Water quality and biology of hot springs waters of Mahapelessa, Sri Lanka

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***Abstract*- One of the major hot springs areas in Sri Lanka is located in Mahapelessa, Hambanthota district. This study was designed as a preliminary study of the biological and physico-chemical properties of hot water wells. Two hot springs (A and B) and one normal well (C) located within 300 m distance were selected. Water samples were collected from the surface, middle and bottom layers of the wells biweekly during August to October 2013 and the water was filtered using 30 µm mesh from the vertical column of bottom to surface for analyzing the biology.**

The mean temperature values were 44.1 ± 0.5 ^{0}C, 33.6 ± 1.0 ^{0}C and 27.8 ± 0.7 ^{0}C respectively in the wells of A, B and C. There was no significant difference of pH, DO and Phosphate concentrations among the two hot springs the normal well. However, salinity, nitrate and total hardness in the wells A and B were significantly different from the normal well ($p<0.05$, post hoc) and conductivity was significantly different among the three water sources. Several phytoplankton species (i.e. *Spirogyra* sp., *Gloecapsa* sp., *Elakatothrix* sp., *Scenedesmus* sp.) and zooplankton species (*Keratella* sp., *Moina* sp.) were identified only in the well A and they can be considered as indicator species of the water temperature above 40 ^{0}C. Also, the organisms such as *Lyngbya* sp., *Amoeba* sp., Harpacticoid and Nematodes were observed only in well B with the average temperature of 33.6 ^{0}C. Filamentous Blue green algae of *Nostoc* sp. was found only in the normal well may be due to its high sensitivity of water temperature. The relatively highest abundant organism of *Paramecium* sp. shows a significant negative correlation between the water temperature and its abundance in the three wells (r^2 = 0.832).

***Index Terms*— Hot Spring, Indicator species, Physico-chemical properties**

I. Introduction

Generally hot water springs locate all over the world at special geological areas, mainly near volcanic regions. World famous hot water springs are located in the countries of United State of America, United Kingdom, Canada, Iceland, New Zealand, Japan, Italy etc. (Ranasinghe, 2005).The major process of thermal water is the meteoric water that brings the heat from the interior to the surface through a permeable path of the aquifer. The main heat source is from magmas within the crust that intrudes to shallower levels from unstable areas such as active volcanic belts or fault zones. Generally water in hot spring is basic, and in some of hot springs the water is acidic. Chemical content of the water in hot springs changes according to the chemical composition of rocks situated on path of the hot water flow. When the temperature of water increases, it caused to increase the dissolving rate of minerals. So it may be a reason to increase the herbal value of water in hot springs (Fonseka, 1995). Saussure (1976) has found that both animals and plants in some European hot spring at the end of the eighteenth century and they can become more and more apparent that the biota of the hot springs is more resistant to heat than other organisms. Saha (1993) noticed the presence of *Oscillatoria formosa, Synechococcus curtus, Fischerella thermalis and Anabaena* sp. at temperature ranges of 53.8 – 55.8 ^{0}C from hot water spring of Agnano, Italy. Primary productivity along thermal gradient has been measured in hot water springs of Mount Lassen and Yellowstone National Park in United State of America in 1966 and two thousand species of diatoms and several genera of other algae were recorded from the hot water springs of Iceland.

There are nine recognized hot water springs in Sri Lanka in Rankihiriya, Galwewa (Nelumwewa), MahaOya, Marangala, Kiwulegama (Jayanthiwewa), Kinniya, Kapurulla, Wahawa, Mahapelessa and Muthugalwela (Fonseka, 1995). All the hot water springs are found within the totally different geological units of Highland and Vijayan complexes in Sri Lanka. These hot springs or thermal springs are distributed along a narrow Eastern low land belt running from Hambantota to

Trincomalee within the boundary of two main geological units - the Highland and Vijayan complexes (Piyadasa et al., 2011).

The geo-physical study of Ranasinghe, (2005) said that there are two fractures along 6 km and 10 km distances at north and south direction and north-east and south-west directions. Due to high hydrogen concentration in the water, this fracture shows more than 10 km depth. Water percolates in to the earth about 3 km through that fracture and heated about 103 ^{0}C temperature and it comes back to the surface of the earth through the fractures (Ranasinghe, 2005).

