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An Epidemiological Survey of Non-municipal Drinking Water Supplies Among Rural Communities in the Blue and John Crow Mountain Ranges, Jamaica, December 2021- June 2022

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Abstract

The unavailability of safe running water is a major problem faced by many residents of rural Jamaica; the use of unsafe drinking water for domestic purposes is also a major public health challenge in developing countries due its contribution to the global burden of disease reported annually. The aim of the research was to assess the microbiological and physiochemical quality parameters of non-municipal drinking water from springs and tributaries within the Blue and John Crow mountains. The study methodology used was sampling through field work and laboratory testing for microbiological water quality parameters using standard procedures. The research is a cross-sectional survey that was conducted over a seven-month period. Fourteen samples of water were collected from the water sources and in the homes of the residents. Five water parameters were assessed against national and internal water quality index. In one hundred percent of the samples the total coliforms levels exceeded the established safe limit as established by the Ministry of Health Jamaica. The initial hypothesis of the research was supported by the findings. The consumption and use of non-municipal water throughout the communities of the Blue and John Crow Mountain bears a significant risk for public health.

Keywords*: Unsafe drinking water, Rural communities, Potable water, Water quality index.*

Introduction

This research is an epidemiological survey of rural non municipal drinking water supplies in the Blue and John Crow Mountain Ranges of St. Andrew Jamaica. The Blue and John Crow mountains is located within the eastern mountain ranges of Jamaica and is home to numerous springs and rivers which serves as tributaries to the municipal reservoirs that provide water for the urban areas.

Due to the terrain of the Blue Mountains and John Crow mountains many communities which lie within these areas are not supplied with municipal water. To provide the well needed resource, many communities' members pool their efforts and construct communal water catchments which are supplied by one or more of the many springs in the area. From these catchments, water is piped into homes along miles of community roads. Some residents also collect and store water for their domestic purposes from entombed springs located along roadways.

Domestic water requirements are 50-100 US gals per person per day minimum [1]. Since non municipally supplied water in these areas is not metered most residents who tap into the sources obtain the required amounts or more per day except in dry periods where the flow rate of the water becomes less due to the changes in weather pattern in the area.

In rural Jamaica as it is in other places biological and physiochemical quality of water is influenced by environmental conditions such as method of solid and liquid waste disposal, land topography, surface run offs as well the location of other properties such as those that facilitate animal rearing and other agricultural

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activities. Throughout the communities of the Blue and John Crow Mountains, waste disposal and wastewater discharge are often indiscriminate and can lead to contamination of water sources. Scientifically it is proven that improvements in drinking water, sanitation, hygiene, and water resource management may reduce the global disease burden by 10%. [2]. 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 [2].

Springs and tributaries are unique ecosystems and signify the height of the water table in a particular area. Management of these resources through zoning, and reduction of environmental pollution is necessary to reduce the likely epidemiological burden that could be faced by the community. This study provides information that can add valuable scientific data for future intervention such a national water quality policy for the management of non-municipal water sources.

The research aimed to assess the microbiological and physiochemical quality parameters of non-municipal drinking water from springs and tributaries within the Blue and John Crow mountains. The specific objectives that guided the methodology as outlined in this paper were to: Assess the bacteriological quality of non-municipal drinking water in the study area by examining Total Plate Count (TPC), Total Coliform (TC), Total Dissolve Solids (TDS) and Hydrogen Ion (pH) concentration as water quality parameters as well as to determine the physical quality of the water supplies by examining color and temperature as water quality parameters.

The lack of municipally piped water is a challenge faced by numerous rural communities in Jamaica. To improve the nations water and sanitation status the Government of Jamaica has embarked on numerous water improvement initiatives supported by agencies under the ambit of the United Nations [3]. Amidst these efforts, many residents of rural Jamaica do not have access to potable running water. To address the need for potable water, many householders in Jamaica, harness and use water provided from sources such as rain, rivers, streams and springs sources which are often used and consumed without the application of any disinfection method. To make the water safer for use, some householders in the rural communities of Jamaica use bleach as a disinfecting agent. Bleach is largely available and widely used in the incorrect concentrations as a disinfecting agent by many householders in Jamaica [4].

The implications for these actions are far reaching as waterborne diseases such as typhoid fever is endemic to the island [5]. Sporadic cases of leptospirosis and other water related illnesses are also experienced annually [6].

