Drinking water quality and handling practices among women in rural households of Oshimili North Local Government Area of Delta State, Nigeria

Elizabeth Omoladun Oloruntoba* and Donald Uzowulu Olannye

Department of Environmental Health Sciences, Faculty of Public Health, College of Medicine, University of Ibadan, Ibadan, Nigeria; Email: li_zzyy@yahoo.com; donalduzowulu@gmail.com

ABSTRACT

Diarrheal diseases associated with inadequate supply of potable water are the leading causes of mortality among children under five years in developing countries. In Nigeria, women are the water managers in most households. However, there is dearth of information on the effect of women's handling practices on drinking water quality. Therefore, this study was aimed at assessing the drinking water quality and handling practices among women in selected rural households in Oshimili North Local Government Area of Delta State, Nigeria. Paired drinking water samples from available sources and Household Storage Containers (HSC) were assessed for physico-chemical and bacteriological parameters using standard methods. The data obtained were compared with the WHO guideline limits. Water samples with 0, 1-10, 11-50 and > 50 *E. coli*/100 mL were graded as A, B, C, and D corresponding to excellent, acceptable, unacceptable, and grossly polluted quality, respectively. Pre-tested semi-structured interviewer-administered questionnaire was used to elicit information from the respondents. A 30-point scale was used to assess water handling practices. Handling practice scores greater or equal to mean handling practice score were grouped into good and those less than that were grouped into bad handling practices. Data were analyzed using descriptive statistics and One-way ANOVA at $\alpha = 0.05$. The results showed physico-chemical parameters for both sources and households within WHO guideline limits. The mean total coliform counts for all sources and household containers exceeded permissible limits. *E. coli* was not detected in harvested rain water while counts for borehole was 10.2 ±2.2 (A) and for stream sources was 44.6±33.3 EC/100 mL (B); drinking water stored in HSC had 36.8±32.3 (A) EC/100 mL, borehole had 62.31±33.2 (C) and stream had 30.00±33.2 (B). Mean handling practice score was 19.4±6.6. Majority (60.0%) practiced some water handling technique. Drinking water from assessed sources was of poor microbial quality and it significantly deteriorated when stored in household storage containers. Therefore, there is a need to improve the microbial quality of drinking water at sources and household level

* **Corresponding author:** li_zzyy@yahoo.com; Telephone number: +234 802 894 6358

through the supply of simple, acceptable, low-cost treatment methods and hygiene education.

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INTRODUCTION

Good quality drinking water is vital for human physiology and survival. However, several households in many developing countries, especially the African countries, depend solely on drinking water from unsafe sources due to lack of access to safe drinking water (UNICEF, 2012). This may be associated with the rapid population growth and migration of people from rural to urban areas that has put much pressure on existing water resources, and therefore surpassed the capacity of many countries to keep up with the demand. In rural areas, dispersed population pattern and poor road networks could also contribute to lack of access to potable drinking water (Olannye, 2015).

The scarce and inconsistent potable water supply leads to the inevitable practice of households storing it in containers for future use. More often than not, water that is fetched that day is not used completely that same day but stored in plastic, metal, concrete reservoirs or earthenware containers, which influence water quality (Mintz *et al*., 1995; Jensen *et al*., 2002; Oloruntoba and Sridhar, 2007; Levy *et al*., 2008; Oloruntoba *et al*, 2016; Olannye, 2015; Kaoje *et al*., 2019). The consumption of unsafe water has been linked to the prevalence of diseases such as diarrhoea, cholera, infective hepatitis and schistosomiasis (Gyoh, 2011; Oloruntoba *et al*., 2014; Miner *et al*., 2015; Gwimbi *et al*. 2019; Kaoje *et al*., 2019). However, diarrhea has recently been confirmed by Gwimbi *et al*. (2019) as the leading cause of illness in majority of rural households in Mohale Basin, Lesotho, where unsafe water consumption was linked to the prevalence of this disease. The World Health Organization (WHO) estimated about 2.2 million deaths from diarrhea cases annually as a result of unsafe water consumption (WHO, 2014).

