Comparative Analysis of Physico-Chemical Parameters for Snow, Ground and River Water of Leh District

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Abstract- Water quality plays a very important role in deciding its suitability for Human consumption and other uses. The physico-chemical parameters of water are the main criteria in determining its quality. This paper deals with study of physico-chemical parameters of different water sources as snow, ground and river water of Leh district. The study was carried out in the month of March 2017. The analysis of collected water samples was carried out using known standard methods. Results were compared for water collected from different sources and it was found that contamination level with respect to physico-chemical and mineral parameters for snow water was less when compared to Leh groundwater, Thiksey monastery and Karu river water. Iron concentration was above the desirable level in all the collected samples. Hence it is recommended that the water should be properly treated for Iron removal before consumption.

Index Terms- Physico-Chemical Parameters, Leh district, Snow, River

I. Introduction

Water is one of the vital components of our life as it is needed for drinking, irrigation, other household/domestic and industrial activities. Among the various needs of water the most essential need is drinking. Generally surface and ground water are two major sources for supply of drinking water. Surface water comes from lakes, reservoirs and rivers. Groundwater comes from wells/aquifers. Nowadays drinking water demand is on the rise due to increasing population and depleting fresh water sources. Initially groundwater was considered as uncontaminated but with time its quality is getting deteriorated due to different natural and anthropogenic causes. Among the anthropogenic causes are heavy use of fertilizers and insecticides for increasing crop yield as well as other industrial effluents. Consumption of contaminated water leads to several water borne diseases in human population.

Leh lies in a cold desert, if seen from the perspective of surrounding area, it is called oasis in a desert since it is surrounded by icy cold mountain range of the Himalayas, one of the highest in the world. From geographic point of view this region is strategically very important since it lies near to Indo-Pakistan, Indo-China border and hence deployment of huge armed forces is there for protecting the border areas.

During winter season, the tough climatic conditions pose a challenge to the soldiers when the temperatures decline rapidly far below zero degree centigrade. Among the challenges faced by defence and civilian population the most severe one is availability of drinking water. At extreme altitudes, most of the water supply systems fail at subzero temperatures and in absence of any power supply the only viable alternative of drinking water which is in abundance is snow.

So far according to literature reports drinking water quality has been studied for Leh region by Dolma K et al (Dolma K et al, 2015) [1] and Bharti V. K et al (Bharti V. K et al, 2017)[2]. They have carried out baseline study of drinking water quality of samples collected from different sources such as ground, river, tube well and spring of Leh District. In this view it was a thought of interest to study the physico-chemical parameters of snow melted water as it has not been included in previous studies.

Hence, In this study we have carried out the analysis of physico-chemical properties of melted water from snow collected from high altitude of the order of 12000 to 18340 ft in Leh region of India, along with supply water and river water of the same district. The properties of snow melted water was compared with supply water as well as river water for assessing its quality with respect to pH, TDS, turbidity, conductivity and salinity, along with essential minerals and contaminants like iron and fluoride.

II. Experimental

A total of 18 samples were collected from nine different locations (Fig 1&2) of Leh (two samples were collected from each location) in the month of March 2017. Prior to sample collection all the plastic bottles were thoroughly washed and dried. The bottles were rinsed with water sample to be collected at the time of collection. For snow the samples were collected as such in dried bottles. Proper labeling was done after collection. Parameters like temperature and pH were measured at the sampling site using a thermometer and portable pH meter.
During samples collection, the latitude, longitude and altitude of all the sampling sites along with the source were recorded [Table I] using a GPS system (Model: Garmin GPS 72H). Sampling location map is made by Google earth 6.1 and QGIS 2.12 software (Fig. 1).

