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Water Quality and Risk of Diarrhoeal Infections among Children under Five in Ibadan, Nigeria

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ABSTRACT

One hundred and thirty two under Five Children (U-5C) with Diarrhoea (cases) and age-matched U-5C without Diarrhoea (controls) were randomly selected from Oni-memorial Children Hospital and University College Hospital in Ibadan. A 10-item observational checklist was used to assess the sanitary status of the drinking water sources and household storage containers of consenting households within 24-48 hours of recruitment. Total Coliform Bacteria (TCB) and *Escherichia coli* in paired drinking water samples were determined using APHA standard procedures. The results were compared with World Health Organization (WHO) guidelines for drinking water quality. Data were analysed using descriptive statistics, t-test, Chi-square and spearman-rank correlation test. The median TCB count for source and household stored drinking water samples for cases (20 and 22/100ml) exceeded the WHO guideline. *Escherichia coli* was absent in water samples from source among cases and controls, while 25% and 5% of cases and controls respectively had *Escherichia coli* in their stored drinking water. Deterioration of stored drinking water quality may be as a result of poor water handling within homes. Results of sanitary inspection show that mean risk scores among cases and controls were 5.4 ± 2.2 and 3.2 ± 1.9 ($p<0.05$) for drinking water sources and 2.4 ± 1.8 and 1.2 ± 0.7 ($p<0.05$) for household storage containers. The results show a significant association between quality of source and stored water and diarrhoeal disease incidence among U-5C (OR=0.076, $p<0.05$). This study therefore recommends training of mothers of children under five years on strategies for improved household water treatment, safe storage, handling and hygiene conditions within households in order to improve water quality.

Keywords: Diarrhoeal disease, Under-five children, hygiene conditions, water quality, Coliform Bacteria.

INTRODUCTION

Diarrhoeal diseases remain a leading cause of illness and death in the developing world (Bern *et al*, 1992). Providing potable water for drinking and washing is critical to reducing diarrhoeal disease transmission in this setting (Esrey *et al*, 1991). However, improving source water quality alone does not always decrease diarrhoeal disease incidence (Briscoe, 1978). Providing a safe drinking water source may fail to reduce diarrhoea because transmission of diarrhoeal pathogens continues through food-borne or person-to-person routes of spread or because people are exposed to contaminated water during bathing and other activities. Drinking water also becomes contaminated after collection, either during transportation or storage in the home (Mintz *et al*, 1995).

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In many parts of the developing world, drinking water is collected from unsafe surface sources outside the home and is then held in household storage vessels. Drinking water may also be contaminated at the source.

Despite the advances in water supply and sanitation, diarrhoeal diseases continue to be one of the most important causes of child morbidity and mortality in the developing world. According to the World Health Organisation (1996), each child in Sub-Saharan Africa experiences an average of five episodes of diarrhoea per year resulting in about 800 000 annual deaths. Again the World Health Organisation (2002) indicated that 5.9 percent of deaths in developing countries are attributable to diarrhoea mainly as a result of unsafe water, sanitation and hygiene practices. Kosek *et al*. (2003) have also estimated that diarrhoea accounts for 21 percent of all deaths of children under- 5 years of age annually, mostly from developing countries.

It is widely recognised that exposure to diarrhoeal pathogens in developing countries is as a result of factors such as quality and quantity of water, availability of toilet facilities, housing conditions, level of education, economic status of households, place of residence and general sanitary conditions (personal or domestic hygiene) of surrounding homes (Diame *et al*., 1990; Timaeus and Lush; 1995). A study of risk factors in rural Africa on diarrhoea in children under 5 years has shown that improvement in water supply and sanitation has the potential of reducing the incidence of diarrhoea within households (Esrey *et al*., 1991). This study was carried out to examine the microbial burden in both source and stored drinking water that predisposes U-5C in Ibadan to Diarrhoea.