II. MATERIALS AND METHODS

Description of the study area

Two hot spring wells and one normal well located within 300 m distance were selected to study the physico-chemical parameters and biology (Figure 1).

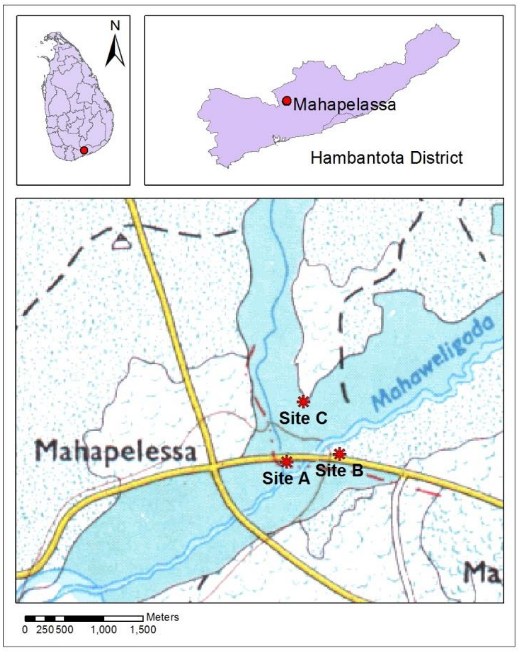


Fig. 1. Locations of the selected wells (A, B, C) in Hambantota district

Analysis of physico-chemical parameters

Temperature, pH, salinity, conductivity and dissolved oxygen, were measured on site and water samples were filtered via nitrocellulose filter papers to analyze nitrate, phosphate and total hardness. All the samples were taken from surface, middle and bottom of each well biweekly during the period of August to October 2013. The summary of analytical methods describes in the Table 1.

TABLE I. ANALYTICAL TECHNIQUES OF WATER QUALITY PARAMETERS

Parameter	Methodology	Unit
pH	AD111 pH/mV/^{0}C Meter	-
Temperature	Water quality meter YSI 85 Japan	^{0}C
Salinity		ppt
Conductivity		mS/cm
Dissolved oxygen		mgL^{-1}
Nitrate	Photometry method (UV spectrophotometer, DR 2800) Sodium salicylate method	ppm
Phosphate	Photometry method (UV spectrophotometer, DR 2800) Ascorbic acid method	ppm
Hardness	Titrimetric method (EDTA method)	ppm

Analysis of Biological parameters

10 L of water from the surface, middle and bottom were filtered by using 30µm phytoplankton net and concentrated in to 100 mL to preserve with Lugol's iodine (Auinger et al., 2007). The number of cells was countered using a Sedgwick rafter and densities were determined using the equation given below (Hotzel and Croome, 1985).

$$n = \frac{a * b * 1000 * 10^6}{N * L}$$

Where, n = number of plankton in m^3
a = counted number of planktons
b = volume of concentrate express in ml
N = number of cells counted
L = volume water filtered

III. RESULTS AND DISCUSSION

Water quality parameters

The mean values of water quality parameters at three water levels in the selected wells are given in the Table 2. However, there were no significant variations of the above parameters at the three water levels and the average temperature of hot spring A, B and the normal well (C) were 44 ^{0}C, 33.6 ^{0}C and 27.8 ^{0}C respectively. A twenty years back research of Fonseka, (1994) has observed the temperature of the Mahapelessa hot spring as 44 ^{0}C and this can be classified as a homo thermal spring (Saha, 1993) or Euthermal spring (Vouk, 1923). Water pH in Kinniya hot water springs in Sri Lanka has been reported as 6.7-7.3 (Piyadasa et al., 2011) and Fonseka (1994) reported the water pH in the present hot spring as 7.1. The average water pH in hot springs of present study was depending on the amount of free CO_2 that dissolve in the water (Birge and Juday, 1911). Fonseka (1995) has observed low percentage of CO_2 in the Mahapelessa hot spring as 0.12 and it may be the reason for basic pH 7.5 (in the hot spring).

