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Assessment of Spring Water Quality In Upper Himalayan Villages Using Water Quality Index

Shikha Verma, Kumar Yuvraj, Shivani Mainwal, Kanika Dogra[1] and Lakshman Singh[2]

Department of Soil and Water Conservation Engineering
GB Pant University of Agriculture and Technology, Pantnagar-263 145, India
[1]University of Petroleum and Energy, Dehradun-248 007, India
[2]Department of Civil Engineering, Dev Bhoomi Uttarakhand University, Dehradun-248 007, India
E-mail: vermsshikha@gmail.com

Abstract: Springwater is a primary source of water in the Himalayan region of Uttarakhand in India. These spring water sources quickly approach degraded water quality in both quantitively and qualitatively patterns because of its population boom, increased industrialization, and usage of pesticides in agriculture. In the present study, 16 spring water samples were collected from 9 upper Himalayan villages of Chamoli during the pre and post-monsoon period. Physic-chemical assessment and analysis of the collected spring water samples were performed to evaluate the water quality indices for drinking as well as irrigation purposes. The analysis of 14 physicochemical parameters including, pH, TDS, EC, Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Cl^{-}, F^{-}, HCO_3^{-}, SO_4^{2-}, PO_4^{3-} and NO_3^{-} were performed during pre and post-monsoon periods whereas Sodium percentage (Na%), Sodium Absorption Ratio, and Residual Sodium Carbonate, Soluble sodium percentage, Permeability index, Kelley's ratio, and, Magnesium hazard were evaluated to assess irrigation water quality. Out of 16 spring water samples, only 44% were in the 'good' water quality range for drinking during pre-monsoon whereas the significant 75% were in the same category water class during post-monsoon period. Three sampling sites had 'poor' water quality during both pre and post-monsoon periods. There were 6 springwater sampling sites that had 'very poor' water quality during pre-monsoon, but no site was found in this class during the post-monsoon period. The average value of irrigation water quality parameters Na%, SAR, RSC, SSP, Permeability index, Kelley's ratio, and, Magnesium hazard was observed as 27.43, 1.26, 1.96, 18.97, 0.24, 82.41, and 45.92 meq/l during pre-monsoon and 22.03, 0.71, 1.07, 24.56, 0.34, 83.34, and 39.41 meq/l during the post-monsoon period in the study area.

Keywords: Springwater, Water quality, Irrigation Water quality, Chamoli

Groundwater is becoming a contentious and important issue around the world. About one-third of the population relies on groundwater for drinking water (Nickson et al 2005). The primary source of freshwater in India is groundwater resources. Groundwater resources supply 85% of India's rural water supplies (World Bank 2010). High-relief and complicated rock geological structures are crucial for the formation of mountain aquifers in mountainous areas like the Himalayas. These mountain aquifers hold a large amount of water, which eventually naturally releases as spring (Mahamuni and Upasani 2011, Khadka and Rijal 2020). India is quickly approaching a significant groundwater crisis as a result of its population boom, increased industrialization, and usage of pesticides in agriculture (Chandra et al 2015). After groundwater becomes contaminated, regular monitoring of its quality becomes crucial because it cannot be restored by ceasing the pollution at its source (Ramakrishnaiah et al 2009). In addition to having a direct impact on human health, water pollution significantly impacts water quality (Milovanovic 2007).

