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Evaluation of spring water quality using water quality index method for Bageshwar District, Uttarakhand, India

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ABSTRACT

The quality of spring water is highly important to the people of hills for their everyday lives in Bageshwar district, which is located in Uttarakhand's Eastern Kumaon area between latitudes 29.49° N and 79.45° E, at an elevation of 1,004 meters above mean sea level. The study area map was created using the open-source freeware software QGIS, and the geocoding of the selected area was performed by entering Latitude and Longitude coordinates. Spring water were collected and analysed based on the standard methods for the eleven springs of Bageshwar city and its nearby villages for two seasons during the winter (December 2019) and in summer (March 2020). The present study assessed the drinking water quality of perennial spring in and around Bageshwar using the WQI by Weighted Arithmetic Water Quality Index Method. For calculating the WQI, 15 physicochemical parameters, namely, pH, alkalinity, Chloride, Electrical Conductivity, Total Dissolved Solid, Turbidity, Total Hardness, Potassium, Sodium, Fluoride, Iron, Nitrate, Calcium, Magnesium and Total Hardness were taken. The WQI values show that spring water with WQI values ranging from 4.57 to 17.83 in winter season 6.72 to 27.72 in summer season falls under excellent category, except for Bhaniya Dhaar-1 (BS_8) village spring, which were classified to good water category. A paired t-test was applied to compare significant variations in water quality between two seasons, revealing a significant difference (p value<0.05) in water quality between seasons. Water from all of the evaluated spring sources is safe to drink, despite the fact that some parameters exceed permitted limits. To ensure the quality and security of the water supply to the people of these regions, it is preferable to conduct a simple filtration process before drinking the water sampled from the springs.

Introduction

Sustainable utilization of natural resources (water sources, biomass and other renewable materials) is one of the prime concerns pertinent to mankind, and as such serious efforts are being put to prevent direct and indirect routes (Pasqual and Souto, 2003). The entire ecosystem, its preservation and the upliftment mankind depend on these resources, especially primarily on water resources (Baunthiyal *et al*., 2015; Tiwari, 2015). Due to increasing anthropogenic activity, spring ecosystems are under great threat, which needs urgent attention and management plans (Krishnan *et al*., 2005; Daghara *et al*., 2019). The increasing human population has led to urbanization and other development activity resulting in the degradation of groundwater (Gupta *et al*., 2019). Spring water is inexpensive and high-quality which flows out to the surface due to natural gravity and hydrostatic pressure. When the spring waters interact with the surface, it undergoes rapid contamination (Vilane *et al*., 2016). The springs are a vital source of water in the entire Himalayan region, particularly for

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isolated villages at higher altitudes. The village population of the Indian Himalayan region especially Uttarakhand has largely depended on spring water since time immemorial and as a result a numerous studies evaluating the quality of spring water and other water bodies have been conducted (Baunthiyal *et al*., 2015; Bhutiani *et al*., 2019; Ruhela *et al.,* 2018). Very few water quality assessments have been done in high-altitude regions like Bageshwar, Uttarakhand. The springs found in the study area are primarily of depression, gravitational and contact category and belong to the sedimentary rocks (limestone, shale and sandstone), metasedimentary and low-grade metamorphic rocks like dolomite, phyllite, quartzite and slate. The occurrence and movement of groundwater are influenced by the type of the litho units and the interspaces/interstices, as well as the degree of interconnection between them, the vertical and aerial extension of faults, joints, and/or shear zones, and the local and regional geomorphology. Groundwater arises as springs and seepage in ideal physiographic conditions, such as smooth sloping slopes, vast river valleys, and lithological connections. Based on the lithology of the area, there are three types of spring prominent and these are categorized under depression spring, gravitational spring and contact spring. Most of the spring water consumed by the local community is of open-source type. Therefore, regular testing and proper treatment of water are recommended for human consumption. Thus, in the present study, physicochemical analysis for spring water was conducted adopting standard methodologies to perceive the degree of contamination/pollution. As per the analysis of the obtained results, the parameters of water samples collected from all eleven perennial springs are of excellent quality with a significant difference in Water Quality Index during two seasons for both years. The paper presents a detailed analysis of the chemistry of spring water quality regarding the drinking water standards. Both the quantity and quality of spring water are depleting at an alarming rate due to various factors. Awareness programmes on the importance of springs, conservation and rejuvenation of the spring among the local communities can help protect the springs in Himalayas.

