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A Preliminary Study of Water Quality in Rural Belize

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Abstract A preliminary study was conducted to analyze the water quality of creek waters used by villagers in the Cayo district of Belize. Three sites on water bodies that are used by the residents of St. Margaret village for various domestic purposes were chosen. Various physical, chemical and microbiological parameters were analyzed by using standard water quality measurements and compared for the wet and dry seasons. The results indicate that the pH was high during dry season especially in the month of April. The phosphate levels were high during the wet season in almost all the sites studied. Dissolved oxygen levels were high during March and April, but were generally low during the wet season. The fecal coliform levels were alarmingly high during the month of October. Further analysis for the presence of other indicator organisms such as *Salmonella* and *Shigella* revealed that these enteric pathogens were generally present in the creek waters around the St. Margaret village. The results from this study suggested that the water bodies are not safe for human consumption especially during rainy season.

Keywords Watershed, Water Quality, Microbial Indicators, Rural Belize

1. Introduction

The availability of good quality potable water is an important feature for preventing diseases and improving quality of life for rural populations of the developing countries [1]. Natural water contains different types of impurities that are introduced in to the aquatic system by different ways such as weathering of rocks and leaching of soils, dissolution of aerosol particles from the atmosphere and from several human activities, including mining, processing and the use of metal based materials [2]. Drinking water pollution causes water born disease which has led to the death of millions of people [3]. Knowledge of the quality of a country's streams and aquifers is important because of the implications to human and aquatic health. Water quality refers to the chemical, physical and biological characteristics of water. It is most frequently referred to a set of standards against which compliance can be assessed. The most common standards used to assess the water quality relate to health of ecosystems, safety of human contact and drinking water [4].

Many studies describe associations between water quality indicators and health effects on human beings. Besides physical and chemical parameters, microbial water quality has been extensively studied in recent years [1, 5]. Most of these studies emphasize on correlation between water borne diseases and exposure to contaminated water sources [6, 7]. Indicator microorganisms such as total and fecal coliforms, and other GI tract related microbes have been used as bench mark for drinking water quality assessment in urban and rural areas [8, 9].

Belize is a small country with a population of approximately 341,000, of which more or less half live in urban areas and half in rural areas [10]. It has a very young population employed in agriculture, tourism, and the service sector. Belize is divided into 18 major watershed areas. These watersheds play a critical role in keeping the overall pristine nature of tropical ecosystem of Belize. Most of the rural populations in the country depend up on these watersheds for their livelihood.

St. Margaret Village is a small rural community located in the Cayo District. The village has a population of approximately 1,500 inhabitants with about 250 households. People from St. Margaret village are not economically well-off and hence cannot afford to buy purified water. Most of the residents get drinking water from the closest river/creek that run adjoining the village on both sides, The villagers use water from both the Santa Martha River and the Dry Creek for various domestic purposes, without any concern for the water quality or the danger of getting water borne diseases. The Santa Martha River and Dry Creek originate from the nearby Maya Mountains (Figure 1) and are part of the Sibun River watershed.

2. Materials and Methods

The overall objective of the study was to compare the physical, chemical and biological aspects of water quality of creeks/rivers around St. Margaret's village, Cayo district

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during the wet and dry season. The study design consisted of an intensive water sampling from the creeks/rivers on a monthly basis for a period of 3 months during wet season (October – December) and 3 months during dry season (February to April). The total rainfall for the study area during the dry season (February to March) is between 150 to 200 mm and the total rainfall for the wet season (October to December) is about 800 mm [11]. The water level in the streams, creeks and rivers fluctuate greatly between the wet and dry season.

Site Description:

Sibun River watershed is one of the main watershed areas in the Central Belize and the tributaries of Sibun River passes through St. Margaret Village [12]. The Sibun watershed is mostly forest and marshland with some agriculture lands that are under milpa, citrus, cacao and pasture land. It can be up to 1000m in elevation at the highest point. Three sites were selected close to the St. Margaret village where the village people go frequently either for drinking purposes or for entertainment. Site 1 is 300 meters from the village on the west and it is used by the villagers for mostly drinking purpose. Site 2 is called the Dry Creek and this site is frequented by villagers for swimming/bathing purpose (Figure 2). Site 3 is called the Santa Martha River and this site is mainly used for swimming. Site 3 is the most frequently used site by the villagers. The GIS coordinates and the elevation data for the three selected study sites are given in table 1.

