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Research Paper

A One Health evaluation of water, sanitation, and hygiene (WASH) services in Butaro Sector, Rwanda

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ABSTRACT

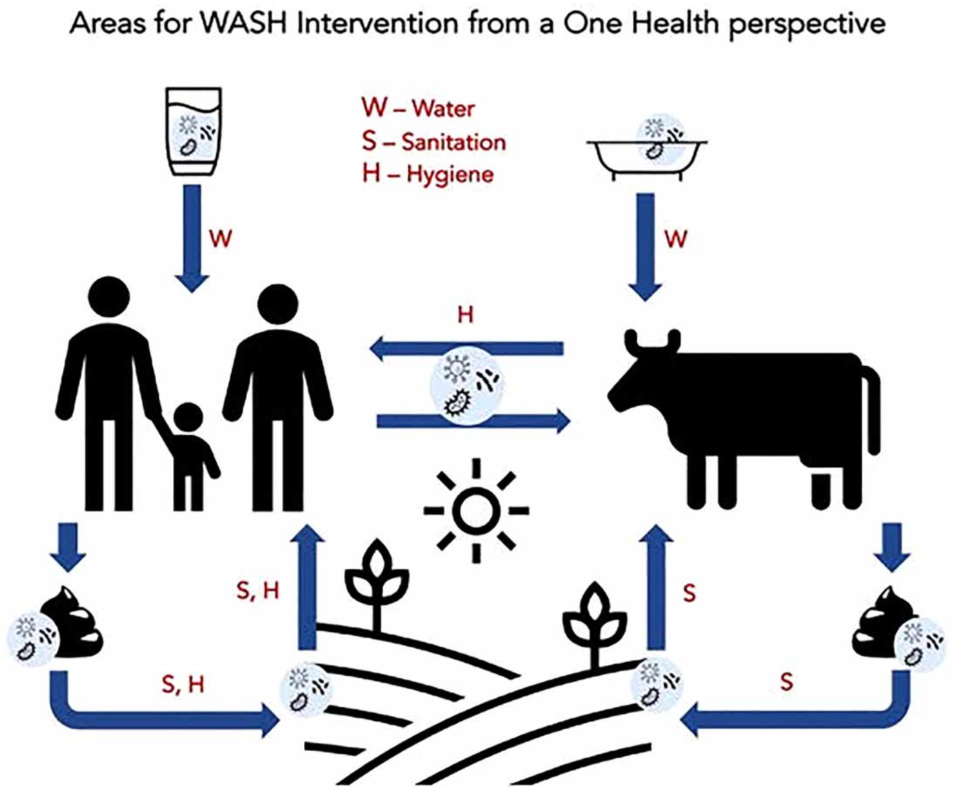
In 2018, rural residents of northern Rwanda raised water, sanitation, and hygiene (WASH) access and availability as a community concern; however, no baseline information was available to prioritize communities for intervention. This study aimed to assess WASH for people and animals in four cells in Butaro Sector and to identify the cell with the lowest WASH access. This cross-sectional, quantitative study utilized telephone surveys to collect data. Households were randomly selected, and 539 male and female heads-of-household agreed to participate. Overall, 56.8% of households reported access to safe drinking water, but this differed significantly by cell ($p < 0.001$). Approximately half (54.2%) of respondents walked 30 min or longer to fetch water, travelling one or more times per day. Nearly all (98.5%) households reported the presence of sanitation infrastructure, most often a pit latrine. Across cells, animals experienced poorer access to clean water and sanitation than people. One cell, Gatsibo, reported the poorest overall access to WASH services. Multi-sector collaboration among public health, water authorities, and local leaders is needed to reduce travel times for fetching water and to ensure that all residents can access sufficient safe water to meet the health and hygiene needs of people and animals.

Key words: drinking water, livestock, One Health, Rwanda, sanitation practices, water treatment

HIGHLIGHTS

- Human, animal, and environmental factors relating to human and animal WASH were characterized in four cells in Butaro Sector, Rwanda.
- Important gaps were identified in access to safe drinking water, including long travel times to water sources and barriers to water treatment.
- Gatsibo was identified to have the poorest overall access to WASH services for human and animal residents.

GRAPHICAL ABSTRACT



INTRODUCTION

In 2020, an estimated 2 billion people lacked access to safely managed drinking water, 3.6 billion lacked access to safely managed sanitation, and 2.3 billion lacked access to adequate hygiene services (United Nations 2021). Water, sanitation, and hygiene, known collectively as WASH, represents a growing field of focus in global health (UNICEF 2021). Adequate WASH conditions are important for maintaining health among both animal and human populations, as a myriad of infectious diseases are transmissible via water and fecal matter (Savage *et al.* 2012). These include diarrheal diseases, enteric infections, hepatitis A and E, and helminths such as schistosomes (Hutton & Chase 2017). Children under the age of 5 years are especially vulnerable to poor WASH conditions, as regular exposure to fecal pathogens is associated with enteropathy, malnutrition, stunting, and cognitive delay (Hutton & Chase 2017). The importance of WASH is recognized by its inclusion in the United Nations Sustainable Development Goals (SDG), of which SDG 6 aims to ensure the availability and sustainable management of water and sanitation for all (United Nations 2021).

Efforts to improve WASH are most impactful when they employ a One Health approach, considering the roles of people, animals, and environment. For example, many conventional WASH interventions address exposure to human feces while exposure to animal feces is overlooked (Prendergast *et al.* 2019). Given that livestock are responsible for an estimated 80% of the global fecal load, including two-thirds of feces at the household level, this oversight severely limits the effectiveness of WASH interventions in areas where livestock ownership is common, such as Rwanda (Prendergast *et al.* 2019). Moreover, numerous pathogens that thrive under poor WASH conditions are zoonotic, spreading between people and animals through shared natural and built environments (Matilla *et al.* 2018). These infections, which include *Escherichia coli*, *Campylobacter*, non-typhoidal *Salmonella*, and *Cryptosporidium*, can impact humans directly by disease and indirectly when livestock disease leads to economic losses (Delahoy *et al.* 2018; Matilla *et al.* 2018). Runoff of untreated fecal matter into natural water bodies results in the emergence of toxic algal blooms that are harmful to aquatic life, animals, and humans who are drawing the water for domestic use (EPA 2003). The influence of gender must also be considered in WASH interventions as women and men play different roles with respect to livestock production, dairy processing, child rearing, and water transportation and management (FAO 2013).

In Rwanda, significant strides have been made to improve WASH access among the human population. Between 2000 and 2017, the percentage of households using improved drinking water sources increased from 64.1 to 87.4% (Government of Rwanda & UNICEF 2014; NISR 2018). Improved sources included protected springs (38.3%), public standpipes (35.4%), piped water into dwellings (9.4%), protected boreholes (3.0%), protected wells (1.2%), and rainwater (0.1%), whereas unimproved sources included unprotected springs (6.5%), surface water (4.4%), unprotected wells (0.5%), tank trucks (0.1%), and other sources (1.0%; NISR 2018). During the same time period, households with access to improved sanitation services increased from 51.5 to 86.2% (Government of Rwanda & UNICEF 2014; NISR 2018). Those with improved sanitation used pit latrines with solid slabs (84.3%) and flush toilets (1.9%), whereas those with unimproved sanitation used pit latrines without slabs (9.8%), or other/no facilities (4.0%; NISR 2018). Despite this progress, some rural regions of Rwanda, such as Butaro Sector in Northern Province, remain underserved. In 2019, the University of Global Health Equity in Butaro Sector began work to support surrounding communities in participatory activities promoting health equity and poverty reduction. WASH emerged as a community concern through these engagements. Therefore, the overall objective of this study was to compile baseline data to inform WASH-related community interventions. Specifically, we aimed to (1) characterize human, animal, and environmental conditions related to WASH services in four cells in Butaro Sector and (2) to identify the cell with the lowest WASH access and availability for the purpose of intervention planning.