The climate in the Blue and John Crow Mountains is cool and is well known for growing crops such as the world-famous Blue Mountain Coffee. Other crops such as spices are also grown in the areas. Due to its natural vegetation, the area is home to numerous species of lizards and birds living in many areas where most of the non-municipally supplied water sources are entombed [7]. Throughout the communities. excreta disposal is mostly via the means of pit latrines and or water closets with absorption pits. Animal waste recycling is also a prominent practice as farmers find it cheaper to use these wastes as soil amendments. Along with organic soil amendments many farmers use chemical fertilizers which have the potential for the contamination of the water sources in the area. Globally, at least 2 billion people use a drinking water source contaminated with faeces [8]. 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 [9].

In Jamaica the government has set policy criteria for potable water which is regulated by the Ministry of Health as follows. Amidst the guidelines presented, more regulations aimed at

improving national supplies are needed to ensure the quality and safety of this important resource for all individuals within the population. Intersectoral policies that address increased regulatory monitoring and management of all water supplies including those which are community based is also essential and will create a foundation for support and sustainability of efforts related to water quality management and the protection of the environment.

Internationally the focus has shifted from Millennium Development Goal (MDG) target 7 which aimed to halve the proportion of the population without sustainable access to safe drinking-water to improving water sources and accessibility to water by 2030 [9].

Ideally drinking water should not contain any microorganisms known to be pathogenic that can cause disease or any bacteria indicative of fecal pollution. UNDP report states that one out of six people do not have access to clean water, that is, about 1.1 billion people lack access to safe drinking water [10]**.** Given this reality residents are compelled to use water from sources like shallow wells, springs, and rivers for domestic purposes. As seen in the Soho England 1852 outbreak of cholera, untreated water sources are often unsafe for domestic use and human consumption and when used is often associated with outbreaks of diarrheal and other communicable and non-communicable illnesses.

An experimental assessment of physicochemical quality of spring water was conducted in Arbaminch, Ethiopia. Water samples were collected from Arbaminch called Forty Springs. Spring water samples were collected in two-liter capacity polythene bottles and analyzed for physiochemical characteristics. From the experimental data it was found that the concentration of chloride was higher than the permissible levels of chloride for safe drinking water as set by WHO [11]. All other parameters such as Total Dissolve Solids and PH were found to be safe for drinking and other domestic purposes [11]. The validity and reliability of the findings from this research could not be proven as the method used to select the sources for sample was not outlined. The methods of analysis used for the samples were suitable based on the physiochemical qualities that were being assessed.

While chemical and physical parameters of drinking water is known to be of major public health significance, most emphasis including research has always focused on biological risk associated with water. The recommendation in the study highlighted the need for further research relating to other chemical contaminants in the water including those which are also associated with agriculture. 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 [12].

The chemical attributes of a water source can be an important indicator of water quality [13]. In villages of Barwari Bala, Duhok, Kurdistan Region Iraq, the chemical quality of spring water was assessed; a total of one hundred and twenty spring water samples were collected from ten villages during the dry and wet seasons in 2018. The samples were analyzed for major physicochemical characteristics, including: (Ca^{2+}), (Na^{+}), (K^{+}), (Cl^{-}), (SO_4^{2-}), (NO_3^{-}), PH, (TDS), and (TH). All parameters except Sulfate (SO_4^{2-}), were found to be higher in the wet season than the dry season. [14]. During each season, six water samples at 10–15-day intervals were collected from each spring. The sample method and intervals employed allowed for a comparative analysis of the water quality and the elimination of bias. Based on the methodology employed in collecting the samples the data generated could be considered generalizable and reliable and could thereby be used to impact policy decisions. Similar to this findings other studies reveal that there is a need to increase vigilance and water quality monitoring activities

relating to the chemical parameters of domestic and drinking water [11].

Washington State Department of Health explains that Total Coliform is a large collection of different kinds of bacteria. While fecal coliform are types of total coliform that exist in feces. Total coliform is commonly found in the environment, whereas fecal coliform is naturally found in the intestines of people and animals [15]. The presence of fecal coliform in drinking water samples indicates recent fecal contamination. Washington State Department of Health further noted that there is a greater risk of other pathogenic microorganisms present if only total coliform bacteria are detected [15]. In water intended for drinking Coliforms should not be detected in 100 mils per sample [16]. Experimental research conducted in Rabak Town Sudan to determine the microbiological safety of drinking water in Sudan revealed that 23.3% and 60% of the samples' examined samples were doubtful while 16.7% of samples showed that the water quality was satisfactory [17].

