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A Seasonal Analysis of the Quality of and Safety of Drinking water harnessed from Roadside Entombments in East Rural, St. Andrew Jamaica

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Abstract

Due to the increase in population density in urban areas and the uncertainty associated with the availability of municipal water supplies, roadside water entombments have remained an important water source for many residents of Jamaica. This research focused on the seasonal, quality and safety of water harnessed from two non -municipal roadside water supplies. The study employs a cross sectional quantitative approach and uses international and national water quality standards as the benchmark. The aim of the study was to describe the seasonal quality and safety of water harnessed from roadside water entombments in East Rural St. Andrew Jamaica. The physiochemical, microbiological quality and safety of the water supplies were assessed. Two microbiological samples were collected from each source during the wet and dry months. In 100 % of the microbiological samples the Total Coliform levels exceeded national and international limits of Zero CFU/L for safe drinking water.

Keywords*: Entombed Water Supplies, Non Municipal Water, Potable Water, Water Quality Index.*

Introduction

Globally less than 10 % of the world's population use drinking water from improved sources while 58% use water from a piped connection in their dwelling, plot or yard, and 33% from other improved drinking water sources [1]. Amidst the importance of water with regards to sanitation and nutrition as well as a determinant of health; water has been a vehicle for numerous diseases such Leptospirosis, Giardiasis, Poliomyelitis and other infectious illnesses. Proper and adequate treatment must therefore take place to ensure that water for domestic use including drinking is kept safe and potable [2]. Recognizing the importance of potable water for the Jamaican and n keeping the United Nations Development Goal [6] the Government of Jamaica has set a target for all Jamaicans to obtain universal access to potable water by 2030 [3].

Though access to water is a target set by the Jamaican government there are still individuals in numerous communities that do not have access to this necessary commodity, and where access is available many persons opt to consume water from non-municipal sources such as roadside water entombments because of the perceived nutritional value. Throughout Jamaica business operators are establishing water processing and dispensing operations which have become a viable business. These entities employ various aesthetic water treatment techniques such as reverse osmosis to produce drinking water via a machine. The source from which these water are supplied are sometimes non potable sources such as the roadside entombments studied in this research. These entombments have existed for more than a century providing water for drinking and other domestic purposes not just for residents

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within the East Rural St. Andrew area but bulk water truckers also harness free, unmetered amounts of water from these sources which are then sold to water shop retailers and processors.

Worldwide waterborne illnesses continue to take a heavy toll on the global community, with developing nations, and particularly young children carrying most of the burden of morbidity and mortality [4]. Water from roadside entombments are not safe biologically, physically or chemically if the facilities are not monitored to ensure the potability of the water dispensed [5]. In 2015 due to the consumption of unsafe water a Roto-viral gastroenteritis outbreak in the Philippines affected 2936 residents' cases with 22 deaths [6].

Since water from these entombments are not metered many residents who tap into the sources obtain the required amounts of 60 US gallons or more per person per day [7]. In the year 2016, water, sanitation and hygiene were responsible for 829 000 annual deaths from diarrhea, and 1.9% of the global burden of disease [8]. This study provides information that can add valuable scientific data for future interventions such a national water quality policy for the management of non-municipal water sources. The research aimed to describe the seasonal physiochemical, microbiological safety and quality of water from roadside entombments in East Rural St. Andrew Jamaica.

The specific objectives that guided the methodology as outlined in this paper were to: Describe the seasonal bacteriological quality and safety of water from roadside entombments by examining Heterotrophic Plate Count [HPC], Total Coliform [TC] and to describe the seasonal physiochemical quality and safety of water from non-municipal roadside entombments by examining Total Dissolve Solids [TDS] and Hydrogen Ion [pH] concentration as water quality parameters. From informal conversations it is believed that these water sources are springs in the mountains located approximately 10-15 Kilometers from the sources. Throughout the communities excreta disposal is mostly via the means of pit latrines and or water closets with absorption pits. The Sustainable Development Goal 6 [SDG 6] outlines that globally by the year 2030 there should be improved water quality by reducing pollution, eliminating dumping, and minimizing release of hazardous chemicals and materials [3]. In Jamaica the government has set policy criteria for potable water which is regulated by the Ministry of Health amidst the guidelines presented, more comprehensive water quality regulations aimed at protecting the health of population is required [9].