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MATERIALS AND METHODS

Description of study Area

The study was carried out in Ibadan, which is located in South-west Nigeria. It is about 78 miles from Lagos and is a prominent transit point between the coastal region and the areas to the north. Its population is estimated to be, about 2,550,593 according to 2006 census and is reputed to be the largest indigenous city in Africa, south of the Sahara. The principal inhabitants of the city are the Yorubas. The city is situated at an altitude ranging from 152 to 213 metres above sea level in a tropical rain forest. The wet season of the year runs from June through October (though occasional showers occur as early as March). In the wet season, temperature ranges from 21°C to 31°C, rainfall from 8.4cm to 18.8cm and humidity from 54% to 77%. In the dry season temperature ranges from 20°C to 31°C, rainfall from 1cm to 4.4cm and humidity from 43% to 83%.

Study design

A prospective case-control study was conducted over a period of 5 months in two purposively selected specialist hospitals responsible for the treatment of Children under five. They are Oni Memorial Children's Hospital and University College Hospital (Otunba Tunwase Children's Emergency Ward), both located in the city of Ibadan. Eligible participants were mothers with children more than one month but less than five years of age whose children present with signs and symptoms of diarrhoea in the two selected health facilities. A similar number of 'controls' was randomly selected from children with infections which are of similar severity to diarrhoea but are unrelated to the exposure of interest.

A multi-phase sampling technique was employed for this study. The first phase was a hospital based identification and random selection of 132 under five children with (cases) and without diarrhoea (controls). Cases were children in the age group of 1 month to 5years confirmed and admitted for diarrhoeal infection during the study period while controls were children 1 month to 5 years of age who were admitted into the same hospital as the cases for non-diarrhoeal complaints during the study period. The second phase was a community based study in which selected cases and controls were followed to their respective houses for sanitary inspection of drinking water sources and drinking water quality assessment. Consent was received from participants before the survey.

The home visit was made within 24hrs of recruitment and data on sanitary inspection of drinking water sources were collected using a 10-1tem observation checklist (sanitary inspection form). Any of the items from the sanitary inspection that constitutes a risk factor was assigned a score of 1 while anyone that does not was assigned a score of 0. Aggregate of the scores gave the sanitary risk scores which were grouped into four categories: 0-2, 3-5, 6-8, and 9-10 for low, moderate, high and very high risk of contamination respectively.

Twenty paired drinking water samples were collected (using 200 ml volume sterile sample bottles) from the sources and household storage containers of consenting households of cases and controls for bacteriological analysis. Participants were asked to collect a sample of water in the storage container as if it were a household drinking cup. Samples were transported on ice as quickly

as possible and analyzed for Most Probable Number (MPN) of total coliform using multiple fermentation technique and aerobic bacteria using pour plate technique within 6 hours of collection.

Statistical analysis

Correlation analyses were performed to determine the relationships between sanitary inspection of sources of drinking water and Total Coliform Bacteria. The Mann–Whitney *U* test was used to find an association between water quality and diarrhoea in children under five years.

RESULTS

Sanitary conditions of sources of drinking water supply

Sanitary conditions of sources of drinking water supply of caregivers/mothers were assessed. Tables 1 sanitary risk score of the sources. The mean risk score for cases was 5.36±2.164 with a minimum and the maximum risk score of 0 and 10 respectively. The mean risk score for controls was 3.17±1.9, with a minimum and maximum risk score of 0 and 8 respectively (Table 2). After rating the sanitary conditions of the drinking water sources, the result shows that 4 (8%) and 23 (46%) cases had low and medium risk of contamination of drinking water sources respectively while 21 (39.6%) and 24 (45.3%) controls had low and medium risk of contamination of drinking water sources respectively. About 19 (38%) and 4 (8%) cases had high and very high risk of contamination of drinking water sources respectively while only 8 (15.1%) controls had high risk of contamination of drinking water sources (Table 2).