To make water safe for drinking chlorine bleach is often the household chemical that is promoted by the Ministry of Health Jamaica [4]. When using chlorine as a disinfecting agent the chemical should be added to water to leave a free residual chlorine concentration of 0.4 to 0.5 mg/l after 30 minutes, which can be determined using a special test kit [4]. In a systematic review of 15 intervention studies for the World Bank, it was revealed that household-based water treatment and safe storage was associated with a 35% reduction in diarrheal disease compared .to a statistically insignificant 11% for conventional interventions [18]. In support of the findings a Cochrane review covering more than 38 randomized, controlled trials and 53,000 people in 19 countries found that, household-based interventions were about twice as effective in preventing diarrheal disease (47%) than improved wells, boreholes, and communal standpipes (27%) [19].

The domestic (point of use) treatment of non-municipal supplied water in rural areas is most times based on the perception that the untreated water is not safe, therefore in order to ensure its safety a process of crude chlorination is often done. A comparative cross-sectional study was conducted among urban and rural households with under-five child in Kersa Health and Demographic Surveillance Site, Eastern Ethiopia. The data was collected from caregivers of systematically selected households and analyzed using multivariable logistic regression [20]. A total of 1,912 households were included in the analysis with a 96.5% response rate. The results showed that in rural areas, 4.6% of caregivers were reportedly chlorinating water at point-of-use. In urban areas, 17.1% of caregivers were reportedly chlorinating water in two settings, caregivers' point-of-use water [20]. A sample size calculator was used to determine the number of participants in the study. A questionnaire with parts adopted from the WHO tool for water quality monitoring was used to collect the data. The results of the study showed that chlorination of domestically used water was associated with chlorine taste and water quality perception. The methodology used in selecting the participants for the study was a useful scientific approach, as with rural communities' population is sparsely spread, therefore selecting participants of a study by using simple random sampling methods is quite difficult, the sample size calculator and systematic random sampling is one of the most suitable methods of sample selection in this case.

The temperature of water can help determine the suitability for inorganic constituents as well as chemical contaminants which has an impact on its taste. Cool water is generally more palatable and acceptable than warm water. Additionally high-water temperature enhances the growth of microorganisms and may increase problems associated with their color, odor, taste, and corrosion [21]. There is also a direct link between the temperature of water and water consumption [21]. Jamaica being in a tropical

zone experiences high climatic temperatures thus naturally occurring throughout the country is expected to be within ambient temperature ranges.

The senses are used as the first line of defense against contaminated water. If the water has an unusual look or smell to it, then chances are individuals will not consume the product. [21]. Color is an indication of the number of suspended solids in water such as tannin, which is caused by organic matter coming from leaves, roots, and plant remains [22].

The kind of contaminant which is present in water can sometimes be deduced by its specific color and taste. ***Pseudomonas aeruginosa is*** particularly good at forming biofilms growth in drinking water and can cause problems with color, taste, odor, and turbidity if found in high numbers [2].

Water used for human consumption in rural communities may contain heavy metals, pesticides, fertilizers, and heavy metals which are known carcinogens [24]. In assessing the safety of water for domestic purposes, biological and physiochemical qualities must therefore be assessed and determined to be within safe and permissible limits if the product is to be considered safe for human consumption. The World Health Organization states that the quality of water sources should be assessed, and the likelihood of contamination determined [8]. In agreement with the WHO, CDC highlighted that water is obtained from two main sources, surface water such as rivers, streams, and reservoirs as well as groundwater which is obtained by drilling wells for water [25]. According to the Water Education Foundation water from natural sources should be treated for microorganisms, bacteria, toxic chemicals, viruses, and fecal matter [26]. Untreated water used for domestic purposes including drinking has been the vehicle for the transmission of many gastrointestinal and other illnesses. Other illnesses which are chronic such as lead poisoning has also been associated with numerous disease outbreaks. The implementation of water safety policies geared towards the protection of the public is important in preventing or reducing incidence of waterborne illnesses.

