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Analysis of Physicochemical and Bacteriological Parameters of Raw and Treated Water of Roseneath Water Purification Plant in Dunumadalawa Forest Reserve in Kandy, Sri Lanka

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aims: To analyze a number of physicochemical and bacteriological parameters of raw and treated water of water purification plant in Dunumadalawa forest reserve in Kandy, Sri Lanka to ensure the continuous supply of clean and safe drinking water for nearby residents.
Study Design: A number of physical, chemical and bacteriological parameters such as colour, turbidity, pH, electrical conductivity, total hardness, free ammonia, nitrates, total phosphates, fluorides, total iron and the presence of coliforms/ *Escherichia coli* were tested in water samples collected at six different stages of drinking water purification process.
Place of Study: Dunumadalawa forest reserve in Kandy, Sri Lanka.
Methodology: Testing of water samples collected from six different stages of purification process was carried out. The obtained values of each parameter were compared with the standard values set by the World Health Organization (WHO) and the Sri Lanka Standards (SLS) for drinking water quality.

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Results: The values of each physicochemical parameter of collected samples were found to be within the maximum permissible limits set by the World Health Organization and Sri Lanka Standards while for few samples a slightly deviated values from the standards were obtained. All samples were negative for *E. coli*, which indicated that the water is not faecally contaminated.
Conclusion: There are no major problems associated with the existing water purification plant functioning at present in the forest reserve and the purified water is certainly safe for drinking purposes.

Keywords: Potable water; drinking water; water quality parameters; water treatment.

1. INTRODUCTION

Water is one of the most abundant resources on which life on earth depends and it is only second to oxygen as being essential for life. People can survive days, weeks, or even longer without food, but only about four days without water [1]. In some countries, the availability of potable water is critical and a matter of great concern. Water quality is a growing concern throughout the world. Drinking water sources are under increasing threat from contamination and pollution by natural influences and anthropogenic activities with detrimental consequences on the health of human beings. The process of pollution of water ranges from simple addition of dissolved or suspended solids to discharge of the most persistent toxic pollutants such as pesticides, heavy metals, and non-biodegradable and bio accumulative chemical compounds [2]. Further, the quality of water for drinking deteriorates due to inadequacy of water treatment plants and inefficient management of distribution systems of purified water as mentioned in United Nations Environment Programme (UNEP) report for 2001. Contamination may also come from agricultural activities in which millions of tons of fertilizers, fungicides and pesticides are employed annually. Therefore, the pollution of drinking water is responsible for a large number of water borne diseases such as typhoid, cholera, dysentery, and hepatitis. Every year over a million of people die from diarrhoeal diseases due to the consumption of unsafe water or poor sanitation and hygiene. According to WHO (2004b), more than half of these are the children under five years who are more at a risk of diarrhea.

Potable water is the water that is free from disease producing microorganisms and chemical substances deleterious to human health [3]. Before water can be described as potable, it has to comply with certain physical, chemical and bacteriological standards, which are designed to ensure that the water is potable and safe for drinking [4]. These standards vary from place to place, but the overall objective of all is to reduce the possibility of spreading water borne diseases in addition to being pleasant to drink [5]. In most of the developing countries, people do not have proper sanitation and access to safe drinking water.

Supplying of purified and safe water is one of the important factors responsible for the sustainability of human and environmental health. The adverse impacts of poor water supply have long been recognized in both developing and developed countries and take the form of outbreaks of water borne diseases [6]. Water purification and distribution systems play a pivotal role in preserving and providing quality water to the public.

Drinking water quality deteriorates during collection and storage [7] as well as in distribution networks [8]. Further, reservoirs from where the water is obtained for purification are located in forests, various wild animals have easy access to the reservoirs and are likely to have been contaminated with animal excreta. These animal excreta contain high amounts of nutrients such as phosphorus and nitrogen and could result in eutrophication of the water body. Additionally, some microorganisms present in animal waste can multiply in nutrient rich water and cause faecal pollution of water. For example, if the members of *Pseudomonas* group present in drinking water, it may result in an overall deterioration of the quality of water and lead to consumer complaints of unpalatable taste and odour [9]. Presence of *Escherichia coli* (*E. coli*), a type of faecal coliform bacteria commonly found in the intestines of warm blooded animals and humans [10, 11], is a strong indication of faecal contamination of water. Although most strains are harmless, some produce a toxin which can cause severe illnesses such as bloody diarrhea and abdominal cramps [12, 13]. The existence of *E. coli* in water does not necessarily imply the presence of disease-causing microorganisms.

