A Comparative Study on the Effect of Household Water Treatment on Diarrhoea Morbidity among Under-Fives in Plateau State, Nigeria Using Two Treatment Modalities

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Abstract

Background: Consumption of unsafe water contributes to diarrhoeal burden in sub-Sahara Africa. This burden can be reduced by simple and affordable methods of household water treatment. The study aims at comparing the effect of two of such methods on diarrheal burden among under-fives in rural communities of Plateau State.

Methodology: A community-based quasi experimental study was conducted among 202 underfive-caregiver pairs in two selected rural communities of Plateau State, involving household water treatment with flocculant-disinfectant powder in intervention group and sodium hypochlorite solution in control group. History of diarrhoea before intervention, at 2 weekly intervals during the intervention and after intervention was assessed. Data obtained was analyzed using SPSS version 23. Prevalence and incidence of diarrhoea were calculated and compared among the two groups.

Result: Diarrhoea prevalence at pre-intervention was 19.6% in flocculant-disinfectant group and 17.0% in sodium hypochlorite group. At post intervention, the prevalence reduced significantly by 94.7% (19.6% to 1%) in intervention group and by 76.5% (17% to 4.2%) in control group. There was no statistically significant difference in the prevalence of diarrhoea between the two groups. However, diarrhoea incidence in the sodium hypochlorite group (1.12 episode per child per year) was significantly higher than the incidence in the flocculant-disinfectant group (0.59 episodes per child per year) with a risk-ratio of 1.93 (95% CI: 1.037 - 3.703).

Conclusion: Household water treatment with flocculant-disinfectant reduced diarrhoea burden better than sodium hypochlorite. This technology should be made more available and assessible to rural communities where diarrhea burden is high.

Keywords: Household water treatment, diarrhoea morbidity, flocculant-disinfectant, sodium hypochlorite

1. Introduction

Diarrhoea is a health condition which is characterized by decreased consistency and increased number of stools.[1] Children especially under-fives, are particularly vulnerable to diarrhoeal diseases and their life-threatening complications. Among under-fives globally, diarrhea remains the second leading cause of death, second only to acute respiratory infections, accounting for 1 in 9 child deaths[2] and caused up to 8% of under-five deaths in 2017.[3] About 1,300 children and 480,000 children die from diarrhoea on a daily and yearly basis respectively. Most under-five deaths from diarrhea are observed in South Asia and sub-Saharan Africa.[3, 4] In Nigeria, up to 194,000 lives are lost annually from diarrhoea, a figure which is second highest in the world, after India.[5] Its prevalence among under-fives in Nigeria continues to increase as it increased from 10% in 2013[6] to 13% in 2018.[7] Similarly in Plateau State, diarrhoeal prevalence increased from 5.6% in 2013[6] to 13.3% in 2018.[7]

Consumption of unsafe drinking water is one of the routes through which diarrhoeal pathogens can be transmitted faeco-orally. Globally, 785 million people lack access to improved drinking water sources and over 2 billion people drink water from sources that are contaminated with faeces.[8] About 88% of the 4 billion cases of diarrhoeal disease that occur annually are as a result of unsafe drinking water, along with poor sanitation and hygiene.[9] These also account for about 60% of diarrhoeal deaths.

Waterborne diseases including diarrhoea, exact a heavy burden for both individuals and the public health care system in developing countries. This burden can be prevented or significantly reduced by the use of appropriate, simple, acceptable and affordable point-of-use/household water treatment methods which have been shown to reduce diarrheal diseases by up to 50-70% even in resource-limited areas.[9] One of such methods is the use of chlorine-based disinfectants commonly available as sodium hypochlorite solution/powders which inactivate bacteria and some viruses.[10] Another technology suitable for resource-limited settings which is quite new in this part of the country, is the combination of chlorination and flocculation using flocculant-disinfectant powders, granules or tablets which has an added advantage against pathogens hidden within flocs or particles in dirty water.[1, 11]

This study aims to determine and compare the effect of household water treatment on diarrhoea morbidity among under-fives in rural communities of Plateau State using the two treatment modalities: use of combined flocculant-disinfectant (flocculation and disinfection) and sodium hypochlorite solution (disinfection alone).

