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Association between household water treatment practices and diarrhea among children under five in Rwanda: a cross-sectional analysis of the 2019-20 Demographic and Health Survey

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Abstract

Background

Diarrhea is a leading cause of illness and death in children under five years. Household water treatment is widely promoted, but national evidence from Rwanda on its association with diarrhea is limited. We studied this association, identified other factors linked to diarrhea, and described differences across provinces and districts.

Methods

We analyzed the 2019-20 Rwanda Demographic and Health Survey (7756 children under five; weighted number 7978). Caregivers reported diarrhea in the two weeks before the survey. Water treatment meant any reported treatment of drinking water. We used weighted prevalence, chi-square tests and weighted multivariable logistic regression to estimate adjusted odds ratios (AOR) with 95% confidence intervals (CI), and we estimated odds ratios by province.

Results

Diarrhea prevalence was 14.3%, and 33.0% of children lived in households that treated drinking water. Diarrhea was less common with water treatment (13.1% versus 14.9%, P = 0.031), but not after adjustment (AOR 1.02, 95% CI 0.87 to 1.20). Soap at the handwashing place was linked to lower odds (AOR 0.75, 95% CI 0.63 to 0.89), but the estimate was weaker in a model that also adjusted for province (AOR 0.82, 95% CI 0.67 to 1.01). Odds were higher at age 12 to 23 months than under 12 months (AOR 2.09, 95% CI 1.66 to 2.61), and for children of mothers with no education than with higher education (AOR 2.67, 95% CI 1.32 to 5.37). Prevalence ranged from 11.4% in the Eastern Province to 18.6% in the Western Province. Water treatment was linked to lower odds of diarrhea only in Kigali City (odds ratio 0.56, 95% CI 0.36 to 0.85) and the Southern Province (odds ratio 0.66, 95% CI 0.48 to 0.92).

Conclusions

Household water treatment was not independently associated with diarrhea among children under five in Rwanda, although results differed by province. Child age, maternal education and handwashing materials were more closely linked to diarrhea. Programs should combine water treatment with handwashing promotion and support for maternal education. Cross-sectional, self-reported data limit causal inference.

Trial registration:

Not applicable.

Background

Diarrhea remains one of the leading causes of illness and death in children under five years. The World Health Organization (WHO) estimates that about 0.44 million children under five die from diarrhea each year [1]. Most of these deaths can be prevented, because a large share of diarrheal disease comes from unsafe drinking water, poor sanitation and poor hygiene [1, 2]. Sub-Saharan Africa carries a large share of the burden [3]. The risk is highest in infants and young children, especially in the first two years of life [4].

Treating drinking water at home is one of the main ways to protect children when the water supply is not safe. Boiling, chlorination, filtration and solar disinfection can all reduce the number of disease-causing microbes in water. Systematic reviews of trials show that these methods can reduce diarrhea in children [5, 6]. The size of the benefit depends on how consistently and correctly people use them [7], and water can become contaminated again between the source and the home [8]. In addition, many trials could not blind participants and relied on caregiver-reported diarrhea, which can make the benefit look larger than it is [9]. It is therefore not clear how much protection household water treatment gives when it is practiced in everyday life, outside of trials.

Rwanda has expanded access to water services, but the quality of water at the point of use is still a concern. The 2019-20 Rwanda Demographic and Health Survey (RDHS) found that about 80% of households used an improved source of drinking water, yet only 35% treated their water with an appropriate method, and boiling was the most common method [10]. A national study found fecal contamination in most household drinking water samples, and only about one in four samples met WHO guidelines [11]. Water kept in household containers in rural Rwanda has also been found not to meet national standards [12]. Programs have promoted chlorine solution and water filters [13–15], and a cluster randomized trial in Western Province reported that filters improved water quality and lowered caregiver-reported diarrhea in children [14].

The 2019-20 RDHS also reported that 14% of children under five had diarrhea in the two weeks before the survey, with the highest levels in the Western Province [10]. A previous analysis of the same survey described the spatial clustering of diarrhea and its general determinants, and found clusters in the Western and Northern provinces [16]. We are not aware of a national analysis that looks at how household water treatment itself is related to diarrhea in Rwandan children, or at whether this relationship differs between provinces. Household surveys such as the Demographic and Health Surveys (DHS) are widely used to measure how common household water treatment is [17], and treatment remains uncommon in much of sub-Saharan Africa [18].

We therefore used the 2019-20 RDHS to examine the association between household water treatment and diarrhea among children under five years. We also identified sociodemographic and hygiene factors linked to diarrhea, and described differences in water treatment and diarrhea across provinces and districts.

Methods

Study design and data source

This was a cross-sectional study based on a secondary analysis of the 2019-20 RDHS. We report it following the STROBE guideline for observational studies [19]. The RDHS was carried out by the National Institute of Statistics of Rwanda with the Ministry of Health. Data were collected from November 2019 to July 2020, with a pause during the COVID-19 lockdown [10]. We obtained the dataset from the DHS Program after approval of a data use request [20].

Sampling in the RDHS

The survey used a two-stage stratified cluster design. Rwanda was divided into 60 strata, made up of the urban and rural parts of each of the 30 districts. In the first stage, 500 enumeration areas (112 urban and 388 rural) were chosen from the 2012 population and housing census frame with probability proportional to size. In the second stage, 26 households were selected from each enumeration area, giving a total of 13000 households. Because the sample size was about equal across districts, the sample is not self-weighting, and sample weights are provided with the data [10].

Study population

The analysis file contained 7796 children under five years from the sampled households. We excluded 40 children whose diarrhea status was recorded as unknown, which left 7756 children (weighted number 7978). No child was excluded because of missing information on water treatment.

Outcome and exposure

The outcome was diarrhea, defined as a caregiver report that the child had diarrhea in the two weeks before the survey (yes or no). The main exposure was household water treatment. It was based on the household question on whether anything was usually done to the water to make it safe to drink. A household was classed as treating its water if it reported at least one treatment method recorded by the survey. The methods were boiling, adding bleach or chlorine, straining through a cloth, using a water filter, solar disinfection, letting the water stand and settle, bottled water, and other methods. We also examined each method separately.

Other variables

We grouped the other variables by level, following our conceptual framework of child, maternal, household and regional factors. Child variables were age in months (0–11, 12–23, 24–35, 36–47 and 48–59), sex, preceding birth interval and twin or multiple birth. Maternal variables were age, marital

status, education, literacy and religion. Household variables were the wealth index (quintiles, calculated separately for urban and rural areas), residence, province, floor and wall material, source of drinking water, time to collect water, distance to the water source, toilet type, toilet sharing, toilet location, and stored drinking water. Improved water source and improved sanitation were classified by the type of source or facility, following DHS categories [10]. Hygiene was measured by whether interviewers saw soap or detergent at the place where household members wash their hands. Children with no information on soap (1386 children, 17.9%) were grouped with those without soap. Questions on stored drinking water and the type of storage container were asked only in households that treat their water.