A total of 103 drinking water sources which majorly include wells were inspected. Majority of the households, 50 (100%) cases and 48 (90.6%) controls had their drinking water source 10m away from available latrine. More cases 19 (38%) than controls 3 (5.7%) had the nearest latrine on higher ground than their drinking water source. Half of cases 25(50%) and only 10 (18.9%) controls had other source of pollution within 10m of water source other than latrine. More cases 30 (60%) than controls 10 (18.9%) had poor drainage causing stagnant water within 2m of drinking water source. Only 5 (10%) cases and 1 (1.5%) controls had their well uncovered and 26 (52%) cases and 15 (28.3%) controls had their well cover in bad shape (Table 2).

Association between diarrhoeal disease occurrence among children under five years and sanitary condition of drinking water sources within households

The association between diarrhoeal occurrence among children under five years and sanitary conditions of drinking water sources used by households is presented in Table 2. The conditions that were statistically associated with diarrhoeal occurrence include: presence of nearest latrine on higher ground than the water source (OR=10.22, p=0.000), presence of other source of pollution within 10m of water source (OR=4.30, p=0.001), poor drainage causing stagnant water within 2m of water source (OR=6.45, p=0.000), inadequate well lining (OR=2.77, p=0.020), well cover in bad shape (OR=2.74, p=0.014) and leaving fetcher in position they may be contaminated (OR=2.77, p=0.012).

After rating the sanitary condition of the drinking water sources, the result of the bivariate analysis shows that there was reduced risk of diarrhoea with low risk of contamination of the drinking water sources (OR=0.133, p<0.005).

Sanitary condition of the household drinking water storage containers

Sanitary condition of household drinking water storage containers of the 66 consenting cases as well as controls was assessed using seven-item observation checklist which was scaled up to 10 point score. The risk scores were grouped into four: 0-2, 3-5, 6-8, and 9-10 for low, moderate, high and very high risk of contamination respectively.

During observation, only 9 (13.6%) cases and 3 (4.5%) controls' households were seen with cracked drinking water storage containers, 18 (27.3%) cases and 3 (4.5%) controls had foul smell around the storage containers, 15 (22.7%) cases and 7 (10.6%) controls used drinking water storage containers with cover in bad shape, 5 (7.6%) cases and 3 (4.5%) controls had house flies around their containers. More cases 30 (45.5%) than controls 14 (21.2%) located their drinking water container in a dirty environment. Fewer cases 28 (42.4%) than controls 36 (54.5%) located their storage container on wet floor and 17 (25.8%) cases and 8 (12.1%) controls did not cover their containers well (Table 3).

Table 1:
Sanitary Risk associated with Sources used by Participants

Risk score range	Risk Categorisation	Cases (n=47)		Control (n=53)	
		Deep Well	Shallow well	Deep Well	Shallow well
		F (%)	F (%)	F (%)	F (%)
0-2	Low risk	3 (6.4)	1 (2.1)	17 (32.1)	4 (7.6)
3-5	Moderate risk	13 (27.7)	8 (17.0)	17 (32.1)	7 (13.2)
6-8	High risk	6 (12.8)	12 (25.5)	5 (9.4)	3 (5.7)
9-10	Very high risk	1 (2.1)	3 (6.4)	-	-

Table 2:
Association between sanitary condition of drinking water sources within households and diarrhoeal disease occurrence among children under five years

