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Original Research

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Relationship Between Household Water Sanitation and Hygiene Behaviors and Diarrhea in Rwanda, 2010–2020

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Abstract

Rwanda has made considerable progressive policy efforts to significantly reduce diarrhea among children under 5 years old, especially since 2010. This cross-sectional study aimed to assess the relationship between household water sanitation and hygiene (WASH) behaviors and diarrhea among children under 5 years old between 2010 and 2020. We used secondary data from the 2010, 2015, and 2020 Rwanda Demographic Health Surveys. We used descriptive statistics, pairwise comparisons, and linear regression designs to assess (a) the prevalence of household WASH behaviors across districts, regions, urban areas, and rural areas, (b) the variation of household WASH behaviors over time, and (c) the relationship between household WASH behaviors and diarrhea in children under 5. The study findings show (a) no statistically significant variation in handwashing, (b) a statistically significant decrease in water treatment ($\mu = 13.230$, 95%CI [8.609; 17.851], $p < .001$) and in safe water storage ($\mu = 4.430$, 95%CI [2.400; 6.460], $p < .001$), and (c) a statistically significant increase in the use of clean toilets ($\mu = 12.197$, 95%CI [8.158; 16.235], $p < .001$) between 2010 and 2020. The study results did not show a statistically significant relationship between WASH behaviors (handwashing, water treatment, safe water storage, and use of clean toilets) and diarrhea among children under 5 years old.

Keywords: *diarrhea, household water treatment, safe water storage, handwashing, clean toilet*

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Introduction

A household often functions as a living space, an occupational space, and a recreational place for children. As such, it contributes to the survival and healthy development of children through its social, environmental, and

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economic conditions. Various studies conducted at different times and places have investigated household drinking water treatment, safe water storage, sanitation, and hygiene, all of which have been found to be potential household-level diarrhea risk factors for children under 5 years old (Darvesh et al., 2017; Pintu, 2020; Saha et al., 2022; Sahiledengle et al., 2021; Sinharoy et al., 2017). In terms of diarrhea prevention and control, household water sanitation and hygiene (WASH) are currently the main components of (a) the content of health promotion, (b) monitoring, and (c) evaluation of interventions and programs to prevent and reduce diarrhea among children under 5 years old. A combination of interventions, including (a) improvement in household access to clean water, sanitation, and hygiene facilities and (b) health education for behavioral change, have shown diarrhea risk reduction between 27% and 53% in children under 5 years old (Darvesh et al., 2017). In this study, we focused on household water treatment, safe water storage, use of clean toilets, and handwashing and the relationship of these to diarrhea among children under 5 years old in Rwanda between 2010 and 2020.

Regarding household water treatment, a study conducted by Nguyen et al. (2021) showed a 43% reduction in diarrhea in Sub-Saharan Africa associated with home-based water treatment. A systematic review conducted by Wolf et al. (2022) revealed a reduction of up to 50% in diarrhea due to home-based water treatment in low- and middle-income countries (LMICs). In the Rwamagana district of Rwanda, a randomized control trial (RCT) showed that using filters for home-based water treatment reduced up to 49% of reported diarrhea among children under 5 years old (Haque et al., 2022). Earlier, however, Sinharoy et al. (2017), in a cluster randomized control trial (cRCT) conducted in the Rusizi district of Rwanda, did not find a relationship between an increase in home-based water treatment and caregiver-reported diarrhea among children under 5 years old.

In Rwanda in 2020, 80% of households had access to improved sources of drinking water, including piped water, public taps, standpipes, tube wells, boreholes, protected dug wells, and bottled water. However, alongside bottled water, home-based quality improvement is more reliable than source-based quality improvement due to poor handling practices that increase the risk of contamination during fetching, transport, and household storage before and/or during its use (Clasen, 2015; National Institute of Statistics of Rwanda, 2020; Soboksa et al., 2020). Household water treatment options in Rwanda include mainly boiling, filtration, and chemical treatment (Sur'eau). A household's ability to access one of the water treatment options depends on the household's awareness, location, and/or purchasing power.

In terms of household water storage, a systematic review identified the protective effect of household water treatment and storage (HWTS) interventions against diarrhea and their apparent advantage over interventions at the source or other points of distribution, such as community wells and tap stands (Fewtrell et al., 2005). According to Clasen's (2015) research findings, the pooled estimate of the effect of home-based water treatment was a reduction in risk of diarrhea of 33% (95% confidence interval [CI] 8–53 %) or 45% when combined with safe storage (95% CI 19–62 %). The stored water in intervention households was significantly less contaminated with *Escherichia coli* than water in control households, with diarrheal disease risk for individuals in intervention households being 48% lower than in control households (95% CI[0.3, 0.9], $P < 0.001$). In Rwanda, the relationship between household safe water storage and diarrhea among children under 5 years old has not been previously known on a large scale.

Since the decade of water and sanitation (1981–1990), household sanitation has included the safe disposal of fecal matter, wastewater/liquid waste, and solid waste in general. However, the current tendency limits household sanitation to the disposal of human excreta (United Nations Children's Education Fund & World Health Organization, 2023). Human wastes (excreta), once ingested, are the main source of pathogens causing diarrhea. The literature review conducted in 1991 revealed that household sanitation interventions reduced diarrhea by 36%, on average, while the most recent systematic review found an overall reduction in diarrhea of 25% attributable to household sanitation (Contreras & Eisenberg, 2019). According to NISR

(2020), the national level of household improved sanitation (in terms of toilet infrastructure) in Rwanda was 72.8%. The present study focused on the use of clean toilets.