Methodology

A cross-sectional survey was conducted to assess the physicochemical and bacteriological quality of non-municipal supplied water in the Blue and John Crow Mountains. Sampling was done through field work and the analysis of water quality parameters were done using calibrated handheld tools and standard laboratory testing.

The Blue and John Crow Mountains is a tropical, mountain rainforest within the eastern part of Jamaica in the Caribbean. These two mountain ranges cover approximately 20% of the island's total landmass and are recognized for their biodiversity and significance within the Caribbean region**.**

The communities within the sample are Middleton, Craig Hill, Dublin Castle, and Cozy Nook. These communities meet the inclusion criteria for the research since the residents use non-municipal supplied water from entombed springs for domestic purposes.

A census was conducted of all non-municipal water sources in the study area, Water samples were collected in sterile water bottles and transported to the laboratory under refrigerated conditions within 24 hours. A total of eight samples were collected during the wet months of the year, which is December to June. Due to the location of some sources, samples were collected in three phases. The samples were analyzed for chemical, physical, and bacteriological parameters. Two of the eight water sources are entombed and located along the roadway. Several individuals from within the community as well as persons from outside these communities that experience water shortage traverse to these areas by foot and vehicle to collect water in containers for domestic and other purposes. Bulk water truckers who sell water to business places and dwellings also fill their water tanks at these locations.

Most entombed water supplies in the study area serves a single dwelling or numerous dwellings. Point of use samples were collected from homes representing each source. A total of six point of use samples were collected from the homes and analyzed for physical chemical and microbiological parameters. Both point of use and source samples were collected on the same day and transported to the laboratory in the same manner. An observation guide was used to capture data on physiochemical characteristics for both source and point of use samples. 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, Temperature, Color/Appearance, and Total Plate Count. The Hydrogen Ion concentration, Total Dissolve Solids and temperature were analyzed by the researcher at the point of collection using calibrated handheld tools. The results of the tests were documented in an observation guide. The remaining parameters were analyzed by the laboratory. The obtained water quality characteristics were compared to national and international drinking water quality index.

Results

Water is one of the most essentials of life. It is retrieved from different sources to be used for a variety of reasons, consumption by drinking being the most important and prominent use. According to the world Health Organization, in 2015, 91% of the world's population had access to an improved drinking-water source. However, at least 1.8 billion people use a drinking-water source contaminated with faeces [27]. Undoubtedly water is important to sanitation and nutrition, yet it has been a vehicle for the transmission of numerous diseases such Leptospirosis, Giardiasis, Poliomyelitis, and other infectious illnesses. Proper and adequate water treatment is therefore necessary to ensure its safety and potability [25].

Table 1. Bacteriological and Physiochemical Characteristics of water samples collected in Phase 1

Parameters	**National standards**	**Results**			**P OU**	**Sample 3 Source**	**POU**
		Sample 1 Source	**POU**	**Sample 2 Source**			
TDS (mg/L)	120-300	164	178	118	137	204	None
PH	7-8.4	8.20	8.28	8.17	8.32	7.62	None
Color	Clear	Clear	Clear	Clear	Clear	Clear	None
TPC (cfu/ml)	<500	350	33	79	70	170	None
TC	0	$8x10^2$	$1.6x10^2$	$1.1x10^2$	$1.7x10^2$	$1x10^2$	None
Temperature ^0C	30-32	25.5	34.4	31	35	32	None

Table 2. Bacteriological and Physiochemical Characteristics of Water Samples Collected in Phase 2

Parameters	**National standards**	**Results**			**P OU**	**Sample 3 Source**	**POU**
		Sample 1 Source	**POU**	**Sample 2 Source**			
TDS (mg/L)	120-300	125	162	118	137	162	None
PH	7-8.4	7.9	8.2	8.17	8.32	8.2	None
Color	Clear	Clear	Clear	Clear	Clear	Clear	None
TPC (cfu/ml)	<500	>1600	1.8	79	70	>1600	None
TC	0	$1.4x10^4$	$7.6x10^1$	$1.2x10^2$	$1.4x10^2$	$1.4x10^5$	None
Temperature ^0C	30-32	26	34.4	26	35	32	None

Table 3. Bacteriological and Physiochemical Characteristics of Water Samples Collected in Phase 3

