Bacteriological Assessment of Drinking Water Sources of Selected Barangays of Barobo, Surigao del Sur, Philippines

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Kay C. Patorgo[1] and Carina M. Magtibay[2]
Master of Science in Medical Laboratory Science
Graduate School, Lyceum of the Philippines University
kcpatorgo@yahoo.com[1]

Abstract *– In rural areas all over the world, the major environmental health problem remains with contaminated drinking water. In Barobo, Surigao del Sur, Philippines, diarrhea cases remain in the top 10 leading causes of morbidity in the municipality despite active drinking water quality monitoring of the Local Government Unit. However, this did not show the association of drinking water and the incidence of this diarrhea cases. This study was conducted to assess bacteriologically the quality of drinking water sources of Barobo, Surigao del Sur, Philippines. The study was conducted in five selected barangays of Barobo with the most number of recorded diarrhea cases were selected for this study. A total of 62 samples were collected both during wet and dry days from different sampling sites of the drinking water sources present in the study barangays and were examined for fecal coliforms. All samples collected were subjected to bacteriological analysis using the multiple tube fermentation technique and the fecal coliform test. From the total samples collected, 34% have unacceptable results for fecal coliform test. Based on the Philippine National Standard for Drinking Water, water with unacceptable fecal coliform test result or >1.1 MPN/100mL of water is unsafe for human consumption as it can be of health risk. This result is due to the fact that the water source from one of the water supply systems and the deep wells found in the barangays do not have any water treatment while the unsanitary handling practices of the water refilling stations probably contributed to the unacceptable results observed in their sealed water containers. Thus, water from these water sources is unsafe for human consumption.*

Keywords *–bacteriological assessment, coliforms, water contamination*

INTRODUCTION

Water is a basic human need. It is basically used for drinking, preparation and cooking of foods and hygiene. It is essential for every human being to have access to safe and quality drinking water as it is a basic human right [1]. Access to quality drinking water is of great significance in improving the public health [2]. According to the World Health Organization's guidelines for drinking water quality, safe drinking water does not pose any significant risk to health over a lifetime of consumption [3].

Water supply sources in the Philippines include, rainwater, surface water, and ground water sources. All water supply sources in the Philippines are considered unsafe for drinking unless further treatment is done [4]. All over the world, the major environmental health problem remains with contaminated drinking water particularly in rural areas where there is no water treatment [5]. A primary determinant of continuing poverty in a country is the high number of people living without access to safe drinking water [6]. World Health Organization's drinking water factsheet's states that in 2015, safely managed drinking water service that is located on premises, available when needed and free from contamination, is used by about 5.2 billion people globally; however, 844 million people lack even a basic drinking-water service. Globally, at least two (2) billion people use a drinking water source contaminated with feces which can transit diseases such as diarrhea, cholera, dysentery, typhoid, and polio. Water is considered as an important preventive measure used in hygiene but it can also be an important cause of diarrhea because of water contamination [7].

Diarrhea is a highly preventable disease yet some 824,000 people are estimated to die yearly of diarrhea due to unsafe drinking water, sanitation and hand hygiene [7]. An estimate was also made that by 2020, as many as 76 million people are to die of preventable water-related diseases such as diarrhea [1]. Diarrhea is one of the leading causes of infant morbidity and mortality in the world. Kosek and Guerrant [8] confirmed that there was a significant decrease in the mortality from diarrhea but morbidity remained high for the last four decades. Diarrhea is prevalent in developing countries with poor environmental sanitation, inadequate water supplies, poverty and limited education [9]. Although infectious diarrhea cannot be attributed to water, sanitation, and hygiene alone, diarrhea is considered as probably the biggest contributor to the disease burden from water, sanitation and hygiene [10].

Diarrhea is an infection in the intestinal tract that can be caused by a variety of bacteria, viral and parasitic organisms as a result from consumption of contaminated food and water sources. Rotavirus and Echerichia coli are the two most common etiologic agents of moderate to severe diarrhea in low income countries. Symptom is characterized by the passage of three or more loose or watery stools per day which can lead to severe dehydration for infants and children. One of the key measures to reduce the cases of diarrhea includes access to safe drinking water [7].