However, it gives an indication of the possible existence of faecal-borne microorganisms such as *Salmonella* and hepatitis A. This is why the reason of using *E. coli* as an indicator organism to examine water samples for faecal contaminations [14].

In Sri Lanka, the highland massif determines the inland water resources which consist of 103 river basins and the quality and the quantity depends on its geological formations [15]. Mostly the water sources are being utilized for irrigation systems in agriculture and more importantly for generation of hydroelectric power. However, urbanization, unplanned human settlements, improper irrigation practices, excess use of fertilizers and rapid developmental programmes pose challenges to the natural water resources in a country, thus leading to a depletion of potable water available for human consumption. Lack of access to safe drinking water has been identified as one of the most prevalent issues in several areas in Sri Lanka. High fluoride content in ground water, high concentrations of pesticides and fertilizers have been identified as the major underlying causes for the Chronic Kidney Disease in north central part of the country and proper investigations and remedies are still lacking. Thus, that would be beneficial to assess the water quality in inland water resources in order to identify the unforeseen threats and to implement proper water resource management practices to overcome those identified issues.

Dunumadalawa forest reserve, also popularly known as Wakarawatta after its original estate name -Walker's estate, comprises mainly of a secondary growth forest since the site has been used earlier for tea, coffee and cocoa plantations. The forest consists of different types of habitats such as woody areas, grass patches, pine plantations, abandoned tea, coffee and cocoa plantations and several permanent and temporary lentic and lotic water bodies. The reserve forms the catchment and protects the watershed of two reservoirs known as Dunumadalawa and Roseneath reservoirs [16]. The Roseneath reservoir which is fed by the rain water and water from a natural stream, provides drinking water to the residents in six villages in the Kandy municipal area close by the reserve. The Dunumadalawa reservoir, established by constructing a dam across the Dunumadalawa stream provides 10% of the water requirement of the Kandy city.

In the present work, attempts have been made to evaluate the quality of raw water entering the purification plant as well as samples collected from different stages of the Roseneath water treatment plant established in the reserve. Various physical, chemical and bacteriological parameters were assessed and the values obtained were compared with the permissible/desirable levels prescribed by the SLS and WHO guidelines to ensure the quality of water for drinking. Data obtained from this research will be vital for policy makers in the implementation of responsible water quality regulations, for characterizing and remediating contaminations if detected for the protection of the health of the consumers as well as the aquatic organisms.

2. METHODS AND MATERIALS

2.1 Study Site

Dunumadalawa forest reserve ($7^o17'00"$ N; $80^o38'49"$ E; 548-972 m above sea level) situated in the northern end of the central massif of Sri Lanka is approximately of about 480 hectares in extent of land and aquatic habitats including two major reservoirs named Dunumadalawa and Roseneath. Based on the information provided by the Strategic Cities Development Project (SCDP) in 2014, the immediate borders of the forest are the Pinus plantation to the southeast at Matinapatana which then run into home-garden villages and a small, private tea estate; the Tea Research Institute (TRI) and Hantana tea estate to the west which is the beginning of extensive tea cultivation leading to Heeresagala, Bowalawatte and the Hantana hills in the southwest; Kandy town to the north; and Ampitiya town and other villages on the east. The water treatment plant built near the reservoir purifies approximately 300 m^3 of water per day and pump to another water purification plant located in the city to distribute among nearly 500 houses in the Kandy municipal area.

2.2 Topography and Drainage

The topography of the forest varies from flat plains with some scattered low hills and gently sloping valleys. The area has a wetter and cooler climate and a dry season from December through April followed by a season of monsoonal rain from May to September and December to February. The mean annual rainfall recorded from the south-west monsoon is 1800-2500 mm. During the intermonsoonal period the city and the suburbs experience light rain and strong humidity, having average between70-79%.