Conditions	Cases n =50	Control n =53	OR (95%CI)	Df	P-value
Latrine within 10m of the water source					
No	49 (98%)	48 (90.6%)	0.196 (0.022-1.739)	1	0.107
Yes	1 (2%)	5 (9.4%)			
The nearest latrine on higher ground than water source.					
No	31 (62%)	50 (94.3%)	10.22 (2.79-27.39)	1	0.000*
Yes	19 (38%)	3 (5.7%)			
Any other source of pollution within 10m of water source					
No	25 (50%)	43 (81.1%)			
Yes	25(50%)	10 (18.9%)	4.30 (1.78-10.41)	1	0.001*
Poor drainage causing stagnant water within 2m of water source					
No	20 (40%)	43 (81.1%)			
Yes	30 (60%)	10 (18.9%)	6.45 (2.65-15.72)	1	0.000*
Inadequate well lining					
No	29 (58%)	42 (79.2%)			
Yes	21 (42%)	11 (20.8%)	2.77 (1.16-6.59)	1	0.020*
Cracks on cement floor around the well					
No	31 (62%)	40 (75.5%)			
Yes	19 (38%)	13 (24.5%)	1.89 (0.81-4.40)	1	0.140
Well uncovered					
No	45 (90%)	52 (98.1%)	5.78 (0.65-51.31)	1	0.079
Yes	5 (10%)	1 (1.5%)			
Well cover in bad shape					
No	24 (48%)	38 (71.7%)			
Yes	26 (52%)	15 (28.3%)	2.74 (1.21-6.20)	1	0.014*
Fetcher left in position they may be contaminated					
No	16 (32%)	30 (56.6%)			
Yes	34 (68%)	23 (43.4%)	2.77 (1.24-6.20)	1	0.012*
More than one fetcher					
No	9 (18%)	17 (32.1%)			
Yes	41 (82%)	36 (67.9%)	2.15 (0.85-5.42)	1	0.100
Rating of sanitary condition of well					
Low	4 (8%)	21 (39.6%)			
Medium	23 (46%)	24 (45.3%)			
High	19 (38%)	8 (15.1%)	0.133 (0.042-0.42)	3	0.000*
Very high	4 (8%)	0 (0%)			
Mean risk score	5.4±2.2	3.2±1.9			
Min	1	0			0.000*
Max	10	8			

*=p<0.05

Table 3:
Relationship between the sanitary condition of the drinking water storage containers and incidence of diarrhoea

Condition	Cases n =66	Control n =66	OR (95%CI)	df	p
Cracks on the storage container					
No	57 (86.4%)	63 (95.5%)	3.316 (0.855-12.853)	1	0.069
Yes	9 (13.6%)	3 (4.5%)			
Foul smell around the storage container					
No	48 (72.7%)	63 (95.5%)			
Yes	18 (27.3%)	3 (4.5%)	7.875 (2.193-28.285)	1	0.000*
Cover in bad shape					
No	51 (77.3%)	59 (89.4%)		1	0.062
Yes	15 (22.7%)	7 (10.6%)	2.479 (0.938-6.554)		
Flies around the storage container					
No	61 (92.4%)	63 (95.5%)			
Yes	5 (7.6%)	3 (4.5%)	1.721 (0.394-7.517)	1	0.466
Container located in dirty environment					
No	36 (54.5%)	52 (78.8%)			
Yes	30 (45.5%)	14 (21.2%)	3.095 (1.442-6.642)	1	0.003*
Container on wet floor					
No	38 (57.6%)	30 (45.5%)	0.614 (0.309-1.221)	1	0.164
Yes	28 (42.4%)	36 (54.5%)			
Cover of container not well placed					
No	49 (74.2%)	58 (87.9%)			
Yes	17 (25.8%)	8 (12.1%)	2.515 (1.000-6.327)	1	0.046*
Rating of sanitary condition of storage container					
Low	37 (56%)	59 (89.4)			
Medium	22 (33.3%)	7 (10.6%)	0.151 (0.060-0.381)	2	0.000*
High	7 (10.6%)	0 (0%)	(1)		
Mean	2.4±1.8	1.2±0.7			

***=p<0.05**

The mean sanitary risk score computed from the sanitary inspection form was 2.4±1.8 for cases and 1.2±0.7 for controls. After rating the sanitary condition of the drinking water storage containers, fewer cases 37 (56%) than controls 59 (89.4%) had low risk of contamination of their drinking water storage containers, 22 (33.3%) cases and 7 (10.6%) controls had medium risk of contamination of containers, and only 7 (10.6%) cases and 0 (0%) controls had high risk of contamination (Table 3).

