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Linkage between water, sanitation, hygiene, and child health in Bugesera District, Rwanda: a cross-sectional study

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Abstract: *Rwanda met the Millennium Development Goal targets for access to drinking water and sanitation. However, the WASH practices of high-risk communities are undocumented. Lack of information may hide disparities that correlate with disease. The purpose of this study was to assess WASH and childhood diarrhoea in Bugesera District. A survey was administered to caregivers. Water and stool samples were collected to assess physical and biological characteristics. Focus groups provided information on community context. Analysis included descriptive statistics, Chi-square, logistic regression, and thematic analysis. Piped water and unimproved sanitation were used by 45.28 per cent and 88.38 per cent of respondents. Most respondents (51.47 per cent) travelled 30–60 minutes per trip for water and 70 per cent lacked access to hand-washing near the latrine. Diarrhoea was less prevalent in children who used a toilet facility (p = 0.009). Disposal of faeces anywhere other than the toilet increased the odds of having diarrhoea (OR = 3.1, 95 per cent CI = 1.2–8.2). Use of a narrow mouth container for storage was associated with decreased intestinal parasites (p = 0.011). The presence of a hand-washing station within 10 metres of the toilet was associated with lower odds of intestinal parasites (OR = 0.54, 95 per cent CI: 0.29–0.99). Water and sanitation access, water handling and storage, and unsanitary household environment underlie high diarrhoeal disease prevalence.*

Keywords: child health, diarrhoea, intestinal parasites, MDGs, Rwanda, WASH

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In 2015, it was estimated that 76 per cent of Rwandans had access to improved drinking water and 62 per cent to sanitation facilities, which meet the Millennium Development Goals' (MDGs) targets (UNICEF and WHO, 2015). However, improvements in water and sanitation access are not a guarantee of zero faecal contamination of drinking water and adequate use and maintenance of sanitation facilities (O'Connell et al., 2017). Despite increased water and sanitation access levels, important associated diseases, such as diarrhoea and intestinal parasites, may remain highly prevalent due to inadequate water, sanitation, and hygiene (WASH) practices (Levy et al., 2009; Bongartz et al., 2016). Diarrhoeal disease is a leading cause of child death in Rwanda. The national prevalence of diarrhoea across age groups is 12.1 per cent, with the highest rate of 21.7 per cent in children aged 12–23 months (NISR et al., 2015). The high burden of diarrhoea and enteric infections is associated with growth shortfalls in children under five (Dillingham and Guerrant, 2004). Bugesera District in Rwanda is considered high risk because 29 per cent of residents use unimproved drinking water. This includes 24 per cent of residents who use surface water (from rivers or lakes) for drinking (African Development Fund, 2020). Direct ingestion of drinking water from unimproved water point sources is associated with considerable risks for childhood diarrhoea due to contamination with excreta (WHO, 2014).

The aim of this study was to assess the linkages between WASH and under-five children's diarrhoea in the Bugesera District of Rwanda.

Methods

Ethical clearance was obtained from the University of Rwanda College of Medicine and Health Sciences Institutional Review Board. The authorization to implement the research project was granted by the Mayor of the Bugesera District. Informed consent was sought from the study participants. All participants provided a written and signed consent before any data collection.

Sample size calculation

For the quantitative part of the study the sample was calculated using Taro Yamane formula:

$$n = \frac{N}{1 + Ne^2}$$

Where: n is the sample size, N is the total number of households with under-five years children, giving a total of 55,632 children, e indicates the margin error which was 5 per cent (0.05) from a confidence level of 95 per cent. The total sample size was then 413 households with under-five children.

In the qualitative part of the study, a purposive sampling was used to select community health workers, community leaders, and nursery teachers who participated in focus group discussions (FGDs).

Sample selection

The Republic of Rwanda is divided into the following administrative units: provinces, districts, sectors, cells, and villages which are the smallest politico-administrative entity of the country. This is the entity through which the problems, priorities, and needs of the people at a grassroots level are identified and addressed.

A multi-stage sampling method was used to draw the *calculated* sample of households from all 15 sectors, or third level administrative units. Each sector has a health centre and two cells from each sector were randomly selected, resulting in the inclusion of 30 villages. Finally, simple random sampling was used to select a sample from each of the villages. The study enrolled 413 households with parents/guardians, locally known as caretakers, and at least one child under age five.

The study included mothers or caregivers from households with children under the age of five who consented to be part of the study. It excluded mothers or caregivers from households with under-five children who refused to consent and those with children who are under anti-parasitic drug(s).

