*International Journal of Biomedical Research*
ISSN: 0976-9633 (Online); 2455-0566 (Print)
Journal DOI: https://doi.org/10.7439/ijbr
CODEN: IJBRFA
**Original Research Article**

# A comparative analysis of the effect of household water treatment with flocculant-disinfectant and sodium hypochlorite on the risk of waterborne diseases

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## Abstract

**Background:** The detection of *Escherichia coli* in water is an indication of the presence of other faeco-orally transmissible microorganisms which increase the risk for waterborne diseases. Simple and effective household water treatment technologies are capable of reducing this risk. This study aims to compare the effect of household water treatment using combined flocculant-disinfectant with that of sodium hypochlorite on the risk of waterborne diseases in rural households of Plateau State.

**Methods:** A quasi-experimental study was conducted in households of two selected rural communities of Plateau State among caregivers of under-fives. Household water treatment was carried out using the relatively new flocculant-disinfectant powder in the intervention group and the more familiar sodium hypochlorite solution in the control group, lasting for a period of 12 weeks. The presence and concentration of *Escherichia coli* was determined in water samples collected before and after intervention to determine households at risk of waterborne diseases. Analysis was carried out using SPSS 23.

**Results:** A total of 100 caregivers per household in intervention group and 96 in control group participated in the study. Less than 25% of households in both groups engaged in household water treatment which was mainly inappropriate methods. Before intervention, 74% of households in intervention group and 61.5% in control group were at risk of waterborne diseases ($p=0.060$). After intervention, more households in intervention group (88.0%) compared to 66.7% in control group had no risk for waterborne diseases ($p < 0.001$).

**Conclusion:** The study demonstrated that household water treatment with combined flocculant-disinfectant is more effective than sodium hypochlorite. There is need for government in collaboration with other stakeholders to provide rural dwellers that are at risk of contracting waterborne diseases with this option.

**Keywords:** Risk, waterborne diseases, flocculant-disinfectant, sodium hypochlorite.

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***Article History:**
**Received:** 27/06/2020
**Revised:** 15/11/2020
**Accepted:** 05/12/2020
**DOI:** https://doi.org/10.7439/ijbr.v12i1.5454

**QR Code**

**How to cite:** Okoh E. O, Miner C. A, Okoh A. F, Igoh C. S, Agada G. O. and Zoakah A. I. A comparative analysis of the effect of household water treatment with flocculant-disinfectant and sodium hypochlorite on the risk of waterborne diseases. *International Journal of Biomedical Research* 2021; 12(1): e5454. DOI: 10.7439/ijbr.v12i1.5454 Available from: https://ssjournals.com/index.php/ijbr/article/view/5454



## 1. Introduction

Waterborne diseases are diseases caused by ingestion of water that has been contaminated by animal or human faeces which contain pathogenic microorganisms [1]. Up to two billion people across the world use a drinking-water source that is faecally contaminated [2]. Water can be contaminated by faeces during open defecation at or close to water sources, leakage from sewage networks, land disposal of non-treated sewage effluents, seepage from septic tanks and pit latrines or improper handling and storage of water in homes [3]. That is why faecally derived pathogens are the principal concerns in setting health-based targets for microbial safety of water [4,5]. The presence of pathogenic organisms in drinking water increases the risk of waterborne diseases. As such, it is important to have a measure that establishes whether water is safe to consume. Of all the pathogens, *Escherichia coli* (*E.coli*) is regarded as the most reliable indicator of faecal contamination of water [6,7]. Using this indicator to monitor access to safe drinking water is a simple method adopted by the WHO due to the logistic constraint of performing direct water quality testing at regional or national levels [8]. The presence of *E. coli* in water is an indication that other faeco-orally transmissible microorganisms such as S*almonella sp.*, hepatitis A virus, *Vibro cholera* may also be present.

Waterborne diseases contribute significantly to human mortality and morbidity globally accounting for over 2.2 million deaths per year mainly among children [9]. In developing countries, they account for up to 80% of all diseases [1]. These diseases are however preventable and this can be done by improving the security of drinking water and sanitation practices. For resource-limited areas which lack universal access to improved drinking water sources, point-of-use or household water treatment (HWT) has become the most promising of all water treatment approaches and may be a more cost-effective means of preventing waterborne diseases than conventional treatment at the source. This approach will also contribute to attaining the drinking water target of the sixth Sustainable Development Goal (SDG) [10]. The use of an appropriate HWT method is capable of reducing microbial contamination and invariably lowering the risk of waterborne diseases associated with consumption of contaminated water.