Several studies have revealed that the rural communities of Nigeria are still faced with the problem of low access to safe drinking water (Ibiene *et al*., 2012; NPC, 2014; Olukanni *et al*., 2014; Olannye *et al*., 2017; Adeniran, 2018; Kaoje *et al*., 2019). Diarrhoeal diseases linked to unsafe water consumption have been confirmed in previous studies as the major health problem that still persists in Nigeria rural communities (Oloruntoba *et al*., 2014; Miner *et al*., 2015; Kaoje *et al*., 2019). Addressing issues relating to household drinking water quality can drastically reduce health problems associated with water consumption from unsafe sources. This study was, therefore, undertaken to assess the water quality and handling practices of women in rural households of Oshimili North Local Government Area of Delta State, Nigeria.

MATERIALS AND METHODS

Study area

Delta State is one of the oil-producing states in Nigeria located in the south-south geo-political zone of the Niger Delta region. The State covers an area of 17,698 km^2 within 5°30′N and 6°00′E and comprises 25 local government areas. Delta State is made up of three senatorial districts, namely Delta North, Delta South and Delta Central. The study area is Oshimili North Local Government Area (LGA), one of the LGAs in Delta North Senatorial district of Delta State, Nigeria. It has a total population of about 157, 819 (77,353 males and 80,466 females) according to the projected 2015 estimates (Delta State Population Census, 2011).The LGA has eight wards, of which the study area (Ward 3) is the largest in terms of geographical area, number of rural households and water sources. In Ward 3 (Illah Community), the rural households share 8 boreholes, 4 streams and 2 rain water harvesting wells. The inhabitants of the area are normally farmers, fishers and traders.

Study design

A community-based descriptive cross-sectional design involving survey and laboratory analyses of drinking water from sources to households was adopted for the study.

Study population

Women within the age group of 18-65 in Illah community constituted the study population.

Sample size

Considering the low number of water sources in the selected study area, total sampling was employed. Eighty rural households in the community that utilize these water sources for drinking were purposively selected to participate in the study.

Sampling procedure

Multi-stage sampling technique was used for sample selection. Delta North senatorial district was purposively selected based on the large number of LGAs. Oshimili North LGA was picked by balloting. Illah community in ward three was purposively selected from eight wards that make up the LGA based on the large geographical land area and the number of rural households and sources. Illah community was stratified into three major strata using the distinctive features on the map (three major roads). In each stratum, only one of the three neighborhoods were picked by balloting. The households in each stratum were then numbered to obtain the total number of 640 households in the community. Out of this number, only 80 households utilizing the identified water sources as at the time of the study consented to participate. Purposive sampling was used to select a female within the age group of 18-65 years from each of the identified rural households. Drinking water samples were collected from the sources used by selected households and from their storage containers.

Data collection methods and instrument

Survey

A semi-structured self-administered questionnaire was used to elicit information from each woman in selected households on the socio-demographic characteristics of the respondents, current household drinking water sources and water handling practices during collection, storage and use.

Sanitary inspection

Sanitary inspection forms were used to capture the sanitary conditions of commonly used sources and household storage containers in the community. The forms comprised of 10 questions designed for a "Yes" (correct answer) or "No" answer.

Sample collection for determination of physico-chemical parameters

Plastic kegs of two liters capacity and plastic bottles of 60 milliliters capacity were washed with detergents and rinsed with distilled water then dried. All the containers were closed afterwards until the point of sample collection. After sample collection from the sources and household storage containers, the levels of physico-chemical parameters: pH, nitrate, lead, iron, and zinc were determined using standard methods developed by United States Environmental Protection Agency (USEPA) (USEPA, 1996) and American Public Health Association (APHA) (APHA, 1998).

Sample collection for microbial analysis

Glass sample bottles were properly washed, rinsed with distilled water, dried and sterilized in an oven at 170 $^{\circ}$C for one hour. All the containers were closed until the point of sample collection.