Data collection and laboratory analysis

This study used a survey and an observational checklist for collecting data. The survey was adapted from the United States Agency for International Development survey (Environmental Health Project 2004). It included questions about basic demographic information, water and sanitation use and practices, hygiene behaviour, and diarrhoea experienced by the respondent and any child below five years. One caretaker per household was interviewed using the survey.

Stool sample collection and examination

Children's fresh stool samples were collected using clean, labelled stool cups, then the direct wet mount technique was used. A portion of the sample was processed by the Kato-Katz method using a thick template delivering 50 mg of faeces. Samples processed by Kato were qualitatively examined on the spot for hookworm ova and other intestinal helminthic infections. Quantitative examination of the Kato-Katz slides for helminthiasis (except for hookworms) was done in the laboratory within one week of stool collection (Ghiwot et al., 2014). In addition, a portion of each sample was emulsified in a 10 per cent formalin solution and transported to the University of Rwanda Biomedical Laboratory, where the formol-ether concentration technique was used to examine for strongyloidiasis and protozoan parasites.

Drinking water sample collection and analysis for physicochemical and microbiological contaminants

Sampling was done following the procedure within the drinking water testing manual developed by the Centre for Affordable Water and Sanitation Technology

(CAWST, 2013). Physicochemical analyses were completed for the following parameters: pH, turbidity, total dissolved solids (TDS), nitrite, and electrical conductivity and Wagtech photometer was used to analyse fluoride, manganese, as per the Centre for Affordable Water and Sanitation Technology Drinking Water Testing Manual (CAWST, 2013). For microbiological analysis, the membrane filtration method was used with a portable test kit. A 100 mL water sample was vacuumed through filter paper using a small hand pump. After filtration, the bacteria remained on the filter paper which was then placed in a Petri dish with M-coli blue culture media. The Petri dishes were then placed in an incubator at 35 ± 0.5°C for 24 hours. After incubation, the bacteria colonies were seen with the naked eye and using a magnifying glass. Finally the bacteria colonies were counted to determine the number of colony forming units (CFU) per 100 mL of water sample. *Escherichia coli* produced blue colonies and thermo tolerant coliforms produced red colonies.[10]

Focus groups

Fifteen FGDs were conducted in all 15 sectors of Bugesera District, one in each sector. They were composed of six participants including two nursery teachers, two community health workers in charge of maternal and child health, and two community leaders. They were invited purposively and were willing to be part of the study because they were directly linked to child health. The FGD started with self-introduction of the moderator, note taker, and of participants. It was followed by an introduction of the purpose of the group discussion by the moderator, signing informed consents, and group discussions of the main topics prompted by the guide questions.

The moderator allowed the group to discuss the main topics among themselves, generating consensus but also allowing differences of ideas. The moderator also ensured consistency of the process, in the framing of questions, and in probing knowledge, attitudes, and WASH practices. The note taker documented attendance, process, and discussion results – points of agreement and individual views/beliefs in flipcharts so that participants could see what was noted.

The themes or topics of the discussion included water quality and quantity used by Bugesera District community, availability of latrines and their use, open defecation, hand-washing with soap, and children's hygiene.

Data analysis

Raw survey data and results from stool and water analyses were entered into MS Excel (Microsoft Corporation) and analysed using Stata Version 13. Frequency tables and charts were used to summarize data. Mean and 95 per cent confidence intervals were reported. Chi–square ($\chi 2$) and logistic regression test were used to test the relationship and association between selected WASH determinants (water quality and quantity, availability and use of latrines, hand-washing practices, and personal hygiene) and childhood diarrhoea with the significance level (α) set at 0.05. The corresponding p-value was reported.

Qualitative data from focus group discussions were transcribed, translated from Kinyarwanda to English, and analysed using thematic analysis technique.

Results

Descriptive analysis

Participating caregivers were predominantly female (96.9 per cent). The majority (90.5 per cent) of caregivers were the child's mother. The age of caregivers ranged from 18 years to 74 years with a mean age of 32.9 years (SD = 8.9). Most caregivers had attained primary or lower education (n = 315, 76.5 per cent). However, 333 caregivers (80.6 per cent) reported knowing how to read and write. The mean age of child participants was 28.6 months (SD = 15.3) with most children (28.2 per cent) aged between 12 and 23 months. In terms of access to electricity, 55.6 per cent of the households did not have electricity. The average family size was five people (SD = 1.7) and more than four people resided permanently in 58.1 per cent of the sampled households.

A total of 413 people, with one respondent from each household, responded to the questions regarding the sources and uses of water. Seven direct water sources to the consumers were reported: standpipe water, surface water, hand dug well, bore-hole, water vendor, rainwater, and piped water. Piped water was used most frequently for drinking (45.3 per cent), while piped water and surface water were used equally for bathing (40.4 per cent). Further, surface water (40.2 per cent) and piped water (39.5 per cent) were used for cooking.