Parameters	National standards	Results			
		Sample 1 Source	POU	Sample 2 Source	P OU
TDS (mg/L)	120-300	444	446	118	137
PH	7-8.4	8.65	8.28	8.17	8.32
Color	Clear	Clear	Clear	Clear	Clear
TPC (cfu/ml)	<500	$6.3x10^1$	$1.8x10^1$	2.0	$1.4x10^2$
TC	0	49	13	2	240
Temperature ^0C	30-32	25	34.4	27	37

Discussions

Hydrogen Ion Concentration/pH

The pH of natural water is 7. The current investigation ranges were 7.62– 8.65 demonstrating that 100 % of the water samples were within alkaline limits and 97 % were in keeping with national water quality index parameters [12]. Alkaline water has been known to positively impact bone health as well as reverse effects of aging. It is also believed that alkaline water improves spine T score in premenopausal women [28]. The results of a study involving aged mice which were treated with alkaline water and regular tap water and then sampled at postmortem after 24 months suggested that mice watered with alkaline water overwhelmed control mice. The findings also inferred a benefit on longevity, in terms of deceleration of aging factor was correlated with the consumption of alkaline water [29].

The pH of water can affect its palatability, as well as suppressing the effectiveness of the disinfection of chlorine. Contrastingly, Low pH water will corrode or dissolve metals and other substances. Water with a pH > 8.5 could indicate that the water is hard and can lead to digestive and metabolic abnormalities if consumed [30].

Total Dissolve Solids /TDS

The quality 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. The concentration of Total Dissolve Solids from analysis was in the range of 118 and 446 mg/l. According to the National Environment and Planning Agency of Jamaica established upper limit for TDS in excellent drinking water is 300 ppm [12]: The findings from the analysis showed that 14 .28 % of the samples showed TDS levels more than the 300mg/L.

A study done in Iraq on the physiochemical chemical quality of water showed that all parameters such as TDS and PH were high in the wet seasons of the year [31]. High TDS levels can have implications for palatability of water [32]. In addition, many studies showing the benefits of alkaline water have revealed that people consuming water with a high level of total dissolved solids (TDS) have shown a higher incidence of coronary heart disease (CHD), cardiovascular disease (CVD), and cancer.

In domestic use situations high TDS in water is normally associated with atopic dermatitis [33]. A systematic review conducted on seven studies 385, 901 participants showed an increased incidence of atopic dermatitis in children exposed to hard water. Children growing up in areas with hard water are slightly more likely to develop atopic dermatitis than children in areas with soft water [33]. High TDS values in drinking water is also harmful to those populations which are suffering from kidney and renal diseases. [34]. Consistent consumption of water with high TDS levels may cause laxative or constipation effects and makes water difficult for domestic use [35].

Total Coliform and Total Plate Count

Coliforms are indicator microorganism associated with contamination from organic matter. Total coliform refers to a large assemblage of gram-negative, rod-shaped bacteria that share several characteristics. These include E. coli, Klebsiella, Enterobacter, Streptococcus, Staphylococcus spp etc. In this study, the Total Coliform and Total Plate Count levels were outside of acceptable ranges. The World Health Organization establishes that there should be no coliform in drinking water [32]. As seen in the tables all samples were positive for coliforms and in 14 % of the samples, the Total Plant count levels were >500 cfu/ml. When microbes are given the right conditions for survival replication is possible. Coliforms are also the most common public health concern in drinking water [8]. Disinfection of drinking is therefore recommended to make water safe for drinking [4].

Globally, at least 1.8 billion people use a drinking-water source contaminated with faeces [27]. The levels of coliform detected at all sources and point of use shows the absence of or inadequate application of disinfection methods which are necessary to reduce the likelihood of water borne diseases. In a systematic review of 15 intervention studies for the World Bank it was revealed that household-based water treatment and safe storage was associated with a 35% reduction in diarrheal disease compared .to a statistically insignificant 11% for conventional interventions [18]. To make water safe, household water treatment using chlorine bleach is encouraged by the government of Jamaica [4]. However, chlorine used in water treatment can react with halides and natural organic matter in raw water to produce numerous carcinogenic halogenated disinfection by-products [36.]

