Asian Journal of Research in Botany

Volume 7, Issue 1, Page 25-35, 2024; Article no.AJRIB.110926

Assessment of Quality of Water from Catchment to Consumers: A Study based on Rahas-Ella Water Purification Plant in Kandy, Sri Lanka

A. B. N. Withanage [a] and P. W. H. K. P. Daulagala [a*]

[a] Department of Botany, Faculty of Natural Sciences, Kandy Regional Centre, The Open University of Sri Lanka, Polgolla, Sri Lanka.

Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

Article Information

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/110926

Original Research Article

Received: 01/11/2023
Accepted: 06/01/2024
Published: 11/01/2024

ABSTRACT

Introduction: Rahas-Ella is one of the fascinating waterfalls located in the Wattegama area in Kandy District, Sri Lanka. By receiving raw water from Rahas-Ella, a water purification plant was established in 2013 to provide safe drinking water to the residents in Wattegama municipal area. An investigation was conducted to evaluate several water quality parameters for both raw and purified water, in response to consumer complaints over the quality of drinking water received from this purification plant.
Methodology: Thirteen sampling locations (L01-L13) were identified along the waterfall, from the onsite water purification plant, two wells, and in addition two tap water sources through which the purified water is distributed. Some selected physicochemical and bacteriological parameters were analyzed.
Results: The study revealed that several parameters were higher than the standards concerned for drinking water. Mainly, the turbidity level was high in both the catchment and the intake and this

**Corresponding author: E-mail: pwdau@ou.ac.lk;*

could be a serious health risk to the community. Further, considerably high total counts of both coliforms and *Escherichia coli* (*E. coli*) were detected in all samples exceeding the standard values. Although oil and grease were not monitored in this present study, several dwellers reported problems associated with oil pollution.

Conclusion: Based on the observations and results of the study, numerous measures were recommended to improve the water quality of the catchment and to upgrade the treatment facility. The relevant authorities must understand the pathways of microbiological and physicochemical contamination of drinking water and their potential health implications and should carry out necessary steps to improve the quality of water distributed from this purification plant and lessen the negative consequences of improperly purified water on human health.

Keywords: Microbiological analysis; physicochemical parameters; Rahas-Ella fall; water quality.

1. INTRODUCTION

Water is one of the most essential materials for the existence of life on Earth. Thus, an adequate supply of safe and clean drinking water must be available to all; otherwise, life would not exist. Access to safe water sources in terms of quality is of utmost importance. Anthropogenic activities are polluting water resources, thus damaging ecosystems, disturbing natural processes, and posing a threat to the existence of all living beings [1]. Particularly unimproved water sources are contaminated not only due to anthropogenic activities but also natural factors such as flooding, climate changes, weathering of parental material, and topography [2]. Water quality of any specific area or specific source can be assessed using physical, chemical, and biological parameters [3]. Water quality is characterized based on physical, chemical, and microbiological parameters of water and human health is at risk if these values exceed the acceptable limits [4,5]. The drinking water purification plants are designed specifically to eliminate chemical and microbiological pollution in raw water through treatment stages in which harmful bacteria, specifically *E. coli* and other pathogens are eliminated from the water.

Drinking water should meet specific standards and criteria for good public health and being free from disease-causing pathogenic microorganisms. Consumption of water polluted with pathogenic microorganisms can cause health problems in humans such as diarrhoea, cholera, typhoid, dysentery, and skin diseases [6]. Agriculture is one of the significant polluters of water bodies on a global scale [7] and the use of chemical and organic fertilizers, growth stimulators, and pesticides has increased pollution in several folds during the last few decades [8].

Sri Lanka is an island in the Indian Ocean and has three climatic zones, the dry zone, with less than 1,900 mm of rainfall, the intermediate zone, with rainfall between 1,900 and 2,500 mm and the wet zone, with rainfall between 2,500 and 5,500 mm (Department of Census and Statistics, 1998). According to the available evidence, there is either little or no water scarcity in Sri Lanka. Even though there are certain dry zone places in the courtyards during the dry season to compete for the water. In the year 2017, the safe drinking water coverage in the country was around 86%, and the population served with pipe-borne water stood at 46%, which constituted 35.2% provided through the national distribution network and 10.8% served by small-scale schemes operated by community-based organizations [9]. Groundwater resources are fairly good in most parts of the country but at present intensive irrigation practices and the overuse of agrochemicals have caused deterioration of the quality of groundwater. Other than this, the tsunami severely affected groundwater, especially in the coastal areas. Besides groundwater resources, the country has about 225 springs out of which about 120 are located in the central highlands (Department of Census and Statistics, 1998). and many fascinating waterfalls. The State authorities have these water sources as well to serve people where the water supply from the national grid is not feasible. In most of these instances, the local community has the responsibility of safeguarding the water source from anthropogenic pollution.