METHODS

Study setting

Butaro Sector is based in Burera District in Northern Rwanda. According to the 2012 Rwanda National Census, Butaro is home to approximately 31,520 residents, of which 52.4% are female, 52.3% are children aged 0–17 years, and 5.6% are aged 60 years or older (NISR 2015). The population density is 539 inhabitants/km^2, and the average household size is 4.5 persons. Butaro is predominantly rural, with 62.9% of total land area in Burera District devoted to agricultural production (NISR 2020b). In 2012, 21.3% of households used unimproved water sources and 90% used improved sanitation facilities, most commonly private pit latrines (89.9%) followed by flush toilets (0.5%; NISR 2015).

Study design

This cross-sectional, quantitative study was conducted between June 2020 and June 2021. Our team worked with the Executive Secretary of Butaro Sector to review the most recent census data and to purposively identify the four cells considered to have the poorest access and availability to WASH services (i.e., Gatsibo, Mubuga, Muhotora, and Nyamicucu; Figure 1). Population estimates for each of the four cells ($N = 5{,}265$ households) were used to calculate a minimum required sample of 93 households per cell ($n = 372$). The minimum required sample was calculated using Slovin's formula and an error tolerance of 0.05. Interviews beyond this minimum were completed to ensure that views of female household owners were adequately represented.

With assistance from the Executive Secretary of cells and village community health workers, the team obtained a list of households in the four cells and selected a random sample to participate in the survey. Inclusion criteria included being 18 years of age or older and residing in the cell for at least 5 years. During the initial data collection period, we obtained a predominantly male sample due to lower telephone ownership among women. We addressed this by generating a random sample of additional women to interview, so that gender parity was achieved in each cell. Due to national COVID-19 control measures, we conducted all interviews by telephone, which was considered reasonable as each household in Butaro Sector has at least one family member with a mobile telephone.

The survey tool was adapted from the USAID Hygiene Improvement Project and World Health Organization (WHO)/ UNICEF Core Questions on Water, Sanitation and Hygiene for Household Surveys to include questions across the three One Health domains (people, animals, and environment) and to be relevant to the local context (USAID 2005; WHO/ UNICEF 2018). Access and availability to household water and sanitation sources were classified as improved or unimproved according to the WHO guidelines (WHO 2021a, 2021b). Improved water sources were those designed to protect water from outside contamination, especially fecal matter. These included piped water to a dwelling or public standpipe, protected springs, protected borehole wells, and rainwater harvested in a closed tank. Unimproved sources included surface water, unprotected springs, unprotected borehole wells, and vendor-provided water (WHO 2021a). Improved sanitation facilities

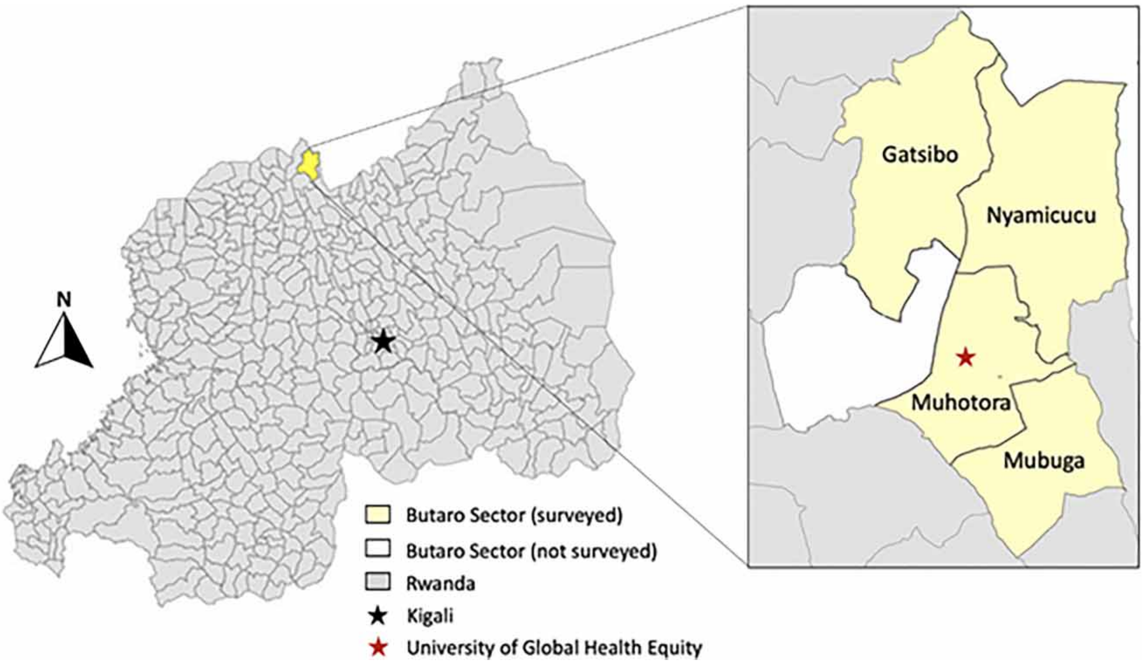


Figure 1 | Map of Butaro Sector with cells colored by survey status. Please refer to the online version of this paper to see this figure in colour: http://dx.doi.org/10.2166/washdev.2022.204.

were those designed to hygienically separate human excreta from human contact, such as composting toilets, flush or pour-flush to piped sewer systems, pit latrines with a slab or covered pit, and ventilated improved pit latrines. Unimproved sanitation facilities included pit latrines without slabs and bucket latrines (WHO 2021b). The survey tool was translated into Kinyarwanda, pre-tested with local residents living outside the target cells, and adapted as needed. The Executive Secretary introduced the survey in each cell to sensitize community members about the project aims prior to data collection. Five enumerators who spoke native Kinyarwanda administered the surveys by telephone, directly inputting responses into a shared Google spreadsheet. Data were checked for errors and cleaned daily throughout the data collection period.

Statistical analysis

The final dataset was imported into SPSS (IBM SPSS Statistics, Version 27) for statistical analysis. Cell-level data were analyzed descriptively to characterize access and availability to improved versus unimproved WASH services. The Fisher Exact test was used to compare the following variables across cells: drinking water source for human consumption (improved or unimproved), drinking water source for animal consumption (improved or unimproved), cooking water source (improved or unimproved), return trip time to human drinking water source, drinking water treatment practices, presence of a household handwashing station, presence of soap at household handwashing stations, presence of a household sanitation facility, and type of household sanitation facility (improved or unimproved). *P*-values less than 5% were considered statistically significant. Data cleaning, coding, and analysis were conducted by two team members in parallel to verify results.

