamination during handwashing, we have already tested the water, and the *E. coli* results were negative. We also implemented a cleaning protocol by using alcohol-based wet wipes to clean tap handles and soap bottles, thus preventing contamination for each child. To collect 'hand before washing' sample, a student's left or right hand was randomly selected. From 137 participants, right hand was sample first in 74 students, and the left hand was sampled first in 63 students. Then, students were asked to spread selected hands, and the wiping swab was rolled on the palm, backside, fingers, and in-between fingers. After that, students were requested to wash hands in the usual way. Immediately after handwashing, the opposite hand (hand that had not yet been sampled) was swabbed using the same method. The same hand was not sampled twice because the hand sampling method used could be considered similar to handwashing, which would remove *E. coli* and introduce bias

into our objective of evaluating the effect of handwashing techniques on *E. coli* count after handwashing. After wiping, the swab was kept in PBS of the kit and delivered to the laboratory within 4 hours for processing. There are some bacteria that serve as indicators to detect the presence of fecal contamination on hands. However, in this study, we focused on *E. coli* as a single indicator, as this research is a follow-up to our previous study in the same area (Otsuka *et al.* 2019). The enzyme-substrate method was used to detect *E. coli*. All bacteria analysis was performed under aseptic conditions in the biosafety cabinet of a microbiology laboratory. Each sample (10 mL) was divided into two volumes (1 mL and 4 mL), and passed through a 47-mm-diameter 0.45-µm sterilized cellulose filter (Advantec, Tokyo) using a membrane filtration unit (vacuum pump). Approximately 10 mL of sterilized PBS buffer was added to facilitate uniform dispersion over the filter surface. Thereafter, the cellulose filter was placed on XM-G Agar growth media (XM-G; Nissui Pharmaceutical Co; Japan). The sample was incubated on the media for 20 ± 2 hours at 37°C. After incubation, the colony had turned blue and were counted. Blue colony indicates the presence of *E. coli* in the sample.

1.3.3 Data analysis

The results were analyzed using JMP SAS version 16 (SAS Institute, Japan) for Microsoft Windows 10. For statistical analysis, the number of colonies was measured as a Colony Form Unit (CFU) and transformed to Log_{10} per hand before and after handwashing. The matched pair sample t-test ($p < 0.05$) was used to compare the mean log_{10} concentration of *E.*

coli before and after handwashing. As the maximum reliable count of *E. coli* on the filter was 300, the upper detection limit was set at 3000 CFU/hand. For the categories of handwashing techniques, we used several key variables, such as duration, soap and water contact, handwashing steps, water used, and hand-drying methods (Aihara *et al*. 2014; Seid *et al*. 2022; Friedrich *et al*. 2017). As each parameter performed might influence the effect, multivariate stepwise logistic regression was used to investigate the association and interconnection between handwashing method/steps and its effect on *E. coli* reduction. The reduction of *E. coli* was categorized into two groups: reduction and no reduction before and after handwashing. The 'no reduction' criterion indicates that the *E. coli* concentration remained the same or even increased after handwashing. Eligible dependent factors for *E. coli* reduction were handwashing steps 2, 4, 9, 10, duration, soap contact, water contact, and hand-drying. These factors were computed using the stepwise forward method to determine those that were significantly associated with *E. coli* reduction. The p-value threshold for entry and removal from the model was 0.25 and 0.1, respectively.

1.4 RESULTS

1.4.1 *E. coli* on the hands and handwashing

The 137 preschool and primary school students who participated in the study were aged 4–12 years and were in grades two, four, and six. More than half of the participants (52%) were females. To investigate fecal contamination, we evaluated *the E. coli* count in 137 paired pre- and post-handwash participants. *E. coli* was detected in 122 (89%) samples before handwashing, which decreased to 81 (59%) after handwashing (Table 1). Except for preschoolers, there was a significant difference in the mean concentration of *E. coli* by grade and gender, before and after handwashing ($p < 0.05$). Second graders had the highest (1.69 ± 1.01 $\log_{10}$ CFU/hand), followed by preschoolers (1.51 ± 1.08 $\log_{10}$ CFU/hand). Overall, handwashing decreased *the E. coli* count by 34%, with the lowest concentration found in the highest grade (Grade-4). There was also a reduction in the number of colonies of *E. coli,* with most of them having *E. coli* concentrations below 100 CFU/hand. Interestingly, in some students, we also observed that *E. coli* levels remained the same or even increased after handwashing. These findings support our hypothesis that children's handwashing technique influences the presence and concentration of *E. coli* after handwashing.

Table 1. Overall mean and number of samples (%) in each category of Escherichia coli pre-and post-handwashing (n=137)

Category	Sample number tested (n)	Pre- handwashing						Post- handwashing						p-value
		Positive, No. (%)	N.D[τ]	Mean log_{10} concn (SD)[‡]	*E. coli* concentration (CFU/hand)*			Positive, No. (%)	N.D[τ]	Mean log_{10} concn (SD)[‡]	*E. coli* concentration (CFU/hand)*			
					0<x<100	100<x<1000	1000<x<3000				0<x<100	100<x<1000	1000<x<3000	
Grade														
Pre-school	25 (18)	19 (76)	6 (24)	1.64 (1.05)	5 (20)	13 (52)	1 (4)	18 (72)	7 (28)	1.51 (1.08)	8 (32)	8 (32)	2 (8)	NS
Grade 2	37 (27)	37 (100)	0 (0)	2.34 (0.58)	10 (27)	22 (59)	5 (14)	30 (81)	7 (19)	1.69 (1.01)	11 (30)	17 (46)	2 (5)	< 0.05
Grade 4	37 (27)	31 (84)	6 (16)	1.51 (0.82)	19 (51)	12 (32)	0 (0)	14 (38)	23 (62)	0.80 (1.12)	4 (11)	9 (24)	1 (3)	< 0.05
Grade 6	38 (28)	35 (92)	3 (8)	1.67 (0.82)	22 (58)	10 (26)	3 (8)	19 (50)	19 (50)	0.83 (0.91)	14 (37)	5 (13)	0 (0)	< 0.05
Gender														
Male	66 (48)	58 (88)	7 (11)	1.81 (0.83)	30 (45)	31 (47)	3 (5)	39 (59)	29	1.51 (1.08)	20 (30)	19 (29)	3 (5)	< 0.05
Female	71 (52)	64 (90)	8 (11)	1.79 (0.92)	26 (37)	26 (37)	6 (8)	42 (59)	27	1.21 (1.11)	17 (24)	20 (28)	2 (3)	< 0.05
Total	137	122 (89)	15 (11)	1.80 (0.87)	56 (41)	57 (42)	9 (7)	81 (59)	56 (41)	1.18 (1.09)	37 (27)	39 (28)	5 (4)	< 0.05

[τ]ND=not detected, [‡]SD = standard deviation

Mean log10 concn (SD) represented the concentration of E. coli by each category. Differences between pre-post handwashing were analyzed using matched pairs t-test P<0.05

Table 2. Difference concentration of *E. coli* pre-and post-handwashing by technique, and relationship with reduction of *E. coli* (n=137)

No	Method of handwashing	Total	Mean log_{10} concn (SD) †		Mean log_{10} Δ pre-post handwashing	p-value	Reduction of *E. coli*¶		p-value
		n=137 (%)	Pre-handwashing	Post-handwashing			Yes	No	
1	Water and soap used								
	Water only	54 (39)	1.77 (0.99)	1.38 (1.17)	0.39	p < 0.05	26 (19)	28 (20)	p < 0.05
	Water and soap	83 (61)	1.82 (0.78)	1.05 (1.02)	0.77	p < 0.05	67 (49)	16 (12)	
2	Total duration of handwashing								
	< 20 seconds	81 (59)	1.89 (0.87)	1.39 (1.11)	0.49	p < 0.05	50 (37)	31 (23)	NS
	≥ 20 seconds	56 (41)	1.67 (0.87)	0.87 (0.99)	0.80	p < 0.05	43 (31)	13 (10)	
3	Duration of soap-contact								
	< 10 seconds	88 (64)	1.81 (0.96)	1.36 (1.12)	0.44	p < 0.05	50 (37)	38 (28)	p < 0.05
	≥ 10 seconds	49 (36)	1.80 (0.69)	0.85 (0.98)	0.94	p < 0.05	43 (31)	6 (4)	
4	Duration of water-contact								
	< 10 seconds	106 (77)	1.87 (0.90)	1.25 (1.11)	0.61	p < 0.05	69 (50)	37 (27)	NS
	≥ 10 seconds	31 (23)	1.58 (0.74)	0.92 (0.99)	0.65	p < 0.05	24 (18)	7 (5)	
5	Number of steps								
	≤ 3 steps	34 (25)	1.63 (1.03)	1.49 (1.08)	1.15	NS	14 (10)	20 (15)	
	4-5 steps	46 (34)	1.87 (0.81)	0.97 (1.11)	0.90	p < 0.05	36 (26)	10 (7)	p < 0.05
	6-8 steps	57 (42)	1.85 (0.81)	1.13 (1.03)	0.71	p < 0.05	44 (32)	13 (10)	
6	Amount of water used								
	< 500 ml	58 (42)	1.98 (0.80)	1.48 (1.09)	0.49	p < 0.05	36 (26)	22 (16)	NS
	≥ 500 ml	79 (58)	1.67 (0.90)	0.95 (1.04)	0.71	p < 0.05	57 (42)	22 (16)	
7	Hand drying method								
	Single use tissue	70 (51)	1.91 (0.83)	1.14 (1.08)	0.76	p < 0.05	56 (41)	14 (10)	
	Uniform/clothes	63 (46)	1.67 (0.92)	1.20 (1.11)	0.47	p < 0.05	36 (26)	27 (20)	p < 0.05
	Cloth towel	4 (3)	2.06 (0.67)	1.56 (1.13)	0.50	NS	1 (1)	3 (2)	

1.4.2 Handwashing techniques and *E. coli* reduction

We measured the mean *E. coli* concentration before and after handwashing by the method practiced (Table 2). Table 2 displays the Log_{10} CFU of *E. coli* before and after handwashing, categorized according to the techniques used by the participants. The average time spent by participants for the entire handwashing process was 18.5 ± 9.3 seconds. A greater reduction in *E. coli* was found when using water and soap (handwashing duration ≥ 20 seconds), soap contact (soap contact during handwashing duration ≥ 10 seconds), 4–5 steps, ≥ 500 ml amount of water, and single-use tissue for the hand-drying method. Handwashing with ≤ 3 steps did not significantly influence *E. coli* reduction. Although we provided tissue paper, some students used hand towels to dry their hands, resulting in no significant reduction after handwashing. Table 2 also shows the correlation between handwashing technique and *E. coli* reduction. Reduction of *E. coli* on children's hands was significantly associated with soap use, duration of soap contact, number of steps, and hand-drying method ($p < 0.05$).

1.4.3 Handwashing step and *E. coli* reduction

Table 3 shows the association between handwashing step and *E. coli* reduction. More than 90% of the participants wet their hands and rubbed them palm to palm and about two-thirds used soap during handwashing. Nevertheless, less than 25% completed scrubbing of the back of their fingers, thumbs, and fingertips, indicating poor knowledge

of this aspect of handwashing. Soap use during handwashing significantly reduced *E. coli* concentration on children's hands, compared to water only ($p < 0.05$). Among those who scrubbed some parts of the hand, cleaning in-between fingers had a significant correlation with *E. coli* after handwashing. Although some students skipped the final two steps in handwashing, we found a significant correlation between rinsing with water and drying hands with a towel or tissue paper and *E. coli* reduction.

