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GEOCHEMICAL INVESTIGATION OF HOT SPRING WATER IN SIKKIM HIMALAYA: A BASELINE APPROACH

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ABSTRACT

The hot springs have gained significant attention owing to its religious faith and medicinal importance in addition to domestic and international tourism. There has been a scarcity of work done in the Sikkim Himalayas at the numerous hot springs. The present study attempts to fill the gap and examines the physico-geochemical characteristics aims of selected hot springs at the northern and western regions of Sikkim. The hardness and ion studies alongwith major and trace elements reveal that Ca and Mg show higher concentration in few springs, whereas Reshi hot spring shows high enrichment of Ca, Fe, K, Mg, Na followed by Borong hot spring. A similar concentration was observed for Se at all the HS water. The observed concentration of different elements and ions are significantly within the permissible limit as recommended by BIS 2012.

KEY WORDS : Hot Springs, Sikkim, Geochemical, Cations, Major and trace elements

INTRODUCTION

The study of Hot Spring (HS) water has witnessed remarkable attention in recent years owing its complex characteristics and diversification in their utilization. The highly mineralized water in these springs consists of meteoric water and gets modified during underground passage of the water (Todd, 2007). The high temperature of HS water leads to higher solubility as compared to normal water and thus, they have high mineral content like calcium, lithium, sulphur, fluorides, carbonic acid, hydrogen sulfide etc. The natural heat with high mineral content of spring water is a key attraction for tourists and recognized as centres for social medicine, religious and faith healing centers for the local community (Das *et al.*, 2012). The sites thermal spring water is widely utilized for agriculture, aquaculture, industrial processing, bottled water and the extraction of rare elements (Shevenell *et al.*, 2002) through the physico–chemical assessment of water quality (Lakshmi *et al*., 2016).

The recent urbanization and industrialization have accelerated a lot of development activities taking a toll on the natural resources and the environment. The stress on natural resources and subsequent deterioration of landscape has intimate implications with the water quality of the region. The quality of water and its impact on health is widely established, whether being used for it has been used for drinking, purposes, recreational, domestic or industrial purposes. The poor water quality has been cited as an important factor in many diseases e.g renal failure due to lead and cadmium, liver cirrhosis due to copper and molybdenum, hair loss due to nickel and chromium, chronic anemia due to copper and cadmium etc

There are numerous HS in Sikkim which often attracts thousands of local, domestic and international tourists due to the social, religious and medicinal values. These HS have emerged as prominent recreational zones with the recent concept of economic and wellness tourism in Sikkim. Moreover, these HS water is also used by the population for bathing as well as for drinking and cooking purposes (Sherpa *et al*., 2012). The physical and chemical characteristics and its evaluation are highly significant to assess whether they are suitable for consumption for the people who are using this water for various purposes.

The study on the qualitative aspect of hot spring water in Sikkim Himalaya has not been given its due significance and very limited study has been reported from this region. A study comprising chemical and the physical properties of four HS of Sikkim viz. Polot, Tecopa, Borong and Reshi was conducted with the assumption that these springs are capable of curing diseases. The analysis revealed calcium and magnesium concentration at 65ppm and 25ppm respectively at Reshi HS (Sherpa *et al.*, 2013). A chemical analysis of major ions along a fault line (Homma *et al.*, 2008) and micro-biological test at some of the HS viz. Polok, Borong, Reshi (Das *et al.*, 2012) was reported in separate studies. A GPS mapping and physical description of Polok, Borong and Reshi HS of Sikkim was carried out (Sherpa *et al.*, 2013), although it did not involve chemical analysis. It is therefore evident that a detailed physico-chemical analysis of HS in Sikkim is scarce. The present study aims to fill the gap through preliminary investigation of geochemical characteristics of HS water at selected HS in Sikkim Himalayan region viz. Borong, Reshi, Yumthang and Yumthang. Since a study on water quality from a geo-chemical perspective has not been conducted so far, hence this study may help to establish a baseline data and have a qualitative assessment of HS water in Sikkim.