Ethics

This research received ethics approval from the University of Global Health Equity Institutional Research Board. Permission to conduct research in Butaro Sector was obtained from the Management of Burera District. All respondents were asked to provide oral informed consent prior to the start of data collection.

RESULTS

Participant and household demographics

We invited 793 households across the four target cells to participate. Of these, 539 (68.0%) households consented. Others did not participate either because attempts to connect were unsuccessful (i.e., respondent did not answer, phone number no longer in service) or because the respondent did not wish to participate. Slightly over half of participants (317, 58.8%)

were male. The age of participants varied, with most (337, 62.5%) participants aged 31–50 years. The most common household size included between four and six persons (any age), and approximately half (266, 49.4%) of households included at least one child under the age of 5 years. Most (312, 57.9%) households owned at least one animal, and animals were usually housed in a separate area outside the household (299, 95.8%; Table 1).

Access to safe water

Across the four cells, 306 (56.8%) households reported obtaining drinking water from improved sources. This differed significantly by cell, with only 42.0% of households in Gatsibo using an improved water source for drinking water compared to 68.7% of households in Mubuga ($p < 0.001$; Figure 2). The most commonly reported source of drinking water by residents

Table 1 | Demographics of study participants from four administrative cells of Butaro Sector in Northern Province, Rwanda ($N = 539$)

	Gatsibo ($n = 131$)	Mubuga ($n = 134$)	Muhotora ($n = 138$)	Nyamicucu ($n = 136$)	Total ($N = 539$)
	Count (%)				
Sex					
Female	54 (41.2)	56 (41.8)	47 (34.1)	64 (47.1)	221 (41.0)
Male	77 (58.8)	78 (58.2)	90 (65.2)	72 (52.9)	317 (58.8)
No response	0 (0)	0 (0)	1 (0.7)	0 (0)	1 (0.2)
Age (years)					
18–30	25 (19.1)	22 (16.4)	37 (26.8)	30 (22.1)	114 (21.2)
31–40	45 (34.4)	36 (26.9)	39 (28.3)	49 (36.0)	169 (31.4)
41–50	42 (32.1)	48 (35.8)	39 (28.3)	39 (28.7)	168 (31.2)
51–64	8 (6.1)	6 (4.5)	4 (2.9)	4 (2.9)	22 (4.1)
>65	11 (8.4)	22 (16.4)	18 (13.0)	14 (10.3)	65 (12.1)
No response	0 (0)	0 (0)	1 (0.7)	0 (0)	1 (0.2)
Number of people (any age) living in household					
1–3	31 (23.8)	30 (22.4)	33 (23.9)	36 (26.5)	130 (24.1)
4–6	65 (49.6)	73 (54.5)	61 (44.2)	72 (53.0)	271 (50.3)
7+	35 (26.8)	31 (23.0)	43 (31.1)	28 (20.5)	137 (25.5)
No response	0 (0)	0 (0)	1 (0.7)	0 (0)	1 (0.2)
Number of children (<5 years) living in household					
0	73 (55.7)	72 (53.7)	62 (44.9)	62 (45.6)	269 (49.9)
1	41 (31.3)	38 (28.4)	45 (32.6)	56 (41.2)	180 (33.4)
2	16 (12.2)	18 (13.4)	28 (20.3)	15 (11.0)	77 (14.3)
3	1 (0.8)	5 (3.7)	0 (0)	3 (2.2)	9 (1.7)
No response	0 (0)	1 (0.7)	3 (2.2)	0 (0)	4 (0.7)
Presence of animals in household					
1+ animals	79 (60.3)	91 (67.9)	79 (57.2)	63 (46.3)	312 (57.9)
No animals	52 (39.7)	43 (32.1)	58 (42.0)	72 (52.9)	225 (41.7)
No response	0 (0)	0 (0)	1 (0.7)	1 (0.7)	2 (0.4)
Animal housing location (among households with 1+ animals)					
Separate[a] area outside house	73 (92.4)	89 (97.8)	76 (96.2)	61 (96.8)	299 (95.8)
Separate[a] area inside house	3 (3.8)	1 (1.1)	1 (1.3)	1 (1.6)	6 (1.9)
Alongside people inside house	1 (1.3)	0 (0)	0 (0)	1 (1.6)	2 (0.6)
No response	2 (2.5)	1 (1.1)	2 (2.5)	0 (0)	5 (1.6)

[a]'Separate' was defined as animals living in a designated space located apart from human living areas. This includes, but is not limited to, built areas such as pens or cages.

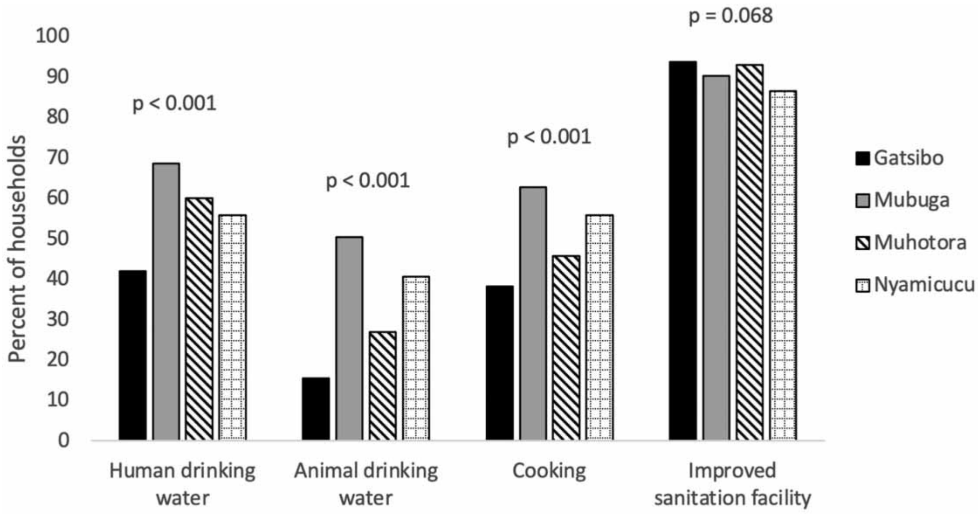


Figure 2 | Percentage of households using an improved water source for selected purposes and access to an improved household sanitation facility, by cell.

of Mubuga, Muhotora, and Nyamicucu was a protected spring, whereas residents of Gatsibo used an unprotected spring (Figure 3). Among households owning animals, one-third (34.2%) obtained water for animals from an improved source. This differed significantly by cell, with 50.5% of Mubuga households using improved sources for animal drinking water compared to 15.5% of Gatsibo households ($p < 0.001$; Figure 2). Surface water was the most common source of animal drinking water in Gatsibo and Muhotora. In Mubuga, the most common source was protected springs, whereas in Nyamicucu, protected and unprotected springs were equally common (Figure 3). The time required for a return trip to the water source used for human consumption was 30 min or greater for more than half (291, 54.2%) of households and did not differ significantly by cell ($p = 0.197$; Tables 2 and 3). Female household owners and male children were most commonly responsible for water collection (Figure 4).