Borehole water

Before collecting water samples from the borehole, the faucet was swabbed with cotton wool soaked with 70% alcohol. Then the tap was turned on for five minutes to clear the water lines. The faucet was then sterilized with flame from a spirit lamp for a minute. The water was allowed to run afterwards for five minutes to clear the pipe lines. Sample bottles were carefully opened and the outside of the cap was held in order not to contaminate the container or cap. The container was filled and the top replaced (after flaming), stored in a cool box with ice packs and transported to the laboratory. Analysis was done within six hours of sample collection.

Stream water

Before collecting water samples from the stream, the sterile sample bottle cover was removed aseptically, and the mouth of the bottle was faced upwards. The neck was plunged downwards about 30 cm below the water surface, and then the neck was tilted slightly upwards to let it fill completely before carefully replacing the cap and cover. The sample bottles were covered, stored in a cool box with ice packs and transported to the laboratory. Analyses were done within six hours. This procedure was the same procedure used for drawing water samples from the shallow well since water in it was of little depth.

Water from household storage containers

Water samples were collected from household storage containers under aseptic conditions. The samples were immediately stored in ice packs and transported to the laboratory for analyses within 6 hours.

Determination of bacteriological quality

Samples were appropriately diluted with sterile diluent up to 1:100/1000 and analysed for total coliforms (TC) and *Escherichia coli* (EC) using standard methods by APHA (1998). Lactose fermentation test was carried out to detect and enumerate the number of TC using MacConkey broth at 37 ^{o}C for 18-24 h. Thereafter, positive bottles showing gas formation (in small 30 mm inverted Durham tubes) and colour change (from purple to yellow) were sub-cultured into sterile brilliant green bile broth and incubated at 44 °C for 18-24 h. Gas formation showed presence of *Escherichia coli*. Results were estimated statistically and expressed as TC or EC count /100 ml.

Data management and statistical analysis

Data was entered and analyzed using statistical package for the social sciences (SPSS) version 20. Data from the survey were analysed using descriptive statistics. The water handling practices was on a scale of 30 points comprising of 6 water handling practice questions whose scoring was based on positive option for correct response, and zero for incorrect response. All correct responses in each questionnaire were summed up to a total score. Then the scores were pooled together into SPSS for analysis using descriptive statistics (mean, standard deviation, maximum and minimum) to get the mean handling practice score. Handling practice score ≥ mean score was grouped into good handling practice and handling practice score <mean score was grouped into bad handling practice. The sanitary inspection form was designed on a scale of ten points. Aggregate scores ranging from 0 – 2 (low risk), 3 – 5 (medium risk), 6 – 8 (high risk) and 9 – 10 (very high risk). The results from sanitary inspection were analysed using descriptive statistics to get the mean, standard deviation, maximum value, minimum value and percentages. Levels of water quality parameters at collection points and household storage containers were summarized using descriptive statistics (mean, standard deviation, maximum and minimum values). ANOVA was used to determine the statistical difference in the mean levels of water quality parameters among the sources and also within the households. Chi-square was used to test the association between qualitative variables (storage conditions) and water quality. Using the classification of Cheesbrough (1984), water sample with 0 faecal coliform count per 100 mL was considered to be of excellent quality (grade A), 1-10 colonies per 100 mL was acceptable (grade B), 11-50 colonies per 100 mL was unacceptable (grade C), and counts of more than 50 colonies per 100 mL was considered as grossly polluted (grade D). All analyses were carried out at 5% level of significance.

Ethical approval

This study is a part of a larger one that looked into household characteristics and use of indigenous treatment methods for treating household drinking water in Illah community of Delta State, Nigeria.

Ethical approval for this study was obtained from Delta State Ministry of Health, while verbal approval was obtained from the participants.

RESULTS

Socio-demographic characteristics of the participants

The results of the survey showed that the overall mean age was 34.8±12.5 years of which 31 (38.7%) were below 30 years, 40 (50.0%) were within 30 – 50 years and 9 (11.3%) were above 50 years of age. Majority of the respondents were Christians and Igbo. From the socio-economic status of respondents, less than half 29 (36.2%) engaged in trading while 8 (10.0%) were full time housewives. The highest level of education attained by all respondents in the study revealed that half 40 (50.0%) of the respondents had up to primary school education; 26 (32.5%) had up to secondary school education and 14 (17.5%) had no formal education (Table 1).

