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A Preliminary Investigation of Physicochemical and Microbiological Parameters of Natural Springs Found in Linden, Guyana

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Authors' contributions

This work was carried out in collaboration between both authors. Author NS designed the study, performed the statistical analysis, wrote the first draft and protocol of the manuscript. Author KC did formal analysis of the study. Both authors read and approve the final manuscript.

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ABSTRACT

A spring is a feature of the hydrosphere where water moves from below the earth's surface to the surface. Spring water is an essential source of water for consumption, agricultural, and industrial needs. The distribution and actions of humans in a given place are determined by the availability of water. Our rising population is putting significant demands on the natural freshwater supply. The waters, however, are occasionally subjected to different types of contaminants, namely agricultural, industrial, and residential pollution. Investigating the water quality of springs is a crucial step in advocating their public use. The goal of this research is to investigate the microbiological and physicochemical quality characteristics of drinking water from springs. The research technique includes field sampling and laboratory testing of water quality parameters using standard

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procedures. A total of five natural springs are included in the research area. A total of ten samples were gathered from the five springs and each sample's physicochemical and microbiological characteristics were analyzed. Then, using international quality standards (WHO), the parameters were analyzed viz., pH, Turbidity, Total Dissolved Solids, Dissolved Oxygen, *E. coli* and Total Coliforms. The majority of the physicochemical characteristics examined are found to be within permissible limits. However, the pH of several samples is below the recommended standard. According to the results, a large percentage of the samples (80%) are severely contaminated by microbes, while one spring (20% of samples) poses no threat to consumers.

Keywords: Spring; water quality; coliform; Guyana; Linden.

1. INTRODUCTION

For centuries, human beings have relied on water springs to sustain both life and agriculture. A spring is defined as a natural discharge of groundwater, emerging as a stream of free-flowing water into surface water or on the surface of the water. This flow is regulated by either gravity or hydraulic pressure [1]. The filtration process of spring water takes place by natural means via physical substrate, chemical means (organic chemicals, pesticides and heavy metals absorbed by chemically activated clay) and biological means (soil inhabiting microbes that assist in filtration process of water by function as biological decomposers) [2]. However, it is important to note that the water discharged from springs is not always clean and clear. This sometimes occurs because the quality of spring water is usually determined by the quality of local groundwater which may differ greatly due to factors like the quality of water that the aquifer is recharged by, as well as the rock types with which the groundwater interacts. Sometimes, the water is roughly filtered in the rock, and the length of time spent underground permits debris and mud to fall out of suspension. If underground for long periods of time, the absence of sunlight leads to the demise of most algae and water plants. Conversely, microorganisms, viruses and bacteria cannot perish just from being underground, neither are any agricultural/industrial contaminants eradicated [3].

Water can be naturally potable (pristine springs) or it may require treatment for it to be considered as potable [4]. Potable water, also called ‘drinking’ water, is naturally or chemically treated and free from all the impurities and pathogenic bacteria, and safe for human and animal consumption. Raw water is considered as non-potable water and is common from water sources such as groundwater, rivers, and lakes. Such raw water types may lead to serious health complications [5].

Though springs appear to be a reliable water source, they must be carefully chosen, developed, and screened for contamination on a regular basis [6]. Today, the world is faced with the task of safeguarding the springs from becoming extinct. Groundwater contamination from point and nonpoint sources is one of the most serious issues facing water resources [7].

Water pollution is described as a shift in the composition/conditions of waterway materials as a result of anthropogenic activities that render water unfit for its natural uses. If water is to be used by humans, then it must be free of pathogenic microbiological contamination. Cholera, Enteric Fever, Hepatitis, and Diarrhea are just a few of the health issues caused by the microbiological pollution of drinking water. The approval limits for uncleansed water resources are up to 25 total coliforms (TC) per 100 mL. pH, Total Solids, Total Dissolved Solids, Total Suspended Particles, Alkalinity, Free Carbon Dioxide, Dissolved Oxygen, Hardness, Chlorine Content, and Salinity are all physical parameters that determine the quality of water. Turbidity in groundwater is a sign of water contamination caused by decomposition of organic materials and poor disposal of domestic and industrial solid wastes and wastewater [8].