In a study conducted in Cambodia, results suggest a weak but positive association between E. coli in household drinking water and diarrheal diseases in a rural village in Kandal Province where the investigation was made. There was no observed increased risk of diarrhea for households having 1 to 10 E. coli per 100mL in drinking water while households having 11-100 and up to >1000 E. coli/100mL in drinking water reported increased risks of diarrheal disease [11]. In Cebu, Philippines, it was observed that the rate of diarrheal disease in children is significantly higher when children consumed water supply that was grossly contaminated with more than 1000 E. coli per 100mL. It also stated that foodborne transmission of diarrheal illness is increased when such highly contaminated water is used to prepare food [12]. In a case study conducted in Nukus, Uzbekistan, it was revealed that poor water quality contributes to a significant diarrheal burden [13]. Findings in the study include an 85% reduction in diarrheal rates among people without piped water at homes and treated their water with chlorine compared to those who did not chlorinate their water. A 62% reduction in diarrheal rates is observed among group of people on chlorination intervention compared to people living with access to piped water. These findings imply that in Nukus, diarrheal pathogens are spread through water. It also suggests that diarrhea among those with piped water is associated with public water supply [13]. Presence of a public water distribution network in a developing country is often an indicator of improved water supply but the water quality should not be assumed to be always safe for human consumption [14].

In Barobo, Surigao del Sur, Philippines, sources of water are classified as Level I (dug wells, springs and piped wells), Level II (communal faucets), and Level III (water supply system) (LGU Barobo, 2000). Barobo is located at the central part of Surigao del Sur. It has 21 barangays with a total land area of 24,250 hectares and a total population of 54,072 as of 2017 (PSA). The municipality is characterized by hilly and mountainous terrain with uneven distribution of lowlands. It has a vast fishing ground where about one third of its perimeter is along coastal areas.

In 2000, diarrhea cases rank second on the causes of morbidity in Barobo. During this time, about 37% of the household were not serve with safe water while 63% availed of Level I, Level II and a small portion of the household mostly from barangay Poblacion availed Level III water supply [15]. At present, the coverage of the water supply system has expanded to some other barangays and there are about five water refilling stations distributing purified drinking water in the municipality. The Local Government Unit of Barobo has been actively monitoring the said drinking water sources. A monthly monitoring on water quality is conducted by the municipal Sanitation Inspector in accordance to the Code on Sanitation of the Philippines to ensure that the community receives quality drinking water. Yet, records from the Municipal Health Office of Barobo shows that diarrhea cases is still on the top 10 leading causes of morbidity in Barobo from year 2012-2017. Records from Lianga District Hospital also show that about 46% of the total number of their reported diarrhea in all forms cases on 2016 are from Barobo. However, this does not show the association of drinking water and the incidence of these reported diarrhea cases.

To date, there is no study conducted to evaluate the quality of water in Barobo. Hence, this study is conducted to establish the relationship of drinking water sources in these barangays and the presence of fecal coliforms. This study can provide the local government of Barobo, Surigao del Sur a baseline data on the bacteriological quality of the drinking water which will be their basis for their programs primarily on safe water consumption. The objectives of this study are to assess bacteriologically the quality of drinking water sources of selected barangays of Barobo and determine the significant difference on the quality of water obtained during wet and dry days based on the number of coliforms. The significance of conducting this study is to know if the quality of drinking water sources of selected barangays of Barobo, Surigao is safe for human consumption

MATERIALS AND METHODS

Sampling Area

Barobo lies within 8o34’00” and 8o25’06” latitude and 125o59’00” and 126o22’00” longitude. The municipality’s climate is characterized by short dry season to very pronounced rain period from October to March.

The average rainfall is 429.89 millimeters and the average temperature is 24.63°C [14]. Out of 21 barangays, five were included in the study conducted. Selection was based on the recorded admitted cases of diarrhea disease on 2016 from the municipality of Barobo. The top five (5) barangays with the most number of cases were the sampling areas. These barangays include, Poblacion, Wakat, Dapdap, Kinayan and Tambis. Wakat and Dapdap are barangays along coastal areas, Tambis and Kinayan are in the lowlands while Poblacion is on hilly areas. Water samples were collected from the drinking water sources from these barangays which include water supply systems, purified water from the refilling stations and from deep wells.

Water Sample Collection

In coordination with LGU of Barobo, water sample collection was conducted by the researcher with the supervision of the municipal sanitation inspector. Before the start of sampling, a written request for consent to conduct the study was sent to the municipal mayor, administrators of the water supply systems, and water refilling stations. The samples were collected from the water supply systems, deep wells that were literally used as drinking water sources, and water refilling stations but limited only to those refilling stations present in the subject barangays. The first sample collection was done after consecutive days of rain while the second sampling was during dry days to account for seasonal changes [16].

