

Drinking Water Quality and Sanitation Issues: A Survey of a Semi-Urban Setting in Nigeria

David O. Olukanni^{1*}; Mercy A. Ebuetsse¹; Winifred U. Anake²

¹Department of Civil Engineering, College of Engineering, Covenant University

²Department of Chemistry, College of Science & Technology, Covenant University

Website: <http://covenantuniversity.edu.ng/Profiles/OLUKANNI-David-O>

Abstract *An assessment on the drinking water quality from major source (borehole) and household in a semi-urban setting in Nigeria was carried out. Structured questionnaire was administered to randomly selected households in seven zones of the municipality to determine the common method of collection and transportation, storage, and sanitation practices. Water samples collected were subjected to laboratory analyses for physico-chemical and microbial properties. The result of the physico-chemical analysis when compared against the World Health Organization (WHO) and Standard Organization of Nigeria (SON) drinking water quality benchmark revealed that the water samples were within standards for consumable water except for the presence of fecal contamination. The result revealed that before water can be totally considered safe for drinking, further treatment is required at the household level due to fecal contamination, and water safety concerns are also highlighted. The result translates to the fact that compliance assessment with standards and impact assessment studies in determining the fate of pollutants is necessary at all levels.*

Keywords: *Borehole water, Household water, Microbial properties, Ota, Physico-chemical properties, Water quality.*

I. Introduction

The continuous reported cases of water related illnesses over the years in many communities of developing nations due to exposure to poor quality water supply are increasing (Pruss et al. 2002; Moszynski 2006; WHO and UNICEF 2010). According to a report by UNICEF and WHO, insufficient water, sanitation, and hygiene issues account for a large part of the burden of illness with the most common waterborne disease as diarrhea, having an annual incidence of 4.6 billion episodes and cause 2.2 million deaths every year in developing countries (WHO 2010; UNICEF and WHO 2012). Ogwueleka (2014) expressed that the impact of anthropogenic activities (industrial wastewater discharge, municipal wastewater effluents, solid waste management practices and agricultural run-off) have inhibited access to quality water supply. Therefore, the need for good quality water that would sustain lives continues to be on the increase globally (Clasen et al. 2007; Olukanni and Ugwu 2013). The effect of the insufficiency in the supply of treated piped-borne water is that people in most communities resort to accessing water from other sources such as boreholes (private and commercial), unprotected hand-dug wells, buying water from carts with small tanks, streams, ponds and springs (Brown and Sobsey 2010; UNICEF 2012; Olukanni, 2013). However, threats associated with collection of water from these sources due to the vulnerability of the areas include anthropogenic activities of people either at source or in the course of collection, transporting and storage due to improper handling practices that results in water pollution (Osibanjo 1994; Clasen & Bastable 2003; Stephen et al. 2004; WHO 2010; Badowski et al. 2011). Previous studies have also shown that the concentrations of contaminants are more pronounced in water sources that are close to domestic refuse waste, abattoir, pit latrine, stagnant water and drainages while with increasing distance, the concentration of pollutants decreases (Ayantobo et al., 2013).

Assessing compliance with standards, facilitating impact assessment studies, determining fate and transport of pollutants among others are some of the several water qualities monitoring objectives (Karaman, 2013). Household water treatment and safe storage is one option for improving the quality of water for consumption within the home, especially where water handling and storage is necessary and recontamination is a risk between the point of collection and point of use. Long distance source, unreliable piped supplies and reliance on rainwater are all factors that make household storage a necessity (UNICEF/WHO 2011). However, water-related illnesses continue to be one of the health challenges in Nigeria. A representative semi-urban city in Nigeria was chosen as a case study. Cases of water related diseases is a clear indication of drinking water contamination, and it was crucial to investigate the physico-chemical and microbial properties of drinking water quality in Ota, examine the extent to which drinking water are contaminated between the source of collection and household storage, as well as compare the observed concentrations with the water quality permissible limits specified by the World Health Organization (WHO) and the National Standard for Drinking Water Quality

(NSDWQ) through the Standard Organization of Nigeria (SON). The happenings in this city are a vivid reflection of situations in many cities within the nation.

II. Materials and Method

Description of Study Area

Ota is the second largest and most industrialized city in Ogun State, Nigeria with a population of 527,242 residents and geographical coordinates 6° 36' 0" North, and 2° 56' 0" East. It is bordered on its Eastern part by Lagos State, on the Northern part, Yewa and Ifo Local Governments and Ipokia Local Government in the west (NPC 2006). Table 1 shows the data on water supply distribution to households by source for domestic purposes which were estimated at a total of 130,821 people.