Waterfalls are one of the inland freshwater sources that receive very little attention from researchers worldwide. In Kandy district, Wattegama is one of the well-known towns having several waterfalls and they give an attractive natural beauty to the area. The Rahas-Ella project, which is currently well working, is one of three projects that make up the water supply system for the population of the Wattegama area. This water supply system provides water to a large number of connections in the Wattegama area, including 1165 domestic and 360 commercial connections.

Even though Rahas-Ella waterfall preserves good quality water, some hotspots of pollution have lately been identified. Consumers claim that the quality of drinking water supplied by the purification plant is deteriorating over time. This may be either due to the high levels of domestic pollutants discharging to the fall, which cannot be eliminated through the purification process, or due to the shortcomings of the existing purification process. Though Rahas-Ella fall is one of the significant sources of supplying drinking water to the consumers in Wattegama urban council, unfortunately, there is no information on the quality of water within the catchment. The research described in this paper was carried out to analyze the ambient water quality of the waterfall concerning the quality of water provided to consumers in the Wattegama area through the distribution network, using certain significant water quality parameters. In addition, prompt and significant remedies were addressed timely important solutions were provided to address the shortcomings of the existing purification plant.

2. METHODS AND MATERIALS

2.1 Study Area

Rahas-Ella is one of the fascinating waterfalls located in the Wattegama area in Kandy District, Sri Lanka (7°21'11.00"N 80°41'39.99" E). This fall is about 15 m in height at the mean sea level and is formed by a stream that starts from the Hunnasgiriya mountain range. According to the data collected from Wattegama Urban Council, Central Province, this Rahas-Ella water supply system provides water to about 2297 connections in Wattegama, including 1165 domestic and 360 commercial connections. Wattegama area has a tropical monsoon climate having considerable rainfall throughout the year (average annual rainfall is 1815 mm, the wettest and driest months of the year are November and June respectively). The average annual temperature of the area is 24.6 °C.

2.2 Selection of Sample Sites and Collection of Water Samples

Thirteen different sampling locations (L01-L13) were identified starting from the origin of the Rahas-Ella waterfall and the onsite water purification plant, tap water sources distributing purified water from the plant, and two wells in the area, one is shallow and the other is deep (Fig. 1).

For laboratory analysis, a total of 39 water samples (in triplicates) from 13 sites were collected. Nine samples were taken from the waterfall and from the purification plant and two samples from shallow and deep hand-dug wells that the residents use for their drinking water. To determine whether there is a chance that purified water could become polluted throughout the distribution process, two samples from taps on Panwila Road and Pinnalanda Road were also taken for analysis (Table 1). All samples were collected to clean and dry polystyrene bottles of 250 ml capacity during the morning hours between 8.00 to 10.00 a.m. Before filling the samples, bottles were rinsed two to three times with the sample water in each location. For bacteriological analysis, water samples were collected in sterile bottles from locations L06, L07, and L09 and delivered immediately to a microbiology laboratory. Samples were analyzed onsite and off-site for selected physical and chemical parameters such as pH, alkalinity, total hardness electrical conductivity (EC), and total dissolved solids. Temperature and pH were noted onsite while other parameters were analyzed in the laboratory.

2.3 Analysis of Water Samples

2.3.1 Analysis of physicochemical parameters

The physicochemical parameters including pH, alkalinity, total hardness, EC, and TDS were analyzed. Temperature and pH were noted onsite while other parameters were analyzed in the laboratory after the samples were safely transported to the laboratory at the National Institute of Fundamental Studies (NIFS), Hantana, Kandy.

The temperature and the pH of the samples were measured in the field (*in-situ*) using a thermometer and a pH meter (HANNA Instruments) while the electrical conductivity and the turbidity values of the samples were taken using an electrical conductivity meter (HANNA Instruments) and a turbidity meter (Thermo Instruments) respectively. The calibrated multi-parameter was used to measure TDS and the alkalinity of samples was measured using the potentiometric titration method with KEM autotitrator (AT-610-ST, Japan).