In accordance to the World Health Organization's guidelines for drinking water quality samples were taken from the locations that are representative of the water source, clean water outlet from the treatment plant, the link or branch of the water supply system that serves the community and the points of use [17]. Five samples were collected from the water supply system (from the source, water tap after treatment, branch of the water supply system that supply the barangay and 2 randomly selected household faucets) in each barangay. Two samples each (water tap after treatment and one (1) from randomly selected sealed water container) were collected from the refilling stations that distribute purified drinking water in barangays of Barobo. One sample for deep wells present in the barangays was also collected.

Samples were collected on a 250mL sterile glass bottle from the Department of Science and Technology (DOST) CARAGA following the Philippine National Standards for Drinking Water sample collection, handling and storage (2007). Tap attachments were removed then cleaned with sterile gauze. The tap was fully opened letting the water to flow freely for about two (2) minutes which facilitated flushing and clearing of the service lines. The sterile bottle was then opened and filled with water from the tap. Sample collection in a deep well with hand pump was done by cleaning first the mouth of the pump using a brush and 10% hypochlorite.

To facilitate flushing, the water was pumped freely for about 5 minutes and water was then collected into the sterile bottle. Each collected samples was labelled with a code assigned to each drinking water source for confidentiality purposes and were securely placed in an upright position in an iced box. The samples were then transported to DOST Regional Standards and Testing Laboratory which is about three (3) to four (4) hours away from the subject area. The samples were subjected for water bacteriology analysis.

Bacteriological Analysis

Presumptive Phase

In accordance to the standard methods for the examination of water and wastewater [18], water samples were subjected to the multiple tube fermentation technique to detect presence of coliforms. On the presumptive phase, triple strength lauryl tryptose broth was prepared in a set of 5 tubes with an inverted vial. Twenty milliliter of the water sample were inoculated to each of the tube with lauryl tryptose broth and then mixed with gentle agitation. Inoculated tubes were then incubated at 35^0C. After 24 hours, the tubes were examined for growth, gas or acidic reaction and tubes without evident gas or acidic reaction were reincubated, and were reexamined at the end of 48 hours. The presence or absence of growth, gas and acidic production were then recorded. Presence of gas or acidic reaction in the tubes was interpreted as positive presumptive reaction. All tubes with positive presumptive reaction were submitted for fecal coliform test [18].

Fecal Coliform Test

The positive presumptive fermentation tubes were gently shaken. Using a sterile 3mm diameter loop, growth from each presumptive fermentation tube was transferred to *E. coli* broth. Inoculated EC broth tubes were then incubated in a water bath at 44.5^0C for 24 hours. Gas production with growth within 24hours or less in the EC broth was considered a positive fecal coliform reaction. Failure to produce gas was considered a negative reaction [18].

Statistical Analysis of Data

All data collected were treated using descriptive and inferential statistics such as mean, standard deviation and Independent Sample T-test to compare the number of coliforms present during wet and dry days and determine if the results are significant. The values were calculated using statistical software, PASW version 18 to further interpret the results of the study.

RESULTS AND DISCUSSION

Water Sampling

Table 1 shows the sampling sites and the number of water samples collected during the wet and dry days.

Table 1. Number of Samples Collected from Drinking Water Sources Sampling Sites

Water Sources	Sampling Sites	Wet Days	Dry Days
Water Supply Systems	Source	3	3
	Water Tap after Treatment	2	2
	Link to Barangays	4	4
	Households Taps	10	10
Water Refilling Stations	Water Tap after Treatment	5	4
	Sealed Water Container	5	4
Deep Wells	Source	3	3
Total		**32**	**30**

A total of 32 samples were collected during wet days; however, one of the refilling stations declined participation on the second sampling resulting to lesser sample size during dry days. This was due to the fact that this particular water refilling station only allowed the researcher to conduct the study in the presence of the municipal Sanitation Inspector who for some important reason was not present during the conduct of second sampling.

Presumptive Phase

Table 2 shows the results of water bacteriological analysis of drinking water sources of selected barangays of Barobo, Surigao del Sur collected during wet and dry days. All samples collected from water supply systems, water refilling stations and deep wells during wet and dry days were positive for coliforms on the presumptive phase of the water bacteriological analysis. This indicates the presence of bacteria on all water samples collected and analyzed. This is most likely due to the presence of either algae, dirt and/or rust which was observed by the researcher during the cleaning preparation done before sample collection at the water supply systems' source water line, water tap after treatment, water line linked to the barangays, households' taps, water refilling stations' water tap after treatment and sealed water containers as well as the mouth of the water pump of the deep wells.