Table 3. Relationship between handwashing step practiced and reduction of *E. coli* (n=137)

Handwashing step	Total (n=137) n (%)	Reduction of *E. coli* Yes n (%)	No n (%)	p-value †
Wet hands with water	136 (99)	92 (68)	44 (32)	0.378
Apply enough soap to cover all hand surfaces	83 (61)	67 (49)	16 (12)	**0.001**
Rub hands palm to palm	129 (94)	86 (63)	43 (31)	0.185
Right palm over left dorsum with interlaced fingers & vice versa	57 (42)	47 (34)	10 (7)	**0.002**
Palm to palm with fingers interlaced	59 (43)	41 (69)	18 (13)	0.726
Backs of fingers to opposing palms with fingers interlaced	2 (0)	1 (0.7)	1 (0.7)	0.597
Rotational rubbing of left thumb clasped in right palm and vice versa	28 (20)	20 (15)	8 (6)	0.689
Rotational rubbing, backwards and forwards with clasped fingers of right hand in left palm and vice versa	28 (20)	21 (15)	7 (5)	0.357
Rinse hands with water	92 (67)	72 (53)	20 (15)	**0.001**
Dry hands thoroughly with a towel/tissue	74 (54)	57 (42)	17 (12)	**0.013**
Interaction of hand-rubbing				
Palm x between fingers x fingertips	18 (13)	13 (10)	5 (3)	0.672
Back x between fingers x fingertips	21 (15)	17 (12)	4 (3)	0.163
Palm x Back x between fingers x fingertips	13 (10)	10 (8)	3 (2)	0.463

**Correlation between handwashing step practiced and reduction of E. coli was analyzed by the Chi-square test, p<0.05)*

Bold values represent the significant variables ($p < 0.05$)

1.4.4 Factor associated with in *E. coli* reduction

The results of the regression analysis model predicting the handwashing technique and *E. coli* reduction are presented on Table 4. This regression model represents the function of the handwashing technique performed and reduction of *E. coli*, which might be influenced by other techniques or steps. The odds of *E. coli reduction* were three times and four times higher when handwashing included the use of soap and water *(*AOR: 2.81, 95% CI: 1.62–11.8) *and fingers interlaced cleaning (*AOR: 4.45, 95% CI: 1.54–12.8), respectively. Additionally, scrubbing the hand with soap for more than 10s was five times (AOR: 5.07, 95% CI: 1.34–19.1) more likely to reduce *E. coli*. Using multi-use towels or clothes for hand-drying had a protective effect in reducing *E. coli* (AOR: 0.03, 95% CI: 0.01–0.47).

Table 4. Factors associated with reduction of *Escherichia coli*

Characteristic	**AOR†**	**P-value**	**CI††**
Handwashing step			
(2) Apply enough soap to cover all hand surfaces			
No	Ref	-	-
Yes	2.81	**0.048**	1.62-11.8
(4) Right palm over left dorsum with interlaced			
No	Ref	-	-
Yes	4.45	**0.006**	1.54-12.8
(9) Rinse hands with water			
No	Ref	-	-
Yes	3.28	0.081	0.86-12.5
(10) Dry hands thoroughly with a towel/tissue			
No	Ref	-	-
Yes	0.09	0.091	0.01-1.46
Number of steps			
<5 steps	Ref	-	-

Characteristic		AOR†	P-value	CI††
	5 steps or more	0.216	0.069	0.04-1.12
Duration of soap-contact				
	<10 seconds	Ref	-	-
	≥10 seconds	5.07	**0.017**	1.34-19.1
Duration of water-contact				
	<10 seconds	Ref	-	-
	≥10 seconds	0.41	0.166	0.11-1.44
Hand drying method				
	Single use tissue	Ref	-	-
	Reusable (hand towels/clothes)	0.03	**0.012**	0.01-0.47

†Multivariable model adjusted for handwashing step 2, 4, 9 and 10, number of steps, duration soap contact, water-contact and hand drying. R^2= 0.242 ††CI, confidence interval; ref, reference value. Bold values represent the significant variables (p<0.05)

1.5 DISCUSSION

A high level of fecal contamination on hands has been observed in an urban slum, which has been linked to poor handwashing technique (Otsuka *et al*. 2019). Contamination may come from the household and environment, such as physical contact with contaminated water or materials (Daneshmand *et al*. 2018). Although several studies have investigated *E. coli* in children's hands (Aihara *et al*. 2014; Paraduth *et al*. 2015; Ogba *et al*. 2018), limited research has documented this during the COVID-19 pandemic. The pandemic may have influenced handwashing behavior, as people increased their frequency of handwashing to prevent the spread of the infection (Dwipayanti *et al*. 2021). Frequent handwashing during the pandemic was associated with a reduction in infections (Seid *et al*. 2022). Our study found that 89% of the children had *E. coli* on their hands. This was lower than the 98.7% previously documented

in the same population (Otsuka *et al*. 2019). However, the level of contamination in this study was higher than in previous studies. For example, a systematic review revealed that the mean *E. coli* prevalence on hands in lower- and middle-income countries was 69% (Cantrell *et al*. 2023). Although different measurements and counting methods were used in a previous study (Cantrell *et al*. 2023), the finding from our present study indicate that there is still a high risk of contamination among young children in urban slums in Indonesia.

The concentration of *E. coli* on hands has been measured to be 0.6–3.5 $\log_{10}$ CFU/ hand (Pickering *et al*. 2011; Friedrich *et al*. 2017; Kundu *et al*. 2018). This is consistent with our study which found that the average *E. coli* concentration by grade was 1.5–2.3 $\log_{10}$ CFU/hand, with higher contamination observed among participants in the lower grades. However, a previous study conducted in an urban slum setting in India found a lower concentration of 0.64 $\log_{10}$ CFU/per two hands in children under five years (Kundu *et al*. 2018). This higher concentration of *E. coli* contamination observed in our study could be attributed to some children spending more time engaging in outdoor activities, which exposes them to more germs and dirt. Some children in this community were involved in garbage sorting to help their parents who worked as garbage collectors (Sai *et al*. 2020).

Except for preschoolers, we found a statistically significant reduction in bacteria after handwashing. Lower graders performed fewer handwashing steps, which could explain the low effectiveness in bacteria reduction. Furthermore, performing three or fewer steps did not result

in significant *E. coli* reduction when compared to four steps or more. We found that in some students, the *E. coli* concentration remained the same or even increased after handwashing. Similar observations have been made by other authors in which young children had limited knowledge of handwashing with soap (Xuan *et al*. 2011) and performed handwashing with a low volume of water and without soap, which could have limited the reduction in *E. coli* on their hands after handwashing (Aihara *et al*. 2014; Agestika *et.al* 2019)). This underscores the importance of the age of children as an essential factor in bacteria reduction handwashing techniques.

Despite the availability of soap, 39% of the students did not use soap during handwashing. A similar trend was found among children in LMICs, with estimates showing that only 27%–39% of children wash their hands with soap (Saboori *et al*. 2013; Otsuka *et al*. 2019). A possible explanation for this is the lack of effectiveness of handwashing promotion or prevalent social practices at home. In urban slum communities, some families cannot provide handwashing soap because it needs an additional cost. Moreover, some respondents describe using soap as challenging because it is a new practice, and they believe washing with water is enough to make hands physically clean. Experimental trials have shown that handwashing with soap is more effective in removing bacteria than using water alone (Burton *et.al* 2011; Amin *et al*. 2014). Similarly, our findings showed that the use of soap was twice as effective as using water alone in eliminating bacteria. Handwashing with soap for 20s has been highlighted as an

effective method for removing bacteria from the hands (WHO 2009). Wetting the hands with water and scrubbing with soap creates a lather that traps and eliminates these bacteria (Burton *et al*. 2011). Although some students performed handwashing for more than 20s, only 6% of them scrubbed their hands with soap for that entire duration, while others did so briefly. It is important to note that scrubbing the hands with soap for more than 10s significantly reduces *E. coli* concentration. This finding adds to our understanding that using soap for a short duration is insufficient to remove bacteria. Therefore, future handwashing promotion campaigns that target children should emphasize the use of soap and appropriate duration of soap contact with the hands.

Previous studies have demonstrated the presence of diverse bacteria on different parts of the hands, such as fingertips (Julian *et al*. 2015), palms (Fierer *et al*. 2008), and in-between fingers (Rosenthal *et al*.2014). Hence, scrubbing specific parts of the hands is essential for effective bacteria removal during handwashing (Julian *et al*. 2015). Similarly, we found a significant correlation between *E. coli* reduction and scrubbing in-between fingers during handwashing. Hand scrubbing during handwashing is an important action that physically destroys germs. However, we observed that more than half (58%) of the students did not wash in-between their fingers during handwashing (Step 4). This confirms a previous finding before the pandemic that only 55% performed step 4 (Otsuka *et al*. 2019), indicating that handwashing promotion during the pandemic did not have a significant effect on accomplishing this step.

Students often consider the palm as the dirtiest part of the hand (Ray *et al*. 2011), and they may overlook other parts, including in-between fingers, during handwashing. Our findings highlight the importance of focusing on specific parts during handwashing promotion campaigns for children.

Our study also revealed that the method of hand-drying has contrasting effects on *E. coli* reduction after handwashing. The largest reduction was found in the hands of students who used single-use tissue. This parallels a previous study that showed that single-use or paper towels could dry hands while causing less contamination in the washroom environment (Huang *et al*. 2012). Drying hands with single-use paper towels results in a larger reduction than air drying (Jensen *et al*. 2015). By contrast, using reusable hand-drying methods such as cloth towels or clothes had a much smaller reduction effect and was considered a limiting factor in reducing *E. coli*. This may corroborate our finding that there was no reduction in *E. coli* levels for some students after handwashing. Clothes may not dry the hand completely, leaving it slightly moist. Residual water on the hand may increase the risk of contamination because bacterial transmission is more effective in wet conditions (Patrick *et al*. 2017), undried hands increase the possibility of recovery of *E. coli* (Ansari *et al*. 1991). Cloth towels have the lowest reduction in the number of fecal bacteria when drying hand compared to warm air and single-use paper (Ansari *et al*. 1991). A possible reason for this is that sharing hand towels with users who practice poor handwashing techniques increases the chance of transfer of bacteria from

poorly washed hands to the towel. Many studies have focused on hand-drying methods by comparing paper towels and air drying. However, most urban slums lack access to these methods due to financial constraints. Therefore, it is crucial to emphasize hand-drying method when promoting handwashing. Private reusable cloth towels may be an effective alternative when a school or household cannot provide single-use paper.

On average, we found that handwashing had a minimal effect on bacteria count (34 %). This finding is consistent with other studies which reported that a single handwashing is insufficient; sustained and consistent hand hygiene behavior is required to reduce bacteria significantly (Aihara *et al*. 2014). Furthermore, the complexity of *E. coli* through environmental contamination in urban slum areas cannot be underestimated. Microbial contamination of water used to wash hands in schools or households poses a greater level of risk of hand contamination (Daneshmand *et al*. 2018; Berhanu *et al*. 2021). Some households and schools in Bandung's urban slum use groundwater for activities, such as handwashing, cooking, or bathing (Otsuka *et al*. 2018). Groundwater in some areas of Bandung is moderately to heavily polluted, which can lead to cross-contamination with humans (Hasanawi 2022). A previous study indicated that high levels of *E. coli* have been detected in various type of water in peri-urban area (Asada *et al*. 2022). If the water is potentially unsafe, it will potentially become a contaminant for hands. This necessitates further research to investigate the pathway of *E. coli* contamination in school and household environments in order to track and identify the sources.

1.6 LIMITATION

This study has some limitations. This study employed a purposive sampling of two schools with relatively small sample size and the same level of sanitation in the study area. Hence, the findings may not be generalizable to all children in LMIC urban slums. In addition, there was no observation at the household level, which would represent students' daily practice in a natural setting. The presence of observers and the facilities provided during the handwashing observation may have biased the participants to modify their handwashing technique. To minimize this bias, we conducted the evaluation in a detached space and consistently reminded participants to wash their hands as they normally would. Nonetheless, this study enabled us to assess the importance of handwashing steps in reducing bacteria. Regarding the method of *E. coli* detection, we used an enzymatic method that cannot specifically recognize the type of *E. coli*. *E. coli* has many types of strains, some of which can cause severe health hazard, such as diarrhea. Lastly, *E. coli* is not the sole indicator for fecal contamination on hands; there are other bacteria that may serve as indicators, which should be considered for future studies.

1.7 CONCLUSION

This study highlights the correlation between poor handwashing practices among young children living in urban slum and faecal contamination on their hands. There may be a misconception that the primary purpose of handwashing is simply to wet hands and clean palms,

while other parts of the hands are overlooked. The study recommends that the focus on handwashing techniques for children should be extended to include scrubbing specific parts of the hands, such as between fingers and under fingernails, where faecal contamination can be found. Additionally, this study found that the low percentage of students who use soap and single-use tissue is likely due to the limited availability of facilities or prevalent social practice at home. To improve the removal of *E. coli* contamination from hands and prevent cross-contamination, it is recommended that schools provide soap and single-use tissue paper. To improve faecal contamination removal on the hands, it is recommended that schools provide soaps and single-use tissue paper. Proper handwashing is critical in preventing the spread of pathogens, and education on proper handwashing should start early for young children. Handwashing intervention should be tailored to the needs of low- and middle-income countries, where resources may be limited. Further research that incorporates a comprehensive assessment of handwashing behaviour and environmental contamination is needed to understand why handwashing does not effectively reduce faecal contamination in some students.

