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Water quality assessment of Bageshwar Block Springs using Weighted Arithmetic Water Quality Index (WAWQI)method, Bageshwar District, Uttarakhand, India

MOHD AZAM, JYOTHI PRASAD and H. J. SHIVA PRASAD

Department of Civil Engineering, College of Technology, G.B. Pant University of Agriculture and Technology, Pantnagar-263145(U.S. Nagar, Uttarakhand)

ABSTRACT: Springs are critical resource for the people of the Bageshwar block of Bageshwar district but are currently facing threats as a result of rapid urbanization and climate change. Here the people mainly depend on springs as the primary source of water. As a result, the majority of people in Bageshwar become reliant on springs to satisfy their daily water demand. The water quality of these springs is declining because of numerous anthropogenic activities, such as construction, deforestation, etc. The current study evaluated the drinking water quality of Bageshwar block springs in Bageshwar district, which are located in Uttarakhand's eastern Kumaon region between latitudes 29°41'60"N to 29°53'60" N and longitudes 79°35'60"E to 80°5'60"E and has an average elevation of 882.30 m 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. Springwater was collected and analysed based on the standard methods for the eleven springs of the Bageshwar block for two seasons the winter (December 2020) and summer (March 2021). The present study assessed the drinking water quality of perennial springs in and around Bageshwar using Weighted Arithmetic Water Quality Index (WAWQI)method. For calculating the Water Quality Index (WQI), 15 physicochemical parameters, namely, pH, alkalinity, Chloride, Electrical Conductivity, Total Dissolved Solids, Turbidity, Total Hardness, Potassium, Sodium, Fluoride, Iron, Nitrate, Calcium and Magnesium were taken. The WQI values shows that spring water ranging from 6.84 to 23.46 in the winter season and 5.98 to 16.46 in the summer season falls under the excellent category. A paired t-test was applied to compare significant variations in water quality between two seasons, revealing a significant difference (p-value is less than 0.05) in water quality between seasons. Water from all of the evaluated spring sources is safe to drink, even though 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.

Key words: Physico-chemical Parameters, QGIS software, springs, Weighted Arithmetic Water Quality Index (WAWQI)

Springs have been a reliable source of freshwater since ancient times. The majority of the population in both rural and urban communities in the Kumaon Himalaya of the Indian Himalayan Region (IHR) rely on natural spring water for domestic and livelihood needs such as drinking water, sanitation and irrigation. This means that a considerable number of villages, hamlets and towns might face drinking water shortages due to changing climatic conditions, rainfall patterns, and human activities. Thousands of communities experienced acute drinking water shortages around 8-10 years ago, according to (NITI Aayog Report, August 2018), a statistic that may be larger and more relevant now. The springs are also locally referred as 'Naula,' 'Dhaara,' 'Seeps,' and 'Gadheras,' among other names.

In every part of the Himalayas, there is mounting evidence that springs are drying up or reducing their flow. The Himalayan ecology is delicate and vulnerable to various changes induced by natural dynamics and anthropogenic actions. Erratic rainfall, seismic activity, and ecological degradation caused by land-use change for infrastructure development influence mountain aquifer systems(NITI Aayog Report, August 2018).

The Bageshwar district of Uttarakhand receives a significant quantity of precipitation. A portion of the precipitation is lost to the atmosphere due to evaporation and evapotranspiration from soil and plants, another significant portion flows as surface runoff due to highly rugged and undulating topography with a steep slope, and the remaining portion directly infiltrates through the soil profile to form groundwater storage in joints, fractures, and fissures.

Water security, specifically in the spring-fed river system, is highly vulnerable to seasonal changes in the spring hydrology. Many Himalayan springs face a decrease in discharge to various natural and anthropogenic stressors. Valdiya and Bartarya (1989) reported that from 1951 to 1986 (35-year period) there has been 40% reduction in discharge of springs of Kumaon region. They identified that 75% of the springs have gone dry and the average stream discharge has declined by approximately 40%.

