

## The effect of household practices on the deterioration of microbial quality of drinking water between source and point of use in Murewa district, Zimbabwe

Rameck Makokove <sup>a,\*</sup>, Margaret Macherera <sup>b</sup>, Tendai Kativhu <sup>c</sup> and Demetria Fungai Gudo<sup>a</sup>

<sup>a</sup> Programs Departments, Plan International Zimbabwe, Harare, Zimbabwe

<sup>b</sup> Department of Crop and Soil Science, Lupane State University, Lupane, Zimbabwe

<sup>c</sup> Department of Environmental Science and Health, National University of Science and Technology, Bulawayo, Zimbabwe

\*Corresponding author. E-mail: rameck.comfort@gmail.com

 RM, 0000-0001-7524-1114; MM, 0000-0002-8415-1388; TK, 0000-0002-5853-1264

### ABSTRACT

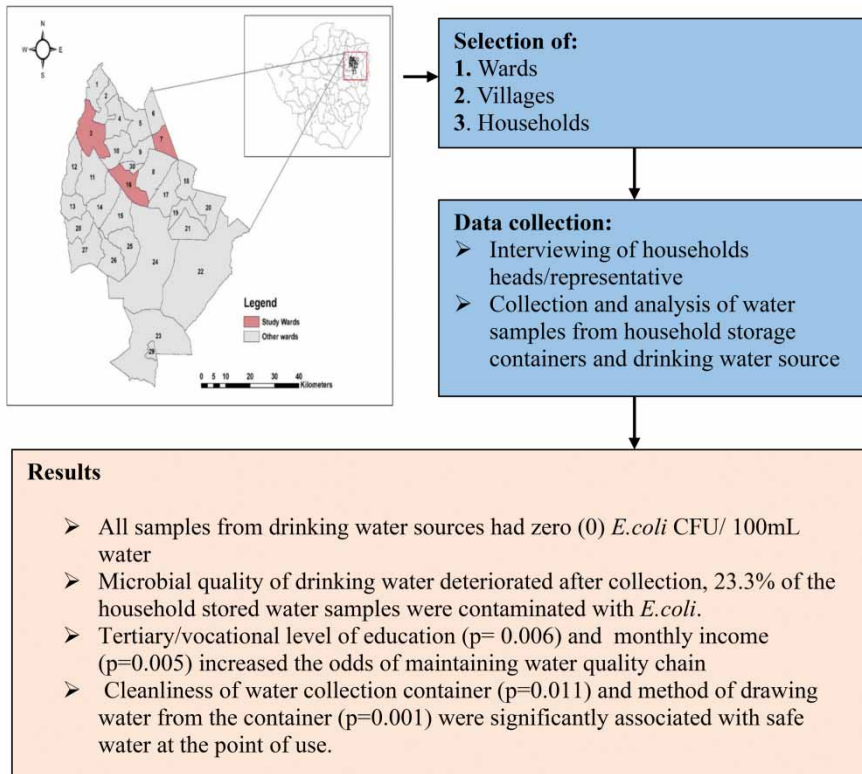
Access to safe drinking water is a key determinant of public health and is considered a basic human right essential to avert waterborne diseases. Understanding the association between household drinking water handling practices and the bacteriological quality of water at the point of use is critical since water quality may deteriorate between source and point of use. This study aimed at determining this association in Murewa district in Zimbabwe. Interviews were conducted with 381 household heads and hygiene practices were observed at selected households. Logistic regression analysis was used to examine the association between household drinking water handling practices and independent variables. The variables that were significantly associated with safe water at the point of use were tertiary education ( $p = 0.006$ ), monthly income ( $p = 0.005$ ), cleanliness of water collection containers ( $p = 0.011$ ) and the method of drawing water from containers ( $p = 0.001$ ). There is a need to intensify health and hygiene education, emphasising the importance of hygienic water handling practices, cleaning of collection containers and hygienic drawing of water from storage containers. The integration of income-generating activities into WASH projects should be strengthened to enable the acquisition of water collection and storage containers that can safeguard the quality of water between collection and consumption.

**Key words:** Murewa, point of use, stored water quality, water handling practices

### HIGHLIGHTS

- The microbial quality of drinking water deteriorated between source and point of use.
- Participants with higher education were 3.79 times more likely to maintain safe water quality between water source and point of use.
- The method of withdrawing drinking water from storage containers and cleanliness of water collection containers were significant predictors of water quality at the point of use.

## GRAPHICAL ABSTRACT

**The effect of household practices on the deterioration of microbial quality of drinking water between source and point of use in Murewa District, Zimbabwe**

## INTRODUCTION

Access to safe drinking water, adequate sanitation and safe hygiene practices were shown to prevent 85% of diarrhoeal diseases in Africa (Clasen & Bastable 2003; Ssemugabo *et al.* 2019). Specifically, water quality improvement interventions have been associated with diarrhoea and infectious disease reductions (WHO 2015). In 2020, it was noted that globally, 771 million people were without safely managed drinking water services, and among these, 8 out of 10 lived in rural areas and nearly 50% lived in sub-Saharan Africa (UN-Water 2021). Access to safe drinking water is a key determinant of public health and is considered a basic human right that must be met to avert waterborne diseases (WHO/UNICEF 2017).

The provision of safe drinking water is a critical area that was highlighted for development in the Millennium Development Goals (MDGs) as it is vital for both human and economic development (Satterthwaite 2016). Most countries, Zimbabwe included, failed to meet the MDG 7 target 10 on drinking water, which aimed 'to halve the proportion of the population without access to safe water by 2015' (WHO 2015). The need to supply safe and sustainable drinking water has been taken forward in the Sustainable Development Goals (SDGs), SDG 6 target 6.1, which aims to achieve universal and equitable access to safe and affordable drinking water for all by 2030 (United Nations General Assembly 2015).