The bottles were then taken to the laboratory in an icebox to avoid unusual change in water quality and stored at 4°C for further analysis of turbidity, TDS, conductivity, salinity, mineral properties like presence of cations and anions, total hardness, iron and fluoride as per standard procedures used for water analysis (APHA ,2005) [3]. AR grade reagents, deionized water and borosil glasswares were used for preparation of solutions. pH was estimated by digital pH meter (EuTech pH 610). TDS, electrical conductivity and salinity were measured by using (Multiparameter EuTech CD 650). Turbidity was determined by using turbidity meter (EuTech TN 100). Mineral properties like presence of cations and anions were determined by using Ion Chromatograph (Metrohm 882 Compact IC Plus). Total hardness was determined by complexometric titration using Erichrome Black-T as an indicator (EDTA method). Iron was estimated via colorimetric method by using UV-Vis spectrophotometer (Analytikjena SPECORD 205). Fluoride was estimated by ion meter. (Thermoscientific ORION 4 STAR)

III. Results and Discussions

Fig 1 and 2 show water collection area along with points of collection (visual photographs, 2D & 3D images). The details of coordinates as well as information regarding source and altitude are shown in Table 1. Thus water samples were collected from three sources i.e. snow, underground supply water from Leh as well as Thiksey monastery and Karu river. The range of altitudes was from 11480 to 18340ft.

Physico-chemical and mineral analysis of all the collected water samples from different locations of Leh was carried out and results are shown in Table 2, 3 and 4 along with comparison with BIS standard values. The results obtained from this study are discussed below.

All the collected water samples were colorless and odourless. At the time of sample collection, the air temperature ranged between -10°C to 10°C. For snow samples the temperature recorded was -4°C.

pH:

The pH of any water body is a measure of its acidic or basic property. It is one of the very important parameters in determination of water quality since it affects solubility of various metallic contaminants. Fluctuations in pH value of any water body are related to discharge of industrial contamination or human waste or sometimes due to biological activity. The change in pH further leads to changes in physico-chemical parameters of water. Higher pH includes the formation of trihalomethanes which are toxic (BIS-10500, 1981)[4]. Alkaline pH value is witnessed due to presence of alkaline earth metals (Na, K) that interact with soluble CO forming carbonates and bicarbonates which result in shifting the pH up over 7 (Jena et al. 2013)[5]. In the present study the value of pH is found to be normal for all sources ranging between 6.54 to 7.63. The highest value of pH 7.63 was for sample collected from Thiksey and lowest 6.54 was for sample collected from Leh.

Turbidity:

Turbidity of water is a measurement of how cloudy or murky it is. It is a good measure of water quality and is affected by a number of factors. It is caused by particles suspended or dissolved in water that scatter light making it appear cloudy. Particulate matter generally includes clay and silt, fine organic and inorganic matter, phytoplanktons, algae and other microscopic organisms (Das and Shrivastva, 2003) [6]. High turbidity being an indicator of presence of large amounts of suspended solids significantly reduces the aesthetic quality of water source (Verma et al. 2012) [7] It increases the cost of water treatment for drinking and food processing. Generally turbidity causing factors can be either natural or human induced. Natural factors include erosion from upland, stream channel movement etc. Human activities can also be a cause of erosion. Although the substances resulting in high turbidity may not be intrinsically harmful, but their effects are because turbidity interferes with disinfection during water treatment and provides a medium for microbial growth. These microbes include bacteria, viruses and parasites which cause symptoms such as nausea, cramps, diarrhea etc.

In this study the turbidity of collected water samples is in the range of 0.12 to 75.5 NTU which exceeded the permissible value. It is observed that snow melted water showed high turbidity compared to water collected from Karu river which showed lowest turbidity. It may be due to human activities and presence of suspended particulate matter.

Total Dissolve Solids (TDS):

TDS is in general proportional to degree of pollution. It is considered as an indicator of salinity of water and describes all solids dissolved in water. TDS comprise inorganic salts (Ca, Mg, Na, K, HCO_3^-, Cl^- and SO_4^-) and some small amount of organic matter dissolved in water. TDS can also be influenced by changes in pH because it leads to precipitation of some of the solutes as well as affects solubility of suspended matter. Water containing more than 500mg/L of TDS is not considered desirable for drinking water supplies. (BIS-2296, 1982; Shrinivasa Rao and Venkateshwaralu, 2000; Murhekar, 2011) [8-10]. In this study TDS of collected water samples varied from 6.45 to 627.0 mg/L which is above the permissible limit of BIS/WHO standards. The minimum value was recorded for snow melted water and maximum for Thiksey monastery ground water.