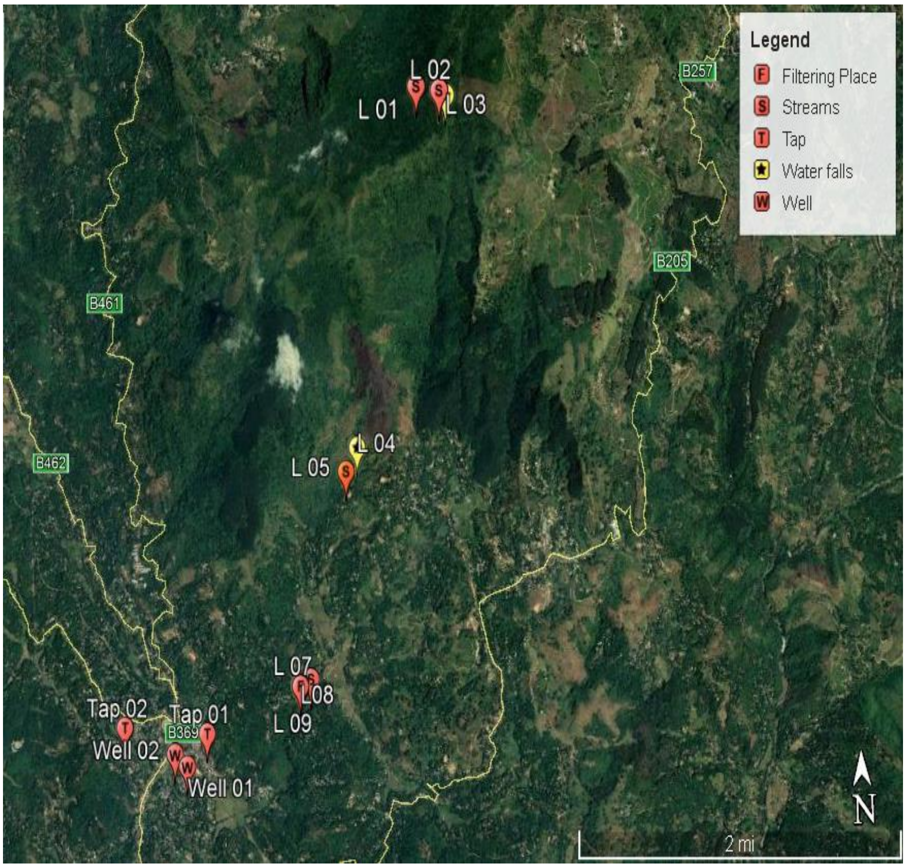

Fig. 1. A Google Earth map of the study area and the sampling locations

Table 1. Description of the locations of collected water samples for analysis

Sample Location	Coordinates (Latitude and Longitude)		Description of location
L01	7°23'30.00"N	80°42'18.01"E	A stagnant water-filled pond close to the beginning of the stream
L02	7°23'29.00"N	80°42'25.01"E	Part of the stream in between the stagnant pond and the Duwili-Ella
L03	7°23'28.08"N	80°42'27.04"E	The starting point of Duwili-Ella falls (upper part of Rahas-Ella falls).
L04	7°22'7.57"N	80°41'57.17"E	The starting point of the Hunasgiri-Ella (middle part of the Rahas-Ella) surrounded by a few mass rocks
L05	7° 22'1.79" N	80° 41'53.36" E	The shallow section of the stream. Residents use water for bathing and washing
L06	7° 21'11.00" N	80° 41'39.99" E	Water intake to the plant. The starting point of the Rahas-Ella falls.
L07	7°21'9.60"N	80°41'36.82"E	Sedimentation tank.
L08	7°21'9.54"N	80°41'36.56"E	Water after filtration
L09	7°21'9.48"N	80°41'36.51"E	Purified water after chlorination
L10	7°20'58.47"N	80°41'5.58"E	Tap 1 at a small village getting purified water from the plant
L11	7°21'0.99"N	80°40'38.83"E	Tap 2 at another small village getting purified water from the plant
L12	7°20'50.66"N	80°40'58.87"E	Deep well closer to the plant
L13	7°20'53.74"N	80°40'54.91"E	Shallow well closer to the plant

2.3.2 Analysis of bacteriological parameters

As an entirely accepted and approved method for monitoring the bacteriological quality of drinking water in many countries, the membrane filter (MF) technique was used in this study to enumerate the total coliforms and *E. coli* of a few selected water samples.

Three water samples collected from the L06, L07, and L09 locations of the waterfall and the purification process (Table 1) were subjected to the MF technique. The colonies grew on M-Endo medium at a temperature of 35 ^{0}C for 24 h of incubation for total coliforms and on an enriched lactose medium (m-FC) at a temperature of 44.5 ^{0}C for 24 h incubation for *E. coli* were counted.