Table 1. Data on water supply distribution to households in Ota

Pipe-borne inside dwelling	3,630
Pipe-borne outside dwelling	17,375
Tanker supply/vendor	17,212
Well	35,641
Borehole	45,901
Rainwater	1,748
River/stream/spring	8,301
Dugout/pond	97
others	916
Total	130,821

Source: NPC 2010

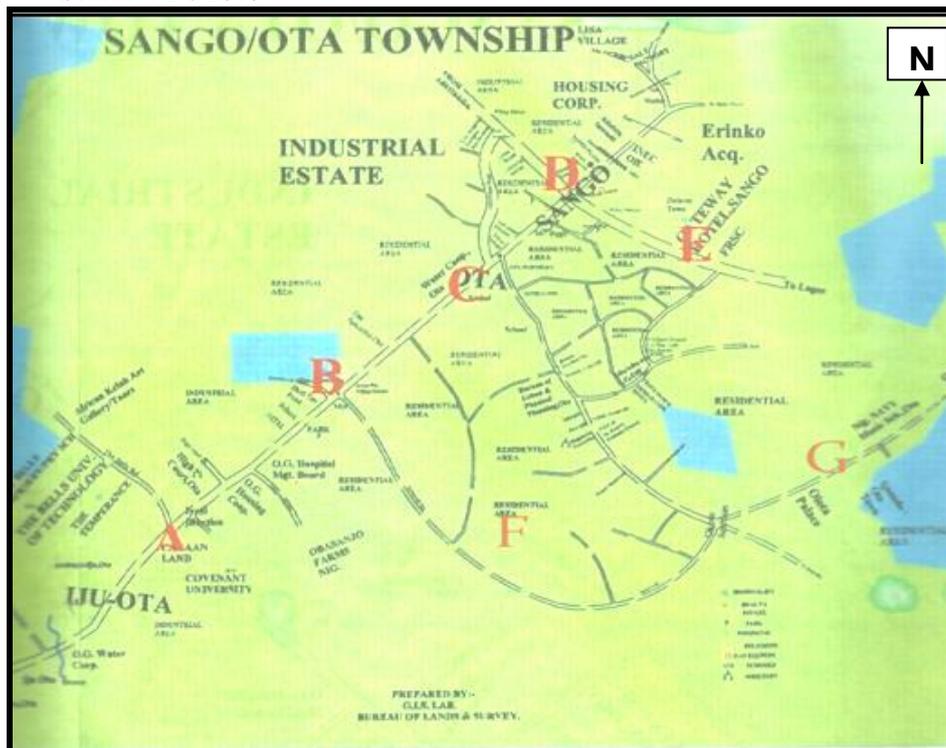


Figure 1 shows the map of Ota and the selected locations for data capture.

III. Assessment Approach

Questionnaires were administered to randomly selected representatives that belonged to 140 households, spread across seven (7) strategic zones of the city in an attempt to assess their most common source of drinking

water, method of collection, and mode of transportation, storage and sanitation practices. The information gathered in the selected locations is a representation of the cases in the entire municipality. Other means adopted for data capture include interviews with residents, observation and focus group discussions. The probability sampling method was adopted. This approach is basically the practice of taking random samples in which selected households within a location in the municipality have the opportunity of being integrated into the survey. The survey captured a population with a minimum of primary school education and within the age bracket of 10 to 75 years old. Other information such as age, education, and quantity of water consumed daily, satisfaction in terms of water quality supplied and other health related problems were captured.

IV. Water Samples Collection and Pretreatment Analysis

Water samples were collected from two different sources namely; household and boreholes, of seven selected zones (Iju-Ota, Oju-Ore, Joju, Sango, Dalemo, Okede and Ijamido-Ota) of Ota municipality, and were studied for physico-chemical and microbial parameters in the month of February through to April, 2013. Prior to the collection of the water samples for physico-chemical tests, the bottles were washed with 20% analytical grade nitric acid, rigorously rinsed with distill water and further rinsed with the samples to be collected. pH and turbidity were tested immediately after sampling to avoid changes during storage and transport. Also, samples were collected for microbial laboratory analysis using sterile sample bottles of 250ml, filled to near full capacity and sealed with the screw cap. The collected samples were stored at 4°C in an ice cooler and transported to the laboratory immediately for physico-chemical and microbial analysis.