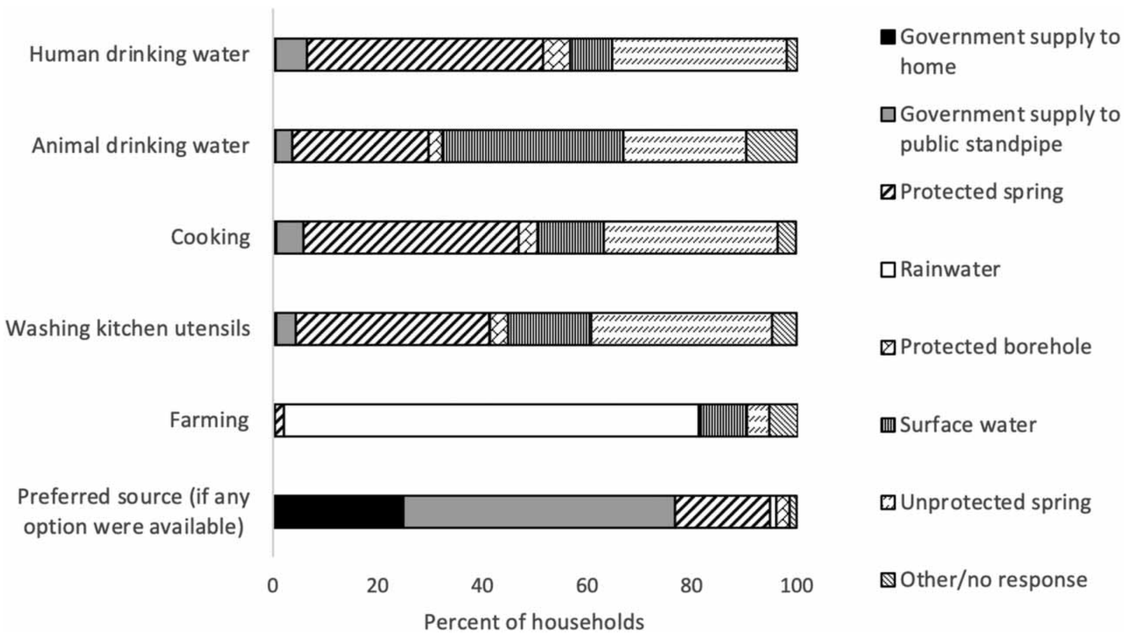


Figure 3 | Water sources used for selected tasks, all cells. *Note*: 'Rainwater' included actively collecting rainwater and passively using rainfall for farming.

Table 2 | Comparison of water access, quality, and hygiene capabilities across households in four administrative cells of Butaro Sector in Northern Province, Rwanda ($N = 539$)

	Gatsibo ($n = 131$)	Mubuga ($n = 134$)	Muhotora ($n = 138$)	Nyamicucu ($n = 136$)	Total ($N = 539$)	
	Count (%)					Fisher's Exact test p-value
Return trip time to drinking water source (human consumption)						
<30 min	62 (47.3)	63 (47.0)	52 (38.2)	69 (50.7)	246 (45.8)	0.197
≥30 min	69 (52.7)	71 (53.0)	84 (61.8)	67 (49.3)	291 (54.2)	
Drinking water treatment practices						
Treat water	60 (45.8)	43 (32.1)	57 (41.3)	61 (45.2)	221 (41.1)	0.082
Do not treat water	71 (54.2)	91 (67.9)	81 (58.7)	74 (54.8)	317 (58.9)	
Presence of handwashing station in household						
Yes	96 (73.3)	117 (87.3)	115 (83.3)	78 (57.8)	406 (75.5)	<0.001
No	35 (26.7)	17 (12.7)	23 (16.7)	57 (42.2)	132 (24.5)	
Presence of soap at handwashing station (among households with handwashing stations)						
Always	33 (35.5)	54 (46.2)	58 (50.4)	37 (47.4)	182 (45.2)	0.284
Sometimes	55 (59.1)	57 (48.7)	54 (47)	40 (51.3)	206 (51.1)	
Never	5 (5.4)	6 (5.1)	3 (2.6)	1 (1.3)	15 (3.7)	

Note: Column total differs from other tables because answers of 'No response' were removed from this table and analysis.

Less than half (221, 41.1%) of all surveyed households reported treating their drinking water and this did not differ significantly by cell ($p = 0.082$; Table 2). Among households that reported using an unimproved source for drinking water, only 37.3% reported treating their drinking water (via boiling, chlorination, or a combination of the two; Table 4). Among all surveyed households, most (432, 80.1%) felt that the drinking water drawn from their source should be treated. Reported barriers for treating water were cost, lack of time, limited availability of water treatment supplies, and lack of information regarding water treatment. Among households that reported treating their water, nearly all (210, 95.0%) boiled it and half (109, 49.4%) always treated their water. Participants reported obtaining water treatment supplies from local markets, shops, pharmacies, and community health workers. Firewood and charcoal were gathered from the surrounding environment for boiling. Approximately half (47.1%) of households needed 30 min or longer to reach the location where treatment supplies were available (Table 3).

Access to hygiene services

The percentage of households with a handwashing station differed significantly across cells ($p < 0.001$; Table 2). Mubuga had the highest percentage of households with handwashing stations (87.3%), followed by Muhotora (83.3%), Gatsibo (73.3%), and Nyamicucu (57.8%). These stations were most often handwash basins (56.4%) or modified containers/tippy taps (29.3%; Figure 5). Among those with handwashing stations, less than half (45.2%) reported that soap was always available (Table 2). Participants reported washing their hands in a variety of situations, including before preparing food (59.2%), before eating food (95.0%), after using the toilet (76.6%), after cleaning a child's bottom (59.0%), after caring for someone who was sick (57.1%), after touching animal waste (84.9%), and after cultivating crops (85.5%; Figure 6).

Access to sanitation services

Most households (531, 99.1%) had a sanitation facility, of which 480 (91.8%) were improved (Figure 2). In all four cells, pit latrines with slabs were the most common household sanitation facility (Figure 5). Approximately half (263, 49.5%) of participants with household sanitation facilities reported cleaning their facility at least once per day, and an additional 36.3% reported cleaning their facility at least once per week but not every day (Table 5). Among those with a pit latrine, most reported that their pit latrine had been operational for 5 years or fewer (427, 91.0%) and had never been emptied (454, 96.8%). Among those who had emptied their pit latrine, many (40.0%) did so by sealing the hole being used as a pit latrine and digging a new hole, whereas others emptied the contents to agricultural land

Table 3 | Access to clean water among study participants across four administrative cells of Butaro Sector in Northern Province, Rwanda ($N = 539$)