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CHAPTER II

Water, sanitation, and hygiene (WASH) facilities, handwashing behavior and incidence of diarrhea among children in urban slum area of Bandung, Indonesia during COVID-19 Pandemic

2.1 ABSTRACT

Water, Sanitation and Hygiene (WASH) in urban slums remains a challenge due to limited facilities, high density, and improper behavior that can influence health outcomes. The COVID-19 pandemic was expected to lead to improvements as households strive to follow health protocols, but few studies have focused on the effect on health outcomes in urban slums in Indonesia. The objective of this research was to examine the relationship between handwashing behavior, WASH facilities, and their associations with the incidence of diarrhea in children. An observational cross-sectional study involved 238 mother-child pairs in the urban slums of Bandung, Indonesia. WASH facilities and handwashing observations are categorized using WHO standards, while handwashing behavior is assessed through a questionnaire. Using multivariate stepwise logistic regression, we analyzed factors associated with the incidence of diarrhea in children. The findings reveal that using a shared toilet, limited access to clean water, and using bar soap are associated with diarrhea in children ($p < 0.05$). Regarding handwashing behavior, the study indicates that the incidence of diarrhea during the pandemic was linked to poor handwashing techniques and inadequate soap usage ($p < 0.05$). The use of soap,

handwashing technique and water availability are predictive factors that can increase the risk of diarrhea in children. Interestingly, the increased handwashing frequency during the pandemic was not followed by an improvement in handwashing techniques among children. The quality of handwashing is a crucial factor in enhancing the effectiveness of reducing the number of contaminants on hands that may potentially cause diseases. This study suggests a specific approach to tackling childhood diarrhea, involving coordinated initiatives such as refining children's handwashing techniques for specific areas of the hands by various media and approach.

Keywords: WASH facilities, handwashing behavior, diarrhea, children, slum urban, Indonesia

2.2 INTRODUCTION

Diarrhea remains a significant global health concern among children, posing substantial risks to their well-being. It is responsible for 29 % child deaths annually and has become the leading cause of morbidity across all age groups (WHO 2017). A systematic review highlighted that poor hygienic practices and a lack of sanitation facilities significantly contribute to the spread of diarrheal diseases (Manetu et al, 2021). This health burden is particularly pronounced in urban slums of low-and middle-income countries. Improved sanitation avoids fecal-oral transmitted infections and was associated with a 16% reduction in the risk of diarrhea among children (Merid et al., 2023). But, the influence of sanitation has different effects depending on the hygiene behavior conditions of the community (Darvesh et al., 2017). These findings

emphasize that improving diarrhea conditions would not be possible without addressing WASH conditions and community hygiene behavior.

Hygiene practices have become more critical during the pandemic to prevent the spread of infectious diseases. Prior studies highlighted a link between lower handwashing adherence and COVID-19 cases (Dwipayanti et al., 2021; Szczuka et al., 2021). This becomes more prominent, especially considering that the COVID-19 virus could cause gastrointestinal problems, including diarrhea. However, the problem remains that most people don't wash their hands properly at critical times, such as before eating, after using the toilet, or after coming from outside. Previous study found that during pandemic hygiene behavior of community were still unsatisfactory. Many people were not aware of using soap during handwashing, which might worsen the impact on their health (Xu et al 2022). The use of soap has been demonstrated to correlate with the risk of diarrhea particularly among slum resident (George et al, 2014; Sima et al 2012). Identifying handwashing skills for populations with limited access to WASH facilities during the COVID-19 pandemic may be a critical step in understanding the role of hygiene practices in child health.

In Indonesia, around 17% of children under the age of five experienced diarrhea, leading to approximately four million cases in 2018 (MoH, 2019). In the urban slum settings of Indonesia, access to handwashing facilities has become a pressing issue, with not all community members having sufficient access. Our prior study indicated that children residing in urban

slums with inadequate facilities face an elevated health risk of diarrhea (Otsuka et al., 2019a). Furthermore, young children have been observed to exhibit poor handwashing skills and engage in improper handwashing behavior during critical times (Otsuka et al., 2019b). A previous study highlighted that untreated drinking water and unimproved sanitation were strong predictors for reducing diarrhea among children (Komarulzaman et al., 2017). The limited handwashing proficiency among children, coupled with restricted access to WASH facilities, may hinder progress in mitigating childhood diarrhea concerns within urban slum areas. However, the relationship between WASH facilities, hygiene behavior, and child diarrhea in urban slums in Indonesia during the pandemic remains unclear.

Therefore, this community-based cross-sectional study focuses on capturing handwashing behavior and facilities during the COVID-19 pandemic and their correlation with the incidence of diarrhea among primary school children in slum area. We assessed WASH facilities, handwashing techniques through observation, and the effect of handwashing behavior on diarrhea incidence among young children. The findings will support evidence-based interventions, tailored policies, and targeted health programs to mitigate the risk of diarrheal diseases and improve overall health outcomes for urban slum residents during and beyond the pandemic.

2.3 MATERIALS AND METHODS

2.3.1 Study area and participants

This study was conducted in the slum area of Kiaracondong, Bandung, Indonesia (Figure 1). Bandung, a densely populated city, is significantly impacted by insufficient sanitation facilities and restricted availability of clean water, particularly in slums area. Data were collected through questionnaire surveys, interviews with parents of primary school students, and direct observation. The data collection took place in August-September 2022, during a period when Indonesia was still implementing ‘’enforcement of restrictions on community activities'' *(PPKM/Pembatasan Pemberlakuan Kegiatan Masyarakat)* due to the COVID-19 pandemic. During *PPKM*, schools could reopen while still adhering to health protocols such as wearing masks, maintaining physical distance, and practicing hand hygiene. Students who were sick or showed symptoms of COVID-19 were allowed to stay home or participate in remote learning/study from home. The participants in the study were primary school students selected purposefully. The initial sample consisted of 252 students and parents, but after data cleaning, the final dataset included 238 mother-child pairs.

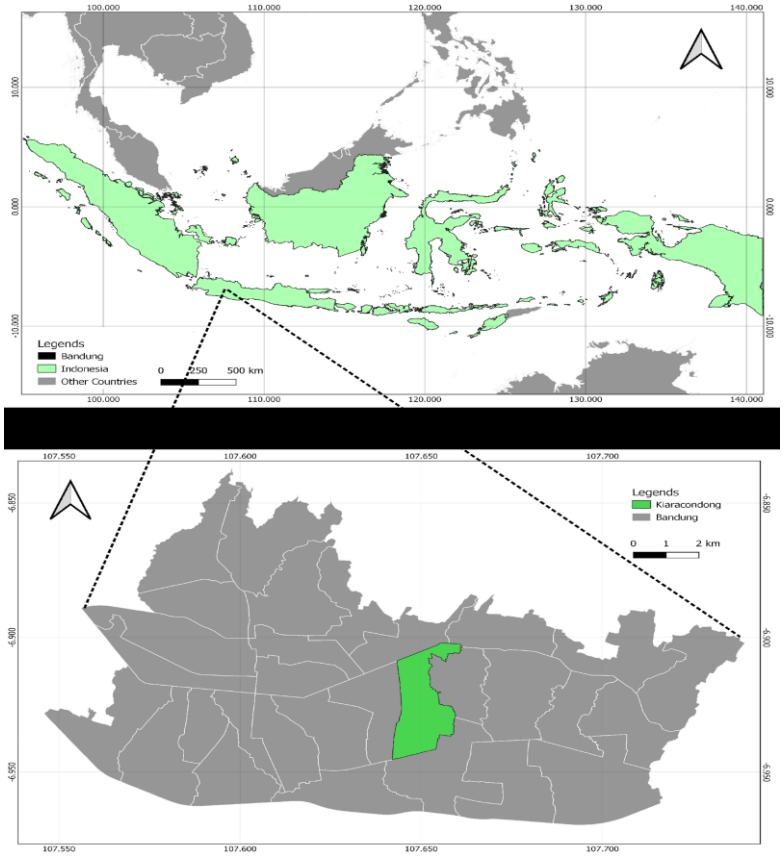

Figure 1. Map of study location

2.3.2 Data collection

2.3.2.1 Household sociodemographic and WASH questionnaire.

Data collection is conducted through a questionnaire that gathers sociodemographic and household WASH (Water, Sanitation, and Hygiene) information. The sociodemographic questionnaire includes gender, age, parents' education, and handwashing education from parents, family income, number of household members, and house ownership (S1 Appendix). To gain a clearer understanding of the conditions of WASH facilities, additional questions related to water, sanitation, and hygiene facilities for households were adapted from the WHO

questionnaire (WHO, 2018). The questionnaire encompasses basic inquiries about household WASH facilities, such as toilet type, soap availability, water availability, drinking water source, and handwashing facilities at home. To verify the accuracy of the information provided by parents, we also conducted direct observations of participants' houses (S2 Appendix).

2.3.2.2 Handwashing behavior

Children's handwashing behavior was assessed through face-to-face questionnaires with parents. The questionnaire includes inquiries about children's handwashing behaviors in six critical situations before and during the pandemic. These critical situations encompass washing hands before eating food, after using the toilet, after touching the nose, coughing, or sneezing, after handling pets or their food, after handling garbage, and after returning from outside the house (CDC, 2022). Parents were also questioned about changes in their children's handwashing behavior before and during the pandemic, as well as challenges they faced from their perspective. The questions about changes in handwashing behavior are open-ended, allowing parents to express any modifications and the types of changes that occurred. If parents reported changes, a subsequent question was asked regarding the nature of these changes, such as frequency, technique, duration of handwashing, and the use of soap or hand sanitizer. Regarding the question about the type of soap used, parents were asked to identify the predominant type of soap (bar soap, liquid soap, dishwashing soap, or hand sanitizer) and whether there were any changes.

2.3.2.3 Handwashing observation

To assess children's handwashing technique, direct observation of handwashing was conducted. One main observer (MAR) and one research assistant observed the handwashing technique using a modified reference from WHO (Otsuka et al., 2019b). The observed steps consisted of 10 steps, namely: 1) 1) wet hands with water; 2) apply enough soap to cover all hand surfaces; 3) rub hands palm to palm; 4) rub right palm over left dorsum with interlaced fingers and vice versa; 5) rub palm to palm with fingers interlaced; 6) rub backs of fingers to opposing palms with fingers interlaced; 7) rub rotationally left thumb clasped in right palm and vice versa; 8) rub rotationally backward and forward with clasped fingers of right hand in left palm and vice versa; 9) rinse hands with water; and 10) dry hands thoroughly with a single-use towel.

2.3.3 Data analysis

The data were analyzed using JMP Pro 17 software for Microsoft Windows 10. A descriptive analysis was conducted for the sociodemographic characteristics of households. The relationships between WASH facilities and handwashing behavior with diarrhea were analyzed using bivariate Pearson's chi-square tests. Regarding handwashing behavior and technique, we compared the data with our previous study data from before the pandemic (Otsuka *et al.* 2019b) and performed difference analysis using t-tests. The analysis of factors influencing diarrhea was conducted using multivariate stepwise logistic regression. To select variables for the stepwise regression, bivariate odds ratios were computed between each dependent and independent

variable. Only those resulting in $p < 0.25$ were included in the multivariate model. The eligible factors influencing diarrhea included grade, handwashing education from parents, household monthly income, availability of drinking water, soap type, improved soap use during the pandemic, and improved frequency of handwashing during the pandemic. The threshold p-values for inclusion and exclusion in the model to calculate the adjusted odds ratio were set at 0.25 and 0.1, respectively. The significance level was set at $p < 0.05$ with a 95% confidence interval.

2.3.4 Ethics

Before data collection, all the information about the instrument and data collection underwent ethical screening. It was approved by the Ethical Review Committee of the Faculty of Health Sciences, Hokkaido University (No: 21-88) and the Health Research Ethic Committee, Faculty of Nursing, Airlangga University (No: 2554-KEPK). All participants included in the study were the students who got their parents' permission by signing the ethical document, information sheet, and consent form provided to all parents.

2.4 RESULTS

2.4.1 Sociodemographic characteristics

The sociodemographic characteristics of the participants are shown in Table 5. Participant information includes gender, grade, age of children, parental education level, number of family members, handwashing education from parents, family income, and house ownership. The majority of participants were boys (52%) with a median age of 10 (IQR: 7-12). Most fathers had an education level of more than 10 years (60%), while mothers had an education level of less than or equal to 9 years (52%), which is equivalent to junior high school. The households typically consisted of fewer than 5 people (62%). Additionally, a significant portion of households had irregular and low income (48%) and resided in rental houses (72%). Only 26% of the population exceeded the regional minimum wage (Rp 3.774.860/ USD 254), aligning with the characteristics of individuals living in slums (Bandung City Government, 2022).