Relationship between the sanitary condition of household drinking water storage containers and incidence of diarrhoea

The association between the sanitary condition of household drinking water storage containers and incidence of diarrhoea is presented in Table 3. The result shows a significant association between diarrhoea incidence and presence of foul smell around household drinking water containers (OR=7.875, p=0.000), household drinking water storage containers located in dirty environment (OR=3.095, p=0.003) and cover of household drinking water storage containers not well placed (OR=2.515, p=.0.046).

The association between the incidence of diarrhoea and rating of the sanitary condition of the household drinking water containers in the Table 3 shows that there was a reduced risk of diarrhoea among children less than five years whose households used drinking water storage containers with low risk of contamination (OR=0.151, p=0.000).

Bacteriological Quality of Household's Drinking Water

Bacteriological analysis was carried out to determine the total viable count, coliform bacteria, faecal Coliform (*Escherichia coli*) and identify bacteria isolates in drinking water samples from source of supply and the storage containers of 40 consenting households (cases and controls).

Table 4: Relationship between diarrhoeal disease and the quality of source water samples

Bacterial count	Case N=20	Control N=20	OR (95% CI)	Df	P-value
TCB (coliform count/100ml)					
≤10	3 (15%)	14 (70%)	0.076 (0.016-0.358)	1	0.000*
>10	17 (85%)	6 (30%)			
Median	20	8			
Min	0	0			
Max	150	75			
TVC (cfu/100ml)					
≤10	1 (5%)	3 (15%)	0.30	1	0.292
>10	19 (95%)	17 (85%)			
Median	7.4×10^2	1.95×10^2			
Min	0	0			
Max	3.2×10^4	3.0×10^3			

***=p<0.05**

Table 5: Relationship between diarrhoeal disease and the quality of stored water samples

Bacterial count	Case N=20	Control N=20	OR (95% CI)	Df	P-value
TCB/MPN (coliform/100ml)					
≤10	3 (15%)	14 (70%)	0.076 (0.016-0.358)	1	0.000*
>10	17 (85%)	6 (30%)			
Median	22	6.5			
Min	4	0			
Max	150	39			
TVC (cfu/100ml)					
≤10	0 (0%)	5 (25%)	-	1	0.017*
>10	20 (100%)	15 (75%)			
Median	6.55×10^2	2.0×10^2			
Min	70	0			
Max	3.2×10^4	1.8×10^3			

***=p<0.05**

Table 6: Relationship between bacteria isolates in source water samples and diarrhoeal incidence

Isolated bacteria	Case N=20	Control N=20	OR (95% CI)	df	P-value
E coli					
Present	0 (0%)	0 (0%)	-	-	-
Absent	100 (100%)	100 (100%)			
Aeromonas spp					
Present	9 (45%)	3 (15%)	4.635 (1.023-21.004)	1	0.038*
Absent	11 (55%)	17 (85%)			
Proteus spp					
Present	9 (45%)	4 (20%)	3.273 (0.802-13.350)	1	0.091
Absent	11 (55%)	16 (80%)			
Klebsiella spp					
Present	17 (85%)	12 (60%)	3.778 (0.827-17.252)	1	0.077
Absent	3 (15%)	8 (40%)			
Pseudomonas spp					
Present	18 (90%)	14 (70%)	3.857 (0.673-22.109)	1	0.114
Absent	2 (10%)	6 (30%)			
Enterobacter spp					
Present	19 (95%)	17 (85%)	3.353 (0.318-35.364)	1	0.292
Absent	1 (5%)	3 (15%)			

***=p<0.05**

Table 7: Relationship between bacteria isolates in stored water samples and diarrhoeal incidence