To improve access to safe water supply and sanitation in sub-Saharan Africa, governments with support from partners implemented water, sanitation and hygiene (WASH) programmes (Venkataraman *et al.* 2018). On the water component, the programmes mainly focused on communal borehole drilling, borehole and piped water scheme rehabilitation and deep well protection, aimed at providing millions of people with access to improved water supplies (Venkataraman *et al.* 2018). However, these improved communal water sources are usually located far away from the places of residence, requiring collection and transportation from the source and storage of water for several days in the dwelling (WHO 2015). Previous research showed that the microbiological quality of water in storage containers in households is poor when compared with that in the drinking water source (Gundry *et al.* 2006; Schmidt & Cairncross 2009). Therefore, in addition to ensuring

access to safe water supplies particularly in rural areas, similar efforts should be made to ensure that water is of good quality at the point of use in the home.

Previous studies (Clasen & Bastable 2003; Hodge *et al.* 2016; Satterthwaite 2016; Ssemugabo *et al.* 2019) showed that contamination of drinking water occurs between sources and point of use. Studies conducted in refugee camps in Uganda, Kenya, Ethiopia and Tanzania also noted recontamination of previously safe drinking water at the point of use (Steele *et al.* 2008). Similar patterns were also shown in a study conducted in the rural communities of South Africa and Zimbabwe (Gundry *et al.* 2006). However, it is unclear how exactly this contamination takes place.

Since 2014, Zimbabwe's access to improved water supply for people living in rural areas has remained stagnant at 68% and the country is off-track to meet the Sustainable Development Goal 6 (SDG 6), the goal of ensuring water and sanitation for all by 2030 (ZIMSTAT & UNICEF 2019). The common sources of drinking water in the rural communities of Zimbabwe are communal boreholes, protected wells, solar-powered piped water schemes and springs. People in the rural areas travel an average round trip of 30 min to collect water from an improved water supply (ZIMSTAT & UNICEF 2019). Despite communities accessing water from improved sources, a recent national survey reported that 83, 7% ( $n = 8,798$ ) of household stored water samples were contaminated with *Escherichia coli* and 34, 2% of the samples had high *E. coli* levels of  $>100/100$  mL water (ZIMSTAT & UNICEF 2019). While the decline in the bacteriological quality of drinking water between source and point of use has been observed in a number of studies (Satterthwaite 2016; Ssemugabo *et al.* 2019), including in Murewa district, information on the association between household drinking water handling practices and the bacteriological quality of water at the point of use is not well documented in Zimbabwe. From 2013 to 2017, Murewa district benefited from a WASH project. The project drilled boreholes, rehabilitated piped water schemes and boreholes, and protected deep wells. In addition, communities received health and hygiene education through Community Health Clubs (CHCs) and Sanitation Action Groups (SAGs). The rural communities in the district obtain water for domestic use from improved water supplies such as boreholes, communal piped water schemes and protected wells.

According to Murewa District WASH Report, 55% ( $n = 929$ ) of household stored water samples were contaminated with *E. coli* (Murewa District WASH Report 2020). This is despite collection of water from safe sources and the water samples collected at source testing negative for *E. coli*.

The aim of this study was to determine the association between household drinking water handling practices and the bacteriological quality of water at the point of use in Murewa district, Zimbabwe. Findings from the study may help policymakers to design effective context-specific interventions to minimise contamination of drinking water during collection, transportation, storage and drawal from containers.

## METHODS

### Study setting and design

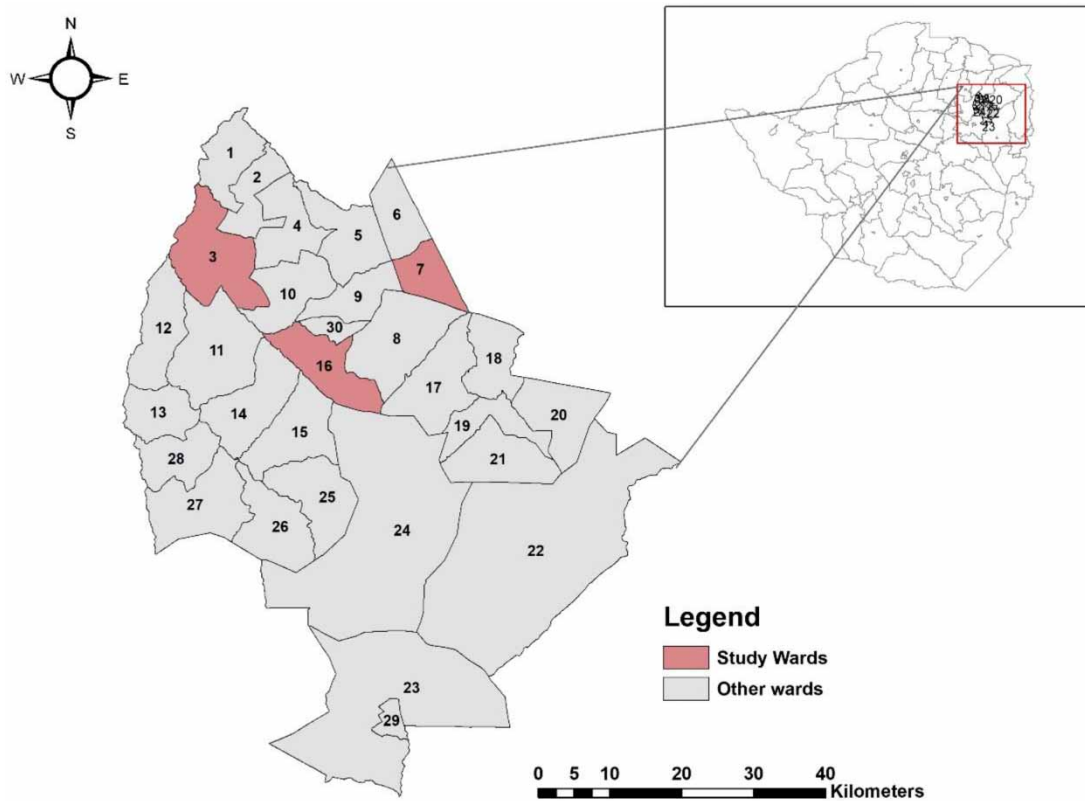
An analytic cross-sectional study was carried out in the rural communities of Murewa district in Mashonaland East Province of Zimbabwe. Murewa district is divided into 30 wards with a total population of 191,162 people (ZCSO 2012). From 2013 to 2017, the district benefited from a rural water sanitation and hygiene project. The project drilled 35 boreholes, rehabilitated one (1) piped water scheme and 164 boreholes, and protected 30 deep wells (Murewa District WASH report 2020). In addition, 500 villages received health and hygiene education through CHCs and SAGs. The rural communities in the district obtain water for domestic use from improved water supplies such as boreholes, communal piped water schemes and protected wells. Wards 3, 7 and 16 benefited from the WASH programme. In each of the three wards, an average of five boreholes were rehabilitated and two new boreholes were drilled. Every village in the three wards had a SAG and a CHC. Figure 1 shows the map of Murewa district and the study sites; wards 3, 7 and 16 are shaded blue on the district map.