2. Materials And Methods

Study Area: This study was carried out in selected communities of Plateau State, located in the North Central zone of Nigeria, West Africa. Plateau State is divided into 17 Local Government Areas (LGAs). Sixty nine percent of inhabitants live in rural areas, while 31% live in urban areas. The State has abundant surface and ground water resources, especially during the rainy seasons which peaks within the months of July and August.[12]

Study Design and population: The study was a community-based quasi-experimental study conducted among under-fives and their adult female primary caregivers involving the use of the more familiar sodium hypochlorite solution (disinfectant alone) and newer combination of flocculant-disinfectant powder in two selected rural communities of Plateau State.

Sample size and sampling Technique: A minimum sample size of 89 was calculated [using the formula: $n = (Z_\alpha + Z_\beta)^2 2p (1-p) / d^2$] for each community. But participants selected ended up being 100 in group A and 102 in group B using a multi-stage sampling technique. Bassa and Jos-East LGAs were selected from the 17 LGAs in the State which was followed by selection of wards and communities, all using Simple Random Sampling (SRS) by balloting. The two communities selected were studied as clusters. For households with more than one under-five, SRS by balloting was used to select one under-five. Foda Fobur community was selected as intervention group A and Igbak community as control group B.

Study instruments: Instruments used for data collection included a semi- structured interviewer administered questionnaire (which collected data on socio-demographic characteristics, history of diarrhoea, water management practices and factors affecting diarrhoea), an observational checklist, basinet and bathroom weighing scales, and laboratory instruments for water collection and analysis.

Data collection method: Recruitment and training of research assistance for data collection was done. Advocacy visits to the two LGA Chairmen, district heads, ward heads and community heads were carried out and their permission obtained. Baseline data was collected from the respondents after obtaining written informed consent. A two-week history of diarrhoea among under-fives was obtained and water samples were collected from each household for microbiological analysis.

The intervention comprised of health education (on HWT, causes and prevention of diarrhoea) and household treatment of drinking water with combined flocculant–disinfectant for the study participants in intervention group A while the participants in the control group B received disinfectant alone as sodium hypochlorite solution for their household drinking water treatment. Participants were followed for 12 weeks with 2-weekly assessment of diarrhoea. At post-intervention, tools used at baseline were also used to collect

information from participants in their households which included history of diarrhoea and drinking water analysis.

Data management and analysis: Data was processed and analyzed using the SPSS version 23 statistical package. Quantitative variables were summarized using mean and standard deviation while qualitative variables were summarized using tables and charts. Logistic regression was done to identify exposure variables that predicted diarrhoea among the under-fives after previously being subjected to bivariate analysis.

Diarrhoea was defined as the passage of 3 or more loose stools over a 24-hour period in an under-five or an increase in stool frequency or liquidity that is considered abnormal for the child. A fresh episode was defined as diarrhoea occurring after a two days period free of diarrhoea. Two-week prevalence, cumulative incidence of diarrhoea (calculated as number of diarrhea episodes during the period / total number of under-fives at the start of the period X 100) and incidence density of diarrhoea (number of diarrhoea episodes during study period / total number of person-time observed X 1000) were calculated for each group. A risk ratio (incidence in control group / incidence in intervention group) was also calculated.

Ethical consideration: Ethical approval for the study was obtained from the Human and Research Ethics Committee of Jos University Teaching Hospital. Verbal and written informed consent were obtained from participants and confidentiality was ensured.

Limitation of the study: There could have been recall bias in measuring responses of participants, especially in reporting diarrhoea. However, it is hoped that a recall period of two weeks is a reasonable period in reporting disease morbidity before significant bias sets in.

3. Results

Household, child and caregiver characteristics
The participants (child-caregiver pair) enrolled in the study were 102 in groups A and 100 in B. There was an attrition rate of 1.9% and 4% respectively. The mean ages of the caregivers were 34.0 ± 12.9 years and 31.0 ± 11.6 years while the mean ages of the under-fives were 31.4 ± 15.7 and 33.9 ± 17.5 months in groups A and B respectively. These showed no statistically significant differences.

Tables 1 and 2 showed that the household and personal characteristics of participants in both groups were largely similar.