V. Physico-Chemical Analysis

The pH of the water samples was determined using portable Hanna microprocessor pH meter and other physicochemical parameters such as total hardness, Total Dissolved Solid (TDS), alkalinity and salinity were analyzed by standard methods given in American Public Health Association (APHA 1992). Turbidity was determined using a standardized Hanna H198703 turbidimeter and conductivity was done using a Jenway conductivity meter (4510 model). Phosphate was determined by colourimetry method and chloride by argentometric method.

VI. Microbial Analysis

Studies have shown a link between the presence of faecal contamination in drinking water and incidence of water related diseases. Therefore, the regulatory monitoring of the microbiological quality of drinking water has relied on the identification of bacterial indicators such as coliforms, and then faecal coliforms, *Escherichia coli* and enterococci (Beaudeau et al. 2010). The bacteriological analyses carried out on the samples include *E.coli*, Faecal Coliform (FC) and number of Total Coliform (TC). The media used for the coliform test microscopy of the water samples were Eosin Methylene blue agar (EMB) and Mackonkey agar (MCK). The samples were inoculated into mackonkey broth and were incubated at 37°C. The Most Probable Number (MPN) technique used in estimating microbial populations in waters, were done in three stages, namely, Presumptive Test, Confirmative Test and Completed Test (APHA 1998). All the collected water samples were analyzed within 24 hours.

VII. Results and Discussion

Basic Demographics and Household Characteristics

There was 100 percent recovery of the questionnaires distributed to the seven different zones selected for the survey. Results obtained from the filled questionnaires showed that about 99% of the people in the municipality depend on boreholes (private and commercial) erected by individuals as their drinking water source, while the other 1% relies on open dug wells for their water source. In spite of the introduction of the Household Water Treatment and Safe Storage (HWTS) scheme initiated by WHO for interventions that would lead to improvements in drinking water quality and reductions in water related diseases, the people of the community are yet to be well informed on this development. Proper sanitation is insufficient and the cost of water and sanitation practices is unbearable by the residents. A significant proportion of the community's population are low income earners, many of who live below an average income \$140 per month. Thus a significant part of the population could not afford some basic treatment and household storage facilities that could prevent contamination. This situation applies to many other cities within the nation and other developing countries.

The 20 liters container is the most commonly used container for collecting water from source (commercial borehole) and 90 percent of these people carry containers on their head as shown in Figure 2, while others carry it by hands with buckets that have handles with most communal users collecting water at least twice a day. Some residents expressed that they use the collected water for only domestic purposes such as cooking,

bathing, cleaning, washing and other general use but without drinking. Most residents buy the popularly called “pure water sachet” for their consumption while some are indifferent, with the mindset that the water they drink would not kill them. Most house types are the long informal type of building popularly called “face to face” with an average of 10 rooms and five (5) household members in each.



Figure 2. Individual Fetching water with an open container at a commercial borehole stand-post

VIII. Mode of Transportation and Storage

The vessels used in transporting water from source to household are of various types. From the study, the trend in the usage of these containers in carrying water from source to household are bucket (53.6%) > jerry can (38.6%) > clay pots (0.7%) > others (4.3%) > not indicated (2.9%). It was noted that good quality water from improved water sources (borehole) is contaminated due to lack of appropriate hygiene practice during transport and storage of water. It was also observed that the greater percentage of persons involved in the fetching of water were children, who most time do not pay attention to good hygiene practice. As such, water transported from commercial source using dirty vessels and vessels without cover (Figure 2) to the household lead to contamination of water in the household (IFRC 2008). More so, studies on water quality have shown that water in rural and poor areas is often contaminated at the household level (the point of water use) (IFRC 2008).

From this study, 51% and 12% household water containers were drums and buckets respectively. Only 17% were stored in jerry cans. Improved containers and storage vessels can protect stored household water from microbial contaminants that could come through contact with hands, dippers and other contaminated objects. Narrow necked vessels and dispensing devices, such as taps or spigots are preferable for storage compared to open containers that are wide enough for cups and hands to be dipped into (Mintz et al. 1995; WHO 2011).