Statistical analysis

We analyzed the data with Stata version 16. We declared the survey design in Stata with the svyset command, using the primary sampling unit, the sampling strata and the DHS sample weight (V005 divided by 1000000), and used survey-adjusted estimation in all analyses. We calculated weighted prevalence of diarrhea and used weighted chi-square tests for crude associations. We then fitted two weighted multivariable logistic regression models and report adjusted odds ratios (AOR) with 95% confidence intervals (CI).

Model 1 looked for sociodemographic and household factors linked to diarrhea. It included child age, sex, preceding birth interval and multiple birth, marital status, maternal education, wealth index, residence, province, floor and wall material, time to collect water, toilet sharing, improved water source, improved sanitation, and soap. Model 2 focused on water, sanitation and hygiene. It included any water treatment, improved water source, improved sanitation and soap, and was adjusted for child age, wealth index, maternal education, residence, time to collect water, toilet sharing, and floor and wall material. We chose the variables from those available in the DHS data, based on earlier studies and our conceptual framework.

To describe regional differences, we calculated weighted crude odds ratios (OR) for the association between any water treatment and diarrhea separately in each province. We also calculated weighted diarrhea prevalence and water treatment coverage for each of the 30 districts and mapped them. Districts were grouped into three equal-sized groups (tertiles) of treatment coverage. The district boundary files used for the maps were taken from the official survey boundaries for the survey year, which are aligned with the administrative boundaries of the National Institute of Statistics of Rwanda. We compared the two district measures using Pearson and Spearman correlation coefficients. A two-sided P value below 0.05 was taken as statistically significant.

Results

Characteristics of the children and households

The analysis included 7756 children (Table 1). Most mothers were aged 25 to 34 years (48.9%) and about half were married (51.7%). Most households lived in rural areas (78.8%). The largest shares of children were in the Western (25.6%) and Eastern (24.0%) provinces. Most mothers had primary education (65.1%), 11.3% had no education, and 25.7% of children lived in households in the poorest wealth quintile. Children were spread evenly across the five age groups, and 50.6% were boys.

Table 1
Characteristics of the 7756 children under five included in the analysis

Characteristic	Children (n)	%
Mother's age (yr)		
15–19	118	1.5
20–24	1104	14.2
25–34	3796	48.9
35–49	2738	35.3
Marital status		
Never in union	683	8.8
Married	4007	51.7
Living with partner	2462	31.7
Widowed	105	1.4
Divorced	171	2.2
No longer together	328	4.2
Province		
Kigali	917	11.8
South	1767	22.8
West	1987	25.6
North	1224	15.8
East	1861	24.0
Residence		
Urban	1645	21.2
Rural	6111	78.8
Mother's education level		
No education	873	11.3
Primary	5050	65.1
Secondary	1451	18.7
Counts and percentages are unweighted.		

Characteristic	Children (n)	%
Mother's age (yr)		
Higher	382	4.9
Wealth index		
Poorest	1993	25.7
Poorer	1581	20.4
Middle	1508	19.4
Richer	1394	18.0
Richest	1280	16.5
Literacy		
Cannot read at all	1368	17.6
Able to read only parts of sentence	841	10.8
Able to read whole sentence	5540	71.4
Blind/visually impaired	7	0.1
Religion		
Catholic	2662	34.3
Protestant	3820	49.3
Adventist	985	12.7
Muslim	149	1.9
Jehovah witness	42	0.5
No religion	80	1.0
Other	17	0.2
Child's age (month)		
0–11	1570	20.2
12–23	1569	20.2
24–35	1578	20.3
36–47	1554	20.0
48–59	1485	19.1
Counts and percentages are unweighted.		

Characteristic	Children (n)	%
Mother's age (yr)		
Child's sex		
Male	3921	50.6
Female	3835	49.4
Counts and percentages are unweighted.		

[Table 1]

Prevalence of diarrhea and water treatment

The weighted prevalence of diarrhea in the two weeks before the survey was 14.3%. Households of 33.0% of children treated their drinking water (33.6% without weights). Boiling was by far the most common method. It was reported for 2419 children (31.2%, unweighted), followed by water filters for 113 children (1.5%) and bleach or chlorine for 107 children (1.4%). Straining through a cloth, solar disinfection, letting the water settle, bottled water and other methods were each reported for fewer than 25 children.

Crude associations with diarrhea

Diarrhea prevalence differed by several child, maternal and household characteristics (Table 2). It fell with increasing maternal age, from 22.1% in children of mothers aged 15 to 19 years to 12.4% in children of mothers aged 35 to 49 years ($P < 0.001$). It was 16.9% among children of mothers with no education and 6.3% among those of mothers with higher education ($P < 0.001$). It was higher in the poorest wealth quintile (17.5%) than in the richest (11.2%) ($P < 0.001$), and higher in rural areas (14.9%) than in urban areas (11.6%) ($P = 0.002$). Children aged 12 to 23 months had the highest prevalence (25.0%), and prevalence fell to 6.5% at 48 to 59 months ($P < 0.001$). Twins and children from multiple births had higher prevalence (20.8%) than single births (14.1%) ($P = 0.009$). Child sex and preceding birth interval were not associated with diarrhea. Children living in homes with unimproved floors (15.6% versus 11.5%) or unimproved walls (16.1% versus 11.9%) had higher prevalence (both $P < 0.001$).

Table 2
Diarrhea prevalence by sociodemographic and housing characteristics (weighted estimates)

Characteristic	Children (n)	Weighted N	Weighted diarrhea cases	Prevalence (%)	P[a]
Mother's age (years)					**< 0.001**
15–19	118	119.8	26.4	22.1	
20–24	1104	1141.8	191.0	16.7	
25–34	3796	3918.0	575.2	14.7	
35–49	2738	2798.6	348.3	12.4	
Marital status					**0.009**
Never in union	683	676.2	112.3	16.6	
Married	4007	4054.9	521.0	12.8	
Living with partner	2462	2606.5	401.1	15.4	
Widowed	105	105.6	17.7	16.7	
Divorced	171	169.5	27.3	16.1	
No longer together	328	365.6	61.6	16.9	
Province					**< 0.001**
Kigali	917	1129.6	132.8	11.8	
South	1767	1592.6	211.0	13.2	
West	1987	1928.9	357.8	18.6	
North	1224	1208.4	196.9	16.3	
East	1861	2118.7	242.4	11.4	
Residence					**0.002**
Urban	1645	1403.2	162.9	11.6	
Rural	6111	6575.0	978.0	14.9	
Mother's education level					**< 0.001**
No education	873	910.8	154.1	16.9	

[a] P value from a weighted chi-square test for each variable. Weighted N is the sum of sample weights. Prevalence is weighted diarrhea cases divided by weighted N, multiplied by 100.