2.3 Selection of Sampling Points

Six points were identified for sample collection; along the natural stream (L1 and L2) and from the Roseneath reservoir (L3) as raw water, from different steps associated with the water purification process as treated water (L4 and L5) and finally the chlorinated water released from the final step of purification process (L6) as purified water.

- L1 - Starting point of the water stream (head of the stream)
- L2 - The place where the stream water enters to the Roseneath reservoir
- L3 - Roseneath reservoir
- L4 - Aeration tank
- L5 - Filtered water before adding chlorine
- L6 - Chlorinated water ready for distribution

2.4 Sample Collection

Samples were collected from six different locations given above (L1-L6) in triplicates. Samples were collected from each location in 500 mL plastic bottles previously cleaned by washing with nonionic detergents and then rinsed with tap water. At each location, sample bottles were rinsed with target water for three times before filling.

Water samples for bacteriological analysis were collected into pre-sterilized 500 mL stoppered glass bottles. Samples were labeled and transported to the Regional Laboratory (Kandy south), National Water Supply and Drainage Board, Old Galaha road, Peradeniya, Sri Lanka, immediately after the collection.

2.5 Physicochemical Parameters

The physicochemical parameters including colour, turbidity, pH, electrical conductivity, total alkalinity, total hardness, free ammonia, chloride, total phosphate, fluoride, total iron and calcium were analyzed (Table 1). The results of each parameter were compared with the guidelines and standards set by [17] and [18] (maximum permissible level for drinking water).

2.6 Bacteriological Parameters

The Membrane Filtration (MF) technique was used to test the bacteriological quality of collected water samples. Each Water sample was filtered using the filtration apparatus with a filter paper of 0.45 µm pore size which retained the bacteria on it. These filter papers were incubated on M Endo medium and enumerated the typical colonies grown on each filter paper.

3. RESULTS AND DISCUSSION

3.1 Physical Parameters of Water

The results of colour and turbidity of the six water samples tested are presented in Table 2.

Water is usually a colourless liquid but colour in drinking water can originate from any impurities present in it. There was no detectible colour in samples collected from the head of the stream which flows through the forest to the Roseneath reservoir (L1) and the purified water (L6). Filtered water sample collected from the plant before the disinfection process had a very low level of colour. Remaining three samples (L2, L3 and L4) had a considerably high colour having the highest in untreated water collected from the reservoir (L3). The filtered water recorded a drop in colour and this indicated a significant level of reduction in colour during the filtration process.

Turbidity is a measurement of the cloudiness of water and the values are expressed in Nephelometric Turbidity Units (NTU). Of the samples tested, L3 sample collected from the reservoir showed the highest turbidity value (6.85 NTU) followed by the sample L4 obtained from the aeration tank (5.12 NTU), which were above the values of both WHO and SLS guidelines. The minimum turbidity (0.48 NTU) was detected in the sample collected from the head of the natural stream where the water was crystal clear. Filtered water also had a low turbidity level (0.61 NTU) and it was further reduced after chlorination to 0.54 NTU, the value obtained for the purified water discharged from the plant. Turbidity is one of the principle physical characteristics used to determine the potability of water. Turbidity should ideally be below 5 NTU and 2 NTU according to [17] and [18] respectively and the appearance of water with a turbidity of less than these values is usually acceptable to consumers. Since the microorganisms such as bacteria, viruses and protozoa are typically attached to the particulates in water [17] turbid waters can be microbiologically contaminated and indirectly create a health issue. High levels of turbidity can protect microorganisms during disinfection and hence turbidity could be considered as a key issue regarding the microbiological quality and disinfection of water [17]. Furthermore, high turbidity increases the temperature of water due to the absorbance of heat by the particles suspending in water [19]. High turbidity in water causes problems in water purification processes and leads to increased treatment cost [20].

3.2 Chemical Parameters of Water

The results of tested chemical parameters of the six water samples are presented in Table 3.