Table 1. The GIS coordinates for the three selected study sites

Site Number	Geographical Coordinates		Elevation (from sea level)
Site 1	N - 17.092º	W - 088.615º	57 meters
Site 2	N - 17.093º	W - 088.604º	72 meters
Site 3	N - 17.089º	W - 088.620º	109 meters

Figure 1. The Maya Mountain – The Main Watershed of Sibun River

Onsite Water Quality Testing

At each site and during each round of sample collection, the physical and chemical parameters were measured by using the DR/850 colorimeter and YSI 599 Replaceable Module kit respectively. The parameters studied were: Temperature (℃), Dissolved Oxygen (mg/L), pH, conductivity (ms/cm), Turbidity (FTU), Nitrate (mg/L), Phosphate (mg/L) and Total Chlorine (mg/L).

Figure 2. The Dry Creek (Site 2) During Wet Season

Testing for Bacterial Indicator Organisms

Water samples were collected in pre-sterilized Wheaton sample bottles in the morning hours and samples were transported in cool boxes to the laboratory for further microbial analysis. For each site two samples were taken. Water samples were tested for presence of Fecal Coliforms by using serial dilution method on appropriate differential media agar plates. Based on the preliminary results, presence of pathogenic indicator organisms such as *Salmonella* and *Shigella* were also tested by using appropriate selective media during the wet season. All protocols were done as per microbiological standards under aseptic conditions. For each sample two plates were used. Samples were diluted as necessary and plates were incubated under required temperature and the colony forming units (CFUs) were enumerated. All chemicals and reagents used in this study were obtained from reputed suppliers and were of Analytical grade.

In addition, A survey was conducted to find out the prevalence of ailments related to usage and consumption of water from the study sites. 50 households were randomly selected and questionnaires were filled by the research team during an interview process.

3. Results

The results for physical, chemical and microbiological parameters were averaged and presented in tables and graphs as necessary. Table 2 summarizes the data for the physical parameters. Belize being a sub tropical country, the temperature remained between 22 and 29 degrees Celsius during the study period. The highest temperature was recorded in the month of April when the temperature was above 28℃. Similarly the pH was also highest during the month of April in all three sites studied. Site 1 and site 2 showed pH above 9 which suggests the water is alkaline. Since the watershed originates from calcium rich Maya

Mountains, when the water level decreased, the pH increased. The water bodies were slightly acidic during the other months of the year. The turbidity was highest during the month of February at site 1 and site 3. Turbidity was lowest during November and December for all three sites.

Table 3 summarizes the results for chemical parameters.. The dissolved Oxygen level was lowest during the wet season. This could be due to degradation of plant materials and higher level of microbial activity in the water bodies. The concentration of chlorine and nitrates were at acceptable level both during wet and dry season. However the phosphate level was high during the month of November (Table 3).

Figure 3 shows the fecal coliforms present in the waters at the three sites studied during dry and wet season. Presence of coliforms were tested on McConkey agar which is a standard selective medium used [13]. It should be noted that the fecal coliforms were present both during wet and dry season. It is evident that there is a significant difference in the fecal contamination of water between the wet and dry seasons. Since human and animal activities are seen in the watershed area, during rainy season, fecal matter leach in to the water bodies and hence the microbial population increased dramatically during the wet season. The highest microbial population was recorded during the month of October for all three sites studied (Figure 3). This correlates with the rainfall level for the month of October in this watershed area as October is one of the highest rainfall months for the year 2014 [11]. However there was no direct correlation between the fecal coliform level and the nutrients such as nitrates and phosphates in the water bodies.

Table 2. Results for the Physical Parameters

Parameter	Temperature (℃)			pH		
Month	**Site 1**	**Site 2**	**Site 3**	**Ste 1**	**Site 2**	**Site 3**
February	22.9 ± 0.12	22.6 ± 0.02	22.6 ± 0.07	5.48 ± 0.12	5.53 ± 0.08	6.15 ± 0.09
March	26.6 ± 0.22	24.0 ± 0.21	24.9 ± 0.12	5.18 ± 0.17	5.54 ± 0.12	4.31 ± 0.14
April	28.4 ± 0.04	28.5 ± 0.02	27.8 ± 0.10	9.37 ± 0.24	9.13 ± 0.31	8.62 ± 0.23
October	24.8 ± 0.13	25.4 ± 0.15	25.4 ± 0.06	5.73 ± 0.09	5.41 ± 0.21	6.09 ± 0.11
November	23.7 ± 0.11	23.9 ± 0.11	23.4 ± 0.12	4.65 ± 0.32	5.63 ± 0.11	5.34 ± 0.22
December	23.5 ± 0.10	24.6 ± 0.13	24.7 ± 0.13	5.13 ± 0.21	5.51 ± 0.08	5.63 ± 0.17
Parameter	**Conductivity (ms/cm)**			**Turbidity (FTU)**		
Month	**Site 1**	**Site 2**	**Site 3**	**Site 1**	**Site 2**	**Site 3**
February	0.07 ± 0.01	0.03 ± 0.00	0.03 ± 0.0	9 ± 0.24	3 ± 0.11	8 ± 0.42
March	0.06 ± 0.02	0.05 ± 0.01	0.04 ± 0.00	6 ± 0.36	2 ± 0.02	5 ± 0.28
April	0.06 ± 0.01	0.05 ± 0.00	0.04 ± 0.01	6 ± 0.22	1 ± 0.01	2 ± 0.13
October	0.03 ± 0.05	0.06 ± 0.01	0.03 ± 0.0	3 ± 0.14	2 ± 0.0	2 ± 0.14
November	0.02 ± 0.04	0.04 ± 0.00	0.03 ± 0.0	2 ± 0.02	1± 0.0	2 ± 0.16
December	0.03 ± 0.02	0.05 ± 0.01	0.04 ± 0.01	1 ± 0.0	1 ±0.0	1± 0.0