### Sample size determination

The following formula for calculating cross-sectional study samples was applied (Kish 1965):

$$N = Z^2 * \frac{P(1 - P)}{\delta^2}$$

The sample size was determined using  $P$  of 45%, the reported percentage of households with safe drinking water at the point of use (Murewa District WASH Report 2020).  $N$  represents the required sample size,  $Z$  is the standard score



**Figure 1** | Map of Zimbabwe and Murewa district. Source: Authors' own illustration. Please refer to the online version of this paper to see this figure in colour: <http://dx.doi.org/10.2166/wh.2022.251>.

corresponding to 95% confidence level and a margin of error/precision of the study ( $\delta$ ) of 5%. Using the above formula, a required sample size of 381 households was obtained. No adjustment for non-response was done because, if a selected household refused to participate in the study, the next household as per the sampling frame replaced that household. Proportionate sampling was used to obtain the number of targeted households in each ward as follows: 34% of the households were from ward 3, 28% from ward 7 and 38% from ward 16.

### Selection of wards, villages and households

A multistage sampling procedure was used. First, purposive sampling was used to select Murewa district into the study because the district recorded a high percentage (55%) of households with contaminated drinking water at the point of use despite access to improved water supply. In the second stage, 10% of the 30 wards (three wards: ward 3, ward 7 and ward 16) in Murewa district were randomly selected. Simple random sampling was used to select 10% of villages in each selected ward. A total of 18 villages were selected; four villages in ward 3, seven villages in ward 7 and seven villages in ward 16. Simple random sampling was used because it gives all participants an equal chance of being selected. After selecting the villages, proportionate sampling was used to determine the households to be selected from each village. A total of 131 households were selected from ward 3, 107 households from ward 7 and 143 households from ward 16. Systematic sampling was conducted in each selected village using a sampling interval of seven households. To determine the sampling interval, the following formula was used:  $i = N/n$  (Kish 1965), where  $i$  represents the sampling interval,  $N$  is the target population and  $n$  represents the sample size. At each household, the household head or the spouse or any regular household member aged above 18 years and involved in fetching drinking water was asked to participate in the study after completing a written informed consent. If a selected household refused to participate in the study, the next household as per the sampling frame replaced that household.

Water samples from household storage containers were collected once from all the households that participated in the study, while water samples from drinking water supplies were collected on one occasion from sources used by participating

households on the survey date. There was a need to make sure that the water that was sampled at the household was collected on the same day when the quality at source was measured in order to determine any contamination after collection.

### Data collection from households

Data were collected using an interviewer administered questionnaire by trained research assistants who were environmental health technicians by profession. All research assistants were fluent in both English and Shona (the local language of the study area). The structured questionnaire was piloted on 30 households at a village similar to the study population but that did not participate in the study. Pretesting observations guided revision and standardisation of the questionnaire. Some of the questions in the questionnaire addressed issues such as the type of drinking water source used by the households, the type of water collection container used to fetch water from the source, washing of water collection containers before fetching water, transporting water in appropriately covered containers, the methods of drawing water from storage containers and storing water in homes. The research assistant also observed the water storage containers used by the households, the methods used to draw water from containers and how drinking water was stored in homes by using an observation checklist. The observations were done at the same time the assistant was interviewing the households. Household water handling practices were assessed using the seven aspects adapted from the International Federation of the Red Cross (IFRC) manual on household water handling and storage in emergencies (IFRC 2008). The seven aspects of water chain that were used to assess water handling practices were: washing water collection containers before fetching water from the source, collecting water using containers with narrow mouths, transporting drinking water from the source in closed containers, storing water in clean environments, storing water in closed containers, the methods of drawing water from storage containers and storing water in homes after drawing from containers. Household water handling practices were assessed on a scale of 1–7, where scoring points between 0 and 4 was regarded as having poor water handling practices, while scoring 5–7 points was considered as having good water handling practices (IFRC 2008).