	Gatsibo ($n = 131$)	Mubuga ($n = 134$)	Muhotora ($n = 138$)	Nyamicucu ($n = 136$)	Total ($N = 539$)
	Count (%)				
Is water source available throughout the year? ('yes' responses)					
Home (government supply)	0 (0)	2 (1.5)	2 (1.4)	1 (0.7)	5 (0.9)
Public standpipe (government supply)	10 (7.6)	6 (4.5)	5 (3.6)	6 (4.4)	27 (5.0)
Protected borehole	0 (0)	43 (32.1)	34 (24.6)	0 (0)	77 (14.3)
Protected spring	44 (33.6)	86 (64.2)	76 (55.1)	68 (50.0)	274 (50.8)
Rainwater	0 (0)	28 (20.9)	64 (46.4)	37 (27.2)	129 (23.9)
Surface water	60 (45.8)	89 (66.4)	90 (65.2)	65 (47.8)	304 (56.4)
Unprotected borehole	5 (3.8)	56 (41.8)	50 (36.2)	1 (0.7)	112 (20.8)
Unprotected spring	75 (57.3)	98 (73.1)	90 (65.2)	59 (43.4)	322 (59.7)
Water vendors	0 (0)	28 (20.9)	34 (24.6)	0 (0)	62 (11.5)
Total time spent fetching water[a] for people in household/day					
<30 min	38 (29.0)	36 (26.9)	35 (25.4)	46 (33.8)	155 (28.8)
30–59 min	57 (43.5)	50 (37.3)	48 (34.8)	37 (27.2)	192 (35.6)
1–2 h	26 (19.8)	40 (29.9)	40 (29.0)	40 (29.4)	146 (27.1)
>2 h	8 (6.1)	7 (5.2)	11 (8.0)	13 (9.6)	39 (7.2)
No response	2 (1.5)	1 (0.7)	4 (2.9)	0 (0)	7 (1.3)
Median Time (min)	35	40	40	35	40
Total time spent fetching water for animals per day (among households with 1+ animals)					
No time required[b]	4 (5.1)	0 (0)	2 (2.5)	3 (4.8)	9 (2.8)
1–29 min	39 (49.4)	34 (37.4)	25 (31.6)	28 (44.4)	126 (40.4)
30–59 min	21 (26.6)	37 (40.7)	33 (41.8)	22 (34.9)	113 (36.2)
1–2 h	8 (10.1)	17 (18.7)	16 (20.3)	9 (14.3)	50 (16.0)
>2 h	0 (0)	1 (1.1)	0 (0)	0 (0)	1 (0.3)
No response	7 (8.9)	2 (2.2)	3 (3.8)	1 (1.6)	13 (4.1)
Median time (min)	20	30	30	30	30
Mode of transportation used for fetching water					
Walking	103 (78.6)	132 (98.5)	103 (74.6)	111 (81.6)	449 (83.3)
Bicycle	0 (0)	1 (0.7)	7 (5.1)	0 (0)	8 (1.5)
No response	28 (21.4)	1 (0.7)	28 (20.3)	25 (18.4)	82 (15.2)
Where water treatment supplies are obtained (among households that treated their water)					
Shops	0 (0)	0 (0)	1 (1.8)	0 (0)	1 (0.5)
Local markets	8 (13.3)	20 (46.5)	12 (21.1)	33 (54.1)	73 (33.0)
Pharmacy	1 (1.7)	1 (2.3)	1 (1.8)	0 (0)	3 (1.4)
Other[c]	45 (75.0)	22 (51.1)	42 (73.7)	24 (39.2)	133 (60.5)
No response	6 (10.0)	0 (0)	1 (1.8)	4 (6.6)	11 (5)
Time to reach location where water treatment supplies are obtained (among households that treated their water)					
<30 min	15 (25.0)	23 (53.5)	16 (28.1)	32 (52.5)	86 (38.9)
30 min–1 h	17 (28.3)	17 (39.5)	24 (42.1)	22 (36.1)	80 (36.2)
>1 h	4 (6.7)	2 (4.7)	15 (26.3)	3 (4.9)	24 (10.9)
No response	24 (40.0)	1 (2.3)	2 (3.5)	4 (6.6)	31 (14.0)

[a]Water collected for all purposes.

[b]These participants reported that they do not collect water for their animals because their animals get water from other sources (i.e., food sources) instead of drinking plain water.

[c]Other' included community health workers and firewood/charcoal gathered from woods in the surrounding environment for use in boiling water.

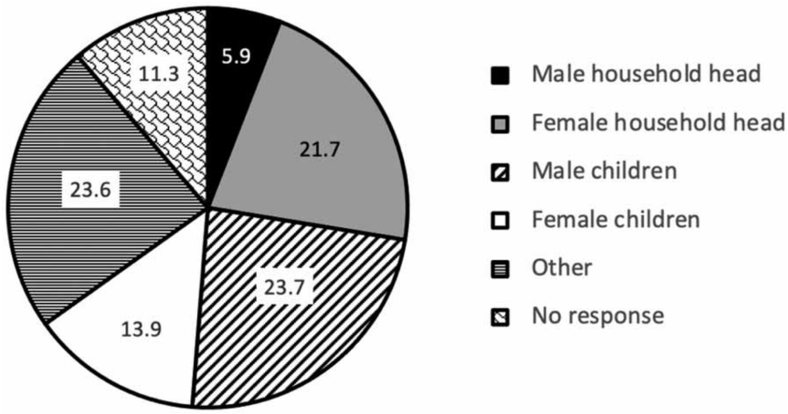


Figure 4 | Household member who most often fetches water, all cells. *Note:* 'Other' included combinations of listed categories, household help, and village children.

(33.3%) or to a landfill (6.7%). Onsite disposal was the most common method by which participants disposed of wastewater, with 79.6% of households reporting using this method (Table 6). Most (323, 59.9%) households disposed of organic waste in landfills, and most (424, 78.7%) disposed of plastic waste through burning. Among households that owned animals, most disposed of animal waste as manure for crops (232, 74.4%) and cleaned the living space of animals at least once per week (128, 41.0%). Only 13.8% cleaned the living space of animals daily.

DISCUSSION

Our evaluation of WASH in Butaro Sector illustrated that additional work is needed to reach national and global goals for WASH development. Across the four cells, 56.8% of households reported using an improved water source for human consumption. Both national (i.e., Vision 2020 and National Strategy for Transformation I) and global (i.e., SDG #6) goals are to raise this percentage to 100% over the next decade (NIRDA 2017, 2020; United Nations 2021). The percentage of households across the four cells with access to improved sanitation facilities (91.8%) was closer to national and global targets and also set at 100% (NIRDA 2017, 2020; United Nations 2021). Moreover, our evaluation highlighted Gatsibo as the study cell having the worst access to WASH services, suggesting that this area be given priority in construction of interventions to improve WASH.

All four study cells reported limited access to improved human drinking water sources. Reliance on drinking water from an unimproved source ranged from 31.3% in Mubuga to 58.0% in Gatsibo. This suggests that even in the cell with the best access to improved sources for drinking water, approximately one in three households still rely on water from an unimproved source. These findings are well below the national and district level averages of households using improved drinking water sources (NISR 2018). Close to half of households in the study cells reported travelling ≥30 min to fetch water for human consumption and this was substantially longer than national and district averages, with return trips reported as 9.6 and 7.5 min, respectively, in 2016–2017 (NISR 2018). Travel times did not differ significantly between cells, suggesting that residents of Gatsibo still have to travel 30 min or longer to obtain water that may not even be safe to drink. Longer trip times represent an opportunity cost as well as burdens on health and safety, especially for the adult women and male children commonly tasked with fetching water. In 2019–2020, 33% of Rwandan children under the age of 5 years had stunted growth and 13% of Rwandan women aged 15–49 years had anemia, both of which are associated with malnutrition (NISR 2020a). Adequate access to safe water is critical for preventing diarrheal diseases, which further exacerbate malnutrition, but require calories to expend the physical burden of human transportation (Pickering & Davis 2012). Finally, as assailants have been reported to use the predictability of water-fetching routines to target women and children in Rwanda, longer trip times could place these household members at increased risk (Pommells *et al.* 2018). These findings illustrate that interventions to improve access to safely managed drinking water are needed across all four cells in Butaro Sector.