Table 5. Socio-demographic characteristics of study participants (N=238)

No	Characteristics	N	%
1	Children's sex		
	Male	123	52
	Female	115	48
2	Children's age [median (IQR)]	238	10 (7-12)
3	Children's grade (age range)		
	Grade 2 (7-8 y.o)	80	34
	Grade 4 (9-10 y.o)	78	33
	Grade 6 (11-12 y.o)	80	34
4	Maternal education*		

No	Characteristics	N	%
	≤ 9 years	123	52
	≥ 10 years	115	48
5	Paternal education*		
	≤ 9 years	96	40
	≥ 10 years	142	60
6	Household members		
	≤ 4 persons	148	62
	≥ 5 persons	90	38
7	Handwashing education from parents		
	Yes	131	55
	No	107	45
8	Household monthly income		
	Low (2,000,000 IDR)	114	48
	Moderate (2,000,000 - 3,700,000 IDR) **	98	41
	High (> 3,700,000 IDR)	26	11
9	House ownership		
	Resident/ family	66	28
	Rental	172	72

** 9 years of education= Junior High School, ≥ 10 years= Senior high school/ university*

*** Minimum wage of Bandung City= Rp 3.774.860/ USD 254 (Bandung City Government, 2022)*

2.4.2 Household handwashing facilities and diarrhea outcome

Table 6 shows the handwashing facilities and their association with the prevalence of diarrhea among children. The types of handwashing facilities were adapted from the WHO questionnaire on water and sanitation surveys of households (WHO, 2018). The selected facilities include the type of toilet owned by the household, sewer system, availability of water, source of water for drinking and other purposes (handwashing, bathing), the main soap used for handwashing, and the type of handwashing facility. According to the WHO-UNICEF categories, handwashing

facilities are differentiated between fixed and mobile facilities with equipment such as buckets, jugs, or kettles. Most participants used private toilets (92%), while the remaining 8% still used shared toilets, primarily households living in boarding houses (rented rooms). The most commonly used type of soap was liquid soap (69%), with the rest using bar soap. Household water sources were mainly used for washing, bathing, handwashing, etc., and most households did not have water available at all times (82%). As a result, most families relied on drinking water vendors for drinking purposes (82%). For handwashing, most households washed their hands inside the toilet using buckets and dippers. Due to the lack of continuous water availability, residents stored water in buckets as a reserve and used it for handwashing. Based on the analysis of the relationship with the incidence of diarrhea in children, it was found that the type of toilet, soap, and water availability ($p<0.05$) were significantly associated. Children from households with shared toilets, used bar soap, and limited water availability were at a higher risk of diarrhea.

Table 6. Household WASH characteristics and diarrheal disease outcome

Characteristics	Total (n=238) n (%)	Diarrhea* (n=42) n (%)	Non-Diarrhea (n=196) n (%)	*p*-value**
Toilet type				
Private	218 (92)	35 (83)	183 (93)	**0.0334**
Shared	20 (8)	7 (17)	13 (7)	
Sewer system				
Septic tank	164 (69)	32 (76)	132 (67)	0.2612
Open drain	74 (31)	10 (24)	64 (33)	
Availability of water				

Characteristics	Total (n=238) n (%)	Diarrhea* (n=42) n (%)	Non-Diarrhea (n=196) n (%)	*p*-value**
Water is available every time	43 (18)	3 (7)	40 (20)	**0.0426**
Water is not available every time	195 (82)	39 (93)	156 (80)	
Source of drinking water				
Pipeline	34 (14)	7 (17)	27 (14)	0.3425
Borehole	9 (4)	0 (0)	9 (5)	
Drinking water vendor/ water kiosk	195 (82)	35 (83)	160 (82)	
Source of water for other purposes (Handwashing, bathing)				
Pipeline	50 (21)	9 (21)	41 (21)	0.9689
Borehole	162 (68)	28 (67)	134 (68)	
Groundwater	26 (11)	5 (12)	21 (11)	
Soap type for handwashing (primarily)				
Bar	74 (31)	19 (45)	55 (28)	**0.0291**
Liquid	164 (69)	23 (55)	141 (72)	
Handwashing facility at home				
Fixed facility inside toilet	55 (23)	7 (17)	48 (24)	0.5449
Fixed facility outside toilet	23 (10)	4 (10)	19 (10)	
Mobile object (bucket/jug/kettle) inside toilet	109 (46)	19 (45)	90 (46)	
Mobile object (bucket/jug/kettle) outside toilet	51 (21)	12 (29)	39 (20)	

**Children having 3 or more watery stools within 24 hours in the last 2 weeks*

***Significance of independences of samples indicated by Pearson chi-square test: p-value < 0.05*

2.4.3 Hand hygiene behavior and diarrhea outcome

Figure 2 illustrates the evaluation of students' handwashing technique based on the modified WHO's 10-step guidelines (2009). We compared students' handwashing techniques through direct observation in the same school in the years 2022 and 2017 (before the pandemic). Significant differences were observed in Steps 1 (wet hands with water) and 8 (rotational rubbing, backward and forwards with clasped fingers of the right hand in left palm and vice

versa) where, during the pandemic, students appeared to have better skills in these two steps ($p<0.05$). On the other hand, in step 2 (apply enough soap to cover all hand surfaces) and step 10 (dry hands thoroughly with a single-use towel), students' abilities were observed to be better and significantly different before the pandemic ($p<0.05$).

The information on the frequency of children's handwashing at selected critical times before and during the pandemic was collected from parents and presented in Figure 3. We also compared it with our previous study from 2017 (Otsuka *et al.* 2019). There were six selected critical times inquired about: before eating, after using the toilet, after touching the nose, coughing or sneezing, after touching garbage, after touching animals/animal food, and after playing in the yard/outside. Overall, the data from 2017 and the reports from parents before the pandemic (2019) show nearly the same trend, while during the pandemic, there is an improvement. Significant differences are observed in 3 conditions, namely after using the toilet, touching animals, and playing outside the house ($p<0.05$). During the pandemic, children tended to be more concerned about handwashing in these conditions, specifically after using the toilet and after playing outside the house.

During the pandemic, there were changes in children's handwashing methods, as reported by parents, including increased handwashing frequency, duration, technique, use of soap, sanitizer, and handwashing at critical points (Table 7). Most children (39%) reported washing their hands 5-6 times per day, while 38% reported washing them more than 7 times

per day. Changes in handwashing behaviors were reported in terms of frequency (61%), use of soap (53%), and use of sanitizer (45%). However, the duration and technique of handwashing changed in less than 15% of children. Among the participants, 42 (18%) reported experiencing diarrhea. Bivariate analysis revealed a significant relationship between improved use of soap by the participants, handwashing technique, and the risk of diarrhea ($p<0.0391$).

Table 7. Handwashing (HW) behavior and diarrheal disease outcome

Hand hygiene behavior	Total (n=238) n (%)	Diarrhea (n=42) n (%)	Non-Diarrhea (n=196) n (%)	*p*-value*
Hand hygiene frequencies during COVID-19				
1-2 times/day	6 (3)	1 (2)	5 (3)	0.696
3-4 times/day	48 (20)	7 (17)	41 (21)	
5-6 times/day	94 (39)	20 (48)	47 (24)	
≥7 times/day	90 (38)	14 (33)	76 (39)	
Handwashing technique				
< 6 steps	110 (46)	33 (79)	77 (39)	**<0.005**
≥ 6 steps	128 (54)	9 (21)	119 (61)	
Handwashing behavior in critical times				
< 4	68 (29)	11 (26)	57 (29)	0.706
≥ 4	170 (71)	31 (74)	139 (71)	
Reported increase HW frequencies				
Yes	145 (61)	14 (33)	79 (40)	0.4
No	93 (39)	28 (67)	117 (60)	
Reported improve HW duration				
Yes	30 (13)	6 (14)	24 (12)	0.717
No	208 (87)	36 (86)	172 (88)	
Reported improve HW technique				
Yes	11 (5)	2 (5)	9 (5)	0.962
No	227 (95)	40 (95)	187 (95)	

Hand hygiene behavior	Total (n=238) n (%)	Diarrhea (n=42) n (%)	Non-Diarrhea (n=196) n (%)	*p*-value*
Reported improve soap used				
Yes	125 (53)	16 (38)	109 (56)	**0.0391**
No	113 (47)	26 (62)	87 (44)	
Reported improve hand-sanitizer used				
Yes	107 (45)	19 (45)	88 (45)	0.989
No	130 (55)	33 (79)	107 (55)	

**Significance of independences of samples indicated by Pearson chi-square test: p-value < 0.05*

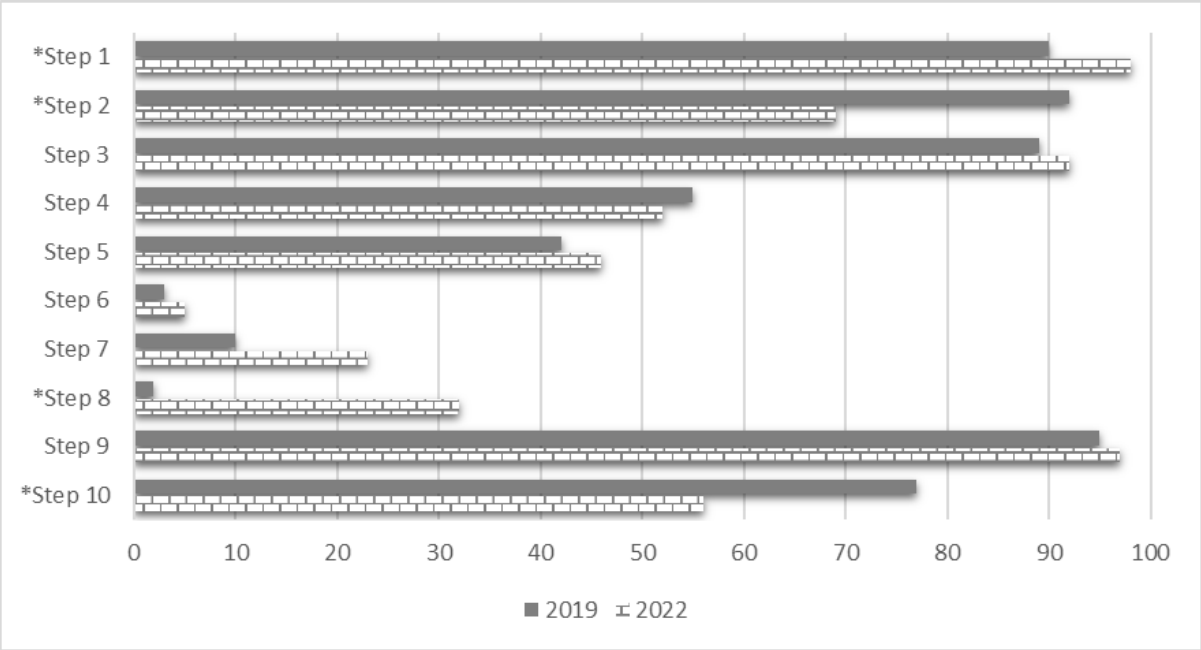

Figure 2. Comparison of handwashing skills of primary school children before (2019) and during the pandemic (2022)

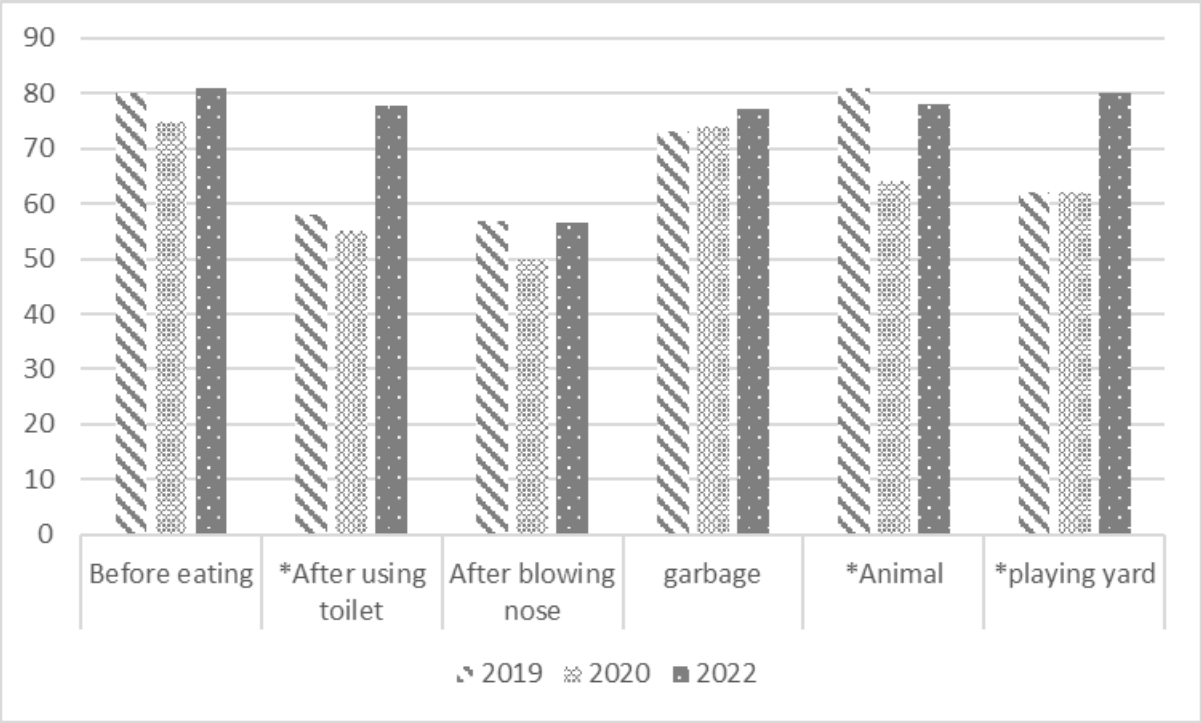

Figure 3. Reported hand hygiene practice at critical time before and during COVID-19 Pandemic

**The significance of the independence of samples is indicated by the Pearson chi-square test: p-value < 0.05.*

2.4.4 Factors contributing to diarrhea prevalence

The results of the regression analysis model predicting the incidence of diarrhea among children are presented in Table 8. According to the findings, using bar soap for handwashing was associated with four times higher odds of diarrhea (Adjusted Odds Ratio [AOR]: 4.7, 95% Confidence Interval [CI]: 1.647–13.34). On the other hand, having water available at all times was found to reduce the risk of diarrhea by 89% potentially (AOR: 0.21, 95% CI: 0.05–0.84). Regarding the handwashing technique, it was observed that individuals who performed handwashing using more than 5 steps were less likely to experience diarrhea (AOR: 0.08, 95%

CI: 0.03–0.26). Similarly, those who improved their use of soap during handwashing showed a 71% lower likelihood of experiencing diarrhea (AOR: 0.29, 95% CI: 0.10–0.81). Furthermore, children whose mothers had an education level of 10 years or more were found to have a 61% lower likelihood of experiencing diarrhea.