There are around 3 million springs are in the Indian Himalayan Region (IHR). On a broader scale, the Himalayan region considered to be the "spring scopes of India," where a gross estimate of approximately 200 million (about 15%) Indians depend on spring water (NITI Ayog 2019). Around 60% of the population of the Himalayas, both in the towns and the rural areas, depends on spring water, and over 80% of them are directly employed in agriculture. Although just 11% of the total cultivable land area is irrigated and only 12.5% of the total land area is cultivated, 64% of that land is fed by natural springs (Gupta et al 2003). Since water is so important, numerous studies have been conducted using various methodologies to evaluate the groundwater quality for drinking, irrigation, and another usage (Molekoa et al 2019, Srivastava 2019, Bahir et al 2020, Madhav et al 2020, Jawadi 2020, Taloor et al 2020, Amiri et al 2021, Deoli and Nauni 2021, Thakur et al 2023, Saw et al 2023). Abdulwahid (2013) used the water quality indexing approach to evaluate the Delizhiyan springs and Shawrawa River's suitability for human consumption and other uses in the Soran area of Erbil, Kurdistan Region of Iraq. Ameen (2019) conducted a study to assess the spring water quality in the Barawari Bala area of Duhok, Iraq, using a WQI based on several physicochemical characteristics. It was found that, out of 118 samples, except 2 samples rest were of good quality. By collecting water from five distinct locations, Chauhan et al (2020) evaluated WQ of Sumari Village in Uttarakhand. Based on the WQI, the authors discovered that, of the 5 samples, 2 are of excellent quality, 2 are of good quality, and 1 is of moderate quality. In accordance with World Health Organization and BIS criteria, Shinde et al (2020) assessed the quality of the groundwater in Thane, India. QGIS software has been used to map the spatial assessment of groundwater quality using a remote sensing technique. To analyze the groundwater quality for the Wanaparthy watershed in Telangana, India, Vaiphei et al (2020) employed WQI and GIS techniques. Thakur et al (2023) used WQI and irrigation WQI to assess drinking and irrigation water quality for Pithoragarh Uttarakhand.The study was carried out to assess the quality of spring water for drinking and irrigation purposes at Himalayan villages of Chamoli block in Uttarakhand.

MATERIAL AND METHODS

Study area: The studied villages are situated at the Chamoli block of Chamoli district in the Uttarakhand state of India. The block lies between 30.2937°N latitude and 79.5603°E longitude and falls under the Chamoli district having a geographical area of 7520 km^2. As the elevation of the block ranges from 800 m to 8,000 m above mean sea level the climate of the district largely depends upon elevation difference. The block receives an average annual rainfall of 1230.8 mm. Most of the rainfall occurs during the month of June to September in the study area. Temperature also varies with the elevation the highest temperature was recorded at 34°C and the lowest was 0°C during the month of January.

Data collection: The 16 spring water samples were collected from 9 villages of Chamoli block during the pre and post-monsoon periods. Physic-chemical assessment and analysis of the collected spring water samples were performed to evaluate the water quality indices (WQI) of the sampling sites during pre and post-monsoon periods in the study area for drinking as well as irrigation purposes (Table 1).

Approach and methodology: Water samples were collected from springs *(Naula and Dhara)* of Chamoli block of Chamoli district of Uttarakhand in 1000 ml sampling bottles. The data was collected on color, odor, taste, temperature, pH, TDS, EC and turbidity, total hardness (TH), calcium content, sodium content, chloride content, magnesium content, free CO_2, acidity, alkalinity, sulphate content, Ca hardness, Mg hardness, sodium adsorption ratio (SAR). Electric conductivity, pH, temperature and TDS were determined in the site using a Pocket EC tester, pH tester, thermometer and Pocket TDS, respectively. All the other tests were performed in the laboratory. Different methods used in the analysis are shown in Table 2. The weighted arithmetic mean method is used to evaluate the Drinking WQI for both pre and post-monsoon periods in the study area.

Table 1. Sample collection points

Village	Spring name	Latitude	Longitude
Karaki	Gada Dhara	30.437	79.305
Karaki	Karaki Dhara	30.436	79.306
Malagaon	Phakuna Dhara	30.436	79.3
Malagaon	Dathi Dhara	30.44	79.298
Malagaon	Lagdi Dhara	30.438	79.293
Romadi	Tapar Dhara	30.432	79.301
Romadi	Talla Dhara	30.432	79.299
PoulDhar	Poul Dhara	30.433	79.304
PoulDhar	Siya Dhjara	30.428	79.305
Baragaina	Road Dhara	30.443	79.285
Kunkuni	Kunkuni Spring	30.454	79.290
Siroli	Kularkudi Dhara	30.467	79.281
Siroli	Bhagial Dhara	30.465	79.280
Khalla	Khalla Magara	30.475	79.274
Khalla	Simar Magara	30.449	79.272
Bandwara	Bandwara Magara	30.436	79.284