The presence of coliforms indicates that a contamination pathway exist between a source of a bacteria and the water supply. This pathway may be use by disease-causing bacteria to enter the water supply [19]. Total coliforms have been utilized as a microbial measure of drinking water quality. It is not an index of fecal pollution or of health risks but can provide basic information on source water quality [20].

Table 2. Results of Water Bacteriological Analysis Drinking Water Sources of Selected Barangays of Barobo, Surigao del Sur Collected during Wet and Dry Season

Water Sources	Sampling Sites	Wet Days Presumptive Phase (Positive)	Dry Days Presumptive Phase (Positive)
Water Supply Systems	Source	3	3
	Water Tap after Treatment	2	2
	Link to the Barangays	4	4
	Household Taps	10	10
Water Refilling Stations	Water Tap after Treatment	5	4
	Sealed Water Container	5	4
Deep Wells	Source	3	3
Total		**32**	**30**

Fecal Coliform Test

Table 3 shows the number of unacceptable results on fecal coliform test on the drinking water collected and analyzed during wet and dry days.

According to the Philippine Standards for Drinking Water [21] results of >1.1 MPN/100mL water on fecal coliform test are considered unacceptable for drinking purposes and are not safe for human consumption. As shown on the table, out of the 32 samples collected during wet days, 21 samples showed acceptable results on fecal coliform test while 11 samples showed unacceptable results. The 30 samples collected during dry days showed 20 acceptable results on fecal coliform test while 10 samples showed unacceptable results.

Unacceptable result from the water supply system source on both seasons was observed from barangay Tambis. This is due to the fact that the source of the barangay's water supply system is from an unprotected cave without water treatment. This is also the reason for the unacceptable results of the two (2) randomly selected household taps both on wet and dry days. The local officials of barangay Tambis, stated that the barangay does not have the budget to improve their water system even through simple water chlorination treatment. Water treatments are significant in reducing the incidence of diarrhea as observed in the study [22]. The water tap after treatment with unacceptable result on wet days was observed from the water supply system of Barangay Wakat. This is may be due to the water tap which is seldom used and have accumulated dirt since samples from water supply system link to barangay Wakat and the household taps have acceptable results.

Table 3. Results of Fecal Coliform Test on Drinking Water Sources of Selected Barangays of Barobo, Surigao del Sur Collected during Wet and Dry Season

Water sources	Sampling Sites	Wet Days Fecal Coliform Test (Unacceptable Results)	Dry Days Fecal Coliform Test (Unacceptable Results)
Water Supply Systems	Source	2	1
	Water Tap after Treatment	1	0
	Link to the Barangays	0	0
	Household Taps	2	3
Water Refilling Stations	Water Tap after Treatment	0	0
	Sealed Water Container	3	3
Deep Wells	Source	3	3
Total		**11**	**10**

Unacceptable results were observed from three (3) out of five (5) randomly selected sealed water containers of the refilling stations both on wet and dry days. The contamination of the water from the containers is probably due to unsanitary handling practices of the workers as observed by the researcher. It was observed that most of the empty water containers were not properly stored while waiting to be filled. The containers which were claimed by the workers as already washed and clean were stored outside the station with the containers' mouth open which can be the source of contamination. It was also observed that workers handled the water container through their mouth even though the containers were ready for filling without proper hand washing observed. One station was even observed washing their floor mop at the water tap where the containers are washed before filling. These unsanitary observations probably contributed to the high number of water refilling stations having unacceptable results of water samples from their sealed water containers even though the refilling stations treated water samples have acceptable results. This supports the statement of Pascual, et. al [23] that water refilling stations can be good sources of safe drinking water in the Philippines as the efficient purification processes can make the quality of water superior to the traditional water systems. However, risk of contamination is possible if the handling practices are not closely monitored.

The deep wells from three (3) different barangays namely, Poblacion, Dapdap, and Kinayan which are used by the residents as alternative source of drinking water and for food preparations were observed with unacceptable results showing >8.0 MPN/100mL water. These deep wells were all untreated, the one from Kinayan was unprotected without pump and the one from Poblacion was located less than 50 meters from the households. This can be the reasons why water from these deep wells is unacceptable for drinking as also stated in P.D. 856 Code on Sanitation of the Philippines.