Springs are exceptional ecosystems; nonetheless, they are often critically endangered, requiring immediate management and conservation efforts. The identification of the chemical, physical, and microbial parameters of water are an important stage in spring management. Such characteristics are vital in ecological planning to ensure that natural resources are used efficiently. They are important elements for steering efforts to eliminate potential pollution sources from the drainage area of the spring, as well as in selecting and designing water purification systems [8].

The intense interaction of surface water and groundwater is responsible for spring water degradation. The hydrogeological conditions and the local environment have significant impacts as well. As a result, comprehensive, long-term management of groundwater level and water quality is required. This could lead to a more accurate assessment of groundwater contamination. Water pollution is not indicated by the presence of Total Coliforms in the water. The presence of Faecal Coliforms in groundwater, on the other hand, indicates contamination from human/animal sewage. Fecal Coliforms are a type of Total Coliforms so where there is a high Total Coliform number, Fecal Coliforms are most likely present [8].

Water quality degradation in Linden and around the world is a major environmental issue that demands immediate attention. Guyana is called the “Land of Many Waters.” However, Linden embodies this moniker better than any other community in the country, as it consists of both surface and groundwater. Linden is crucially situated inside the Coastal Aquifer's recharging zone where water is very abundant. Approximately twenty major/minor creeks drain Linden, all of which run into the Demerara River. It is home to hundreds of springs that run into the creeks daily, supplying thousands of cubic meters of clear water. Raw water from the river, springs and creeks were traditionally used for cooking, washing and bathing. In fact, selected springs are still utilized for drinking and other domestic needs. Springs are so prevalent that many homes have their private springs. Linden generates a contamination pulse/spike in the Demerara River, resulting in water quality degradation due to coliform bacteria, *E. coli*, suspended particles, and metals. Springs in areas including Victory Valley, Blueberry Hill, Silvertown, Christianburg and Coomacka, are still multifaceted as it relates to their use. Unfortunately, the majority of these are contaminated with microbes [9].

Against this background, the research investigated the drinking water potential of natural springs located in Coomacka, Blueberry Hill, Third Alley, Silvertown and Victory Valley, Linden. The main objectives were to determine potability of the selected springs, test water quality content from the springs, determine if the springs were sustainable sources of drinking water and determine which of the sampled springs were safest for human consumption.

1.1 Study Sites and Sampling Areas

Sampling areas were selected based on the dependence of the community on these springs. Water samples were collected from five natural springs located all across Linden, Guyana; namely Coomacka Spring, Blueberry Hill Spring, Third Alley Spring, Silvertown Spring and Victory Valley Spring.