Electrical Conductivity (EC):

EC is a measure of ability of water to conduct electrical current which provides a general indication of water quality with respect to amount of total dissolved solids such as presence of cations and anions, their concentration and mobility etc. Thus as the concentration of dissolved salts increases, electrical conductivity also increases. Conductivity of water also varies with changes in temperature. In the present study the conductivity of collected water samples is found to be in the range of 5.56 to 537.5 µS/cm.

Salinity:

Salinity of any water body is correlated to its TDS, since it indicates the presence of dissolved salts. Small amounts of dissolved salts in natural waters are required for the life of aquatic plants and animals but higher quantities lead to severe health issues like increased blood pressure (BP) or hypertension

leading way to cardiovascular diseases (CVD) (Mcmichael, 2003) [11]. The minimum salinity value was recorded at Khardung La with 15.15 mg/L and maximum at Thiksey with 626.7.

Total Hardness:

Total hardness (TH) is the property of water which prevents the lather formation with soap leading to precipitation of soap by forming of complex with cations present in water (Jena et al. 2013) [5]. It is caused due to the presence of cations like Ca^{2+}, Mg^{2+}, Fe^{3+} etc. TH of collected water samples was observed to be in the range of 15 to 225mg/L. Snow samples showed lower values whereas Thiksey monastery ground water showed highest value.

Anions: F^-, Cl^-, PO_4^{3-}, SO_4^{2-}, NO_3^{2-}

Fluoride is required in low concentration by human body to prevent dental caries but very high concentration of fluoride causes fluorosis which affects the teeth and bones. Moderate amounts lead to dental effect but long term ingestion of large amounts result in severe skeletal disorders (Bharti et al. 2017) [12]. In the present study the concentration of fluoride in water samples was observed to be in the range of trace amounts to 1.24mg/L which is within the permissible limit of BIS standard.

Chloride generally occurs in natural, surface and ground water in varying concentrations. It is not harmful to human beings unless present in high concentration. At high concentrations (>250mg/L) it imparts a salty taste to water along with increasing the corrosive property of water. Chloride usually comes from inorganic salts like NaCl, KCl, $CaCl_2$ and $MgCl_2$ which may be provided by soil, industrial, municipal and animal waste (Gopalkrishna, 2011) [13]. In the present study Cl^- concentration is below the permissible level of BIS guideline. The Cl^- in the study area varied between 2.85 to 28.75mg/L. This clearly indicates that all water samples of study area are within desirable limit and hence fit for consumption.

Nitrate is found in surface and ground water due to human activities like excessive use of nitrogenous fertilizers in agriculture as well as disposal of domestic and industrial waste (Tank and Chippa, 2013 ; Puckett and Cowdery, 2002) [14-15]. Excess of nitrates consumed by humans particularly infants is likely to cause health hazards and may lead to Methaemoglobinemia (blue baby) disease. In our study distribution of nitrate in water samples is observed to be in the range of trace amounts to 0.83mg/L which is well below the permissible limit in all sources of water.

It has been reported that Sulphate occurs naturally in water because of leaching from gypsum and other common minerals (WHO, 2003) [16]. The sulphide minerals add the soluble sulphate into the groundwater through oxidation process. In the present investigation sulphate concentration ranged from trace amounts to 64.42 mg/L. Samples collected from ground water Leh, Karu river and Thiksey monastery showed very levels of sulphate contamination which may be due to leaching from rocks of this region or anthropogenic causes.

Phosphate occurs in surface or ground water due to discharge of domestic waste, detergents, fertilizers, insecticides and industrial wastes. Discharge of municipality sewage also results in high amount of phosphate (Benzamin, et al. 1996) [17]. The phosphate content in most of the study area was detected in trace amounts. The samples were collected during March when it was snow all over hence most of the samples showed no phosphate contamination. However the remaining samples showed phosphate concentration in the range of trace amounts to 0.93mg/Lit. Comparative high values in some of the collected samples may be due to rain, surface water runoff, agriculture run off etc.