The majority of the respondents (51.5 per cent) reported requiring 30 to 60 minutes per trip to bring water to the home. Most respondents (86.7 per cent) stored water in their homes. The containers used to keep water were primarily jerry cans (74.7 per cent). To remove water from the storage container, pouring was most common (95.5 per cent), while the use of a container with a tap (the safest method) was used least (1.7 per cent). Most (89.6 per cent) reported cleaning their water storage container and 43.4 per cent said that water containers were cleaned within one week preceding the study. While 95 per cent of respondents reported washing their hands frequently, more than 15 per cent of the participants did not wash their hands after defecation. Most used soap (85.7 per cent) and water (87.2 per cent) for handwashing.

Livestock were observed in 40.2 per cent of the interviewed households. Animal waste was observed in the house or yard of 79.6 per cent of households, garbage in 75.4 per cent, sewage in 88.6 per cent, and smoke from burning garbage in 17.2 per cent. Community health workers observing latrines reported that 98.0 per cent of the participants had a latrine and many had a path leading to the toilet that was clear (46.5 per cent). However, only 29.2 per cent of toilets had signs of regular use. The latrine status was also recorded, with nearly 85 per cent of toilet facilities having walls and 37.0 per cent of these facilities having doors. However, 12.7 per cent of these facilities could not be closed. Child friendly features included the presence of a small hole (51.1 per cent), toilet bowls available (11 per cent), and 9.7 per cent had a lower seat. Only 28.5 per cent had a hand-washing station within 10 metres of the latrine, and many did not have the necessary items to wash hands, including water (67.0 per cent), soap or detergent (69.6 per cent), and a bucket, basin, sink, or tippy tap (53.8 per cent). However, in nearly all cases, these items could be brought to the surveyor within one minute. The dominant sanitation type was a pit latrine without a concrete floor (88.4 per cent). Most of the participants (92.4 per cent) confirmed that the toilet was cleaned, with 182 respondents (48.5 per cent) stating that it had been cleaned that day.

Diarrhoea prevalence and type among children age five and under was also established (Table 1). Diarrhoea was reported for 39 (15.2 per cent) breastfed children during 24 hours prior to data collection. Eight children (17.4 per cent) experienced both vomiting and diarrhoea, 7 children (12.1 per cent) had diarrhoea that contained blood, and mucus in stools was reported for 34 children (57.6 per cent). Prevention and treatments for diarrhoea included a government or non-governmental organization (NGO) recommended homemade water treatment (disinfection with chlorine, boiling, and filtration) (25.5 per cent) and pill or syrup (25.5 per cent). Half of respondents sought treatment at the government health centres (50.0 per cent). One-half of the respondents did not seek treatment due to lack of money (50.0 per cent) and child's health status not seriously deteriorated (41.67 per cent). Few caretakers had diarrhoea in the last 24 hours (4.4 per cent) or last week (16.9 per cent).

Factors that were significantly associated with the presence of diarrhoea during the last 24 hours underwent a multivariate regression analysis as indicated in Table 2. The final model indicated that only the place where faeces were disposed of remained associated with the occurrence of diarrhoea.

Table 1 *Relationship between* WASH and childhood diarrhoea

Variables	*Having diarrhoea during the last 24 hours*			
	No, n(%)	*Yes, n(%)*	*Total, n(%)*	*p*
Where faeces are disposed of (n = 392)				0.009
Toilet facility	320 (93.8)	42 (82.4)	362 (92.4)	
Elsewhere	21 (6.2)	9 (17.7)	30 (7.6)	
Breastfeeding status (n = 412)				0.109
No	140 (39.1)	15 (27.8)	155 (37.6)	
Yes	218 (60.9)	39 (72.2)	257 (62.4)	
Treating drinking water (n = 397)				0.212
No	76 (22.2)	17 (32.7)	93 (23.5)	
Yes	267 (77.8)	35 (67.3)	302 (76.5)	
Use of supplementary food (n = 273)				0.475
No	55 (23.8)	7 (18.0)	62 (23.0)	
Yes	176 (76.2)	32 (82.0)	208 (77.0)	

(Continued)