Water supply

The sources of drinking water for the 80 respondents were borehole, stream, and harvested rainwater recharged well. Majority 64 (80.0%) of the respondents used boreholes as their source of drinking water, 13 (16.2%) used streams and 3 (3.8%) used harvested rainwater recharged wells (Figure 1).

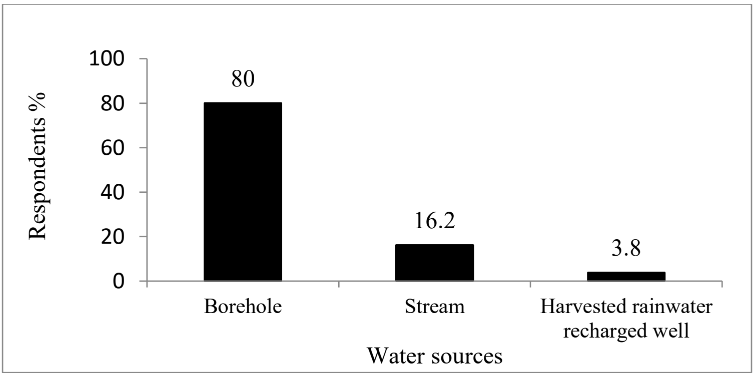

Figure 1. Respondents' drinking water sources in Illah Community.

Water handling practices

Results of the survey showed that during transportation majority of the respondents 76 (95.0%) covered their drinking water containers after collecting water from the sources. Also, majority of the respondents 76 (95.0%) claimed not to use the bucket for fetching drinking water for other domestic purposes.

Table 1. Socio-demographic characteristics.

Socio-demographic factors		Number	%
Sex	All females	80	100
Age	< 30	31	38.7
	30 – 50	40	50.0
	> 50	9	11.3
Ethnicity	Ibo	69	86.2
	Non – ibo	11	13.8
Religion	Christian	68	85.0
	Islam	3	3.8
	Traditional	9	11.2
Occupation	Trade	29	36.2
	Artisan	11	13.8
	Farming	17	21.2
	Student	15	18.8
	House wife	8	10.0
Level of Education	No formal education	14	17.5
	Primary school	40	50.0
	Secondary school	26	32.5

The results of the survey also showed that more than half of the respondents in the households (58.8%) stored their drinking water in wide-mouthed containers (plastic containers like buckets and clay pots) and drew water from them to drink by dipping cups while 41.2% stored drinking water in narrow-mouthed containers (plastic kegs/ jerricans) and drew water by pouring (Table 2). The mean water handling practice was 19.4±6.6 (range: 5–30). Forty-eight (or 60%) of the respondents had bad water handling practices.

Sanitary condition of drinking water sources and household storage containers of the respondents

Observation using the sanitary inspection forms showed that the mean risk score for the water sources (2.6 $\pm$ 1.5) was slightly higher than that of the household storage containers (2.2 $\pm$ 1.4). The risk scores varied between 0 and 4 for the water sources; and 0 - 6 for the household storage containers. Figure 2 shows the level of risk associated with the water sources and household storage containers.

Physico-chemical quality of drinking water from sources and households

The mean values for physico-chemical parameters of drinking water from sources and households are presented in Table 3. The mean values obtained for pH, nitrate, lead, zinc and iron were within the WHO guideline limits of 6.5, 500 mg/L, 50 mg/L, 0.01 mg/L, 3 mg/L and 0.3 mg/L, respectively. Water sources significantly varied in all parameters analysed except nitrates. However, for the household storage containers, only iron showed a significant difference (Table 4).

Table 2. Water handling practices.