Rapid demographic changes, infrastructure (dams, roads etc.) and socio-economic have affected many springs in the Kumaon region of Uttarakhand. Apart from decreasing discharge, deteriorating water quality of some springs has also been reported (Kumar and Rawat, 1996). In a report of (Central Ground Water Board, Annual Report 2019-20) the Ground Water Scenario of the Himalayas, various water quality parameters were tested for several groundwater samples of the Indian Himalayan States. It was also reported that water quality parameters exceeded the BIS acceptable limit in states including Uttarakhand.

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.

MATERIALS AND METHODS

Study Area

Uttarakhand, formerly known as Uttaranchal, is located in northern India that consists primarily of a mountainous and terai province with 13 districts primarily comprised of hill areas and located 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. The Bageshwar district is further divided in to three blocks (Bageshwar, Garur and Kapkot). The climate in Bageshwar district is moderate to sub-humid. The northern part of the district experiences sub-zero temperature almost throughout the year, whereas the central and southern parts are comparatively warm and humid. The primary climatic characteristic of the Bageshwar district is a harsh winter. In general, the district experiences a tropical to sub-tropical and sub-humid climate except for the northern part where a cold temperate climate prevails.

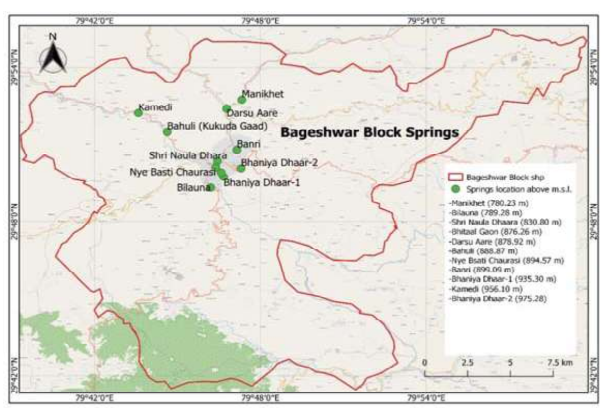

Fig. 1: Location map of study

January is the coldest month with mean maximum temperature of 10°C, the mean minimum temperature being about 2°C. The temperature drops down to – 6°C during January and February in the northern part of the district. June is the warmest month with the mean maximum and the mean minimum temperatures of 25°C and 15°C, respectively.

Most of the rainfall, about 75% of the annual value, occurs during monsoon months of June to September. July is the rainiest month, followed by August. In September, depressions from Bay of Bengal occasionally reach Uttarakhand and affect the weather of the Bageshwar district also. This phenomenon may cause heavy rains. The total annual rainfall at Bageshwar is 1360 mm and total numbers of rainy days are 119 days (District Survey Report, Bageshwar, 2019).

Major physiographic units of the Bageshwar are Central Himalayan Zone and Lesser Himalayan Zone and major drainage rivers are Saryu, Gomti, Pindar, Pungar and Bhadrapati. Bageshwar district comprises two broad physiographic divisions from north to south *viz.*, Central Himalayan Zone (north of the Main Central Thrust) and Lesser Himalayan Zone (south of the Main Central Thrust). The area shows an extremely rugged topography characterised by precipitous hills and deep gorges with sharp variation of high magnitude in surface relief. The general slope is towards south. In the northern parts, the land surface elevation rangesfrom about 3000 m to 6861 m above mean sea level whereas in the valleys of southern part, the altitude is as low as 795 m.

The soil of Bageshwar district can be broadly classified into two types, *viz.*Soil of Lesser Himalaya and Soil of Greater or Central Himalaya region. The first type covers the majority of the area. The soil in this area is exposed in massive mountainous tracts and tangled mass of series of ridges divided from each other by deep, narrow valleys. The soil of Lesser Himalaya region is further subdivided into a) Soil of Summits and Ridge tops, b) Soil of Side Slopes, c) Soil of Glacio-Fluvial Valleys, d) Soil of Fluvial Valleys and e) Soil of Cliffs. The soilof Greater Himalaya has been broadly classified under a) Soil of Summits, Ridge Tops and Mountain Glaciers, b) Soil of Side Slopes, c) Soil of Upper Glacio-Fluvial Valleys and d) Soil of Cliffs.