Table 1 Continued

Variables	*Having diarrhoea during the last 24 hours*			
	No, n(%)	*Yes, n(%)*	*Total, n(%)*	*p*
Water containers cleaned (n = 397)				0.355
No	40 (11.6)	9 (18.0)	49 (12.4)	
Yes	304 (88.7)	41 (82.0)	345 (87.6)	
Amount of water fetched per day (n = 412)				0.978
≤60 litres	238 (66.5)	36 (66.7)	274 (66.5)	
>60 litres	120 (33.5)	18 (33.3)	138 (33.5)	
Drinking water comes from the main source (n = 412)				0.705
No	105 (24.5)	17 (32.1)	122 (29.8)	
Yes	251 (70.5)	36 (67.9)	287 (70.2)	
Reading and writing skills (n = 413)				0.234
Neither reading nor writing	54 (15.0)	5 (9.3)	59 (14.3)	
Either reading or writing	20 (5.6)	1 (1.8)	21 (5.1)	
Reading and writing	285 (79.4)	48 (88.9)	333 (80.6)	
Respondent's education level (n = 412)				0.350
Primary or lower	271 (75.7)	44 (81.5)	315 (76.5)	
Secondary and above	87 (24.3)	10 (18.5)	97 (23.5)	
Child's age in months (n = 411)				0.032
≤11	49 (13.8)	11 (20.4)	60 (14.6)	
12–23	95 (26.6)	21 (38.9)	116 (28.2)	
24+	213 (59.7)	22 (40.7)	235 (57.2)	
Child's gender (n = 413)				0.371
Male	176 (49.0)	30 (55.6)	206 (49.9)	
Female	183 (51.0)	24 (44.4)	207 (50.1)	
Presence of soap at hand-washing station (n = 347)				0.335
No	286 (94.7)	41 (91.1)	327 (94.2)	
Yes	16 (95.3)	4 (8.9)	20 (5.8)	
Where the child defecated when passing stool the last time (n = 410)				0.032*
Sanitation facility	120 (33.7)	7 (13.0)	127 (31.0)	
Potty	53 (14.9)	10 (18.5)	63 (15.4)	
Diaper or clothes	39 (11.0)	9 (16.7)	48 (11.7)	
In-house/yard	131 (36.8)	24 (44.4)	155 (37.8)	
Elsewhere	13 (13.7)	4 (7.4)	17 (4.1)	

Note: * Fisher's exact test value

Table 2 Logistic regression analysis of linkage between childhood diarrhoea and WASH

Variables	*Odds ratio*	*Std. err.*	*z*	*P>z*	*95% Confidence intervals*
Where faeces are disposed of					
Toilet facility	1.00				
Elsewhere	3.12	1.53378	2.31	0.021	1.19–8.18
Child's age in months					
≤11 months	1.00				
12–23 months	1.05	0.4690708	0.11	0.912	0.44–2.52
24+ months	0.61	0.2731063	–1.11	0.268	0.25–1.47
Where child defecated the last time					
Sanitation facility	1.00				
Potty	2.38	1.359769	1.52	0.129	0.78–7.29
Diaper or clothes	1.86	1.222661	0.94	0.348	0.51–6.75
In-house/yard	2.27	1.164904	1.6	0.109	0.83–6.21
Elsewhere	1.74	1.564638	0.61	0.54	0.30–10.15

Specifically, disposal of faeces in a place other than the toilet was associated with increased odds of having diarrhoea among children (OR = 3.1, 95%CI = 1.2–8.2). Other factors were not statistically associated with diarrhoea occurrence as depicted in the analysis.

Water quality testing results are summarized in Figure 1. In summary, 88.2 per cent of tested water samples had a pH of 6.5 to 8.5; 269 (70.8 per cent) of these water samples had turbidity levels of ≤ 5 NTU. With regard to the presence of coliforms, 42 samples (11 per cent) were tested to have total coliforms (>0 CFU/100 ml), while 292 samples (76.4 per cent) were positive with faecal coliforms (>0 CFU/100 ml). The presence of *E. coli* (>0 CFU/100 ml) was found in 260 samples (68.1 per cent).

Findings from stool samples indicated that intestinal parasites were diagnosed in 88 children (21.7 per cent). Of these children, 77 children were diagnosed with *Entamoeba histolytica* at different stages. Many of them (36.4 per cent) had four *E. histolytica* and nearly 30 per cent of the children had three *E. histolytica*. Significant (α = 0.05) protective factors for diarrhoea included disposal of faeces into a toilet facility, child's age, and location of child's last defecation. Significant protective factors for intestinal parasites included narrow mouth of water container for storage. These results are displayed in Table 3. Table 5 shows significant correlation for diarrhoea and nitrite levels, and for intestinal parasites, faecal coliforms, and conductivity.