Material and Methods

Study Area

Uttarakhand, formerly known as Uttaranchal, located in northern India with 13 districts with coordinates between latitude 28°45'N and 31°30'N and longitude 77°30'E to 81°05'E, with an altitude of 200 to 7,800 m above mean sea level. Bageshwar district is located in the hilly region of Uttarakhand. Bageshwar district has a moderate to subhumid climate. While the centre and southern parts of the region are relatively warm and humid, the northern part is entirely sub-zero throughout the year. The primary climatic characteristic of Bageshwar district is a harsh winter. The total annual rainfall at Bageshwar is 1360 mm and the total number of rainy days is 119 days. Major physiographic units of the district are Central and Lesser Himalayan Zone and its main drainage rivers are Bhadrapati, Gomti, Pindar, Pungar and Saryu. The soils of the Bageshwar district are categorised into lesser and greater or central Himalaya soils. The first type covers the majority of the area. The geological framework of Bageshwar region is so vast that the region is divided into different litho-tectonic units. The geology of the area consists of three Stratigraphic and tectonic units, namely (a) The Central Crystalline, (b) The Baijnath Crystalline and (c) The Garhwal Group.

Sampling Site and Water Quality Parameter Analysis

Spring water samples were obtained from eleven sampling locations of Bageshwar district, namely Banri (BS_1), Manikhet (BS_2), Darsu Aare (BS_3), Kukudagaad (BS_4), Kamedi (BS_5), Bilauna (BS_6), Bhaniya Dhaar-1 (BS_7), Bhaniya Dhaar-2 (BS_8), Bhitaal Gaon (BS_9), Nye Basti Chaurasi (BS_{10}) and Shri Naula Dhaara (BS_{11}). The spring water samples were collected in two seasons (one during the winter season (December 2019) and another in the summer season (March 2020)) in narrow necked polyethylene plastic bottles of one litre volume. Before sampling these bottles were washed and triple-rinsed with distilled water followed by rinsing with collected sampled water of spring. pH, total dissolved solids (TDS) and electrical conductivity were measured at the sampling site using Hand-handle pH-meter and TDS meter (TDS-3, HM digital)) then remaining parameters tested in the laboratory using the methods of APHA (2012) and (Tripathi and Govil, 2001).

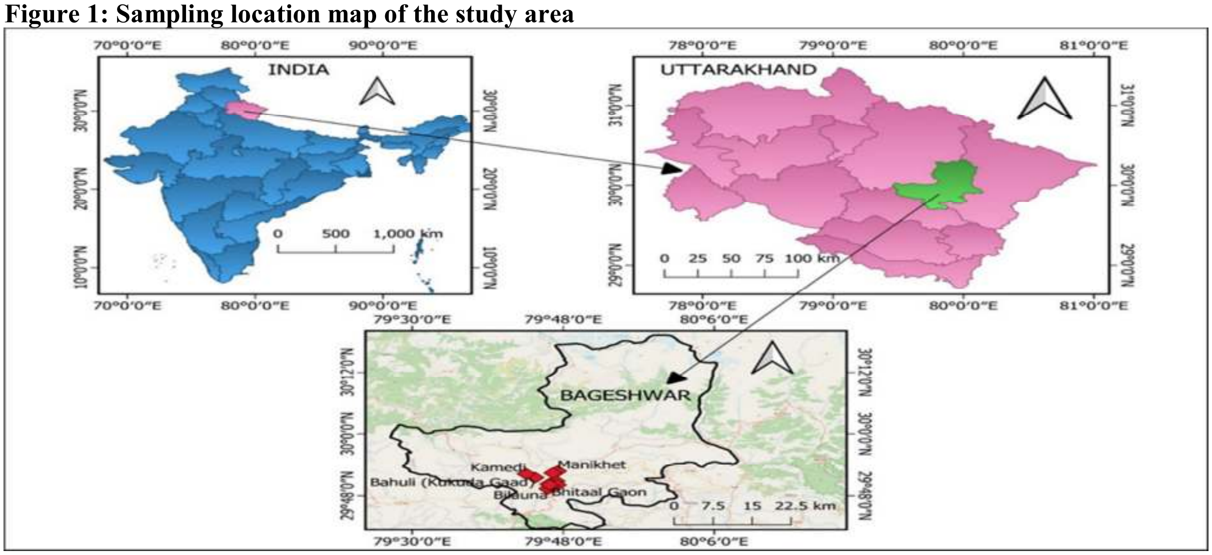
Preparation of Study Area Maps and Springs Location Points