### Drinking water sample collection and microbial analysis of water samples

*E. coli* bacteria are some of the most common microbial quality indicators for drinking water quality and their identification in water is not a complicated exercise. In addition, the results of microbial analysis can be obtained quickly and efficiently. Here, samples from both water supply and household storage containers were tested for *E. coli* bacteria, which indicated recent faecal contamination of water. The collected water samples were processed on-site using the Wah-tech Potable water test kit. The membrane filtration technique was used to analyse both stored water and water supply samples at the point of collection. The aseptically collected water samples were filtered through a cellulose acetate membrane with a pore diameter of 0.45 µm. Three hundred and eighty-one water samples were collected from drinking water storage containers of households that participated in the study. Water in the storage containers (collected from the source on the day of the survey and was in use at the time of the survey) was agitated before sample collection to resuspend any particles in the water. The household representative collected the sample using utensils commonly used by households for drawing water from the storage containers. Three hundred and eighty-one samples from boreholes and deep wells where participating households fetched water on the day of the survey were collected after flame-heating the spout for 3 min to sterilise it, after which the water was allowed to flow, undisturbed, for 1 min to cool the spout (World Health Organisation 2004). A sterile water sampling jar was used to collect water samples from deep protected wells used by the participating households.

Immediately after collecting water samples from sources and household storage containers, growth pads were dispensed into a sterilised Petri dish and a dissolved media solution was poured over the growth pad. The freshly collected water sample was filtered through the membrane. When all the 100 mL water were filtered, the membrane was placed on top of the pad, which was saturated with the Membrane Lauryl Sulphate Broth (MLSB) media. The Petri dish in which the membrane and the pad were placed were adequately labelled to indicate the source of the water sample, date of collection and time. The Petri dishes were then placed on a Petri-dish rack and then into the incubator and transported to the Murewa district hospital laboratory. The samples were incubated for 24 h at a temperature of 44 °C. The results were read the following day, after 24 h. The water quality results were reported as colony-forming units per 100 mL (CFU/100 mL) of water sample.

### Data analysis

The data on the questionnaires and water quality monitoring form were double-entered in MS Excel and imported into Epi Info version 7.0 for data analysis. Data cleaning was done by comparing duplicate entries. Where there were variations,

verification was done by checking the source of the datasheets. Descriptive analysis, specifically proportions, was used to summarise household characteristics such as age, level of education and income. Drinking water handling practices such as washing of water collection containers, the type of collection container and transporting water in appropriate covered containers, the methods of drawing water from containers as well as the bacteriological quality of source and stored water samples were studied. A comparison of the bacteriological quality of the drinking water source samples and stored water samples was done using the number of colony-forming units (CFU) per 100 mL of water to determine the difference in contamination levels or the lack of it.

Statistical analyses were applied with a bivariate analysis using the  $\chi^2$  test to determine associations between drinking water handling practices and the bacteriological quality of household stored water. A 5% confidence limit and 95% confidence level were used in determining the significance level of the findings. To control variables for other associations, a multivariate regression using a logistic regression model was performed on variables that showed a statistically significant association in bivariate analysis with a  $p$ -value of  $<0.05$ .

### Ethical considerations

Approval to conduct the study was obtained from the Medical Research Council of Zimbabwe (Reference No. MRCZ/B1418) and the Mashonaland East Provincial Medical Director. Interviewed participants gave informed consent before participation in the study.

## RESULTS

### Socio-demographic characteristics of participants

A total of 381 respondents participated in the study and they were all females due to the nature of gender roles in water supply and management at the household level in the study area. It was noted that women and girls are the ones who mainly collect water for domestic purposes. The majority of the respondents were married, 359 (94.23%), and more than half, 276 (72.44%), had completed secondary education. Table 1 summarises the results of the socio-demographic characteristics of the respondents.

### Access to drinking water supply and household water handling practices

Most (345, 90.6%) households obtained drinking water from boreholes and all the sources that the respondents drew water from were improved and protected. A greater proportion of the respondents (279, 73.2%) used water sources within a radius of 500 m from their place of residence. About 218 (57%) of the respondents collected water with clean containers and 345 (90.1%) of the study participants transported water in well-covered containers. Only 56 (14.7%) of the respondents were not storing drinking water hygienically and 94 (25%) of the respondents used unhygienic methods to draw drinking water from containers at the point of use.

The overall rating of household drinking water handling practices revealed that 150 (40%) of the respondents had poor/unsafe (collecting water in uncleaned containers, collecting water in uncovered containers and drawing water using the dipping method) drinking water handling practices. The results revealed that 299 (77%) of the samples drawn at the point of use had no *E. coli* (Table 2).

### Independent predictors of safe drinking water handling practices

The socio-demographic characteristics of the study participants that were significant predictors of safe water handling practices were marital status [AOR = 0.68, 95% CI (0.48–0.97),  $p = 0.032$ ] and level of education of the participants [AOR = 0.51, 95% CI (0.32–0.82),  $p = 0.006$ ] adjusting for age, employment status, monthly income and religion (Table 3).

### Independent predictors of water quality maintenance from source to point of use

Adjusting for covariates in multivariable logistic regression analysis, participants with higher education were 3.79 times more likely to maintain safe water quality between source of collection and point of use [AOR = 3.79, 95% CI (1.64–8.78),  $p =$

**Table 1** | Demographic characteristics of participants

Characteristics	Frequency (N = 381)	Percentage (%)
All participants	381	100
Gender		
Female	381	100
Age (years)		
18–21	6	1.57
22–25	28	7.35
26–29	138	36.22
30–35	160	41.99
>35	49	12.86
Marital status		
Married	359	94.23
Single	4	1.05
Widow	9	2.36
Separated	1	0.26
Divorced	8	2.10
Education		
Primary	21	5.51
Secondary	276	72.44
Tertiary/vocational	79	20.73
No formal education	5	1.31
Employment status		
Full time	98	25.72
Self-employed	167	43.86
Unemployed	110	28.87
Retired	6	1.57
Monthly income (USD)		
<50	210	55.12
50–100	86	22.57
>100	85	22.31
Religion		
Catholic	118	30.97
Protestant	4	1.05
Adventists	40	10.50
Muslim	8	2.10
Evangelical	132	34.65
Traditional	79	20.73

0.002]. Better employment status increased the odds of maintaining water quality chain by 148% [AOR = 2.48, 95% CI (1.55–3.97),  $p = 0.001$ ] (Table 4).