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

Table 1: Methods to be used in physio-chemical analysis of water samples

S. No.	Parameters	Units	Methods/Instruments
1.	pH	-	Digital pH meter
2.	EC	µS/cm	Digital Conductivity-TDS meter
3.	TDS	ppm or mg/l	Digital Conductivity-TDS meter
4.	Alkalinity as $CaCO_3$	mg/l	Titration by 0.01N HCL
5.	Chloride	mg/l	Titration by 0.02N AgNO3
6.	Hardness as $CaCO_3$	mg/l	EDTA titration
7.	Potassium	mg/l	Flame photometric method
8.	Sodium	mg/l	Flame photometric method
9.	RFC	mg/l	ORLAB Field Water Test Kit
10.	Turbidity	NTU	ORLAB Field Water Test Kit
11.	Fluoride	mg/l	ORLAB Field Water Test Kit
12.	Iron	mg/l	ORLAB Field Water Test Kit
13.	Nitrate	mg/l	ORLAB Field Water Test Kit
14.	Calcium	mg/l	EDTA titration
15.	Magnesium	mg/l	EDTA titration

Shri Naula Dhaara (BS_{11}). The spring water samples were collected in two seasons (one during the winter season (December 2020) and another in the summer season (March 2021) 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 remainingparameters tested in the laboratory (Table 1) using the methods of American Public Health Association (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 2) 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 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 2).

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 (1972). To determine the suitability of spring water for human consumption, we have used Weighted Arithmetic Water Quality Index (WAWQI)method. Various scientists widely used this method to assess water quality (Adimalla and Venkatayogi, 2018;Aly *et al*., 2015;Chowdhury *et al*., 2012**;** Balan *et al*., 2012**;** Rao *et al*., 2010; Ramakrishnaiah *et al*., 2009;Brown *et al*., 1972). The WQI was calculated using the following formula:

Following three steps are followed for computing WQI:
Each parameter's unit weight is inversely

Table 2: 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	29° 50′ 49″	79° 47′ 9″	899.09 m
Manikhet	BS_2	29° 52′ 52″	79° 47′ 23″	780.23 m
Darsu Aare	BS_3	29° 52′ 24″	79° 46′ 47″	878.92 m
Kukudagaad (Bahuli)	BS_4	29° 51′ 30″	79° 44′ 38″	888.87 m
Kamedi	BS_5	29° 52′ 9″	79° 43′ 12″	956.1 m
Shri Naula Dhaara	BS_6	29° 52′ 22″	79° 46′ 27″	830.8 m
Bilauna	BS_7	29° 49′ 41″	79° 46′ 15″	789.28 m
Bhaniya Dhaar-1	BS_8	29° 50′ 26″	79° 46′ 48″	935.3 m
Bhaniya Dhaar-2	BS_9	29° 50′ 5″	79° 47′ 18″	975.93 m
Bhitaal Gaon	BS_{10}	29° 50′ 7″	79° 46′ 23″	876.26 m
Nye Basti Chaurasi	BS_{11}	29° 50′ 7″	79° 46′ 23″	894.57 m

proportional 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,

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

K= constant of proportionality, given as

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

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 3).

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.

Table 3: 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

RESULTS AND DISCUSSION

According to the results of 15 physicochemical parameters given in Table 5 and Table 6 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 4 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. The overall water found to be alkaline in both seasons (Azam *et. al.,* 2022). The highest value of pH was measured in summer at the spring-BS_7 8.42 (Table 6). 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). However, 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 maximum amount of EC was measured from Manikhet spring-BS_2 (493.68 µS/cm) and Banri spring-BS_1 (486.32 µS/cm) for winter and summer, respectively, while minimum amount of EC was measured from Bahuli spring-BS_4 (25.57 µS/cm and 33.49 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

Table 4: Standards values of physicochemical parameters given by BIS and WHO

S. No.	Physico-chemical 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

chemical compounds and other substances. The maximum amount of TDS was measured from the spring-BS_2 (335.50 ppm and 315.26 ppm for winter and summer, respectively). In comparison, the minimum amount of TDS was measured from the Bahuli spring-BS_4 (17.39 ppm and 16.28 ppm for winter and summer, respectively). All of the TDS values were within the BIS (2012) and WHO (2011) permissible limits.