The elevation, latitude and longitude of each of the locations sampled was measured (Table 1) using an app Kobo Collect working on Global Position System (GPS). The X (Latitude) and Y (Longitude) axis findings were expressed in Universal Transverse Mercator (UTM) system units, which are employed in a software application (QGIS) to construct the location map of the examined area displayed in Figure 1. Study area map was created using the open-source freeware software QGIS, and the geocoding of the selected area was performed by entering latitude and longitude coordinates. The GPS maps marks the study area's chosen spring water sources on the Google Earth map. The chosen analysis area and its borderlines are mapped and saved as a QGIS file on the QGIS application. The research area was digitised using QGIS tools. The chosen springs' latitude, longitude, and location were obtained using the app Kobo Collect. The spring positions were marked on the QGIS map using a point attribute. The water quality data derived from the non-spatial database were saved in excel format and combined with the spatial data. The spatial and non-spatial databases produced are combined to delineate the spatial distribution of groundwater pollutants to create Spatio-temporal distribution maps of water quality parameters. All the selected eleven springs were given spring id from BS_1 to BS_{11} (Table 1).

Table 1: The location and altitude of the springs sampling sites within the Bageshwar district

Name of the Site/Village	Spring ID	X (Latitude)	Y (Longitude)	Z (Altitude)
Banri	BS_1	29º 50′ 49"	79º 47′ 9"	899.09 m
Manikhet	BS_2	29º 52′ 52"	79º 47′ 23"	780.23 m
Darsu Aare	BS_3	29º 52′ 24"	79º 46′ 47"	878.92 m
Kukudagaad (Bahuli)	BS_4	29º 51′ 30"	79º 44′ 38"	888.87 m
Kamedi	BS_5	29º 52′ 9"	79º 43′ 12"	956.1 m
Shri Naula Dhaara	BS_6	29º 52′ 22"	79º 46′ 27"	830.8 m
Biluana	BS_7	29º 49′ 41"	79º 46′ 15"	789.28 m
Bhaniya Dhaar-1	BS_8	29º 50′ 26"	79º 46′ 48"	935.3 m
Bhaniya Dhaar-2	BS_9	29º 50′ 5"	79º 47′ 18"	975.93 m
Bhitaal Gaon	BS_{10}	29º 50′ 7"	79º 46′ 23"	876.26 m
Nye Basti Chaurasi	BS_{11}	29º 50′ 7"	79º 46′ 23"	894.57 m

Figure 1: Sampling location map of the study area



Water Quality Index (WQI)

The Water Quality Index (WQI) was first developed by (Horton, 1965). Later, a new modified WQI similar to Horton's index was introduced by Brown (1970). To determine the suitability of spring water for human consumption, we have used WQI by Weighted Arithmetic Water Quality Index Method. Various scientists widely used this method to assess water quality (Adimalla and Venkatayogi, 2018; Aly *et al*., 2015; Bhutiani *et al.,* 2018; Balan *et al*., 2012; Brown *et al*., 1972; Chowdhury *et al*., 2012; Rao *et al*., 2010; Ramakrishnalah *et al*., 2009; Ruhela *et al.,* 2022). The WQI was calculated using the following formula: Following three steps are followed for computing WQI:

Each parameter's unit weight is inversely proportionate to its standard permissible value.