Variables	Number	%
Use of bucket for fetching drinking water for other domestic purpose		
Yes	4	5.0
No	76	95.0
Covering drinking water during transportation		
Yes	76	95.0
No	4	5.0
Types of storage container		
Jerrican (Narrow-mouthed)	33	41.2
Plastic Buckets (Open-mouthed)	38	47.5
Clay Pots (Open-mouthed)	9	11.3
Frequency of cleaning storage container		
Daily	14	17.5
Once a Weekly	41	51.3
When dirty	25	31.2
Special container for water collection from storage container		
Yes	78	97.5
No	2	2.5
Mode of collecting drinking water from storage containers		
By pouring	33	41.2
By dipping	47	58.8
Keeping of your drinking water		
In the room	57	71.2
Outside room	4	5.0
In the Kitchen	17	21.3
Outside Kitchen	2	2.5

Bacteriological quality of drinking water from sources and households

The mean values for bacteriological quality of drinking water from sources and households are presented in Table 5. The mean values obtained for total coliforms and *E. coli* counts exceeded the WHO guideline limits of 10 TC/100mL and 0 EC/100mL except for harvested rain in the well, which had no *E. coli* count.

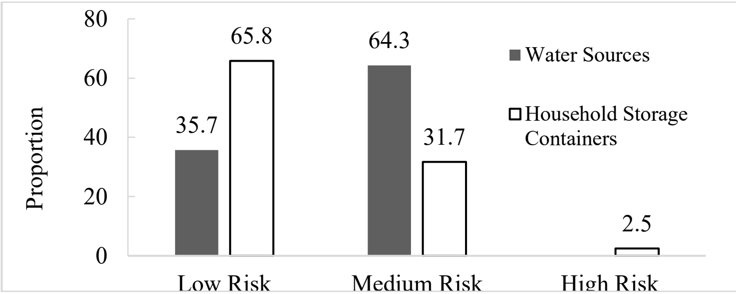

Figure 2. Sanitary conditions of water sources and household storage containers.

Table 4. Variations in physico-chemical quality of drinking water from source and household.

Parameter	**Sources**			**Households**	
	***F* value**	***P*-value**		***F* value**	***P*-value**
pH	24.028	0.000		1.554	0.218
Nitrate	1.030	0.362		1.203	0.306
Lead	3.833	0.026		0.654	0.523
Zinc	3.236	0.045		0.327	0.722
Iron	5.744	0.005		3.904	0.024

Table 5. Bacteriological quality of drinking water.

Parameter	**Borehole (n=64)**		**Stream (n=13)**		**Well (n=3)**		**WHO STD**
	Source	**Household**	**Source**	**Household**	**Source**	**Household**	
TCC (TC/100mL)							
Mean	49.38	96.72	76.15	118.46	80.00	103.33	10
SD	± 20.6	± 43.3	± 46.5	± 64.9	± 17.3	± 11.6	
Minimum	20	20	40	40	60	0	
Maximum	90	170	170	260	90	70	
***E.coli* (EC/100mL)**							
Mean	10.31	36.56	44.62	62.31	ND	30.00	0
SD	± 2.3	± 32.1	± 33.3	± 33.2	ND	± 20.8	
Minimum	0	0	20	20	ND	0	
Maximum	70	110	90	110	ND	70	
Category	B	C	C	D	A	C	

NOTE- ND- Not Detected; A- Excellent quality; B- Acceptable; C- Unacceptable; D- Grossly Polluted

Table 3. Physico-chemical quality of drinking water.