Table 4. Fecal Coliform of the Drinking Water Sources of Selected Barangays of Barobo, Surigao del Sur During Wet and Dry Days

Type of Water Source	Sampling Sites	Fecal Coliform (Wet Days)	Fecal Coliform (Dry Days)
Water Supply Systems	Source	Positive	Positive
	Water Tap after Treatment	Positive	Negative
	Link to the Barangays	Negative	Negative
	Households Taps	Positive	Positive
Water Refilling Stations	Water Tap after Treatment	Negative	Negative
	Sealed Water Container	Positive	Positive
Deep Wells	**Source**	**Positive**	**Positive**

Table 4 shows the fecal coliforms on the water sources samples collected during wet and dry days. Out of the seven (7) water sources, five (5) were positive for fecal coliforms while two (2) water sources were negative for fecal coliforms during wet days. On the other hand during dry days, four (4) out of the seven (7) water sources were positive for fecal coliforms while three (3) water sources were negative. Both on wet and dry days, samples from the links to the barangays of the water supply systems showed negative result for the presence of fecal coliforms. This means that the water supplies that enter the barangays of Wakat, Poblacion, Dapdap and Kinayan are safe for drinking. Based on the results, water source and the supply of water to households from the water system of barangay Tambis is strongly not recommended for drinking as all samples from these sites showed presence of fecal coliforms both on wet and dry days.

The table also showed the positive result for the presence of fecal coliforms on water refilling stations sealed water containers. This makes the water from the water refilling stations containers and also water from deep wells with positive presence of fecal coliforms both on wet and dry days unsafe for drinking purposes. Drinking water should not have the presence of fecal coliforms as it is an indicator of the quality of water not safe for human consumption.

This supports the study conducted in Ibadan metropolis and Ile-Ife city in South Western Nigeria, wherein marketed packaged drinking water brands being studied were found to have the presence of coliforms and E. coli in concentrations that made the drinking water unfit for human consumption as stipulated by the WHO guidelines and recommendations [24].

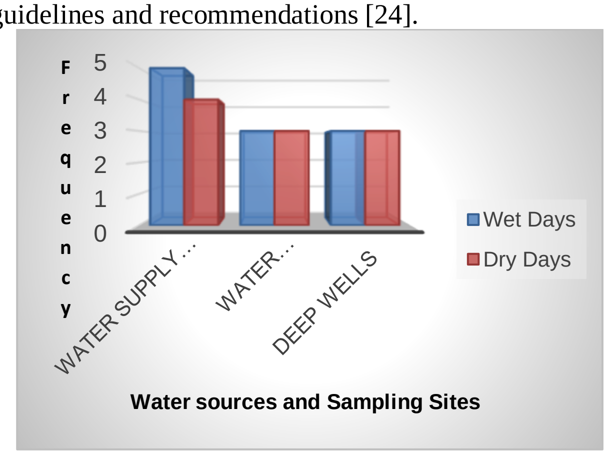

Figure 1. Number of Fecal Coliform during the Two Types of Season

Figure 1 shows the number of coliform during the two types of season. Based from the test conducted, there were no significant difference observed on the fecal coliform during wet days (1.571 ± 0.942, n=7) and dry days (1.429 ± 1.12, n=7) with a difference of mean of 0.143 ± 2.062 and 95% confidence interval of 2.514 to 0.309.

This indicates that regardless of the seasonal changes these water sources with positive coliforms are unsafe for drinking. This only means that whatever days in it in a season, there is always an existence of bacteria in different water sources. This supports the study of Thomas, et. al [25], in the assessment of seasonal variation on microbiological quality of drinking water which showed no significant difference in the mean E. coli count in between seasons.

Conclusion and Recommendation

This study was conducted to bacteriologically assess the quality of drinking water sources of selected barangays of Barobo, Surigao del Sur, Philippines. Based on the results of the bacteriological analysis, it can be concluded that different drinking water sources contain fecal coliforms which makes the water unacceptable and unsafe for human consumption based on the Philippine National Standards of Drinking Water. Moreover, there is always an existence of bacteria in the different sources of drinking water in Barobo during wet or dry season.

Based on the results, it is suggested that the Local Government Unit of Barobo, Surigao del Sur must strengthen its drinking water quality monitoring of the water sources in the locality and closely monitor the handling practices of water refilling stations. Water treatment for the water source of barangay Tambis and the deep wells in Barangays Poblacion, Kinayan and Dapdap is highly recommended to improve the quality of water and minimize the health risk from its consumption. Bacterial isolation and speciation can also be performed to identify the specific bacteria present on contaminated water sources.

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