IX. Water Handling Behaviour and Hygiene

From the survey, buckets are used more frequently than any other vessel. It was discovered that higher percentages (59.3%) of persons in the study area do not wash their hand before taking drinking water from the household containers. This calls for awareness creation on the safe hygienic handling of water in the household. It was also noted as shown in Figure 3 that in some households, the location of the water source is close to the septic tank which could also be a source of fecal contamination.



Figure 3. A household having water source close to the septic tank

X. Discussion on Physico - Chemical and Microbial Results

The water quality analysis of borehole and household water samples has been carried out for twelve physico-chemical parameters i.e.; pH, total dissolved solids (TDS), conductivity, salinity, turbidity, alkalinity, total hardness, chloride, iron, manganese, phosphate, and nitrate. Water samples collected from the borehole were traced to the household where such water was stored to examine the extent to which drinking water is contaminated between the source of collection and storage. The results shown in Tables 2 and 3 are the average values of the measurements of the physico-chemical analysis of the water samples. BH and HH represent borehole and household water qualities of the seven locations respectively.

Table 2: pH, Total Dissolved Solid, Conductivity, Salinity, Turbidity, Alkalinity, and Nitrate values of drinking water in the borehole and household samples.

Sample Zones	Iju Ota		Oju-Ore		Joju		Sango		Dalemo		Okede		Ijamido		SON	WHO
Source ID	BH	HH	BH	HH	BH	HH	BH	HH	BH	HH	BH	HH	BH	HH		
pH	5.9	5.4	6.4	6.8	6.3	7.3	5.6	5.9	6.7	6.1	5.7	6.9	5.6	6.7	6.5-8.5	6.5-8.5
Total dissolved solids (mg/L)	19.6	17.6	11.3	25.7	32.5	47.9	98.4	97	17.6	23.5	32	31.9	16.8	24.3	500	< 600
Conductivity (S/cm)	29.4	26.4	17	38.6	48.9	71.3	147	144.9	26.7	35.1	47.7	47.8	25.3	36.2	1000	-
Salinity (mg/L)	14.7	13.2	8.5	19.3	24.5	35.7	73.5	72.5	13.4	17.5	23.9	23.9	12.7	18.3	-	200
Turbidity (NTU)	0.53	1.79	1.94	0.87	0.64	0.47	0.79	0.39	1.9	0.2	1.02	0.61	1.01	1.02	5	<1
Alkalinity (mg/L)	10	6	6	12	2	6	4	6	7.5	2	6	4	7	11	-	120

Table 3: Total Hardness, Chloride, Iron, Manganese and Phosphates values of drinking water in the borehole and household samples.

Sample Zones	Iju Ota		Oju-Ore		Joju		Sango		Dalemo		Okede		Ijamido		SON
Source ID	BH	HH	BH	HH	BH	HH	BH	HH	BH	HH	BH	HH	BH	HH	
Total Hardness (mg/L)	18	23	25	22	31	35	33	34	29	29	41	43	35	31	150
Chloride (mg/L)	37.43	21.46	19.96	19.96	23.95	37.43	48.4	37.92	17.47	18.46	22.95	19.96	17.47	17.47	250
Phosphate (mg/L)	10.2	9.3	7.96	10	9.2	8	9.74	10	8.9	9.9	9.4	8.2	6.9	9.7	-

pH

Table 2 shows an increase in pH concentrations from the borehole to households in five samples namely Oju-Ore, Joju, Sango, Okede, and Ijamido. The pH values ranged from 5.6 (Sango and Ijamido) to 6.7 (Dalemo) and 5.4 (Iju-Ota) to 7.3 (Joju) for borehole and household drinking water respectively. On the contrary, a decrease in two sample locations from 5.9 to 5.4 (Iju-Ota) and from 6.7 to 6.1 (Dalemo) was observed. A comparative study of the pH values of both drinking water sources indicates that the quality of water varies from source to source and from location to location. The permissible limit of pH in the water is 6.5 to 8.5 (SON 2007). Results of pH in the household drinking water sources showed that three locations, Iju-ota (5.4), Sango (5.9) and Dalemo (6.1) out of seven were below the permissible limit, while the borehole source had only one location, Dalemo (6.7) complying within the permissible limit. Maximum pH value of 7.3 was found in the sample collected from Joju, while minimum value of 5.4 was found in Iju-Ota sample, both from household sources. The results show that 71% of the pH value for both water sources was observed in the acidic scale.

