Chapter 7
Influence of Water, Sanitation, and Hygiene (WASH) on Children's Health in an Urban Slum in Indonesia

Taro Yamauchi, Yumiko Otsuka, and Lina Agestika

Abstract Unsafe drinking water, poor sanitation, and inadequate hygiene are key contributors to deteriorating child health in low- and middle-income countries. This chapter focuses on (1) evaluating child health and nutritional status; (2) clarifying the factors contributing to undernutrition and diarrhea prevalence by focusing on water, sanitation, and hygiene (WASH); and (3) evaluating fecal contamination and children's hand hygiene. The study was conducted at a preschool and two elementary schools in densely populated Bandung, Indonesia, targeting children and their caretakers, using anthropometric measurements, handwashing observation, hand bacteria testing, and questionnaires. The results showed that not using a towel after handwashing was significantly associated with increased risk of stunting. Children from households using tap water instead of tank water as drinking water suffered from increased risk of stunting and thinness. Moreover, children from households using open containers for water storage were associated with increased risk of diarrhea. Most children (98.7%) had hand fecal contamination, with girls having significantly less *Escherichia coli* (*E. coli*) than boys. *E. coli* counts were negatively correlated with handwashing technique, handwashing with soap, and a developed WASH index. The findings suggest that successful home drinking water management and proper personal hygiene practices are important for attaining better child health.

Keywords Child health · Water, sanitation and hygiene (WASH) · Fecal contamination · Urban slum

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In this chapter, we adopted and reorganized two papers published in the *American Journal of Tropical Medicine and Hygiene* (https://doi.org/10.4269/ajtmh.18-0063) and *Tropical Medicine and International Health* (https://doi.org/10.1111/tmi.13279).

T. Yamauchi (✉)
Faculty of Health Sciences, Hokkaido University, Sapporo, Japan

Research Institute for Humanity and Nature, Kyoto, Japan
e-mail: taroy@med.hokudai.ac.jp

Y. Otsuka · L. Agestika
Graduate School of Health Sciences, Hokkaido University, Sapporo, Japan

T. Yamauchi et al. (eds.), *The Sanitation Triangle*, Global Environmental Studies,
https://doi.org/10.1007/978-981-16-7711-3_7

7.1 Introduction

Contaminated drinking water and poor sanitation and hygiene lead to the deterioration of children's health, indirectly causing undernutrition (WHO et al. 2015). According to a report by the World Health Organization (WHO) and United Nations Children's Fund (UNICEF), 89% of the world's population used (at least) basic drinking water services, but only 68% used (at least) basic sanitation services in 2015 (WHO and UNICEF 2017). The United Nations Sustainable Development Goals, therefore, were implemented to achieve universal, equitable access to safe, affordable drinking water and adequate, equitable sanitation, and hygiene for all by 2030 (Targets 6.1 and 6.2) (United Nations 2015).

Although the number of deaths among children under 5 years of age has decreased globally from 12.6 million in 1990 to 5.6 million in 2016, many children still die from preventable diseases (UNICEF et al. 2017). Worldwide, diarrhea is the second-greatest cause of death among children under 5 years of age (UNICEF et al. 2017), and it is a children's health challenge requiring prioritization. According to recent estimates, access to improved water, sanitation, and hygiene (WASH) could prevent 58% of diarrheal deaths among children under the age of five worldwide per year (United Nations 2015). The pathogens that cause diarrhea are transmitted via the fecal-oral route, but their transmission can be prevented by handwashing (Curtis et al. 2000). Handwashing with soap (HWWS) reduces the risk of diarrhea by 48% (Cairncross et al. 2010) and is important in reducing the risk of infectious diseases, as more bacteria of fecal origin can be eliminated by HWWS than handwashing using water alone (Burton et al. 2011). However, in a recent systematic review, it was estimated that only 19% of the world's population performs HWWS after using the toilet or touching children's feces (Freeman et al. 2014), putting the remainder at high risk for fecal contamination. This statistic emphasizes the importance of clean water, sanitary conditions, and proper hygiene (i.e., HWWS) in promoting children's health.

Numerous researchers have investigated the relationship between children's health and WASH in low- and middle-income countries. Previous studies have shown that the level of household sanitation and the household caretaker's personal hygiene practices are strong predictors of child stunting (Jee et al. 2015) and that the use of a high-quality toilet protects against diarrhea and stunting in children (Fink et al. 2011). Urban slums in low- and middle-income countries face several challenges, such as high population density, a lack of durable housing, housing with an insufficient living area, housing insecurity, and poor access to improved water and sanitation (UN-HABITAT 2006), and these challenges can affect children's health. Moreover, although a previous study revealed that children in slums are subject to greater health risks than those in non-slum urban areas, the risk is lower than it is among children living in rural areas (Fink et al. 2014). For example, in Indonesia, untreated drinking water and unimproved sanitation were strong predictors of child stunting (Torlesse et al. 2016), and the use of piped water reduced the risk of diarrhea in children (Komarulzaman et al. 2017). Nevertheless, the relationship between WASH and children's health in urban slums remains unclear and requires thorough examination.

Therefore, an evaluation of fecal contamination through handwashing practices is important and must be conducted to counteract the problem of poor child health in urban slums. That said, there is no "gold standard." Several researchers have investigated the relationship between fecal contamination of a child's hands and handwashing behaviors (Kyriacou et al. 2009; Padaruth and Biranjia-Hurdoyal 2015) and their level of knowledge and awareness (Grimason et al. 2014), but few studies have been conducted on the relationship between handwashing techniques and fecal contamination levels. Furthermore, targeting the frequency and technique of handwashing simultaneously is effective for changing handwashing behaviors (Friedrich et al. 2018), making an investigation of these practices—especially those of children—necessary. Thus, a comprehensive assessment of the various aspects of behavior, knowledge and awareness, and technique must be conducted.

As already discussed, the assessment of handwashing behaviors requires international attention. A previous study suggested that self-reported data regarding handwashing behaviors were rife with overestimations of actual behaviors (Hirai et al. 2016). Therefore, a comprehensive evaluation of handwashing behaviors requires the simultaneous use of questionnaires and observations of participants' actual handwashing practices. However, such approaches are time- and labor-intensive and can thus be difficult to apply to a large sample. Hence, it is important to consider conceptualizing and developing a more efficient way to mitigate the above-mentioned challenges.