Characteristic	Children (n)	Weighted N	Weighted diarrhea cases	Prevalence (%)	P[a]
Mother's age (years)					**< 0.001**
Primary	5050	5166.9	762.4	14.8	
Secondary	1451	1547.2	202.1	13.1	
Higher	382	353.4	22.3	6.3	
Wealth index					**< 0.001**
Poorest	1993	1875.9	328.0	17.5	
Poorer	1581	1604.3	266.0	16.6	
Middle	1508	1591.8	216.9	13.6	
Richer	1394	1474.9	170.1	11.5	
Richest	1280	1431.4	160.0	11.2	
Literacy					**< 0.001**
Cannot read at all	1368	1411.7	263.0	18.6	
Able to read only parts of sentence	841	831.6	102.3	12.3	
Able to read whole sentence	5540	5729.6	775.1	13.5	
Blind/visually impaired	7	5.4	0.6	11.2	
Religion					**0.019**
Catholic	2662	2650.2	330.4	12.5	
Protestant	3820	4018.6	621.0	15.5	
Adventist	985	1017.7	144.7	14.2	
Muslim	149	144.4	18.4	12.8	
Jehovah witness	42	49.9	5.5	11.1	
No religion	80	75.0	15.9	21.2	
Other	17	21.5	4.9	22.8	

[a] P value from a weighted chi-square test for each variable. Weighted N is the sum of sample weights. Prevalence is weighted diarrhea cases divided by weighted N, multiplied by 100.

Characteristic	Children (n)	Weighted N	Weighted diarrhea cases	Prevalence (%)	P[a]
Mother's age (years)					**< 0.001**
Child's age (months)					**< 0.001**
0–11	1570	1626.8	244.1	15.0	
12–23	1569	1630.0	408.0	25.0	
24–35	1578	1622.0	238.1	14.7	
36–47	1554	1583.0	151.4	9.6	
48–59	1485	1516.5	99.3	6.5	
Child's sex					**0.128**
Male	3921	4022.4	599.5	14.9	
Female	3835	3955.8	541.4	13.7	
Preceding birth interval					**0.399**
<1 year	32	37.7	5.5	14.7	
1–2 years	789	834.9	118.2	14.2	
2–3 years	1533	1584.2	224.8	14.2	
4–5 years	1950	2010.2	294.2	14.6	
6–10 years	1307	1331.2	164.5	12.4	
11 + years	162	158.8	27.4	17.3	
Twin or multiple birth					**0.009**
Single birth	7554	7771.7	1098.0	14.1	
Twin/multiple	202	206.5	43.0	20.8	
Main floor material					**< 0.001**
Improved	2398	2518.0	289.5	11.5	
Unimproved	5260	5350.1	834.8	15.6	

[a] P value from a weighted chi-square test for each variable. Weighted N is the sum of sample weights. Prevalence is weighted diarrhea cases divided by weighted N, multiplied by 100.

Characteristic	Children (n)	Weighted N	Weighted diarrhea cases	Prevalence (%)	P[a]
Mother's age (years)					**< 0.001**
Main wall material					**< 0.001**
Improved	3272	3449.6	411.5	11.9	
Unimproved	4386	4418.5	712.8	16.1	

[a] P value from a weighted chi-square test for each variable. Weighted N is the sum of sample weights. Prevalence is weighted diarrhea cases divided by weighted N, multiplied by 100.

[Table 2]

Among water, sanitation and hygiene characteristics (Table 3), diarrhea was less common in households that treated water than in those that did not (13.1% versus 14.9%, P = 0.031). Boiling showed a similar difference that was borderline (13.1% versus 14.8%, P = 0.053). The other treatment methods were rare and showed no clear differences. Prevalence was lowest when water was available on the premises (10.7%) and rose to 16.7% when the round trip to the water source took 61 to 180 minutes (P = 0.001). Prevalence was lower with improved sanitation (13.6% versus 16.1%, P = 0.003) and when the toilet was inside the dwelling (6.7%) than in the yard (13.2%) or elsewhere (16.6%) (P < 0.001). Soap or detergent at the handwashing place was linked to lower prevalence (10.7% versus 15.5%, P < 0.001). Among households that treated their water, prevalence was lower in those that stored drinking water (12.8%) than in those that did not (19.6%) (P = 0.041), but only 127 children were in the group without storage. An improved water source was not significantly associated with diarrhea (14.0% versus 15.4%, P = 0.147).

Table 3
Diarrhea prevalence by water treatment, water, sanitation and hygiene characteristics (weighted estimates)

Characteristic	Children (n)	Weighted N	Weighted diarrhea cases	Prevalence (%)	P[a]
Any water treatment					**0.031**
Yes	2603	2631.7	344.1	13.1	
No	5153	5346.5	796.8	14.9	
Boiling					**0.053**
Yes	2419	2445.0	321.2	13.1	
No	5337	5533.3	819.7	14.8	
Adding bleach or chlorine					**0.264**
Yes	107	104.2	10.4	10.0	
No	7649	7874.0	1130.5	14.4	
Using a water filter					**1.000**
Yes	113	109.1	15.2	13.9	
No	7643	7869.1	1125.8	14.3	
Straining through a cloth					**0.318**
Yes	14	11.9	0.0	0.0	
No	7742	7966.3	1140.9	14.3	
Solar disinfection					**1.000**
Yes	1	1.0	0.0	0.0	
No	7755	7977.2	1140.9	14.3	
Letting water stand and settle					**0.692**
Yes	6	5.8	0.0	0.0	
No	7750	7972.4	1140.9	14.3	

[a] P value from a weighted chi-square test for each variable. [b] Recorded only for households that treat their water (n = 2603). [c] Seen by interviewers at the place where household members wash their hands. Children with no information on soap (n = 1386) are included in the No group. Prevalence is weighted diarrhea cases divided by weighted N, multiplied by 100.