#### Association between safe water handling practices and water quality at point of use

After adjusting for covariates in multivariate logistic regression analysis, the method of withdrawing drinking water from storage containers [AOR = 0.01, 95% CI (0.001–0.04),  $p = 0.001$ ] and cleanliness of water collection containers [AOR = 0.06, 95% CI (0.01–0.53),  $p = 0.011$ ] were significant predictors of water quality at the point of use (Table 5).

**Table 2** | Access to drinking water supply and household water handling practices

Variables	Frequency (N = 381)	Percentage (%)
<i>Water source-related characteristics</i>		
Main water sources		
Boreholes	345	90.55
Protected wells	36	9.45
Distance to the water sources (m)		
<500	279	73.23
500–1,000	71	18.64
2,000–5,000	31	8.14
Main containers for collecting water		
Plastic buckets	381	100
<i>Practices on safe water chain</i>		
Obtain drinking water from improved water sources		
Yes	381	100
Water collected in clean containers		
Yes	218	57.22
No	163	42.78
Water collection containers well covered		
Yes	345	90.55
No	36	9.45
Drinking water storage is clean, covered and stored hygienically		
Yes	325	85.30
No	56	14.70
Method of drawing drinking water from storage prevents contamination		
Yes	287	75.33
No	94	24.67
Rating of water chain practices (scores)		
Poor (0–4)	154	40.42
Good (5–7)	227	59.58
Measured value of <i>E. coli</i> CFU/100 mL of water at the water source		
0	381	100
Measured value of <i>E. coli</i> CFU/100 mL of water at the point of use		
0	291	76.58
>1	89	23.42

## DISCUSSION

The study found that access to improved drinking water supply was high in the study area and the majority of participants had improved water supply source within 500 m from the place of residence. All samples from drinking water sources had zero (0) *E. coli* CFU/100 mL water. This was expected because improved sources of drinking water such as boreholes and protected deep wells are known to provide relatively high-quality water (World Health Organisation 2006). The boreholes and wells are disinfected after fitting with head works and the water is tested for both bacteriological and chemical quality before commissioning with routine tests conducted to monitor quality. Boreholes and deep protected wells in the study area were tested for quality and proved to be safe. Although access to safe water was high in the study area, there was a common problem of poor stored water quality, with 23.3% of the household water samples contaminated with *E. coli*. The contamination of stored



**Table 3** | Independent predictors of safe drinking water handling practices

Variables	Rating of safe water chain practices		Crude OR (95% CI)	P-value	AOR (95% CI)	P-value
	Poor (154)	Good (227)				
Age (years)						
18–21	3(1.9)	3(1.1)	1			
22–25	8(5.2)	20(7.2)	0.32(0.03;3.17)	0.071	0.02(0.11;1.15)	0.18
26–29	61(39.6)	77(27.8)	0.21 (0.07;1.01)	0.181	0.11(0.03;0.24)	0.891
30–35	46(29.9)	114(41.2)	0.79(0.62;1.01)	0.056	0.95(0.73; 1.24)	0.693
>35	36(23.4)	13(4.7)	2.95(0.95; 5.81)	0.071	1.93(0.97;3.05)	0.799
Marital status						
Married	136(88.3)	223(98.2)	4.32(3.56;11.2)	0.001*	2.35(1.98;5.8)	0.041*
Single	4(2.6)	0(0.0)	0.64(0.47; 0.89)	0.008*	0.68(0.48;0.97)	0.032*
Widow	8(5.2)	1(0.4)	0.25(0.12;1.98)	0.075	0.19(0.01;2.95)	0.081
Separated	0(0.0)	1(0.4)	1			
Divorced	6(3.9)	2(0.9)	0.03(0.02;0.53)	0.059	0.02(0.018; 9.5)	0.079
Education						
Primary	9(5.8)	70(30.8)	2.3(0.91;7.7)	0.061	1.9(0.81;3.8)	0.861
Secondary	2(1.3)	3(1.3)	3.5(0.73;9.8)	0.057	2.8(0.73; 5.4)	0.352
Tertiary/vocational	122(79.2)	154(67.8)	0.32(0.22; 0.46)	<0.001*	0.51(0.32;0.82)	0.006*
No formal education	21(13.7)	0(0.0)	1			
Employment status						
Full time	18(11.7)	80(35.2)	1			
Self-employed	58(37.7)	109(48.0)	0.49(0.40; 0.61)	<0.001*	0.78(0.56; 1.07)	0.128
Unemployed	75(48.7)	35(15.4)	0.21 (0.07;1.03)	0.078	0.12(0.01;1.15)	0.215
Retired	3(1.9)	3(1.3)	0.04(0.02;0.53)	0.059	0.02(0.018; 9.5)	0.313
Monthly Income (USD)						
<50	116(75.3)	94(41.4)	1			
50–100	26(16.9)	60(26.4)	2.9(0.85;5.9)	0.053	1.9(0.91; 3.9)	0.651
>100	12(7.8)	73(32.2)	1.85(1.20; 2.84)	0.005*	1.38(0.86; 2.22)	0.183
Religion						
Catholic	59(38.3)	61(26.9)	1.2(0.34;4.59)	0.381	0.5(0.1; 1.89)	0.312
Protestant	3(1.9)	1(0.4)	1.1(0.26, 3.86)	0.151	0.08(0.01; 1.23)	0.781
Adventists	9(5.8)	31(13.7)	2.76(2.03;3.76)	<0.001*	1.10(0.98; 1.23)	0.108
Muslim	3(1.9)	5(2.2)	1			
Evangelical	49(31.8)	83(36.6)	3.5(0.83–10.9)	0.052	2.9(0.98; 8.4)	0.081
Traditional	33(21.4)	46(20.3)	2.4(0.63; 5.8)	0.218	1.3(0.71; 3.3)	0.414