As seen from the literature review globally microbiological quality of water remains a public health concern experimental research conducted in Rabak Town Sudan to determine the microbiological safety of drinking water in Sudan revealed that 23.3% and 60% of the samples' examined samples were doubtful while 16.7% of samples showed that the water quality was satisfactory [17]. Every effort should therefore be made to achieve a drinking-water quality as safe as practicable. Improving global access to safe drinking-water is therefore an effective way of improving global public health standards. High Total Plate counts in water are often associated with the creation of biofilms in water distribution systems. The Total Plate Count in this study ranged from 2 to less than 1600 CFU/mL. As seen from the results 7 % of the Point of Use samples had higher reading of TPC than the source. Premises plumbing water quality can be compromised by long water residency times and reduced disinfectant levels thereby creating environments where pathogens such as *Pseudomonas*, and *Legionella* can amplify in biofilms [37].

Temperature and Appearance/Color

The mean temperature of the water samples in the study was 25°C, which was within permissible national standards (30°C). A study done on temperatures of well water in Ethiopia generated slightly lower temperatures of result (27-28°C) [38]. Climate change has affected water temperatures globally. The water samples in this research were all taken from natural sources of non-municipal supplies namely tributaries and springs. The geographical location of these supplies is within the Blue and John Crow Mountains that normally experiences cool weather with temperatures as low as 13 degrees Celsius [7]. These weather conditions could have influenced the temperatures of the water samples. The palatability of water may be influenced by temperature [21]. There is also a direct link between the temperature of water and water consumption [21]. Color is also an indication of the safety of water. Water can also be impacted by organic materials such as tannins from leaves debris and roots [22]. The senses are therefore used as the first line of defense against contaminated water. If the water has an unusual look or smell to it, then chances are individuals

will not consume the product because it is believed that it might be contaminated [21]. In 100 percent of the samples the color of the water was clear.

Summary

The World Health Organization outlines their responsibility as the international authority on public health and water safety. As s seen from results and discussions safety of water cannot be determined with the naked eyes, various strategies and interventions are necessary to reduce incidence of waterborne illnesses whose causes might not be readily identifiable by the population at risk. Many actions and circumstances can lead to the contamination of drinking water; water for drinking and domestic purposes must therefore be free from harmful physical, chemical, and biological contaminants including pathogens such as *E. coli* and *Klebsiella*. Established policies and guidelines are 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 supplied water holds major negative implications for public health. The assessment of water quality is therefore essential to ensure the suitability of a water source for the designated use. In this research five water quality parameters were assessed and compared with national and international standards to determine the epidemiological implications associated with the use and consumption. The aim of the research was to assess the microbiological and physiochemical quality parameters of non-municipal drinking water from springs and tributaries within the Blue and John Crow mountains. The research shows that except for Total Coliforms, no more than 14 % of the samples showed adverse results when compared to ideal standards for excellent drinking water. Enhanced research in this area can therefore provide much needed data for water quality and safety policies that will benefit public health. Total Dissolve solids is an indication of water quality, High Total Dissolve Solids in water can also result in calcification in water distribution systems which can ultimately lead to the growth of biofilms which reduces the ability for effective disinfection. Coliforms, in particular E. coli are indicator organisms associated with numerous outbreaks. The data presented highlights the risk for the occurrence of waterborne diseases associated with the use and consumption of all these water sources in the study.

As seen from the findings, safety of water cannot be determined with the naked eyes, various strategies and interventions are therefore necessary to reduce incidence of diarrheal illnesses whose causes might not be readily identifiable by the population at risk. The literature reviewed demonstrates that many actions and circumstances can lead to the contamination of drinking water. Established policies and guidelines are therefore required in Jamaica to ensure that these and other similar water sources are regulated ultimately reducing the impact on public health associated with the outbreak of waterborne illnesses.

Recommendations

1. 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.
2. The Government of Jamaica/ regulatory stakeholders should establish water quality monitoring and management policies that includes the treatment and management of the sources included in this research.

3. The municipal corporation and other responsible agencies should post "Boil Water," advisories where feasible such as at the water sources located along roadways.
4. Community health workers when conducting home visits, should advise householders of the need to disinfect water at the point of use.

Conflict of Interest Statement

I Karlene Atkinson, author of this manuscript declares that I have no conflict of interest relating to any matter or material discussed in this manuscript. I also certify that this research is my original work and that the content has not received any previous publication nor is it under consideration elsewhere. I therefore attest to the validity and legitimacy of the data and agree to its submission to Texila American University Journal of Public Health.