Table 1: Baseline socio-demographic characteristics of caregivers and household

Characteristics	Group A (n = 102)		Group B (n = 100)		χ^2 value	df	P-
	Freq	%	Freq	%			
Marital status							
Currently married	84	82.4	91	91.0			
Not currently married	18	17.6	9	9.0	3.244	1	0.072
Ethnicity							
Iindigenous tribes	82		90				
Non indigenous Tribes	80.4		90.0		3.686	1	0.239
	20	19.6	10				
			10.0				
Level of education							
No formal education	16	15.7	10	10.0			
Primary	39		52	52.0	6.346	3	0.096
Secondary	38.2		35	35.0			
Tertiary	38		3	3.0			
	37.3						

	Group A (n=102) Freq (%)	Group B (n=100) Freq (%)	χ^2	df	P-value
	9 8.8				
Occupation					
None/house wife	29 28.4	14 14.0			
Petty trading	28 27.5	26 26.0	9.732	4	
Farming	31 30.4	44 44.0	**0.045***		
Artisan	8 7.8	13 13.0			
Others	6 5.9	3 3.0			
Household monthly income (Naira)					
<5000	10 9.8	14 14.0			
5000 – 20000	58 56.9	56 56.0	1.302	3	0.729
21000 – 50000	25 24.5	24 24.0			
≥51000	9 6.9	6 6.0			
Number of persons in household					
1 -5 persons	51 50.0	39 39.0	2.473	1	0.116
≥6 persons	51 50.0	61 61.0			
Number of under-fives in household					
1 or 2	91 89.2	94 94.0	1.500	1	
≥3	11 10.8	6 6.0	0.221		
Care-giver of under-five					
Mother	88 86.3	90 90.0	-		-
Grandmother	12 11.8	8 8.0	0.803*		
Aunt/neighbor	2 2.0	2 2.0			

*= Fisher's exact

Table 2: Personal characteristics of under-five

Child Characteristics	Group A(n=102) Freq (%)	Group B (n=100) Freq (%)	χ^2	df	P-value
Age of child					
≤24 months	39 (38.2)	39(39.0)	0.01	1	
>24 months	63 (61.8)	61 (61.0)	0.911		
Birth order					
1st – 3rd	68 (66.7)	65 (65.0)			

≥4th	34 (33.3)	35 (35.0)	0.06 0.803	1
School enrolment In school Not in school	58 (56.9) 44 (43.10	44 (44.0) 56 (56.0)	3.33 0.068	1
Exclusively breastfed No Yes	3 (2.9) 99 (97.1)	4 (4.0) 96 (96.0)	0.17 0.681	1
Fully immunized Yes No No idea	81 (79.4) 17 (16.7) 4 (3.9)	90 (90.0) 6 (6.0) 4 (4.0)	- 0.051*	-
Weight for age ≤ -2 Z-scores > -2 Z-scores	3 (2.9) 99 (97.1)	2 (2.0) 98 (98.0)	0.18 0.668	1
Height for age ≤ -2 Z-scores > -2 Z-scores	1 (1.0) 101 (99.0)	2 (2.0) 98 (98.0)	0.36 0.550	1

*= Fisher's exact

Household drinking water quality
As depicted in table 3, the proportions of households with *E. coli* contamination of water in the two groups were comparable before intervention even though more households in group A had contaminated water. There was however, a significant difference observed after intervention with group A having fewer households with contaminated water when compared with group B households.

Table 3: Comparison of drinking water contamination of households before and after intervention

E. coli contamination of drinking water	Before intervention		After intervention	
	Group A Freq (%)	**Group B Freq (%)**	**Group A Freq (%)**	**Group B Freq (%)**
E. coli Absent	26 (26.0)	37 (38.5)	88 (88.0)	64 (66.7)
Present	74 (74.0)	59 (61.5)	12 (12.0)	32 (33.3)
	χ^2 = 3.52; df = 1; p = 0.060		χ^2 = 12.80; df = 1; **p < 0.001***	

Diarrhoea prevalence and incidence
The prevalence of diarrhoea significantly reduced after intervention by 94.7% in group A (flocculant-disinfectant group) and 76.5% in group B (sodium hypochlorite group).

Table 4: Comparison of diarrhoea prevalence within each group

Diarrhoea	Group A (post-intervention)			Group B (post-intervention)		
	Absent (% of total)	Present (% of total)	Total	Absent (% of total)	Present (% of total)	Total
Pre-intervention Absent Present	81 (81.0) 18 (18.0	0 (0.0) 1 (1.0)	81 (81.0) 19 (19.0)	76 (79.1) 16 (16.7)	3 (3.1) 1 (1.0)	79 (82.3) 17 (17.7)

	)					
Total	99 (99.0)	1 (1.0)	100 (100.0)	91 (94.8)	4 (4.1)	96 (100.0)
	McNemar's P < 0.001			McNemar's P = 0.003		
Percentage reduction in diarrhoea prevalence	94.7%			76.5%		

Diarrhoea prevalence before intervention was 19.6% in group A and 17% in group B (table 5). After intervention, the prevalence was reduced to 1% and 4% respectively in the two groups. The two groups did not statistically differ in diarrhoea prevalence before or after interventions. However, more households were diarrhoea-free in group A (99%) compared to group B (92%) after intervention.