Table 8. Logistic regression analysis of factor associated with children diarrhea

Characteristics	Having diarrhea N (%)	*p*-Value	AOR (95% CI)*
Soap type			
Liquid	23 (14)	0.0034	Ref
Bar	19 (26)		4.7 (1.67-13.34)
Handwashing step			
< 6	33 (30)	0.0001	Ref
≥ 6	9 (7)		0.08 (0.03-0.26)
Improve soap use during pandemic			
No	16 (13)	0.0179	Ref
Yes	26 (23)		0.29 (0.10-0.81)
Availability of water			
Not available every time	39 (20)	0.0171	Ref
Available every time	3 (7)		0.11 (0.02-0.68)

**Multivariable models were adjusted for grade, handwashing education from parents, household monthly income, toilet type, sewage system, handwashing facility, and handwashing frequency. CI, confidence interval; ref, reference value.*

2.5 DISCUSSION

In this study, we identified that children's handwashing behavior is a critical factor influencing the incidence of diarrhea in children in urban slum area. Our findings regarding diarrhea incidence align with several previous studies in similar settings, such as in India (Basa, 2015), Bangladesh (Ferdous et al., 2014), and Uganda (Nantege et al., 2022), which revealed that children in urban slum areas are at a higher risk of experiencing diarrhea. While some studies emphasize poor environmental sanitation conditions as influencing factors (Kamm et al., 2014; Merid et al., 2023), others highlight that children's handwashing behavior was poor, thereby increasing the risk of children being exposed to diarrhea (Khan et al., 2021; Roy et al., 2023). Poor handwashing skills lead to ineffectiveness of handwashing in reducing the number of fecal contaminations on hands (Rifqi et al., 2023). Previous studies highlight that the frequency and quality of handwashing behavior significantly influence the risk, but the association between these factors and diarrhea need to be clarified.

The direct association between the steps performed by participants during handwashing (6 steps or more) has proven to be a significant protective factor in reducing the risk of diarrhea in children in this community. In contrast, the frequency of handwashing does not seem to have a significant impact. The effect of handwashing aligns with some studies that highlight handwashing can reduce the risk of diarrhea by 30-53% in children (Luby et al., 2004; Ejemot et al., 2008; Khan et al., 2021), but it seems necessary to further clarify whether

frequency and skills have a similar effect. The effectiveness of handwashing appears to decline when the frequency of handwashing is not followed by handwashing practices at some critical times. This study found a significant increase in the frequency of handwashing among the majority of children, consistent with several studies during the pandemic (Wise et al., 2020; Dwipayanti, 2021). However, it turns out that this increase in frequency is not accompanied by children's awareness of handwashing at some critical times. The study found an increase in frequency only at the points before eating and after using the toilet. However, there was no significant increase at other critical times, such as after sneezing and coughing, playing outside, and touching animals. The impact of handwashing in reducing risks could be increased by convincing people to apply hand hygiene procedures correctly and at the correct critical times (Bloomfield et al., 2007). This study proves that handwashing at critical times is crucial and needs to be reinforced as a factor in children's behavior to reduce the risk of diarrhea.

There are several previous studies that indicate hand hygiene procedures or handwashing skills are related to the risk of disease exposure in children (Luby et al., 2011; Roy et al., 2023), but findings are not conclusive. Our study typically provides a comprehensive understanding where we not only inquire about handwashing behavior through questionnaires but also observe and directly evaluate children's handwashing practices (Figure 3). Our study found significant changes in children's handwashing skills, but only at the first step (wetting hands with water) and the eighth step (rotational rubbing, backward and forwards with clasped

fingers of the right hand in the left palm and vice versa), compared with the study before the pandemic. While there were no significant differences in other steps, especially steps 5 to 7, which focus on the areas between fingers and fingertips. These areas are crucial, where many bacteria reside (Rosenthal et al., 2014; Julian et al., 2015), but are often overlooked. This finding is consistent in our study before (Otsuka et al., 2019a; Agestika et al., 2019) and during the pandemic (Rifqi et al., 2023). This may be due to children's limited ability to understand handwashing steps or not being aware that handwashing is important. A specific approach needs to be taken to address this oversight, such as using education through games or simulations to make children aware that bacteria reside in this area, and can impact their health.

The increased risk of diarrhea in children is also observed among those who use soap less frequently when washing hands. These findings align with several studies that emphasize the crucial role of washing hands with soap in reducing the bacterial count on hands compared to using water alone (Burton et al., 2011; Amin et al., 2014; Noguchi et al., 2021). A previous systematic review highlighted that substances in soap can effectively reduce the bacterial count on hands, thereby lowering the risk of hand contamination (Curtis & Cairncross, 2003). This study found that the pandemic could enhance children's awareness of soap usage, with as many as 53% of children showing improvement in their soap usage. This is consistent with a previous studies that demonstrated an increase in the use of hand hygiene products during the COVID-19 pandemic (Al-Tawfiq et al., 2019; Israel et al., 2020). Furthermore, the numerous campaigns

related to soap usage during the pandemic appeared effective in raising awareness among people. Additionally, soap is readily available at home and school, facilitating the instillation of this behavior in children compared to other alternatives like hand sanitizers. This study underscores the crucial role of soap in enhancing the impact of children's handwashing on health. However, special education efforts are still needed to encourage children to consistently use soap.

Interestingly, this study found that the majority of families switched from using bar soap to liquid soap for handwashing during the pandemic. The research demonstrates that the use of liquid soap is more effective in reducing the risk of diarrhea in children. While some studies have presented conflicting results regarding the efficacy of liquid soap (Kamm et al., 2014; Khan et al., 2021), this study affirms that liquid soap is indeed more effective. Liquid soap is generally recommended over bar soap for cleaning hands due to its ease of use, prevention of germ spread, and minimization of the risk of cross-contamination (MNH, 2008). However, this does not imply that bar soap is not recommended. Given its affordability for residents in slum areas, the choice of using bar soap requires careful consideration to prevent cross-contamination. As this study found that most households lack a fixed handwashing station facility, the presence of bar soap poses a higher risk of cross-contamination. Additionally, a previous study mentioned that most children wash their hands with soap in less than 10 seconds, which may not significantly affect bacteria removal. Therefore, the duration of handwashing,

especially when using bar soap, needs to be highlighted (Rifqi et al., 2023). The use of bar soap demands special attention to maintain cleanliness by placing it in a clean area to minimize cross-contamination among family members, and the duration of soap contact during handwashing should be considered.

The proper handwashing behavior and the use of soap pose common challenges observed in this study. While some studies revealed that handwashing among young children was poor (Xuan et al., 2013; Otsuka et al., 2019a), this study emphasizes overlooked critical times and areas related to the risk of diarrhea. There is a need for a special approach to children's education on proper handwashing. Based on the results from parents' interviews, children could not recognize that handwashing is important for their health, so they lack the motivation to do it. Children's motivation is influenced by the learning process, particularly through play-based learning. Motivation arises when children are curious about the activities they engage in. Additionally, the learning process for young children also needs to consider self-efficacy, which affects the maintenance of healthy behaviors. When children have good self-efficacy, they tend to exhibit strong motivation (Piaget, 1964; Bandura et al., 2001; Seimet et al., 2017). Therefore, this study recommends a specialized form of education for young children in the future, involving a specific approach such as learning through play and simulation. This study emphasizes the need for a specific approach to handwashing in children, such as conducting simulation games about the presence of bacteria in overlooked areas like between fingers and

demonstrating the impact of bacteria on hands with or without soap. Additionally, there needs to be a depiction of the effects of handwashing at critical times. This study proves that the quality of children's handwashing and the proper use of soap are key factors in efforts to reduce the risk of diarrhea in children.

2.6 LIMITATIONS

This study has some limitations. Firstly, the sample size and representativeness of the study population might be limited as the focus was only on one specific school. This could impact the generalizability of the findings to other similar settings. Secondly, data collection might be subject to recall bias as participants may have difficulty accurately recalling their children’s handwashing practices before and during the pandemic. Additionally, the study may face challenges in accurately assessing handwashing behavior and frequency due to potential social desirability bias, where participants might over-report their handwashing practices in response to societal norms or perceived expectations. Moreover, the presence of observers and the facilities provided during the handwashing observation may have influenced the participants to modify their handwashing technique. Despite these limitations, this study could still provide valuable insights into the importance of handwashing in reducing diarrhea incidence in urban slum communities during a pandemic, guiding future interventions and public health strategies to address WASH needs in vulnerable populations.

2.7 CONCLUSION

The main findings of this study underscore that diarrhea remains a critical issue experienced by children in the urban slum area of Bandung, Indonesia. The handwashing skills plays a crucial role in reducing the risk of diarrhea. During the COVID-19 pandemic, there has been an increase in children's awareness regarding the frequency of handwashing; however, unfortunately, this has not been followed by an improvement in the quality of children's handwashing skills. Additionally, the role of soap is also quite important, with the study highlighting the relationship between the use and type of soap and the risk of diarrhea in children. Future challenges that need attention include the necessity for a specific approach to children regarding the importance of handwashing, supported by WASH facilities in schools and homes, especially the availability of soap. Furthermore, there is a need to involve children in the learning process through games or simulations to enhance motivation and awareness regarding handwashing, with the aim of reducing the incidence of diarrhea in slum areas.

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CHAPTER III

Assessing malnutrition in urban slum children: A mixed-methods study of nutrition-related water, sanitation, and hygiene (WASH) in Bandung, Indonesia

3.1 ABSTRACT

Malnutrition remains a pressing concern in developing countries, especially in urban slum areas where inadequate sanitation and improper hygiene negatively impact children's health and nutrition status. To address this issue, understanding local knowledge and perspectives on malnutrition related to water, sanitation, and hygiene (WASH) is crucial, yet often overlooked. This study aimed to explore the association and perspective of nutrition and WASH among children in an urban slum. A convergent parallel mixed-methods study was conducted in an urban slum area in Bandung, West Java, Indonesia. Quantitative data were collected from 273 young children and their mothers, and qualitative assessments involved 47 mothers. The study utilized questionnaires, observations, anthropometric measurements, and semi-structured interviews. The quantitative study revealed that malnutrition was prevalent among children, with 13.1% being stunted and 19.7% wasted. The association between mothers' knowledge of WASH, the WASH index, and dietary intake with malnutrition was statistically significant ($p < 0.05$). Four themes emerged from the qualitative study, describing mother's perspective on WASH-nutrition issues: (1) misperceptions about WASH and poor hygiene behavior (2) WASH behavior and health outcomes (3) perspectives on nutrition status and health, and (4) household experience with food insecurity. Findings from the qualitative and quantitative studies were integrated into three main themes from the joint display: (1)

perspectives on hygiene behavior and nutrition status, (2) the knowledge-behavior gap related to WASH, and (3) decisions on food choices. The study found a gap between mothers' knowledge of WASH and the WASH index of children. The knowledge of mothers about WASH does not reflect family practices in daily life, indicating the need for a comprehensive assessment through the WASH index for the family. Most children have a poor WASH index linked to their poor nutrition status, but mothers are unaware of this interconnectedness. The lack of awareness of mothers about the importance of hygiene behavior leads to the normalization of poor behavior in children. This study highlighted that mothers have a crucial role in influencing children's behavior. A specific approach is needed to enhance family awareness in urban slums, with a particular focus on highlighting the effect of hygiene practice and health outcomes.