When practiced adequately, handwashing constitutes a cost-effective intervention that plays a key role in preventing diarrhea. Precisely, handwashing with water and soap after defecating, after touching feces, before breastfeeding, before preparation of food, and before eating prevents between 25% and 53% of diarrhea among children under 5 years old (Nguyen et al., 2021; Solomon et al., 2021). This is the most impactful of all the WASH practices and yet the least adopted (11.9% when considering a fixed place for household handwashing) in Rwanda (NISR, 2020). Indeed, addressing the handwashing issue can serve to limit the ingestion of pathogens, prevent the effect of poor sanitation, and ensure safe feeding practices (Esrey et al., 1985).

The purpose of this study was to assess the relationship between household WASH behaviors (home-based water treatment, safe water storage, handwashing, and use of clean toilets) and diarrhea among children under 5 years old between 2010 and 2020 in Rwanda.

Methods

This study consisted of a cross-sectional design; it used descriptive statistics, pairwise comparisons, and linear regression designs to assess (a) the prevalence of WASH behaviors across communities, regions, and urban-rural areas in 2010, 2015, and 2020, (2) the variation of WASH behaviors over time, and (3) if household WASH behaviors (household water treatment, household safe water storage, household sanitation, and handwashing) are predictors of diarrhea among children under 5 years old in Rwanda.

We collected and used secondary data from the 2010, 2015, and 2020 Rwanda Demographic Health Surveys (RDHS) obtained from the National Institute of Statistics of Rwanda, and the study participants were households. After data cleaning, the following samples of 12,538 households, 12,699 households, and 12,949 households from 2010, 2015, and 2020 RDHS, respectively, were used for data analysis.

The variables included household water treatment, household safe water storage, household sanitation, and handwashing as independent variables, and diarrhea among children under 5 years old as the dependent variable. Household water treatment included any household water treatment used to make water safe, including boiling, filtration, and chemical treatment. Safe storage of water consisted of the frequency of washing water containers (at least 7 times per week). Safe household sanitation was limited to the use of clean toilets with clean and dry platforms. For handwashing, we considered an observed fixed place/facility for washing hands in the household. The data analysis used descriptive and pairwise comparison designs to assess respectively the prevalence and the variation of household water treatment, household safe water storage, household sanitation, and handwashing. The linear regression design was used to assess the relationship between household water treatment, household safe water storage, household sanitation, and handwashing and diarrhea.

Results

Prevalence of Household WASH Behaviors Between 2010 and 2020

Descriptive analysis was used to calculate the prevalence of household WASH behaviors between 2010 and 2020 (Tables 1, 2, and 3). Table 1 shows the prevalence of handwashing, water treatment, safe water storage, and use of clean toilets per district/community and region, as well as by urban or rural area, in 2010. In a national sample of 12,538 households in 2010, the prevalence of household handwashing, water treatment, safe water storage, and clean toilets was 10.5%, 50%, 7.9%, and 40.8%, respectively.

Table 1. *Prevalence of Household WASH Behaviors in 2010*

		Handwashing facility			Water treatment			Safe water storage			Clean toilet		
		Yes	No	Total	Yes	No	Total	Yes	No	Total	Yes	No	Total
Community (district)													
Nyarugenge	*N*	78	431	509	324	185	509	65	444	509	314	195	509
	%	15.4	84.6	100	63.7	36.3	100	12.7	87.3	100	61.7	38.3	100
Gasabo	*N*	41	460	501	356	145	501	71	430	501	224	277	501
	%	8.2	91.8	100	71.1	28.9	100	14.2	85.8	100	44.7	55.3	100
Kicukiro	*N*	56	456	512	410	102	512	86	426	512	356	156	512
	%	11	89	100	80.1	19.9	100	16.8	83.2	100	69.5	30.5	100
Nyanza	*N*	43	362	405	186	219	405	22	383	405	164	241	405
	%	10.6	89.4	100	45.9	54.1	100	5.4	94.6	100	40.5	59.5	100
Gisagara	*N*	145	268	413	113	300	413	19	394	413	162	251	413
	%	35.1	64.9	100	27.4	72.6	100	4.5	95.5	100	39.3	60.7	100
Nyaruguru	*N*	22	386	408	147	261	408	35	373	408	134	274	408
	%	5.4	94.6	100	36	64	100	8.7	91.3	100	32.9	67.1	100
Huye	*N*	26	388	414	245	169	414	62	352	414	128	286	414
	%	6.3	93.7	100	59.2	40.8	100	14.9	85.1	100	31	69.0	100
Nyamagabe	*N*	37	372	409	177	232	409	76	333	409	157	252	409
	%	9	91.0	100	43.3	56.7	100	18.6	81.4	100	38.4	61.6	100
Ruhango	*N*	8	400	408	177	231	408	4	404	408	143	265	408
	%	2	98.0	100	43.4	56.6	100	0.9	99.1	100	35	65.0	100
Muhanga	*N*	39	361	400	317	83	400	77	323	400	174	226	400
	%	9.8	90.2	100	79.3	20.8	100	19.2	80.8	100	43.5	56.5	100
Kamonyi	*N*	6	397	403	271	132	403	22	381	403	159	244	403
	%	1.5	98.5	100	67.2	32.8	100	5.5	94.5	100	39.5	60.5	100
Karongi	*N*	10	396	406	168	238	406	14	392	406	190	216	406
	%	2.5	97.5	100	41.4	58.6	100	3.4	96.6	100	46.7	53.3	100
Rutsiro	*N*	26	375	401	127	274	401	18	383	401	134	267	401
	%	6.5	93.5	100	31.7	68.3	100	4.6	95.4	100	33.4	66.6	100
Rubavu	*N*	3	409	412	152	260	412	33	379	412	130	282	412
	%	0.7	99.3	100	36.9	63.1	100	7.9	92.1	100	31.6	68.4	100