EC of Kinniya hot spring in Sri Lanka has been reported as 288-428 µS/cm (Piyadasa et al., 2011) and it has been reported as 710 µS/cm and 6800 - 7890 µS/cm in Mahapelessa according to Fonseka, (1994) and Piyadasa et al., (2011) respectively. The current EC value of 962 µS/cm explains that the geological background of the hot springs in the world can change the conductivity of them.

Salinity of Wilbur hot springs in California was 22 ppt (Barnby, 1987) and Salinity of Mahapelessa was 4.21 ppt which can be categorized as oligo haline water (USEPA, 2006). DO of Vashisht hot spring has been reported as 2.52 mg/L (Naresh, 2013) and the value is more or less similar to values in the present study.

According to Fonseka (1994), Phosphate concentration in Mahapelessa hot spring was 1.78 ppm. However, phosphate concentration in Mahapelessa was lower than the above value during the present study and the phosphate concentration in the normal well was higher than the maximum permissible level of 2 ppm for drinking purposes (BOI, 2011). Other important parameter is nitrate and it is also essential source to phytoplankton (Saha, 1993). Nitrate level in Unkeshwar hot spring in India was 9.5 ppm (Pathak et al., 2011) and the nitrate level in Monopol hot spring in Ethiopia was 0.14 ppm (Haki, 2012). In Mahapelessa hot spring the nitrate level has been observed as 1.02 ppm (Fonseka, 1994) and the level was similar to the value in present study. Normally, thermophilic bacteria live in hot springs are nitrifying and some others are denitrifying bacteria and the nitrate concentration in hot spring water effects on their activities (Dodsworth, 2011). However, nitrate level was lower than the maximum permitted level of 45 ppm for drinking water in the wells selected for the present study (BOI, 2011). Hardness of Unkeshwar hot spring was 27.7 ppm (Pathak et al., 2011) and in Vashisht hot spring it was 165.2 ppm (Naresh, 2013). Ca^{2+} concentration (533 ppm) has been recorded in Mahapelessa hot spring more than 15 years back (Fonseka, 1994) and observed hardness in the current study was relatively high (1262 ppm). According to BOI standards acceptable hardness value in drinking water is 250 ppm (BOI, 2011) and the water in normal well was at the recommended level.

TABLE II. MEAN VALUES OF THE WATER QUALITY PARAMETERS AT THE THREE LEVELS OF THE THREE WELLS (MEAN SD)

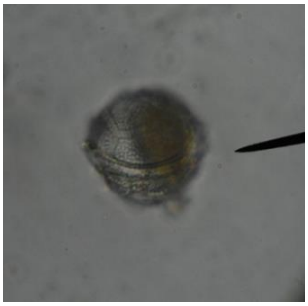
Site	Position	Temperature (^{0}C)	pH	Salinity (ppt)	Conductivity (mS/cm)	Dissolve oxygen (mg/L)	PO_4^{-2} (ppm)	NO_3^- (ppm)	Hardness (ppm)
Hot Spring (A)	Surface	43.8±0.5	7.47±0.20	4.2±0.0	10.16±5.78	2.16±1.28	0.06±0.07	0.13±0.19	1288.42±30.12
	Middle	44.2±0.6	7.56±0.36	4.2±0.0	9.63±1.58	1.75±0.58	0.07±0.08	0.08±0.07	1270.97±28.56
	Bottom	44.4±0.6	7.54±0.24	4.2±0.0	9.09±2.57	1.92±0.71	0.08±0.08	0.04±0.02	1234.57±32.89
Inter mediate Spring (B)	Surface	33.8±0.4	7.60±0.24	4.2±0.0	8.77±0.63	2.29±1.21	0.18±0.20	0.04±0.01	1324.41±35.55
	Middle	33.3±1.8	7.51±0.22	4.2±0.0	8.08±2.15	1.85±1.29	0.09±0.11	0.38±0.65	1366.19±31.70
	Bottom	33.6±1.1	7.44±0.28	4.2±0.0	7.35±3.80	1.68±1.25	0.11±0.12	0.04±0.02	1285.18±30.23
Normal well (C)	Surface	27.8±1.0	7.47±0.32	0.4±0.0	0.75±0.14	3.80±1.79	0.22±0.13	1.08±0.48	259.39±14.80
	Bottom	27.7±0.6	7.42±0.34	0.4±0.0	0.81±0.03	3.29±1.01	0.27±0.17	0.56±0.32	243.22±14.45