Parameters	**Borehole (n=64)**		**Stream (n=13)**		**Well (n=3)**		**WHO Limits**
	Source	Household	Source	Household	Source	Household	
			pH				
Mean± SD	6.63± 0.5	7.13± 0.5	7.31± 0.4	7.34± 0.6	7.21± 0.02	7.64± 0.5	6.5-
Minimum	6.04	6.10	6.80	6.30	7.20	7.10	8.5
Maximum	7.47	7.70	7.67	8.20	7.24	8.02	
			Nitrate (mg/L)				
Mean± SD	14.30± 5.1	16.21± 7.1	15.87± 1.3	22.37± 4.6	12.52± 1.5	17.28± 6.3	50
Minimum	5.10	4.87	14.40	17.06	10.19	5.54	
Maximum	23.92	42.53	16.61	25.47	16.39	26.14	
			Lead (mg/L)				
Mean± SD	0.0069± 0.0006	± 0.002	0.0070± 0.0004	± 0.002	0.0060± 0.0005	0.0045± 0.0008	0.01
Minimum	0.0061	0.0016	0.0067	0.0025	0.0055	0.0036	
Maximum	0.0076	0.0083	0.0076	0.0077	0.0063	0.0050	
			Zinc (mg/L)				
Mean± SD	1.25± 0.6	1.36± 0.7	1.60± 0.1	1.53± 0.4	0.98± 0.02	1.42± 0.5	3
Minimum	0.53	0.10	1.54	0.93	0.956	1.12	
Maximum	2.61	3.07	2.01	2.41	0.984	1.99	
			Iron (mg/L)				
Mean± SD	0.18± 0.1	0.14± 0.09	0.13± 0.05	0.16± 0.05	0.30± 0.2	0.29± 0.1	0.3
Minimum	0.06	0.01	0.09	0.06	0.10	0.10	
Maximum	0.50	0.40	0.26	0.20	0.50	0.40	

Thus, all water samples from harvested rainwater recharged wells had excellent quality (Figure 3). When all sources were pulled together, only 42.9% had excellent quality, while 28.6% were completely polluted (Figure 4). With regards to the household storage containers only 17.5% were of excellent quality (Figure 5). Table 6 shows the variations in bacteriological quality of drinking water from source and household.

Table 6. Variations in bacteriological quality of drinking water from source and household.

Parameter	**Sources**		**Households**	
	F-value	**P-value**	**F-value**	**P-value Decision**
TCC	7.007	0.002	1.139	0.325
EC	15.211	0.000	3.478	0.036

Association between storage condition and water quality

Collection of water by pouring and cleaning of storage containers daily showed a significant reduction in the concentration of faecal coliform count at the point of storage. Furthermore, water stored in jerricans were found to have significantly better bacteriological quality than water stored in plastic buckets and clay pots (Table 7; Figures 6, 7 and 8).

Table 7. Association between storage condition and water quality.

Variables	**Household Water**		**Chi square** χ^2	***P*-value**
	≤10 faecal coliform counts/ 100mL	**>10 faecal coliform counts /100mL**		
Storage containers				
Jerican	14	19	24.17	0.00*
Plastic Buckets	0	38		
Clay Pots	0	9		
Frequency of Cleaning Storage Containers				
Daily	14	0	80.00	0.00*
Once a week	0	41		
When Dirty	0	25		
Mode of water collection from storage container				
Pouring	14	19	24.17	0.00*
Dipping	0	47		

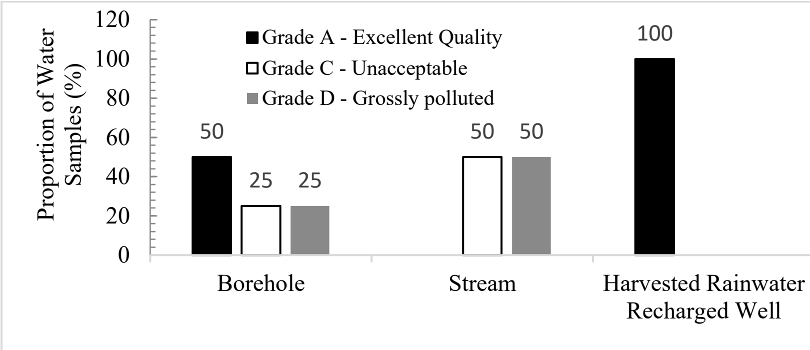

Figure 3. Grade levels of water samples from different sources.

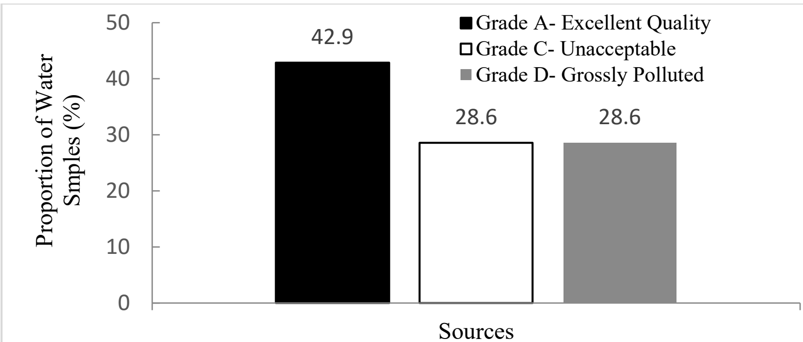

Figure 4. Grade levels of water samples from all sources.