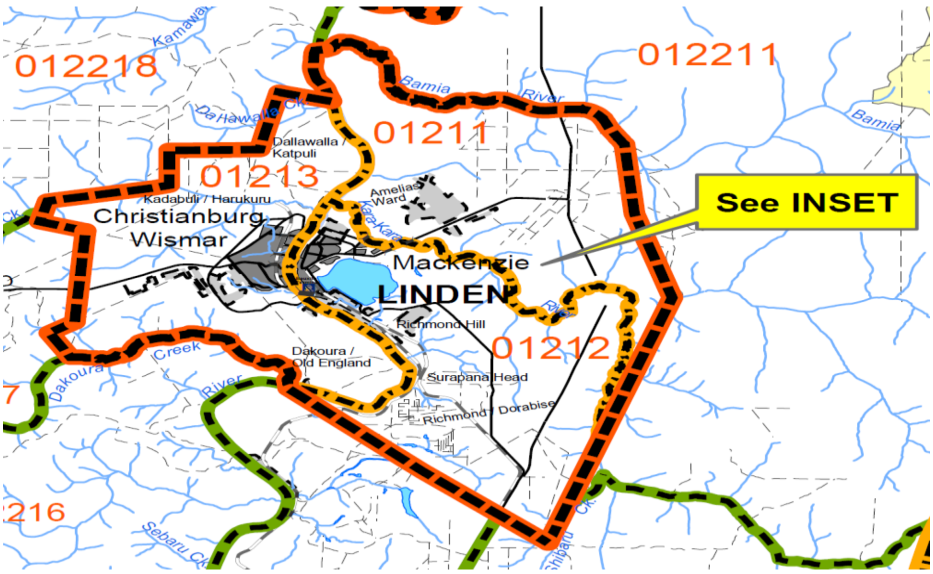

Fig. 1. Map of Linden, Guyana highlighting various sampling sites (Source: Guyana Lands & Surveys Commission)

2. METHODOLOGY AND MATERIALS

2.1 Study Design

In this study, purposive sampling was used. Purposive sampling is the intentional selection of a sample, based on the value it brings to the research [10]. As such, the five springs were selected based on their use as drinking water by local people. These springs were identified by community liaisons from within the aforementioned study areas.

2.2 Study Sample Collection

A total of ten spring samples (five sample bags and five sterilized bottles) were obtained over a two-day period on April 14, 2021 and April 20, 2021. The samples were collected from the five natural springs found in Linden, Guyana. Materials required for sample collection included hand sanitizer, Whirl-Pak® Thio Water Sampling Bags 3031-00 (100mL)/Sterilized bottles, pen and cooler box with ice. Upon arrival to study areas, an on-site analysis was performed which entailed the possible source of pollution, condition of the water, photographs of the site, a brief site description and GPS coordinates. Prior to sampling, hands were sanitized with 70% ethyl alcohol and sample bags/sterilized bottles were labelled (Date, Time, Place, Sampler). Subsequently, the sample bag was opened by pulling the tabs located on the front and back of the bag; the bag was then held by both ends of the tape and filled to the 100mL mark, directly from the point of discharge. To close the bag both ends of the tape were pulled and then whirled until the bag was shut. After this, tape ends were locked and the bag was placed in the cooler box. Sample bags were used for the microbiological tests while sterilized bottles were used to test physicochemical parameters. The procedure for the bottled samples collection almost mirrors that of the collection of bag samples, however, the bottles were rinsed twice before samples were taken and the bottles were filled all the way to the top when samples were taken. This procedure was done for all the samples collected. After all samples were collected and placed in the cooler box, they were transported to the Guyana Water Incorporated Laboratory, located in Georgetown, Guyana.

2.3 Water Testing

Upon arrival at the Guyana Water Incorporated Laboratory, the temperature within the cooler box was recorded and all samples in the box were logged into the log book. Samples were then removed from the cooler box and transported to the Laboratory for the microbiological /physicochemical tests.

2.4 Microbiological Tests

2.4.1 HACH Membrane Filtration Method 10029 (Total coliforms and *E. coli*)

The five samples were tested for the presence of fecal coliforms and *E. coli* by use of the Membrane Filtration Method. Materials/Apparatus required for membrane filtration included m-ColiBlue24 (broth ampule), membrane filter (0.45 micron), petri dish with absorbent pad (47-mm), filtration apparatus with pump, forceps (sterilized), incubator and a low-powered microscope. After inverted incubation at 35 ± 0.5 °C (95 ± 0.9 °F) for 24 hours, the petri dish was then removed from the incubator and using a 10x to 15x microscope the number of bacteria colonies on the membrane filter was counted.

2.5 Physicochemical Tests

2.5.1 HACH Nephelometric Method 8195 (Turbidity)

The turbidity of the five samples was tested by the above methods. Materials/Apparatus required for nephelometric method included Hach 2100Q turbidity meter, stablcal ® stabilized formazin turbidity standards and sample cell. Results were recorded off the display.