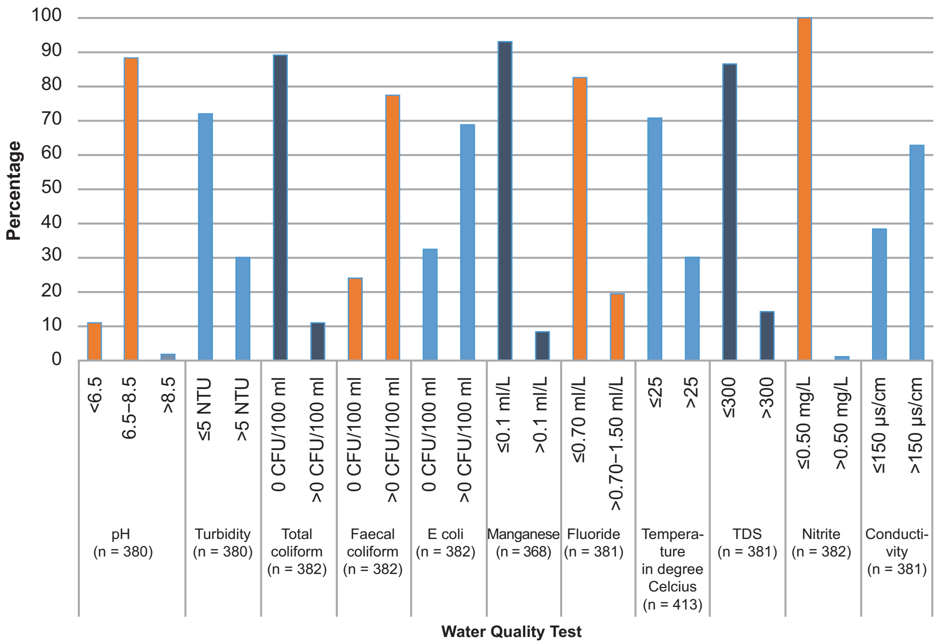

Figure 1 Water quality testing results

Table 3 Relationship between WASH and childhood parasitic infections

Variables	*Presence of intestinal parasites*			
	No, n(%)	*Yes, n(%)*	*Total, n(%)*	*p*
Presence of livestock inside living quarters (n = 405)				0.658
No	125 (39.4)	37 (42.0)	162 (40.0)	
Yes	192 (60.6)	51 (58.0)	243 (60.0)	
Mouth of water container (n = 398)				0.011
Narrow	230 (73.3)	51 (60.7)	281 (70.6)	
Wide	19 (6.0)	13 (15.5)	32 (8.0)	
Both narrow and wide	65 (20.7)	20 (23.8)	85 (21.4)	
Presence of hand-washing station within 10 metres of the toilet facility (n = 399)				0.072
No	217 (69.8)	67 (77.0)	284 (71.4)	
Yes	94 (30.2)	20 (23.9)	114 (28.6)	
Interviewee's education (n = 404)				0.344
Primary or lower	245 (77.3)	63 (72.4)	308 (76.2)	
Secondary and above	72 (22.7)	24 (27.6)	96 (23.8)	
Drinking water comes from main source (n = 404)				0.824
No	95 (30.0)	25 (28.7)	120 (29.7)	
Yes	222 (70.0)	62 (71.3)	284 (70.3)	

(Continued)

Table 3 Continued

Variables	*Presence of intestinal parasites*			
	No, n(%)	*Yes, n(%)*	*Total, n(%)*	*p*
Drinking water is treated (n = 389)				0.779
No	70 (23.2)	22 (25.6)	92 (23.7)	
Yes	232 (76.8)	64 (74.4)	296 (76.3)	
Child's defecation venue the last time s/he passed stool (n = 402)				0.165*
Sanitation facility	92 (29.1)	33 (38.3)	125 (31.1)	
Potty	49 (15.5)	14 (16.3)	63 (15.7)	
Diaper or clothes	34 (10.8)	12 (14.0)	46 (11.4)	
In-house/yard	125 (39.6)	26 (30.2)	151 (37.6)	
Elsewhere	16 (5.0)	1 (1.2)	17 (4.2)	
Child's age group (n = 403)				0.132
≤11 months	52 (16.5)	7 (8.0)	59 (14.6)	
12–23 months	87 (27.6)	26 (29.5)	113 (28.1)	
24+ months	176 (55.9)	55 (62.5)	231 (57.3)	
Child's gender (n = 405)				0.156
Male	153 (48.3)	50 (56.8)	203 (50.1)	
Female	164 (51.7)	38 (43.2)	202 (49.9)	

Note: * Fisher's exact test p value

Table 4 Logistic regression analysis between WASH and childhood parasitic infections