		Handwashing facility			Water treatment			Safe water storage			Clean toilet		
		Yes	No	Total	Yes	No	Total	Yes	No	Total	Yes	No	Total
Nyabihu	*N*	27	377	404	251	153	404	35	369	404	110	294	404
	%	6.7	93.3	100	62.1	37.9	100	8.7	91.3	100	27.3	72.7	100
Ngororero	*N*	7	396	403	239	164	403	20	383	403	152	251	403
	%	1.7	98.3	100	59.3	40.7	100	5.0	95.0	100	37.7	62.3	100
Rusizi	*N*	16	397	413	142	271	413	31	382	413	142	271	413
	%	3.9	96.1	100	34.4	65.6	100	7.6	92.4	100	34.5	65.5	100
Nyamasheke	*N*	34	367	401	210	191	401	23	378	401	193	208	401
	%	8.5	91.5	100	52.4	47.6	100	5.7	94.3	100	48.1	51.9	100
Rurindo	*N*	27	384	411	118	293	411	32	379	411	139	272	411
	%	6.6	93.4	100	28.7	71.3	100	7.8	92.2	100	33.7	66.3	100
Gakenke	*N*	48	359	407	256	151	407	42	365	407	94	313	407
	%	11.8	88.2	100	62.9	37.1	100	10.3	89.7	100	23.1	76.9	100
Musanze	*N*	23	390	413	236	177	413	24	389	413	160	253	413
	%	5.6	94.4	100	57.1	42.9	100	5.7	94.3	100	38.8	61.2	100
Burera	*N*	79	326	405	195	210	405	29	376	405	146	259	405
	%	19.5	80.5	100	48.1	51.9	100	7.2	92.8	100	36	64.0	100
Gicumbi	*N*	15	396	411	165	246	411	45	366	411	139	272	411
	%	3.7	96.3	100	40.1	59.9	100	10.9	89.1	100	33.9	66.1	100
Rwamagana	*N*	28	380	408	212	196	408	13	395	408	218	190	408
	%	6.9	93.1	100	52	48	100	3.3	96.7	100	53.4	46.6	100
Nyagatare	*N*	29	379	408	214	194	408	9	399	408	172	236	408
	%	7.1	92.9	100	52.5	47.5	100	2.1	97.9	100	42.2	57.8	100
Gatsibo	*N*	161	255	416	146	270	416	10	406	416	188	228	416
	%	38.7	61.3	100	35.1	64.9	100	2.5	97.5	100	45.1	54.9	100
Kayonza	*N*	129	279	408	248	160	408	25	383	408	200	208	408
	%	31.6	68.4	100	60.8	39.2	100	6.1	93.9	100	49.0	51.0	100
Kirehe	*N*	61	350	411	217	194	411	27	384	411	176	235	411
	%	14.9	85.1	100	52.8	47.2	100	6.5	93.5	100	42.8	57.2	100
Ngoma	*N*	77	329	406	140	266	406	15	391	406	128	278	406
	%	19	81.0	100	34.5	65.5	100	3.6	96.4	100	31.6	68.4	100
Bugesera	*N*	10	402	412	110	302	412	5	407	412	185	227	412

		Handwashing facility			Water treatment			Safe water storage			Clean toilet		
		Yes	No	Total	Yes	No	Total	Yes	No	Total	Yes	No	Total
	%	2.4	97.6	100	26.7	73.3	100	1.2	98.8	100	45.0	55.0	100
Total	*N*	1311	11227	12538	6269	6269	12538	988	11550	12538	5111	7427	12538
	%	10.5	89.5	100	50.0	50.0	100	7.9	92.1	100	40.8	59.2	100
Region													
Kigali City	*N*	175	1347	1522	1090	432	1522	222	1300	1522	894	628	1522
	%	11.5	88.5	100	71.6	28.4	100	14.6	85.4	100	58.7	41.3	100
Southern	*N*	326	2934	3260	1633	1627	3260	316	2944	3260	1221	2039	3260
	%	10.0	90.0	100	50.1	49.9	100	9.2	90.8	100	37.5	62.5	100
Western	*N*	122	2718	2840	1289	1551	2840	174	2666	2840	1051	1789	2840
	%	4.3	95.7	100	45.4	54.6	100	5.9	94.1	100	37.0	63.0	100
Northern	*N*	192	1855	2047	970	1077	2047	171	1876	2047	678	1369	2047
	%	9.4	90.6	100	47.4	52.6	100	8.2	91.8	100	33.1	66.9	100
Eastern	*N*	496	2373	2869	1287	1582	2869	104	2765	2869	1267	1602	2869
	%	17.3	82.7	100	44.9	55.1	100	3.7	96.3	100	44.2	55.8	100
Total	*N*	1311	11227	12538	6269	6269	12538	988	11550	12538	5111	7427	12538
	%	10.5	89.5	100	50.0	50.0	100	7.9	92.1	100	40.8	59.2	100
Urban/rural													
Urban	*N*	267	1742	2009	1329	680	2009	295	1714	2009	1139	870	2009
	%	13.3	86.7	100	66.2	33.8	100	14.2	85.8	100	56.7	43.3	100
Rural	*N*	1044	9485	10529	4940	5589	10529	693	9836	10529	3972	6557	10529
	%	9.9	90.1	100	46.9	53.1	100	6.3	93.7	100	37.8	62.2	100
Total average	*N*	1311	11227	12538	6269	6269	12538	988	11550	12538	5111	7427	12538
	%	10.5	89.5	100	50.0	50.0	100	7.9	92.1	100	40.8	59.2	100
												Total sample	12,538

Table 2 shows the prevalence of handwashing, water treatment, safe water storage, and use of clean toilets per district/community and region, and by urban or rural area in 2015. In a national sample of 12,699 households in 2015, the prevalence of household handwashing, water treatment, safe water storage, and clean toilets was 12.5%, 46.2%, 4.0%, and 46.1%, respectively.