Table 3. Results for the Chemical Parameters

Parameter	Dissolved O_2 (mg/L)			Chlorine (mg/L)		
Month	**Site 1**	**Site 2**	**Site 3**	**Site 1**	**Site 2**	**Site 3**
February	6.37 ± 0.17	6.34 ± 0.18	6.25 ± 0.32	0.05 ± 0,0	0.01±0.0	0.59±0.02
March	6.09 ± 0.20	7.25 ± 0.28	5.51±0.23	0.07 ± .01	0.01±0.0	0.04±0.01
April	2.52 ± 0.12	3.62 ± 0.14	3.5±0.18	0.12 ± 0.02	0.02±0.01	0.05±0.01
October	1.70 ± 0.04	1.76 ± 0.02	1.8±0.02	0.01 ± 0.0	0.01±0.0	0.02±0,0
November	1.51 ± 0.03	1.11 ± 0.0	1.33±0.01	0.06 ± 0.0	0.03±0.01	0.01±0.0
December	1.12 ± 0.02	2.10 ± 0.12	1.53±0.05	0.03 ± 0.0	0.02±0.0	0.02±0.0
Parameter	**Nitrates (mg/L)**			**Phosphates (mg/L)**		
Month	**Site 1**	**Site 2**	**Site 3**	**Site 1**	**Site 2**	**Site 3**
February	0.055±0.01	0.045±0.01	0.035±0.01	0.76±0.10	0.54±0.04	0.81±0.02
March	0.08±0.01	0.07±0.01	0.04±0.02	0.89±0.12	0.78±0.08	0.89±0.03
April	0.03±0.00	0.02±0.00	0.03±0.00	0.62±0.02	0.27±0.01	0.72±0.02
October	0.04±0.00	0.01±0.00	0.03±0.00	0.27±0.01	0.21±0.00	0.14±0.02
November	0.03±0.00	0.02±0.00	0.03±0.00	1.16±0.02	2.75±0.01	1.38±0.12
December	0.035±.0.01	0.015±0.00	0.03±0.01	0.72±0.02	1.48±0.01	0.76±0.02