Cations: Na^+, K^+, Ca^{2+}, Mg^{2+}, Fe^{3+}

Sodium is one of the most abundant elements of the alkali earth group in the earths crust. Sodium concentration plays an important role in evaluating the groundwater quality for irrigation because its presence causes an increase in the hardness of soil as well as a reduction in its permeability (Tizani, 1994) [18]. For low level of sodium in any area the cultivation might be affected with low production. In our study sodium was present in the range of trace amounts to 9.12 mg/L. higher values were observed for samples collected from Thiksey monastery.

Potassium is an essential element for both plants and animals. Major source of potassium in natural fresh water is weathering of rocks but the quantities increase in the polluted water due to disposal of waste water (PATIL and PATIL, 2010)[19]. Very high potassium concentration may be harmful to human nervous and digestive system. In the present investigation potassium concentration ranged from trace amounts to 0.69 mg/L.

The range of concentration of Ca, Mg and Fe cations was observed to be from trace amounts to 0.82mg/L, trace amounts to 25.03mg/L and 0.56 to 0.81mg/L respectively. Concentration of Ca was comparatively higher in some snow samples whereas Mg concentration was higher in river, Leh and Thiksey monastery samples. Iron was present in almost all samples above the desirable limit of 0.30mg/L but below 1.0mg/L.

IV. Comparison of different water sources

Snow melted water

Samples 1-6(a,b) are snow melted water samples, altitude varying from 12,744 (sample no. 1) to 18,340ft (sample no. 5). pH for all the samples was observed to be within permissible limit varying from 6.6 for sample no. 5b and 6a to 7.5 for sample no. 1a respectively. Turbidity is in the range 2.89 for 1a (12,744ft) located near Leh to 75.5 for 2a (13,450ft) within the same location. Such a huge variation of Turbidity values for snow samples could not be understood. However from the photographs for snow collection of samples Fig (1a-d) it becomes clear that the mud beneath the snow which is clearly visible as patches between snow covered areas may be responsible for high turbidity values for the melted water from the snow. So the samples were kept undisturbed for 24hr. The turbidity of all the collected snow samples came drastically down (<1NTU) in the range 0.15 to 0.86NTU.

This shows that initially observed high turbidity values may be due to suspended impurities, mud etc which settled on keeping the samples undisturbed. Hence it can be assumed that turbidity of decanted snow melted water samples was within desirable limit as per BIS standard.

The TDS was observed to be in the range of 6.45 (5a sample, ht 18,340ft) to 59.5 (1b sample, ht 12,744ft). Hence

results show that snow melted water from the highest point of collection does not contain any dissolved matter which is reflected in its very low TDS value whereas samples from lower heights show some dissolved impurities although both values are within the desirable limit as per BIS standard.

Total hardness values range from 15 to 30 which signify presence of trace quantities of alkali and alkaline earth metals salts.

With respect to cationic contamination it was observed that sample 1b (ht 12,744ft) showed presence of Na, K, Ca and Mg ions (max conc) in amounts 0.69, 0.33, 0.82 and 0.17mg/L respectively. Sample 2a also showed presence of K and Ca ions in 0.18 and 0.69mg/L conc. Some more samples 3b, 6a and 5b also showed presence of very small amounts of Na, Ca and Mg. Surprisingly snow melted water showed presence of Fe in the range 0.57 to 0.81mg/L which may be due to leaching from beneath the surface soil and rocks.

Thus, on average it can be stated that the concentration of all the present cations is either within the permissible or desirable limit.

Regarding anionic contamination F was not observed in any of the samples. Cl was in range 2.85 for 1a to 9.27mg/L for 4b. Phosphate was in range 0.05 for 2a to 0.16 for 6a, sulphate was in the range of trace amounts to 0.19 for 5b and nitrate in the range from trace amounts to 0.09 for most of the samples.

All the physico-chemical analysis results show that maximum obtained values are within desirable limit or if exceed are still within permissible limit. None of the results show high deviation from permissible values subject to melt water has to be consumed after sedimentation and decantation. Hence under above conditions water is fit for consumption.