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References

[1] Water System Planning: Estimating Water Needs. (2022, August 26). Water System Planning: Estimating Water Needs. Retrieved November 3, 2022, from https://extension.psu.edu/water-system-planning-estimating-water-needs.

[2] Global WASH Fast Facts | Global Water, Sanitation and Hygiene | Healthy Water | CDC. (2022, May 31). Global WASH Fast Facts | Global Water, Sanitation and Hygiene | Healthy Water | CDC. Retrieved November 3, 2022, from https://www.cdc.gov/healthywater/global/wash_statistics.html.

[3] Project, B. (2016, November 1). Water Quality in Jamaica. The Borgen Project. Retrieved November 3, 2022, from https://borgenproject.org/water-quality-in-jamaica/.

[4] Householders Urged to Purify Stored Water – Jamaica Information Service. (2022, November 2). Householders Urged to Purify Stored Water – Jamaica Information Service. Retrieved November 3, 2022, from https://jis.gov.jm/householders-urged-to-purify-stored-water.

[5] Caribbean epidemiology Center. (n.d.). Epidemics Investigated. https://www.paho.org/spc-crb/dmdocuments/history-of-carec/Epidemics%20investigated.pdf.

[6] Westmoreland chief health inspector urges precaution against leptospirosis. (2020, June 23). Westmoreland Chief Health Inspector Urges Precaution Against Leptospirosis | News | Jamaica

Gleaner. Retrieved November 3, 2022, from https://jamaica-gleaner.com/article/news/20200623/westmoreland-chief-health-inspector-urges-precaution-against-leptospirosis.
[7] Super User. (n.d.). Blue and John crow mountains. https://www.blueandjohncrowmountains.org/do/bird-watching.
[8] Drinking-water. (2022, March 21). Drinking-water. Retrieved November 3, 2022, from https://www.who.int/news-room/fact-sheets/detail/drinking-water.
[9] Goal 6 | Department of Economic and Social Affairs. (2023, May 1). Goal 6 | Department of Economic and Social Affairs. Retrieved November 3, 2022, from https://sdgs.un.org/goals/goal.
[10] Dinka, M.O (2017). Safe Drinking Water: Concepts, Benefits, Principles and Standards [Unpublished doctoral dissertation].
[11] Haile Reda, A. (2015). Assessment of physicochemical quality of spring water in Arbaminch, Ethiopia. Journal of Environmental Analytical Chemistry, 02(05). https://doi.org/10.4172/2380-2391.1000157.
[12] National Environment and Planning agency. (2009). water_quality_standard_freshwater.pdf. https://www.nepa.gov.jm/new/legal_matters/policies_standards/docs/standards/water_quality_standard_freshwater.pdf.
[13] Water quality indicators. (2022, July 7). Environment | Department of Environment and Science, Queensland. https://environment.des.qld.gov.au/management/water/health-indicators.
[14] Ameen, H. A. (2019, October 14). Spring water quality assessment using water quality index in villages of Barwari Bala, Duhok, Kurdistan Region, Iraq. Applied Water Science, 9(8). https://doi.org/10.1007/s13201-019-1080-z.
[15] Coliform Bacteria and Drinking Water. (2016). https://doh.wa.gov/sites/default/files/legacy/Documents/Pubs//331-181.pdf.
[16] Guidelines for drinking-water quality, 4th edition, incorporating the 1st addendum. (2017, April 24). Guidelines for Drinking-water Quality, 4th Edition, Incorporating the 1st Addendum. Retrieved November 3, 2022, from https://www.who.int/publications/i/item/9789241549950.
[17] Abdallah. (2010). Assessment Of Drinking Water Quality According to WQI Based on Turbidity in Rabak Town White Nile State Sudan 2010.
[18] Fewtrell, L., et al. (2005) Water, sanitation, and hygiene interventions to reduce diarrhea in less developed countries: A systematic review and meta-analysis. The Lancet Infectious Diseases, 5, 42. doi:10.1016/S1473-3099(04)01253.
[19] Clasen, Thomas Frank; (2006) Household-based water treatment for the prevention of diarrheal disease. PhD thesis, London School of Hygiene & Tropical Medicine. DOI: https://doi.org/10.17037/PUBS.00682347.
[20] Geremew, A., et al. (2018) Point-of-use water chlorination among urban and rural households with under-five-year children: A comparative study in Kersa health and demographic surveillance site, Eastern Ethiopia. Journal of Water, Sanitation and Hygiene for Development, 8(3), 468-480. https://doi.org/10.2166/washdev.2018.173.
[21] Gallagher, C. D., & Dietrich, A. M. (2010). TDS and temperature affect consumer taste preferences. Opflow, 36(12), 20-22. https://doi.org/10.1002/j.1551-8701.2010.tb03058.x.
[22] Campbell, B. (2022, July 22). What are Tannins in water? Water Quality Products. https://www.wqpmag.com/home/article/21014398/what-are-tannins-in-water.
[23] Assurity Consulting. (2019, June 1). Explore drinking water quality: Pseudomonas aeruginosa. Assurity Consulting Ltd. https://www.assurityconsulting.co.uk/knowledge/guides/what-is-important-to-know-about-drinking-water-quality-pseudomonas-aeruginosa.
[24] Gautam, R. K., et al. (2014). Chapter 1. Contamination of heavy metals in aquatic media: Transport, toxicity, and technologies for remediation. Heavy Metals in Water, 1-24. https://doi.org/10.1039/9781782620174-00001.
[25] A guide to drinking water treatment and sanitation for Backcountry and travel use. (2022, October 19). Centers for Disease Control and Prevention.