Table 2. *Prevalence of Household WASH Behaviors in 2015*

		Handwashing facility			Water treatment			Safe water storage			Clean latrine		
		Yes	No	Total	Yes	No	Total	Yes	No	Total	Yes	No	Total
Community (district)													
Nyarugenge	*N*	37	483	520	355	165	520	24	496	520	284	236	520
	%	7.1	92.9	100	68.3	31.7	100	4.6	95.4	100	54.7	45.3	100
Gasabo	*N*	78	423	501	301	200	501	29	472	501	278	223	501
	%	15.6	84.4	100	60.1	39.9	100	5.8	94.2	100	55.5	44.5	100
Kicukiro	*N*	165	350	515	374	141	515	33	482	515	410	105	515
	%	32	68	100	72.6	27.4	100	6.4	93.6	100	79.6	20.4	100
Nyanza	*N*	7	409	416	154	262	416	8	408	416	246	170	416
	%	1.7	98.3	100	37.0	63.0	100	2	98	100	59.1	40.9	100
Gisagara	*N*	9	405	414	105	309	414	37	377	414	87	327	414
	%	2.2	97.8	100	25.4	74.6	100	9	91	100	21	79	100
Nyaruguru	*N*	128	287	415	129	286	415	13	402	415	209	206	415
	%	30.8	69.2	100	31.1	68.9	100	3.2	96.8	100	50.4	49.6	100
Huye	*N*	173	241	414	213	201	414	17	397	414	227	187	414
	%	41.8	58.2	100	51.4	48.6	100	4.1	95.9	100	54.8	45.2	100
Nyamagabe	*N*	49	365	414	210	204	414	24	390	414	217	197	414
	%	11.8	88.2	100	50.7	49.3	100	5.8	94.2	100	52.4	47.6	100
Ruhango	*N*	56	360	416	124	292	416	8	408	416	188	228	416
	%	13.5	86.5	100	29.8	70.2	100	1.9	98.1	100	45.2	54.8	100
Muhanga	*N*	60	356	416	277	139	416	16	400	416	176	240	416
	%	14.4	85.6	100	66.6	33.4	100	3.9	96.1	100	42.2	57.8	100
Kamonyi	*N*	21	395	416	198	218	416	18	398	416	156	260	416
	%	5	95	100	47.6	52.4	100	4.3	95.7	100	37.6	62.4	100
Karongi	*N*	5	407	412	236	176	412	24	388	412	159	253	412
	%	1.2	98.8	100	57.3	42.7	100	5.8	94.2	100	38.5	61.5	100
Rutsiro	*N*	17	395	412	211	201	412	15	397	412	139	273	412
	%	4.1	95.9	100	51.2	48.8	100	3.7	96.3	100	33.7	66.3	100

		Handwashing facility			Water treatment			Safe water storage			Clean latrine		
		Yes	No	Total	Yes	No	Total	Yes	No	Total	Yes	No	Total
Rubavu	*N*	124	288	412	146	266	412	18	394	412	163	249	412
	%	30.1	69.9	100	35.4	64.6	100	4.3	95.7	100	39.5	60.5	100
Nyabihu	*N*	144	265	409	98	311	409	0	409	409	126	283	409
	%	35.2	64.8	100	24.0	76.0	100	0	100	100	30.8	69.2	100
Ngororero	*N*	15	397	412	194	218	412	7	405	412	94	318	412
	%	3.6	96.4	100	47.1	52.9	100	1.8	98.2	100	22.9	77.1	100
Rusizi	*N*	21	395	416	206	210	416	16	400	416	205	211	416
	%	5	95	100	49.5	50.5	100	3.8	96.2	100	49.2	50.8	100
Nyamasheke	*N*	79	335	414	189	225	414	29	385	414	195	219	414
	%	19.1	80.9	100	45.7	54.3	100	6.9	93.1	100	47.2	52.8	100
Rurindo	*N*	41	374	415	185	230	415	7	408	415	160	255	415
	%	9.9	90.1	100	44.6	55.4	100	1.7	98.3	100	38.6	61.4	100
Gakenke	*N*	23	386	409	276	133	409	13	396	409	163	246	409
	%	5.6	94.4	100	67.5	32.5	100	3.1	96.9	100	39.8	60.2	100
Musanze	*N*	23	387	410	255	155	410	9	401	410	143	267	410
	%	5.6	94.4	100	62.2	37.8	100	2.1	97.9	100	34.9	65.1	100
Burera	*N*	6	407	413	130	283	413	8	405	413	129	284	413
	%	1.5	98.5	100	31.5	68.5	100	2	98	100	31.2	68.8	100
Gicumbi	*N*	57	357	414	165	249	414	7	407	414	242	172	414
	%	13.8	86.2	100	39.9	60.1	100	1.6	98.4	100	58.4	41.6	100
Rwamagana	*N*	38	375	413	142	271	413	19	394	413	226	187	413
	%	9.2	90.8	100	34.4	65.6	100	4.7	95.3	100	54.7	45.3	100
Nyagatare	*N*	19	391	410	167	243	410	8	402	410	253	157	410
	%	4.6	95.4	100	40.7	59.3	100	1.9	98.1	100	61.7	38.3	100
Gatsibo	*N*	14	402	416	123	293	416	87	329	416	147	269	416
	%	3.4	96.6	100	29.6	70.4	100	20.8	79.2	100	35.4	64.6	100
Kayonza	*N*	141	275	416	210	206	416	4	412	416	220	196	416
	%	33.9	66.1	100	50.5	49.5	100	0.9	99.1	100	52.9	47.1	100
Kirehe	*N*	10	403	413	203	210	413	7	406	413	203	210	413
	%	2.4	97.6	100	49.2	50.8	100	1.8	98.2	100	49.2	50.8	100
Ngoma	*N*	18	396	414	138	276	414	8	406	414	215	199	414
	%	4.3	95.7	100	33.3	66.7	100	1.9	98.1	100	51.9	48.1	100