3. RESULTS AND DISCUSSION

The study was conducted aiming the unsafe water quality issue which is one of the major problems in rural areas in Sri Lanka. Standard methods and calibrated equipment were used for testing water quality parameters. Physical, chemical, and bacteriological water quality parameters were assessed concerning the standards defined and recommended by the World Health Organization (WHO 2011) [10] and Sri Lanka Standards (SLS614:2013) [11].

3.1 Statistical Analysis of Physicochemical Parameters

3.1.1 Turbidity

One of the most important factors in determining the quality of water is turbidity, which is the cloudiness of water brought by various particles. The findings of the turbidity of water samples collected from locations L01 to L13 are shown in Fig. 2. The maximum permissible level of turbidity (accepted) should be 5 NTU, while the maximum permissible level of turbidity (Drinking water) should be 2 NTU (SLS614:2013). No health-based guideline value has been proposed for turbidity by the WHO. However, the turbidity readings of the water samples taken from all thirteen locations ranged from 8 to 14.5 NTU, and all of the values were above the accepted and permissible limits.

The water sample from sampling point L01 had a substantial amount of turbidity and contained algae. A significant growth of algae was seen in the sampling location L02 as well. The water from L03 and L04 was also turbid and strongly colored due to the presence of silt. Turbidity at sample point L06 and the rest (L06-L13) was much too high to be used as drinking water, with an average of 9.18 NTU. The average amount of turbidity in the water that was released from the purification plant to the consumers (L09) was 9.75 NTU, which was well above the recommended level. This result showed that the current treatment plant is unable to efficiently handle excessive turbidity of water. The shallow well L13 has a turbidity rating of 14.5 NTU, which is unusually high. The well is exposed to the runoff from the paddy field that it shares a boundary with. There is a high probability that agricultural fertilizers will leak nutrients. However, it makes sense to assume that silt and enhanced algal growth are the main causes of excessive turbidity of L13.

3.1.2 Temperature

Drinking water temperature can significantly increase or decrease during the purification process and through the distribution system to the consumer. However, according to the data, the temperature of the water samples from all sampling points was within the range of 26 ^{0}C to 30 ^{0}C and was therefore all above the WHO standard of 25 ^{0}C. These results imply that all samples had temperatures that were suitable for the development of a wide variety of algae, cyanobacteria, and other microorganisms as particles in water. The presence of particles increases the turbidity of water. Turbidity is a measure of water clarity and high turbidity increases water temperature due to such particles absorbing sunlight. It was found that the turbidity of water samples showed a considerable consistency trend with the temperature of the water detected at the locations (Fig. 3).

3.1.3 Alkalinity

Low levels of alkalinity were found in the water at sample stations L01 to L05, and a significant rise in alkalinity was found at L06 (Fig. 4). This high alkalinity level was maintained throughout the purification procedure and even slightly increased after chlorine was added to the water. The alkalinity of the samples taken from wells was somewhat decreased.