1. Each parameter's unit weight is inversely proportional to its

standard permissible value. Unit weight of i^{th} water quality parameter,

$$W_i = \frac{K}{S_i}\text{, where}$$

K= constant of proportionality, given as

$$K = 1/\sum_{i=1}^{n} \left(\frac{1}{S_i}\right)$$

n= number of parameters,

S_i= standard permissible value of the i^{th} parameter.

2. Development of quality rating scale

$$Q_i = \frac{V_i - V_o}{S_i - V_o} \times 100$$

where

Q_i= quality rating of i^{th} water quality parameter,

V_i= measured concentration of i^{th} water quality parameter,

V_o= ideal value of i^{th} water quality parameter

Generally, the value of V_o is zero for all water quality parameters except for pH and dissolved oxygen (DO); for pH, V_o= 7; For DO, V_o=14.6 mg/l.

3. Calculating WQI

$$WQI = \frac{\sum Q_i W_i}{\sum W_i}$$

The Weighted Arithmetic Water Quality Index (WAWQI) method converts several water quality criteria into a mathematical equation that assigns a numerical value to the health of the water body.

The obtained value of WQI of all parameters were then classified according to range Value into five categories in order to determine degree of purity of spring water and its suitability for human consumption (Table 2).

Table 2: WQI classification range.

Range	Type of Water
0-25	Excellent water
26-50	Good Water
51-75	Poor water
76-100	Very Poor water
>100	water unsuitable for drinking purpose

Statistical Analysis

To determine any significant differences in WQI for two selected seasons (Winter and summer), a paired *t-test* at 0.5 significant level (at 95% confidence level) was performed using R-studio software.

Results and Discussion

The results of studied physicochemical parameters are given in Table 4 and Table 5 shows that the average values of all 15 physicochemical parameters are below the maximum allowable limits of the Bureau of Indian Standard 10500: 2012 given in Table 3 for drinking water.

pH: The pH value indicates a change in the source's quality. Water that is extremely acidic or alkaline has a sour or alkaline flavour. Furthermore, higher pH values limit chlorine's germicidal potential. The pH values from all the spring sites were within the desirable limits except from the spring- BS_1, BS_4 and BS_7 (6.93, 6.93 and 6.71, respectively), which were recorded slightly acidic during winter. Bhat *et al.* (2010), Chauhan *et al*. (2020) and Kumar *et al.* (1997) discovered the acidic composition of water samples while researching natural springs in Kashmir, Pauri (Uttarakhand) and Almora (Uttarakhand), respectively. The highest value of pH was measured in summer at the spring-BS_7 8.38 (Table 5). The rise in pH in some springs could be due to bicarbonate and carbonate of calcium and magnesium in water which may be due to the geology of the region in which limestone is the most common (Zeb *et al*., 2011). The pH values of all the spring water were within the permissible limits of BIS (2012) and WHO (2011).

EC: To measure the concentration of soluble salts in water, the electrical conductivity (EC) is used. Drinking water with a high concentration of dissolved solids has an unpleasant flavour. The

Table 3: Standards values of physicochemical parameters given by BIS and WHO

SN	physicochemical Parameters	BIS 10500: (2012)		WHO (2011)	
		Acceptable Limit	Permissible Limit	Acceptable Limit	Permissible Limit
1.	pH	6.5-8.5	No relaxation	6.5-8.5	No relaxation
2.	EC (µS/cm)	770	1500	770	1500
3.	TDS (ppm)	500	2000	500	No relaxation
4.	Alkalinity as $CaCO_3$ (mg/L)	200	600	200	No relaxation
5.	Chloride (mg/L)	250	1000	250	No relaxation
6.	Hardness as $CaCO_3$ (mg/L)	200	600	100	300
7.	Potassium (mg/L)	12	No relaxation	12	No relaxation
8.	Sodium (mg/L)	200	No relaxation	200	No relaxation
9.	RFC (mg/L)	0.2	1	5	No relaxation
10.	Turbidity (NTU)	1	5	1	4
11.	Fluoride (mg/L)	1	1.5	0.5	1
12.	Iron(mg/L)	0.3	No relaxation	0.5	No relaxation
13.	Nitrate(mg/L)	45	No relaxation	50	No relaxation
14.	Calcium (mg/L)	75	200	75	No relaxation
15.	Magnesium(mg/L)	30	100	30	No relaxation