Measurement of pH relates to the acidity or alkalinity of the water and it is one of the desirable quality parameters of water. The pH values of the collected water samples ranged from 5.68 (reservoir) to 7.13 (purified water). Majority of the samples had a pH lower than the neutrality, while only the purified water discharging from the plant had pH just above the neutrality. There is no health based guideline for pH, although a range of 7.0–8.5 is suggested in WHO and Sri Lanka standards. Of the samples tested, 83% fell outside the recommended pH range by WHO, being acidic in nature. The minimum and maximum pH values (5.68 and 7.13) were observed respectively in the sample collected from the reservoir and in the purified water released to the consumers. The pH of drinking water has no immediate direct effect on human health but can cause some indirect health effects by making changes in other water quality parameters such as solubility of metals and survival of pathogens [21]. Literature data [22] demonstrated that at low pH, water can become corrosive and cause damage to equipment, since it can increase leaching of metals such as copper and lead from pipes and fixtures.

Table 1. Analytical methods and instruments used for measuring the physicochemical parameters of water

Parameter	Unit	Analytical method	Instrument used
Colour	Hazen units	Colorimetry	DR 5000 UV spectrophotometer
Turbidity	NTU	Turbidimetry	ORION AQ 3010 turbidity meter
pH	--	--	WTW Multi 3510 IDS meter
Electrical conductivity	µs/cm	--	WTW Multi 3510 IDS meter
Total alkalinity	mg/l	Titrimetry	--
Total hardness	mg/l	Titrimetry	--
Free ammonia	mg/l	Colorimetry	DR 5000 UV spectrophotometer
Chloride	mg/l	Titrimetry	-
Total phosphate	mg/l	Colorimetry	DR 5000 UV spectrophotometer
Fluoride	mg/l	Colorimetry	DR 5000 UV spectrophotometer
Total iron	mg/l	Colorimetry	DR 5000 UV spectrophotometer
Calcium	mg/l	Titrimetry	--

Table 2. Physical parameters of the collected water samples

Parameter	SLS (614.2013) Maximum Permissible Level	WHO (2011) Maximum Permissible Level	L1	L2	L3	L4	L5	L6
Colour (Hazen unit)	15	15	00	26	53	36	06	00
Turbidity (NTU)	02	05	0.48	3.1	6.85	5.12	0.61	0.54

Table 3. Chemical parameters of the collected water samples

Parameter	SLS (614.2013) Maximum Permissible Level	WHO (2011) Maximum Permissible Level	L1	L2	L3	L4	L5	L6
pH	7.5	7.0-8.5	6.07	5.86	5.68	6.11	5.98	7.13
Electrical conductivity (µs/cm)	750	750	69.5	74.6	78.7	79.2	83.7	89.6
Total alkalinity (as $CaCO_3$) (mg/l)	200	300	17	22	24	25	27	19
Total Hardness (as $CaCO_3$) (mg/l)	250	500	16	23	19	21	21	24

High pH in water has been demonstrated to cause eye irritation, skin disorders, swelling of hair fibers and gastrointestinal irritations in sensitive people [17].

The electrical conductivity (EC) is another parameter used in assessing the water quality and it is an indirect indicator of water pollution particularly in case of discharging wastewater or sewage into a water body [23]. The EC values of the samples tested were ranged from 69.5 - 89.6 µs cm^{-1} which were well below the maximum permissible levels set by both SLS (614.2013) and WHO (2011) showing 100% conformity. The work carried out by [24] explained that various factors such as agricultural and industrial activities and land use affect the electrical conductivity of water. Intensive use of artificial fertilizers causes leaching of excess fertilizer to the water bodies, which can increase the EC of water beyond the safe levels and ultimately impair with the uptake of water and nutrients by roots. However, due to the conserving status of the Dunumadalawa forest reserve, entering inorganic fertilizers or wastewater to the streams and reservoir is impossible and could be the reasons for having very low levels of electrical conductivity in water.