\*Significance  $p < 0.05$ .

water could be attributed to the amount of handling involved between water collection, transportation, storage and drawal from containers. The results of the current study are consistent with those of other studies that demonstrated faecal contamination of stored water after collection from improved sources that were less prone to faecal contamination (Clasen & Bastable 2003; Usman *et al.* 2018; Ssemugabo *et al.* 2019). A study conducted in Nigeria by Shrestha *et al.* (2017) that compared the bacteriological quality of drinking water at a water collection source and the point of use found that more household stored water samples tested positive for *E. coli* compared with source water samples. Similar findings were observed in Malawi by Cassivi *et al.* (2021). These indicate that water handling practices influence water quality after

**Table 4** | Independent predictors of water quality between source and point of use

Variables	Water contamination at point of use (%)		Crude OR (95% CI)	P-value	AOR (95% CI)	P-value
	No (291)	Yes (89)				
Age (years)						
18–21	5(1.7)	1(1.1)	0.49(0.40; 1.61)	0.081	0.32(0.01;2.01)	0.371
22–25	23(7.9)	4(4.5)	0.21(0.07;1.03)	0.063	0.19(0.01; 1.01)	0.832
26–29	110(37.8)	27(30.3)	1.61(1.20; 2.18)	0.001*	1.19(0.86;1.65)	0.281
30–35	129(44.3)	31(34.8)	1			
>35	24(8.2)	25(28.1)	3.2(0.75; 8.5)	0.233	2.1(0.63;6.3)	0.189
Marital status						
Married	280(96.2)	78(87.6)	1.29(0.99;1.70)	0.052	1.12(0.84;1.49)	0.429
Single	2(0.7)	2(2.2)	0.96(1.17;5.33)	0.875	0.78(0.65;4.11)	0.632
Widow	3(1.0)	6(6.7)	11(0.93; 13.41)	0.279	8.7(0.79;10.12)	0.547
Separated	1(0.3)	0(0.0)	0.03(0.001;3.2)	0.751	0.02(0.01; 2.1)	0.499
Divorced	5(1.7)	3(3.3)	1			
Education						
Primary	77(26.5)	17(19.1)	2.64(0.46; 15.30)	0.291	1.24(0.23;12.11)	0.681
Secondary	3(1.0)	2(2.2)	0.96(0.17; 5.33)	0.962	0.05(0.01; 3.33)	0.989
Tertiary/vocational	210(72.2)	66(74.2)	7.38(3.38; 16.1)	<0.001*	3.79(1.64;8.78)	0.002*
No formal education	1(0.3)	4(4.5)	1			
Employment status						
Full time	93(32.0)	5(5.6)	3.91(0.95; 14.90)	0.051	1.91(0.91; 10.2)	0.099
Self-employed	146(50.2)	21(23.6)	3.35(2.33;4.83)	<0.001*	2.48(1.55;3.97)	<0.001
Unemployed	47(16.2)	62(69.7)	7.9(0.99; 18.9)	0.071	5.1(0.68; 12.10)	0.091
Retired	5(1.7)	1(1.1)	1			
Monthly Income (USD)						
<50	136(46.7)	73(82.0)	1			
50–100	73(25.1)	13(14.6)	3.15(0.97; 15.10)	0.067	2.13(0.95; 12.1)	0.214
>100	82(28.2)	3(3.4)	0.29(0.18; 0.45)	<0.001*	0.94(0.52;1.70)	0.847
Religion						
Catholic	86(29.6)	32(40.0)	3.91(0.95; 14.90)	0.056	1.19(0.51; 9.21)	0.421
Protestant	2(0.7)	2(2.2)	0.32(0.03;3.17)	0.18	0.08(0.01;3.10)	0.871
Adventists	33(11.3)	6(6.7)	0.97(0.86; 1.09)	<0.001*	0.92(0.81;1.03)	0.216
Muslim	6(2.1)	2(2.2)	1			
Evangelical	110(37.8)	22(24.7)	1.2(0.34;4.59)	0.38	0.11(0.01; 2.12)	0.531
Traditional	54(18.6)	25(28.0)	0.66(0.18, 2.35)	0.27	0.09(0.01; 1.12)	0.718

\*Significance  $p < 0.05$ .

collection from relatively safe sources. These also call for interventions to reduce the contamination of water at the point of use. Chlorination, use of Aquatabs and boiling are some of the small-scale water treatment methods that can be used in poor resource settings, together with safe water handling practices (Shrestha *et al.* 2017).

Participants with a higher (tertiary/vocational) level of education were 3.79 times more likely to maintain safe drinking water quality between source and point of use (Table 4). This could be because formal education empowers both men and women through shaping their knowledge, attitudes, beliefs and practices. Our findings are in line with those of other studies (Ssemugabo *et al.* 2019; Mugumya *et al.* 2020), which showed that high literacy levels coincided with the adoption of hygienic