Isolated bacteria	Case N=20	Control N=20	OR (95% CI)	df	P-value
E coli					
Present	5 (25%)	1 (5%)	6.333 (0.667-60.163)	1	0.077
Absent	15 (75%)	19 (95%)			
Aeromonas spp					
Present	10 (50%)	3 (15%)	5.667 ()	1	0.018*
Absent	10 (50%)	17 (85%)			
Proteuss spp					
Present	9 (45%)	3 (15%)	4.636 (1.023-21.004)	1	0.038*
Absent	11 (55%)	17 (85%)			
Klebsiella spp					
Present	12 (60%)	11 (55%)	1.227 (0.350-4.307)	1	0.749
Absent	8 (40%)	9 (45%)			
Pseudomonas spp					
Present	17 (85%)	14 (70%)	2.429 (0.512-11.511)	1	0.256
Absent	3 (15%)	6 (30%)			
Enterobacter spp					
Present	19 (95%)	15 (75%)	6.333 (0.667-60.163)	1	0.077
Absent	1 (5%)	5 (25%)			

***=p<0.05**

Total Coliform Bacteria (TCB) in Source and Stored Water Samples.

Coliform counts in both source and stored water samples are shown in Tables 4 and 5. The TCB count in source water samples among cases ranged from 0 coliform/100ml to 150 coliform/100ml with a median count of 20 coliform/100ml while the TCB count in source water samples among controls ranged from 0 coliform/100ml to 75 coliform/100ml with a median count of 8 coliform/100ml. The TCB count in stored water samples among cases ranged from 4 coliform/100ml to 150 coliform/ 100ml with a median count of 22 coliform/100ml while the TCB count in stored water samples among controls ranged from 0 coliform/100ml to 39 coliform/100ml with a median count of 6.5 coliform/100ml. About 5 (25%) cases and 1 (5%) control had *E coli* present in their stored water sample (Table 7). *E coli* was absent in source water samples. Only 3 (15%) of the water samples from source and storage containers of cases satisfied WHO water quality guideline (<10coliform/100ml) while 14 (70%) of water samples from source and storage containers of controls satisfied the guideline.

Viable Bacterial Count from Source and Stored Water Samples

The result in Table 4 shows the Total viable bacteria count from various water samples. The Total Viable Count (TVC) of bacteria ranged from 0 to 3.2×10^4 cfu/ml in source water sample among cases, and 0 to 3.0×10^3 cfu/ml in source water samples among controls. The TVC of bacteria ranged from 70 to 3.2×10^4 cfu/ml in stored water samples among cases and 0 to 1.8×10^3 cfu/ml among controls. The major source of water supply among the study population was well followed by tap.

Relationship between diarrhoeal disease occurrence and quality of source and stored water samples

The relationship between diarrhoeal disease and quality of source and stored water samples is shown in Tables 4 and 5. The results show that there is a significant association between diarrhoeal disease and quality of drinking water from source of supply and household storage containers with TCB count less than or equal to 10 coliform/100ml (OR=0.076, p=0.000) which is the WHO guideline for drinking water quality

Bacteria isolates from source water samples

The bacteria that were isolated from the source water samples of cases and controls are presented in Table 6. Five different bacteria species were identified. These include; *Enterobacter spp*, 19(96%) cases and 17(85%) controls, *Pseudomonas spp*, 18 (90%) cases and 14 (70%) controls, *Klebsiella spp*, 17 (85%) cases and 12 (60%) controls, *Proteus spp*, 9 (45%) cases and 4 (20%) controls and *Aeromonas spp*, 9 (45%) cases and 3(15%) controls. *E coli* was absent in all the drinking water samples from source of supply.

Bacteria isolates from stored water samples

Bacteria that were isolated from the stored water samples of cases and controls are presented in Table 7. Six different bacteria species were identified. These

include; *Enterobacter spp*, 19(96%) cases and 15(75%) controls, *Pseudomonas spp*, 17 (85%) cases and 14 (70%) controls, *Klebsiella spp*, 12 (60%) cases and 11 (55%) controls, *Proteus spp*, 9 (45%) cases and 3 (15%) controls and *Aeromonas spp*, 10 (50%) cases and 3(15%) controls. *E coli* was present in some of the stored drinking water samples, 5 (25%) cases and 1 (5%) control.