The researchers primarily aimed to evaluate children's nutritional status and the prevalence of fecal contamination on the hands of children living in an urban slum. Regarding the former, we conducted direct observations and administered a questionnaire to clarify the factors contributing to undernutrition and the prevalence of diarrhea by focusing on WASH from three perspectives: the household environment, children's personal hygiene practices, and their level of knowledge and awareness. With respect to the latter, we identified the factors related to fecal contamination on hands and developed an index to comprehensively evaluate handwashing techniques, HWWS compliance, and knowledge and awareness of WASH; we later investigated their relationship with fecal contamination.

7.2 Materials and Methods

7.2.1 Study Area and Participants

This cross-sectional study was conducted in the densely populated area of Bandung, West Java Province, Indonesia, from August to September 2017. The data were collected in cooperation with a preschool facility, Pendidikan Anak Usia Dini

(PAUD), and two elementary schools in the area. All the children and their caretakers at PAUD, as well as the children in grades 2, 4, and 6 and their caretakers in the elementary schools, were enrolled. After explaining the purpose and content of the survey, we have obtained informed consent and assent from 228 pairs of caretakers and their children, respectively. The children who were unable to obtain consent from their caretakers and/or were absent during the investigation period were excluded.

7.2.2 Anthropometric Measurements

The participants' height was measured to the nearest 0.1 cm using a stadiometer (Seca 213; Seca, Hamburg, Germany), and their body weight was measured to the nearest 0.1 kg using a digital scale (BC-754-WH; Tanita, Tokyo, Japan). Their body mass index (BMI; in kg/m^2) was calculated from these measurements. The ages of the children were calculated by software (WHO AnthroPlus version 1.0.3 (WHO 2009a); WHO, Geneva, Switzerland) using their date of birth (as reported by their caretakers) and the research date. Their height-for-age *z*-scores (HAZ) and BMI-for-age *z*-scores (BMIAZ) were calculated from the anthropometric measurements using international references (de Onis et al. 2007; WHO Multicentre Growth Reference Study Group 2006) (WHO AnthroPlus version 1.0.3 software). The children with HAZ scores < -2 were categorized as stunted, and those with BMIAZ scores < -2 and $> +2$ were classified as thin and obese, respectively (de Onis et al. 2007; WHO 2009a, 2018).

7.2.3 Handwashing Technique Check

To evaluate the children's handwashing techniques, a checklist was modified based on WHO handwashing procedures (WHO 2009b). The following ten steps were included: (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 hands palm-to-palm with fingers interlaced; (6) rub backs of fingers to opposing palms with fingers interlaced; (7) rub rotationally with 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. The children were also instructed to freely use the water, soap, and towels that were provided and to do what they normally would at home before demonstrating their handwashing practices. A single researcher (Y.O.) noted the children's actions according to the steps.

7.2.4 Fecal Hand Contamination

The level of fecal contamination on children's hands was examined for participants in grades 2, 4, and 6 ($n = 169$). The enumerators used a wiping kit, which contained a cotton swab and 10 mL of sterile phosphate buffered saline (PBS) in a test tube (Swab test ST-25PBS; ELMEX, Tokyo, Japan). Before the children demonstrated their handwashing practices, a cotton swab moistened with sterile PBS was rolled on the surface of the dominant hand of each child (i.e., palm, backside, and fingers). All the samples were kept on ice and transported to a field laboratory within 4 h of sampling. The samples were processed in a laboratory by membrane filtration to detect *Escherichia coli (E. coli)*. Under aseptic conditions, each sample (10 mL) was divided into low and high volumes (1.0 and 9.0 mL or 0.5, 1.0, and 8.5 mL) and passed through a 47-mm-diameter 0.45-μm cellulose filter. After filtration, the filter was placed in XM-G growth media (XM-G; Nissui Pharmaceutical Co., Tokyo, Japan) and incubated at 37 °C for 20 ± 2 h. The bacterial load on each sample of media was assessed in terms of colony-forming unit (CFU) counts per hand. The presence of *E. coli* was determined by size and color of the colony (i.e., a blue and purple colony larger than 1 mm). The purple colony was included in our analysis to prevent overlooking *E. coli* because of the growth media's manual's instructions: *E. coli* may produce a blue to blue-purple reaction. For each sample, both the media (low and high volumes) were used to estimate the concentrations of *E. coli*. When both the media counts included 100 or fewer colonies, the concentrations were added to determine the sample concentration (CFU per hand). If the high-volume media's count exceeded 100 colonies, the low-volume media sample was used to estimate the concentration. In addition, when colonies were not successfully formed or they fused together, we deemed them "uncountable" and excluded them from analysis. A blank test was performed more than once a day to ensure that there was no contamination during the inspection process.

7.2.5 Questionnaires

Structured questionnaires were developed according to the preliminary research and after discussion with local people to ensure their suitability for the local context. They were then administered to the caretakers and elementary-school children. The questions for the caretakers included items related to the following: (1) basic demographics including age, educational background, occupation, household monthly income, and household environment (drinking water source, toilet type, sewerage); (2) level of WASH knowledge and awareness and handwashing behaviors; and (3) reported prevalence of diarrhea and respiratory symptoms during the preceding 2 weeks.

The following questions were focused on assessing levels of sanitation knowledge and awareness: (1) Do you know that boiling water kills germs? (2) Do you know that water containers need cleaning and covering? (3) Do you know that human feces contain germs? (4) Do you think that drinking water can be contaminated by fecal bacteria? (5) Do you think that unclean drinking water can make you sick? (6) When do you think it is most important to wash one's hands? (7) Do you think that your hands can be contaminated by bacteria if you don't wash them after using the toilet? (8) Do you think that handwashing is important for disease prevention? (9) Do you think that inadequate drainage facilities can cause environmental pollution and health problems? The scores were calculated based on the number of correct answers to the sanitation knowledge and awareness items.

7.2.6 WASH Index

Water, sanitation, and hygiene knowledge and awareness scores were calculated based on the number of correct answers to the items in the WASH knowledge and awareness section. Regarding handwashing behaviors, the participants were asked what their usual procedure for cleaning their hands was on various occasions with reference to the recommendations of the Centers for Disease Control and Prevention (2016). Handwashing behaviors were categorized as "always wash hands with soap" and the converse according to their answers. Diarrhea was indicated in cases of three or more loose or liquid stools per day (WHO 2005). For elementary-school children, a questionnaire regarding WASH knowledge and awareness (only questions 1–8) and handwashing behaviors (only 6 occasions) was selected and modified for children by using easily understood vocabulary. The scores for handwashing techniques, HWWS, and knowledge and awareness of WASH were converted into full scales of ten points each. The total score was obtained by adding the scores of the three items together, and it was set as the WASH index (maximum 30 points).