Total 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 three springs sites at Manikhet spring-BS_2, Darsu Aare spring-BS_3 and Bilauna spring-BS_7 (250.49 mg/l, 210.82 mg/l and 209.36 mg/l in winter season and 288.19 mg/l, 237.38 mg/l and 231.46 mg/l in summer season), respectively and given in Table 6. 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) and in summer season at spring site BS_6 (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 (17 mg/l and 14 mg/l) and minimum value of sodium, i.e., 1 mg/l reported from the springs BS_2 in the both seasons. 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 winter season, higher and lower values of chloride were detected at spring-BS_{11} (83.49 mg/l) and BS_7 (14.63 mg/l), respectively given in Table 6, and in the summer season, higher and lower values of chloride were detected at spring-BS_{10} (46.37 mg/l) and BS_9 (17.29 mg/l) respectively given in Table 6. 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 (72 mg/l and 50 mg/l), respectively. The minimum calcium concentration in both seasons was recorded at the same spring-BS_4 (8 mg/l and 12 mg/l), respectively. The calcium content in all the spring water samples was within the permissible limit.

Magnesium: During the winter season, the highest concentration of magnesium recorded was 32.81 mg/l, 47.39 mg/l, 35.24 mg/l, 37.18 mg/l and 36.45 mg/l at the spring sites of BS_1, BS_2, BS_3, BS_6 and BS_7, respectively and also in the summer season highest concentration of magnesium recorded were 39.15 mg/l, 58.19 mg/l, 49.58 mg/l and 47.29 mg/l at the spring sites of BS_1, BS_2, BS_6 and BS_7, respectively, which is beyond the acceptable limit prescribed by (BIS, 2012) (Table. 4). 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.

Table 5: Physico-chemical properties of springs Bageshwar Block in December, 2020

S. No.	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	7.01	7.87	8.24	7.20	7.04	7.63	8.42	7.08	7.62	7.98	7.76
2.	EC (µS/cm)	406.73	493.68	287.73	25.57	190.17	336.7	307.63	100.9	73.31	69.69	246.11
3.	TDS (ppm)	276.50	335.50	195.30	17.39	129.33	228.4	209.16	68.33	49.71	47.33	167.23
4.	Alkalinity as $CaCO_3$ (mg/l)	161.89	**250.49**	**210.82**	92.59	99.46	169.96	**209.36**	108.54	95.26	84.69	173.19
5.	Chloride (mg/l)	52.18	18.43	17.34	73.41	29.23	31.17	14.63	19.73	18.32	16.79	83.49
6.	Hardness as $CaCO_3$ (mg/l)	**425.52**	**408.49**	**446.81**	148.92	**255.31**	**382.98**	**425.53**	159.57	148.93	106.38	**340.42**
7.	Potassium (mg/l)	3	2	2	0	5	3	0	2	1	0	3
8.	Sodium (mg/l)	17	1	6	2	8	19	2	4	2	8	10
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)	0.6	0.35	0.45	0.5	0.6	0.65	0.4	**2.0**	0.3	0.8	0.3
12.	Iron(mg/l)	0.05	0.05	0.02	0.08	0.09	0.1	0.08	0.04	0.03	0.02	0.03
13.	Nitrate(mg/l)	4.5	3.5	6	2	1.5	3	3.5	3	2	5	1.5
14.	Calcium (mg/l)	36	72	48	12	30	38	40	14	8	14.8	28
15.	Magnesium(mg/l)	**32.81**	**47.39**	**35.24**	1.94	3.65	**37.18**	**36.45**	14.58	25.52	3.65	22.38