Keywords *Malnutrition, mixed methods study, nutrition-related WASH, urban-slum children, Indonesia*

3.2 INTRODUCTION

Malnutrition continues to be a significant global health concern, with approximately 45% of deaths among children under 5 years of age attributed to undernutrition (WHO 2018). This issue is most prevalent in low- and middle-income countries, significantly affecting vulnerable populations, such as those in urban slums (*Awasthi et al.* 2003; Glewwe *et al.* 2022). In urban settings, the problem extends beyond mere food availability, encompassing a complex web of challenges. In urban slums, child growth is described as a complex process characterized by independent factors, including dietary intake, inadequate health, poverty, household food insecurity, and an unhealthy household environment (UNICEF 1998; Islam *et al*. 2018). Moreover, children in urban slums are

at a high risk of cross-contamination from the environment, which might impact health outcomes (Rifqi *et al.* 2023). However, the impact of WASH related to children malnutrition remains unclear, particularly in resource-limited settings.

In these densely populated areas, the intersection of limited resources in household, inadequate access to nutrition, and suboptimal water, sanitation, and hygiene (WASH) conditions exacerbates the risk of malnutrition (Das *et al*. 2020). Several studies have found that a common problem in urban communities is the dietary origin problem. Previous studies mentioned that children in urban slum areas face inadequate macronutrients (Kumar *et al.* 2005; Aguayo *et al.* 2016), but dietary intervention alone have not been able to normalize growth (Dewey and Adu-Afarwuah, 2008). The situations can be further worsened by chronic malnutrition, including cross-contamination from a poor environment (Fahim et al. 2018; Fahim et al. 2020). Some experimental trials have confirmed that cross-contamination may impacting the malabsorption of nutrients, and WASH intervention positively affect height for age and health outcome (Arnold *et al.* 2013; Prendegast *et al.* 2015). On the contrary, some studies state that the WASH approach cannot be effective due to the minimal behavior change in families (Gizaw & Worku *et al.* 2019). The family's perception of nutrition-related WASH is an important factor that needs clarification, especially in urban slum areas.

Indonesia is one of the countries facing a significant malnutrition problem among children. Approximately 30.8% of children were categorized as stunted in 2018 (MoH 2019). The combination of unimproved latrines and untreated drinking water was associated with an increased odds of stunting in Indonesia compared with improved conditions (Torlesse *et al.* 2016). Our previous study in the slum areas of Bandung found that poor knowledge of WASH and handwashing behavior among children in this area

(Otsuka *et al.* 2019b; Rifqi *et al.* 2023). Previous studies in Indonesia have primarily focused on direct malnutrition-related issues such as children's dietary intake at the national scope (Titaley *et al.* 2013; Bell *et al.* 2017). Research combining a quantitative and qualitative approach is needed, to further understand this phenomenon.

Therefore, by adopting this mixed-methods approach, the study aims to bridge quantitative and qualitative insights, providing a nuanced understanding of the multifaceted challenges faced by children in slum areas. This community-based mixed-methods study focuses on capturing malnutrition and factors related to nutrition and WASH among young children in slum area. We assessed knowledge and perspective of nutrition and WASH, hygiene practices through observation and dietary assessment. The findings are intended to facilitate a more informed policy development process, with the ultimate goal of ensuring the right to combat malnutrition problems for slum communities.

3.3 MATERIALS AND METHOD

3.3.1. Study area and participants

This study was conducted in Kiaracondong, Bandung, a slum area characterized by high population density. People in this area face significant challenges stemming from insufficient sanitation facilities and restricted access to clean water. The study involved 273 preschool and primary school students, along with their mothers, who were purposefully selected. A qualitative approach was employed to collect insights from 43 mothers.

3.3.2. Design

We employed a convergent design, combining quantitative and qualitative methods to capture the knowledge and perspectives mothers. This mixed-method approach

summarized comprehensive phenomena, offering an integrated overview of the interconnectedness between WASH and nutrition through a joint display of quantitative and qualitative data.

3.3.3 Data collection

3.3.3.1 Questionnaire survey

Data were collected through questionnaires administered to both children and parents. The questionnaire covered various aspects, including sociodemographic information (gender, age, parents' education, family income, number of household members, and house ownership), as well as knowledge and awareness of WASH and hygiene with soap (HWWS) practices. Handwashing practices in six critical situations were assessed: before eating, after using the toilet, after touching the nose, coughing, or sneezing, after handling pets or their food, and after touching garbage or playing outside. From a nutritional perspective, the questionnaire for mothers also included inquiries about their knowledge and perspectives regarding nutrition-growth and nutrition-related WASH. Additionally, a dietary intake assessment was conducted using a food record for 3x24 hours (2 days during weekdays and 1 day during the weekend), along with a food insecurity questionnaire (Food Insecurity Experience Scale/FIES).

3.3.3.2 Handwashing observation and microbial tests

To assess the handwashing technique of the children, we conducted direct observations. One primary observer and a research assistant observed the handwashing procedure using a modified reference based on WHO guidelines. The observed steps checklist comprised 10 stages (WHO 2009; Otsuka et al., 2019b). After handwashing, we swabbed all students' hands to check for fecal contamination, specifically *E. coli* and coliform. The detailed procedures for handwashing observation and microbial analysis are provided

elsewhere (Rifqi et al., 2023).

3.3.3.3 Anthropometric measurement

The height was measured with a stadiometer (SECA 213, Germany) to the nearest 0.1 cm, and body weight was measured using a digital weight scale (BC-754-WH; Tanita, Tokyo, Japan) to the nearest 0.1 kg. Body mass index (BMI) in kg/m² was then calculated based on these height and weight measurements per-age using software (WHO Anthroplus; WHO). Height-for-age z-scores (HAZ) and BMI-for-age z-scores (BMIAZ) were computed from the anthropometric measurements, employing an international reference Children with HAZ < −2 were classified as stunted, while those with BMIAZ < −2 were categorized as wasted.

3.3.3.4 WASH Index

The score of handwashing technique, HWWS, and knowledge and awareness of WASH were converted into full scales of 10 points each. The total score was obtained by adding the score of the three items and was set as the WASH index (maximum 30 points) (Otsuka et al., 2019).

3.3.3.5 Semi-structured interview

An interview guide was developed based on previous studies regarding the factor and perspective related malnutrition and WASH. The following five questions were asked: 1) How do you describe the nutrition status and growth of your children? 2) How do you describe the hygiene behavior of your children? 3) What are the challenges for nutrition and WASH behavior? 4) What factors are related to malnutrition in your opinion? And 5) Do you think there is a link between WASH behavior and health and nutrition status? Researchers conducted direct semi-structured interviews with each participant. Each interview lasted 20-30 minutes and was conducted in Bahasa Indonesia. The interviews

were recorded and transcribed verbatim. To ensure the reliability of the verbatim transcripts, the two researchers who conducted the interviews independently checked all transcripts for accuracy. MAXQDA software version 2020 (The Art of Data Analysis) was utilized for the analysis of the interviews.

3.3.4 Data analysis

The methodology used for a quantitative survey and a qualitative study is illustrated in Figure 4, summarizing a convergent parallel mixed methods approach to investigate the multidimension of malnutrition among children.

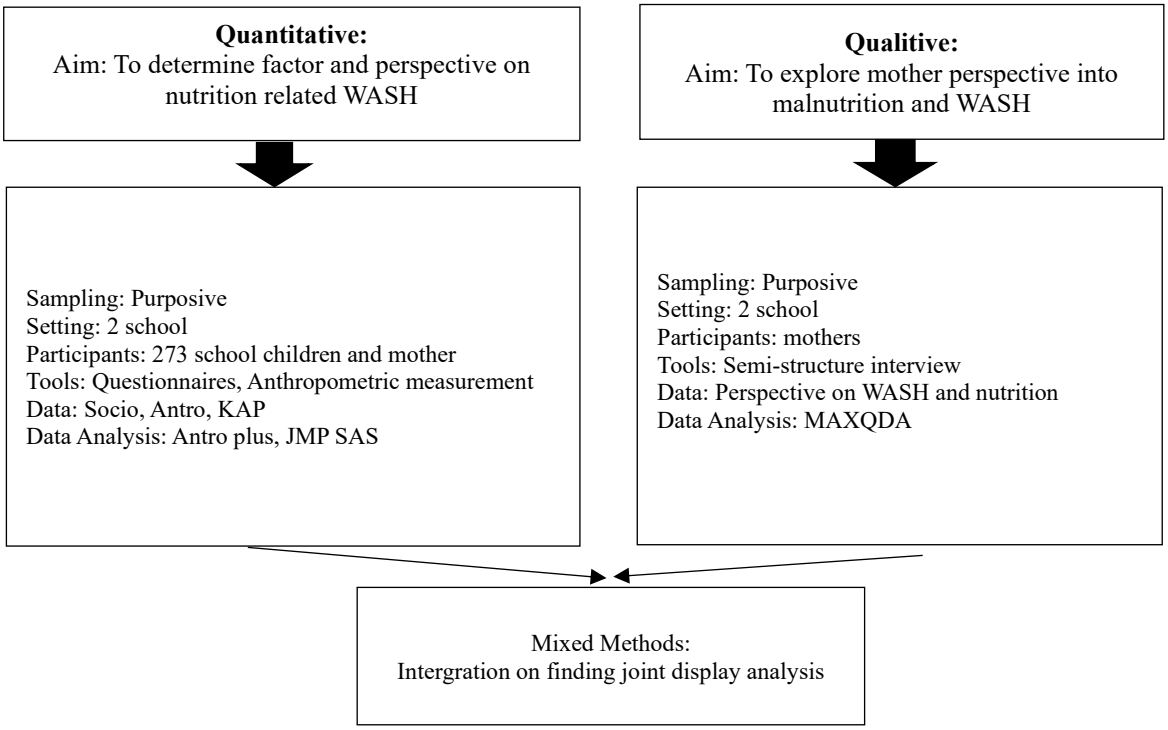

Figure 4. Mixed methods integration design

3.3.5 Ethics

This study was approved by the Ethical Review Committee of the Faculty of Health Sciences, Hokkaido University (No: 21-88) and the Health Research Ethic Committee, Faculty of Nursing, Airlangga University (No: 2554-KEPK).

3.4 RESULTS

3.4.1 Household demographics

Table 9 provides an overview of the participants' attributes. The children's age ranged from 4 to 12 years old, with an average of 9 ± 2.17 years. Most fathers had an education level of more than 10 years (60%), while mothers had an education level of less than or equal to 9 years (52%), equivalent to junior high school. Most households had irregular and low income (48%) and resided in rental houses (72%).

Table 9. Socio-demographic characteristics of study participants

Characteristics	Quantitative (n=273)		Qualitative (n=47)	
	N	%	N	%
Children's sex				
Male	138	51	25	53
Female	135	49	22	47
Children's grade (9±2.17 y.o)				
Pre-school (4-5 y.o)	35	13	9	19
Grade 2 (7-8 y.o)	80	29	13	28
Grade 4 (9-10 y.o)	78	29	12	26
Grade 6 (11-12 y.o)	80	29	13	28
Maternal education				
≤ 9 years	143	52	27	57
≥ 10 years	130	48	20	43
Paternal education				
≤ 9 years	99	36	16	34
≥ 10 years	174	64	31	66
Household members				
≤ 4 persons	177	65	35	74
≥ 5 persons	96	35	12	26
Household monthly income				
Low (2,000,000 IDR)	136	50	28	60
Moderate (2,000,000 - 3,700,000 IDR)	101	37	10	21
High (> 3,700,000 IDR)	36	13	9	19
House ownership				
Resident/ family	72	26	38	81
Rental	201	74	9	19

3.4.2 WASH, dietary and malnutrition

Table 10 displays WASH and nutrition factors related to malnutrition. This study revealed

that 13.1% of children are stunted and 19.7% are wasted. The majority of children have a low (51%) and moderate (40%) WASH index, knowledge and handwashing practices. Concerning knowledge related to WASH, 56% of mothers demonstrated good knowledge. Table 10 also illustrates nutritional variables in children. Most children experience deficiencies in macronutrients such as energy, carbohydrates, proteins, and fats. Over 50% of children experience protein deficiency, significantly associated with the occurrence of stunting in children. Meanwhile, maternal nutritional knowledge is evenly distributed, majority ranging from low and moderate. The majority of families experience food insecurity at a moderate level (53%). Bivariate tests showed a significant relationship between the WASH index and knowledge of WASH with children's nutritional status and protein intake ($p<0.05$).