Table 2. Different methods used for physic-chemical analysis

Parameter (s)	Method
Colour	Visual Interpretation
Odour	Smelling
Taste	Drinking (with precautions)
Total dissolved solids (TDS)	Electrometric
Electrical conductivity (EC)	Electrometric
Temperature	Electrometric
pH	Electrometric
Acidity	Titration by 0.05N NaOH solution
Alkalinity	Titration by 0.01N HCL
Turbidity	Absorbance method
Free CO_2	Titration by 0.05N NaOH
Dissolved O_2	Titration by Sodium thiosulphate
TH	Titration by EDTA
Ca and Mg	Titration by EDTA
Chloride	Titration by 0.02N $AgNO_3$
Na and K	Flame photometry
Sulphate	Absorbance method

Water quality indexing for drinking water: Water Quality Index (WQI) is a single-valued term used to represent the overall quality of water depending upon a huge variety of parameters. The weights are assigned to each parameter based on their evident significance in overall water quality and the final index was evaluated by taking the weighted average of all the parameters. The water quality index has been broken down into five essential categories: excellent, good, poor, very poor, and unsafe for consumption.

The weightage to each of the parameter was assigned using the methodology given by Aabbasi and Arya (2000) as:

$$W_i \propto \frac{1}{S_i} \quad \dots (1)$$

Where, W_i = Unit weight for i^{th} parameter; and S_i = Standard permissible value for i^{th} parameter.

$$W_i = \frac{K}{S_i} \quad \dots (2)$$

Where, K is proportionality constant, which can be defined as:

$$K = \frac{1}{[\frac{1}{S_1}+\frac{1}{S_2}+\cdots\dots\dots\dots+\frac{1}{S_n}]} \quad \dots (3)$$

The summation of all the values of W_i must be equal to 1.

Water quality rating: The following equation was used to determine the rating of water quality (Qi) for each selected parameter for potable water (Brown et al 1970).

$$Q_i = \frac{V_a - v_i}{S_i - v_i} \times 100 \quad \dots (4)$$

Where, V_i and V_a are the ideal and actual values of water quality parameters of water samples. For all the parameters, except pH (7) and DO (14.6 mg/l) the ideal value (V_i) is 0.

Indexing: The overall water quality indices (WQI) for drinking water were (Brown et al 1970) .

$$WQI = \frac{\sum_{i=1}^{n} Q_i W_i}{\sum_{j=1} W_i} \quad \dots (5)$$

Q_i and W_i are the quality rating and relative weight for i^{th} parameter.

Evaluation of water quality for irrigation: The water derived from natural springs may contain chemicals in some proportion which affects crop yield and fertility of soil. To evaluate suitability of spring water for irrigation in this study area, sodium adsorption ratio (SAR), Magnesium hazard and Permeability Index (PI) have been calculated.

Sodium adsorption ratio: SAR was calculating using following eq.:

$$SAR = \frac{Na}{\sqrt{\frac{Ca+Mg}{2}}} \quad \dots (6)$$

Magnesium hazard: The Mg hazard of irrigation water was calculated using the relationship given by Szabolcs and Darab (1964) as:

$$Mg_{hazard} = \frac{Mg}{Ca+Mg} \times 100 \quad \dots (7)$$

Permeability index: Based on the Permeability Index (PI), the following equation proposed by Kacmaz and Nakoman (2010) was used to assess the suitability of irrigation water:

$$PI = \frac{Na + \sqrt{HCO_3}}{Ca + Mg + Na} \times 100 \dots (8)$$

Irrigation water quality indexing: For irrigation water quality indexing, several parameters are to be determined .Parameters used for water quality indexing for irrigation purpose electrical conductivity sodium adsorption ratio, sodium chloride and bicarbonates were estimated . Rating for irrigation water quality was estimated using the following equation for each of the selected parameter, a method suggested by Meireles et al (2010) and criteria and permissible limit recommended by Ayers and Westcot (1985) (Table 3).

$$Q_i = Q_{imax} - \left[\frac{X_{ij} - X_{inf}}{X_{amp}}\right] \times Q_{iamp} \dots (9)$$

Q_{imax} is the class's highest value of Q_i; x_{ij} is the parameter's actual value; x_{inf} is the corresponding value for the class's lower limit; q_{iamp} is the class amplitude; x_{amp} is the class amplitude to which the parameter belongs. To evaluate x_{amp}, for the last class of each parameter the highest value of parameter obtained from the physico-chemical analysis of water samples was used to the upper limit.