The identified organisms in the three wells their family and special features are given in the Table 3. *Paramecium* sp. and *Chaetonotus larus* were common organisms presence in the three wells and there were some organisms presence only in the hot spring wells. Saha, (1993) said that algae (eg. *Navicula*, *Spirogyra*) can tolerate very high range of temperatures and form the dominant group of thermal spring biota. Some green algae have been found at 44 ^{0}C in Nevada hot spring at Yellow stone national park in America (Brues, 1928). Both ammonia and nitrate could be used directly by some kinds of species of blue green algae and diatoms (Chu, 1943) and water pH from 7.3-8.4 provided the optimum conditions for the favorable growth of plankton (Villadolid et al., 1954).

The present study shows that the presence of cyanobacteria, diatoms, annelids, micro crustaceans, dianoflagellates, ciliates, desmids etc. in the hot spring. Even though the temperature of the hot spring was 44 ^{0}C, *Spirogyra*, *Peridinium*, *Gloeocapsa*, *Pediastrum*, *Staurastrum*, *Scenedesmus*, *Keratella* and *Tubifex* species were observed there. Table 4 gives the abundance of major organisms except those with lower abundance than $(5\times10^4)/m^3$ in the wells. Among the organisms the most abundant organism was *Paramecium* sp. in the three wells. According to the abundance, the most prominent group was *Paramecium.* However, *Paramecium* sp. is extremely sensitive to slight changes in its environment and in consequence has been used, since the days of Spallanzani, as a biological indicator and the rate of forward movement in *Paramecium* sp. as affected by changes in temperature (Glaser, 1924).

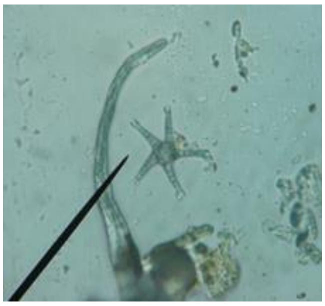
TABLE III. IDENTIFIED ORGANISMS, THEIR FEATURES AND PRESENCE/ABSENCE IN THE THREE WELLS.

Name of the Organism	Family	Features	Well A	Well B	Well C
Spirogyra sp.	Zygnemataceae	Spiral band like Chloroplast.	✓		
Peridinium sp. (P1.1)	Peridiniaceae	Grooves on cell surface and encircling the cell.	✓		
Gloeocapsa sp.	Microcystaceae	Sheath with grouped in 2, 4 or 8 cells.	✓		
Pediastrum sp. (P1.2)	Hydrodictyaceae	Spiny like outer margin of cells of colony.	✓		
Staurastrum sp. (P1.3)	Desmidiaceae	Star shaped, spiny like terminal ends.	✓		
Scenedesmus sp. (P2.8)	Scenedesmaceae	Four curved spines on corner of cell wall.	✓		
Paramecium sp. (P2.6)	Parameciidae	Cilia presented around the body.	✓	✓	✓
Elakatothrix sp.	Elakatotrichaceae	Boat shaped body. Green color.	✓		
Chaetonotus larus	Chaetonotidae	Posterior part divided into two spines.	✓	✓	✓
Philodina sp. (P2.4)	Philodinidae	Two rotating wheels, straight body.	✓	✓	
Keratella sp. (P2.1)	Brachionidae	Spiny like tail, serrated spines on anterior end.	✓		
Tubifex sp. (P2.2)	Naididae	Each segment has parapodia on both sides.	✓		
Lyngbya sp. (P2.10)	Oscillatoriaceae	Filamentous with firm sheath.		✓	
Amoeba sp. (P2.12)	Amoebidae	Pseudopods were presented.		✓	
Navicula sp. (P2.11)	Naviculaceae	Boat shaped body. Brown color.	✓	✓	
Actinosphaerium sp. (P2.3)	Actinophryidae	Spherical cell body with pseudopodia.	✓	✓	
Harpecticoid		A very short pair of first antennae.		✓	
Moina sp. (P2.7)	Moinidae	Well-developed 2nd antenna and apical spine.	✓	✓	
Nematoda		Worm.		✓	
Nostoc sp. (P2.5)	Nostocaceae	Spherical cells and heterocyst.			✓
Oscillatoria sp. (P2.9)	Oscillatoriaceae	Filamentous without firm sheath.		✓	✓



P1.1: *Peridinium* sp.