Characteristic	Children (n)	Weighted N	Weighted diarrhea cases	Prevalence (%)	P[a]
Any water treatment					**0.031**
Bottled water					**0.135**
Yes	22	26.8	0.6	2.3	
No	7734	7951.5	1140.3	14.3	
Other treatment method					**0.878**
Yes	5	4.3	0.0	0.0	
No	7751	7974.0	1140.9	14.3	
Improved drinking water source					**0.147**
Yes	6098	6274.6	878.2	14.0	
No	1658	1703.7	262.7	15.4	
Time to water source					**0.001**
On premises	1356	1350.2	145.1	10.7	
<15 minutes	1149	1148.6	164.5	14.3	
15–29 minutes	1329	1376.6	191.9	13.9	
30 minutes	1135	1158.7	169.3	14.6	
31–60 minutes (Limited)	2077	2178.0	342.8	15.7	
61–180 minutes (High risk)	686	740.9	123.8	16.7	
>180 minutes (High risk)	22	23.3	2.6	11.3	
Distance to water source					**0.163**
Less than 200 meters	1755	1750.5	239.1	13.7	
200–500 meters	2289	2358.0	361.0	15.3	

[a] P value from a weighted chi-square test for each variable. [b] Recorded only for households that treat their water (n = 2603). [c] Seen by interviewers at the place where household members wash their hands. Children with no information on soap (n = 1386) are included in the No group. Prevalence is weighted diarrhea cases divided by weighted N, multiplied by 100.

Characteristic	Children (n)	Weighted N	Weighted diarrhea cases	Prevalence (%)	P[a]
Any water treatment					**0.031**
More than 500 meters	2349	2511.5	394.6	15.7	
Location of water source					**0.209**
In own dwelling	7	6.2	0.9	14.9	
In own yard/plot	58	59.5	13.8	23.3	
Elsewhere	6408	6635.2	997.0	15.0	
Drinking water stored[b]					**0.041**
Yes	2476	2508.9	320.1	12.8	
No	127	122.9	24.0	19.6	
Observed water container[b]					**0.152**
Jerry can	2245	2269.6	277.7	12.2	
Bottle	81	85.8	8.1	9.5	
Water filter	40	42.2	6.5	15.4	
Cooking pot	2	1.8	0.0	0.0	
Pot	2	3.3	0.0	0.0	
Other	46	50.5	12.1	24.0	
Improved sanitation					**0.003**
Yes	5470	5691.7	772.0	13.6	
No	2286	2286.6	368.9	16.1	
Toilet shared with other households					**0.074**
No	6166	6230.7	868.4	13.9	
Yes	1352	1506.8	237.7	15.8	

[a] P value from a weighted chi-square test for each variable. [b] Recorded only for households that treat their water (n = 2603). [c] Seen by interviewers at the place where household members wash their hands. Children with no information on soap (n = 1386) are included in the No group. Prevalence is weighted diarrhea cases divided by weighted N, multiplied by 100.

Characteristic	Children (n)	Weighted N	Weighted diarrhea cases	Prevalence (%)	P[a]
Any water treatment					**0.031**
Location of toilet facility					**< 0.001**
In own dwelling	198	180.6	12.1	6.7	
In own yard/plot	4473	4679.0	617.4	13.2	
Elsewhere	2847	2877.9	476.6	16.6	
Soap or detergent at handwashing place[c]					**< 0.001**
Yes	1903	2011.0	214.8	10.7	
No	5853	5967.2	926.1	15.5	

[a] P value from a weighted chi-square test for each variable. [b] Recorded only for households that treat their water (n = 2603). [c] Seen by interviewers at the place where household members wash their hands. Children with no information on soap (n = 1386) are included in the No group. Prevalence is weighted diarrhea cases divided by weighted N, multiplied by 100.

[Table 3]

Factors independently associated with diarrhea

In Model 1 (Table 4), child age remained strongly associated with diarrhea. Compared with children aged 0 to 11 months, children aged 12 to 23 months had higher odds (AOR 2.09, 95% CI 1.66 to 2.61), whereas children aged 36 to 47 months (AOR 0.70, 95% CI 0.54 to 0.91) and 48 to 59 months (AOR 0.43, 95% CI 0.32 to 0.58) had lower odds. Maternal education was also associated with diarrhea. Compared with mothers with higher education, the odds were higher for children of mothers with no education (AOR 2.67, 95% CI 1.32 to 5.37), primary education (AOR 2.24, 95% CI 1.15 to 4.38) and secondary education (AOR 2.06, 95% CI 1.05 to 4.04). Twins and children from multiple births had higher odds than single births (AOR 1.57, 95% CI 1.02 to 2.41). Children in households more than 60 minutes from water had higher odds than those with water on the premises (AOR 1.49, 95% CI 1.02 to 2.17). Compared with Kigali City, children in the Southern Province (AOR 0.71, 95% CI 0.51 to 1.00) and the Eastern Province (AOR 0.65, 95% CI 0.47 to 0.91) had lower odds. Wealth index, residence, marital status, child sex, birth interval, toilet sharing, improved water source and improved sanitation were not significantly associated with diarrhea. The odds were lower where soap was present, but this was borderline (AOR 0.82, 95% CI 0.67 to 1.01, P = 0.058).

Table 4
Adjusted odds ratios of diarrhea from the sociodemographic and household model (Model 1)

Variable	AOR	95% CI	P
Child's age (months)			
0–11 (reference)	1.00		
12–23	2.09	1.66–2.61	< 0.001
24–35	1.16	0.91–1.48	0.225
36–47	0.70	0.54–0.91	0.008
48–59	0.43	0.32–0.58	< 0.001
Marital status			
No longer together (reference)	1.00		
Married	0.75	0.50–1.12	0.157
Living with partner	0.83	0.55–1.25	0.369
Widowed	0.86	0.42–1.73	0.667
Divorced	1.03	0.56–1.90	0.924
Never in union	0.93	0.54–1.59	0.796
Wealth index			
Richest (reference)	1.00		
Poorest	0.96	0.63–1.46	0.839
Poorer	1.01	0.69–1.47	0.978
Middle	0.74	0.52–1.07	0.113
Richer	0.78	0.56–1.08	0.138
Mother's education level			
Higher (reference)	1.00		
No education	2.67	1.32–5.37	0.006
Primary	2.24	1.15–4.38	0.018
Secondary	2.06	1.05–4.04	0.037

AOR, adjusted odds ratio; CI, confidence interval. Weighted logistic regression using the DHS sample weight. It did not include water treatment. [b] Seen by interviewers at the place where household members wash their hands.

Variable	AOR	95% CI	P
Child's age (months)			
Type of residence			
Urban (reference)	1.00		
Rural	1.15	0.86–1.54	0.352
Province			
Kigali (reference)	1.00		
South	0.71	0.51-1.00	0.048
West	1.07	0.78–1.46	0.680
North	1.04	0.73–1.48	0.817
East	0.65	0.47–0.91	0.013
Child's sex			
Male (reference)	1.00		
Female	0.93	0.80–1.09	0.392
Preceding birth interval			
2–3 years (reference)	1.00		
Less than 1 year	1.05	0.36–3.08	0.927
1–2 years	1.04	0.80–1.35	0.791
4–5 years	1.15	0.94–1.41	0.172
6–10 years	0.90	0.71–1.13	0.361
11 + years	1.25	0.78–2.01	0.360
Twin or multiple birth			
Single birth (reference)	1.00		
Twin/multiple	1.57	1.02–2.41	0.042
Time to water source			
On premises (reference)	1.00		

AOR, adjusted odds ratio; CI, confidence interval. Weighted logistic regression using the DHS sample weight. It did not include water treatment. [b] Seen by interviewers at the place where household members wash their hands.