The use of chlorine-based products such as sodium hypochlorite (NaOCl), have become prevalent in the disinfection of water especially at the household level when compared to the use of other disinfectants like iodine, ozone and ultraviolet light [11]. The flocculant-disinfectant is a relatively new technology that was developed to replicate the municipal water treatment process at the household level by combining the processes of precipitation, coagulation, and flocculation with disinfection. It has been adopted as a safe HWT product that meets international standards by the WHO. Just like chlorine, it has been shown to significantly reduce diarrhea among families that use it consistently [12].

The aim of this study is to compare the effect of combined flocculant-disinfectant and sodium hypochlorite (disinfectant alone) as treatment methods for household drinking water on the risk of waterborne diseases in rural households of Plateau State.

## 2. Materials and methods

### 2.1 Study area

The study was carried out in Plateau State, located in North-central Nigeria. The State is divided into 17 Local Government Areas (LGAs), 15 of which are predominantly rural. Majority of the rural populace rely on surface and underground water as their main sources of drinking water.

### 2.2 Study design

The study was a community-based, quasi-experimental study involving two treatment groups. The intervention group received treatment of household drinking water with the combined flocculant-disinfectant powder while the control group received treatment of household drinking water with sodium hypochlorite solution.

### 2.3 Study population

The study was conducted among adult females who were primary care-givers of children under five years of age in households within selected rural communities of Jos East and Bassa LGAs of Plateau State.

### 2.4 Sample size and sampling technique

The minimum sample size was calculated using the following formula:

$$n = \frac{(Z_\alpha + Z_\beta)^2 \times 2 \times p\,(1-p)}{d^2} \text{ per group}$$

Considering an attrition rate of 10%, the sample size was calculated to be 96 per group. Participants were selected using a multistage sampling technique by first selecting 2 rural LGAs, one ward per LGA and one community per ward, all using simple random sampling technique by balloting. Finally, both communities were studies as clusters whereby 102 participants per household were selected in the intervention group while 100 participants were selected per household in control group.

### 2.5 Study instruments

A semi-structured, interviewer administered questionnaire adapted from the Demographic and Health Survey (DHS) and WHO core questions on household drinking water treatment and quality, an observational checklist and laboratory equipment for water analysis were instruments used for the study.

### 2.6 Data collection

Permission was sought from LGA chairmen, community heads and household heads while written informed consent was obtained from each participant. Research assistants were recruited and trained.

At preintervention, questionnaires were administered to the selected participants after obtaining consent from them. An observational check list was filled by research assistants for each household. Household drinking water samples were collected and transported within 6-8 hours of collection for bacteriological analysis in the laboratory. *E. coli* strains were detected using the Agar Plate Count method for coliform count in which samples were incubated for 48 hours at temperatures of 32-37$^{o}$C in Eosin Methylene-Blue (EMB) agar.

The intervention phase involved health education of participants on the risks of waterborne diseases and HWT using the methods provided. Participants in the intervention group were taught to treat 10 litres of water using one sachet of flocculant-disinfectant powder by emptying the contents into the 10-litre buckets provided for them; stirring the water vigorously for up to 3-5 minutes and allowing the flocs formed to sediment for another five minutes, before decanting into another clean container. They were also taught to wait for another 20 minutes to allow for proper disinfection before consumption of the water [13]. Participants in the control group were taught how to use sodium hypochlorite solution to treat 20 litres of water by pouring a cover cap full of the solution into the 20-litre bucket provided. This is followed by mixing thoroughly and waiting for 30 minutes after which the water is ready for consumption [11]. The two groups were observed for a period of 12 weeks. Two-weekly unannounced visits were made where they were observed for their water management practices and supplied with more HWT products based on need.

At post intervention, water samples were also collected and analyzed for *E. coli*.