Literature Review

Water sources can include surface water, dug wells, boreholes, standpipe and springs which provide water for a population. The World Health Organization states that the quality of these sources should be assessed and the likelihood of contamination determined [10]. The Center for Disease control also outlines that water is obtained from two main sources, surface water such as rivers and reservoirs as well as groundwater which is obtained by drilling wells for water [11]. Prior to human consumption or use, water from natural sources should be treated for microorganisms, bacteria, toxic chemicals, viruses and fecal matter.[9] Drinking raw, untreated water can cause the transmission of diseases such as cholera and other gastrointestinal problems such as diarrhea, vomiting and fever [1]. In addition to that, if large levels of contaminants are present in drinking water, chronic diseases such as lead poisoning may result [12].

The quality of raw water harnessed from a source is also a reflection of the environment it passed through [13]. If the water has not undergone any preliminary treatment to reduce or eliminate contaminants, then the risk posed to the user or consumer is very high. [9]. The World Health Organization has basic parameters or standards used to determine the quality of safe water and this guideline has been

the background for setting drinking water related regulation and standards across the world [14]. Guidelines for drinking water quality assist in the promotion and the protection of the health of the public, it also forms the basis of surveillance and monitoring of water and water safety plans to ensure compliance and effectiveness. Total dissolved solids are inorganic salts are small amounts of organic matter that are dissolved in water [14]. High levels of dissolved solids result in corrosion, excessive hardness, unpalatability and mineral deposition. Globally acceptable levels of Total Dissolve Solids in water are established in keeping with the Environmental Protection Agency of the United States which is <500 ppm [15].

In Jamaica, the acceptable levels of TDS for drinking water is 120-300 ppm [16]. In surface water, the most common sources of high total dissolved solids [TDS] are inorganic compounds found in water, such as salts, heavy metals, and some traces of organic compounds [17]. The pH or Hydrogen Ion concentration is an important parameter indicating the acidity or alkalinity characteristics of the water. In surface water pH is also influenced by the geological nature of the drainage basin [18]. While chemical and physical parameters of drinking water are known to be of major public health significance, most emphasis including research has mostly focused on biological risk associated with drinking water. In Jamaica there are established water quality standards which are monitored by the Ministry of Health and the National Environment and Planning Agency. These parameters are as follows: Zero CFU / Coliforms, 0.2ppm of residual chlorine, Chloride 5-20 Mg/L, Nitrate 0.1- 7.5 Mg/L, PH 7-8.4 Mg/L, Total Dissolve Solids 120-300 Mg/L [10]. Since pH can be affected by chemicals in the water, pH is an important indicator of water that is changing chemically [16]. High pH will result in a bitter taste, as well as it suppresses the effectiveness of the disinfection of chlorine. [17]. The World Health Organization indicates that the pH of drinking water should range between 6.5 and 8.5. Water with a pH > 8.5 could indicate that the water is hard and can lead to digestive and metabolic abnormalities if consumed [4]. Total Coliform is a large collection of different kinds of bacteria. Total coliform is commonly found in the environment, whereas fecal coliform is naturally found in the intestines of people and animals. Presence of fecal coliform in drinking water samples indicates recent fecal contamination. [18] Coliforms are recognized as a suitable microbial indicator of drinking water quality. The World Health guideline for drinking water explained that Coliform bacteria should not be detected in drinking water supply [10] the established guideline states that if these indicator organisms are present in drinking water it suggests that there was inadequate treatment, post treatment contamination or excessive nutrients. [10]. A study conducted in drinking water depots in Tembalang District in Indonesia used total coliform and E. coli as microbiological quality parameters. In the study, samples were taken from 37 depots. The results from the samples revealed that 79% of the samples did not meet the quality based on the presence of coliform, while 9% were positive for *E. coli* [9]. The presence of coliform in water is an indication of pollution [10].