Area of Study

The present study has been undertaken at four thermal springs viz. Borong, Reshi, Yumthang and Yumthang in the Himalyan state of Sikkim (Fig. 1). The Borong and Reshi HS are located at the banks of river Rangeet in West district of Sikkim, The Yumthang hot spring, also known as Cha-cha hot spring, is located near the bank of Yumthang Chhu at an altitude of 3570 meter above msl and Yumesamdong HS is located at an altitude of 4700 m at the bank of river Sebu Chhu river bed at North district of Sikkim. The local people usually visit these HS because of its religious faith and medicinal importance in as well as the domestic and international tourism.

The climate of the Sikkim has been roughly divided into the tropical, temperate and alpine zone. The climate in Sikkim is mostly cold and humid and it receives heavy rainfall during monsoon. The climate is comparatively drier during October-March. The extreme northern parts, adjoining Tibet, however, receives relatively little rainfall.

The lithology is dominated by sandstone, carbonaceous shale and coal (Gondwana), stromatolitic dolomite and variegated slate (Buxa and Reyang Formation of Daling Group) and a thick metasedimentary sequence of dominantly pelites with subordinate psammite and wacke (Gorubathan Formation of Daling Group), constituting the Lesser Himalayan Belt. Towards the north, Daling sequence is overlain by Higher Himalayan rocks of medium to high grade dominantly pelitic schist with minor interbanded quartzite, calc-silicate and metabasites (Chungthang/Paro Formation) and small bodies of granites (Lingtse Gneiss). This sequence in turn towards north overlies a migmatitic terrain known as Darjeeling Gneiss/Kanchenjunga Gneiss and thought to be equivalent Central Crystalline/ Greater Himalayan Crystalline /Higher Himalayan Crystalline (GHC/HHC). In the far north, a thick pile of fossiliferous Cambrian to Eocene sediments, belonging to the Tethyan Belt (Tethyan Sedimentary Sequence) overlies the Higher Himalayan Crystallines. Three distinct mappable and regional lithotectonic assemblages have been recognized within the Daling Group by Acharyya (1989) which are described as Gorubathan Formation, Reyang Formation and Buxa Formation

MATERIALS AND METHODS

The samples from HS water were collected from four different HS located at Yumesamdong, Yumthang, Borong and Reshi in sterile bottles in October 2016. At each sampling site, 500 mL of sample was collected in triplicate and then 2 mL of HNO_3 was added to each sample for trace element analysis (Ural *et al.*, 2011). For the analysis of cations and anions, 500 mL of water samples were also collected in triplicate which is then preserved by microfiltration and acidification to pH below 2 (Alfaro, 2005). The concentration of calcium and magnesium was determined by EDTA Titration (Mahapatra and Ghosal, 2011) and that of carbonate and bicarbonates was estimated by pH and alkalinity method (Hydrology Project, 1999); while, the concentration of chloride was determined by argentometric titration method (Hydrology project, 1999). The hardness of water is subsequently determined by using (Total Permanent Hardness = $2.3[Ca^{2+}] + 4.1[Mg^{2+}]$), the calcium and magnesium ions concentrations of the sample water (IS:3025 (Part 21)– Reaffirmed, 2002). The major and trace