		Handwashing facility			Water treatment			Safe water storage			Clean latrine		
		Yes	No	Total	Yes	No	Total	Yes	No	Total	Yes	No	Total
Bugesera	*N*	18	394	412	156	256	412	0	412	412	195	217	412
	%	4.4	95.6	100	37.9	62.1	100	0	100	100	47.3	52.7	100
Total	*N*	1595	11104	12699	5870	6829	12699	512	12187	12699	5855	6844	12699
	%	12.6	87.4	100	46.2	53.8	100	4.0	96.0	100	46.1	53.9	100
Region													
Kigali City	*N*	280	1256	1536	1030	506	1536	86	1450	1536	972	564	1536
	%	18.2	81.8	100	67.1	32.9	100	5.6	94.4	100	63.3	36.7	100
Southern	*N*	503	2818	3321	1410	1911	3321	142	3179	3321	1506	1815	3321
	%	15.1	84.9	100	42.5	57.5	100	4.1	95.9	100	45.3	54.7	100
Western	*N*	404	2483	2887	1280	1607	2887	109	2778	2887	1081	1806	2887
	%	14	86	100	44.3	55.7	100	4.0	96.0	100	37.4	62.6	100
Northern	*N*	150	1911	2061	1011	1050	2061	43	2018	2061	837	1224	2061
	%	7.3	92.7	100	49.1	50.9	100	2.2	97.8	100	40.6	59.4	100
Eastern	*N*	258	2636	2894	1139	1755	2894	133	2761	2894	1459	1435	2894
	%	8.9	91.1	100	39.4	60.6	100	4.0	96.0	100	50.4	49.6	100
Total	*N*	1595	11104	12699	5870	6829	12699	512	12187	12699	5855	6844	12699
	%	12.6	87.4	100	46.2	53.8	100	4.0	96.0	100	46.1	53.9	100
Urban/rural													
Urban	*N*	580	2315	2895	1947	948	2895	166	2729	2895	1792	1103	2895
	%	20.0	80.0	100	67.3	32.7	100	5.4	94.6	100	61.9	38.1	100
Rural	*N*	1015	8789	9804	3923	5881	9804	346	9458	9804	4063	5741	9804
	%	10.4	89.6	100	40	60	100	3.4	96.6	100	41.5	58.5	100
Total average	*N*	1595	11104	12699	5870	6829	12699	512	12187	12699	5855	6844	12699
	%	12.6	87.4	100	46.2	53.8	100	4.0	96.0	100	46.1	53.9	100
													Total sample 12,699

Table 3 shows the prevalence of handwashing, water treatment, safe water storage, and use of clean toilets per district/community and region, and by urban or rural area in 2020. In a national sample of 12,949 households in 2020, the prevalence of household handwashing, water treatment, safe water storage, and clean toilets was 11.5%, 36.7%, 3.3%, and 52.9%, respectively.

Table 3. *Prevalence of Household WASH Behaviors in 2020*

		Handwashing facility			Water treatment			Safe water storage			Clean latrine		
		Yes	No	Total	Yes	No	Total	Yes	No	Total	Yes	No	Total
Community (district)													
Nyarugenge	*N*	73	440	513	284	229	513	11	502	513	337	176	513
	%	14.2	85.8	100	55.4	44.6	100	2.2	97.8	100	65.7	34.3	100
Gasabo	*N*	63	483	546	253	293	546	20	526	546	365	181	546
	%	11.5	88.5	100	46.3	53.7	100	3.6	96.4	100	66.8	33.2	100
Kicukiro	*N*	145	371	516	275	241	516	19	497	516	375	141	516
	%	28.1	71.9	100	53.3	46.7	100	3.7	96.3	100	72.7	27.3	100
Nyanza	*N*	85	383	468	186	282	468	8	460	468	212	256	468
	%	18.2	81.8	100	39.7	60.3	100	1.8	98.2	100	45.3	54.7	100
Gisagara	*N*	29	386	415	67	348	415	26	389	415	180	235	415
	%	7	93	100	16.1	83.9	100	6.2	93.8	100	43.4	56.6	100
Nyaruguru	*N*	27	380	407	110	297	407	12	395	407	223	184	407
	%	6.6	93.4	100	27	73	100	2.9	97.1	100	54.8	45.2	100
Huye	*N*	55	357	412	107	305	412	33	379	412	224	188	412
	%	13.3	86.7	100	26	74	100	7.9	92.1	100	54.4	45.6	100
Nyamagabe	*N*	21	396	417	89	328	417	10	407	417	222	195	417
	%	5	95	100	21.3	78.7	100	2.4	97.6	100	53.2	46.8	100
Ruhango	*N*	54	388	442	198	244	442	5	437	442	196	246	442
	%	12.2	87.8	100	44.8	55.2	100	1.1	98.9	100	44.3	55.7	100
Muhanga	*N*	44	372	416	192	224	416	2	414	416	224	192	416
	%	10.6	89.4	100	46.2	53.8	100	0.5	99.5	100	53.8	46.2	100
Kamonyi	*N*	42	374	416	194	222	416	13	403	416	248	168	416
	%	10.1	89.9	100	46.6	53.4	100	3.1	96.9	100	59.6	40.4	100
Karongi	*N*	43	368	411	189	222	411	14	397	411	193	218	411
	%	10.5	89.5	100	46	54	100	3.3	96.7	100	47	53	100
Rutsiro	*N*	28	388	416	73	343	416	18	398	416	136	280	416
	%	6.7	93.3	100	17.5	82.5	100	4.3	95.7	100	32.7	67.3	100
Rubavu	*N*	20	395	415	172	243	415	7	408	415	214	201	415
	%	4.8	95.2	100	41.4	58.6	100	1.8	98.2	100	51.6	48.4	100
Nyabihu	*N*	16	400	416	203	213	416	11	405	416	142	274	416
	%	3.8	96.2	100	48.8	51.2	100	2.6	97.4	100	34.1	65.9	100