Variables	*Odds ratio*	*Std. Err.*	*z*	*P>z*	*95% Confidence intervals*
Mouth of water container					
Narrow	1				
Wide mouthed	3.37	1.34	3.04	0.002	1.54–7.36
Of both types	1.49	0.45	1.32	0.188	0.82–2.70
Presence of hand-washing station within 10 metres of the toilet facility					
No	1.00				
Yes	0.55	0.17	–1.97	0.048	0.30–1.00

Table 5 Individual association between water quality and diarrhoea during the last 24 hours

Water quality variables	*Diarrhoea during the last 24 hours*			
	No n(%)	*Yes n(%)*	*Total n(%)*	*p*
pH (N = 380)				0.240*
<6.5	33 (10.0)	6 (11.8)	39 (10.3)	
6.5–8.5	292 (88.8)	43 (84.3)	335 (88.2)	
>8.5	4 (1.2)	2 (3.9)	6 (1.5)	

(Continued)

Table 5 Continued

Water quality variables	*Diarrhoea during the last 24 hours*			
	No n(%)	*Yes n(%)*	*Total n(%)*	*p*
Total coliforms (N = 382)				0.210
0 CFU/100 ml	292 (88.2)	48 (94.1)	340 (89.0)	
>0 CFU/100 ml	39 (11.8)	3 (5.9)	42 (10.9)	
Faecal coliform (N = 382)				0.475
0 CFU/100 ml	80 (24.2)	10 (19.6)	90 (23.6)	
>0 CFU/100 ml	251 (75.8)	41 (80.4)	292 (76.4)	
Presence of *E. coli* (N = 382)				0.460
No (0 CFU/100 ml)	108 (32.6)	14 (27.5)	122 (31.9)	
Yes (>0 CFU/100 ml)	223 (67.4)	37 (72.5)	260 (68.1)	
Fluoride (N = 381)				0.311
<0.70 mg/L	265 (80.3)	44 (86.3)	309 (81.1)	
0.70–1.50 mg/L	65 (19.7)	7 (13.7)	72 (18.9)	
TDS (N = 381)				0.739
≤300	284 (86.1)	43 (84.3)	327 (85.8)	
>300	46 (13.9)	8 (15.7)	54 (14.2)	
Nitrite (N = 382)				0.018*
≤0.50 mg/L	331 (100.0)	49 (96.1)	380 (99.5)	
>0.50 mg/L	0 (0.0)	2 (3.9)	2 (0.5)	
Conductivity (N = 381)				0.185
≤150 µS/cm	129 (39.1)	15 (29.4)	144 (37.8)	
>150 µS/cm	201 (60.9)	36 (70.6)	237 (62.2)	
Turbidity (N = 380)				0.840
≤5 NTU	233 (70.6)	36 (72.0)	269 (70.8)	
>5 NTU	97 (29.4)	14 (28.0)	111 (29.2)	
Manganese (N = 368)				0.117
≤0.1 mg/L	294 (92.7)	44 (86.3)	338 (91.9)	
>0.1 mg/L	23 (7.3)	7 (13.7)	30 (8.1)	

Note: *Fisher's exact test p value

The regression analysis (Table 4) indicated that the presence of intestinal parasites was statistically associated with the width of the mouth of the water container. Specifically, a wide-mouthed water container was significantly associated with having intestinal parasites among children (OR = 3.0, 95%CI: 1.4–6.7). Furthermore, the presence of a hand-washing station within 10 metres of the toilet facility was unsurprisingly associated with lower odds of the presence of intestinal parasites among children (OR = 0.54, 95%CI: 0.29–0.99) (Table 6).

Table 6 Individual association between water quality and the presence of intestinal parasites