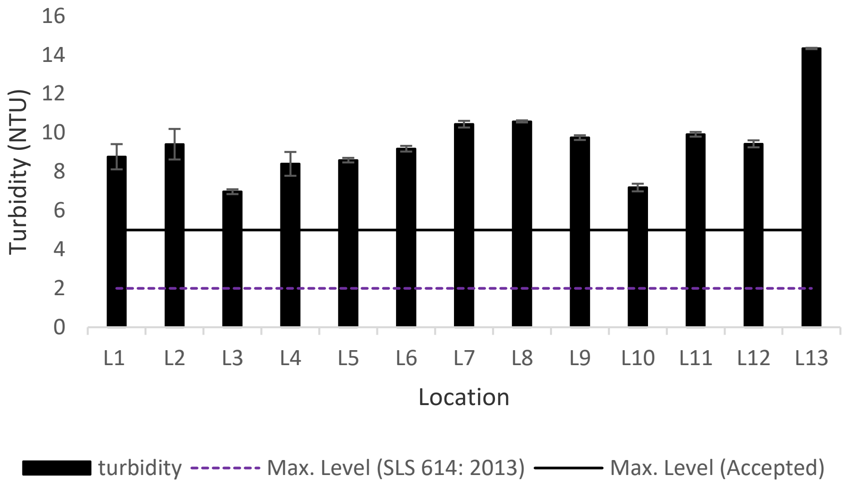

Fig. 2. Turbidity of water samples collected from the locations L01 to L13

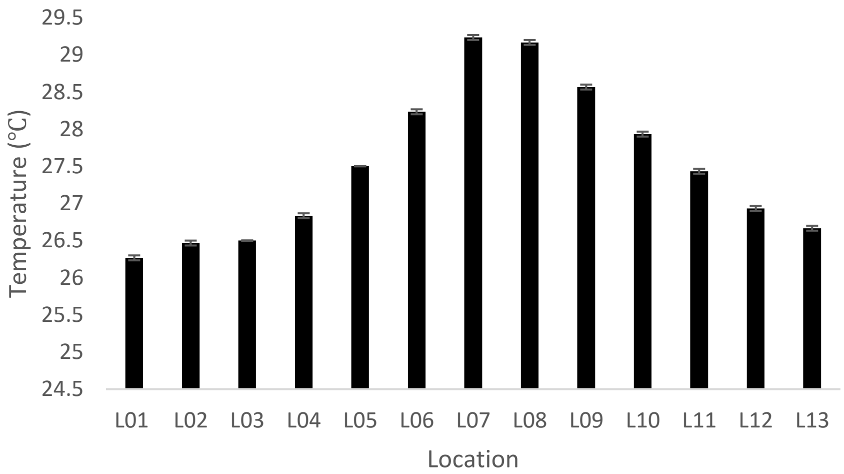

Fig. 3. Temperature variations of water samples collected from the locations L01 to L13

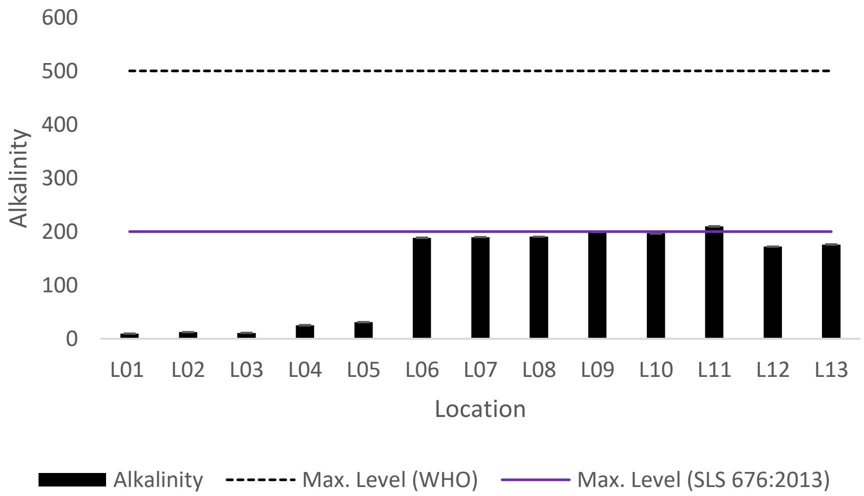

Fig. 4. Alkalinity of water samples collected from the locations L01 to L13

Alkalinity refers to the ability of the water to neutralize acids. Most of the water treatment processes reduce the alkalinity of raw water. However, in this study, samples of water from the intake and up to the filtered water sent through the pipelines to consumers had high alkalinity. Alkaline water generally contains a higher amount of total dissolved solids (TDS) which affects the pH levels of the water. The samples that had lower TDS values showed a pH less than 7 and were slightly acidic.

3.1.4 pH

pH is considered as one of the most important water quality parameters and the values are related to the acidity or alkalinity of the water samples. It is noticed that water with low pH tends to be toxic and with a high degree of pH it is turned into bitter taste. According to the regulations of WHO (2011) and SLS (614:2013), the acceptable and safe pH range of drinking water is 6.5-8.5. The pH values of the collected water samples are found to be within the range between 5.9 and 7.9. Out of thirteen, seven collection points had a pH lower than the neutrality. However, the samples taken from points L06 to L11 and L08, showed a pH higher than 7 and the pH observed from the samples collected at various stages of the purification process and the purified water distributed through the taps (L06 to L11) yielded the maximum pH of between 7.5 and 8.0. However, the pH value of the water distributed to the consumers did not exceed the standard limits (Fig. 5).

3.1.5 Total Dissolved Solids (TDS)

The findings of this study demonstrate that the samples taken from the top portion of the canal (L01- L05) had low TDS values, however, location 6 had a greater TDS value and stayed more or less constant for the samples taken from L06 to L11 (Fig. 6). The sample collected from the shallow well (L13), which was next to a paddy field, had the greatest TDS value, while the deep well (L12), which was in a residential neighborhood, also had a significantly higher TDS value. However, none of the examined samples had TDS levels that exceeded the WHO limit of 600 mg/L water.