Across the four cells, trends in human water sources extended to the types used for animal consumption. For example, Mubuga households reported the highest use of improved water sources for both humans (68.7%) and animals (50.5%),

Table 4 | Water treatment perceptions and practices among study participants from four administrative cells of Butaro Sector in Northern Province, Rwanda ($N = 539$)

	Gatsibo ($n = 131$)	Mubuga ($n = 134$)	Muhotora ($n = 138$)	Nyamicucu ($n = 136$)	Total ($N = 539$)
	Count (%)				
Drinking water treatment practices					
Treat water	60 (45.8)	43 (32.1)	57 (41.3)	61 (44.9)	221 (41.0)
Do not treat water	71 (54.2)	91 (67.9)	81 (58.7)	74 (54.4)	317 (58.8)
No response	0 (0)	0 (0)	0 (0)	1 (0.7)	1 (0.2)
Drinking water treatment perceptions					
Water should be treated	99 (75.6)	113 (84.3)	112 (81.2)	108 (79.4)	432 (80.1)
Water should not be treated	27 (20.6)	19 (14.2)	24 (17.4)	24 (17.6)	94 (17.4)
No response	5 (3.8)	2 (1.5)	2 (1.4)	4 (2.9)	13 (2.4)
Among participants who reported treating drinking water					
Water treatment method used					
Boiling	59 (98.3)	42 (97.7)	55 (96.5)	54 (88.5)	210 (95.0)
Chlorination	1 (1.7)	1 (2.3)	1 (1.8)	4 (6.6)	7 (3.2)
Other[a]	0 (0)	0 (0)	1 (1.8)	0 (0)	1 (0.5)
No response	0 (0)	0 (0)	0 (0)	3 (4.9)	3 (1.4)
Frequency of water treatment					
Water treated every time	14 (23.3)	24 (55.8)	35 (61.4)	36 (59.0)	109 (49.4)
Water treated sometimes	44 (73.3)	19 (44.2)	19 (33.3)	22 (36.1)	104 (47.1)
No response	2 (3.3)	0 (0)	3 (5.3)	3 (4.9)	8 (3.6)
Confidence in water treatment method					
Very confident	8 (13.3)	14 (32.6)	29 (50.9)	37 (60.7)	88 (39.8)
Somewhat confident	45 (75.0)	28 (65.1)	26 (45.6)	21 (34.4)	120 (54.3)
Not confident	4 (6.7)	1 (2.3)	1 (1.8)	1 (1.6)	7 (3.2)
No response	3 (5.0)	0 (0)	1 (1.8)	2 (3.3)	6 (2.7)
Perceived affordability of water treatment method					
Affordable	2 (3.3)	11 (25.6)	2 (3.5)	13 (21.3)	28 (12.7)
Medium	13 (21.7)	16 (37.2)	13 (22.8)	10 (16.4)	52 (23.5)
Expensive	8 (13.3)	9 (20.9)	25 (43.9)	17 (27.9)	59 (26.7)
No response	37 (61.7)	7 (16.3)	17 (29.8)	21 (34.4)	82 (37.1)
Preferred water treatment method					
Boiling	53 (88.3)	39 (90.7)	53 (93.0)	42 (68.9)	187 (84.6)
Chlorination	5 (8.3)	1 (2.3)	1 (1.8)	4 (6.6)	11 (5.0)
Other[b]	2 (3.3)	3 (7.0)	2 (3.5)	13 (21.3)	20 (9.0)
No response	0 (0)	0 (0)	1 (1.8)	2 (3.3)	3 (1.4)

[a]'Other' included a combination of boiling and chlorination.

[b]'Other' included the use of disinfectant powder, water filters, and clean water supplied by the government or another entity such that treatment is unnecessary.

whereas Gatsibo households reported the lowest use of improved water sources for both (humans 42.0% and animals 15.5%). This suggests that increasing access to improved water sources would benefit both human and animal residents, which included cattle, sheep, chickens, and goats. Water is an important and often overlooked nutrient necessary for animal health, and the quantity and quality of water consumed by livestock animals can dramatically affect their productivity (Meehan & Stokka 2021). Some animals, like sheep, are able to satisfy the majority of their water requirements from forage, whereas others, like dairy cattle, must drink large volumes of water (20–40 gallons/day) to meet their nutritional

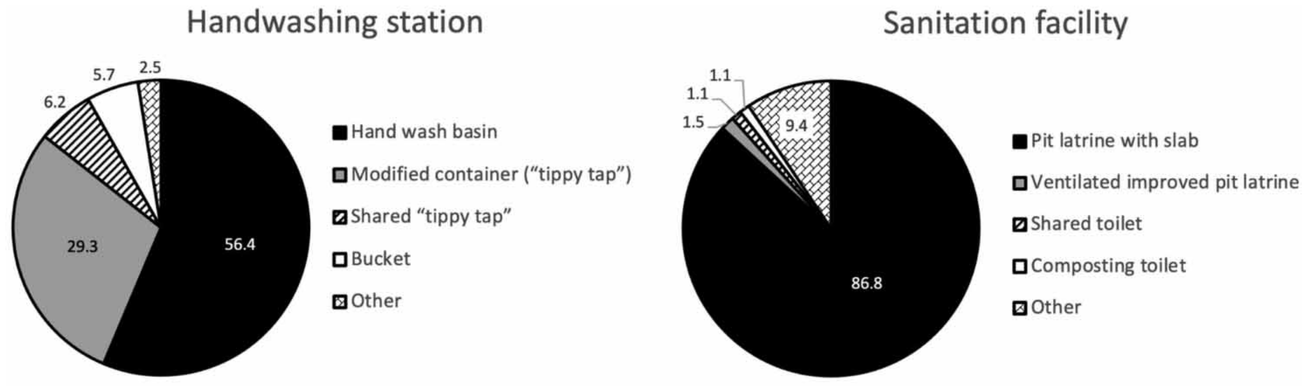


Figure 5 | Type of handwashing station and type of sanitation facility present in household, all cells. *Note:* 'Other' handwashing stations included small jerry cans or a combination of options. 'Other' sanitation facilities included pit latrines without slabs, pit latrines without doors and/or roofs, private outdoor latrines (not further specified), and pour toilets without doors and/or roofs.