Table 8:
Association between risks for sanitary inspection and bacteriological quality of drinking water sources used by households belonging to cases

Grade	TCB grouped	Grade	Sanitary Inspection group scores	df	Correlation coefficient (r)	P-value
No	3(15%)	Low	3 (20%)	19	0.214	0.444
Low	11(55%)	moderate	3 (20%)			
High	6(30%)	High	5 (33.3%)			
Very high	0(0%)	Very high	4 (26.7%)			

TCB group: No risk =0 coliform/ml, low=1-10 coliform/ml, high=11-100 coliform/ml and very high risk $\geq 101 coliform/ml$
Sanitary inspection risk scores group: low=0-2, moderate= 3-5, high=6-8, very high risk =9-10

Table 9:
Association between risks for sanitary inspection and bacteriological quality of drinking water sources used by households belonging to controls

Grade	Coliform count/ml	Grade		Sanitary Inspection scores	df	Correlation coefficient (r)	P-value
Low	1(5%)	Low		10 (55.6%)	19	0.223	0.374
Moderate	2(10%)	Moderate		5(27.8%)			
High	13(65%)	High		3(16.7)			
Very high	4(20%)	Very high		0(0%)			

TCB group: No risk =0 coliform/ml, low=1-10 coliform/ml, high=11-100 coliform/ml and very high risk $\geq 101 coliform/ml$
Sanitary inspection risk scores group: low=0-2, moderate= 3-5, high=6-8, very high risk =9-10

Relationship between bacteria isolates in source water samples and diarrhoeal incidence

The relationship between bacteria isolates in source water samples and diarrhoea incidence among children under five is presented in Table 6. The result showed a significant association between presence of *Aeromonas spp* in source drinking water samples and diarrhoea (OR=4.636, p=0.038).

Relationship between bacteria isolates in stored water samples and diarrhoeal incidence

The relationship between bacteria isolates in stored water samples and diarrhoeal incidence among children under five is presented in Table 7. The result showed a significant association between presence of *Aeromonas spp* in stored drinking water samples and diarrhoea (OR=5.667, p=0.018). There is also a significant association between presence of *Proteus spp* in stored drinking water and diarrhoeal disease incidence (OR=4.636, p=0.038).

Association between sanitary condition and bacteriological quality of drinking water sources

Correlation of water quality (total coliform) with the sanitary inspection risk scores shows that there was no significant correlation between the Total Coliform Bacteria and sanitary inspection scores of the drinking water sources used by households belonging to cases p>0.05 (Table 8) and controls (Table 9).

DISCUSSION

Water supply in households belonging to cases was of poor quality compared to controls. The Most Probable Number (MPN) of total coliform (TC) in source water samples ranged from 0 to 150 coliform/100ml (with a median count of 20 coliform/100ml); and 0 to 75 coliform/100ml (with a median count of 8 coliform/100ml) for households belonging to cases and controls respectively. The TC count for stored water samples also ranged from 4 to 150 coliform/100ml (with a median count of 22 coliform/100ml); and 0 to 39 coliform/100ml (with a median count of 6.5 coliform/100ml) for households belonging to cases and controls respectively. Only 15% of source water samples

as well as stored water samples from households belonging to cases satisfied WHO guideline for drinking water quality while 70% of source as well as stored water samples from households of controls satisfied WHO guideline for drinking water quality of <10/100ml TC. The result showed a significant association between quality of source water and stored water and diarrhoeal disease incidence among children less than five (OR=0.076, p<0.001). There was no difference in the number of source and stored water samples that satisfied WHO guideline among the case and the control groups. This finding is in keeping with that of Oloruntoba (2005) that majority of water supplies in Ibadan are contaminated and that the contamination is higher at point of use. The presence of coliform group in these water samples generally suggests that certain selection of water may have been contaminated with faeces either of human or animal origin.