The catchment (L06) is subject to several human activities, and the TDS seemed to rise as the treatment operations progressed. As a result, the TDS level increased slightly after sampling point L06 but remained steady. The samples taken from the wells (L12 and L13) had greater TDS levels, which may have been caused by organic compounds and other ions dissolved in the well water.

3.1.6 Electrical Conductivity (EC)

According to the WHO guidelines, the electrical conductivity of drinking water should not exceed 400 μS/cm. This present investigation indicated that the EC value was 30 – 450 μS/cm with an average of 188 μS/cm (Fig. 6). The samples taken from L06 to L11 revealed greater EC values, but they were more or less steady for all six samples and none of them exceeded the maximum value, quite similar to the TDS values.

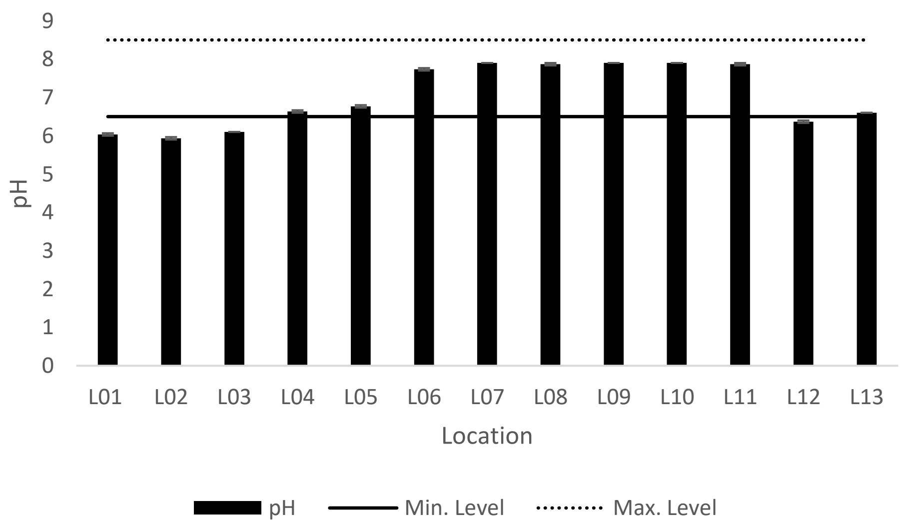

Fig. 5. Variation in pH of the water samples collected from the locations L01 to L13

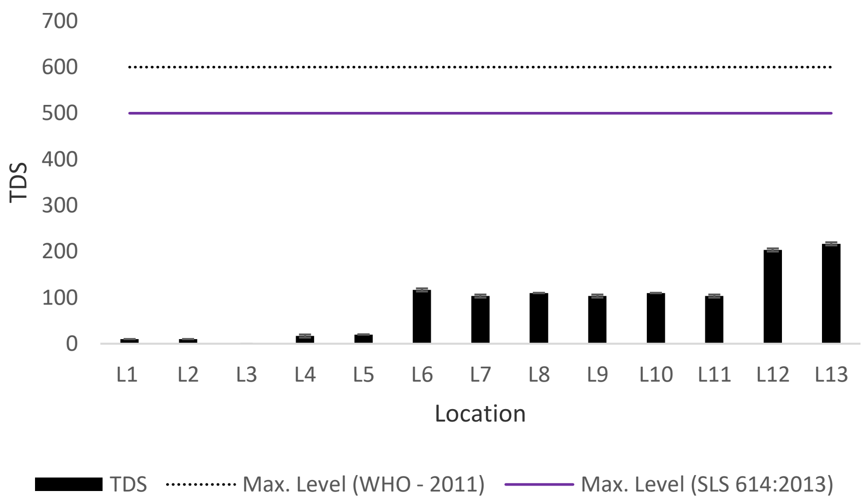

Fig. 6. Variation in total dissolved solids of the water samples collected from the locations L01 to L13