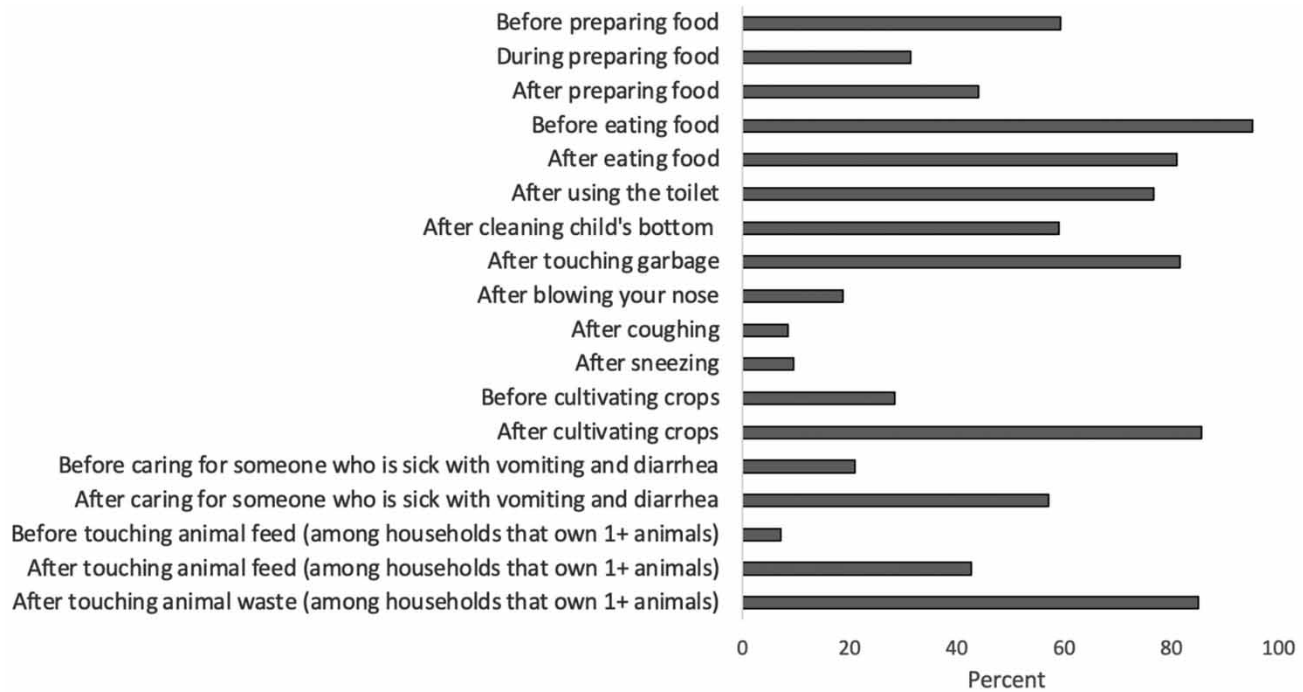


Figure 6 | Percent of participants reporting washing their hands in various situations, all cells.

and lactation requirements, as milk is largely composed of water (Meehan & Stokka 2021). Growth, productivity, and overall health decline when water needs are not met. Providing clean drinking water to livestock also reduces the potential for zoonotic disease transmission, as shared unimproved water sources may provide a pathway for disease transmission (Waters *et al.* 2016). Contact with surface water can promote the spread of bacteria such as *E. coli*, as grazing animals frequently contaminate surface water with fecal pathogens, which can then cause diarrheal disease in humans (Vinten *et al.* 2004). As a result, efforts to improve WASH access in the four cells should implement a One Health approach, considering the water needs of both human and animal residents of Butaro.

For those households reliant on unimproved sources, water treatment, such as boiling, chlorination, or filtration, is important for eliminating waterborne pathogens and reducing the risk of illness. However, while a high proportion (80.1%) of surveyed households felt their water should be treated, only a fraction of households using unimproved sources treated their water (37.3%). Barriers to water treatment were widespread and included cost, availability, lack of information, and

Table 5 | Sanitation access and practices among study participants from four administrative cells of Butaro Sector in Northern Province, Rwanda ($N = 539$)

	Gatsibo ($n = 131$)	Mubuga ($n = 134$)	Muhotora ($n = 138$)	Nyamicucu ($n = 136$)	Total ($N = 539$)
	Count (%)				
Sanitation cleaning frequency (among households with sanitation facility)					
At least once per day	56 (43.8)	87 (65.4)	86 (62.8)	34 (25.6)	263 (49.5)
At least once per week	40 (31.3)	31 (23.3)	40 (29.2)	82 (61.7)	193 (36.3)
Other[a]	31 (24.2)	13 (9.8)	9 (6.6)	11 (8.3)	64 (12.1)
No response	1 (0.8)	2 (1.5)	2 (1.5)	6 (4.5)	11 (2.1)
Animal pen cleaning frequency (among households with animals)					
At least once per day	6 (7.6)	18 (19.8)	14 (17.7)	5 (7.9)	43 (13.8)
At least once per week	31 (39.2)	29 (31.9)	32 (40.5)	36 (57.1)	128 (41.0)
At least once per month	37 (46.8)	34 (37.4)	19 (24.1)	18 (28.6)	108 (34.6)
At least once per year	3 (3.8)	7 (7.7)	6 (7.6)	4 (6.3)	20 (6.4)
Other[b]	0 (0)	2 (0)	3 (2.5)	0 (0)	5 (0.6)
No response	2 (2.5)	1 (1.1)	5 (6.3)	0 (0)	8 (2.6)
Pit latrine operational time (among households with pit latrine)					
<1 year	32 (27.4)	34 (28.8)	25 (20.8)	18 (15.8)	109 (23.2)
1–5 years	74 (63.2)	73 (61.9)	85 (70.8)	86 (75.4)	318 (67.8)
5–10 years	8 (6.8)	8 (6.8)	7 (5.8)	10 (8.8)	33 (7.0)
>10 years	3 (2.6)	3 (2.5)	2 (1.6)	0 (0)	8 (1.7)
No response	0 (0)	0 (0)	1 (0.8)	0 (0)	1 (0.2)
Pit latrine time last emptied (among households with pit latrine)					
<1 year	3 (2.6)	4 (3.4)	0 (0)	4 (3.5)	11 (2.3)
1–5 years	1 (0.9)	2 (1.7)	1 (0.8)	0 (0)	4 (0.9)
Never	113 (96.6)	112 (94.9)	119 (99.2)	110 (96.5)	454 (96.8)
Diaper disposal (among households with children wearing diapers)					
Burning	37 (74.0)	0 (0)	4 (9.3)	1 (4.2)	42 (29.2)
Latrine	6 (12.0)	21 (77.8)	11 (25.6)	16 (66.7)	54 (37.5)
Wash and reuse	0 (0)	5 (18.5)	25 (58.1)	5 (20.8)	35 (24.3)
Garbage	3 (6.0)	1 (3.7)	1 (2.3)	2 (8.3)	7 (4.9)
Other[c]	4 (8.0)	0 (0)	2 (4.7)	0 (0)	6 (4.2)

[a]'Other' included not knowing how often the facility was cleaned or cleaning the facility whenever it appeared dirty or 'sometimes' (not further specified).
[b]'Other' included cleaning the living space of the animals 'never' or 'as needed'.
[c]'Other' included not knowing how the diapers were disposed of and leaving the diapers where they are (not further specified).

insufficient time. The Rwandan Ministry of Health's Community-Based Environmental Health Promotion Program (CBEHPP) is working to address these barriers through education and environmental health financing for vulnerable households (Republic of Rwanda Ministry of Health 2020). Among households that did treat their water, respondents almost exclusively reported boiling as their method of water treatment. While boiling water is simple and effective at killing most pathogens, disadvantages include that it is time-consuming; includes a risk of injury, especially in households with small children (49.4% of study households had at least one child <5 years), and can become costly due to fuel use (Shrestha *et al.* 2020). When traditional fuels such as firewood are used, widespread and consistent use of boiling as a water treatment method can contribute to deforestation and indoor air pollution (Shrestha *et al.* 2020). Because many of these disadvantages align with respondents' reported barriers to treating water, the availability and community opinions of other water treatment methods (e.g., chlorination and sand filtration) should be further explored as a means of increasing the safety of water obtained from unimproved sources when improved sources are not available.