Groundwater Leh and Thiksey monastery

Samples 7a and 7b were collected from groundwater Leh and 9a and 9b from Thiksey Monastery. pH was observed to be in the range of 6.5 to 7.6. Turbidity was also in the range 2.3 to 51NTU. TDS ranged from 207 to 627. Thiksey monastery sample showed higher TDS with respect to desirable limit but is still within permissible limits. Total hardness ranged from 90 to 225mg/L. These values signify presence of alkaline earth metal cations. IC analysis confirmed the presence of sodium in range 2.5 to 9.1mg/L for groundwater Leh and Thiksey monastery respectively. Magnesium was also observed in the range 15 to 25mg/L. Hence it can be assumed that high concentration of Mg may be responsible for hardness of water. The iron concentration was in range 0.56 to 0.58mg/L. Iron concentrations have exceeded the desirable limit of 0.3mg/L.

Among the anionic species fluoride was found in Leh groundwater samples in conc range 0.12 to 1.24. Chloride was present in range from 16 to 28mg/L. Phosphate was observed in range trace amounts to 0.37mg/L and sulphate from 12 to 64mg/L Nitrate was present in trace quantities.

As per the literature reports Bharti et al have reported hardness values as high as 300 for the tube well water samples of Leh district [34°07'46.27" N and 77°31'33.40"E Ht 10,547ft]. According to them hardness contributing ion was calcium but according to our results main contributing ion is Mg as Ca was present in trace quantities.

River water

Samples 8a and 8b are river water samples. The height was 13,490ft. The collected water samples showed pH from 7.3 to 7.4, turbidity in the range of 0.12 to 57.40. TDS was from 224 to 287mg/L. Total hardness was observed to be in range 90-150mg/L. Among anions fluoride, phosphate and nitrate were present in trace quantities or <1mg/L. Chloride was observed in range from 14.6 to 21.7mg/L and sulphate from 32.51 to 47.50mg/L. Among the cationic impurities K and Ca were present in trace quantities, Na in the range from 2.05 to 3.72mg/L and Mg from 3.23 to 13.45mg/L. Iron was observed to be in the range of 0.71 to 0.74mg/L.

V. Conclusion

In the present study the values for different physico-chemical parameters in most of the collected snow and water samples were found within the desirable or permissible limit as prescribed by BIS standards. The snow melted water samples showed high turbidity values which came down after leaving them undisturbed overnight. TDS for nearly all the samples was within desirable limit except for Thiksey monastery groundwater sample which was within permissible limit. Presence of small amounts of chloride and sulphate was observed in most of the samples but far below the desirable limit. Presence of cationic minerals as Na, K and calcium was observed either in trace quantities or in very low concentration except Mg which was present in higher quantities compared to other cations but still within desirable limit. Iron was found in concentration above desirable limit for all the collected samples. Hence it is recommended that the water should be properly treated for Iron removal before consumption.