7.2.7 Statistical Analysis

A bivariate analysis was performed with the data for stunting, thinness, diarrhea prevalence, and each individual variable (i.e., household, caretaker, and child characteristics). The independent variables were chosen from covariate variables: (1) those that had significant differences in stunting, thinness, and diarrhea prevalence on bivariate analysis; (2) children's health status and relevance as pointed out in previous studies; and (3) WASH items of interest in this study. Stepwise forward selection method was applied to these variables in three multivariate logistic regression analyses, where each of stunting, wasting, and diarrhea was dependent variable.

Bivariate analyses were also performed to determine differences in the handwashing techniques, HWWS, levels of knowledge and awareness, and *E. coli* counts based on participants' gender and grade level. All *E. coli* counts were normalized to CFU per hand and log 10 (hereafter referred to as "log") transformed before analysis. We used Pearson's correlation to assess the relationship between *E. coli* counts (log) and the scores for handwashing techniques, HWWS, level of awareness of WASH, and the WASH index.

A *p*-value of <0.05 was considered statistically significant. JMP 13.1.0 software (SAS Institute Japan, Tokyo, Japan) was used for all the statistical analyses.

7.3 Results

7.3.1 Child, Caretaker, and Household Characteristics

The household and caretaker characteristics are shown in Table 7.1. More than half of the caretakers had more than a high-school diploma. When dividing household income into low (<2,000,000 rupiah or US $160), middle (2,000,000 to <4,000,000 rupiah or US $160 to < US $320), and high (≧4,000,000 rupiah or ≧US $320) categories, low- and middle-income households comprised the majority. Households using tank water (purchase/refill) as drinking water were the most prevalent, at 65%; the remaining households used tap and ground water, which were boiled before use. Most of the households had installed their own toilets (private). The households using septic tanks for toilet wastewater treatment comprised only a quarter of the total, whereas the remaining three quarters discarded untreated wastewater in the river directly or indirectly. More than half of the participants attained the maximum total score for WASH knowledge and awareness. The proportion of caretakers who said that handwashing before eating was important exceeded 95%; however, the corresponding proportion when asked after using toilet was below 70%.

Table 7.2 shows the characteristics of the children. The prevalence of diarrhea and respiratory symptoms in the preceding 2 weeks was 14.0% and 39.9%, respectively. A significant association was found between the presence of diarrhea and respiratory symptoms ($p < 0.05, \chi^2$ test). The proportion of children who answered that it was important to wash one's hands before eating reached 90%, but the corresponding proportion when asked about toilet use was only 43%. This tendency was like that of the caretakers. Furthermore, the handwashing technique check yielded an average score of 5.0 points, and only 11 children (5%) did not use soap.

The results of the analysis of the children's nutritional status are shown in Table 7.3. The scores for HAZ using the WHO as a reference ranged from -1.27 to -1.04, and the BMIAZ scores ranged from -0.66 to -0.49. The prevalence of stunting, thinness, and obesity according to the WHO's criteria indicated that boys experienced higher prevalence in all categories ($p < 0.05, \chi^2$ test). When comparing the mean BMIAZ score in this study and the SEANUTS study (Sandjaja et al. 2013) with children aged 5–12 years, all the values fell between those of the rural and urban categories (Fig. 7.1).

Table 7.1 Characteristics of households and caretakers (n = 228) (Otsuka et al. 2019a)

Characteristics	n	Proportion (%)
Educational background		
Completed primary education	112	49.1
Completed secondary education	116	50.9
Occupation		
Working	52	22.8
Nonworking[a]	176	77.2
Monthly income (rupiah)		
<2,000,000	133	58.3
2,000,000 to <4,000,000	74	32.5
≥4,000,000	20	8.8
No response	1	0.4
Household water and sanitation		
Source of drinking water		
Tap water	60	26.3
Tank water	147	64.5
Groundwater	21	9.2
Drinking water storage type		
Closed container	217	95.2
Open container	11	4.8
Toilet type		
Private	206	90.4
Shared	22	9.6
Treatment for toilet sewage		
Septic tank	60	26.3
No treatment	168	73.7
Water, sanitation, and hygiene knowledge and awareness		
Total score (median, range)	9 (6–9)	
Important times for handwashing		
After using the toilet	159	69.7
Before eating	217	95.2
After eating	128	56.1
Handwashing behaviors		
Always wash hands with soap	61	26.8

[a]Unemployed or homemaker

7.3.2 Factors Contributing to Children's Health and Nutritional Status

Tables 7.4 and 7.5 present the results of the logistic regression analysis. Being male (adjusted odds ratio [AOR] = 3.96; 95% confidence interval [CI], 1.80–8.88) and not using a towel after handwashing (AOR = 2.37; 95% CI, 1.13–4.96) were associated with an increased risk of stunting. Being from a middle-income household was associated with a reduced risk of thinness compared to being from a

Table 7.2 Characteristics of children (n = 228) (Otsuka et al. 2019a)

Characteristics	n	Proportion (%)
Gender		
Boy	117	51.3
Girl	111	48.7
Grade		
Preschool	59	25.9
Grade 2	58	25.4
Grade 4	51	22.4
Grade 6	60	26.3
Disease symptoms[a]		
Diarrhea	32	14.0
Respiratory illness	91	39.9
Water, sanitation, and hygiene knowledge and awareness (n = 169)		
Total score (median, range)	7 (2–8)	
Important times for handwashing		
After using the toilet	73	43.2
Before eating	151	89.3
After eating	50	29.6
Handwashing behaviors (n = 169)		
Always wash hands with soap	47	27.8
Handwashing skills (n = 221)		
Checklist total score (mean ± SD)	5.0 ± 1.8	
With water and soap	210	95.0
With water	11	5.0
Using a towel	158	71.5

[a]Prevalence during a 2-week period

Table 7.3 Children's nutritional status by gender (n = 228) (Otsuka et al. 2019a)

	Gender	
	Boy (n = 117)	Girl (n = 111)
Height-for-age z-scores (mean ± SD)	−1.27 ± 0.99	−1.04 ± 0.78
Boys' mass index-for-age z-scores (mean ± SD)	−0.66 ± 1.39	−0.49 ± 1.15
Stunting (%)	27.4 (n = 8)	9.0 (n = 10)
Thinness (%)	15.4 (n = 18)	8.1 (n = 9)
Obesity (%)	7.7 (n = 9)	1.8 (n = 2)

low-income one (AOR = 0.26; 95% CI, 0.07–0.92). Children from households using tap water instead of tank water as their drinking water source were more likely to suffer from stunting and thinness (AOR = 2.26; 95% CI, 1.03–4.93; and AOR = 2.88; 95% CI, 1.13–7.35, respectively). Regarding diarrhea prevalence, children from households using open containers for water storage suffered from an increased risk (AOR = 5.01; 95% CI, 1.08–23.15), and being from a middle-income