https://www.cdc.gov/healthywater/drinking/travel/backcountry_water_treatment.html.
[26] Potable water. (n.d.). Water Education Foundation. https://www.watereducation.org/aquapedia-background/potable-water.
[27] Water. (2017, 7). WHO | Regional Office for Africa. https://www.afro.who.int/health-topics/water.
[28] Fasihi, S., et.al. (2021). Effect of alkaline drinking water on bone density of postmenopausal women with osteoporosis. Journal of Menopausal Medicine, 27(2), 94. https://doi.org/10.6118/jmm.20036.
[29] Magro, M., et.al. (2016). Alkaline water and longevity: A murine study. Evidence-Based
[30] Saanvi. (2021, October 12). Alkaline water: Possible side effects of drinking high PH water. Styles At Life.
[31] Kumpel, E. (2017). Environmental solid matrices - Determination of total dissolved solids (TDS) in water and eluates. Seasonal Variation in Drinking and Domestic Water Sources and Quality in Port Harcourt, Nigeria. https://doi.org/10.3403/30133766u.
[32] World Health Organization. (1997). Guidelines for drinking-water quality.
[33] Jabbar-Lopez, Z. (2020). The effect of water hardness on atopic eczema, skin barrier function: A systematic review, meta-analysis. Clinical & Experimental Allergy, 51(3), 430-451. https://doi.org/10.1111/cea.13797.
[34] Gobalarajah, K., Subramaniam, P., Jayawardena, U. A., Rasiah, G., Rajendra, S., & Prabagar, J. (2020). Impact of water quality on chronic kidney disease of unknown etiology (CKDu) in Thunukkai division in Mullaitivu district, Sri Lanka. BMC Nephrology, 21(1). https://doi.org/10.1186/s12882-020-02157-1.
[35] Bothe, G., et. al. (2015). Efficacy and safety of a natural mineral water rich in magnesium and sulphate for bowel function: A double-blind, randomized, placebo-controlled study. European Journal of Nutrition, 56(2), 491-499. https://doi.org/10.1007/s00394-015-1094-8.
[36] Vizioli, B., Hantao, L. W., & Montagner, C. C. (2022). Disinfection byproducts in emerging countries.
[37] Moore, G., & Walker, J. (2014). Presence and control of legionella pneumophila and pseudomonas aeruginosa Biofilms in hospital water systems. Biofilms in Infection Prevention and Control, 311-337. https://doi.org/10.1016/b978-0-12-397043-5.00017-7.
[38] Gebresilasie, K. G., et.al. (2021). Assessment of some physicochemical parameters and heavy metals in hand-dug well water samples of Kafta Humera Woreda, Tigray, Ethiopia. International Journal of Analytical Chemistry, 2021, 1-9. https://doi.org/10.1155/2021/8867507.