2.5.2 HACH pH Electrode Method 8156 (pH)

The pH of the five samples was tested by the above method. Materials/Apparatus required for the pH electrode method included HACH HQ4lld pH/mv meter, pH probe and deionized water. The pH meter was turned on. The probe was rinsed with deionized water and carefully blotted with lint free tissue until dry. The probe was then inserted into a water sample avoiding the sides and bottom of the sample bottle and then the sample was stirred moderately. The ‘read’ button was pressed and the results were recorded from the display.

2.5.3 HACH Direct Measurement Method 10360 (Dissolved Oxygen)

The dissolved oxygen of the five samples was tested using the above method.

Materials/Apparatus required for direct measurement method included HACH HQ40d meter/multimeter, LDO Probe and Deionized water. Readings were recorded.

2.5.4 HACH Direct Measurement Method 8160 (Total Dissolved Solids)

Materials/Apparatus required for the Direct Measurement Method included HD 40d meter, Polypropylene beaker (100ml), CDC probe, deionized water and lint free tissue. Results were recorded from the display.

3. RESULTS AND DISCUSSION

3.1 Physical Features of the Environment

Upon arrival at the various sampling sites, an on-site analysis was performed. This on-site analysis gathered information such as possible pollution sources, water condition, photograph of the site, brief site description and GPS coordinates. Most springs are isolated and as such had no visible sources of pollution, however, springs such as Blueberry Hill and Third Alley have persons living distantly to the top of them and as such it is possible that these springs are

contaminated by sewage runoff. The condition of all spring waters was clear as springs had no visible particles floating in them. The vegetation type, soil type, terrain and settlement patterns were also documented and were found to vary among the sampling sites. Springs were also noted to be of various locations across the face of Linden as shown by the GPS coordinates.

3.1.1 Coomaka Spring

GPS: N05^{0}57.740’ W058^{0}17.119: This spring had indications of nearby pollution (Fig. 2). The site displayed hilly terrain with nearby isolated settlements. The spring water was clear. There appeared to be dense vegetation types with mixed soil types of sand, rocks, and loam.

3.1.2 Blueberry Hill Spring

GPS: N06^{0}00.955’ W058^{0}18.514’: This spring bore dense vegetation types with mixed soil type (sand and clay) (Fig. 3). Settlements were dispersed nearby. Pollution was absent.

3.1.3 Third Alley Spring

GPS: N06^{0}00.637’ W058^{0}18.595’: Vegetation type at this spring was found to be dense. Mixed soil type was present as sand, clay and loam (Fig. 4). The terrain was hilly and settlements were in a linear fashion. Pollution was absent at this location.

Fig. 2. Coomacka Spring in Linden

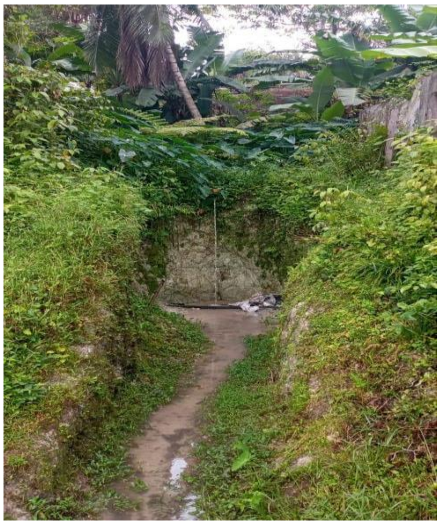

Fig. 3. Blueberry Hill Spring in Linden

3.1.4 Silvertown Spring

GPS: N06000.025’W058018.616’: Vegetation Type is sparse and soil type is sandy (Fig. 5). The terrain was hilly. Settlements were found to be linear. There was no pollution noted.