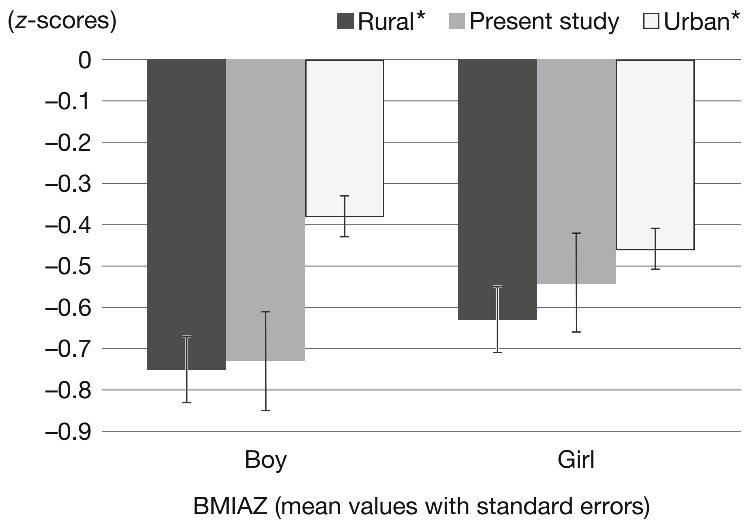

Fig. 7.1 Comparison of children's nutritional status in areas in Indonesia (rural and urban) *South East Asian National Survey; rural: boy ($n = 691$), girl ($n = 729$); urban: boy ($n = 682$), girl ($n = 670$). *BMIAZ* body mass index-for-age *z*-scores (Otsuka et al. 2019a)

household instead of a low-income one was associated with a reduction in risk (AOR = 0.36; 95% CI, 0.13–0.99).

7.3.3 Handwashing Technique Check

The results of the handwashing technique of children by gender and grade level are shown in Table 7.6. The average score for handwashing techniques was only adequate for about half of the ten steps, at 5.5 points. Although over 90% of the children used soap, fewer than 10% performed steps six (backs of fingers to opposing palms with fingers interlaced), seven (rotational rubbing of the left thumb clasped in the right palm and vice versa), and eight (rotational rubbing backward and forward with the fingers of the right hand in the left palm and vice versa). In addition, none of the 166 subjects completed all ten steps. There was no significant difference in the average score by gender, but it was significantly higher among those in grades 4 and 6 than those in grade 2; there was no significant difference between those in grades 4 and 6.

Table 7.4 Factors associated with undernutrition in the multivariate logistic regression analysis (Otsuka et al. 2019a)

Variables		Adjusted odds ratio	95% confidence interval	*P*-value
Stunting				
Gender	Girl	1.00	–	–
	Boy	3.99	1.80–8.88	0.001
Handwashing step ten	Observed	1.00	–	–
	Not observed	2.37	1.13–4.96	0.022
Toilet sewage treatment type	Septic tank	1.00	–	–
	No treatment	2.06	0.81–5.19	0.127
Drinking water source	Tank water	1.00	–	–
	Tap water	2.26	1.03–4.93	0.042
	Ground water	0.55	0.11–2.65	0.453
Thinness				
Monthly income	Low	1.00	–	–
	Middle	0.26	0.07–0.92	0.037
	High	0.39	0.05–3.25	0.381
Water storage type	Closed container	1.00	–	–
	Open container	2.95	0.69–12.60	0.144
Drinking water source	Tank water	1.00	–	–
	Tap water	2.88	1.13–7.35	0.027
	Ground water	1.40	0.34–5.81	0.646
Gender	Boy	1.00	–	–
	Girl	0.51	0.21–1.27	0.148
Age		1.17	0.98–1.40	0.072

Table 7.5 Factors associated with diarrhea prevalence in the multivariate logistic regression analysis (Otsuka et al. 2019a)

Variables		Adjusted odds ratio	95% confidence interval	*P*-value
Monthly income	Low	1.00	–	–
	Middle	0.36	0.13–0.99	0.049
	High	0.32	0.04–2.58	0.284
Drinking water source	Tank water	1.00	–	–
	Tap water	0.40	0.13–1.26	0.118
	Groundwater	0.77	0.19–3.10	0.716
Water storage type	Closed container	1.00	–	–
	Open container	5.01	1.08–23.15	0.039
Water, sanitation, and hygiene knowledge and awareness				
Important times for handwashing	More than two choices	1.00	–	–
	One choice	2.15	0.94–4.93	0.069

Table 7.6 Handwashing techniques by gender and grade (Otsuka et al. 2019b)

Handwashing step	Total ($n = 166$) %	Boy ($n = 85$) %	Girl ($n = 81$) %	*P*-value	Grade 2 ($n = 55$) %	Grade 4 ($n = 51$) %	Grade 6 ($n = 60$) %	*P*-value
1 Wet hands with water	90	87	93	NS	91	92	87	NS
2 Apply enough soap to cover all hand surfaces	92	92	93	NS	80	100	97	<0.05
3 Rub hands palm-to-palm	89	86	91	NS	76	96	93	<0.05
4 Rub right palm over left dorsum with interlaced fingers and vice versa	55	48	62	NS	27	69	68	<0.05
5 Rub hands palm-to-palm with fingers interlaced	42	38	47	NS	24	41	60	<0.05
6 Rub hands with backs of fingers to opposing palms with fingers interlaced	3	5	1	NS	0	8	2	<0.05
7 Rotationally rub hands with the left thumb clasped in the right palm and vice versa	10	11	10	NS	2	24	7	<0.05
8 Rotationally rub hands backward and forward with the fingers of the right hand clasped in the left palm and vice versa	2	2	3	NS	0	4	3	NS
9 Rinse hands with water	95	94	95	NS	84	100	100	<0.05
10 Dry hands thoroughly with a single-use towel	77	74	80	NS	56	98	78	<0.05
Total score (mean ± SD)	5.5 ± 1.7	5.4 ± 1.7	5.7 ± 1.6		$4.4^{ab} \pm 1.8$	$6.3^{b} \pm 1.2$	$6.0^{b} \pm 1.4$	

NS not significant

A value between the same superscript character denotes a significant difference, $p < 0.05$

Table 7.7 Prevalence of handwashing with soap by gender and grade (Otsuka et al. 2019b)