Total hardness of water is due to the presence of bicarbonate, sulphates, chloride, and nitrates of calcium and magnesium [25]. In most natural waters, the predominant ions are those of bicarbonates associated mainly with calcium to a lesser degree with magnesium [26]. Maximum permissible limit for total hardness of water is 250 and 500 mg/l, as per SLS and WHO standards respectively and the total hardness recorded for the tested water samples was far below the limits and ranged between 16 - 24 mg/l, with 100% conformity with both standards. Hardness has no adverse effect on human health, but water with hardness above 250 mg/l may result scale deposition in the water distribution systems and more soap consumption [17]**.**

The concentrations of other nutrients such as ammonia, nitrate, phosphate, fluoride and iron in the water samples were also determined (Table 4). Ammonia, nitrate, phosphate and fluoride levels were found to be below the maximum permissible levels set by WHO and Sri Lanka standards. Iron is considered as an indicator parameter of water. The presence of high concentrations of iron changes colour, taste and odour of water [27] and makes water turbid [28].

This study showed that the total iron in water samples collected from the locations L2, L3 and L4 was higher than the recommended values of WHO and SLS. According to [28], water containing iron expose to air or oxygen, become cloudy and turbid due to the oxidation of iron to Fe^{3+} state, which forms colloidal precipitates. This could be one of the reasons of having high colour and turbidity of the samples collected at locations L2, L3 and L4. The lowest level of iron was obtained in the sample collected at L1; the head of the stream (0.04 mg/l). As revealed by [29], water percolating through soil and rocky surfaces can dissolve iron and hold them in the solution. Apparently, since this stream water percolates through soil and rocks for about 500 m in length before it reaches the Roseneath reservoir, dissolved iron can seep into the water body. This could be the reason of having a considerably high amount of iron in the non-treated samples collected at L2, L3 and L4 locations. The highest iron concentration was found in the reservoir (L3). Iron forms rust in water and can cause clogs and stains water pipes **[**30, 26]. However, WHO states that 0.3mg/l of iron does not affect the taste of water. Interestingly, a great reduction of the levels of iron in filtered and purified water was detected in samples L5 and L6, having 0.08 mg/l and 0.06 mg/l respectively.

3.3 Bacteriological Parameters of Water

The results of bacteriological parameters of the six water samples tested are presented in Table 5.

The membrane filtration technique used in enumeration of coliform bacteria in this study is fully accepted and approved as a procedure for monitoring microbial quality of drinking water in many countries. Total coliforms and fecal coliforms are detected using selective and differential culture media. For total and faecal coliforms m-Endo agar and m-FC agar are used respectively. On m-Endo agar, coliforms form red colonies with a metallic sheen and on m-FC agar, fecal coliforms form dark blue colonies.

Table 5 shows the numbers of coliform bacteria and *E.coli* in 100ml samples of water collected from six different locations of the study site. According to the WHO permissible limits, a zero count of *E. coli* per 100 ml of water is considered as safe for drinking. A count of 1–10 cells/100 ml is regarded as low risk and 11–100 cells/100 ml as medium risk. The *E. coli* count greater than

Table 4. The concentrations of other nutrients of the collected water samples

Parameter	SLS (614.2013) Maximum Permissible Level	WHO (2011) Maximum Permissible Level	L1	L2	L3	L4	L5	L6
Free ammonia (as NH_3)	0.06	0.5	0.04	0.17	0.26	0.29	0.05	0
Nitrite (as NO_2^-)	3	3	0.013	0.02	0.01	0.021	0.019	0.019
Total phosphates (as PO_4)	2	5	0.03	0.35	0.29	0.32	0.34	0.03
Fluoride (as F)	1	1.2	0.12	0.13	0.22	0.08	0.09	0.26
Total iron (as Fe)	0.3	0.3	0.04	0.36	0.53	0.36	0.08	0.06

Table 5. Coliform and *E. coli* counts of collected water samples

Parameter	WHO (2011) Maximum Permissible Level		L1	L2	L3	L4	L5	L6
	Pipe-born water	Well water						
Total coliforms/100 ml sample	< 3	< 10	1	3	4	2	2	1
E.coli/100 ml sample	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil

100 cells/100 ml is declared as high risk. With reference to the Table 5, it is evident that the water from all six locations had 100% compliance with WHO standards. The total coliform counts for samples examined during this study were lower than the WHO limit and a slightly higher count was obtained only for the untreated water sample collected from the reservoir. This was an indication that the water sample obtained from the reservoir was slightly faecally contaminated. The reason could be the addition of excreta of wild animals such as deers and monkeys those who are coming to the reservoir for searching water.