3.1.5 Victory Valley Spring

GPS: N06^{0}00.458’ W058^{0}18.097’: There was no vegetation type at the location (Fig. 6). Soil type of sandy and hilly terrain. Settlements were dispersed and pollution absent.

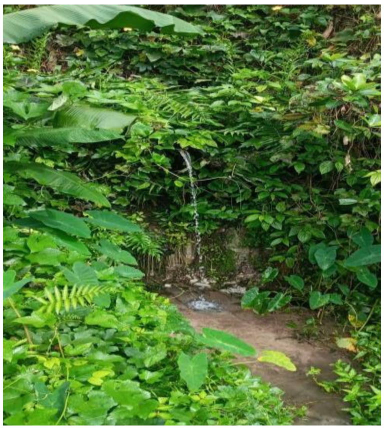

Fig. 4. Third Alley Spring in Linden

Fig. 5. Silvertown Spring, Linden

Fig. 6. Victory Valley Spring, Linden

3.2 Microbiological Tests

Water is an excellent medium for the growth of microbes. Bacteria, viruses, fungi, and algae are commonly found in groundwater and surface water, making it unfit for human consumption as well as for domestic uses [11]. In this study, spring water samples were tested for the presence of total coliforms and *E. coli*. The measured values of total coliforms ranged from 0 to TNTC (too numerous to count) CFU (Table 1).

Microbiological analysis revealed that Blueberry Hill spring, Third Alley spring, and Victory Valley spring all have much higher levels of total coliforms and *E. coli* than the recommended limit. The Coomacka spring had a large number of total coliform colonies but zero *E. coli*, whereas the Silvertown spring was devoid of both total coliforms and *E. coli*. Thus it can be concluded that four out of the five springs tested positive for coliform bacteria, indicating that they are unsafe for human consumption. Infiltration of sewage and contaminated water into water supply networks can cause contamination of spring water through connection and leakage points, back siphoning, seepage framework, and brokenness. Waterborne infections such as typhoid, cholera, diarrhea, and hepatitis, as well as protozoan and helminth infection, lead to mortality and morbidity [8].

Results also show the quantities of total coliform/ E. coli colonies and the degree of risk associated with the majority of the spring consumers are at a very high risk/high risk (Table 2). The only exception is Silvertown spring which has neither pollutants. These findings suggest that water treatment is required before the contaminated springs can be used. Treatment methods include boiling, solar disinfection, and chlorination of the water [11].

3.3 Physicochemical Tests

3.3.1 pH

Water with a pH between the range of 6.5 to 8.5 is usually deemed acceptable. The pH levels of the water samples were found ranging from 4.98 to 6.74 (Fig. 7). The Silvertown spring water sample recorded the lowest pH value of 4.98, while the Blueberry Hill spring water sample recorded the highest pH value of 6.74.

Four of the springs investigated samples were slightly acidic, and were reported to be below the minimum permissible level (6.5) established by the World Health Organization (WHO). Long-term subjection to pH below the permissible limit can cause blood acidity. pH decrease can be attributed to events such as acid rain caused by CO_2 in the atmosphere as well as other air pollutants, the bedrock and soil composition through which rainwater flows, waste water/ agricultural/industrial/mining operation runoff and degradation of plant materials [12].

Table 1. Total CFUs per spring

Location	Batch #	Sample # (Microbiology)	Total Coliforms (CFU)	*E. coli* (CFU)
WHO Guidelines	**-**	**-**	**Low 0-25**	**0**
Coomacka Spring	B-21-110	2104/0317	TNTC	0
Blueberry Hill Spring	B-21-110	2104/0318	TNTC	TNTC
Third Alley Spring	B-21-110	2104/0319	TNTC	TNTC
Silvertown Spring	B-21-110	2104/0320	0	0
Victory Valley Spring	B-21-110	2104/0321	TNTC	181