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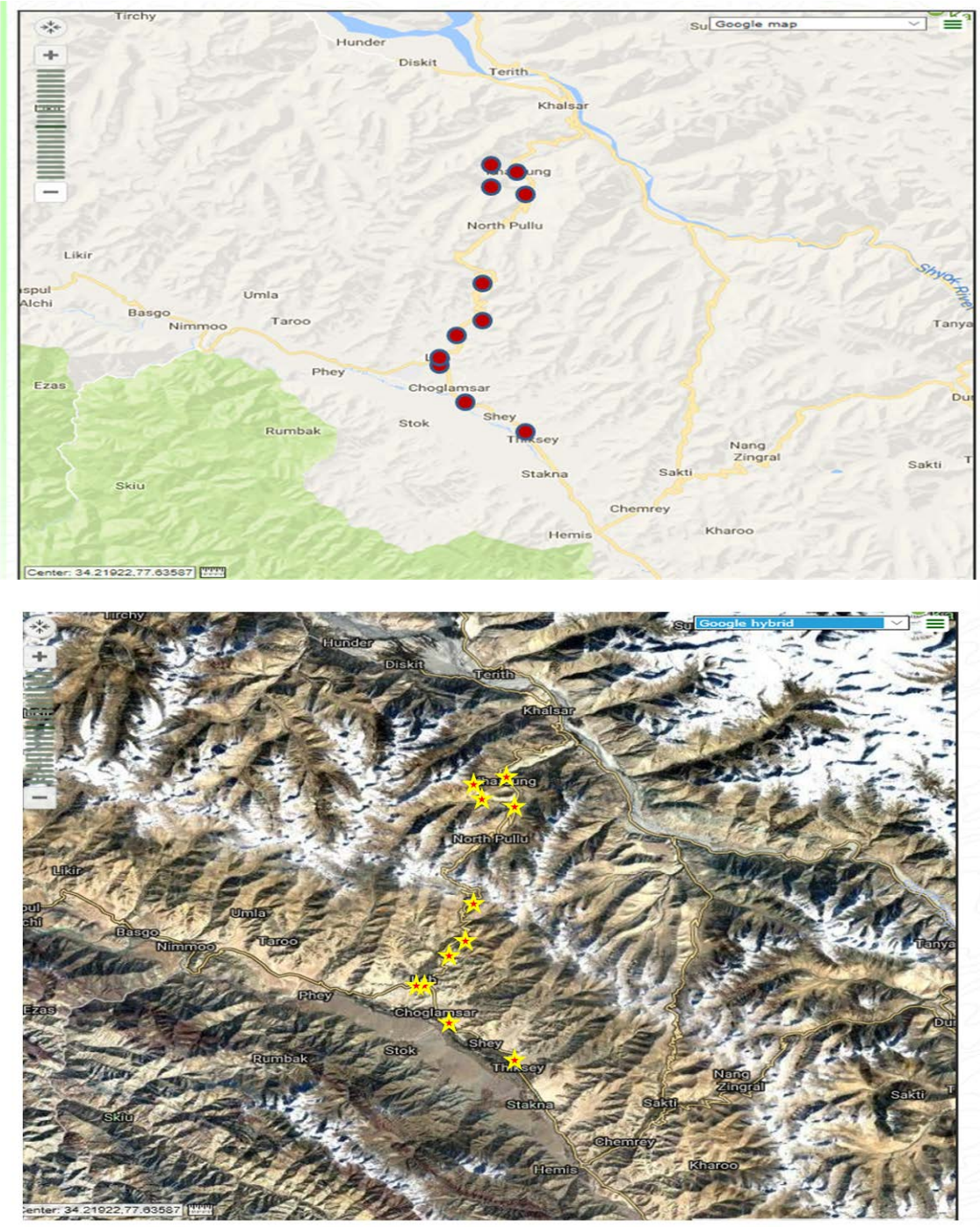

Figure 1: Location map of water collection points (2D & 3D image)

Figure 2: (a) Snow collection spots

(b)

(c)

Figure 2: (b) Groundwater Leh collection point and (c) Thiksey Monastery collection point

Figure 2: (d) River water collection points

Table 1: Details of sampling sites and sources of collected water samples

S.No.	Sample code	Water source/ Locality	Latitude	Longitude	Altitude
1.	1a	Snow	34.184832	77.596092	12744
2.	1b	Snow	34.185020	77.595448	12744

3.	2a	Snow	34.203574	77.620125	13450
4.	2b	Snow	34.205267	77.620018	13450
5.	3a	Snow	34.252966	77.621498	15100
6.	3b	Snow	34.252370	77.621931	15100
7.	4a	Snow	34.370367	77.664070	17059
8.	4b	Snow	34.371437	77.664649	17059
9.	5a	Snow	34.402768	77.656732	18340
10.	5b	Snow	34.402766	77.656731	18340
11.	6a	Snow	34.253612	77.621563	14370
12.	6b	Snow	34.252743	77.621971	14370
13.	7a	Ground water (Leh)	34.147334	77.578926	11480
14.	7b	Ground water (Leh)	34.147335	77.578928	11480
15.	8a	Karu river	34.38224	77.632742	13490
16.	8b	Karu river	34.40224	77.632742	13490
17.	9a	Ground water (Thiksey monastery)	34.056103	77.665358	11490
18.	9b	Ground water (Thiksey monastery)	34.096106	77.602036	11490