Total Dissolved Solids (TDS)

The concentration of TDS in the BH and HH water samples were in the range of 11.3(Oju- Ore) to 98.4 mg/L (Sango) and 17.6 (Iju-Ota) to 97 mg/L (Sango), respectively. The result showed that 57% of the analyzed samples showed an increase in TDS from BH to HH as shown in Table 2. However, the obtained result indicated values of TDS within maximum desirable limit (MDL) of 600 mg/L as recommended by W.H.O. High levels of TDS may cause excessive scaling in water pipes, industrial and household appliances and adversely affect taste of drinking water.

Conductivity and Salinity

Conductivity is a good indicator of pollution and it relates to the amount of total dissolved solids present in water, but does not indicate the exact minerals that are present (Johnson and Scherer 2012; Narasimha et al. 2011). From Table 2, conductivity of the samples had values varying from 17 (Oju-Ore) to 147 μ s/cm (Sango) and 26.4 (Iju- Ota) to 144.9 μ s/cm (Sango) for the BH and HH water respectively. The conductivity of drinking-water varied from the borehole to the household in 71% of the samples. Despite the observed increase, all the conductivity values were still within the SON permissible limits for unpolluted water of 1000 μ s/cm. From Table 1, salinity was between 73.5 (Sango) to 8.5 mg/L (Oju-Ore) and 13.2 (Iju-Ota) to 72.5 mg/L (Sango) borehole (BH) and household (HH) water respectively. There was an observed increase in salinity of the water in 57% of the observed samples, when traced from point of collection (borehole) to the household where this water are being stored. Notably, the recorded results were far below the maximum permissible limit of 200mg/L prescribed by World Health Organization (WHO, 2011). Individuals who consume water with salinity value above the maximum permissible limit may suffer the consequence of hypertension.

Turbidity and Alkalinity

The range of mean turbidity value obtained for BH and HH water were, 0.53 (Iju - Ota) to 1.94 NTU (Oju-Ore) and 0.2 (Dalemo) to 1.79 NTU (Iju-Ota) respectively. An increase in turbidity was observed in 29% of the samples from borehole to household as shown in Table 2. However, all the water samples had turbidity values within the WHO permissible value of 5NTU (Table 2). Detection of turbidity in drinking water is important because high turbidity reduces the effectiveness of disinfection by chlorine, and stimulates bacterial growth thereby increasing the health risk to the consumer. Turbidity reduction in drinking water could cause visual improvement in treated water that could help encourage correct and consistent use for water users (Preston et al. 2010).

The alkalinity of the BH and HH water ranged between 2 (Joju) to 10 mg/L (Iju-Ota) and 2 (Dalemo) to 12 mg/L (Oju- Ore) respectively. Also, the variation from the borehole to households revealed an increase in alkalinity levels of four samples out of the seven samples. These four samples are: Oju-Ore, Joju, Sango, and Ijamido. Alkalinity values for all the water samples as observed in Table 1, falls within the stipulated permissible level. High-alkalinity waters may have a distinctly flat and unpleasant taste. A change in alkalinity is an indication of pollution problems which is detrimental to humans. The permissible limit by WHO in water is 120 mg/L (WHO 2011).

Total Hardness

From Table 3, the total hardness values in the studied samples for BH and HH water ranged from 18 (Iju- Ota) to 41 mg/L (Okede) and 22 (Oju-Ore) to 43 mg/L (Okede), respectively. The variation in total hardness concentrations from the borehole to households revealed an increase in concentration in three samples namely Iju Ota, Oju-Ore and Okede. On comparing with stipulated standards, it was observed that results were far

below the 150 mg/L maximum permitted limit of Standard Organization of Nigeria (SON, 2007). Hence, the borehole and household water samples are suitable for domestic purpose.

Chloride (Cl⁻) and Phosphates (PO₄³⁻)

The concentration of Cl⁻ as shown in (Table 3) ranged between 17.47 mg/L(Ijamido and Dalemo) to 48.4 mg/L (Sango) and 17.47 (Ijamido) to 37.92mg/L (Sango) obtained for BH and HH respectively. An increase in chloride concentration was observed in 29% of the samples from borehole to household. However, levels greater than 250 mg/L may cause a salty taste to water and beverages as well as speed up corrosion in plumbing materials (WHO 2011). The concentration of PO₄³⁻ in the BH and HH water as shown in Table 3 ranged from 6.9 mg/L (Ijamido) to 10.2 mg/L (Iju Ota) and 8 mg/L (Joju) to 10 mg/L (Oju-Ore and Sango) respectively. Increase in Phosphate levels in 57% of the sample was observed, when traced from point of collection, borehole to the household.