**Table 5** | Predictors of water quality at point of use

Variables	Water contamination at point of use		Crude OR (95% CI)	P-value	AOR (95% CI)	P-value
	No (291)	Yes (89)				
<i>Water source-related characteristics</i>						
Main water sources						
Boreholes	258(88.7)	86(96.6)	1			
Protected wells	33(11.3)	3(3.4)	0.27(0.08 ;0.91)	0.035*	1.19(0.86; 1.65)	0.281
Distance to the water sources (m)						
<500	239(82.1)	39(43.8)	1			
500–1,000	49(16.8)	22(24.7)	2.71(1.81;3.79)	0.035	1.96(0.89–3.21)	0.799
2,000–5,000	3(1.1)	28(31.5)	4.95(3.31;7.38)	<0.001*	1.12(0.84; 1.49)	0.429
<i>Practices on safe water chain</i>						
Obtain drinking water from improved water sources						
Yes	291(100.0)	89(100.0)	–	–	–	–
Water collected in clean containers						
Yes	216(74.2)	2(2.2)	0.01(0.001;0.03)	<0.001	0.06(0.01;0.53)	0.011*
No	75(25.8)	87(97.8)	1			
Water collection containers well covered						
Yes	289(99.3)	55(55.6)	0.01(0.00; 0.05)	<0.001	2.50(0.89;7.1)	0.083
No	2(0.7)	34(44.4)	1			
Drinking water storage is clean, covered and stored hygienically						
Yes	289(99.3)	35(39.3)	0.004(0.00;0.002)	<0.001	1.37(0.04; 51.5)	0.993
No	2(0.7)	54(60.7)	1			
Method of drawing drinking water from storage prevents contamination						
Yes	282(96.9)	85(95.5)	0.002(0.00;0.004)	<0.001	0.011(0.00;0.04)	<0.001*
No	9(3.1)	4(4.5)	1			
Rating of water chain practices (scores)						
Poor (0–4)	66(22.7)	88(98.9)	1			
Good (5–7)	225(77.3)	1(1.1)	0.003(0.000;0.02)	<0.001	0.53(0.05;5.93)	0.604

\*Significance  $p < 0.05$ .

drinking water handling practices. A literate person is more likely to understand health-related issues, including the need to consume safe water. In Zambia, a study to assess the effects of formal education on the practice of hygiene in order to prevent diarrhoeal diseases showed similar findings, where the higher the level of formal education attained, the less likely the household was exposed to unsafe hygiene practices [Hodge et al. \(2016\)](#). Audiovisual aids can be used during hygiene promotion sessions to address and consider the needs of the illiterate ([Partum & Khananthai 2017](#)).

Having high income increases the odds of maintaining water quality by 148% ([Table 4](#)). This can be attributed to the fact that households that earn more may have resources that will make them more hygienic, and such households can afford covered containers or special storage vessels that can be used to safeguard water, thereby reducing contamination. Poverty and unemployment have long been associated with poor access to social services, including access to safe drinking water. Recent studies in low-income countries show that wealthier households have better water quality at the point of use compared with poorer households ([Satterthwaite 2016](#); [Partum & Khananthai 2017](#)). Since monthly income is significantly associated with the quality of water at the point of use, it is necessary and important to integrate livelihood programmes into water supply and

hygiene projects to enable communities to increase their income, so that they can afford to buy the resources required to preserve water quality during the water chain.

Extracting water from storage containers through pouring was found to be protective against contamination of household stored water. This finding is in line with that documented by [Ssemugabo \*et al.\* \(2019\)](#), who noted higher chances of drinking water contamination where dipping was used as a method of drawing water from storage containers. A study by [Hutton & Chase \(2016\)](#) found that dipping of water-drawing utensils in storage containers contaminated the water by introducing dirt and dust from the external environment into the water.

Cleanliness of water storage containers was significantly associated with safe (zero *E. coli* CFU/100 mL of water) drinking water quality at the point of use ([Table 5](#)). The practice of washing water collection containers before fetching water, especially with soap/ash, helps prevent the formation of a slimy layer and build-up of biofilm inside the storage containers ([Hutton & Chase 2016](#)). A study by [Sharma \*et al.\* \(2013\)](#) found that inappropriate washing and inadequate rinsing of containers resulted in algal growth inside the containers, which provides favourable conditions and an environment for the growth of pathogens. Previous studies elsewhere suggest that drinking water storage practices ([WHO 2015](#)), the use of containers that were not properly cleaned to collect and store water in homes ([Satterthwaite 2016](#); [Ssemugabo \*et al.\* 2019](#)), and unsafe storage of water-drawing utensils ([WHO 2015](#); [Hutton & Chase 2016](#)) are possible routes of drinking water contamination in homes.

## CONCLUSION

This study found that 90.6% of households had access to improved sources of water with safe drinking water, the majority of which were located within the recommended 500-m distance from places of residence. Poor water handling practices were common in the study area and the quality of water deteriorated between collection from source and point of consumption. Having tertiary/vocational level of education ( $p = 0.006$ ), monthly income ( $p = 0.005$ ), cleanliness of water collection containers ( $p = 0.011$ ) and the method of drawing water from containers ( $p = 0.001$ ) were significantly associated with safe water at the point of use. There is a need to intensify health and hygiene education among the people, emphasising the importance of hygienic water handling practices, especially cleaning of water collection containers before fetching water and drawing water from storage containers through pouring. Efforts to integrate income-generating activities into WASH projects should be strengthened in order to improve participants' disposable income. This may enable them to acquire suitable water collection and storage containers that can safeguard the quality of water between collection and consumption.

## LIMITATIONS

The results of this study should be interpreted with caution due to some limitations. The information on most water handling practices was self-reported and we could not rule out social desirability bias. However, we believe that the study makes an important contribution to the maintenance of a safe water chain, which has been under-researched in Zimbabwe. The findings can be generalised to other rural communities with a similar context.

## ACKNOWLEDGEMENTS

We are grateful to all participants, research assistants and local leadership in Murewa district who made this study possible. This study did not receive any external funding support.

## CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this paper.

## DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

## REFERENCES

- Cassivi, A., Tilley, E., Waygood, E. O. D. & Dorea, C. 2021 Household practices in accessing drinking water and post collection contamination: a seasonal cohort study in Malawi. *Water Research* **189**, 116607. doi:10.1016/j.watres.2020.116607.