4. CONCLUSION

Improving the quality of water before used by consumers is depending on the efficiency of drinking water treatment processes, which must be safe and meet the standard criteria for public health. The statistical analysis of treated water (L6) clearly indicated lower values for all physicochemical and bacteriological parameters than the maximum permissible levels of WHO and Sri Lanka standards. Thus, it can be concluded that there are no major problems associated with the existing water purification plant in the forest and the purified water is certainly safe for drinking purposes. But the regular monitoring of water as currently undertaking is emphasized. Filtration represents a barrier for some of the most common issues encountered in the water purification industry such as removal of colour, turbidity and harmful microorganisms. Comparing the level of colour and turbidity of water samples collected before filtration, it was found that the samples collected before filtration (L1-L4), had values above the permissible levels of SLS and WHO, but found to be extremely below the maximum limits after filtration. This result indicated that the efficiency of filtration unit at the Roseneath water treatment plant is in the correct order. Interestingly, the analyzed data showed that the water sample collected from the head of the stream (L1) is certainly safe for drinking purposes without any form of treatment.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Nagarnaik PB, Patil PN. Analysis of ground water of rural areas of Wardha-city using physico-chemical and biological

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2. Gellu A, Rajitha J, Praveen P, Kumar JV. Assessment of total dissolved solids and pH of wastewater, Musi river study area. International Journal of Research Studies in Science, Engineering and Technology. 2015;2(11):65-68.
3. Li P, Wu J. Drinking water quality and public health. Exposure and Health. 2019;11(2):73–79.
4. Tebutt THY. Principles of quality control. Pergamon, England; 1983.
5. Edema MO, Omemu AM, Fapetu OM. Microbiology and physicochemical analysis of different sources of drinking water in Abeokuta. Nigeria. Nigerian Journal of Microbiology. 2001;15(1):57-61.
6. Payment P, Hunter PR. Endemic and epidemic infectious intestinal disease and its relationship to drinking water. In: Fewtrelland L, Bartram J (eds) Water Quality: Guidelines, Standards and Health Risk Assessment and Management for Water-related Infectious Disease. IWA Publishing. London; 2001.
7. García-Betancourt T, Higuera-Mendieta DR. González-Uribe C. Cortés S. Quintero J. Understanding water storage practices of urban residents of an endemic dengue area in Colombia: Perceptions, rationale and socio-demographic characteristics. PLoS ONE. 2015;10 (6):e0129054.
8. Karavoltsos S, Sakellar A, Mihopoulo N, Dassenakis M, Scoullos MJ. Evaluation of the quality of drinking water in regions of Greece, Desalination. 2008;224(1–3):317–329.
9. Afkar E, Al-Sheikh HM, Khalifa AYZ. *Pseudomonas* spp. - the most popular water contaminants of fresh water storage tanks in Al-Ahsa providence, KSA. Journal of Pure and Applied Microbiology. 2014;8(5):3609-3616.
10. Edrington TS, Looper ML. Duke SE. Callaway TR. Genovese KJ. Anderson RC. Nisbet DJ. Effect of ionophore supplementation on the incidence of *Escherichia coli* O157:H7 and *Salmonella* and antimicrobial susceptibility of fecal coliforms in Stocker cattle. Foodborne Pathogens and Disease. 2006;3:281-294.
11. Mallin MA, Cahoon LB, Toothman BR, Parsons DC, Mclver MR, Ortwine ML, Harrington RN. Impacts of a raw sewage spill on water and sediment quality in an urbanized estuary. Marine Pollution Bulletin. 2007;54:81-88.
12. Derlet RW, Carlson JR. Coliform bacteria in Sierra Nevada wilderness lakes and streams: What is the impact of backpackers, pack animals and cattle? Wilderness and Environmental. Medicine. 2006;17:15-20.
13. Blatchley ER, Gong WL, Alleman JE, Rose JB, Huffman DE, Otaki M, Lisle JT. Effects of wastewater disinfection on waterborne bacteria and viruses. Water Environment Research. 2007;79:81-92.
14. Price RG, Wildeboer D. *E. coli* as an indicator of contamination and health risk in environmental waters. In: *Escherichia coli*-Recent Advances on Physiology, Pathogenesis and Biotechnological Applications, IntechOpen, London; 2017.
15. Silva EIL. Status of water quality in Sri Lanka. In: Recent trends in environmental biogeochemistry. V. Ittekot and V. Subramanian (eds.), SCOPE publicaction, Hamburg University, Hamnburg, Germany; 1999.
16. Dharmasena C, Ekanayake H, Abeysinghe S, Dharmasena C. Dunumadalawa Forest Reserve. Loris. 2001;22:55-57.
17. Sri Lankan Standards 614: Drinking water standard - First Revision; 2013.
18. WHO (World Health Organization). Guidelines for drinking water quality, 4rd ed. Recommendations, vol. 1. WHO Press, World Health Organization, Geneva, Switzerland; 2011.
19. Paaijmans KP, Takken W, Githeko AK, Jacobs AF. The effect of water turbidity on the near-surface water temperature of larval habitats of the malaria mosquito *Anopheles gambiae*. International Journal of Biometeorology. 2008;8:747-753.
20. Heberling MT, Nietch CT, Thurston HW, Elovitz M, Birkenhauer KH, Panguluri S, Ramakrishnan B, Heiser E, Neyer T. Comparing drinking water treatment costs to source water protection costs using time series analysis. Water Resources Research. 2015;51:8741– 8756.
21. Zabed H, Suely A, Faruq G, Sahu JN. Water quality assessment of an unusual ritual well in Bangladesh and impact of mass bathing on this quality. Science of the Total Environment. 2014;472:363–369.
22. Kim EJ, Herrera J.E, Huggins D, Braam J, Koshowski S. Effect of pH on the concentrations of lead and trace contaminants in drinking water: A