maximum amount of EC was measured from Manikhet spring-BS2 (552.03 µS/cm and 553.29 µS/cm for winter and summer, respectively), while minimum amount of EC was measured from Bahuli spring-BS_4 (37.21 µS/cm and 38.92 µS/cm for winter and summer, respectively). The electrical conductivity values of all the spring water were within the permissible limits of BIS (2012) and WHO (2011).

TDS: Total Dissolved Solid (TDS) is a term that refers to dissolved solids and colloids in the form of chemical compounds and other substances. The maximum amount of TDS was measured from the spring-BS_2 (356.69 ppm and 287.19 ppm for winter and summer, respectively). In comparison, the minimum amount of TDS was measured from the Bahuli spring-BS_4 (24.35 ppm and 18.55 ppm for winter and summer, respectively). All of the TDS values were within the BIS (2012) and WHO (2011) permissible limits.

Alkalinity: The presence of dissolved minerals such as carbonate, bicarbonate, and hydroxide results in the alkalinity of water. The total alkalinity value of all the spring water was lower than the permissible limits (BIS, 2012) in the winter season. However, it exceeded the acceptable limit at two springs sites in the summer season, i.e., Manikhet-BS_2 and Darsu Aare-BS_3 (225.31 mg/L and 215.28 mg/L), respectively given in Table 5. This may be due to higher carbonate, bicarbonate compounds in the soil or bedrock around these two spring water sources which gets dissolved and travel with the water in summer. This difference in summer in two in springs might be associated with the human activities during the summer season (Barakat *et al.,* 2018).

Potassium: Based on the prescribed limit of (WHO,2011) and (BIS,2012) difference in potassium concentration has been recorded during two seasons. Winter month recorded the highest value of potassium at spring site BS_5 (5 mg/L) are within the permissible limit, but at three spring sites, BS_4, BS_7 and BS_{10} are zero in both seasons. The potassium content of all of the spring water samples is within the permissible range in both seasons.

Sodium: Sodium is a vital component required by the human body for a variety of tasks such as muscle and nerve function. Blood pressure and kidney failure are both linked to an increased concentration of Na^+ in the blood. The presence of sodium in low concentration was also detected in all spring water samples (lower than the permissible range of 200 mg/L); during both seasons (winter and summer), the maximum value of sodium was recorded from a spring and BS_6 (15 mg/l and 12 mg/L) and minimum value of sodium, i.e., 1 mg/L reported from the springs BS_2, BS_4, BS_7 and BS_9 in

Table 4: Physicochemical properties of springs during Winter (2019).

SN	Physicochemical Parameters	BS_1	BS_2	BS_3	BS_4	BS_5	BS_6	BS_7	BS_8	BS_9	BS_{10}	BS_{11}
1.	pH	**6.93**	7.89	8.07	**6.93**	**6.71**	7.3	8.28	7.11	7.46	7.92	7.82
2.	EC (µS/cm)	438.13	552.03	316.8	38.92	136.13	399.57	344.05	116.5	80.46	95.76	287.37
3.	TDS (ppm)	285.15	356.69	200.2	24.35	89.93	248.55	215.15	71.85	49.88	96.56	179.05
4.	Alkalinity as $CaCO_3$ (mg/L)	103.09	185.56	144.33	51.55	41.24	113.4	123.71	82.47	30.93	61.85	92.78
5.	Chloride (mg/L)	47.45	12.35	8.79	5.27	14.06	24.66	7.03	7.03	10.54	8.79	26.36
6.	Hardness as $CaCO_3$ (mg/L)	**377.19**	**438.6**	**333.33**	192.98	**219.3**	**350.88**	**342.11**	**210.53**	**201.75**	**228.07**	**324.56**
7.	Potassium (mg/L)	3	1	3	0	5	4	0	2	1	0	4
8.	Sodium (mg/L)	15	1	4	1	5	15	1	2	1	5	11
9.	RFC (mg/L)	0	0	0	0	0	0	0	0	0	0	0
10.	Turbidity (NTU)	0	0	0	0	0	0	0	0	0	0	0
11.	Fluoride (mg/L)	0.35	0.45	0.35	0.45	0.55	0.6	0.25	**1.5**	0.2	0.55	0.4
12.	Iron(mg/L)	0.04	0.03	0.05	0.02	0.03	0.04	0.08	0.03	0.02	0	0.03
13.	Nitrate(mg/L)	6	4	3	2	3	5	4	2	3	4.5	1.5
14.	Calcium (mg/L)	38	46	40	14	28	38	44	20	16	18	37.2
15.	Magnesium(mg/L)	**39.54**	**58.26**	28.49	5.24	12.16	**48.29**	**38.29**	22.39	8.19	11.78	20.69