Physicochemical variables of water quality	*Presence of intestinal parasites*			
	No n(%)	*Yes n(%)*	*Total n(%)*	*P*
pH (N = 373)				0.663
<6.5	27 (9.2)	10 (12.5)	37 (9.9)	
6.5–8.5	261 (89.1)	69 (86.3)	330 (88.5)	
>8.5	5 (1.7)	1 (1.2)	6 (1.6)	
Total coliforms (N = 375)				0.613
0 CFU/100 ml	264 (89.5)	70 (87.5)	334 (89.1(	
>0 CFU/100 ml	31 (10.5)	10 (12.5)	41 (10.9)	
Faecal coliform (N = 375)				0.032
0 CFU/100 ml	62 (21.0)	26 (32.5)	88 (23.5)	
>0 CFU/100 ml	233 (79.0)	54 (67.5)	287 (76.5)	
Presence of *E. coli*(N = 375)				0.448
No (0 CFU/100 ml)	98 (33.2)	23 (28.7)	121 (32.3)	
Yes (>0 CFU/100 ml)	197 (66.8)	57 (71.3)	254 (67.7)	
Fluoride (N = 374)				0.753
66 (82.5)	238 (80.9)	66 (82.5)	304 (81.3)	
0.70–1.50 mg/L	56 (19.0)	14 (17.5)	70 (18.7)	
TDS (N = 374)				0.964
≤300	253 (86.1)	69 (86.3)	322 (86.1)	
>300	41 (13.9)	11 (13.7)	53 (13.9)	
Nitrite (N = 375)				0.321
≤0.50 mg/L	294 (99.6)	79 (98.7)	373 (99.5)	
>0.50 mg/L	1 (0.4)	1 (1.3)	2 (0.5)	
Conductivity (N = 374)				0.007
≤150 μS/cm	102 (34.7)	41 (51.3)	143 (38.2)	
>150 μS/cm	192 (65.3)	39 (48.7)	231 (61.8)	
Turbidity (N = 373)				0.467
≤5 NTU	210 (71.7)	54 (67.5)	264 (70.8)	
>5 NTU	83 (28.3)	26 (32.5)	109 (29.2)	
Manganese (N = 361)				0.250
≤0.1 mg/L	257 (90.8)	74 (94.9)	331 (91.7)	
>0.1 mg/L	26 (9.2)	4 (5.1)	30 (8.3)	

Binary logistic regression analysis indicated an association between the presence of intestinal parasites among children and water quality indicators such as faecal coliform and water conductivity. See Table 7 for binary regression results.

Table 7 Binary regression analysis between the presence of intestinal parasites among children and water quality indicators

Variables	*Odds ratio*	*Std. err.*	*z*	*P>z*	*95% Confidence intervals*
Faecal coliform					
0 CFU/100 ml	1.00				
>0 CFU/100 ml	0.58	0.16	–1.94	0.052	0.33–1.01
Conductivity					
≤150 µS/cm	1.00				
>150 µS/cm	0.52	0.13	–2.55	0.011	0.31–0.86

Focus group discussion results

Thematic areas: water quality and quantity

The community of Bugesera District rely on rivers, lakes, and rainwater for domestic purposes.

> *We use water from lakes and rivers for drinking, cooking and even washing clothes, domestic animals are accessing water sources and they even defecate around it therefore they become contaminated [with] animal faeces in addition to open defecation surrounding drinking water sources by people who wash clothes or fetch water* (five FGD participants).

During the rainy season, lakes and rivers used to collect drinking water became more unsafe to use due to increased contamination.

With regard to household drinking water treatment, the results showed that Bugesera community do not have access to drinking water treatment supplies.

> *We do not have access to water purification materials such as water filters as they are very expensive. Moreover we cannot afford to pay on a regular basis [for] chlorine for water treatment.*
>
> *And also getting firewood is not easy therefore only some few households use firewood to boil drinking water as most of us use firewood only for cooking purposes* (seven FGD participants).

When people use water sources that are contaminated with faeces, without treatment to eliminate microbiological contamination, they increase their risk of experiencing diarrhoea.

Sanitation

Generally most community members have latrines though some community members used shared latrines leading to children's open defecation and urination in the compound especially during the night. 'Because we share latrines with our two neighbors children are afraid of going to the toilet during the night and they defecate and urinate in the compound', according to four female FGD participants.

Open defecation is also practised by some community members who do not have latrines. 'Some people who do not have latrines use the bushes, tall grassy areas and agricultural fields as defecation area', said six FDG participants.

Hygiene

Hand-washing with soap and running water was not a common practice in Bugesera District. This is not surprising because it is highlighted that only 4.5 per cent of households had an observable hand-washing station (DHS 2014-15).

> *We do not have running water at our homes, and it is taking us more than two hours to fetch water for a round-trip. Similarly, not all household have soaps on a regular basis and even those who have soaps cannot put them nearby [the] installed tippy tap because they are stolen* (nine FGD participants).

Taking care of children's hygiene was not a primary priority for caregivers in Bugesera District.

> *It is not easy to follow up cleanliness of children when you have additional tasks at household level including cooking, fetching water and so on therefore our children sometimes eat fallen food on the ground or suck dirty stuffs that can lead them to get diarrhoea* (six FGD participants).