Coliforms were considered as indicators of faecal pollution in water which is of public health importance. Nearly all studies used total and faecal coliforms as indicators of faecal contamination and as available testing technology in most developing countries (Wright *et al*, 2004). *E. coli* is WHO indicator for recent contamination. *E. coli* was found in 25% and 5% of stored water samples in households belonging to cases and controls respectively while none was found in all the source water samples from households belonging to both the case and control groups. There was no significant but positive association between the presence of *E. coli* in stored water samples and childhood diarrhoea (OR=6.33, p<0.05). This contamination may be as a result of poor water handling within homes such as dipping of hands inside the storage containers during water collection especially after using the toilet without handwashing with soap. This finding is in support of that of Tembekar *et al* (2006) that dipping hand into water can lead to contamination. Clasen and Bastable (2003) examined faecal contamination of drinking water during collection and household storage and reported that even water from safe sources was subject to frequent and extensive faecal contamination (with over 90% of samples containing thermotolerant coliforms after collection).

The weak correlation between diarrhoea risk and presence of faecal indicator bacteria such as E. coli has been previously reported. Brown *et al* (2008) suggested a weak but positive association between E. coli counts in household drinking water and diarrhoea; and for diarrhoea with blood (dysentery), after adjusting for clustering within households and within individuals over time. A meta-analysis by Gundry *et al* (2004) concluded that there was no clear association between levels of indicator bacteria (E. coli, thermotolerant coliforms) and diarrhoea in a systematic review of intervention trials. April *et al* (1991) found no relationship between diarrhoeal illness rates and good quality versus moderately contaminated drinking water in a field study from the Philippines.

Most of the water sources were on higher ground than the toilets even though they were at least 10 metres away from the toilets. Clogged drainages, stagnant water, refuse bins and dumping sites were located about 10 metres to the water sources. The lining of some wells were inadequate and also with bad cover. Most buckets used in drawing water from the wells were left on dirty floors and near dust bins where they may be contaminated. Conditions of the water sources that were significantly associated with childhood diarrhoea are: nearest latrine on higher ground than water (OR=10.22, p<0.001), source of pollution within 10 meter of water source (OR=4.30,p<0.05), poor drainage causing stagnant water within 2 meters of water source, inadequate well lining (OR=2.77, p<0.02), well cover in bad shape (OR=2.74, p<0.05) and buckets left in position they may be contaminated (OR=2.77, p<0.05). This study shows that low contamination of drinking water source is significantly associated with low risk of childhood diarrhoea (OR=0.133, p<0.005). Punyaratabandhu *et al* (1991) also reported that unsanitary water source for drinking and other use had strong association with diarrhoea.

Some of the drinking water storage facilities were either not covered or covers were not well placed, located in dirty environment and on wet floor. Conditions of the storage facility that were significantly associated with childhood diarrhoea include: Foul smell around the container (OR=7.88, p<0.001), container located in a dirty environment (OR=3.10, p<0.05) and cover of container not well placed. This study shows that low contamination of drinking water storage facility is significantly associated with low incidence of childhood diarrhoea. This findings is similar to the report of Heller *et al* (2005) on a case-control study carried out in Betim, southern Brazil that domestic water reservoir and storage conditions were significantly associated with diarrhoea. Contamination of water during collection, transport, and storage at home presents a serious risk to health for millions of households in developing countries. Several studies have shown an increased risk of diarrhoea because of inadequate water storage (Knight *et al*, 1992).

Conclusion

Although this study did not report a significant association between presence of *E. coli* in household

drinking water and diarrheal disease outcomes, it cannot be concluded that household water quality is not an important determinant of diarrhoeal disease. The fact that there was no E-coli found in source water but was found to be present in some of the stored water samples showed a degree of poor water handling which was found to be a major source of contamination of stored water. This can also be evident in the significant association between increased sanitary risk score from sanitary inspection of storage containers and diarrhoea among children under five years. There was a significant association between diarrhoeal disease outcome and coliform count in both source and stored water.

The increase in contamination of stored drinking water may be as a result of poor water handling within homes such as dipping of hands inside the storage containers during water collection especially after using the toilet without hand washing with soap. This study therefore recommends training of mothers of children under five years on strategies for improved household water treatment, safe storage, handling and hygiene conditions within households in order to improve water quality.

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