Table 2. E. coli risk assessment per spring

Location	Amount of Total Coliforms (CFU)	Degree of Risk
Coomacka Spring	TNTC	Very high risk
Blueberry Hill Spring	TNTC	Very high risk
Third Alley Spring	TNTC	Very high risk
Silvertown Spring	0	No risk
Victory Valley Spring	TNTC	Very high risk

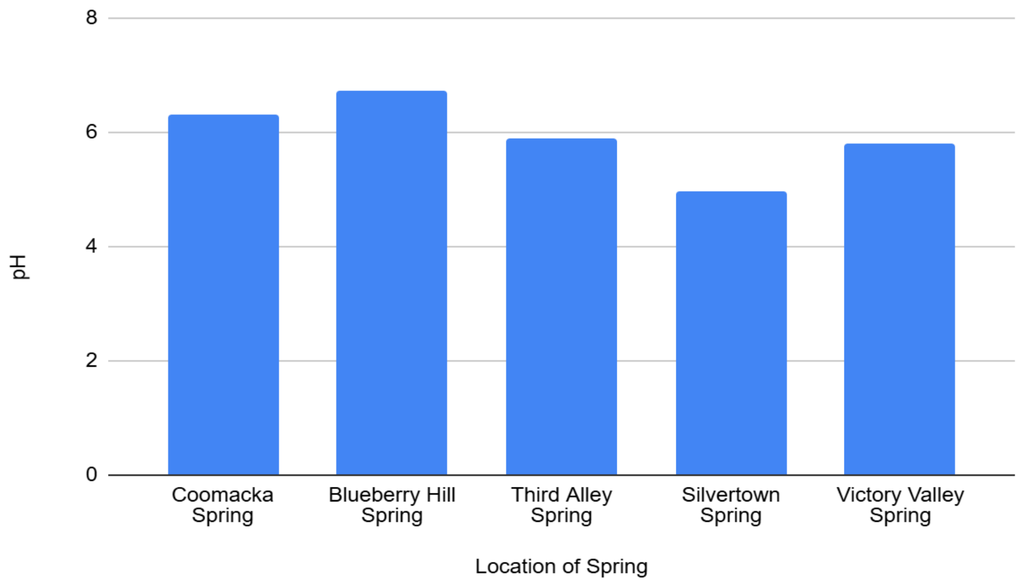

Fig. 7. Comparison of pH of springs

3.3.2 Turbidity

In the Linden study areas, turbidity was found varying between spring water sources. The highest turbidites (1.290) were recorded in the Coomacka and Third Alley spring samples, whereas the lowest turbidity was recorded in Silvertown spring sample (0.218). All examined samples were reported to be within the recommended limits established by the World Health Organization (<5 NTU). Though not recorded in samples, it is still important to note that anthropogenic activities, water level decline, and a rise in the suspended particulate matter can all lead to high turbidity values. This implies that suspended particles, natural colloids (silt and clays), inorganic particulate matter as well as non-soluble metal oxides are polluting the springs [8]. This contamination is due to springs coming into contact with surface water, particularly amid heavy rains/spring runoff. Excessive turbidity can safeguard infectious microbes from disinfectant effects, which poses a health risk for those consuming high turbid waters [12].

3.3.3 Total dissolved solids (TDS)

In Linden study areas, the concentrations of total dissolved solids across all sampling sites varied from 18.97 to 65.3 mg/L. All of the samples tested were found to be in conformity with World Health Organization's guidelines for drinking water quality. As a result, the spring water's low TDS content permits it to be used for drinking and other domestic purposes [13]. The presence of TDS in groundwater beyond recommended standard would lead to an unpleasant taste and gastrointestinal discomfort [12].

3.3.4 Dissolved oxygen (DO)

The DO of the samples in the Linden sampling sites varied from 3.83 to 9.24 mg/l, with the highest value recorded at the Blueberry Hill sample site and the lowest value recorded at the Silvertown sample site. All assessed samples were found to be within the acceptable limits recommended by WHO (>2).