**2.7 Data management and statistical analysis**

*E.coli* concentrations were expressed in Colony Forming Units (CFU). The households within each intervention group were classified into two broad categories and further into five sub-categories. The classification was based on the WHO's risk classification for waterborne diseases using *E. coli* concentrations in drinking water samples as follows[14]:

1. Households with *E.coli* concentrations less than 1 CFU/100 ml were regarded as 'no risk'.
2. Households with *E. coli* concentrations of 1 or more CFU/100 ml were generally regarded as being 'at risk'. These were further classified into:

A. 'Low risk'- *E. coli* concentrations of 1-10 CFU/100 ml.
B. 'Medium or intermediate risk' - *E. coli* concentrations of 11-100 CFU/100 ml.
C. 'High risk' - *E. coli* concentrations of 101-1000 CFU/100 ml.
D. 'Very high risk' - *E. coli* concentrations of more than 1000 CFU/100 ml.

The IBM Statistical Package for Social Sciences (SPSS) version 23 was used to analyze data. Data were presented in tables and proportions. Chi-square test was used to compare risk categories between the two groups while McNemar's test was used to compare risks within groups. Logistic regression analysis was also done to identify predictors of risks for waterborne diseases after identifying significant factors from chi-square analysis. At 95% confidence level, all p-values of$\leq$ 0.05 were considered statistically significant.

**2.8 Ethical consideration:**

Ethical approval was obtained from the Health Research Ethics Committee of the Jos University Teaching Hospital. A written, informed consent was also obtained from each participant before enrolment into the study. Permission for the study was obtained from the Chairmen of the two LGAs, the District, Ward and Village Heads of the communities involved in the study. All the data collected were used only for the purpose of the research and kept confidential on a password protected computer.

## 3. Results

**3.1 Baseline Household water treatment practices**

A total of 100 households in intervention group and 96 households in the control group fully participated in the study. The main source of drinking water for over 90% of households in both groups at baseline was well water. The practice of HWT was less than 25% in both groups out of which more households practiced inappropriate HWT methods.

**Table 1: Household water treatment practices at baseline**

| Characteristics | Intervention group (n = 100) | | Control group (n = 96) | | $\chi^2$ | df | p-value |
|---|---|---|---|---|---|---|---|
| | Freq | % | Freq | % | | | |
| **Main drinking water source** | | | | | 0.167 | 1 | 0.920 |
| Well | 95 | 95.0 | 92 | 95.8 | | | |
| Sachet water | 3 | 3.0 | 2 | 2.1 | | | |
| Surface water | 2 | 2.0 | 2 | 2.1 | | | |
| **Practice of HWT** | | | | | 5.252 | 1 | 0.022 |
| No | 76 | 76.0 | 85 | 88.5 | | | |
| Yes | 24 | 24.0 | 11 | 11.5 | | | |
| **Most common method of HWT** | | | | | 8.8355 | | 0.136 |
| None | 76 | 76.0 | 85 | 88.5 | | | |
| Straining through cloth | 19 | 19.0 | 6 | 6.4 | | | |
| Boiling | 2 | 2.0 | 3 | 3.1 | | | |
| Use of chlorine/waterguard | 1 | 1.0 | 0 | 0.0 | | | |
| Letting water stand to settle | 1 | 1.0 | 1 | 1.0 | | | |
| Use of alum | 1 | 1.0 | 1 | 1.0 | | | |
| **Appropriateness of HWT[#]** | | | | | 1.660 | 1 | 0.198 |
| Inappropriate HWT | 20 | 83.4 | 7 | 63.6 | | | |
| Appropriate HWT | 4 | 16.7 | 4 | 36.4 | | | |
| **Frequency of appropriate HWT practice[##]** | | | | | 1.750 | 1 | 0.186 |
| About once or twice a month | 3 | 75.0 | 1 | 25.0 | | | |
| Less than once a month | 1 | 25.0 | 3 | 75.0 | | | |

[#] = For respondents who practice HWT; [##] = For respondents who practice appropriate HWT

### 3.2 Risk for waterborne diseases before intervention

Table 2 shows the proportion of households in both groups that were at risk for waterborne diseases at baseline, based on *E. coli* detection in their stored drinking water.

**Table 2: Risk for waterborne diseases at baseline**

| Risk category | Intervention group (n = 100) | Control group (n = 96) | $\chi^2$ | df | p - value |
|---|---|---|---|---|---|
| No risk | 26 (26.0) | 37 (38.5) | | | |
| At risk | 74 (74.0) | 59 (61.5) | 3.52 | 1 | 0.060 |

### 3.3. Predictors of waterborne disease risk at baseline

In both groups, households with large sizes (of six or more persons) had about 4 times the odds for waterborne disease risk compared to households with smaller sizes. The odds were also higher in households with longer duration of water storage (more than three days) than those that stored water for a shorter duration in both groups. Defecation area/toilet distance of more than 30 metres from water source was likely to be protective against waterborne disease risk in the control group.