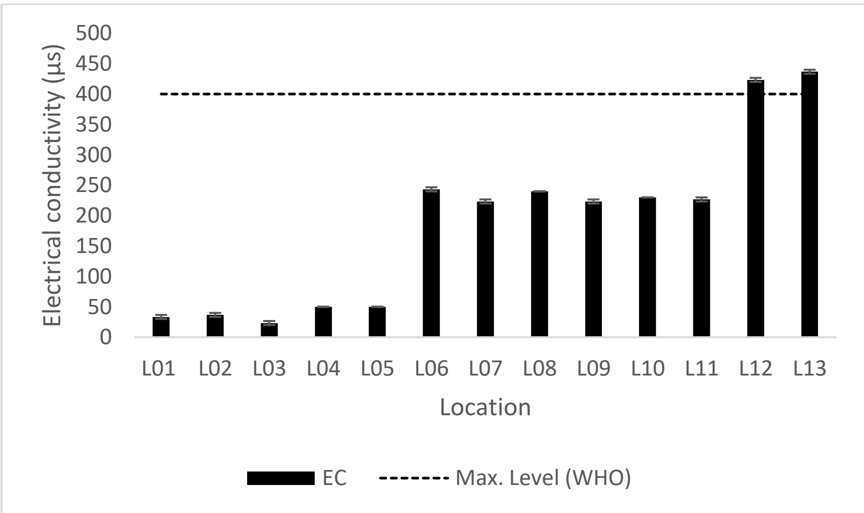

Fig. 7. Electrical conductivity of the water samples collected from the locations L01 to L13

The relationship between TDS and EC is a function of the type and nature of the dissolved cations and anions in the water. The two samples taken from wells had considerably higher TDS as well as EC values and the EC values exceeded the maximum level, as shown in Fig. 7. The surface water that percolates into the ground due to gravity and the spring water passes through the soil might dissolve materials in the rocks and soil they come into contact with and this could explain why tested well water samples had higher EC values.

3.2 Microbiological Assessment of Water for Faecal Contamination

The assessment of the microbiological quality of water from different sources is essential for detecting the presence or absence of microorganisms that might constitute health hazards in the water. These results could be used as a guide to monitor and protect the water sources. A majority of problems regarding the quality of community drinking water are related to faecal contamination by the bacterium *Escherichia coli*. *E. coli* is best suited as an indicator for faecal coliforms because there are fewer instances of encountering false positives [12].

Three points from where the water samples were collected for microbiological assessment are shown in Table 2. The results obtained revealed that all samples tested were positive for both total coliforms and *E. coli* (Table 3).

Table 2. Description of three points from where the water samples were collected for microbiological assessment

Sampling point	Description of the point
L06	The starting point of the Rahas-Ella falls. A Dam is built up to collect water used by residents for bathing and washing. Paddy fields in the surrounding area
L07	Sedimentation tank
L09	Purified water released from the plant after chlorination

Table 3. Total coliform and the *E-coli* count of the water samples

Type of bacteria	Results /100ml			WHO standard	
	L06	L07	L09	Pipe-borne water	Well water
The total number of all types of Coliform bacteria present in the 100ml sample at 35 ± 0.5 ^{0}C	408	396	74	Nil	Nil
Number of *E. coli* in 100ml of sample at 44.5 ± 0.2 ^{0}C	194	188	32	Nil	Nil

The numbers of total coliforms and *E. coli* detected in the given water samples were exceedingly high against the standard limits of WHO. However, the temperature readings recorded in these three locations were considerably high and this also may contribute to the high bacterial counts recorded.

The high coliform count obtained in the samples can be considered as an indication that the water samples collected from those points were somehow contaminated with faecal matter. Samples L06 and L09 were collected from points before the purification process started, and there may be possibilities for entering sewage into the water as a result of some human activities. Additionally, the very high concentrations of coliforms in samples L076 and L07 may be the result of animals living in forest patches that may have been visiting to drink water and then discharging waste into the stream water. Unfortunately, the sample collected after the completion of the purification process (L09) also contained a massive number of coliforms as well as *E. coli*, compared with the standards. This result indicated the improper purification process of water which ultimately results in faecally contaminated water being distributed for human consumption.

4. CONCLUSION

Although the water from Rahas-Ella falls is treated, an investigation of the samples collected from the catchment area, treatment process, and the consumer end outlets confirmed that the effectiveness of the water treatment plant is not satisfactory. The study evidenced that several parameters were higher than the WHO (2011) and SLS614:2013 standards for drinking water. Mainly, the turbidity level was high in both the catchment and the intake. There could also be health risks to the community that uses contaminated water for washing, cooking, and other purposes. Therefore, to lower the higher levels of pollutants, proper treatment procedures and management strategies are required.