Overall results revealed that the Silvertown spring is the only potable spring (20%) among those tested. Both the spring's physicochemical and microbial parameters (except pH) were found to be in conformity with the recommended standards established by the World Health Organization (Fig. 7). Though the water recorded a low pH value, this water can still be consumed due to the fact that pH is not considered to be a health based parameter. The physicochemical characteristics (except pH of some springs) of the other springs were found to be in conformity with the guidelines for drinking water quality prescribed by the World Health Organization. However, in relation to the microbiological characteristics, they were all found to be teeming with total coliforms/*E. coli*. Thus, far exceeding the maximum permissible limit set by WHO. As a result, these springs can be deemed non-potable/unfit for human consumption due to associated health risks (80%).

Due to the poor management and maintenance of springs, over the years, spring water quality has degraded and many springs now suffer greatly from microbial contamination. As a result, Health professionals and environmental officials have advised the locals to desist from drinking these spring waters since pathogenic organisms commonly occur within these water sources and pose a serious health risks (cholera, typhoid, dysentery etc.). This dilemma is not limited to only Guyana but to other countries as well. Countries such as India, Nigeria, Ethiopia etc., all face similar issues and in some of those countries springs are the primary water source. Potable water is a major challenge faced by the world today. In fact, the lack of it causes a significant number of deaths annually. Some countries have come up with solutions to combat the issue while others are still in the process of resolving said issues. In Guyana, there are currently no systems or programs in

Table 3. Physicochemical parameters of tested springs in comparison with WHO standards

Location	Batch #	Sample # (Chemistry)	pH	Turbidity (NTU)	Dissolved Oxygen (mg/L)	Total Dissolved Solids (mg/L)
WHO Guidelines	**-**	**-**	**6.5-8.5**	**<5.0**	**>2**	**<600**
Coomacka Spring	B-21-116	2104/1002	6.30	1.290	7.87	57.1
Blueberry Hill Spring	B-21-116	2104/1003	6.74	1.070	9.24	30.9
Third Alley Spring	B-21-116	2104/1004	5.91	1.290	8.92	18.97
Silvertown Spring	B-21-116	2104/1005	4.98	0.218	3.83	65.3
Victory Valley Spring	B-21-116	2104/1006	5.81	0.419	4.42	39.2

place responsible for the management and maintenance of springs. Most springs require treatment, so if a treatment plan is set in motion for the country's spring waters, the springs will once again be safe for human consumption. This is how this problem can be curbed: by the appropriate treatment of the waters. Though many of the springs are in conformity to WHO guidelines as it relates to physicochemical characteristics, they are teeming with total coliforms and *E. coli*. Clear water is not an indication of potability as water can be polluted on the microbial/physicochemical level.

One-way ANOVA was performed to compare the differences between the different sites for various parameters. The F test statistic (19.8837) was found to be much greater than the F critical value (3.23887) and as such it was concluded that there are statistical differences among physicochemical characteristics.

4. CONCLUSION

The purpose of this study was to assess the quality of selected spring waters in Linden, Guyana by using a series of physicochemical and microbiological characteristics. In the springs tested, varying concentrations of contamination were revealed. Except for a few physicochemical samples where pH was close to or beyond WHO acceptable limits, the bulk of water samples were found to be suitable for drinking and within permissible limits as per the chosen standard. On the other hand, microbiological tests revealed that four out of the five tested springs contained microbial contamination way beyond the recommended limits prescribed by WHO. As such, the Silvertown spring was found to be the only potable spring of the springs tested in Linden, Guyana. It is suggested that spring water quality be assessed on a regular basis to raise awareness among communities and local administrations about the need to secure and upgrade spring water resources. Government should develop a framework for the effective monitoring, maintenance and treatment of spring as it can be very beneficial in the future.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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