**Table 3: Predictors of waterborne disease risk at baseline**

| Predictors | Intervention group | | | Control group | | |
|---|---|---|---|---|---|---|
| | Adj. Odds Ratio | 95% Confidence Interval | p-value | Adj. Odds Ratio | 95% Confidence Interval | p-value |
| **Household size** | | | | | | |
| 1-5 persons | 1 | | | 1 | | |
| ≥6 persons | 3.98 | 1.30 – 12.20 | **0.016*** | 3.96 | 1.51 – 10.39 | **0.005*** |
| **Duration of water storage** | | | | | | |
| 1-3 days | 1 | | | 1 | | |
| ≥4 days | 4.00 | 1.38 – 11.30 | **0.010*** | 3.08 | 1.17 – 8.15 | **0.023*** |
| **Observed to touch water with hands while fetching** | | | | | | |
| No | 1 | | | 1 | | |
| Yes | 1.72 | 0.54 – 5.42 | 0.357 | 1.57 | 0.60 – 4.08 | 0.356 |
| **Distance of defaecaton area from water source** | | | | | | |
| <30 Metres | 1 | | | 1 | | |
| ≥30 Metres | 0.37 | 0.11 – 1.21 | 0.099 | 0.25 | 0.18 – 0.79 | **0.019*** |
| **Turbidity level of water** | | | | | | |
| <5 NTU | 1 | | | 1 | | |
| ≥5 NTU | 2.39 | 084 – 6.78 | 0.103 | 1.15 | 0.43 – 3.05 | 0.776 |

*= statistically significant

### 3.4 Comparing risk for waterborne diseases (within and between group comparisons)

Table 4 showed that there was a significant decrease in proportion of 'at risk' households from pre- to post-intervention in both intervention (flocculant-disinfectant) and control (sodium hypochlorite) groups ($p < 0.001$). Up to 65% of households in intervention group and 42.7% in control group were converted from being at risk to having no risk for waterborne diseases.

**Table 4: Comparing the risk for waterborne diseases among households within each group**

| Before intervention | After intervention: No Risk Freq (% of total) | After intervention: At Risk Freq (% of total) | After intervention: Total Freq (% of total) | McNemar's $\chi^2$ | p - value |
|---|---|---|---|---|---|
| **INTERVENTION GROUP (n=100)** | | | | | |
| No risk | 23 (23.0) | 3 (3.0) | 26 (26.0) | | |
| At risk | 65 (65.0) | 9 (9.0) | 74 (74.0) | | |
| **Total(% of total)** | **88 (88.0)** | **12 (12.0)** | **100 (100.0)** | 54.72 | <0.001 |
| **CONTROL GROUP (n=96)** | | | | | |
| No risk | 23 (24.0) | 14 (14.6) | 37 (38.5) | | |
| At risk | 41 (42.7) | 18 (18.8) | 59 (61.5) | | |
| **Total(% of total)** | **64 (66.7)** | **32 (33.2)** | **96 (100.0)** | 20.90 | <0.001 |

Key: WBD = Waterborne Diseases; *=statistically significant

Before intervention, there was no significant difference in waterborne disease risk between the groups as depicted in table 2 ($p = 0.060$). After intervention, there was a statistically significant difference as 88 (88.0%) of households in intervention group compared to 64 (66.7%) of households in control group had no risk for waterborne diseases ($p < 0.001$).

**Table 5: Comparing the risk for waterborne diseases among households between groups**

| Risk of WBD | Intervention Group (n = 100) Freq (%) | Control Group (n = 96) Freq (%) | $\chi^2$ | df | p-value |
|---|---|---|---|---|---|
| Before intervention | | | | | |
| No risk | 26 (26.0) | 37 (38.5) | 3.52 | 1 | 0.060 |
| At risk | 74 (74.0) | 59 (61.5) | | | |
| After intervention | | | | | |
| No risk | 88 (88.0) | 64 (66.7) | 12.80 | 1 | **< 0.001*** |
| At risk | 12 (12.0) | 32 (33.3) | | | |

Key: WBD = Waterborne Diseases; *=statistically significant

Table 6 shows that the various risk categories for water-borne diseases were similar across the two groups (p = 0.366) at baseline. After intervention, there were more households in the low- to very high-risk categories in the control group compared to the intervention group (p = 0.003).