Table 3. Parametric permissible values for irrigation water quality

Q_i	EC (dS/cm)	SAR $(meq/l)^{1/2}$	Na (meq/l)	Cl (meq/l)	HCO_3 (meq/l)
85-100	0.20≤EC<0.75	2≤SAR<3	2≤Na<3	1≤Cl<4	1≤HCO_3<1.5
60-85	0.75≤EC<1.50	3≤SAR<6	3≤Na<6	4≤Cl<7	1.5≤HCO_3<4.5
35-60	1.50≤EC<3.00	6≤SAR<12	6≤Na<9	7≤Cl<10	4.5≤HCO_3<8.5
0-35	0.20>EC≥3.00	2>SAR≥12	2>Na≥9	1>Cl≥10	1>HCO_3≥8.5

Source: Meireles et al (2010)

Table 4. Drinking water quality indices of study area during pre-monsoon period

Station	pH	TDS	TH	EC	Chloride	HCO_3^-	Ca	Mg	Na	K	Phosphate	Sulphate	Nitrate	Fluoride	WQI
Gada Dhara	7.53	431.00	488.00	713.50	46.15	400.00	51.40	48.40	48.40	7.30	0.64	117.07	51.30	1.14	80.42
Karaki Dhara	7.55	611.50	558.00	955.50	31.95	455.00	48.20	27.56	27.56	4.00	0.08	53.53	76.40	1.11	78.57
Phakuna Dhara	8.08	294.00	353.00	478.50	53.56	260.10	27.10	18.40	18.40	4.50	0.57	85.14	41.20	0.64	50.26
Dathi Dhara	7.85	212.80	261.00	518.50	22.72	249.00	27.90	32.40	32.40	5.50	0.17	50.84	76.00	1.14	81.88
Lagdi Dhara	8.01	577.70	457.00	946.28	103.56	382.50	25.60	22.60	22.60	3.60	0.15	18.80	21.60	0.82	46.78
Tapar Dhara	7.05	282.50	360.00	406.50	22.72	247.50	38.60	13.20	13.20	6.50	0.59	57.07	36.90	0.45	45.84
Talla Dhara	7.79	309.50	388.00	524.60	58.93	295.00	36.40	15.40	15.40	1.60	0.35	51.16	88.70	0.78	84.54
Poul Dhara	7.55	656.48	294.00	1182.00	28.40	157.50	41.20	29.90	29.90	1.70	0.32	60.12	34.50	0.34	45.01
Siya Dhara	7.70	345.50	576.00	746.00	41.89	430.00	39.60	22.70	22.70	1.60	0.19	101.52	12.80	0.05	40.44
Road Dhara	8.35	614.50	237.00	975.00	18.46	180.00	23.30	0.90	0.90	3.50	0.17	103.47	7.50	0.42	28.31
Kunkuni Spring	8.05	376.20	266.00	406.50	28.40	287.50	23.60	7.80	7.80	4.50	1.08	76.73	79.00	1.11	77.97
Kularkudi Dhara	7.64	401.50	498.00	721.50	48.99	387.50	38.20	12.80	12.80	1.50	0.55	39.02	22.60	0.55	42.63
Bhagial Dhara	7.44	640.50	569.00	1022.40	43.31	535.80	21.20	28.30	28.30	1.40	0.13	116.15	41.80	1.03	57.94
Khalla Magara	7.82	434.70	398.00	648.10	22.72	382.50	24.50	8.77	8.77	6.50	0.17	77.60	77.80	1.25	71.00
Simar Magara	8.15	268.00	190.00	623.50	28.40	380.00	38.90	10.39	10.39	3.50	1.30	7.39	85.90	1.10	78.60
Bandwara Magara	7.89	306.40	236.00	498.80	105.64	166.10	35.20	21.50	21.50	1.60	0.44	34.97	47.10	0.64	44.75