The Heterotrophic Plate Count [HPC] test or Total Plate Count is widely used to measure the heterotrophic microorganism population in drinking-water and other media. High HPC counts indicate ideal conditions for bacterial regrowth and should be corrected when identified in drinking water supplies [11]. Understanding the seasonal variation of water quality and safety is therefore important to effectively protect a water source [20]. The literature reviewed demonstrates that many actions and circumstances can lead to the contamination of drinking water. Water for drinking purposes must therefore be made free from disease-producing organisms [pathogens],

such as viruses, protozoa, fungi, and bacteria. Established policies and guidelines are therefore required in Jamaica to ensure that the water sources mentioned in this research are monitored and regulated ultimately reducing the impact on public health associated with the outbreak of waterborne illnesses.

Methodology

A cross-sectional survey was conducted to assess the seasonal; physicochemical and bacteriological quality of roadside water entombments in East Rural St. Andrew, Jamaica. Sampling was done through field work and the analysis of water quality parameters were done using calibrated handheld tools and standard laboratory testing. The two roadside entombments are located in Craig Hill and Cozy Nook Communities of East Rural St. Andrew, Jamaica Microbiological water samples were collected in sterile water bottles and transported to the laboratory under refrigerated conditions within 24 hours for microbiological analysis. Physiochemical analysis were conducted on the field. A total of six samples were collected during the wet months of the year which is December to June and six collected during the wet months September to November. An observation guide was used to capture the data on the physiochemical characteristics for both water supplies. The instrument consisted of drinking water quality index parameters which was used to guide the analysis. For each water sample, the physicochemical and biological characteristics were measured using standard testing procedures. The qualities assessed were Total coliform, Hydrogen Ion Concentration, Total Dissolve Solids, Heterotrophic Plate Count.

Results

The findings from the samples collected for analysis are outlined below,

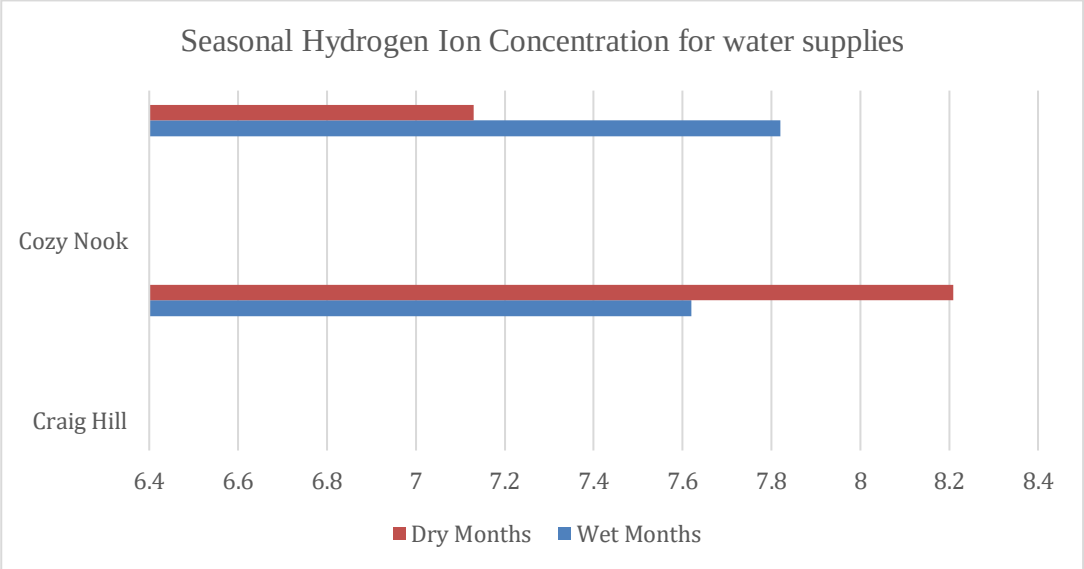

Figure 1. Hydrogen Ion Description of Entombed Roadside Non Municipal Drinking water sources

Table 1. Seasonal Variation in Total Dissolve Solids of Entombed Roadside Non Municipal Water Sources

Sources	**Physiochemical Parameters**	
	Total Dissolve Solids	**Total Dissolve Solids**
	Wet Months	**Dry Months**
Craig Hill	204 Mg/L	144 Mg/L