- Clasen, T. & Bastable, A. 2003 Faecal contamination of drinking water during collection and household storage: the need to extend protection to the point of use. *Journal of Water and Health* **1**, 109–115.
- Gundry, S. W., Wright, J. A., Conroy, R., Du Preez, M., Genthe, B., Moyo, S., Mutisi, C., Ndamba, J. & Potgieter, N. 2006 Contamination of drinking water between source and point-of-use in rural households of South Africa and Zimbabwe: implications for monitoring the Millennium Development Goal for water. *Water Practice and Technology* **1** (2). doi:10.2166/wpt.2006.032.
- Hodge, J., Chang, H. H., Boisson, S., Collin, S. M., Peletz, R. & Clasen, T. 2016 Assessing the association between thermotolerant coliforms in drinking water and diarrhoea: an analysis of individual level data from multiple studies. *Environmental Health Perspectives*. doi:10.1289/EHP156.
- Hutton, G. & Chase, C. 2016 The knowledge base for achieving the sustainable development goal targets on water supply, sanitation and hygiene. *International Journal of Environmental Research and Public Health* **13** (6), 536. doi:10.3390/ijerph13060536.
- IFRC 2008 *Household Water Treatment and Safe Storage in Emergencies: A Field Manual for Red Cross/Red Crescent Personnel and Volunteers [Online]*. Water and Sanitation Unit, Health and Care Department, International Federation of Red Cross and Red Crescent Societies, Geneva, Switzerland. Available from: <https://www.ifrc.org/Global/Publications/disasters/142100-hwt-en.pdf> (accessed 20 August 2021).
- Kish, L. 1965 *Survey Sampling*. Wiley, New York, USA.
- Mugumya, T., Isunju, J. B., Ssekamatte, T., Wafula, S. T. & Mugambe, R. K. 2020 Factors associated with adherence to safe water chain practices among refugees in Pagirinya refugee settlement, Northern Uganda. *Journal of Water and Health* **18** (3), 398–408. doi:10.2166/wh.2020.230.
- Murewa District WASH Report 2020 *Water and Sanitation Update 2020*. Murewa.
- Partum, C. & Khananthai, N. 2017 Assessment of factors affecting drinking water quality from free water dispensers in the higher education institution. *International Journal of Environmental and Science Education* **12** (4), 787–797.
- Satterthwaite, D. 2016 Missing the Millennium Development Goal targets for water and sanitation in urban areas. *Environment and Urbanization*. **28** (1), 3–18.
- Schmidt, W. P. & Cairncross, S. 2009 Household water treatment in poor populations: is there enough evidence for scaling up now? *Environmental Science and Technology* **43**, 986–992.
- Sharma, R. H., Worku, W., Hassen, M., Tadesse, Y., Zewdu, M., Kibret, D., Gashe, A., Meseret, M., Gessesse, D. & Kebede, A. 2013 Water handling practices and level of contamination between source and point-of-use in Kolladiba Town, Ethiopia. *Environment and International Journal of Science and Technology* **8**, 25–35.
- Shrestha, A., Sharma, S., Gerold, J., Erismann, S., Sagar, S., Koju, R. & Cisse, G. 2017 Water quality, sanitation, and hygiene conditions in schools and households in Dolakha and Ramechhap Districts, Nepal: results of a cross-sectional survey. *International Journal of Environmental Research and Public Health* **14** (1), 89.
- Ssemugabo, C., Wafula, S. T., Ndejjo, R., Oporia, F., Osuret, J., Musoke, D. & Halage, A. A. 2019 Knowledge and practices of households on safe water chain maintenance in a slum community in Kampala City, Uganda. *Environmental Health and Preventive Medicine* **24**, 45.
- Steele, A., Clarke, B. & Watkins, O. 2008 Impact of jerry can disinfection in a camp environment – experiences in an IDP camp in Northern Uganda. *Journal of Water and Health* **6**, 559–564.
- United Nations General Assembly 2015 *Draft Resolution a/69/l.85: Transforming Our World: The 2030 Agenda for Sustainable Development*. United Nations, New York, NY, USA.
- UN-Water 2021 Summary Progress Update 2021 - SDG 6 - water and sanitation for all. Version: July 2021. Geneva, Switzerland.
- Usman, M. A., Gerber, N. & Pangaribowo, E. H. 2018 Drivers of microbiological quality of household drinking water – a case study in rural Ethiopia. *Journal of Water and Health* **16** (2), 275–288. doi:10.2166/wh.2017.069.
- Venkataramanan, V., Crocker, J., Karon, A. & Bartram, J. 2018 Community-led total sanitation: a mixed-methods systematic review of evidence and its quality. *Environmental Health Perspectives* **126** (2), 026001. <https://doi.org/10.1289/EHP1965>.
- World Health Organisation 2004 *Guidelines for Drinking-water Quality*. Fourth Edition. Geneva, Switzerland.
- World Health Organisation 2006 *Almost a Quarter of All Disease Caused Is by Environmental Exposure*. World Health Organization, Geneva, Switzerland.
- World Health Organisation 2015 *Drinking Water: Fact Sheet No. 391*. World Health Organization, Geneva.
- World Health Organisation/United Nations Children's Fund 2017 *Progress on Drinking Water, Sanitation and Hygiene: 2017 Update and SDG Baselines*. World Health Organization (WHO) and the United Nations Children's Fund (UNICEF), Geneva.
- Zimbabwe Central Statistics Office 2012 *National Population Census Report*. Central Statistics Office, Harare.
- ZIMSTAT (Zimbabwe National Statistics Agency) and UNICEF 2019 *Zimbabwe Multiple Indicator Cluster Survey 2019, Survey Findings Report*. Harare, Zimbabwe: ZIMSTAT and UNICEF.

First received 9 October 2021; accepted in revised form 26 January 2022. Available online 8 February 2022