Occasion	Total ($n = 169$) %	Boy ($n = 87$) %	Girl ($n = 82$) %	*P*-value	Grade 2 ($n = 58$) %	Grade 4 ($n = 51$) %	Grade 6 ($n = 60$) %	*P*-value
Before eating	80	77	83	NS	76	76	86	NS
After using the toilet	58	55	61	NS	45	59	70	<0.05
After blowing one's nose, coughing, or sneezing	57	46	69	<0.05	66	45	60	NS
After touching an animal, animal food, or animal waste	81	76	87	MS	66	88	90	<0.05
After touching garbage	73	67	79	NS	64	67	87	<0.05
After playing in the yard	62	52	71	<0.05	45	69	72	<0.05
All occasions	28	23	34	NS	19	20	43	<0.05
Total score (median, range)	4 (0–6)	4^{a} (0–6)	5^{a} (0–6)		3.5^{b} (0–6)	4^{c} (0–6)	5^{bc} (0–6)	

NS not significant
A value between the same superscript character denotes a significant difference, $p < 0.05$

7.3.4 Handwashing with Soap (HWWS)

Table 7.7 shows the prevalence of HWWS among children by gender and grade. The proportion of children who answered that they usually performed HWWS on all occasions was 30%; before eating, 80% did; and under 60% did so after using the toilet. The girls had significantly higher total scores than the boys. Those in grade 6 had a higher total score than those in grades 2 and 4. The girls reported practicing HWWS more often than boys ($p < 0.05$) after blowing their noses, coughing, and sneezing and after playing in the yard.

7.3.5 Knowledge and Awareness of Water, Sanitation, and Hygiene (WASH)

The children's level of knowledge and awareness of WASH by gender and grade level are shown in Table 7.8. About 26% of the children obtained full marks (data not shown). There was no significant difference in the total score by gender. There were, however, significant differences in the total scores between the grades, with those in the higher grades having significantly higher scores. The children who answered that washing their hands before eating was important reached 90%, but only half of those indicated knowledge of its importance after toilet use.

7.3.6 Fecal Hand Contamination

The differences in *E. coli* counts on hands by gender are shown in Fig. 7.2. *E. coli* was detected in 148 of the 150 samples (98.7%). The median CFU counts per hand in sixth graders were significantly lower than in fourth graders (data not shown). According to the median scores, the girls demonstrated significantly fewer *E. coli* bacteria than the boys ($p < 0.05$). Table 7.9 shows the correlation between *E. coli* counts and scores for handwashing techniques, HWWS, knowledge and awareness of WASH, and the WASH index. There were significant negative correlations between *E. coli* counts and handwashing techniques ($r = -0.171$, $p < 0.05$), HWWS ($r = -0.225$, $p < 0.01$), and the WASH index ($r = -0.205$, $p < 0.05$).

7.4 Discussion

The first part of the discussion is focused on the factors contributing to children's health and nutritional status, with a special focus on households' socioeconomic status, caretakers' level of WASH knowledge and awareness, and each household's

Table 7.8 Knowledge and awareness of WASH by gender and grade (Otsuka et al. 2019b)

Question	Total (n = 169) %	Boy (n = 87) %	Girl (n = 82) %	*P*-value	Grade 2 (n = 58) %	Grade 4 (n = 51) %	Grade 6 (n = 60) %	*P*-value
Do you know that boiling water kills germs?	78	82	73	NS	64	84	85	<0.05
Do you know that water containers need cleaning and covering?	92	97	88	<0.05	81	96	100	<0.05
Do you know that human feces contain germs?	91	89	93	NS	83	92	98	<0.05
Do you think that drinking water can be contaminated by fecal bacteria?	72	77	67	NS	41	78	97	<0.05
Do you think that unclean drinking water can make you sick?	88	86	89	NS	76	92	95	<0.05
Which of the following do you think are important times for handwashing?								
After using the toilet	43	47	39	NS	26	33	68	<0.05
Before eating	90	87	91	NS	79	98	92	<0.05
Do you think that you can spread germs if you don't wash your hands after going to the toilet?	92	91	94	NS	79	98	100	<0.05
Do you think that handwashing is important for disease prevention?	93	95	91	NS	88	94	98	NS
Total score (median, range)	7 (2–8)	7 (2–8)	7 (2–8)		5^{ab} (2–7)	7^{ac} (4–8)	8^{bc} (3–8)	

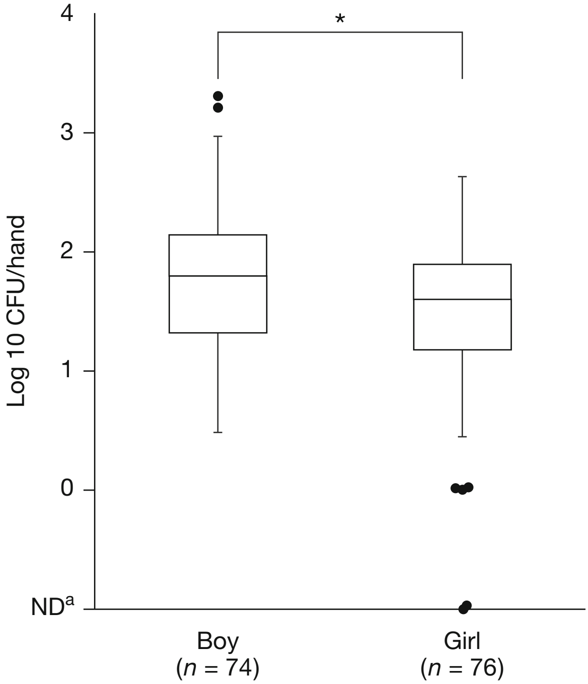

Fig. 7.2 Comparison of *Escherichia coli* counts by gender. It includes box and whisker plots showing the levels of *E. coli* contamination per hand among children. The line in each box represents the median, the tops and bottoms of the boxes represent the 75th (Q3) and 25th (Q1) percentiles, and the top and bottom whiskers extend to the $Q3 + 1.5 \times IQR$ and $Q1 - 1.5 \times IQR$, respectively. [a]Not detected. *Wilcoxon rank sum test, $p < 0.05$ (Otsuka et al. 2019b)

Table 7.9 Correlation with detected *Escherichia coli* amounts (Log10 CFU/hand) (Otsuka et al. 2019b)

Variable (score)	Correlation coefficient
Handwashing technique	-0.171^{*}
Handwashing with soap	-0.225^{**}
Knowledge and awareness of WASH	0.002
WASH index	-0.205^{*}

WASH water, sanitation, and hygiene
$^{*}p < 0.05$, $^{**}p < 0.01$

WASH status. Then, based on the results obtained from the tests of elementary-school children’s levels of fecal hand contamination, in the second part, we delve into a deeper discussion of children’s hand hygiene, handwashing with soap (HWWS), levels of WASH knowledge and awareness, fecal hand contamination, and handwashing techniques while noting differences in gender and grade level. Lastly, a WASH index developed to evaluate comprehensive competency in terms of handwashing techniques, HWWS, and knowledge and awareness of WASH is introduced.