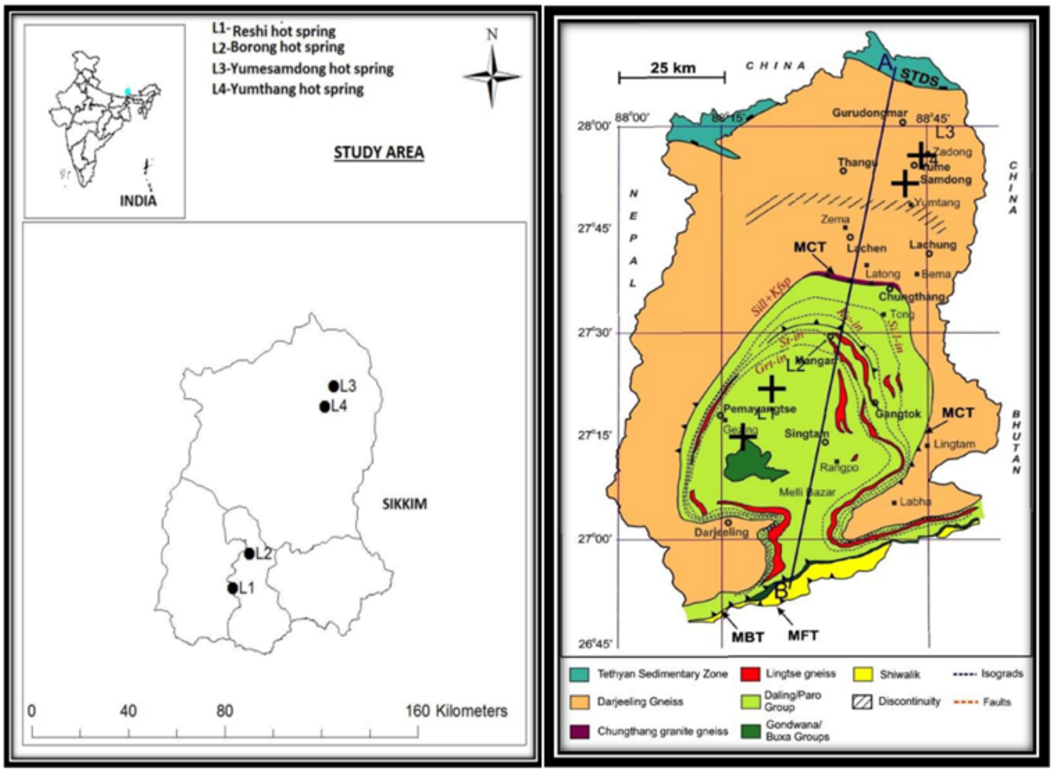

Fig. 1. Location Map of the area of study and the four Hot Spring (Source : Chakraborty *et al.,* 2016)

element concentration was determined by using Ion Coupled Plasma-Mass Spectrometer (ICP-MS).

RESULTS AND DISCUSSION

The summary of ions present in HS water has been presented in Table 1.

The in-situ temperature of the spring water ranges from 57 to 65°C in the month of October 2016. The Mg^{2+} was found to be highest at Reshi (43 mg/l) followed by Yumthang (11 mg/l), Borong (8 mg/l) and Yumesamdong (5 mg/l). The concentration of Ca^{2+} is also found to be highest at Reshi (58.8 mg/l) followed by Borong (19.6 mg/l), Yumthang (11.2 mg/l) and Yumesamdong (5.6 mg/l). The concentration of carbonate and bicarbonate ions ranges from 0.51-2.83 mg/l and 1.54-5.5 mg/l respectively. It is pertinent to mention that concentration of the ions present in the hot spring water is below the BIS permissible limit.

The chloride level is beyond detection. Usually, the source of magnesium is dolomite (sedimentary origin), serpentinite, talc, diopside (metamorphic origin) and olivine, hornblende and augite (igneous origin). However, calcium is generally derived from sedimentary origin (calcite, aragonite, dolomite, anhydrite and gypsum) and also released through weathering of igneous and metamorphic minerals like apatite, wollastonite, fluorite, feldspar, amphibolite and pyroxene (Fetter, 2000).

It is evident from the fact that the concentration of Ca^{2+} and Mg^{2+} is relatively higher at Reshi hot springs as compared to other three hot springs, whereas while the bicarbonate tends to be rich at

Table 1. Geochemical analysis of cations in the area of study

S. No.	Sample location	Date of Sampling	Temp (°C)	Concentration (mg/l) Mg	Ca	CO_3	HCO_3	Cl
1	Borong	26/10/16	65	8	19.6	0.51	2.5	0.01
2	Reshi	26/10/16	57	43	58.8	2.83	1.54	0.00
3	Yumthang	27/10/16	60	11	11.2	0.51	2.5	0.00
4	Yumesamdong	27/10/16	60	5	5.6	2.83	2.5	0.00