Table 6 | Waste disposal practices among study participants from four administrative cells of Butaro Sector in Northern Province, Rwanda ($N = 539$)

	Gatsibo	Mubuga	Muhotora	Nyamicucu	Total
	($n = 131$) Count (%)	($n = 134$)	($n = 138$)	($n = 136$)	($N = 539$)
Manure disposal (among households with animals)					
Farm	47 (59.5)	74 (81.3)	66 (83.5)	45 (71.4)	232 (74.4)
Compost	27 (34.2)	11 (12.1)	7 (8.9)	17 (27.0)	62 (19.9)
Other[a]	2 (2.5)	5 (5.5)	3 (3.8)	0 (0)	10 (3.2)
No response	3 (3.8)	1 (1.1)	3 (3.8)	1 (1.6)	8 (2.6)
Wastewater disposal					
Onsite disposal	113 (86.3)	102 (76.1)	103 (74.6)	111 (81.6)	429 (79.6)
Soak pit	10 (7.6)	21 (15.7)	10 (7.2)	14 (10.3)	55 (10.2)
Sewer line	0 (0)	1 (0.7)	3 (2.2)	1 (0.7)	5 (0.9)
Septic tank	4 (3.1)	0 (0)	4 (2.9)	0 (0)	8 (1.5)
Landfill	2 (1.5)	1 (0.7)	1 (0.7)	0 (0)	4 (0.8)
Other[b]	2 (1.6)	8 (5.8)	15 (10.7)	6 (4.4)	31 (5.9)
No response	0 (0)	1 (0.7)	2 (1.4)	4 (2.9)	7 (1.3)
Organic waste disposal					
Animal feed	14 (10.7)	25 (18.7)	15 (10.9)	20 (14.7)	74 (13.7)
Farming	8 (6.1)	50 (37.3)	40 (29.0)	30 (22.1)	128 (23.8)
Landfill	108 (82.4)	57 (42.5)	81 (58.7)	77 (56.6)	323 (59.9)
Other[c]	1 (0.8)	1 (0.7)	1 (0.7)	6 (4.4)	9 (1.7)
No response	0 (0)	1 (0.7)	1 (0.7)	3 (2.2)	5 (0.9)
Plastic waste disposal					
Burning	62 (47.3)	111 (82.8)	125 (90.6)	126 (92.6)	424 (78.7)
Landfill	7 (5.3)	14 (10.4)	5 (3.6)	3 (2.2)	29 (5.4)
Recycling/reuse	54 (41.2)	0 (0)	3 (2.2)	0 (0)	57 (10.6)
Composting toilet	3 (2.3)	2 (1.5)	1 (0.7)	3 (2.2)	9 (1.7)
Other[d]	3 (2.3)	6 (4.4)	2 (1.4)	2 (1.4)	13 (2.6)
No response	2 (1.5)	1 (0.7)	2 (1.4)	2 (1.5)	7 (1.3)

[a]'Other' included selling the manure, throwing in the garbage, and putting outside.
[b]'Other' included using wastewater as a fertilizer or disposing in latrine/animal living space/outdoors.
[c]'Other' included disposing organic waste in a composting toilet, using as animal bedding, using for farming/gardening, or placing in a dug hole.
[d]'Other' included disposing plastic waste in a latrine, dug hole, or field, and participants who reported they had no plastic waste.

Altogether, 91.8% of surveyed households reported access to improved sanitation facilities, exceeding both national (86.2%) and district averages (81.4%; NISR 2018). Among households that owned animals, most (74.4%) disposed of animal waste through farming. The use of animal feces as manure without prior treatment can lead to contamination of vegetables and other plants with *E. coli* and microorganisms, which can then cause disease in humans when consumed (WHO 2012). Handwashing stations appeared to differ significantly, with fewer households in Nyamicucu having a household handwashing station compared to the other three cells. These stations often lacked soap. Respondents most often washed their hands before eating food (95.0%), after cultivating crops (85.5%), and after touching animal waste (84.9%). Few respondents reported washing their hands before touching animal feed (7.1% of households that owned animals), after coughing (8.5%), or after sneezing (9.5%). It is important to note that these are likely overestimates of true handwashing behavior, as handwashing is a socially desirable behavior and self-reporting often results in higher rates of handwashing than direct observation (Manun'Ebo *et al.* 1997). Good hygiene, in addition to good sanitation infrastructure, is a cornerstone for reducing human and animal exposure to infectious diseases. Improved access to handwashing has been associated with a 31% reduction in gastrointestinal illness and a 21%

reduction in respiratory illness (Aiello *et al.* 2008). While handwashing with soap is most effective for eliminating fecal pathogens, handwashing with water alone has also been associated with a significant reduction in diarrhea in children (Luby *et al.* 2011). Therefore, while efforts to improve access to soap should be implemented in all cells, handwashing stations should be constructed in households that currently lack handwashing stations, prioritizing Nyamicucu.

This study had several limitations. While the survey was designed to be implemented via in-person interviews, COVID-19 restrictions required that the study be adapted to telephone interviews. This meant that data collectors were unable to validate responses through direct observations and relied on respondents to self-report the presence of infrastructure and their WASH-related behavior. Data collectors were also unable to report on the structural integrity or hygiene of WASH infrastructure, to observe handwashing or water treatment, or to take water samples for testing, as originally planned. These activities will take place once COVID-19 restrictions have been lifted. An additional issue imposed by the telephone survey is that it initially resulted in a higher proportion of male participation, simply due to differing rates of cell phone ownership among males and females. We corrected this by conducting additional interviews with female household owners after our minimum sample size had been met to balance the gender ratio. In some areas, using a telephone format could bias results by excluding households with the lowest socioeconomic status. However, we feel this potential bias was low in this study because prior to switching to a telephone format, we engaged local community leaders who informed us that each household in Butaro Sector had at least one family member with a mobile telephone. An additional potential source of bias was our high non-response rate (32%). However, we feel the responses we received are representative of the total population because (1) the non-response rate was primarily due to survey enumerators being unable to connect with selected households (i.e., phone not answered and phone number no longer in service) rather than respondents declining to participate and (2) the demographics of our study population (i.e., sex, age, and average household size) are similar to the published data for Butaro Sector (NISR 2015).

CONCLUSIONS

These findings show that human and animal residents of Butaro Sector experience gaps in their access to WASH services, with Gatsibo experiencing the poorest overall access. Supplementing this evaluation with information on water quality, location of water bodies and homes, and community preferences will be vital to improving community access to clean water and improved health outcomes. Continued investigation into rainwater and groundwater sources as possible candidates for supply sources is recommended, as both are abundant in the region.

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DATA AVAILABILITY STATEMENT

Data cannot be made publicly available; readers should contact the corresponding author for details.

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