Table 5: Physico-chemical properties of springs during summer (March, 2020).

SN	Physicochemical Parameters	BS_1	BS_2	BS_3	BS_4	BS_5	BS_6	BS_7	BS_8	BS_9	BS_{10}	BS_{11}
1.	pH	7.48	8.01	7.51	7.3	7.44	7.88	**8.38**	7.81	7.76	7.35	8.03
2.	EC (µS/cm)	434.35	553.29	267.28	37.21	141.98	404.86	348.14	114.78	78.25	120.69	352.18
3.	TDS (ppm)	232.16	287.19	140.59	18.55	72.87	212.09	184.49	59.38	38.46	61.13	183.78
4.	Alkalinity as $CaCO_3$ (mg/L)	129.38	**225.31**	**215.28**	88.48	81.73	159.64	189.47	118.58	68.35	89.49	157.29
5.	Chloride (mg/L)	64.19	35.46	20.26	49.59	52.28	88.65	53.19	29.14	26.32	53.19	54.16
6.	Hardness as $CaCO_3$ (mg/L)	**358.19**	**381.49**	**309.36**	76.67	189.43	**328.34**	**389.82**	173.38	155.69	143.63	**334.18**
7.	Potassium (mg/L)	2	1	3	0	4	4	0	2	1	0	3
8.	Sodium (mg/L)	13	2	3	1	4	12	2	3	4	6	12
9.	RFC (mg/L)	0	0	0	0	0	0	0	0	0	0	0
10.	Turbidity (NTU)	0	0	0	0	0	0	0	0	0	0	0
11.	Fluoride (mg/L)	0.25	0.5	0.5	0.4	0.65	0.5	0.5	2.5	0.4	0.45	0.6
12.	Iron(mg/L)	0.05	0.05	0.04	0.05	0.06	0.05	0.1	0.03	0.02	0.02	0.04
13.	Nitrate(mg/L)	7	5	4	3	3	10	5	2	4	5	2
14.	Calcium (mg/L)	32	30	44	12	26	40	50	18	14	20	38
15.	Magnesium(mg/L)	**37.66**	**54.67**	12.15	6.07	10.94	**42.53**	30.37	19.44	12.15	14.15	14.58

the summer season. The salinity of the water is mainly due to the presence of sodium chloride (NaCl) in water. The sodium content of all of the spring water samples is within the permissible range.

Chloride: Chloride is a significant indication of water quality and is abundant in nature in the form of sodium chloride (NaCl), potassium chloride (KCl), and calcium chloride ($CaCl_2$). During the summer season, higher and lower values of chloride were detected at spring-BS_6 (88.65 mg/L) and BS_3 (20.26 mg/L), respectively given in Table 5, and in the winter season, higher and lower values of chloride were detected at spring-BS_1 (47.45 mg/L) and BS_4 (5.27 mg/L) respectively given in Table 5. Comparatively, chloride concentration in spring-BS_6 was higher during summer which may be attributed to anthropogenic factors that contribute to chloride levels in spring water, including geological weathering, leaching from rocks, domestic effluent, irrigation discharge, agricultural use, etc. (Barakat *et al*. 2018), although it remained below the permitted level prescribed by (WHO, 2011) and (BIS, 2012).