combined batch, pipe loop and sentinel home study. Water Research. 2011;45: 2763–2774.
23. De Sousa DN, Mozeto AA, Carneiro RL, Fadini PS. Electrical conductivity andemerging contaminant as markers of surface freshwater contamination by wastewater. Science of the Total Environment. 2014;484:19–26.
24. Scatena FN. “Drinking water quality,” in Drinking Water from Forests and Grasslands: A Synthesis of the Scientific Literature, G. E. Dissmeyer, Ed., General Technical Report SRS-39, Department of Agriculture, Southern Research Station, Asheville, NC, USA; 2000.
25. Kumar A, Bisht BS, Joshi VD, Singh AK, Talwar A. Physical, chemical and bacteriological study of water from rivers of Uttarakhand. Journal of Human Ecology. 2010;32:169-173.
26. Khan RM, Jadhav MJ, Ustad R. Physicochemical analysis of Triveni Lake water of Amravati district in (MS) India. Bioscience Discovery. 2012;3:64-66.
27. Behera B, Das M, Rana GS. Studies on ground water pollution due to iron content and water quality in and around, Jagdalpur, Bastar district, Chattisgarh, India. Journal of Chemical and Pharmaceutical Research. 2012;4(8): 3803-3807.
28. Khadse GK, Patni PM, Labhasetwar PK. Removal of iron and manganese from drinking water supply. Sustainable Water Resources Management. 2015;1:157–165.
29. Dvorak BI, Skipton SO. Drinking water: iron and manganese. Neb guide published by University of Nebraska-Lincoln extension, Institute of Agriculture and Natural Resources; 2007.
30. Rajini K, Roland P, John C, Vincent R. Microbiological and physicochemical analysis of drinking water in George town. Nature and Science. 2010;8(8):261-265.

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