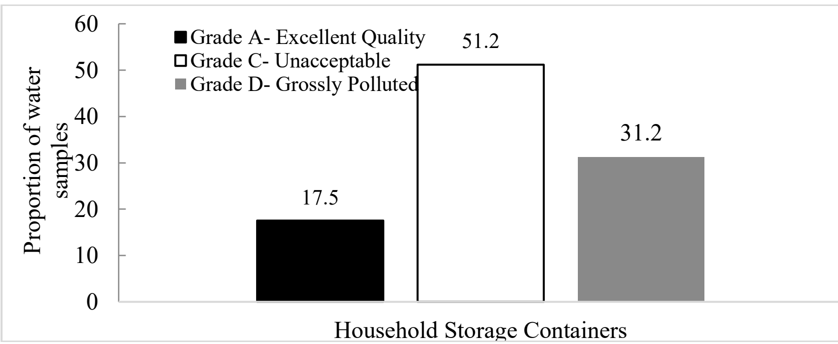

Figure 5. Grade levels of water samples from household storage containers.

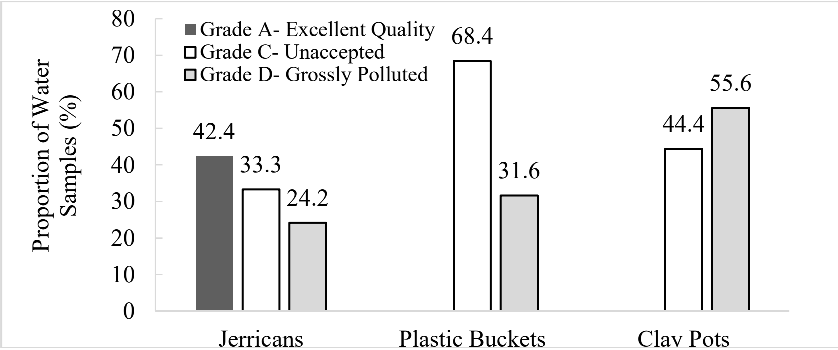

Figure 6. Grade levels of water samples from different storage containers.

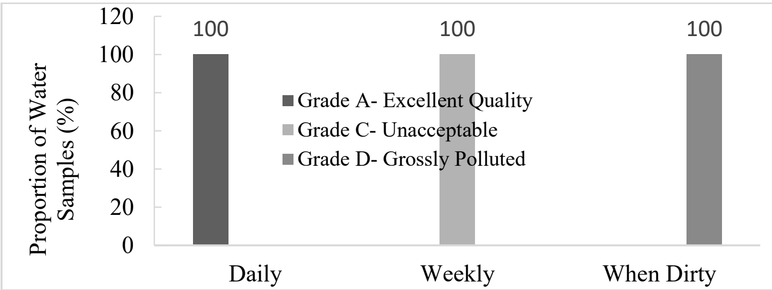

Figure 7. Grade levels of water samples by frequency of cleaning storage containers.

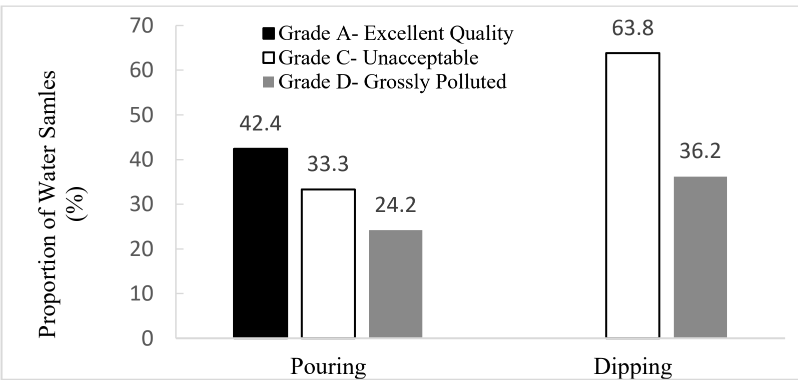

Figure 8. Grade levels of water samples by mode of collection from storage container.