Table 5: Comparison of diarrhoea prevalence between groups at pre- and post-intervention

Diarrhoea Prevalence	Before intervention			After intervention		
	Group A Freq (%)	Group B Freq (%)	χ^2 P-value	Group A Freq (%)	Group B Freq (%)	χ^2 P-value
Diarrhoea Present Absent	20 (19.6) 82 (80.4)	17 (17.0) 83 (83.0)	0.23 0.632	1 (1.0) 99 (99.0)	4 (4.2) 92 (92.0)	1 92 0.161

At post intervention, both cumulative incidence and incidence density of diarrhoea were significantly lower among under-fives in group A than B (table 6). Under-fives in control group B were found to be 93% more likely to have diarrhoea than those in the intervention group A.

Table 6: Incidence of diarrhoea among under-fives

Parameters	Flocculant-disinfectant Group A	Disinfectant-only Group B
No. of under-fives at risk at baseline	102	100
No. of under-fives who reported diarrhoea during intervention	12	24
Total No. of new episodes of diarrhoea	15	28
Total No. of observation days	8526	8246
Cumulative incidence in 12 weeks	0.15 episodes per child in 12 weeks	0.28 episodes per child in 12 weeks
Estimated Incidence per year	0.59 episodes per child per year	1.12 episodes per child per year
Incidence Density	18 episodes per 10,000 person days of observation	34 episodes per 10,000 person days of observation
Relative risk=Inc. in group B Inc. in group A	1.930 (95% CI: 1.037 - 3.703)	

Predictors of diarrhoea
After bivariate analysis was done, 5 factors in group A and 4 factors in group B were significantly associated with diarrhoea at baseline. These were further subjected to logistic regression and in group A, age of child and duration of storage of drinking water were found to be predictors of diarrhoea. However, in

group B, marital status, method of refuse disposal and *E. coli* contamination of drinking water were significant predictors of diarrhoea.

Table 7: Predictors of under-five diarrhoea in groups A and B

	Adjusted Odds Ratio	95% CI	P-value
Group A			
Age of child			
≤24 months	6.88	1.35 – 35.12	**0.041***
>24 months	1		
School enrolment of child			
In school	1	0.37 – 9.01	0.460
Not in school	1.82		
Duration of drinking water storage			
≤3 days	0.15	0.02 – 0.74	**0.020***
>3 days	1		
Type of toilet			
Non-improved	1		
Improved	0.41	0.09 – 1.88	0.251
***E.coli* contamination of water**			
Absent			
Present	4.57	0.51 – 41.18	0.175
Group B			
Education of caregiver			
No formal education	1		
Formal education	0.34	0.08 -1.52	0.157
Marital status of caregiver			
Currently married	1		
Not currently married	8.14	1.17 – 32.14	**0.032***
Refuse disposal method			
Open dumping	1		
Burning	0.09	0.01 – 0.77	**0.028***
***E.coli* contamination of water**			
Absent			
Present	2.14	1.09 - 17.22	**0.035***

4. Discussion

The prevalence of diarrhoea obtained in both groups is an indication that about 1 in 5 children suffer from diarrhoeal disease in these areas. These figures are slightly higher than the national averages of 10% in 2013[6] and 13% in 2018,[7] but closer to the prevalence of 14.8% found in another study conducted among children of rural households in Nigeria.[7] The diarrhoeal prevalence of 13.3% for Plateau state as determined by the NDHS 2018 is also lower than the prevalence obtained in this study probably because of the combination of both rural and urban households in the NDHS. However, findings from studies conducted in rural areas of Ethiopia and Liberia similarly found prevalence that ranged from 19.6%- 20.3%.[13] Some studies have found higher prevalence of diarrhoea among children such as one conducted in Burundi which detected a prevalence of 32.6%[14] and another health-facility-based Ethiopian study which found a

prevalence of 31.7%.[15] Contrary to our findings, a lower diarrhoeal prevalence of 6.1% was found among under-fives in a Tanzanian study.[16] Diarrhoea is a symptom of many diseases which shows biological, geographical and seasonal variations which may explain the variations in prevalence rates found in these studies.