Variable	AOR	95% CI	P
Child's age (months)			
Less than 15 min	1.12	0.80–1.57	0.506
15–30 min	1.07	0.78–1.46	0.692
31–60 min	1.21	0.88–1.67	0.249
>60 min	1.49	1.02–2.17	0.038
Toilet shared with other households			
No (reference)	1.00		
Yes	1.17	0.94–1.47	0.168
Improved drinking water source			
Yes versus no	1.06	0.87–1.29	0.566
Improved sanitation			
Yes versus no	0.92	0.77–1.11	0.387
Soap or detergent at handwashing place[b]			
Yes versus no	0.82	0.67–1.01	0.058

AOR, adjusted odds ratio; CI, confidence interval. Weighted logistic regression using the DHS sample weight. It did not include water treatment. [b] Seen by interviewers at the place where household members wash their hands.

[Table 4]

In Model 2 (Table 5), any water treatment was not associated with diarrhea after adjustment (AOR 1.02, 95% CI 0.87 to 1.20, P = 0.786). Improved water source (AOR 1.09, 95% CI 0.92 to 1.29) and improved sanitation (AOR 0.97, 95% CI 0.83 to 1.14) were also not associated. Soap or detergent at the handwashing place was the only water, sanitation or hygiene variable linked to lower odds of diarrhea (AOR 0.75, 95% CI 0.63 to 0.89, P = 0.001). Children in households that shared a toilet had higher odds (AOR 1.23, 95% CI 1.03 to 1.47). The associations with child age and maternal education were similar to those in Model 1. Children aged 12 to 23 months had higher odds (AOR 1.92, 95% CI 1.59 to 2.31), and children of mothers with no education had higher odds than children of mothers with higher education (AOR 2.35, 95% CI 1.38 to 3.99).

Table 5
Adjusted odds ratios of diarrhea from the water, sanitation and hygiene model (Model 2)

Variable	AOR	95% CI	P
Water, sanitation and hygiene variables			
Any water treatment (yes versus no)	1.02	0.87–1.20	0.786
Improved drinking water source (yes versus no)	1.09	0.92–1.29	0.307
Improved sanitation (yes versus no)	0.97	0.83–1.14	0.723
Soap or detergent at handwashing place (yes versus no)[b]	0.75	0.63–0.89	0.001
Child's age (reference 0–11 months)			
12–23 months	1.92	1.59–2.31	< 0.001
24–35 months	0.98	0.80–1.21	0.866
36–47 months	0.63	0.50–0.79	< 0.001
48–59 months	0.41	0.32–0.53	< 0.001
Wealth index (reference richest)			
Poorest	1.14	0.81–1.62	0.446
Poorer	1.14	0.83–1.56	0.413
Middle	0.92	0.68–1.25	0.599
Richer	0.85	0.64–1.12	0.248
Mother's education (reference higher)			
No education	2.35	1.38–3.99	0.002
Primary	1.97	1.20–3.24	0.007
Secondary	1.86	1.14–3.05	0.013
Residence (reference urban)			
Rural	1.09	0.85–1.38	0.509
Time to water source (reference on premises)			
Less than 15 min	1.08	0.82–1.43	0.591
15–30 min	1.09	0.84–1.41	0.529

AOR, adjusted odds ratio; CI, confidence interval. Weighted logistic regression using the DHS sample weight. The model was adjusted for all variables listed. It did not include province. [b] Seen by interviewers at the place where household members wash their hands.

Variable	AOR	95% CI	P
Water, sanitation and hygiene variables			
31–60 min	1.18	0.90–1.54	0.235
More than 60 min	1.27	0.93–1.75	0.133
Toilet shared with other households (reference no)			
Yes	1.23	1.03–1.47	0.025
Main floor material (reference improved)			
Unimproved	1.05	0.82–1.34	0.726
Main wall material (reference improved)			
Unimproved	1.19	0.98–1.44	0.079

AOR, adjusted odds ratio; CI, confidence interval. Weighted logistic regression using the DHS sample weight. The model was adjusted for all variables listed. It did not include province. [b] Seen by interviewers at the place where household members wash their hands.

[Table 5]

Differences between provinces and districts

Diarrhea prevalence was highest in the Western Province (18.6%) and the Northern Province (16.3%), and lower in the Southern Province (13.2%), Kigali City (11.8%) and the Eastern Province (11.4%) (Table 6). Household water treatment was most common in Kigali City (46.4%) and similar in the other provinces (29.2% to 32.8%). Kigali City also had the highest coverage of improved water (96.9%) and improved sanitation (92.2%).

Table 6
Diarrhea, water treatment and service coverage by province (weighted percentages)

Province	Children (n)	Diarrhea (%)	Any water treatment (%)	Improved water source (%)	Improved sanitation (%)
Kigali City	917	11.8	46.4	96.9	92.2
South	1767	13.2	29.2	79.6	62.2
West	1987	18.6	32.8	76.0	73.0
North	1224	16.3	32.4	80.5	56.0
East	1861	11.4	29.2	69.5	74.3

Children (n) is unweighted.

[Table 6]

The association between water treatment and diarrhea differed by province (Table 7). Treatment was linked to lower odds of diarrhea in Kigali City (OR 0.56, 95% CI 0.36 to 0.85, P = 0.007) and in the Southern Province (OR 0.66, 95% CI 0.48 to 0.92, P = 0.013). There was no clear association in the Western Province (OR 0.90, 95% CI 0.70 to 1.15), the Northern Province (OR 0.82, 95% CI 0.59 to 1.15) or the Eastern Province (OR 1.02, 95% CI 0.75 to 1.38). These province estimates are crude.

Table 7
Province-specific odds ratios for the association between water treatment and diarrhea

Province	Children (n)	OR	95% CI	P
Kigali City	917	0.56	0.36–0.85	0.007
South	1767	0.66	0.48–0.92	0.013
West	1987	0.90	0.70–1.15	0.413
North	1224	0.82	0.59–1.15	0.254
East	1861	1.02	0.75–1.38	0.921

OR, odds ratio; CI, confidence interval. Crude weighted logistic regression of diarrhea on any water treatment (yes versus no), fitted separately in each province. Differences between provinces were not formally tested.