Table 5. Drinking water quality indices of study area during pos-monsoon period

Station	Longitude	Latitude	pH	TDS	TH	EC	Chloride	HCO3-	Ca	Mg	Na	K	Phosphate	Sulphate	Nitrate	Fluoride	WQI
Gada Dhara	79.5314	29.0397	7.28	426	342	682.6	22.65	301	47.6	28.2	22.5	6.8	0.63	92.5	47.56	1.04	73.77
Karaki Dhara	79.4738	29.0195	7.41	574.5	381	922.1	19.87	281.6	41.5	21.5	11.3	3.9	0.04	51.25	51.23	1.07	62.50
Phakuna Dhara	79.4143	29.0242	7.8	305	315	418.6	7.8	195.2	26.9	14.8	14.3	3.2	0.42	74.25	39.25	0.52	49.22
Dathi Dhara	79.52	28.9947	6.9	114.2	154	208.9	18.64	238.4	19.8	23.5	21.4	5.1	0.13	42.65	45.1	1.09	47.77
Lagdi Dhara	79.4123	28.9733	7.28	534.8	304	864	79.46	301.5	25.9	18.7	21.2	3.5	0.12	9.74	20.55	0.43	47.95
Tapar Dhara	79.389	28.953	7.01	215.5	205	332.4	13.5	136.5	33.8	5.4	18.4	6.3	0.46	53.24	21.2	0.35	37.77
Talla Dhara	79.3445	28.9864	7.5	304.7	288	474.7	29.85	158.4	31.2	10.2	17.6	0.9	0.31	45	46.87	0.66	44.54
Poul Dhara	79.4605	28.9403	7.6	625.4	119	1025.6	16.62	87	29.5	17.5	15.1	1.5	0.27	59.87	28.7	0.22	38.55
Siya Dhjara	79.5192	28.9125	7.25	210	330	341.4	36.5	358.5	38.4	21.6	18.7	1.3	0.12	93.2	7.54	0.06	41.96
Road Dhara	79.5208	28.9625	7.48	542	134	874.8	8.92	87.1	23.1	0.8	11.2	2.8	0.16	102.46	3.12	0.35	28.77
Kunkuni Spring	79.437	28.901	7.62	376.2	142	452.7	25.4	197.4	18.7	1.7	15.3	3.4	0.94	41.65	48.68	1.05	21.34
Kularkudi Dhara	79.3231	29.0506	7.1	205.5	445	361	36.52	306.9	35.4	11.4	18	1.5	0.42	36.02	22.14	0.56	48.92
Bhagial Dhara	79.302	29.1131	7.41	542.7	432	899	21.36	430.7	16.5	17.3	16.3	1.2	0.11	74.8	23.65	0.94	28.40
Khalla Magara	79.2879	29.0827	6.9	390.3	195	649.3	9.78	171.3	22.2	4.6	24.2	5.2	0.14	65.49	53.46	1.13	46.78
Simar Magara	79.2466	29.0448	7.54	222.5	75	378.9	15.4	246.3	22	8.9	19.6	3.3	1.23	5.4	55.67	1.05	52.40
Bandwara Magara	79.9722	28.9221	7.8	301.8	215	484.9	73.2	52.3	32.6	7.7	15.9	0.9	0.38	36.52	46.9	0.61	40.73

The overall water quality indices (WQI) for irrigation water were calculated by

Eq. 10 given by Meireles et al (2010) as follows:

$$IWQI = \sum_{i=1}^{n} Q_i W_i \qquad \dots (10)$$

Where,

Q_i and W_i are the quality rating and relative weight for i^{th} parameter, respectively.