Table 10. WASH and nutrition factors related to malnutrition

Variable	Total (n=273)		Height for age z score (HAZ)					Body Mass Index for age z score (HAZ)				
			Stunted (n=36)		Not stunted (n=237)		p-value	Wasted (n=54)		Not wasted (n=219)		p-value
	N	%	n	%	N	%		N	%	n	%	
1. Water, Sanitation and Hygiene (WASH)												
WASH index of children												
Poor	138	51	23	64	115	49		26	48	112	51	
Moderate	108	40	11	31	97	41	NS	22	41	86	39	p<0.05
Good	27	10	2	6	25	11		6	11	21	10	
Mother's Knowledge on WASH												
Poor	36	13	2	6	34	14		2	4	34	16	
Moderate	84	31	21	58	63	27	p<0.05	23	43	61	28	p<0.05
Good	153	56	13	36	140	59		29	54	124	57	
2. Nutrition												
Mother's Knowledge on nutrition and child growth												
Poor	94	34	8	22	86	36		14	26	80	37	
Moderate	92	34	18	50	74	31	NS	21	39	71	32	NS
Good	87	32	10	28	77	32		19	35	68	31	
Household Food Security												
Food secure	31	11	1	3	30	13		2	4	29	13	
Food insecure												
Mild	91	33	16	44	75	32	NS	21	39	70	32	NS
Moderate	144	53	18	50	126	53		29	54	115	53	
Severe	7	3	1	3	6	3		2	4	5	2	
Dietary Intake												
Energy												
Inadequate	112	41	17	47	142	60	NS	24	44	88	40	NS
Adequate	161	59	19	53	95	40		30	56	131	60	
Carbohydrate												
Inadequate	118	43	17	47	101	43	NS	22	41	94	43	NS
Adequate	155	57	19	53	136	57		22	41	125	57	

Variable		Total (n=273)		Height for age z score (HAZ) Stunted (n=36)		Not stunted (n=237)		p-value	Body Mass Index for age z score (HAZ) Wasted (n=54)		Not wasted (n=219)		p-value
		N	%	n	%	N	%		N	%	n	%	
Protein													
	Inadequate	140	59	25	69	140	59	p<0.05	39	72	135	62	NS
	Adequate	97	41	11	31	97	41		15	28	84	38	
Fat													
	Inadequate	134	49	19	53	115	48	NS	28	52	106	48	NS
	Adequate	139	51	17	47	122	52		26	48	113	52	

3.4.3 Qualitative results

Forty-seven mothers participated in this study. Most of participants had not graduated from high school as their major education level (57%), and their household income was low (60%). Through the analysis of the interview data, four themes with seven subthemes and 255 codes emerged. The themes and subthemes are listed in Table 11: (1) Misperceptions about WASH and poor hygiene behavior (2) WASH behavior and health outcomes (3) Perspectives on nutrition status and health, and (4) Household experience with food insecurity.

Table 11. Main finding from interview with four emerged themes (n=47)

Themes		Subthemes
Perspective on WASH and poor hygiene behavior	1.1	Normalization of poor hygiene behavior
	1.2	Overrated of school education
WASH behavior and health outcome	2.1	Underestimated on the poor hygiene and health impact
Perspective on nutrition status and growth	3.1	Misperception on child growth
	3.2	Lack of awareness on nutrition
Household experience on food insecurity	4.1	Limited food access
	4.2	Lack of knowledge lead to unbalanced dietary

Table 12. Integrated qualitative and quantitative results

Integrated Themes	Qualitative results	Quantitative results	Interpretation
Perception on WASH and child growth	Theme: 1 Miss-perception and poor hygiene behavior Theme 2: WASH behavior and health outcome Theme 3: Perspective on nutrition status and growth	- Anthropometric measurement - Knowledge on WASH and nutrition - WASH index	Mothers perceive their children's hygiene behavior as poor, leading to frequent illness, but they are unaware of its impact on their health Additionally, mothers believe that their children are growing well; however, undernutrition remains prevalent. The quantitative study found an association between the WASH index and children's growth. Nevertheless, mothers unaware that WASH might be drivers in malnutrition.
Attitude-behavior gap related to WASH	Theme: 1 Miss-perception and poor hygiene behavior Theme: 3 Perspective on nutrition status and growth	- Knowledge on WASH - Knowledge on child growth - WASH Index	Children and mothers have enough knowledge of WASH. However, this knowledge is not applied in their daily practices, aligning with the low WASH index among most children. Mothers tend to normalize poor behavior since their children are still young and living in slums. This habit seems to underestimate the link between WASH and health outcomes.
Decision on food choices	Theme: 4 Household experience on food insecurity	- Family Income - Household food security status - Dietary intake	Participants face limitations in accessing food due to low family income. This is corroborated by quantitative findings that reveal children experience nutrient deficiencies. Lack of awareness further worsens this condition, limiting options for nutritious food.

1. Perspective on WASH and poor hygiene behavior

Many mothers feel that the hygiene practices of their children are limited, but they consider this to be normal. Mothers believe that their children's behavior will improve with age

1.1 Normalization of poor hygiene behavior

Mothers normalize their children's poor handwashing behavior due to their young age and living in a slum environment.

"The child is reluctant to wash hands, hard to remind, well, you know how small kids are, sometimes they want to, sometimes they don't. Yes, sometimes I remind, but it's difficult to change." (ID-10)

"Since they're still young, I'm not too fussy about their hand-washing skills. They'll figure it out on their own when they grow up." (ID-23)

1.2 Overrated of school education

Some mothers feel that educating children about WASH and hygiene has already been covered at school.

"When it comes to handwashing, I simply show them, as they are taught by their teachers at school. Sometimes I don't have enough time to remind them since busy with work. As far as I know, they are always taught at school, so they should already know the proper way to wash their hands." (ID-4)

2. WASH behavior and health outcome

Many mothers feel that their children's ability in terms of WASH and handwashing is low. However, they believe that this does not have a significant impact on their children's health.

2.1 Underestimated on the poor hygiene and health impact

We live in a slum area, and so far, there haven't been any health issues. When the children get sick, it's usually due to fatigue or being infected by someone else. Besides, living in this kind of environment makes it challenging to make children overly concerned about cleanliness. (ID-23)

3. Perspective on nutrition status and growth

Most mothers believe that there were no issues with their children's nutritional status and growth. The majority of participants responded positively to the condition of their kids.

3.1 Misperception on child growth

Most mothers feel that their children's growth is normal. Participants define 'normal' as the child being active and free from serious illnesses.

'The growth of each child is different. It can't be compared with other kids. In my opinion, my child is doing just fine. (ID-8)

"The nutritional status of the child is fine, no issues at all, what matters is that the child is active. Mild illnesses are usually just the flu, and that's a common thing." (ID-12)

3.2 Lack of awareness of nutrition and growth

Some mothers were aware that their children's growth (height or weight) differs from other children of the same age; some realize that their children are shorter or thinner. However, they perceive this as normal.

"My child is a bit shorter than his peers, but it's okay, as long as he's healthy. It's because of our family's genetics; both his mom and dad are also on the short. Even my parents (his grandparents) are short, so if he's a bit short or slim, it's just a normal thing for us." (ID-4)

'*"My kid is doing fine. Eating can be a bit tricky, so she is shorter than her friend. But, it's fine, it's not growth problem.'* (ID-15)

4 Household experience on food insecurity

Many mothers feel that access to food is a major problem for their households. Irregular and low family income makes mothers worry about the availability of food for their families and children.

4.1 Food access

Just like families living in urban slums, family income is a primary concern expressed by parents. This income has an impact on the family's ability to meet food access.

"My husband has an uncertain income—sometimes there's money, sometimes there isn't. The income source is not steady. So, when it comes to food, I have to be clever in strategizing. Things like chicken and meat are not frequent; we have to be thrifty." (ID-

8)

''When it comes to food, we just go with whatever's there; the kids are okay with it. Our family income is kind unpredictable, so we just eat whatever we've got" (ID-11)

4.2 Lack of knowledge lead to imbalanced dietary

Mothers lack knowledge about healthy food choices and tend to provide high-calorie meals, overlooking the selection of a balanced diet.

Kids usually have noodles with rice for breakfast, because it's easy to prepare, as long as they're full, it's totally okay. Chicken and meat are expensive, we can't access it frequently (ID-10)

3.4.4 Integrated qualitative and quantitative results

Table 4 presents the integrated themes between qualitative and quantitative approaches. There are three main themes identified: 1) perceptions on child growth and health 2) attitude-behavior gap related WASH, and 3) decision on food choices. Participants have a good knowledge regarding WASH but sometime not applied in daily life due to various reasons, including limited access, a tendency to normalize unhealthy behaviors, and misconceptions about child growth and nutritional status. The study found an association between WASH and hygiene behavior with health outcomes and the nutritional status of children, but this connection is often not well understood.

3.5 DISCUSSION

In this study, we identified that WASH plays a crucial role in the malnutrition condition of children in urban slum area. This finding about malnutrition aligns with research conducted in similar settings across low- and middle-income countries, highlighting malnutrition prevalence ranging from 12% to 31% (Islam et al., 2018; Huey et al., 2019). Our quantitative study showed that childhood undernutrition was prevalent, with around 13.1% stunted and 19% in the wasted category. An estimated 50% of undernutrition is associated with the recurrence of diarrhea caused by insufficient hygiene, sanitation, and unsafe water (Pruss-Ustun et al., 2008). Poor WASH access in urban slum areas has long-term effects on children's health (Harper et al., 2018; Lauer et al., 2020), rendering malnutrition interventions ineffective. While current malnutrition interventions through the WASH approach target children and families, further investigation is needed to understand the factors and family perspectives.

Previous studies have stated that mother's WASH knowledge and practice significantly correlate with malnutrition cases in urban slums (Kuddus et al., 2022; Manjabin et al 2022). In contrast, this study found that mothers have adequate knowledge related to WASH, but it is not reflected in the hygiene practices of children. Mothers' knowledge seems to be inconsistent with the real scenario of family practices (Pedroso et al 2017), and it can be assumed that mothers failed to point out the critical effect of hygiene on health outcomes. Although some studies suggest that maternal knowledge reflects practices in children (Webber et al., 2010; Kim et

al.,2021), but this study asserts that assessing maternal knowledge is insufficient to describe family and children's behavior. In-depth observation using the WASH index is necessary to understand the true situation of family hygiene practices. Qualitative approach found that mothers tend to underestimate WASH-related behaviors of children, considering their children still young and living in poor sanitation area. The results of this mixed-method approach emphasize that the asynchrony between mothers' knowledge and hygiene practices in children is one of the main drivers causing health problems in children. Most mothers are unaware of the association between WASH practices and malnutrition; it might reduce the effectiveness of nutrition-WASH programs.

Misperception in the concept of WASH and malnutrition is worsened by the limited knowledge of mothers on nutrition and child growth, and poor hygiene practices of the family. Some parents feel that their child's nutritional status is normal, but undernutrition is prevalent. Previous studies have shown an association between mothers' nutrition knowledge, hygiene practices, and undernutrition (Appoh et al., 2005; Fadare et al., 2019; Manjabin et al., 2022). Mothers typically have the main responsibility for caring for children; their perception has been shown to influence maternal practices and education for children (Apparicio et al., 2013; Webber et al., 2010; Binkin et al., 2013). The practice of eating and hygiene is formed during childhood, and mothers have a strong influence on children's lifestyle (Scaglioni et al., 2011). This study highlights that mothers play a significant role in WASH practices and child nutrition,

making family-based interventions crucial.

This study also discovered that the majority of families face food insecurity problems. Mothers are concerned that there won't be enough food in the family due to limited income. Food insecurity is a common issue in urban slum areas due to income limitations, impacting food accessibility (Murage et al., 2014). The lack of access to sufficient food results in inadequate macronutrient intake among children (Faye et al., 2011; Fiorentino et al., 2016; Wicks et al., 2006). However, quantitative findings revealed no significant association between the food security of the family and the nutrition status of children. This result may be explained by the fact that most families are under low and middle income and face food insecurity issues. A systematic review indicates that urban poverty is a barrier to accessing healthy diets and is associated with poorer nutrition outcomes (Compte et al., 2021). Access to nutritious food is a common problem for slum families that may cause malnutrition, and a special approach is needed.

The study identified a trend of families consuming high-calorie but nutritionally unbalanced food. Mothers narrated their difficulty in affording nutritious food due to a limited ability to purchase foods. Therefore, they could only focus on rice or noodles, while protein sources are perceived as more expensive and are often overlooked. Unbalanced diets based mainly on energy-dense foods lead to childhood malnutrition (Chakona 2020; Moedjadi et al. 2021). Protein is considered as a second-optional food item, and when families face economic

problems, food is prioritized accordingly. Previous studies have suggested providing logistic support to families, but this single approach is not effective because of a lack of sustainability (Erokhin et al. 2021). This program should be accompanied by special approach for families to choose local food, raising awareness among mothers that there are many alternatives for nutrient-rich food that is more accessible.