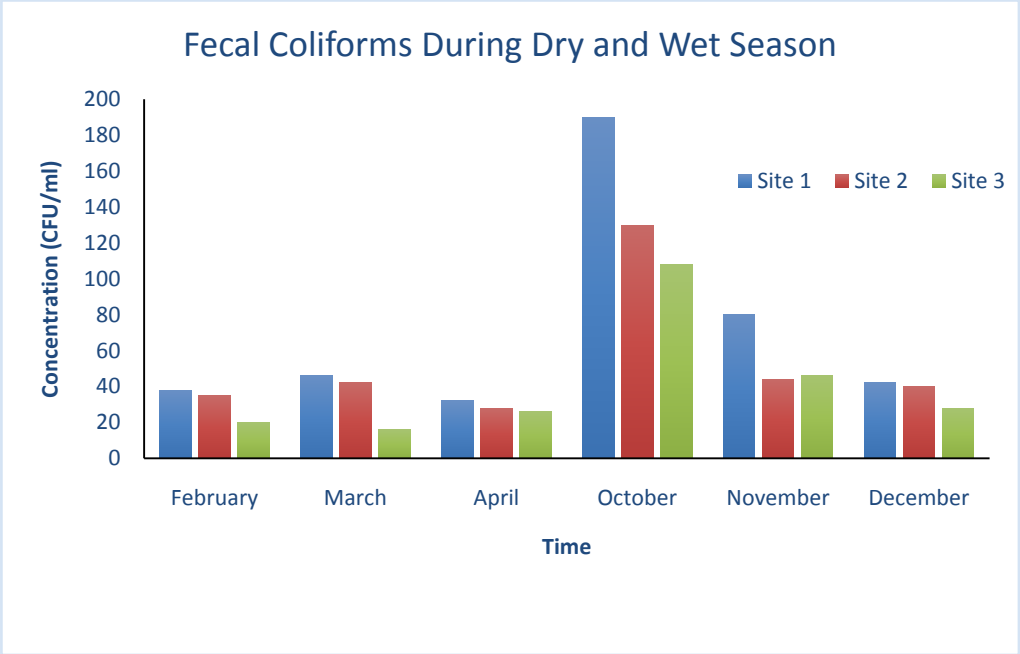

Figure 3. Concentration of Fecal Coliforms During Wet and Dry Season

Table 4. Presence of *Salmonella* and *Shigella* During Wet Season

Shigella (CFU/mL)				*Solmonella* (CFU/mL)			
Month	Site 1	Site 2	Site 3	Month	Site 1	Site 2	Site 3
October	460±12.4	330±5.6	340±10.4	October	0	52±1.6	33±1.8
November	600±28.3	310±4.0	240±16.8	November	14±1.2	10±1.2	12±0.4
December	650±24.2	720±14.6	300±17.5	December	0	12±1.8	0

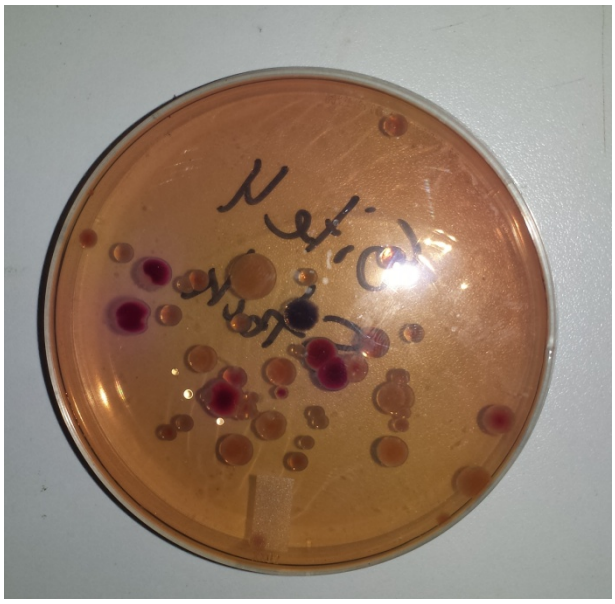

Figure 4. *Salmonella* and *Shigella* on SS agar

Since the fecal coliform level was alarmingly high during the month of October, test for presence of patogenic organisms such as *Salmonella* and *Shigella* were carried out on SS agar media (Figure 4). This is a selective and differential medium used in isolating enteric pathogens from water bodies [14]. The results showed (Table 4) that *Shigella* was present during all three months of the wet season at an alarmingly high level. However the presence of *Salmonella* was intermittent. Presence of pathogenic enteric baceria in the water bodies around the village indicates human fecal contamination reaching water bodies.

The survey carried out among the residents of the St. Margaret village revealed that 55% of the village population used water from the sites included in this study for drinking purpose. About 75% of the people used the water bodies for swimming or recreational purpose. 54% of the people surveyed experienced some form of GI tract related health issues. Among those experienced health problems, 24% of the people experienced diarrhea, 20% reported abdominal problems/vomiting, and 10% experienced hepatitis.

4. Discussion

Availability of quality of water is an important component of human life. Water quality monitoring is the critical step towards creating awareness among the general public. Many studies relate fecal contamination of water bodies to enteric diseases in human populations [15 – 17]. Since microbial contamination was high during the wet season it can be inferred that these ailments are related to consumption of

contaminated water. Our survey results support that inference. Rain fall has a direct impact on the nutrient leaching and fecal contamination of water bodies as run-off water carries human and animal waste in to the nearby water bodies [18]. Since farming activities are found around the watershed area of St. Margaret village, there is high chance of animal fecal contamination reaching the creeks during rainy season. Water quality monitoring is necessary for prevention of waterborne diseases and organisms such as *Shigella* and *Salmonella* are important indicator microorganisms in that exercise [19].

5. Conclusions

Water quality monitoring is an expensive process because of the significant costs associated with the constant testing as well as development and implementation of regulations. Many people living in rural Belize do not have access to treated potable water. The main source of water for rural population is mainly nearby rivers and creeks. These water bodies are used for recreational as well as domestic purpose including drinking water. The study highlights the need for awareness of water quality for the people living in the villages of Belize. Government also ought to provide healthy drinking water for the public to avoid serious health risk associated with the consumption of contaminated water.

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