Discussion

Our study findings paint a picture of WASH quality, access levels, practices, and the Bugesera community perspectives on WASH issues, sustainability, and WASH stakeholders. The study also highlights the relationships between WASH practices and water quality with diarrhoeal disease and intestinal parasites. Although almost half of the community members had access to treated piped water for drinking, water fetching distances were high and multiple avenues for drinking water contamination and water-related infection transmission existed in the home because household members still used surface water. There is a potential for children to become infected with pathogens if they ingest surface water during play at home or if surface water contacts drinking water in the home during storage and use. Additionally, water contamination was possible from observed poor water handling, storage, and hand hygiene practices, such as low use of a container with a tap during water transfer, less frequent cleaning of water storage containers, and lack of hand-washing after defecation. The study suggests that water storage and handling practices could be improved by the use of a narrow mouth container, which was associated with a decreased likelihood of diarrhoeal disease. The quality of the piped water was also called into question by the community members as they testified to observing visible contamination during collection. While the study did not differentiate between water quality results by source types, high levels of *E. coli* and fecal coliforms were observed in over two-thirds of tested samples.

The sanitation situation was even more alarming as 88.38 per cent of community members did not have access to an improved sanitation facility. This is more than twice the national statistic of 38 per cent used in global sanitation target reporting (UNICEF and WHO, 2015). Pit toilets without slabs, an unimproved sanitation type, were available to 9 out of 10 community members but less than a third of them appeared to be regularly used. Our analysis indicates the location of defecation and disposal of faeces is linked to diarrhoeal disease in children younger than five years.

Roughly 70 per cent of households did not have a hand-washing station within 10 metres of the latrine, increasing the likelihood of poor hand hygiene which has been linked to an increased incidence of diarrhoeal disease (Luby et al., 2005). The household environment was also unhealthy because animal waste, garbage, and sewage were observed by the CHWs involved in the study. Additionally, findings from focus groups suggest that the majority of WASH stakeholders were more focused on the provision of water than sanitation and that attitudes about hand-washing influence hygiene behaviours, including not handwashing with soap and water at critical times.

The lack of the relationship between the two WHO-approved faecal indicator bacteria, *E. coli* and thermotolerant (fecal) coliforms, and diarrhoea disease was unexpected, but there are several possible reasons. First, faecal indicators are an imperfect proxy for pathogens. A review of pathogen-indicator relationships published from 1970 to 2009 found that only 41 per cent of 540 studies showed correlation between indicator and pathogen (Wu et al., 2011). Second, diarrhoea has other non-infectious causes and it is possible that the diarrhoea seen in the community may not have pathogenic origin. Diarrhoeal disease can also be transmitted by other routes, and the confounders of the relationship between faecal indicators and diarrhoeal disease were not adjusted for. Third, the collected exposure data may not reflect the actual exposure associated with disease. Ercumen et al. (2016) demonstrated that cross-sectional assessment of the relationship between water quality and diarrhoea could result in an attenuation of effect estimates, potentially due to exposure misclassification and reverse causation. Despite these limitations, the study captures baseline faecal contamination levels to support further research.

The authors found a relationship between thermotolerant (fecal) coliforms and intestinal parasites. Thermotolerant coliforms are theoretically not a reliable indicator of *E. histolytica* because *E. histolytica* cysts are resistant to disinfectants like chlorine which wipe out thermotolerant coliforms (World Health Organization, 2008). The relationship observed could result if the water is not properly chlorinated. The number of infections with *E. histolytica* is interesting since this is not commonly a pathogen of concern in developed countries and even in developing countries in other regions. However, *E. histolytica* is dominant in areas of poor sanitation mostly in tropical countries. This warrants further investigation to determine the validity and reliability of the observed association.

Conclusion

These results contribute to current understanding of WASH and childhood disease. Our findings that proper disposal of faecal matter and use of a sanitation facility was protective for diarrhoeal disease while a narrow mouth container for water storage was associated with decreased intestinal parasites provides potential intervention targets in Rwanda. Nevertheless, it is important to add that the current evidence on the effectiveness of safe child faeces disposal for diarrhoeal disease prevention is inconclusive due to the heterogeneity of available studies (Morita et al., 2016). It is plausible that narrow mouth containers could decrease intestinal parasitic infection because the majority of children in the study were infected with *E. histolytica*. Research studies have shown that *E. histolytica* transmission occurs mainly via contaminated hands (Pham Duc et al., 2011; Mahmud et al., 2015). Thus, decreasing hand contact with stored household drinking water through the use of narrow mouth containers, and perhaps ensuring that drinking water is covered at all times and collected through a spigot, may be impactful.

The present study is limited by the cross-sectional design which prevents assessment of causality and the reliance on diarrhoeal disease self-reports. However, overall the findings add to information available about WASH linkages to childhood disease as well as methods of studying these linkages. Specifically, focus group findings on hand-washing attitudes and practices emphasize the need for training to increase prioritization of hand-washing.

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