Both interventions were found to significantly reduce prevalence of diarrhoea in the studied communities. Although there was no statistically significant difference in diarrhoeal prevalence after intervention in the two groups, a higher reduction was observed in the flocculant-disinfectant group. Households in the flocculant–disinfectant group also had significantly lower incidence of diarrhoea when compared to households in the sodium-hypochlorite group with the sodium-hypochlorite group having almost twice the risk of childhood diarrhoea compared to flocculant-disinfectant group. Similarly, it has been demonstrated that flocculant–disinfectant reduced prevalence of diarrhoea by 83% when compared with baseline in a Liberian study[17] and up to 90% reduction in other Randomized Controlled Trials.[18, 19] It was also found to have reduced prevalence of diarrhoea by 40% among infants when compared to a control group that used standard water treatment practices.[11] Sodium hypochlorite and other household bleach products have also been demonstrated to reduce both prevalence and incidence of diarrhoea, but not up to the reductions observed with flocculant-disinfectant.[20-22] These findings may be attributed to the fact that flocculant-disinfectant has more effect on *E. coli* and other microbes, as demonstrated in this study and other studies[23, 24] when compared to sodium hypochlorite. It has been found to have better effect on organisms hidden withing flocs in turbid water. However, findings from a meta-analysis has demonstrated lesser degrees of reduction for flocculant-disinfectant and sodium hypochlorite at 31% and 29% respectively.[25]

The first 24 months of life was found to be a significant predictor of childhood diarrhoea, accounting for over 6 times the prevalence when compared to older ages. This is corroborated by a joint report of UNICEF/WHO indicating that diarrhoeal incidence is highest in the first two years of life and declines as child advances in age.[26] Similarly, diarrhoea incidence and prevalence were higher among children 6 -23 months old in studies conducted in India and Ethiopia.[27-29] A study conducted in Zaria, Nigeria, particularly found the ages between 12-24 months more vulnerable to diarrhoea[30] and this was also corroborated in a Tanzanian study.[16]

Water contamination with *E. coli* was also associated with increased likelihood of diarrhoea in both groups. However, this was only statistically significant in group B. Many other studies have made this observation.[31-33] Verification of the microbial quality of drinking-water could be done by testing for indicator microorganisms. A reliable indicator of fecal contamination of water is *E. coli*.[34] Contamination of water with fecal organisms increases the chances of diarrhoeal diseases especially in children.

Marital status in group B was significantly associated with diarrhoea and this is similar to what was observed in an Ethiopian study.[29] Being in a marital relationship was found to be protective for childhood diarrhoea probably because of the added benefit of having a father figure or a partner who can reinforce the care of the child. The two main methods of refuse disposal were open dumping and burning and in group B, open dumping was more likely to be associated with childhood diarrhoea. Refuse disposal method has also been found to significantly affect diarrhoea and other health conditions in developing regions.[35, 36] Long duration of water storage increased the risk of diarrhoea as found in group A probably due to increased frequency of handling and proliferation of micro-organisms on storage.

Although not statistically significant, school attendance of child and caregiver's lack of formal education increased the likelihood of childhood diarrhoea in groups A and B respectively. Low educational level of mothers has been shown in other studies to be associated with more frequent reporting of diarrhoea.[37, 38] Generally, mothers and caregivers who are educated are tend to have better access to information about prevention and management of diarrhoea. On the other hand, not being in school could be related to younger age of child which has been shown to be a significant predictor in group A.

5. Conclusion
The prevalence of diarrhoea among under-fives in rural households of Plateau State was found to be high and their drinking water also contaminated. The level of contamination and prevalence of diarrhoea were reduced significantly by water treatment with combined flocculant-disinfectant and sodium hypochlorite

(disinfectant alone). Flocculant-disinfectant was also more effective in reducing the incidence of childhood diarrhoea when compared to sodium hypochlorite.

6. Recommendation

Water treatment with combined flocculant-disinfectant should be made available and affordable to rural households where access to improved water sources is a challenge and prevalence of childhood diarrhoea continues to rise. This technology has proven to be acceptable to rural households just like sodium hypochlorite solution. The Nigerian Government can make efforts to ensure subsidized distribution of this technology to rural households.

Conflict Of Interest

We declare no conflict of interest in this study. The study was solely funded by the principal researcher.

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