**Table 6: A comparison of the various risk categories between groups**

| Risk categories | Before intervention | | After intervention | |
|---|---|---|---|---|
| | Intervention grp n = 100 Freq (%) | Control grp n = 96 Freq (%) | Intervention grp n = 100 Freq (%) | Control grp n = 96 Freq (%) |
| No risk | 27 (27.0) | 36 (37.5) | 88 (88.0) | 64 (66.7) |
| Low risk | 11 (11.0) | 5 (5.2) | 2 (2.0) | 4 (4.1) |
| Int. risk | 36 (36.0) | 30 (31.3) | 4 (4.0) | 12 (12.5) |
| High risk | 10 (10.0) | 12 (12.5) | 6 (6.0) | 9 (9.4) |
| Very high risk | 16 (16.0) | 13 (13.5) | 0 (0.0) | 7 (7.3) |
| | $\chi^2$ = 4.31; df = 4; p = 0.366 | | $\chi^2$= 15.98; df = 4; p = **0.003*** | |

*=Statistically significant

### 3.5 Likes and dislikes with HWT methods

After intervention, most of the respondents in both groups appreciated the fact that the HWT method rendered their water safe to drink and this was comparable (p = 0.686). More of the respondents in the flocculant-disinfectant group liked that their water appeared clearer and also reported that their drinking water smelt and tasted better compared to respondents in sodium hypochlorite group. The concerns reported by users of sodium hypochlorite which were more than those reported by users of flocculant-disinfectant were mainly lack of water clarity, the taste and smell produced in water after treatment. Respondents in the flocculant-disinfectant group however, reported that the process of HWT was labour intensive.

**Table 7: Comparing likes and concerns about HWT methods after intervention**

| Characteristics | Flocculant disinfectant/ Intervention group (n = 100) | | Sodium hypochlorite/ Control group (n = 96) | | $\chi^2$ | p-value |
|---|---|---|---|---|---|---|
| | Freq | % | Freq | % | | |
| **What do you like about HWT method?** | | | | | | |
| Water is rendered safe to drink | 96 | 96.0 | 91 | 94.6 | 0.163 | 0.686 |
| Water appears clearer | 100 | 100.0 | 27 | 28.1 | 110.925 | <0.001* |
| Water smells better | 84 | 84.0 | 35 | 36.5 | 46.413 | <0.001* |
| Water tastes better | 91 | 91.0 | 71 | 74.0 | 9.921 | 0.002* |
| **What are your concerns about HWT method?** | | | | | | |
| No concerns | 77 | 77.0 | 32 | 33.3 | 32.053 | 0.001* |
| Water does not appear clearer | 0 | 0.0 | 9 | 9.4 | - | 0.001** |
| The smell | 9 | 9.1 | 61 | 63.5 | 62.797 | <0.001* |
| The taste | 5 | 5.1 | 22 | 22.9 | 13.042 | <0.001* |
| It is labour intensive | 6 | 6.0 | 0 | 0.0 | - | 0.029** |
| I am afraid of possible adverse effects | 2 | 2.0 | 2 | 2.1 | - | 0.246** |

*=Statistically significant; **= Fischer's exact;

## 4. Discussion

This study assessed waterborne disease risks in the selected rural communities using *E. coli* as the indicator organism. The risk for waterborne diseases was generally high in households of both communities at baseline. This is not surprising as majority of households did not treat their drinking water and those who did, used more of inappropriate water treatment options. Studies conducted in other rural parts of Nigeria have also demonstrated faecal contamination of household drinking water in large proportions of the studied households, thus increasing their risks for waterborne diseases [15,16]. Other studies demonstrated that water sources including well water which was the major source found in this study, had high risk for waterborne diseases [6,17]. Drinking water obtained from households in low- and middle-income countries has been found to be twice as contaminated as water obtained from source. For this reason, more emphasis has been placed on the microbiological quality of drinking water at the household level [18].

In this study, the odds for waterborne disease risk increased with higher household size. A study conducted in Kano State had similarly shown that households with large sizes had higher chances of drinking water contamination when compared with smaller-sized households [19]. This may be as a result of many persons handling drinking water stored for household consumption. Although not statistically significant, there was also an increased likelihood of water contamination when hands of participants touched water during fetching in this study. This likelihood of contamination especially with dirty unwashed hands, may also be higher with large household sizes. Just like food, drinking water can also be contaminated through hands that harbor enteric pathogens usually present in faeces, thus increasing the risk for waterborne diseases [20].