7.4.1 Factors Contributing to Children's Health and Nutritional Status

To our knowledge, the research regarding children's nutritional status in urban slums has mostly been carried out in India and low- and middle-income African countries. While there are some studies focused on Indonesian urban slums, most include relatively old data, for example, from the Nutrition and Health Surveillance System. We compared the current study with the SEANUTS study (Sandjaja et al. 2013) conducted in 48 rural and urban districts in Indonesia to evaluate the nutritional status of children in urban slums (Fig. 7.1). The mean BMIAZ score of this study fell between those of the rural and urban areas in the SEANUTS study. In particular, the BMIAZ score of the boys in this study was almost the same as that of those in rural areas in the SEANUTS study. It is possible that children's nutritional status in low- and middle-income countries tends to be poorer in urban slums than in general urban areas. The nutritional status of Indonesian children was generally good (Fig. 7.1). However, we must pay attention to children's nutritional status in low- and middle-income countries, especially in urban slums, because obesity rates might increase as the economic situation improves in the future.

In a multilevel study in low- and middle-income countries including Indonesia, a high level of wealth was reported as a preventive factor for diarrhea in children under 5 years of age (Pinzón-Rondón et al. 2015). The current study shows that the prevalence of diarrhea among children from middle-income households is lower than among those from low-income ones (Table 7.5). Generally, children under 5 years of age are more likely to suffer from infectious diseases than those of other ages; however, this study revealed that the prevalence of diarrhea was higher in children above 5 years of age (14.8%) than among those under 5 years of age (11.4%). This may be the case because PAUD is a supplementary education facility, and, according to the locals, the families of the children who attend PAUD have relatively high socioeconomic status. In fact, the proportion of families with low household incomes was lower for preschool children (36%) than for elementary-school children (67%) (data not shown). Thus, household income should receive higher consideration when examining diarrhea prevalence, regardless of the child's age.

Although it is an important factor to consider, there are few studies investigating the relationship between the prevalence of diarrhea and a caretaker's knowledge and awareness of WASH. However, a previous study in Ethiopia reported the relationship between knowledge regarding diarrhea (i.e., the causes of diarrhea) and the prevalence of diarrhea in children (Nigatu and Tadesse 2015). Even so, no relationship was found between the prevalence of diarrhea and a caretaker's knowledge and awareness of WASH in the current study (Table 7.5), probably because caretakers' levels of knowledge and awareness of WASH were generally high, resulting in a lack of remarkable differences between the caretakers (Table 7.1). Therefore, the small number of caretakers who had relatively low levels of knowledge and awareness may have prevented the observation of true differences. Moreover, the data regarding diarrhea prevalence were collected based on each caretaker's recall of the previous 2 weeks instead of an official diagnosis, so the data-collection method may have affected the results.

7.4.2 Children's Health, Nutritional Status, and Household WASH Knowledge

In addition to assessing the caretakers' levels of WASH knowledge and awareness, the households' WASH facilities were reviewed in relation to the children's health and nutritional status. Previous studies have reported that improved water sources were linked to a lower risk of stunting in parts of Ethiopia and Tanzania (Altare et al. 2016; Gebregyorgis et al. 2016). This study showed that over 85% of families used tank water or tap water for drinking (Table 7.1). Between these two water-source types, tank water reduced the risk of stunting more (Table 7.4). This could be related to the tap water's quality, since, in Bandung, residents purchasing bottled water considered other water sources to be of poorer quality (Anindrya et al. 2017). This study revealed that water sources contributed to both stunting and thinness (Table 7.4), indicating that the use of tank water could improve children's nutritional status.

As in a survey of villages in Bangladesh (Kunii et al. 2002), this one revealed that appropriate water storage is important for reducing the risk of diarrhea. Water stored in covered areas was less likely to be associated with high-level contamination by *E. coli* (Heitzinger et al. 2015). For example, in villages in the slums of Nairobi, the prevalence of soil-transmitted helminths was lower in children whose households used covered storage areas for drinking water than in children whose households did not (Caitlin et al. 2016). Furthermore, in the studied area, even if there were water-supply facilities within the home, the amount of water provided to each household was insufficient. As shortages of water were a daily problem in the area, storing water for extended periods was both common and necessary. Therefore, the availability of appropriate water storage facilities must be ensured to prevent contamination by pathogens in low- and middle-income countries where the water supply is inadequate.

Regarding household sanitation, several studies in India (Jee et al. 2015) and low- and middle-income African countries (Curtis et al. 2000) reported that the quality of sanitation facilities was associated with children's nutritional status; however, there was no relationship between sanitation and children's nutritional status in our findings (Table 7.4), possibly because the quality of the sanitation facilities in the studied area was relatively high compared to those in the areas in the aforementioned studies. Moreover, there was no considerable difference in the quality of sanitation facilities among the households in this study. In fact, 90% of the households had private toilets, and there were no cases of open defecation in the studied area

(Table 7.1). On the other hand, in this study, a lack of treatment for toilet wastewater was not a significant factor in children's nutritional status (Table 7.4). It is unlikely that the availability of septic tanks affected the nutritional status of the children, since sewage eventually flowed into the nearby river regardless of whether a septic tank had been installed. Although sanitation did not directly contribute to the nutritional status of children in this study, it is necessary to clarify how untreated wastewater affects the health of children and the environment in other areas in future studies.

As mentioned previously, diarrhea is caused mainly by the ingestion of pathogens but can be prevented by handwashing (Curtis et al. 2000). An estimated 50% of undernutrition is associated with the repetition of diarrhea and intestinal nematode infections caused by unsafe water, inadequate sanitation, and insufficient hygiene (Prüss-Üstün et al. 2008). We found that the risk of stunting increased in children who did not use towels after handwashing, but not in children who did not use soap (Table 7.4), possibly because almost every child used soap in their handwashing routine (Table 7.2), while 71.5% of children used towels. Another possible reason is that using a towel after handwashing increases the likelihood of eliminating bacteria. A previous study demonstrated the effectiveness of using towels and revealed that using a clean towel after handwashing led to the presence of fewer *E. coli* bacteria on hands than air-drying (Friedrich et al. 2017). Thus, using towels can reduce the risk of infectious diseases, which lead to undernutrition. Moreover, the importance of the towel-use step, which the WHO incorporated into the recommended handwashing procedure, was confirmed in this study.