P1.2: *Pediastrum* sp.

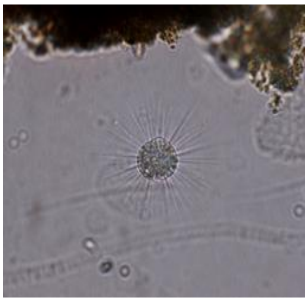


P1.3: *Staurastrum* sp.

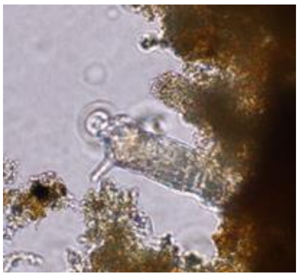
Plate 1

P2.1: *Keratella* sp.

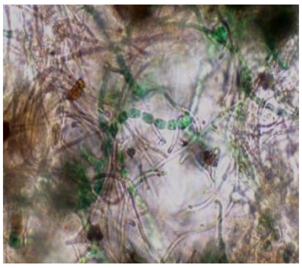
P2.2: *Tubifex* sp.



P2.3: *Actinosphaerium* sp.

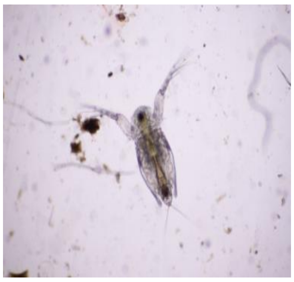


P2.4: *Philodina* sp.



P2.5: *Nostoc* sp.

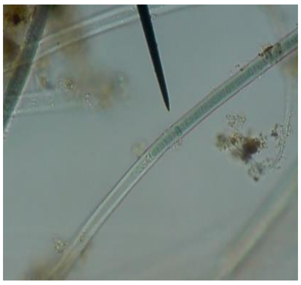
P2.6: *Paramecium* sp.



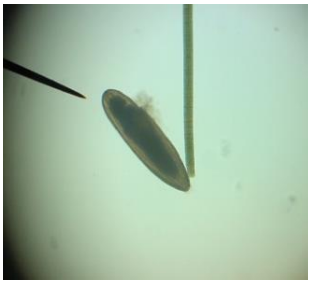
P2.7: *Moina* sp.

P2.8: *Scenedesmus* sp.

P2.9: *Oscillatoria* sp.



P2.10: *Lyngbya* sp.



P2.11: *Navicula* sp.

P2.12: *Amoeba* sp.

Plate 02

TABLE IV. THE ABUNDANCE OF MAJOR ORGANISMS IN THE WELLS

Site	Species name	Density ($\times 10^4$)/m^3
Well A	*Paramecium* sp.	09
	Staurastrum sp.	08
	Pediastrum sp.	05
	Peridinium sp.	05
Well B	*Heliozoa* sp.	15
	Paramecium sp.	12
	Oscillatoria sp.	06
	Chaetonotus sp.	05
Well C	*Oscillatoria* sp.	08
	Paramecium sp.	20
	Nostoc sp.	05
	Chaetonotus sp.	05

IV. CONCLUSION

According to the results and comparisons, water temperature, pH and dissolved oxygen of the hot spring were not significant variables with the time among the studied three wells. *Paramecium* sp. was the most abundant and most common species in the three wells. The average water temperature of 44 ^{0}C represented by *Spirogyra*, *Peridinium*, *Gloeocapsa*, *Pediastrum*, *Staurastrum*, *Scenedesmus*, *Keratella* and *Tubifex* species in the well A. The average water temperature of 33 ^{0}C represented by *Lyngbya* sp., *Amoeba* sp., Harpecticoid and Nematodes in the well B. *Nostoc* was the only organism found at average temperature of 27 ^{0}C in the normal well.

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