During winter the season, the hardness values of all the spring sites were found to be above (BIS, 2012) the acceptable limits at spring-BS_1, BS_2, BS_3, BS_5, BS_6, BS_7 and BS_{11} (425.52 mg/l, 408.49 mg/l, 446.81 mg/l, 255.31 mg/l, 382.98 mg/l, 425.53 mg/l and 340.42 mg/l) respectively, and maximum value of hardness found at the spring of BS_3 (446.81 mg/l) given in (Table 6). 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} (386.49 mg/l, 376.34 mg/l, 313.48 mg/l, 339.99 mg/l, 370.82 mg/l and 320.80 mg/l) respectively, and the lowest value recorded at the spring-BS_{10} (81.76 mg/l) given in (Table 5) 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 and 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 winter season, the maximum amount of fluoride was recorded at spring-BS_8 (2.0 mg/l), which exceeded the permissible limit (1.5 mg/l) of BIS (2012) and in winter minimum amount found at spring-BS_9 (0.30 mg/l) and in summer at the spring-BS_2 (0.30 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 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_6 (0.1 mg/l and 0.07 mg/l) and at spring-BS_{10} (0.02 mg/l and 0.01 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-BS_3 (6 mg/l), and the minimum amount of nitrate was rerecorded from a spring-BS_{11} (1.5 mg/

Table 6: Physico-chemical properties of Bageshwar Block springs in March, 2021

S. No.	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	7.17	7.59	8.26	7.11	6.92	7.89	8.47	7.29	8.01	**8.89**	8.13
2.	EC (µS/cm)	486.32	431.59	378.19	33.49	159.15	419.29	401.79	125.82	99.18	131.56	324.66
3.	TDS (ppm)	245.36	315.26	186.15	16.28	72.49	206.27	196.19	59.69	41.96	60.18	161.49
4.	Alkalinity as $CaCO_3$ (mg/l)	153.28	**288.19**	**237.38**	78.96	101.63	178.36	**231.46**	135.29	69.87	87.92	159.28
5.	Chloride (mg/l)	28.77	19.89	21.08	38.36	25.29	33.19	23.21	18.59	17.29	46.37	27.49
6.	Hardness as $CaCO_3$ (mg/l)	**386.49**	**376.34**	**313.48**	82.83	195.39	**339.99**	**370.82**	129.93	92.28	81.76	**320.80**
7.	Potassium (mg/l)	2.5	1.5	2	0	4	5	0	2	1	0	4
8.	Sodium (mg/l)	14	1	3.5	1	4	14	1.5	3	3.5	5	9.5
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)	0.45	0.3	0.5	0.4	0.5	0.45	0.55	0.45	0.3	0.55	0.45
12.	Iron(mg/l)	0.04	0.05	0.03	0.05	0.07	0.06	0.09	0.05	0.02	0.01	0.04
13.	Nitrate(mg/l)	5	4.5	4	2	2.5	4	4.5	2.5	3	4	2
14.	Calcium (mg/l)	46	50	42.5	16	32	34	48	14	12	24	40
15.	Magnesium(mg/l)	**39.15**	**58.19**	28.45	7.82	13.78	**49.58**	**47.29**	26.36	15.81	16.45	19.61

l). In the summer season, the maximum amount of nitrate was reported from a spring-BS_7 (4.5 mg/l) and the minimum amount of nitrate was rerecorded from a spring-BS_4 and BS_{11} (2.0 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 7). All springs' water quality index value falls below 25 in both (winter and summer) seasons, indicating an "excellent" class for drinking purposes. 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 7), except the water sample of Bhaniya Dhaar-1 spring (BS_8) lies in the good quality category in the summer season.

Table 7: WQI and Paired t -test analysis (at 0.05 Significance level)

Spring Code	WQI (Winter 2020)	WQI (Summer 2021)
BS_1	11.705	9.411
BS_2	10.149	9.514
BS_3	8.045	9.470
BS_4	13.338	9.239
BS_5	15.624	12.531
BS_6	17.883	12.269
BS_7	13.832	16.460
BS_8	23.462	10.200
BS_9	6.843	5.978
BS_{10}	10.486	7.910
BS_{11}	11.181	9.954
t Stat	2.119	
P value	0.030	

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 = 0.030) 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 both (winter and summer) seasons. Additionally, there is a significant difference in WQI for all spring water during the two seasons. In the present scenario, Bageshwar 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 Bageshwar region. Awareness and capacity building of local community members is also needed to rejuvenate the Himalayan springs.

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