Table 2: Physico-chemical quality of collected water samples

Sample No.	pH	Conductivity (µs/cm)	TDS (mg/L)	Turbidity (NTU)	Salinity (mg/L)	Total Hardness (mg/l)
BIS Standard (desirable-permissible)	6.5-8.5	-	500-2000	1-5	-	200-600
1a	7.59	12.54	14.56	2.89	21.19	15
1b	7.30	51.47	59.55	28.90	60.78	15
2a	7.09	15.07	17.54	75.50	23.58	15
2b	6.88	11.61	13.51	53.60	20.34	15
3a	6.96	8.47	9.66	16.89	17.29	15
3b	7.09	9.40	11.00	14.94	18.33	15
4a	6.95	8.25	9.68	7.20	17.66	15
4b	7.09	6.58	7.65	4.89	15.99	15
5a	6.95	5.56	6.45	5.30	15.15	15
5b	6.64	20.28	23.45	39.60	28.56	15
6a	6.69	23.78	27.10	40.00	31.72	30
6b	6.78	19.05	22.30	22.50	27.52	30
7a	6.54	418.6	484.10	3.65	476.9	120
7b	7.06	247.4	286.20	51.40	280.2	90
8a	7.47	248.4	287.30	57.40	283.9	150
8b	7.39	194.1	224.50	0.12	217.8	90
9a	7.31	537.5	627.00	2.31	626.7	225
9b	7.63	179.1	207.70	2.30	199.7	105

Table 3: Anionic composition of water collected from different sites

Sample code/Property	F^- (mg/L)	Cl^- (mg/L)	PO_4^- (mg/L)	SO_4^-(mg/L)	NO_3^-(mg/L)
BIS Standard (desirable-permissible)	1.0-1.5	250-1000	-	200-400	45-no relaxation
1a	Tr	2.85	Tr	0.07	Tr
1b	Tr	6.67	0.01	0.03	Tr
2a	Tr	7.40	0.05	0.18	0.07
2b	Tr	9.06	0.03	0.16	Tr
3a	Tr	9.10	0.09	0.01	0.09
3b	Tr	8.15	Tr	Tr	Tr
4a	Tr	9.15	Tr	0.10	0.08
4b	Tr	9.27	Tr	0.02	0.09
5a	Tr	9.13	Tr	0.11	0.09
5b	Tr	3.68	0.11	0.19	Tr
6a	Tr	9.13	0.16	0.03	Tr
6b	Tr	7.45	0.02	0.05	0.01
7a	0.12	19.03	0.21	64.42	0.07
7b	1.24	28.75	Tr	26.62	Tr
8a	Tr	14.6	0.53	32.51	0.06
8b	Tr	21.7	0.93	47.50	0.83
9a	Tr	16.13	0.37	12.31	Tr
9b	Tr	19.00	0.20	15.80	Tr

Table 4: Cationic composition of water collected from different sites

Sample code/Property	K(mg/L)	Na(mg/L)	Ca(mg/L)	Mg(mg/L)	Fe(mg/L)
BIS Standard (desirable-permissible)	-	-	75-200	30-no relaxation	0.3-no relaxation
1a	Tr	Tr	Tr	Tr	0.81
1b	0.69	0.33	0.82	0.17	0.60
2a	0.18	Tr	0.69	Tr	0.66
2b	Tr	Tr	Tr	Tr	0.71
3a	Tr	Tr	0.17	Tr	0.63
3b	Tr	Tr	0.20	Tr	0.58
4a	Tr	Tr	Tr	Tr	0.57
4b	Tr	Tr	Tr	Tr	0.59
5a	Tr	Tr	Tr	Tr	0.57
5b	Tr	0.21	0.23	Tr	0.72
6a	Tr	0.39	0.63	0.16	0.62
6b	Tr	Tr	Tr	0.12	0.60
7a	Tr	3.51	Tr	25.03	0.58
7b	Tr	2.54	Tr	15.63	0.56
8a	Tr	3.72	Tr	3.23	0.74
8b	Tr	2.05	Tr	13.45	0.71
9a	Tr	9.12	Tr	23.31	0.56
9b	Tr	3.58	Tr	16.09	0.56