		Handwashing facility			Water treatment			Safe water storage			Clean latrine		
		Yes	No	Total	Yes	No	Total	Yes	No	Total	Yes	No	Total
Ngororero	*N*	17	399	416	182	234	416	10	406	416	190	226	416
	%	4.1	95.9	100	43.8	56.2	100	2.4	97.6	100	45.7	54.3	100
Rusizi	*N*	29	382	411	112	299	411	23	388	411	261	150	411
	%	7.1	92.9	100	27.3	72.7	100	5.5	94.5	100	63.5	36.5	100
Nyamasheke	*N*	46	367	413	141	272	413	24	389	413	235	178	413
	%	11.1	88.9	100	34.1	65.9	100	5.9	94.1	100	56.9	43.1	100
Rurindo	*N*	22	391	413	200	213	413	17	396	413	191	222	413
	%	5.3	94.7	100	48.4	51.6	100	4.2	95.8	100	46.2	53.8	100
Gakenke	*N*	135	280	415	192	223	415	11	404	415	275	140	415
	%	32.5	67.5	100	46.3	53.7	100	2.7	97.3	100	66.3	33.7	100
Musanze	*N*	50	368	418	170	248	418	26	392	418	215	203	418
	%	12	88	100	40.7	59.3	100	6.3	93.7	100	51.4	48.6	100
Burera	*N*	13	399	412	88	324	412	15	397	412	188	224	412
	%	3.2	96.8	100	21.4	78.6	100	3.6	96.4	100	45.6	54.4	100
Gicumbi	*N*	22	392	414	113	301	414	0	414	414	152	262	414
	%	5.3	94.7	100	27.3	72.7	100	0	100	100	36.7	63.3	100
Rwamagana	*N*	57	356	413	120	293	413	11	402	413	258	155	413
	%	13.8	86.2	100	29.1	70.9	100	2.6	97.4	100	62.5	37.5	100
Nyagatare	*N*	60	382	442	164	278	442	8	434	442	258	184	442
	%	13.6	86.4	100	37.1	62.9	100	1.9	98.1	100	58.4	41.6	100
Gatsibo	*N*	42	372	414	110	304	414	0	414	414	204	210	414
	%	10.1	89.9	100	26.6	73.4	100	0	100	100	49.3	50.7	100
Kayonza	*N*	56	362	418	139	279	418	35	383	418	212	206	418
	%	13.4	86.6	100	33.3	66.7	100	8.3	91.7	100	50.7	49.3	100
Kirehe	*N*	101	367	468	146	322	468	10	458	468	272	196	468
	%	21.6	78.4	100	31.2	68.8	100	2.1	97.9	100	58.1	41.9	100
Ngoma	*N*	62	354	416	164	252	416	5	411	416	271	145	416
	%	14.9	85.1	100	39.4	60.6	100	1.3	98.7	100	65.1	34.9	100
Bugesera	*N*	33	407	440	118	322	440	19	421	440	176	264	440
	%	7.5	92.5	100	26.8	73.2	100	4.4	95.6	100	40	60	100
Total	*N*	1489	11460	12949	4751	8198	12949	423	12526	12949	6848	6101	12949
	%	11.5	88.5	100	36.7	63.3	100	3.3	96.7	100	52.9	47.1	100

		Handwashing facility			Water treatment			Safe water storage			Clean latrine		
		Yes	No	Total	Yes	No	Total	Yes	No	Total	Yes	No	Total
Region													
Kigali City	*N*	281	1294	1575	813	762	1575	50	1525	1575	1077	498	1575
	%	17.8	82.2	100	51.6	48.4	100	3.1	96.9	100	68.4	31.6	100
Southern	*N*	356	3037	3393	1143	2250	3393	108	3285	3393	1729	1664	3393
	%	10.5	89.5	100	33.7	66.3	100	2.7	97.3	100	51.0	49.0	100
Western	*N*	200	2698	2898	1072	1826	2898	107	2791	2898	1371	1527	2898
	%	6.9	93.1	100	37.0	63.0	100	3.4	96.6	100	47.3	52.7	100
Northern	*N*	242	1830	2072	762	1310	2072	70	2002	2072	1021	1051	2072
	%	11.7	88.3	100	36.8	63.2	100	3.6	96.4	100	49.3	50.7	100
Eastern	*N*	409	2602	3011	961	2050	3011	88	2923	3011	1650	1361	3011
	%	13.6	86.4	100	31.9	68.1	100	2.9	97.1	100	54.8	45.2	100
Total	*N*	1489	11460	12949	4751	8198	12949	423	12526	12949	6848	6101	12949
	%	11.5	88.5	100	36.7	63.3	100	3.3	96.7	100	52.9	47.1	100
Urban/rural													
Urban	*N*	552	2340	2892	1567	1325	2892	107	2785	2892	1932	960	2892
	%	19.1	80.9	100	54.2	45.8	100	3.5	96.5	100	66.8	33.2	100
Rural	*N*	937	9120	10057	3184	6873	10057	316	9741	10057	4916	5141	10057
	%	9.3	90.7	100	31.7	68.3	100	2.9	97.1	100	48.9	51.1	100
Total average	*N*	1489	11460	12949	4751	8198	12949	423	12526	12949	6848	6101	12949
	%	11.5	88.5	100	36.7	63.3	100	3.3	96.7	100	52.9	47.1	100
												Total sample	12,949