However, the treatment plant is failing to reduce the turbidity and as a result, consumers are supplied water with high turbidity. In addition to being unattractive visually, excessive turbidity may indicate health problems. Although turbidity is not a direct indicator of health risk, it can promote regrowth of pathogens in water. When the presence of *E-coli* and the total coliform bacteria of the water samples collected before, during, and after the purification process was enumerated, considerably high total counts for all samples were detected, exceeding the standard values. The primary sources of bacterial contamination might include surface runoff, sewage entering the waterfall and improper management activities of the inhabitants like washing, refuse dumping, and faecal droppings to the water source. Although there is an apparent reduction of the total count of both *E-coli* and total coliforms after the treatment process, the counts are still exceeding the permissible level (0/100 mL) recommended for drinking water.

The attention to catchment conservation is almost neglected, although the pollution was high despite the presence of the treatment plant. Therefore, it is recommended to improve the catchment and improve water quality of the water intake. Strict actions should be taken against the entities which discharge polluted water into the catchment. Although oil and grease were not monitored presently, several dwellers reported problems associated with oil pollution. These pollution sources were identified, especially as agricultural activities, car wash, and farms.

The technical awareness of the labourers regarding the maintenance of the treatment plant is not satisfactory and they require adequate technical training. Compilation of an operation and maintenance manual for the treatment facility is required. Water waste is commonly seen through the leaked pipe network. The well water can be easily mixed with the runoff and the nutrients that are leaching from the paddy fields as there are no protective mechanisms installed. Therefore, it is recommended to build walls for both wells and to plaster and seal. Further, it is required to block the runoff which enters directly and mixes with the well water. Dug wells should be regularly cleaned properly before using their water.

Based on the observations and results of the study, the following activities are recommended to improve the water quality of the catchment and to upgrade the treatment facility.

1. Conservation of catchment area.
2. Awareness of the local authorities regarding water quality issues
3. Upgrade the existing water treatment plant with expert assistance to control turbidity
4. Preparation of operation and maintenance manual for the treatment plant
5. Conduct community water safety programs

ACKNOWLEDGEMENTS

A.B.N. Withanage is grateful to Prof. Rohan Weerasooriya at the National Institute of Fundamental Studies (NIFS) in Sri Lanka for his support and for providing the necessary lab facilities for carrying out the chemical analysis of water for this research which is a component of her Masters of Science degree. Additionally, the authors thank the Municipal Council of Wattegama for supplying the essential details and data about the study site and the operational drinking water purification facility.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Bhat SA, Meraj G, Yaseen S, Pandit AK. Statistical assessment of water quality parameters for pollution source identification in Sukhnag stream: An inflow stream of lake Wular (Ramsar Site), Kashmir Himalaya. Journal of Ecosystems. 2014;1-18.
2. Vadde K, Wang J, Cao L, Yuan T, McCarthy A, Sekar R. Assessment of water quality and identification of pollution risk locations in Tiaoxi River (Taihu watershed), China. Water. 2018;10(2):183.
3. USEPA, Recent Recommended Water Quality Criteria, United States Environmental Protection Agency; 2007.
4. Tyagi S, Sharma B, Singh P. Dobhal R. Water quality assessment in terms of water quality index. American Journal of Water Resource. 2013;1(3):34-38.
5. Akter T, Jhohura FT, Akter F, Chowdhury TR, Mistry SK, Dey D, Barua MK, Islam MA, Rahman M. Water quality index for measuring drinking water quality in rural Bangladesh: A cross-sectional study. Journal of Health Population and Nutrition. 2016;35:1-12.
6. Goel PK. Water pollution: Causes, effects and control. New Age International, New Delhi; 2006.
7. Ongley ED, Xiaolan Z, Tao Y. Current status of agricultural and rural non-point source pollution assessment in China. Environmental Pollution. 2010;158(5): 1159-1168.
8. Savci S. An agricultural pollutant: Chemical fertilizer. International Journal of Environmental Science and Development. 2012;3(1):77-80.
9. Wijesekera NS, Kamaladasa MB, Nanayakkara MA, Daluwatta D. Study on sustainable water resource management for drinking purposes. University of Moratuwa: Sri Lanka; 2020.
10. WHO, Guidelines for Drinking Water Quality. 4th Edition. World Health Organization, Geneva, Switzerland; 2011.
11. SLS 614: 2013, Specification for Potable Water (First Revision). Sri Lanka

Standards Institution. Colombo, Sri Lanka; 2013.
12. Rodrigues C. Cunha MA. Assessment of the microbiological quality of recreational waters: indicators and methods. Euro-Mediterranean Journal of Environmental Integration. 2017;2(1):1-18.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/110926