DISCUSSION

The levels of pH, nitrate, lead, iron and zinc in the household drinking water sources were in compliance with the WHO guideline limit of drinking water. It was partly in agreement with the report on comparative assessment of the quality of harvested rainwater, ground water and surface water in one of the rural communities in Delta State, which showed that the levels of pH and zinc in harvested rainwater, ground water and surface water were within the WHO permissible standard. In contrast, the report revealed that the iron concentrations which were higher in the surface water showed unacceptable levels when compared to well water and harvested rain water that showed acceptable levels (Ushurhe and Origho, 2013). Majority of the water samples collected from the household water supplies in this study were positive for total and faecal coliform counts. This finding does not conform to the WHO guidelines (WHO, 1996) which required that water intended for drinking should be free of pathogens and bacterial indicative of faecal contamination. However, the results corroborate other works (Ibiene *et al*., 2012; Olukanni *et al*., 2014; Olannye *et al*., 2017; Adeniran, 2018; Kaoje *et al*., 2018; Gwimbi *et al*., 2019), who reported total and faecal coliform counts far exceeding the WHO guideline limit of drinking water in all the water sources present in one of the rural communities in Delta State.

The study also revealed that the stream water had the highest faecal coliform counts. This corroborates reports by Albert *et al*. (2010), which assessed rural drinking water quality in Kenya and reported that the stand pipe (tap) water and harvested rain had significantly less *E. coli* than surface water (earth pan and rivers). The type of storage containers in this study significantly influenced the water quality consumed by the household. Similar results were reported before (Jensen *et al*., 2002; Oloruntoba and Sridhar, 2007; Levy *et al*., 2008; Oloruntoba *et al*., 2016; Olannye, 2015; Kaoje *et al*., 2018). Storage containers and level of microbial contamination have significant association (Jensen *et al*., 2002; Oloruntoba *et al*., 2014)). The influence of water storage on microbial levels was also evident in the interventional study where *Escherichia coli* counts in stored household waters were <1/100 mL in most intervention households (household where water chlorination and storage in a special container was practiced) but readily detectable at high levels in control households (Sobsey *et al*., 2003).

Furthermore, the use for water storage of plastic buckets and clay pots with wide mouth in this study led to dipping of containers/cups to draw water for use. This method of water collection significantly influenced the water quality via using contaminated container used to draw water from the storage container. Also, the possibility of dipping contaminated hands into the containers during the process of collection cannot be ruled out (Sobsey *et al*., 2003; Tambekar and Mahore, 2005). It has also been confirmed in previous studies that bacteriological quality of drinking water generally deteriorated in household storage containers (Jensen *et al*., 2002; Oloruntoba and Sridhar, 2007; Levy *et al*., 2008; Olannye, 2015; Oloruntoba *et al*., 2016).

CONCLUSION AND RECOMMENDATION

Bacteriological quality (total coliform and *E. coli* counts) of drinking water sources (boreholes, stream and wells) and at the household levels (only *E. coli* count) significantly varied. Also, significant relationship exists between bacteriological quality and handling practices. This implies that since the proportion of contaminated water samples and bacteria counts were high at the household level; there is also high risk of contracting water-borne diseases through the consumption of these sources of water. Therefore, it should be recommended that household drinking water quality could be improved through hygiene education with the propagation of the use of simple, acceptable, low-cost treatment methods (such as solar disinfection, household sand filters and boiling) and use of narrow mouthed containers like jerricans and bottles for storage to reduce dipping of cups, bowls and hands to improve the microbial quality of household stored drinking water.

CONFLICT OF INTEREST

The authors have no competing interests to declare.

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