7.4.3 Hand Hygiene and HWWS

A more in-depth assessment of fecal contamination and hand hygiene showed the presence of *E. coli* on 98.7% (148/150) of children's hands (Fig. 7.1). In an urban area in India, bacterial pathogens were detected in all specimens taken from students' hands (*E. coli* was 20%) (Tambekar and Shirsat 2009), and, in another study, 61% of children had potential pathogens on their hands (*E. coli* was present in 12% of cases) (Ray et al. 2011). In two elementary schools in Malawi, *E. coli* bacteria were detected on the hands of 67 and 75% of pupils (Grimason et al. 2014), and, in Kenya, on the hands of 41% of students (Greene et al. 2012). Thus, the detection rate for bacteria on children's hands is inconsistent, perhaps because of differences in sampling and detection methods. It is thought that there is a high risk of undetected fecal contamination, since the detection rate for *E. coli* on children's hands in this study was overwhelmingly greater than in previous ones; however, it is difficult to compare the rates of detection directly.

The reason for high levels of fecal contamination in this study may have been children's failure to wash their hands with soap after using the toilet at school.

Problems with unavailability of soap for handwashing in schools were pointed out in a previous study, (Lopez-Quintero et al. 2008) and it is a barrier to the effective practice of HWWS. In Greece, the fecal *Streptococci* detection rate on children's hands in 20 elementary schools that provided soap was lower than that of those attending a school that did not provide it (Kyriacou et al. 2009). The handwashing technique check (Table 7.1) in this study revealed that most children normally use soap at home; however, at the schools where the children spend half of the day, there was no soap in the restrooms. Providing soap in schools' restrooms may improve HWWS behaviors and reduce fecal contamination.

HWWS reduces the risk of diarrhea by 48% (Cairncross et al. 2010), since more bacteria potentially of fecal origin can be removed by HWWS than with water alone (Burton et al. 2011). A previous study in Tanzania (Pickering et al. 2010) reported that people who always performed HWWS had significantly less *E. coli* and fecal *Streptococci* contamination than those who did it occasionally or rarely. Thus, it is important to consistently practice HWWS to remove bacteria. This study supported the importance of frequently practicing HWWS, since it was revealed that there was a significant negative correlation between the number of *E. coli* and the practice of HWWS (Table 7.4). Moreover, promoting effective handwashing techniques is important for reducing contamination (Friedrich et al. 2017); hence, there was a significant negative correlation between the number of *E. coli* present and the use of effective handwashing techniques (Table 7.4). Therefore, fecal contamination decreased as the frequency with which children used soap in various situations increased, and the importance of effective handwashing techniques was supported.

The most critical times for handwashing are before preparing food or cooking, before eating or feeding a child, after cleaning a child's bottom, and after defecation (United Nations 2015). In terms of the six occasions investigated in this study, the ones matching these critical times were before eating and after toilet use. Approximately 80% of children indicated that handwashing before eating was important, while only half of this number reported the same for toilet use (Table 7.3). Inadequate handwashing after toilet use can promote the direct transmission of pathogens through interpersonal contact or indirect transmission through food and the environment (Pickering et al. 2010); therefore, effective handwashing after toilet use is important for preventing fecal-oral bacterial transmission. In this study, more than 90% of the children said that they usually washed their hands (with either water alone or soap) after toilet use and that they did so more effectively than elementary-school students in other low- and middle-income countries (Vivas et al. 2010; Xuan and Hoat 2013). However, the rate of children who usually performed HWWS after toilet use was not high, at 58% (Table 7.2), since only 43% thought that it was important to wash one's hands after toilet use (Table 7.3: the children in lower grades had especially low rates of 26 and 33%). Therefore, awareness of the importance of handwashing after toilet use and the practice of HWWS must be increased.

7.4.4 HWWS, WASH Knowledge and Awareness, and Fecal Hand Contamination by Gender and Grade

Pertaining to gender-related differences in fecal contamination levels, previous studies that measured *E. coli* and fecal *Streptococci* on the hands of high school students in Tanzania (Pickering et al. 2010) and elementary school students in Greece (Kyriacou et al. 2009) revealed that boys' hands showed more bacterial contamination than girls', perhaps because boys tend to engage in more outdoor activities and games, making them more prone to contact with the soil and subject to more contamination, as the Greek study suggests (Kyriacou et al. 2009). As in the previous studies, the amount of *E. coli* found on the hands of the children was significantly greater among boys than girls (Fig. 7.2). Furthermore, boys' compliance with HWWS behaviors was significantly lower, and, in terms of the six occasions, boys scored significantly lower on "a person who washes hands with soap" after "playing outside" (Table 7.3). This is considered a reason for the larger number of *E. coli* bacteria on the hands of boys. The risk of fecal contamination from one's surroundings is considered higher for boys than girls, making it necessary to thoroughly impress the importance of practicing good hygiene on boys, especially HWWS. In this study, no distinction was made between urination and defecation. However, handwashing behaviors may differ by gender after urination and defecation; therefore, further research is needed on this point.

It is important to emphasize the importance of education about HWWS practices in the lower grades (Xuan and Hoat 2013). A previous study conducted in Vietnam reported that it was less common for children to practice HWWS in the lower grades (Xuan and Hoat 2013). Likewise, in this study, the children in the lower grades had significantly lower scores for handwashing techniques, HWWS behaviors, and knowledge and awareness of WASH than those in the upper grades (Table 7.6), possibly because children in the higher grades have had more exposure to hygiene education (En and Gan 2011; Xuan and Hoat 2013). On the other hand, there was a significant difference between children in the second and fourth grades in terms of handwashing techniques, but there were none between those in the fourth and sixth grades (Table 7.6). Considering that the handwashing techniques of preschool children (not published) were less effective than those of second graders, this implies that there is a gradual improvement in handwashing techniques between the preschool phase, when children begin learning about handwashing, and the fourth grade, with a plateau at the latter age. Further studies are needed to investigate how such changes in handwashing techniques by grade level occur after the sixth grade and whether this can be reproduced in other regions and populations.