borong hot springs. Both Borong and Reshi hot springs are located in south sikkim, belonging to Daling and Gondwana Group. Borong hot spring lies at the crucial dividing junction or at the border zone of West Sikkim and South Sikkim. Thus, it is very important to understand the geological setting of West Sikkim and South Sikkim, as they relate to the Tatopani niche. The characteristic geological feature of West Sikkim district is mountainous terrain whereas South Sikkim shows rugged and immature topography. The lithology of the Tatopani area of West Sikkim consists of Sillimanite Granite Gneiss, Migmatite, Biotite Gneiss, Mica Schist and Kyanite which evolved during the Proterozoic era. Daling group which generally characterized by dolostones (Ca, Mg) CO_3, quartzites, metagreywacke, phyllite, pyriferrous black slate, whereas Damuda Formation of Gondwana Group is highly characterized by sandstone, calcareous sandstone, shale, carbonaceous shale (Bhattacharyya, 2009). Reshi hot spring generally lies in between Damuda and Buxa Formation consisting of cherty mature quartzite, chert and dolostone. The region is rich in sedimentary and metamorphic lithology. The dolostone units show the presence of stromatolites in its upper horizons, in the Rangit River section, Tatapani, West Sikkim (Kumar *et al.*, 2019). Thus, the presence of high concentration of calcium, magnesium, carbonates reveals that these ions have undergone water rock interaction throughout time. On the other hand Yumesamdong and Yumthang hot spring belong to complete pelatic migmatites and interbanded politic schist and metabasites and Kanchenjunga Augen Gniess.

Table 2. Determination of Hardness at the area of study

S.No	Sample location	Permanent Hardness, H_T (mg/l)	Water class
1	Borong	77.38	Moderately hard
2	Reshi	311.54	Very hard
3	Yumthang	70.86	Soft
4	Yumesamdong	33.38	Soft

Hardness

The hardness estimated from Ca^{2+} and Mg^{2+} has been illustrated in Table 2.

The water from Reshi HS is very hard as the highest hardness is reported from Reshi HS (311.54 mg/l) followed by Borong (77.38 mg/l), Yumthang (70.86 mg/l) and yumesamdong (33.38 mg/l). The hardness of the water from all the hot springs is much below the BIS permissible limit for hardness (600 mg/l). The principal natural sources of hardness in water are dissolved polyvalent metallic ions from sedimentary rocks, seepage and runoff from soils.

Major and Trace Elements

The concentrations of major elements viz. Al, Ca,Fe, K, Mg, Mn, Na and Si and trace elements viz. Cs, Ga, Hg, Rb, Se, Sr, and U has been tabulated in the Table 3.

The geochemical analysis of major and trace

Table 3. Concentration (ppb) of Major and Trace Elements

S.No	Element	Borong	Reshi	Yumesamdong	Yumthang
Major element					
1	Al	131.29	104.42	0.01	0.32
2	Ca	6.99	30.91	0.32	1.35
3	Fe	76.19	152.34	BDL	BDL
4	K	16.35	23.42	3.96	6.42
5	Mg	18.56	132.29	BDL	BDL
6	Mn	4.14	5.69	BDL	BDL
7	Na	73.66	354.25	173.57	187.12
8	Si	47.78	39.27	0.57	0.79
			Trace element		
1	Cs	1.62	7.66	5.19	0.82
2	Ga	0.37	2.61	1.19	0.45
3	Hg	0.49	0.06	0.74	1.12
4	Rb	4.61	7.88	1.56	1.62
5	Se	7.42	7.6	7.44	7.43
6	Sr	11.15	46.48	1.24	1.24
7	U	0.14	1.33	0.01	0.01

elements illustrates that Reshi HS shows high enrichment of Ca, Fe, K, Mg, Na followed by Borong hot spring. The concentration of Al and Si was found to be highest at Borong followed by Reshi HS. A relatively higher enrichment has been noticed for trace elements Cs, Ga, Rb, Se, Sr, and U at Reshi HS, while the highest concentration of Hg has been reported from Yumthang HS. A similar concentration was observed for Se at all the HS water.

CONCLUSION

The geochemical analysis at four selected hot springs in north and south sikkim HS shows variable concentration. Reshi and Borong HS show higher concentration of Ca and Mg whereas Carbonate ion concentration is higher at Reshi and Yumesamdong HS. The HS water shows higher bicarbonate concentration except Reshi, where it is the minimum in concentration. Reshi hot spring shows high enrichment of elements following Borong hot springs. The study indicates that the observed concentration of different elements and ions are significantly within the permissible limit as recommended by BIS 2012.

The hot springs have an intimate connection with the society and can be utilized for medicinal advancements. An in depth physical and geochemical study is the current requirement because the health of these hot springs have an association with tourism and thousands of people benefiting directly or indirectly from it. An investigation of temporal variability of physico-geo-chemical characteristics can be explored further to assess its linkages with climate change, if any.

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