[Table 7]

District estimates are shown in Figs. 1, 2 and 3. Diarrhea prevalence ranged from 5.0% in Rwamagana to 24.3% in Nyabihu, and treatment coverage ranged from 9.8% in Gisagara to 51.1% in Kicukiro. The average of the 30 district values was 14.2% for diarrhea and 32.5% for treatment. The highest prevalence was in Nyabihu (24.3%), Ngororero (22.1%), Nyaruguru (20.8%), Nyamasheke (20.6%) and Gicumbi (19.9%). Treatment coverage was highest in Kicukiro (51.1%), Nyarugenge (50.3%), Rubavu (46.6%), Karongi (46.1%) and Muhanga (45.4%). At district level, the correlation between treatment coverage and diarrhea prevalence was weak and not statistically significant (Pearson r = 0.15, P = 0.43; Spearman rho = 0.11, P = 0.57). The maps show why. Nyabihu had high treatment coverage (43.4%) and the highest diarrhea prevalence, while Gatsibo had low coverage (24.4%) and one of the lowest prevalence values (5.4%).

Panel A shows the weighted percentage of children under five who had diarrhea in the two weeks before the survey in each of the 30 districts. Panel B shows the weighted percentage of households that treat their drinking water. Bold lines mark provinces and thin lines mark districts. Blue areas are water bodies. District boundaries are the official survey boundaries aligned with National Institute of Statistics of Rwanda administrative boundaries. Source: Rwanda Demographic and Health Survey 2019-20.

Districts are shaded by tertile of household water treatment coverage: high (38% or more), medium (27% to under 38%) and low (under 27%). The number under each district name is the weighted percentage of children under five with diarrhea. Source: Rwanda Demographic and Health Survey 2019-20.

Panel A ranks districts by weighted diarrhea prevalence among children under five. Panel B ranks districts by weighted household water treatment coverage. Dashed lines show the mean of the 30 district values (14.2% for diarrhea and 32.5% for water treatment). Darker bars mark the 15 districts with the highest values. Source: Rwanda Demographic and Health Survey 2019-20.

Discussion

In this national analysis of children under five in Rwanda, diarrhea was somewhat less common in households that treated their drinking water, but this difference did not remain after we accounted for child, maternal and household characteristics. Soap at the handwashing place, child age and maternal education were more closely linked to diarrhea. Provinces differed in both diarrhea and water treatment, and treatment was linked to lower odds of diarrhea only in Kigali City and the Southern Province.

The lack of an adjusted association should not be read as showing that water treatment does not work. Trials and reviews show that treatment can reduce diarrhea when it is used correctly and consistently [5, 6, 14]. Our exposure was a single yes or no answer on whether the household usually treats its water. It does not show how often water is treated, whether the method is used correctly, or whether treated water is kept safe. Protection falls quickly when use is not consistent [7], and water can be contaminated again during storage [8]. Studies in Rwanda have found contaminated water in household containers [11, 12]. Boiling accounted for nearly all treatment in our data, and its effectiveness in real homes depends on how it is done [21]. The crude difference we saw may also reflect who treats water. Treatment was most common in Kigali City, where water and sanitation services are better, and treating households may differ from others in education and income. Finally, households with a sick child may start treating water after illness begins. This would hide a protective effect in a cross-sectional design.

Soap or detergent at the handwashing place was the only water, sanitation or hygiene variable that was linked to lower odds of diarrhea in Model 2. This agrees with evidence that handwashing with soap lowers the risk of diarrhea [22–24]. We interpret it with care for three reasons. First, the estimate became weaker and borderline when province and other factors were added in Model 1. Second, soap seen at a handwashing place is a marker of a household, not a measure of handwashing behavior, and it is likely to go together with education and income. Third, children with no information on soap made up 17.9% of the sample and were grouped with children from households without soap.

The strong links with child age and maternal education fit earlier work. Diarrhea is most common in the second year of life, when children begin complementary foods and move around more [3, 4]. Children of mothers with more education had lower odds of diarrhea, which is consistent with earlier DHS analyses of water, sanitation and child health [25]. The estimate for twins and multiple births is based on 202 children and has a wide confidence interval, so it should be treated cautiously. The higher odds among

children with a long trip to water, and among those in households that share a toilet, point to the effect of crowding and limited access to services, although the second finding appeared only in Model 2. We found no independent link with improved water source or improved sanitation. These indicators describe the type of facility and not the safety of the water or whether the facility is used. This agrees with trial evidence that a sanitation program did not reduce diarrhea when use and coverage were limited [26], although a multi-country DHS analysis reported lower diarrhea among rural children with access to both improved water and sanitation [27].

Diarrhea was most common in the Western and Northern provinces, which matches the clusters reported in an earlier analysis of the same survey [16]. The protective association with water treatment in Kigali City and the Southern Province, but not elsewhere, may reflect differences in water quality, in how consistently treatment is done, and in other household conditions. Earlier national testing found poorer household water quality in the Eastern Province and in rural areas [11]. However, we did not test whether the association differed by province, and the province estimates are crude, so some of the differences may be due to chance. At district level, treatment coverage and diarrhea were not correlated. Group-level patterns can differ from patterns in individuals, and this should be kept in mind when reading maps of areas [28, 29]. The district maps are descriptive and each district has only a few hundred children.

Strengths and limitations

The main strengths of this study are the large national sample, the high survey response, and the use of survey weights. The overall prevalence and the patterns by child age, residence, province and maternal education are in line with the official RDHS report [10]. The study also has limits. The design is cross-sectional, so we cannot say which factor came first, and we cannot show cause and effect. Diarrhea and water treatment were reported by caregivers, and recall and reporting bias are possible [30]. Water treatment was recorded as one yes or no item, without checking use, correct practice or water quality. Soap was recorded by observation at the handwashing place and had missing information. The two models did not contain the same variables: Model 1 did not include water treatment, and Model 2 did not include province. We did not use multilevel models, did not test for differences by province, and could not adjust for factors that were not in the data, such as nutrition, breastfeeding, vaccination and season. Data collection covered several months and was paused during the COVID-19 lockdown.

Conclusions

Household water treatment was not independently associated with diarrhea among children under five in Rwanda. The association differed by province, but the province estimates are crude and should be confirmed. Child age, maternal education and soap at the handwashing place were more closely linked to diarrhea than water treatment or the type of water source and toilet. Programs to reduce childhood diarrhea should combine water treatment with handwashing promotion and support for maternal education, and they should be adapted to the needs of each province. Programs should also check whether treatment is used consistently and whether treated water stays safe in the home. Longitudinal

studies that test water quality and measure how consistently treatment is used are needed to clarify cause and effect.