Households in both groups that stored water for more than three days had higher odds of waterborne disease risk when compared to those that stored for shorter durations. This may imply that the longer the duration of storage after collection from source, the more the likelihood of recontamination with *E. coli* or other feaco-orally transmitted microbes. A study in Northern Coastal Ecuador showed that household drinking water quality slightly improved (shown by *E. coli* reductions) within three days of collection from source probably due to settling and die-off of micro-organisms. The quality however declined after the third day due to recontamination and probably re-suspension of micro-organisms [21]. Other studies have also shown that the longer the duration of water storage, the greater the level of recontamination [19,22]. A study conducted in Ibadan has shown presence of indicator organisms in stored water samples which were originally absent in source water implying that water was contaminated during storage [23]. Recontamination of drinking water occurs more commonly in households where water is not stored safely or not properly handled leading to contamination during fetching.

Open defecation is a common method of sewage disposal among many rural populations of developing countries [3]. Location of water source at a safe distance of 30 metres away from toilet or source of contamination such as defaecation fields conferred lower likelihood for waterborne disease risk in this study. Toilets or defaecation fields that are close to underground and surface water sources could leak or be washed into these sources to further contaminate them and compromise their microbiological quality. This finding is in keeping with findings from Kano in which short distance of few meters of water source from a source of contamination such as toilet was associated with bacterial contamination [19].

Combined flocculant-disinfectant and disinfectant alone (sodium hypochlorite) were both found to be effective in converting households from having the risk for water-borne diseases to having 'no risk' at all. This is based on their effectiveness in reducing microbial or *E. coli* concentration in drinking water. In general, when HWT technologies are employed effectively in households coupled with safe storage and handling of water, improvement in microbiological water quality is observed which can lead to reduction in the occurrence of water-borne diseases including diarrhoeal diseases. Other studies have also shown significant reductions in drinking water contamination with faecal micro-organisms when treated with either combined flocculant-disinfectants or disinfectants alone [13,24-26]. This shows the effectiveness of these methods in reducing waterborne disease risk.

When the two technologies were compared, combined flocculant-disinfectant was better than sodium hypochlorite in reducing waterborne disease risk. Flocculant-disinfectant has also been demonstrated in a Kenyan study to be better in reducing feacal organisms in drinking water after a period of treatment at the household level when compared to using disinfectant alone especially in turbid water[24]. Contrary to our findings, sodium hypochlorite was demonstrated to be better in improving the risk of waterborne diseases in a study conducted in Bangladesh where fewer households had low- to high-risk, based on drinking water *E.coli* concentrations, compared to households that used flocculant-disinfectant [27]. Another study showed that the two water treatment methods had equal effects on improving microbial contamination and risk levels [28].

The HWT methods were generally acceptable to participants in both groups. Majority were convinced that their water was rendered safe to drink. However, more respondents in sodium hypochlorite group complained about taste and odour of the treated water which was more of a complaint at the initial phase of intervention, while few respondents in the flocculant-disinfectant group reported that the method was labour intensive. A few had concerns of possible harmful effects of the HWT products, none of which was observed during this intervention and other interventions that employed the use of these products [29].

The study has demonstrated that rural households in Plateau State are at risk of contracting waterborne diseases. This risk was significantly reduced when household drinking water was treated with either combined flocculant-disinfectant or disinfectant alone (sodium hypochlorite). Combined flocculant-disinfectant was however found to be better in reducing the risk than sodium hypochlorite.

The government in collaboration with community stakeholders, should improve access of rural dwellers to improved water sources and make efforts to increase their awareness on the practice of appropriate treatment options. There is also the need to provide rural dwellers with the option of flocculant-disinfectant which has been shown to be more acceptable and highly effective in reducing the risk of waterborne diseases compared to the more readily available sodium hypochlorite.

## Acknowledgement

This is to acknowledge the Community Heads and Officers-in-charge of the Primary Health Care centres of Igbak and Foda-fobur communities of Plateau State for their immense support and technical assistance in carrying out this study.

## Conflict of Interest

The authors declare that there are no conflicts of interest.

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