Cozy Nook	167 Mg/L	86 Mg/L

Table 2. Seasonal Variation in Microbiological Parameters of Entombed Roadside Non Municipal Water Sources

Sources	**Microbiological parameters**			
Samples	**Heterotrophic Plate Count (CFU/mL)**	**Heterotrophic Plate Count (CFU/mL)**	**Total Coliform (CFU/mL)**	**Total Coliform (CFU/mL)**
	Wet Months	**Dry Months**	**Wet Months**	**Dry Months**
Craig Hill	1 x 10 ^{2}	1.8 x 10^{2}	170	33
Cozy Nook	1.4 x 10^{2}	1	79	<1.8

Discussions

Even with good intentions governments globally will not be able to provide potable water at the required amounts per day for the worlds nine billion people. The management of water supplies such as those which are non-municipal and harvested from sources such as springs tributaries and rivers.is important in ensuring that the United Nations Sustainable development Goals regarding water and sanitation becomes a reality. The current investigation ranges in this research for Hydrogen Ion Concentrations [pH] the water samples were 7.13 – 8.21 demonstrating that 100 % the water samples were within alkaline limits and were in keeping with national water quality index parameters of 7-8.65.

For the Craig Hill source, the pH value was higher in the dry season than the wet season. This may be due to the low water levels produced by the facility during the dry season causing a concentration of base cations. Many factors contribute to the Hydrogen Ion quality of spring water. Factors such as agriculture, use of soil amendments animal husbandry activities, and deforestation have been commonly named. The pH or Hydrogen Ion concentration is an important parameter indicating the acidity or alkalinity characteristics of the water. In surface water pH it is also influenced by the geological nature of the drainage basin [14]. The pH of water can affect its palatability, as well as suppressing the effectiveness of the disinfection [17] Although the water from the sources were untreated the physiochemical quality of water from the analysis does prove to be a major public health risk and possibly explains why for over a century residents and nonresidents alike continue to harness water from the sources for drinking and other domestic purposes. The results prove that seasonality did not impact the safety of water as both in wet and dry seasons the results were within safe limit [<8; 5].

The Total Dissolve Solids /TDS measurement of water is known to reflect the environment it passes through; as water it usually absorbs high levels of inorganic minerals such as calcium and potassium salts [14]. The concentration of Total Dissolve Solids from this analysis was in the range of 86 Mg/L -167 Mg/L. According to the National Environment and Planning Agency of Jamaica established upper limit for TDS in excellent drinking water is 300 Mg/L [15]. The findings from the analysis showed that in 100 % of the samples TDS levels were less than the 300 Mg/L. The environmental protection agency of the United States establishes 500 Mg/L as upper limit for TDS in water [15] as levels is known to affect palatability of the water.

The results show was a significant correlation between pH and TDS for the site at Cozy Nook as both values were lower in the dry months when compared to the wet months. A more distinct trend was also observed with this source when compared to the results obtained from the source at Craig Hill. The chief causes of TDS include agricultural operations,

domestic runoff, soil contamination caused by leaching, and point source water pollution discharged by industrial or sewage treatment plants. Whilst within safe limits that TDS levels with the wet months 204Mg/L and 167 Mg/L respectively were higher in the wet months pointing to the likely impact of surface run offs or other types of contamination on the water sources.

At the water sources Total Coliform levels and Heterotrophic plate count levels were significantly lower in the dry months when compared to the wet season. Better physiochemical and microbiological levels in the dry months compared to wet months signifies a lower risk associated with the use of these water sources.

.Enteric infections and water-related illnesses are more frequent during times of relative water abundance, especially in regions that experience bimodal rainfall patterns[10] Water, sanitation, and hygiene measures remain critically important to reduce exposure to pathogens causing water-borne illness such as Rota viral gastroenteritis which is more prevalent in Jamaica during the wet months of the year [3] Lower risk at the water source in the dry season would suggest lowest risk for waterborne infections in the dry season . In 75 % of these samples microbiological quality of water was better in the dry season than the wet season. Total Coliform and Heterotrophic Plate Count are indicator microorganism associated with contamination from organic matter [10].