Variation of Household WASH Behaviors Over Time Between 2010 and 2020

A pairwise comparison design was used to assess the variation of household WASH behaviors over time between 2010 and 2020 (Tables 4, 5, 6, 7, and 8). The pairwise comparison shows the effect size ($F = 17.471$, $p < .001$) for water treatment, ($F = 11.343$, $p<.001$) for safe water storage, and ($F = 18.258$,$p<.001$) for safe sanitation, based on a Greenhouse-Geisser test within subjects (Table 4). The results in Table 5 show no statistically significant variation in handwashing occurred between 2010 and 2020.

Table 4. *Effect of Time on Household WASH Behaviors Between 2010 and 2020*

	Handwashing		Water treatment		Safe water storage		Safe sanitation	
Factor	*F*	Sig.	*F*	Sig.	*F*	Sig.	*F*	Sig.
Time	.317	.694	17.471	<.001	11.343	<.001	18.258	<.001

Table 5. *Variation of Household Handwashing Between 2010 and 2020*

(I) Handwashing facility	(J) Handwashing facility	Mean difference (I–J)	Std. error	Sig.	95% Confidence interval for difference	
					Lower bound	Upper bound
1	2	-2.007	2.956	.503	-8.052	4.038
	3	-.850	2.021	.677	-4.984	3.284
2	1	2.007	2.956	.503	-4.038	8.052
	3	1.157	2.521	.650	-4.000	6.313
3	1	.850	2.021	.677	-3.284	4.984
	2	-1.157	2.521	.650	-6.313	4.000

Table 6 shows a decrease in water treatment (μ = 13.230, 95%CI [8.609; 17.851], $p<.001$) between 2010 and 2020. Table 7 shows a decrease in safe water storage (μ = 4.430, 95%CI [2.400; 6.460], p<.001) between 2010 and 2020.

Table 6. *Variation of Household Water Treatment Between 2010 and 2020*

(I) Water treatment	(J) Water treatment	Mean difference (I–J)	Std. error	Sig.	95% Confidence interval for difference	
					Lower bound	Upper bound
1	2	3.800	2.281	.107	-.866	8.466
	3	13.230*	2.260	<.001	8.609	17.851
2	1	-3.800	2.281	.107	-8.466	.866
	3	9.430*	2.372	<.001	4.579	14.281
3	1	-13.230*	2.260	<.001	-17.851	-8.609
	2	-9.430*	2.372	<.001	-14.281	-4.579

* The mean difference is significant at the .05 level.

Table 7. *Variation of Household Water Storage Between 2010 and 2020*

(I) Safe water storage	(J) Safe water treatment	Mean difference (I–J)	Std. error	Sig.	95% Confidence interval for difference	
					Lower bound	Upper bound
1	2	3.723*	1.142	.003	1.388	6.059
	3	4.430*	.992	<.001	2.400	6.460
2	1	-3.723*	1.142	.003	-6.059	-1.388
	3	.707	.841	.408	-1.013	2.426
3	1	-4.430*	.992	<.001	-6.460	-2.400
	2	-.707	.841	.408	-2.426	1.013

* The mean difference is significant at the .05 level.

Table 8 shows an increase in household safe sanitation (use of clean toilets) ($\mu = 12.197$, 95%CI [8.158; 16.235], $p < .001$) between 2010–2020.

Table 8. *Variation of Household Safe Sanitation Between 2010 and 2020*

(I) Safe sanitation	(J) Safe sanitation	Mean difference (I–J)	Std. error	Sig.	95% Confidence interval for difference	
					Lower bound	Upper bound
1	2	-5.347*	2.073	.015	-9.586	-1.107
	3	-12.197*	1.975	<.001	-16.235	-8.158
2	1	5.347*	2.073	.015	1.107	9.586
	3	-6.850*	2.022	.002	-10.985	-2.715
3	1	12.197*	1.975	<.001	8.158	16.235
	2	6.850*	2.022	.002	2.715	10.985

* The mean difference is significant at the .05 level.

Relationship Between Household WASH Behaviors and Diarrhea Between 2010 and 2020

The linear regression design was used to assess the relationship between WASH behaviors, including household handwashing, water treatment, safe water storage, safe sanitation, and diarrhea between 2010 and 2020. The linear regression model does not demonstrate statistical significance in 2010, 2015, and 2020 (Tables 9, 10, and 11).

Table 9 shows that there was no statistically significant relationship between WASH behaviors, including household handwashing, water treatment, safe water storage, safe sanitation, and diarrhea in 2010. None of these behaviors were predictors of diarrhea in 2010.

Table 9. *Relationship Between Diarrhea and Household WASH Behaviors in 2010*

Health outcome: Diarrhea 2010				
Predictors	B	Sig.	95.0% Confidence interval for B	
			Lower bound	Upper bound
Handwashing facility 2010	.082	.380	-.106	.270
Water treatment 2010	-.083	.274	-.235	.069
Safe water storage 2010	.338	.113	-.085	.761
Safe sanitation 2010	-.132	.192	-.336	.071

Table 10 shows that none of the household behaviors, including handwashing, water treatment, safe water storage, and safe sanitation, were predictors of diarrhea in 2015. There was no statistically significant relationship between said behaviors and diarrhea in 2015.