Calcium: Magnesium and Calcium are also significant indicators for evaluating water quality since they have a direct relationship with the development of water hardness of water. Natural water contains different concentrations of these two elements depending on the type of rocks in the area. The maximum calcium concentration in both winter and summer seasons was found at spring-BS_7 and BS_2 (50 mg/L and 46 mg/L), respectively. The minimum calcium concentration in both seasons was recorded at the same spring-BS_4 (12 mg/L and 14 mg/L), respectively. The calcium content in all the spring water samples were within the permissible limit.

Magnesium: During the winter season, the highest concentration of magnesium recorded was 39.54 mg/l, 58.26 mg/l, 48.29 mg/l and 38.28 mg/L at the spring sites of BS_1, BS_2, BS_6 and BS_7, respectively and also in the summer season highest concentration of magnesium recorded were 37.66 mg/L, 54.67 mg/L, 42.53 mg/L and 30.37 mg/ L at the same springs as in winter season, which is beyond the acceptable limit prescribed by (BIS, 2012) (Table 3). This variation in Mg level might be related to the weathering of rocks and mineral content of each ion, such as sedimentary rocks, limestone, dolomite, gypsum, aragonite, the mineral of igneous rock, feldspars amphibole and pyroxene, and the pH value of each source (Hem, 1985). As a result, a basic physical treatment of the spring water is desirable in order to limit nutrient loading. However, magnesium values in all other spring water samples are within the permissible limit during two seasons.

Total Hardness: Spring water is considered hard due to the presence of a high concentration of calcium ions and magnesium ions. The higher value of total hardness was recorded for both seasons. During winter the season, the hardness values of all the spring sites were found to be above (BIS, 2012) the acceptable limits, except at spring-S_4 (192.98 mg/L) and maximum value of hardness found at the spring of BS_2 (438.6 mg/L) given in (Table 5). Similarly, total hardness was also found to be exceeding the acceptable limits in the spring-BS_1, BS_2, BS_3, BS_6, BS_7 and BS_{11} (358.19 mg/L, 381.49 mg/L, 309.36 mg/L, 328.34 mg/L, 389.82 mg/L and 334.18 mg/L) respectively, and the lowest value recorded at the spring-BS_4 (76.67 mg/L) given in (Table 4) during the summer season. The reason for higher value of total hardness could be attributed to anthropogenic activity and weathering action of host carbonate rock (Bui & Lodhi, 2020). To reduce the hardness of spring water of study area, a simple filtration treatment is preferable.

Fluoride: Traces of fluorides are present in many water samples, with higher concentrations often associated with groundwaters. During both seasons (Winter and Summer), the maximum amount of Fluoride was recorded from a spring-BS_8 (1.5 mg/L and 2.5 mg/l), which exceeded the permissible limit of BIS (2012) and in winter minimum amount found at spring-BS_{10} (0.20 mg/L) and in summer at the spring-BS_1 (0.25 mg/L). The probable reason of elevated fluoride may be the abundance of fluorspar, cryolite, fluorapatite and hydroxyapatite around the spring-BS_8 (Agarwal *et al.,* 1997). Fluoride can cause dental fluorosis and skeletal fluorosis if the concentration is too high. Filtration through a membrane Fluoride may be removed from water using reverse osmosis and electrodialysis membrane filtration methods.

Iron: Iron encourages the formation of "iron bacteria," which obtain their energy from the

Table 6: WQI and Paired t -test analysis (at 0.05 Significance level).