RESULTS AND DISCUSSION

The results are shown in Table 4 and 5 for drinking WQI during the pre and post-monsoon period, respectively. The descriptive statistics of spring water quality in the study area has been shown in Table 6. The comparative study showed significant improvement in spring water quality during the post-monsoon period and out of 16 spring water samples, only 44% (7 samples) were in the 'good' water quality range for drinking during pre-monsoon whereas significantly 75% (were in the same category water class during the post-monsoon period. Three sampling sites had 'poor' water quality during both pre and post-monsoon periods. There were 6 spring water sampling sites that had 'very poor' water quality during pre-monsoon, but no site was in this class during the post-monsoon period. The one sampling site was found with excellent water quality for drinking.

Table 6. WQI of Springwater during pre and post monsoon period

WQI range	Rating of groundwater quality	No. of samples	
		Pre-monsoon	Post-monsoon
≤25	Excellent	0	1
>25-50	Good	7	12
>50-75	Poor	3	3
>75-100	Very poor	6	0
≥100	Unsuitable	0	0

Talla Dhara has the poorest and *Siya Dhara* has the purest water quality during the pre-monsoon period whereas *Gada Dhara* and *Kunkuni Spring* were most impure and pure spring water sites during pre and post-monsoon period, respectively in the study area. No sampling site was with excellent drinking water quality during pre-monsoon whereas 1 sampling site (*Kunkuni Dhara)* was in this category during the post-monsoon period, Though, no sampling site was found unsuitable for drinking during both pre and post-monsoon periods in the study area but 6 sampling sites were found with very poor water quality during pre-monsoon in the study area. According to the sodium absorption ratio of spring water to assess its suitability for irrigation purposes all the samples were found excellent except only one location during the pre-monsoon period. All the sampling sites were found excellent for irrigation during post-monsoon in the study area.

Irrigation WQI: The descriptive statistics of the irrigation water quality during the pre and post-monsoon period in the study area are shown the Table 7 and 8, respectively. During

Table 7. Descriptive statistics of irrigation water quality during pre-monsoon period

Parameters (meq/l)	Sample range				Range	Classification	No. of samples
	Minimum	Maximum	Average	S.D.			
Na% (Wilcox 1955)	16.66	47.45	27.43	8.48	≤20	Excellent	2
					>20 - ≤40	Good	12
					>40 - ≤60	Permissible	2
					>60 - ≤80	Doubtful	0
					>80	Unsuitable	0
SAR (Rechards 1954)	0.05	11.16	1.26	2.65	≤10	Excellent	15
					>10 - ≤18	Good	1
					>18 - ≤26	Doubtful	0
					>26	Unsuitable	0
RSC (Raghunath 1987)	-1.97	5.37	1.96	1.97	≤1.25	Good	5
					>1.25 - ≤2.5	Doubtful	3
					>2.5	Unsuitable	8
SSP	3.06	26.47	18.97	5.73			
KI	0.03	0.36	0.24	0.08			
PI	49.68	137.35	82.41	24.99			
MR	6.05	68.99	45.92	15.77			

post-monsoon irrigation water was more suitable for irrigation. The detailed characteristic values of the spring water samples in the study area during pre and post-monsoon (Tables 9 and 10). The average value of irrigation water quality parameters Na%, SAR, RSC, SSP, Permeability index, Kelley's ratio, and Magnesium hazard were 27.43, 1.26, 1.96, 18.97, 0.24, 82.41, and 45.92 meq/l during pre-monsoon and 22.03, 0.71, 1.07, 24.56, 0.34, 83.34, and 39.41 meq/l during the post-monsoon period in the study area.

Table 8. Descriptive statistics of irrigation water quality during post-monsoon period

Parameters (meq/l)	Sample range				Range	Classification	No. of samples
	Minimum	Maximum	Average	S.D.			
Na% (Wilcox 1955)	13.26	33.72	22.03	6.24	≤20	Excellent	7
					>20 - ≤40	Good	9
					>40 - ≤60	Permissible	0
					>60 - ≤80	Doubtful	0
					>80	Unsuitable	0
SAR (Rechards 1954)	0.35	1.22	0.71	0.19	≤10	Excellent	16
					>10 - ≤18	Good	0
					>18 - ≤26	Doubtful	0
					>26	Unsuitable	0
RSC (Raghunath 1987)	-1.51	4.79	1.07	1.56	≤1.25	Good	9
					>1.25 - ≤2.5	Doubtful	9
					>2.5	Unsuitable	0
SSP	11.27	41.33	24.56	7.70			
KI	0.13	0.70	0.34	0.15			
PI	51.56	141.46	83.34	24.59			
MR	5.46	66.42	39.41	17.30			