Poverty-malnutrition is a common problem in urban slum areas. This study highlights a lack of mothers' knowledge about affordable food-based sources. Specific nutrition education is needed for mothers, and it has a significant impact on increasing maternal knowledge and children's nutritional status (Sultana & Hasan, 2020; Prasetyo et al. 2023). Mothers play a key role in this regard, so in addition to government assistance, there is a need for special education for parents about the crucial role of nutrients in child growth. Our study highlighted that there should be a program to familiarize mothers with proper eating concepts. This includes a more conscious selection and use of food products, especially local protein sources, making consumption choices that involve locally grown food, and diversifying diets by introducing more local foods.

3.6 LIMITATIONS

The strength of this study lies in using a mixed-method integration, potentially offering a comprehensive perspective by combining qualitative and quantitative methods. Nevertheless,

we acknowledge several limitations in this study. The design employed is cross-sectional, preventing the analysis of reciprocal relationships among various variables concerning WASH and malnutrition. Additionally, the sample selected for the study is purposive, involving some parents of students, which might introduce bias and uneven distribution of the family's socio-economic background. The study was also conducted during the COVID-19 pandemic, potentially limiting the generalizability of the findings to the pre- or post-pandemic situations. However, the mixed-method design used in this study can provide an overview of the WASH and nutrition conditions within families, offering valuable insights for future studies aimed at addressing malnutrition issues.

3.7 CONCLUSION

In conclusion, this study found that WASH has a crucial association with the nutrition status of children. Mothers play a crucial role in influencing the hygiene behavior of children. However, the study identified a gap between maternal knowledge and the WASH index in children. Maternal knowledge does not adequately represent the real condition of hygiene practices in the family; thus, a comprehensive assessment using the WASH index is necessary for future WASH studies. This aligns with the results from the qualitative approach, indicating a lack of attention from mothers to the poor quality of child hygiene and a tolerance due to misperception on hygiene practices. This misperception leads some mothers to normalize poor hygiene behavior in children. Additionally, mothers' knowledge about accessible nutritious food in the

environment is also limited, leading to a limited variety of foods consumed by the family and children. This phenomenon might reduce the effectiveness of malnutrition intervention programs through WASH, requiring special attention, especially in slum areas. The study highlights that a special education approach about WASH needs to be undertaken for both mothers and children through a combination of learning and practice.

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CHAPTER IV

CONCLUSION, LIMITATIONS AND NEW INSIGHT

4.1 Overall Conclusion

This study analyzes the correlation between water, sanitation, and hygiene (WASH) and health outcomes in urban slum communities. Findings from this study highlight the importance of children's handwashing skills in effectively reducing bacteria on their hands. The study reveals that fecal bacteria were found in almost all children, posing a risk of cross-contamination and impacting children's health. Additionally, the study identifies that children's handwashing skills, including steps, soap usage, duration, and hand drying, were generally poor. During the COVID-19 pandemic, it was expected that children's behavior to practice good hygiene would improve due to extensive education efforts. However, the study's findings state that there were no significant changes during the pandemic. While awareness on the frequency of handwashing increased, it was not accompanied by improvements in the quality of handwashing, soap usage, and handwashing duration. Furthermore, limited WASH facilities, such as access to clean water, handwashing facilities, soap, or drying tissue, are estimated to impact children's handwashing behavior.

The study highlights that the poor hygiene behavior of children and inadequate WASH facility support from families significantly correlate with health impacts on children, especially diarrhea and malnutrition. Poor WASH and hygiene practices have a crucial influence, leading

to high cases of diarrhea and malnutrition among children in urban areas. Knowledge and perception of children and mothers are also important highlights from this study. Misperceptions about the behavior of young children and their growth can be main drivers that lead to unawareness of WASH and health outcome. This study uncovers a substantial gap between knowledge and practices, particularly regarding nutrition and WASH, underscoring the importance of targeted specific education for mothers and children. The key finding was the need for local and community-based education, which cover the specific situation in urban slum. Despite the challenges identified, the study acknowledges the resilience of families facing adverse conditions in urban slums. The recommendations stemming from this research advocate for holistic interventions that encompass educational programs, infrastructure improvements, and family and local community engagement to address the intricate web of factors influencing children's health in urban slum environments.

4.2 Limitations

The overall studies in this research have limitations, here are some general limitations of the study:

1. **Geographical specificity:** The study focused exclusively on urban slums in Bandung, Indonesia. Consequently, the findings may lack generalizability to other urban or rural areas, both within Indonesia and globally. Variations in cultural practices, socioeconomic conditions, and WASH infrastructure may affect the transferability of the study's results.
2. **Limited temporal scope:** The study's assessment was conducted during the COVID-19 pandemic, reflecting a specific period influenced by public health measures and community responses. The temporal constraints may limit the ability to discern broader trends or evaluate the long-term impact of the pandemic on hygiene, sanitation, and nutritional practices.
3. **Cross-sectional design:** The research utilized a cross-sectional design, capturing a snapshot of the situation during a specific timeframe. The lack of a longitudinal approach hinders the exploration of trends and changes in hygiene practices and health outcomes over an extended period. Additionally, a more comprehensive approach is needed for this research, involving a longer duration of observation.

4. **Data collection challenges:** The study encountered challenges related to data collection, including potential recall bias in self-reported information (such as handwashing behavior and disease history) and limitations in comprehensive direct observation. These challenges may affect the accuracy and reliability of the collected data.
5. **Reliance on observation bias:** The potential influence on participants' handwashing technique and reported on dietary intake due to the presence of observers and the provision of specific facilities during the observational process is noteworthy, as the awareness of being observed and the availability of designated facilities could introduce a form of response bias, leading participants to consciously or unconsciously adjust their typical handwashing practices.

4.3 New Insight

Overall, this study provides new insights into health-WASH research. The cumulative findings of this study are summarized in Table 13, depicting the objectives, findings, and recommendations of each respective chapter.

Table 13. objectives, findings and recommendation summary

Objective	**Summary**
Chapter 1	School-based assessment on the effect of handwashing techniques on reducing *E. coli* on children's hands
Finding	Childrens exposed with fecal contamination on hands; poor handwashing technique affect *E. coli* removal
Recommendation	Media education based on age group; Role of teacher, mother or family
Chapter II	Community-based assessment on handwashing behavior and facilities during the COVID-19 pandemic and their correlation with diarrhea incidence among primary school children
Finding	Diarrhea related to hygiene behavior; Limited soap access; Not significant change of behavior during pandemic
Recommendation	Specific education on handwashing (play-simulation learning), Family-based intervention include mothers
Chapter III	Community-based assessment on exploring factors and perspectives about malnutrition related to WASH among children and mothers.
Finding	Gap of knowledge and practice; Miss-perception on WASH and health concept; food insecurity and low of knowledge on nutritious food choices
Recommendation	Family and community-based education required; local and cultural approach needed; WASH index for comprehensive assessment

The table above depicts the conclusions of each study and the recommendations that can be provided. Some key points from the above recommendations can be outlined as follows:

1) Effective education on promoting handwashing skills

The study found that the current education provided was not effective enough to improve children's handwashing behavior, as well as other WASH and health practices. Disseminating information through posters and lessons in school alone is not sufficiently effective in improving children's behavior. There is a need for comprehensive and sustained practices; behavior change takes time to adapt, so it is important to shift from conventional education/ teacher-based to play-simulation education. Young children need a special approach that raises their motivation by using games, videos, pictures, and simulations.

2) Empowering mother and community-based approach

Involving mothers is crucial in addressing hygiene practice issues. This study found that mothers can be crucial mediators for education, but this does not operate optimally due to limited knowledge and misperceptions among mothers. Furthermore, the low educational background of mothers also contributes to the misconceptions that occur. Family and community-based education is a key point in solving WASH problems, with mothers being one of the key figures involved. Mothers must be involved in educational activities by providing them with simple yet easily understandable information. Some key points that need to be highlighted for mothers are overlooked parts during handwashing, the concept of WASH and health outcomes, and how to encourage children to adopt proper hygiene behavior.

3) Community engagement and multisectoral approach

The involvement of various sectors is necessary in addressing WASH issues in urban areas. The primary sector is community leaders, who should take the lead in discussing the challenges of limited access to food, water, soap, and other WASH facilities. They should also act as mediators between the government, NGOs, and other stakeholders. Moreover, there is a need for educational programs that engage local health cadres, youth leaders, and religious figures to serve as role models for good behavior. Education solely in schools is deemed not sufficiently effective, emphasizing the importance of a community-based approach.

5.0 ACKNOWLEDGMENTS

I would like to express my gratitude to Universitas Airlangga, which provided a scholarship through the Rector Scholarship program that allowed and supported my education fund during my study in Japan. I extend my thanks to my supervisor, Prof. Taro Yamauchi, who gave me the opportunity to join his lab, providing valuable lessons, especially in research and article writing. Thank you for all the motivation and continuous support. I also express my thanks to Prof. Atsuko Ikeda-Araki as the sub-supervisor, Prof. Katsuhiko Ogasawara, and Dr. Bomme Gowda Siddabasave Gowda as examiners for their support during my study.

Gratitude is also conveyed to Dr. Akira Sai (Sai sensei) and Dr. Sikopo Nyambe (Sikopo sensei). Thank you for your guidance during my studies; it has been truly meaningful for the progress of my studies. A big thank you to current and former lab mates and friends in the Lab of Human Ecology (Smile Lab). Our engaging conversations assisted me in going beyond my initial expectations and accomplishing more than I had envisioned. Thanks to fellow members of Indonesian Student Association (PPI Jepang), PPI Hokkaido, Hokkaido Islamic Society (HIS), who have been study partners, discussion partners, and provided support during my studies.

I would also like to express my sincere gratitude to my parents, Mr. Syamsurizal and Mrs. Helena, Mrs. Selvinar and the late Mr. Syahriwal. Special thanks to my wife, Mrs. Fithria Rahmadhani, and my children, Muhammad Athar Rifqi and Muhammad Aqsha Rifqi. I never would have made it without you. Words cannot express my gratitude for your endless guidance,

patience, and support throughout the ups and downs of my journey.

All praise and gratitude are due to Allah, the Almighty, the Most Compassionate, the Most Merciful. It is with His divine guidance and blessings that I have completed this thesis. I acknowledge and recognize His infinite wisdom that has illuminated my path and granted me strength throughout this academic journey.

6.0 ACHIEVEMENTS

- **Publication**

  - Rifqi, M.A., Hamidah, U., Sintawardani, N., Harada, H., Nyambe, S., Sai, A & Yamauchi, T. Effect of handwashing on the reduction of *Escherichia coli* on children's hands in an urban slum Indonesia. Journal of Water and Health, 21(11), 1651 doi: 10.2166/wh.2023.121. (2023 published)

- **Oral/Poster Presentation**

1. Assessing malnutrition in urban slum children: The influence of water, sanitation and hygiene (WASH) and dietary intake during the COVID-19 pandemic. Mahmud Aditya Rifqi, Umi Hamidah, Neni Sintawardani, Akira Sai and Taro Yamauchi. The International Society for Sanitation Studies, Annual Conference 2023. Sapporo, November 28th 2023.
2. Handwashing behavior and child diarrhea in urban-slum Indonesia during the COVID-19 Pandemic. Mahmud Aditya Rifqi, Umi Hamidah, Neni Sintawardani, Akira Sai and Taro Yamauchi. The 7th International Symposium on Green Technology for Value Chains 2023. Bandung, November 14th-15nd, 2023.
3. Water, sanitation and hygiene facilities and child diarrhea in urban-slum Indonesia during the COVID-19 Pandemic. Mahmud Aditya Rifqi, Umi Hamidah, Neni Sintawardani, Akira Sai and Taro Yamauchi. The 6th FHS International Conference. Sapporo, October

20th, 2023.

4. Knowledge and behavior of handwashing during the COVID-19 Pandemic: study on age-group disparity in urban-slum Bandung, Indonesia. Mahmud Aditya Rifqi, Umi Hamidah, Neni Sintawardani, Akira Sai and Taro Yamauchi. The International Society for Sanitation Studies, Annual Conference 2022. Sapporo, December 19th 2022.
5. Handwashing skills and contamination of coliform bacteria in the hands of urban slum students in Indonesia. Mahmud Aditya Rifqi, Umi Hamidah, Neni Sintawardani, Akira Sai, Hidenori Harada and Taro Yamauchi. The 6th International Symposium on Green Technology for Value Chains 2022. Bandung, November 22nd, 2022.
6. Physical activity and energy balance as emerging factors for nutritional status in rural-urban Indonesian adolescents. Mahmud Aditya Rifqi, Septa Indra Puspikawati, Taro Yamauchi. The 5th FHS International Conference. Sapporo, September 17-18th, 2021.