Table 10. *Relationship Between Diarrhea and Household WASH Behaviors in 2015*

Health Outcome: Diarrhea 2015				
Predictors	B	Sig.	95.0% Confidence interval for B	
			Lower bound	Upper bound
Handwashing facility 2015	-.028	.765	-.219	.163
Water treatment 2015	.035	.671	-.134	.204
Safe water storage 2015	.275	.329	-.294	.845
Safe sanitation 2015	-.112	.245	-.307	.082

Table 11 shows that none of the household WASH behaviors, including handwashing, water treatment, safe water storage, and safe sanitation, was a predictor of diarrhea in 2020. There was no statistically significant relationship between said behaviors and diarrhea in 2020.

Table 11. *Relationship Between Diarrhea and Household WASH Behaviors in 2020*

Health Outcome: Diarrhea 2020				
Predictors	B	Sig.	95.0% Confidence interval for B	
			Lower bound	Upper bound
Handwashing facility 2020	-.089	.616	-.451	.273
Water treatment 2020	.164	.100	-.034	.362
Safe water storage 2020	.215	.642	-.724	1.154
Safe sanitation 2020	-.189	.122	-.432	.054

Discussion

Interpretation

In the linear regression analysis, the regression model did not reveal statistical significance. There was no relationship between household WASH behaviors and diarrhea in 2010, 2015, and 2020 (Tables 9, 10, and 11). The level of handwashing practice (the most cost-effective behavior to prevent the ingestion of pathogens and diarrhea in general) did not change between 2010 and 2020 (Table 5). Household water treatment and safe

water storage (Tables 6 and 7) decreased between 2010 and 2020. This lack of improvement in household WASH behaviors may be due to irregularities in the design and/or implementation of related interventions, which themselves can influence a sustainable adoption of safe behaviors while addressing the issue of underlying factors.

The increase in safe sanitation (12.197%; Table 8) between 2010 and 2020 had no effect on diarrhea between 2010 and 2020 (Table 11). Maybe the positive changes in sanitation observed were too small to trigger a significant reduction in diarrhea in the context of this study, which can explain the absence of a relationship between sanitation behavior and diarrhea among children under 5 years old. Additionally, the relationship may be influenced by the presence of other non-WASH factors playing the role of moderating variables that this study did not cover. The findings of this study are consistent with the study conducted by Sinharoy et al. (2017) in the Rusizi district of Rwanda, which found that improvements in home-based water treatment (20%) and sanitation (14%) between 2013 and 2015 had no effect on diarrhea.

On the other hand, a similar study conducted in Nepal showed that an increase in household safe sanitation (22%), coupled with an increase in safe water (40%) and handwashing (up to 35.3%), reduced diarrhea by 12%–85% (Meierhofer et al., 2023). Higher adoption and sustainability of WASH behaviors, including handwashing, drinking water treatment, safe water storage, and safe sanitation, are required to reduce the risks of diarrhea (Darvesh et al., 2027; Haque et al., 2022; Nguyen et al., 2012; Wolf et al., 2022). An experimental study conducted in Zambia by Quick et al. (2002) on household water treatment and safe storage, with a compliance of 97% chlorine use and 89.2% safe storage, showed a diarrhea risk reduction of 48% for individuals in the intervention households compared to the control households.

Local underlying factors, including motivators and inhibitors of adoption and sustainability of WASH interventions, must be considered in the context of the socioecological model for improved control of diarrhea (Alemu et al., 2017; Golden & Earp, 2012). Effective and consistent implementation of WASH interventions with a higher and sustainable rate of adoption is mandatory for improved and sustained diarrhea control (Chirgwin et al., 2021; Durlak & DuPre, 2008; Golden & Earp, 2012; Martin et al., 2018). Given the results of the present study, the fluctuations of WASH and non-WASH factors have had an antagonistic influence on the relationship between household WASH behaviors and diarrhea (moderator variables); these need to be investigated to address their potential for significant reduction of diarrhea (Bennion et al., 2021; Slekiene & Mosler, 2017). A systematic review conducted by Stelmach & Clasen (2015) on household water quantity and health indicated that an increase in water consumption is associated with a significant reduction of gastrointestinal parasites and diarrheal diseases in low- and middle-income countries. This variable, though very important, was not verified in this study because it could not be well defined from the datasets employed. The research findings of Nsabimana et al. (2017) and Negesse et al. (2021) showed additional household characteristics, including the prevalence of domestic violence, employment status, and education level, as having an association with diarrhea among children under 5 years old.

The research results of this study suggest the importance for stakeholders of being consistent and comprehensive in the design, implementation, and monitoring of diarrhea-related interventions for (a) maximum and sustainable adoption of household WASH behaviors and (b) a significant reduction of diarrhea among children under 5 years old across communities in Rwanda (Ahsan et al., 2017; Cavalcanti et al., 2019).

Limitations

Our study was limited to secondary data analysis and interpretation. The variables used in the study were defined in the context of Rwanda Demographic Health Surveys. We relied on the information provided by the survey respondents, irrespective of their intent, other than the survey purpose.

Conclusion

The study results did not find a statistically significant relationship between WASH behaviors (handwashing, water treatment, safe water storage, and use of clean toilets) and diarrhea among children under 5 years old between 2010 and 2020 in Rwanda. The variation of handwashing, household water treatment, safe water storage, and the use of clean toilets had no effect on diarrhea between 2010 and 2020. While effective and consistent implementation of WASH interventions for higher and sustainable rates of adoption of household WASH behaviors is a sine qua non-condition for significant reduction of diarrhea, there is a need to investigate (a) inhibitors of the maximum and sustainable adoption of household WASH behaviors and (b) moderating factors that can affect the relationship between household WASH behaviors and diarrhea among children under 5 years old.

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