The World Health Organization establishes that there should be no coliform in drinking water and that Heterotrophic plate count should be less than 500 CFU/mL [10] As seen in Table 2 all samples were positive for coliforms even at low levels, 170 CFU/mL, 79 CFU/mL, 33 CFU/mL < 1.8 CFU/mL. This result is of importance to public health as when microbes are given the right conditions for survival, rapid multiplication is possible. Coliforms are also the most common public health concern in drinking water. Whilst Heterotrophic Plate counts were within acceptable limits it cannot be concluded that these water supplies are safe as depending on the organism's virulence and the vulnerability of the user's consumption of water from these supplies could have debilitating effects on the user. Disinfection of drinking is therefore recommended to make water safe for drinking [17]. The increase in bacterial load during the wet season could be caused by increased runoff carrying bacteria from contaminated sources to these water sources [20]. These data suggest that seasonal variations play an insignificant role in altering the water quality.

The consumption and use of untreated water remains a public health concern globally. Government's intervention through strategies such as education of the users of these water sources is necessary to curtail any adverse effect that might result from the use of these water sources as safe drinking water is not just a determinant of health but water is also a social and economic indicator.

Summary

It is undeniable that these water sources if managed properly can provide safe water to numerous householders and visitors to the East Rural St. Andrew Communities. The water sources are also treasured as while other communities face water insecurity issues, these sources has continued to provide drinking water for community members as well as visitors to the area. As seen from the results and discussions access to safe and clean drinking water is a critical determinant of health, with social, economic, and environmental consequences. Low levels of microorganisms in dry months does not in any way make the water sources safer for use as depending on the infective dose of the organism, the organisms virulence as well as host susceptibility waterborne illness are still risk for the population that uses these water sources. Unsafe drinking water has contributed to numerous waterborne illness outbreaks in

Jamaica and beyond. Access to safe drinking water is necessary throughout the year. The government of Jamaica even though desirous of meeting the United Nations Sustainable Development Goal 6 by 2030 cannot achieve this desire if water sources such as those mentioned in this research are not carefully assessed and managed in the interest of the populace and ultimately Public health... Established policies and guidelines are immediately required in Jamaica to ensure that non municipal water supplies are monitored and regulated ultimately reducing the impact on public health associated with the outbreak of waterborne illnesses.

Conclusion

The risk of waterborne diseases associated with the use and consumption of non-municipal supplies water holds major negative implications for public health. The management of non-municipal water sources is therefore essential to ensure the suitability of the harnessed water for the designated use. In this research four water quality parameters were assessed and compared with national and international standards to describe the seasonal physiochemical and microbiological quality and safety of two entombed non municipal water sources. The aim of the research was to describe the seasonal microbiological and physiochemical quality and safety parameters of roadside entombed water sources in East Rural St. Andrew Jamaica

The findings from the research showed that 100 % of the samples were positive for Coliforms, Coliforms in particular E. coli are indicator organisms associated with numerous waterborne illness outbreaks. The data presented in this research, highlights the risk for the occurrence of waterborne diseases associated with the use and consumption of water from both sources in the study.

Recommendations

It is suggested that in the future:

[1] The methodology used in this research be advanced to assess, serotypes of microorganisms identified during the microbiological analysis of the water supplies in this research.

[2] The Ministry of Health should conduct research on non-municipal water supplies in Jamaica, these studies should be designed to address the epidemiological association between the use and consumption of non-municipal water and occurrence of communicable and non-communicable diseases in Jamaica.

[3] The Government of Jamaica/ regulatory stakeholders should establish water quality monitoring and management policies that includes the registration, treatment and management of the sources included in this research.

[4] The municipal corporation and other responsible agencies should post “Boil Water,” advisories where feasible such as at the water sources located along roadways.

[5] Community health workers when conducting home visits, should advise householders of the need to properly disinfect water at the point of use.

[6] Establish a joint agency for the monitoring of water quality and safety in Jamaica (in light of water insecurity, bulk water trucking, packaged water plants, increase in number of wells and entombed water sources.

Declaration

The authors of this manuscript Dr. Karlene Atkinson and declares that I have we have no conflict of interest relating to any matter or material discussed in this manuscript. We also certify that this research is our original work and that the content has not received any previous publication nor is it under consideration elsewhere.

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