Abbreviations

AOR
Adjusted odds ratio
CI
Confidence interval
COVID-19
Coronavirus disease 2019
DHS
Demographic and Health Survey
OR
Odds ratio
RDHS
Rwanda Demographic and Health Survey
STROBE
Strengthening the Reporting of Observational Studies in Epidemiology
WASH
Water, sanitation and hygiene
WHO
World Health Organization

Declarations

Ethics approval and consent to participate

This study used de-identified secondary data from the 2019-20 RDHS, which we obtained from the DHS Program after approval of a data use request (26 January 2025). The RDHS protocol was reviewed and approved by the Rwanda National Ethics Committee and the ICF Institutional Review Board [10], and the survey obtained informed consent from participants. The analysis plan for this study was reviewed and approved by the Mount Kigali University Ethical Review Board (reference MKUR04/ERC/0546, application approval number 0526, dated 17 October 2025). All methods were carried out in accordance with relevant guidelines and regulations and with the Declaration of Helsinki. We had no contact with participants, so no new consent was needed.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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Author Contribution

EN conceived the study, curated the data and wrote the original draft. JT and EM designed the methods. TDB did the software work and the formal analysis. EM, ER, FAB and AH reviewed and edited the manuscript. All authors read and approved the final manuscript.

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Data Availability

The data analysed in this study are from the 2019-20 Rwanda Demographic and Health Survey (Standard DHS). They are available from the DHS Program (https://dhsprogram.com/data/dataset/Rwanda_Standard-DHS_2019.cfm?flag=0) to registered users after approval of a data request. Restrictions apply: under the DHS terms of use, the authors cannot redistribute the individual-level data. All summary estimates that support the findings, including district-level estimates, are included in this article and its Additional file 1.

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Figures

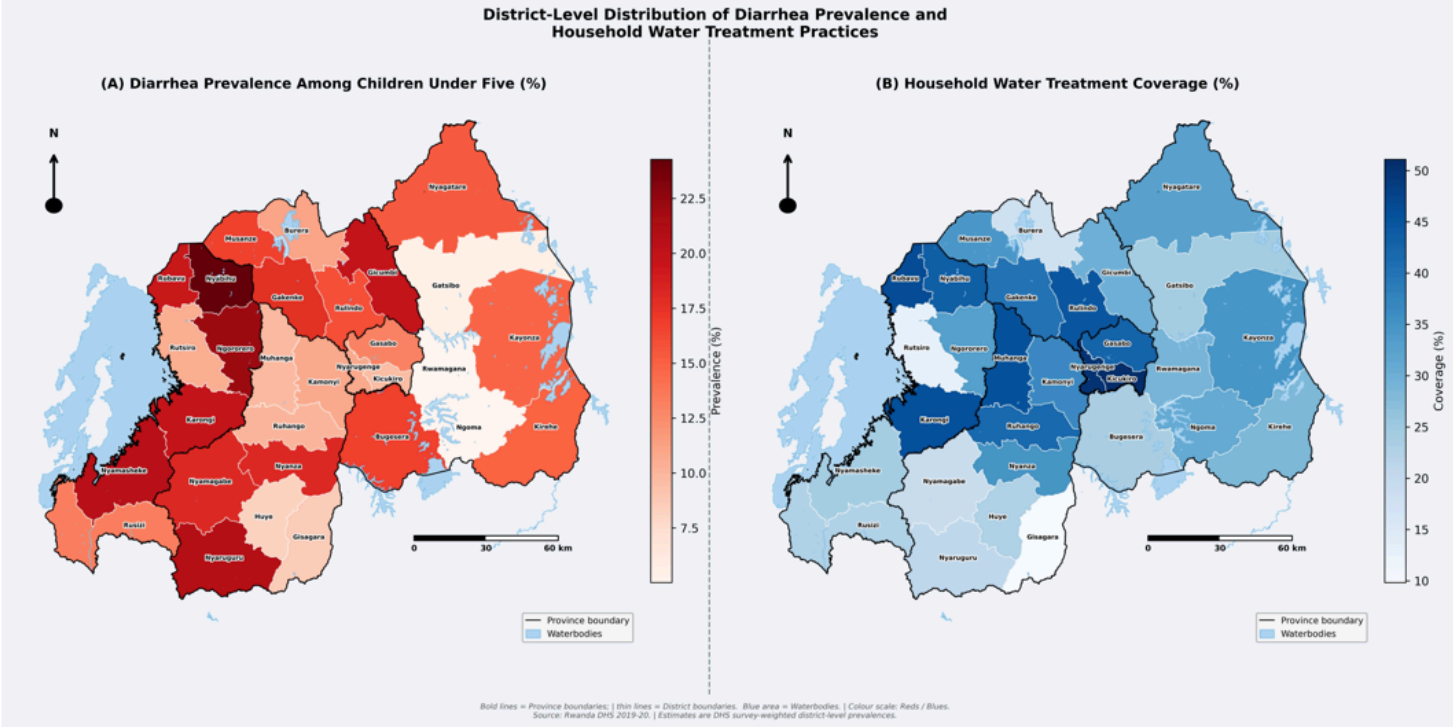


Figure 1

Maps of diarrhea prevalence and water treatment coverage by district in Rwanda

Panel A shows the weighted percentage of children under five who had diarrhea in the two weeks before the survey in each of the 30 districts. Panel B shows the weighted percentage of households that treat their drinking water. Bold lines mark provinces and thin lines mark districts. Blue areas are water bodies. District boundaries are the official survey boundaries aligned with National Institute of Statistics of Rwanda administrative boundaries. Source: Rwanda Demographic and Health Survey 2019-20.