Spring Code	WQI (Winter 2019)	WQI (Summer 2020)
BS_1	8.309	8.727
BS_2	9.018	10.868
BS_3	10.042	9.840
BS_4	6.427	9.361
BS_5	8.697	13.239
BS_6	11.072	11.586
BS_7	12.308	16.052
BS_8	17.826	27.721
BS_9	4.571	6.718
BS_{10}	6.113	6.867
BS_{11}	8.196	10.443
t Stat	-3.081	
P value one-tail	0.012	
t Critical one-tail	-4.518	
t Critical one-left tail	-0.726	

oxidising of ferrous iron to ferric iron, depositing a slimy layer on the piping in the process. During both seasons (Winter and Summer), the maximum and minimum amount of Iron was reported from a spring-BS_7 (0.08 mg/l and 0.1 mg/L) and at spring-BS_{10} (0 mg/l and 0.02 mg/L). The iron content of all of the spring water samples was observed within the permissible range.

Nitrate: Nitrate (NO_3^-) is a plant nutrient that can be found naturally in the environment. Excessive nitrate and nitrite levels in drinking water can result in significant ailments such as "blue baby syndrome," increased cancer risk, starchy deposits, and spleen haemorrhage. During the winter season, the maximum amount of Nitrate was reported from a spring-BS1 (6 mg/l), and the minimum amount of Nitrate was rerecorded from a spring-BS_1 (1.5 mg/L). In the summer season, the maximum amount of Nitrate was reported from a spring-BS_6 (10 mg/l) and the minimum amount of Nitrate was rerecorded from a spring-BS_8 and BS_2 (2 mg/L). The nitrate concentration of all of the spring water samples was found to be within the permissible range.

WQI: The WQI is the highly effective way to communicate water quality because it presents the overall water quality results, rather than the results for each separate parameter (Toma *et al*. 2013). In order to know the degree of purity of spring water and its suitability for human consumption, a weighted arithmetic WQI method was applied. WQI values for all the water samples of springs for two seasons are shown in the (Table 6). All springs' water quality index value falls below 25 in winter season, indicating an "excellent" class for drinking purposes, except BS_8 spring which lies in a good class for drinking purposes with water quality values between 25 and 50 in summer season. The variation in water quality during different seasons may be due to the contact of rainwater with the sedimentary rock in the region leading to dissolution of ions into the aquifer or could be due to various anthropogenic activities, such as agricultural activities and anthropogenic pollution from the nearby area.

In general, the parameters of all the spring water samples were recorded to be in potable and excellent water category (Table 6), except the water sample of Bhaniya Dhaar-1 spring (BS_8) lies in the good quality category in the summer season. The paired *t-test* analysis was conducted at a significance level of 0.05 and 95% confidence level. These were calculated to compare the variation change in WQI during two seasons. Computation of paired *t*-test results shows that p-value (p = 0.012) is less than significant value 0.05, which revealed that the difference in WQI of the winter and summer seasons is significant. The results revealed that most of the springs' water quality is potable and excellent, with a significant variation in water quality during the two seasons.

Conclusion

Based on the results, individual parameters indicated that the majority of water samples were suitable for drinking and within permissible range according to the (BIS, 2012) standard, with the exception of a few samples where Total Hardness, Fluoride and Magnesium were found to be near or above the acceptable range of (BIS, 2012), which indicates that the water is safe to drink without any further treatment after a simple physical treatment of the spring water is preferable to minimise the risk of contamination. For Fluoride, Membrane filtration process reverse osmosis and electrodialysis are two membrane filtration processes which can be used for removal of fluoride. The overall WQI found that, when all physicochemical criteria were considered, all spring water samples were categorised as "excellent" quality during the winter season, with the exception of one site, Bhaniya Dhaar-1 spring (BS_8), which was categorised as "good" quality during the summer season. Additionally, there is a significant difference in WQI for all spring water during the two seasons. In the present scenario, Himalayan springs are gradually turning non-perennial. The anthropogenic activities within the catchment of springs are also significantly affecting the water quality. Water quality and discharge of the springs need to be checked at regular intervals, particularly during the rainy season, as many water-borne diseases are prevalent during this season. In the future, more studies should be conducted on the monitoring of discharge and water quality of springs in the Himalayan region. Awareness and capacity building of local community members is also needed to rejuvenate the Himalayan springs.

Conflict of interest

The authors declare that they have no conflict of interest.

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