Microbial Analysis

The results of the microbial analysis for three main indicators of microbial quality namely total coliform (TC), thermo tolerant coliform and Escherichia coli (E.coli) for household water sources are presented.

Total Coliform and Thermotolerant coliforms

Total coliform are not indicators of health risk or faecal pollution, rather they inform on the quality of water from the source of supply. The total coliform count from this study range between 25cfu/100ml in Joju and too numerous to count (TNTC) in Oju-Ore, Sango, Okede and Ijamido HH water samples as shown in Table 4.

Table 4: Result of E.coli, Faecal Coliform and Total Coliform of the household samples

Zones	Iju-Ota	Oju-Ore	Joju	Sango	Dalemo	Okede	Ijamido	SON	WHO
E.coli (cfu/100ml)	19	6	12	TNTC	TNTC	10	13	0	0
Faecal Coliform (cfu/100ml)	2	2	4	4	3	3	2	0	0
Total Coliform (cfu/100ml)	41	TNTC	25	TNTC	TNTC	TNTC	TNTC	10	0

The observed values exceeded the maximum accepted concentration limit of 0cfu/100ml and 10cfu/100ml established by WHO and SON respectively. This result indicates poor water quality due to the presence of pathogenic bacteria capable of causing significant illnesses. From Table 4, it was revealed that thermotolerant coliform, were present in all the water samples and higher than maximum accepted concentration of 0cfu/100 ml standard set by both WHO and SON. The thermo tolerant coliform present in each water sample were, 2cfu/100 ml (Iju-Ota, Oju-Ore and Ijamido), 3cfu/100 ml (Okede) and 4cfu/100 ml (Joju and Sango) respectively. This is an indication of household drinking-water quality deterioration, which may occur as a result of multiple factors such as hand contact, method used to draw water, and dirty collection containers. Also, there could be possibility of inadequate treatment and disinfection and bacterial re-growth from the source due to seepage of sewage from septic tank into the borehole water as shown in Figure 2.

Escherichia coli

E.coli, were found in all the water samples as follows: Oju- Ore (6cfu/ml), Okede (10cfu/ml), Joju (12cfu/ml), Ijamido (13cfu/ml), Iju-Ota (19cfu/ml) and Sango (TNTC). The Oju-Ore sample showed low levels of contamination (less than 10colonies per100ml), Okede, Joju , Ijamido and Iju-Ota samples showed medium levels of contamination (between10 and19colonies per100ml), while Sango HH water sample revealed high levels of contamination (too numerous to count). The observed result indicates that all water samples were all excessively greater than E.coli maximum accepted concentration of 0cfu/ml for both WHO and SON, as shown in Table 4. The detection of the E.coli indicator in the HH drinking water is a definite proof of the recent occurrence of faecal contamination and the possible presence of enteric pathogens. Potential sources of contamination could be from shallow borehole, underground waste seepage, and poor personal and domestic hygiene practices.

XI. Conclusion

The study reveals that poor sanitation characterizes the challenges affecting a significant proportion of the population. However, in areas where the quality of water was better in the households, it implies that certain treatment methods were applied by the minority and there was proper storage. This includes boiling of water and addition of alum for which many residents complained of cost of fuel and electricity to boil water which in most cases is not available. The residents complained of lack of power supply to drive pumps that will transfer water into overhead tanks. Therefore, there is the need for a sustainable, efficient and affordable technology to be put in place to forestall

the challenges associated with lack of access to adequate water supply and proper sanitation. The study revealed that failure in treating water can be linked to the problem of water related illnesses such as diarrhea, typhoid, and cholera in the municipality. Hence, to ensure access to safe drinking water, adequate storage vessel along with point-of-use chemical disinfection of water and good hygiene practice should be encouraged.

Recommendation

In order to ensure safe drinking water in the study area, and other cities within the nation, the following steps should be carried out; 1). Sanitary education such as safe collection and transport of water from source to household should be conducted for everyone in the community; 2). There should be community education organized by the government or water related bodies on treatment procedures that can be carried out at the household level; 3). Previous studies have shown that vessels that are narrow necked often protect from contamination at the household level. Therefore, government should make available suitable storage vessels at affordable prices for purchase by the households; 4). There should be set rules and regulations by the government for individuals who sink boreholes to ensure the quality of water.

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