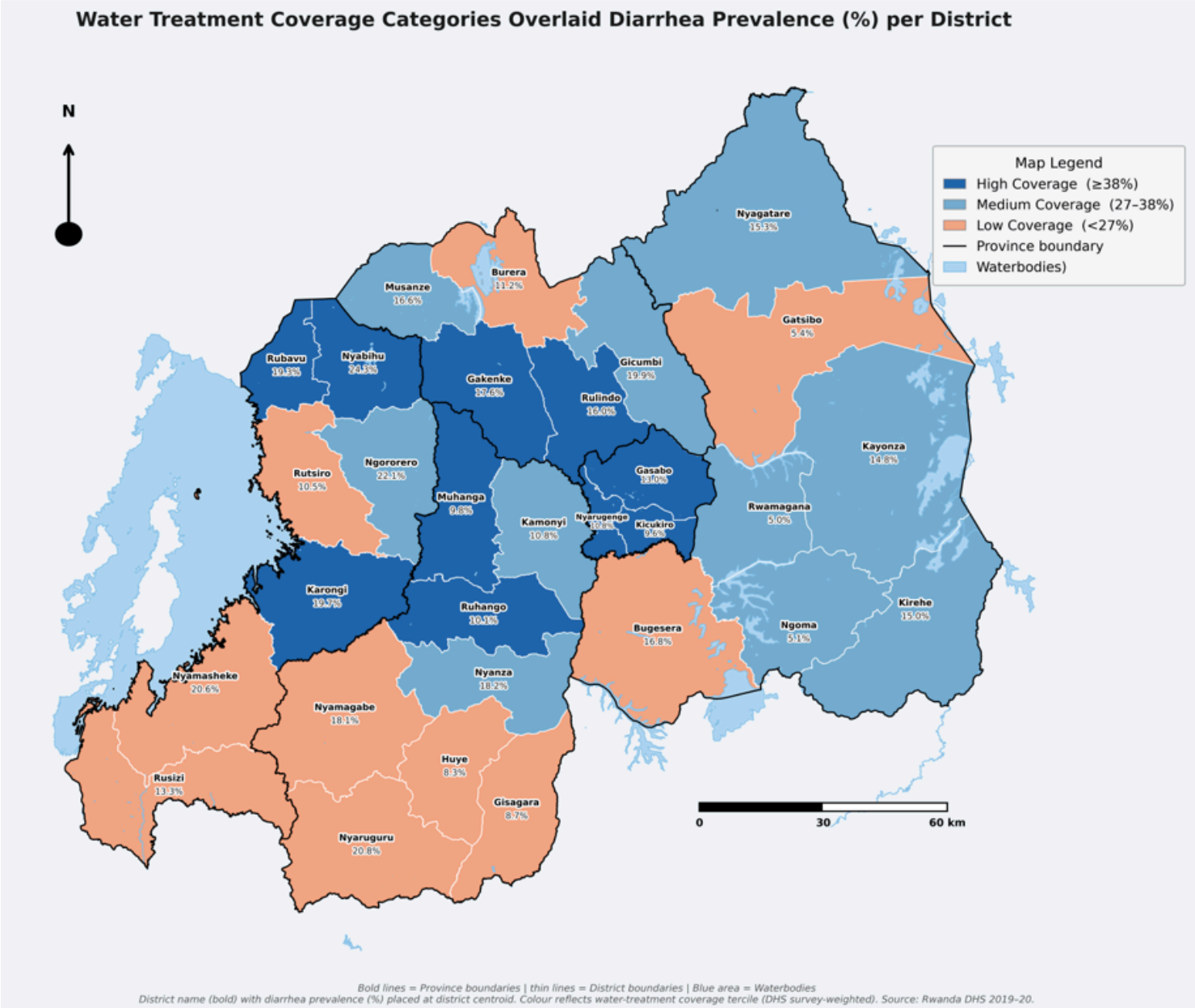


Figure 2

Water treatment coverage group of each district with diarrhea prevalence

Districts are shaded by tertile of household water treatment coverage: high (38% or more), medium (27% to under 38%) and low (under 27%). The number under each district name is the weighted percentage of children under five with diarrhea. Source: Rwanda Demographic and Health Survey 2019-20.

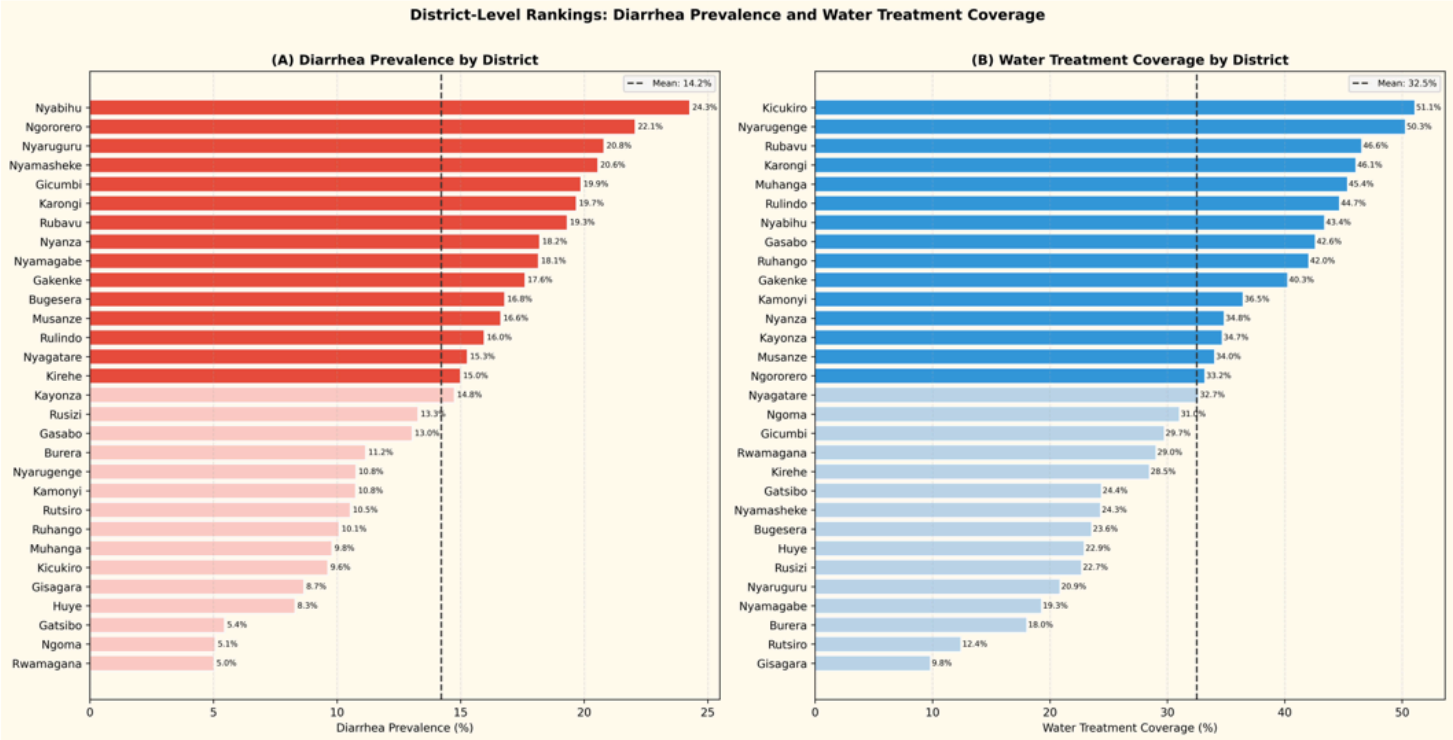


Figure 3

Districts ranked by diarrhea prevalence and by water treatment coverage

Panel A ranks districts by weighted diarrhea prevalence among children under five. Panel B ranks districts by weighted household water treatment coverage. Dashed lines show the mean of the 30 district values (14.2% for diarrhea and 32.5% for water treatment). Darker bars mark the 15 districts with the highest values. Source: Rwanda Demographic and Health Survey 2019-20.

Supplementary Files

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