Table 9. Details of the spring water quality during pre-monsoon period

Station	SSP	SAR	RSC	%Na	KI	MR	PI
Gada Dhara	24.17	11.16	-0.05	25.76	0.32	61.08	53.57
Karaki Dhara	20.29	0.78	2.75	21.65	0.25	48.80	66.54
Phakuna Dhara	21.69	0.67	1.38	24.07	0.28	53.09	77.68
Dathi Dhara	25.60	0.98	-0.01	47.45	0.34	65.93	62.31
Lagdi Dhara	23.70	0.78	3.11	25.36	0.31	59.54	84.10
Tapar Dhara	15.92	0.47	1.03	39.64	0.19	36.30	71.82
Talla Dhara	17.75	0.54	1.73	18.63	0.22	41.35	76.03
Poul Dhara	22.22	0.86	-1.97	22.79	0.29	54.74	49.68
Siya Dhjara	20.31	0.71	3.18	40.98	0.25	48.86	74.96
Road Dhara	3.06	0.05	1.71	29.41	0.03	6.05	137.35
Kunkuni Spring	15.63	0.35	2.88	29.90	0.19	35.52	115.72
Kularkudi Dhara	15.75	0.46	3.38	16.66	0.19	35.83	87.09
Bhagial Dhara	26.47	0.94	5.37	27.03	0.36	68.99	90.22
Khalla Magara	16.32	0.39	4.31	21.89	0.19	37.37	123.46
Simar Magara	13.85	0.38	3.42	26.15	0.16	30.80	90.35
Bandwara Magara	20.84	0.70	-0.83	21.55	0.26	50.45	57.62

Table 10. Details of the spring water quality during post-monsoon period

Station	SSP	SAR	RSC	%Na	KI	MR	PI
Gada Dhara	17.14	0.64	0.20	19.59	0.21	49.68	56.05
Karaki Dhara	11.27	0.35	0.75	13.26	0.13	46.34	60.58
Phakuna Dhara	19.43	0.55	0.62	21.44	0.24	47.83	75.33
Dathi Dhara	23.99	0.77	0.96	16.47	0.32	66.42	74.96
Lagdi Dhara	24.42	0.77	2.09	26.17	0.32	54.61	83.31
Tapar Dhara	27.21	0.77	0.10	31.00	0.37	21.03	78.09
Talla Dhara	24.10	0.70	0.19	14.65	0.32	35.27	74.85
Poul Dhara	18.29	0.54	-1.51	19.15	0.22	49.72	51.56
Siya Dhjara	17.94	0.60	2.16	18.53	0.22	48.39	71.42
Road Dhara	28.50	0.62	0.21	31.38	0.40	5.46	98.44
Kunkuni Spring	38.19	0.91	2.16	21.14	0.62	13.16	141.46
Kularkudi Dhara	22.34	0.67	2.31	23.19	0.29	34.93	86.38
Bhagial Dhara	23.82	0.67	4.79	24.60	0.31	63.60	113.13
Khalla Magara	41.33	1.22	1.31	14.25	0.70	25.67	107.17
Simar Magara	31.63	0.89	2.20	33.72	0.46	40.27	106.23
Bandwara Magara	23.33	0.65	-1.41	23.92	0.30	28.25	54.58

CONCLUSIONS

The physicochemical analysis was performed for 16 sampling sites of the Chamoli block of the Chamoli district of Uttarakhand during the pre and post-monsoon period. From the study, it has been concluded that 7 samples are good for drinking whereas 9 samples are in the poor and very poor categories. In post-monsoon season, 1 sample is of excellent water quality whereas 12 samples are of good water quality. From the result, it might be calculated that the major water pollution problem is in the pre-monsoon season for the studied area. Similarly, in irrigation water quality the post-monsoon season water is better to use in than pre-monsoon water for irrigation purposes.

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