7.4.5 Children's Handwashing Techniques

Although it is important to evaluate children's handwashing techniques, it is difficult to evaluate them accurately. In addition, there are few studies evaluating the handwashing techniques of children based on observations of participants at each step of the process with the use of universal procedures. A study in Vietnam (Xuan and Hoat 2013), in which the handwashing techniques of children (in grades 1, 4, and 7) were investigated by observation, evaluated the use of the procedure (eight steps) recommended by the country's Ministry of Education and Training and showed that only 3% of the children performed all the steps correctly. However, the data of those performing each step showed a 46–82% rate of completion, and approximately half of the children performed each step. In contrast, in our study, we evaluated the handwashing techniques of children using a modified procedure based on recommendations by the WHO (2009b). None of the children performed all ten steps perfectly, and only two (1.2%) performed nine of the steps (Table 7.6). It seems difficult for elementary-school children to perform all the handwashing steps perfectly according to the WHO's recommended procedure.

Focusing on each step, the procedure was divided into three levels. Most children were relatively capable of doing steps one, two, three, nine, and ten. Steps four and five were done by half the children; 90% of them were unable to do steps six (with the backs of the fingers to the opposing palms with the fingers interlaced), seven (rotationally rubbing with the left thumb clasped in the right palm and vice versa), and eight (rotationally rubbing backward and forward with the fingers of the right hand in the left palm and vice versa; Table 7.6). The elementary-school children were unable to carry out all the steps completely, since the WHO's recommended procedure was designed for use in healthcare centers/facilities like hospitals, and it was too detailed for them to grasp. Still, considering that half of the children successfully performed steps four and five (washing the palms and backsides with fingers crossed), it can be inferred that education on these steps will lead to improvements in children's handwashing techniques. Furthermore, it would be beneficial to develop procedures that could be used universally considering the field conditions surrounding the evaluation and guidance of children's handwashing techniques.

7.4.6 WASH Index

To reduce the fecal contamination level of children and prevent diarrhea, it is important to comprehensively evaluate not only handwashing behaviors and knowledge and awareness of WASH but also handwashing techniques. Although several researchers have investigated the relationship between fecal contamination on children's hands, handwashing behaviors (Kyriacou et al. 2009; Padaruth and Biranjia-Hurdoyal 2015), and knowledge and awareness (Grimason et al. 2014), investigations of the relationship between handwashing techniques and fecal contamination are rare. Equally, few researchers have analyzed the relationship between comprehensive abilities in terms of (1) handwashing behaviors, (2) knowledge and awareness of WASH, and (3) handwashing techniques and fecal contamination. Nobody appears to have integrated handwashing behaviors, knowledge and awareness of WASH, and handwashing techniques into a single index yet. We, therefore, developed a WASH index to evaluate a comprehensive ability reflecting handwashing techniques, HWWS, and knowledge and awareness of WASH. The results showed a significant negative correlation between the WASH index and number of *E. coli* on a subject's hands. Overall, we uncovered associations between the comprehensive ability composed of handwashing techniques, HWWS, and knowledge and awareness of WASH and fecal contamination (Table 7.4). The validity of the WASH index must be verified in other regions and populations.

7.4.7 Limitations

There are limitations in the current study that must be addressed in future work. The findings may not be generalized to all children in urban slums in low- and middle-income countries, because the sample size was relatively small, and the quality of the sanitation facilities was generally high and consistent in the studied area. In addition, the subjects may have overreported their levels of WASH knowledge and awareness and overestimated their handwashing behaviors on the questionnaire. Considering the participants' educational level and the time required to complete the questionnaire, we prioritized ease of answering to reduce the burden on the participants. However, the simplicity of the questionnaires may have made it easy for them to guess the correct answers. The handwashing observations were conducted by a single researcher to minimize observation bias, although the presence of the researcher may have caused the participants to alter their hand hygiene behaviors, as previously reported (Srigley et al. 2014). Therefore, we investigated hygiene behaviors with a comprehensive approach using both the questionnaire and a direct observation of each child's handwashing technique to compensate for this issue. Our findings revealed that household characteristics, such as monthly income and drinking water management, as well as children's hygiene practices, had an association with children's health. The influence of the school and community environment should also be considered, because most children spend many hours outside their homes.

Moreover, differences in handwashing abilities were found between second and fourth graders (Table 7.6). However, it is unclear when the shift in technique occurred, since we only sampled students in grades 2, 4, and 6. Even so, the study revealed that there was a difference between students in the lower and upper grades. We found a relationship between the number of *E. coli* on a student's hands and their WASH index, which we developed for comprehensive evaluation. However, contrary to expectations, a student's level of knowledge and awareness of WASH was unrelated to the number of *E. coli* on their hands (Table 7.9). This may have been due to the simplicity of the questionnaire (only simple "yes" or "no" answers were required); it may also have been too easy for children to guess the correct answers. In addition, the evaluation standard for the children's handwashing techniques was relatively high (designed for adults in a healthcare setting). Even so, the evaluation clarified which steps in the handwashing process need to be emphasized more in elementary schools. Lastly, the *E. coli* detection method presented a challenge: since this study was aimed at identifying the contamination risk among children, we decided to focus strictly on *E. coli*, counting the blue and purple colonies. It was, however, possible to overcount the *E. coli* bacteria due to the means of detection (only by the color of the colony reflecting enzymatic activity based on the measurement principle).

7.5 Summary

In conclusion, the nutritional status of the children living in an urban slum in Indonesia was generally good. Not only were household characteristics, like monthly income and drinking water source, significantly associated with the children's nutritional status, but the characteristics of the children themselves, such as gender and handwashing techniques, were as well. On the other hand, the households' monthly income and water storage type were significantly associated with the prevalence of diarrhea in children. Therefore, home drinking water management and proper personal hygiene practices among children are important for maintaining and improving children's health in Indonesian urban slums.

Almost all the children at the study site exhibited fecal contamination on their hands. However, using proper handwashing techniques and practicing HWWS at appropriate times can reduce fecal contamination. The data showed that handwashing techniques, HWWS, and knowledge and awareness of WASH were poor among children in the lower grades and that boys were at especially high risk of fecal contamination. Hence, it is important that grade- and gender-specific elementary school education on handwashing be considered. It is equally important to develop easier handwashing methods and tools for children. The study indicated the presence of a relationship between fecal contamination and the WASH index, which comprehensively captured handwashing techniques, HWWS practices, and knowledge and awareness of WASH. Further verification of the validity of the WASH index and the development of comprehensive indicators are needed.

Acknowledgments This work was supported by "The Sanitation Value Chain: Designing Sanitation Systems as an Eco-Community Value System Project" (Project Reader: Prof. Taro Yamauchi) of the Research Institute for Humanity and Nature (RIHN; Project No. 14200107). The authors are grateful to the survey respondents and teachers at the preschool and two primary schools included in the study. The authors also wish to thank all the project's members, members of the Research Unit for Clean Technology (LPTB), and the Indonesian Institute of Sciences (LIPI) of Bandung for their support and advice.

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