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Qualitative Assessment of Water Resources Using Water Quality Index in Lower Shivalik Himalaya Region, Uttarakhand, India

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ABSTRACT

This study aimed at the qualitative assessment of selected water sources in the lower Shivalik Himalayas at Haridwar province of India using the water quality index (WQI) approach. Samples were collected from three sources (spring water, groundwater, and river water) at different locations. The findings of this study provided information regarding the quality status of different water sources and their suitability for human consumption in the selected region. According to the WQI analysis, it was observed that the water quality of spring and groundwater was good which can be utilized for drinking purposes. Only a bit of fluctuation was observed that can be managed by prior treatment and using disinfectants. However, the water quality of the aqueduct of the Ganga canal was poor as it is lying under the poor-quality range of the WQI score. According to the outcomes of the findings, we concluded that regular and proper management of water quality at these sites should be done and anthropogenic activities should be limited to avail the water in a good state.

Key words : *Physicochemical parameters, Water sources, Groundwater, Spring water, Canal water, Water quality index.*

Introduction

Water is one of the prime natural resources that is required to fulfill most of the necessary biological and non-biological events that occur in the environment. It is one of the most overabundantly found compounds on the earth whose maximum proportion is found in the sea as saline or brackish water, which is non-consumable and also not fit for agricultural activities (Kamboj and Kamboj, 2019). Only, 3% of water is found in a freshwater state, out of which approximately 1% is available for drinking purposes and is utilized for a long to fulfill basic needs (Singh and Kamal, 2014).

In the last few decades, with growth in urbanization, industrialization, dumping, and inappropriate disposal of solid waste, mining, population explosion, etc., the quality of water sources including surface and groundwater is deteriorating at a greater pace (Kamboj and Pandey, 2017; Kamboj and Kamboj, 2019). Mostly, the urban areas are at the peak that is readily affected (Singh *et al.*, 2013). Lower Shivalik drains a lot of water via a network of streams through which the sediments get deposited into the adjoining areas, making the soil fertile and productive. Different sources of water reside in the Lower Shivalik region such as spring water, deep aquifer (Govt. tube-well), shallow aquifers (private tube-well), river canal, rainfall, Govt. supply from In-Hoff water tanks, etc. Any contamination in these resources affects the aquatic biota and when utilized for human consumption, severely affects health

(Bashir *et al*., 2020).

Therefore, it becomes a necessity to monitor the quality of water resources regularly to validate their utility. The monitoring can be attained by incorporating the Water Quality Index tool in fetching out the information about the quality status. Water Quality Index (WQI) can be well-defined as the method by which one can rate out the composite effect of a single water quality parameter on overall water quality (Singh *et al.,* 2013). It proves to be an effective tool in providing data about water accessibility, quality, and also sustainable use for drinking and other activities (Ruhela *et al.,* 2022). The study aimed to evaluate the quality status of different water resources in the Shivalik region based on the Water Quality Index.

Materials and Methods

Study area

The study was conducted in the Haridwar region of Uttarakhand which lies in the lower Shivalik region of the Himalayas. The grid location of Haridwar is 28°44' to 31°28' N and 77°35' to 81°01' E covering an area of about 53,483 sq. km. with different types of land-use forms such as agriculture, residential, construction, industrial set-up, etc. and forest (Bharti *et al.,* 2020; Kamboj *et al.,* 2017). Several water sources are present in this area in the form of groundwater, river or canal system, spring, etc. that fulfills the demand of drinking, irrigation, industrial usage, etc. Based on these three water sources each containing 3 sampling sites were selected for evaluating the quality status of the respective water resources. The detailed information about the sampling sites is well depicted in Table 1 and Fig. 1.

Methodologies for water sample collection

Water samples from the three different selected sites of Shivalik region *viz*., Springwater, deep groundwater aquifer (Govt. tube-well), and Aqueduct of Ganga canal (Sarai) were collected in the morning hours using of grab method in previously sterilized Tarson bottles. The samples were brought to the laboratory and analyzed for various selected parameters using the standard methodology of APHA (2012).

Water quality index (WQI)

WQI is one of the important and useful mathematical tools for measuring the quality status of water

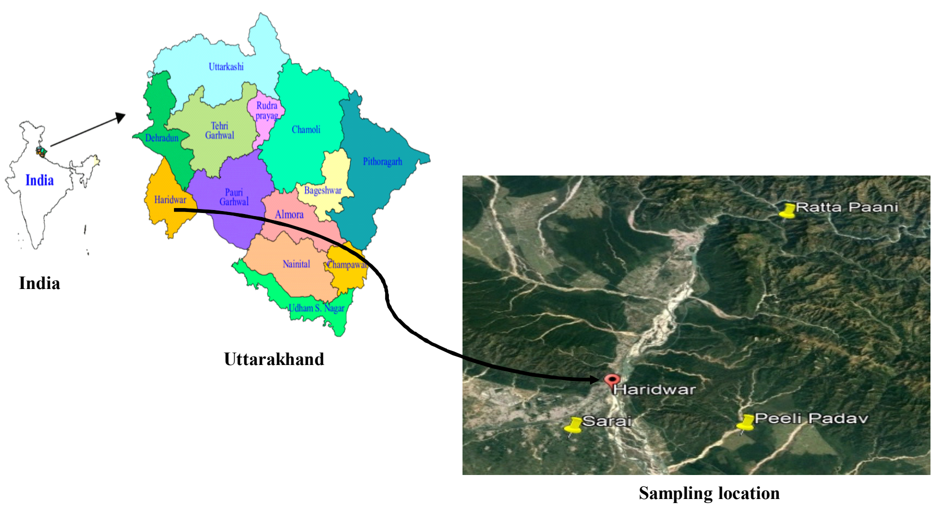

Fig. 1. Sampling sites map of different water sources.

Table 1. The Geo-location of different sampling sites for the collection of water samples.

Sampling site location and code	Geo-Location	Water source type (In Lat. and Long.)	Altitude
RattaPaani (SS1)	30°06′27.13" N; 78°22′52.74" E	Spring water	1275 ft.
PeeliPadav (SS2)	29°51′28.8" N; 78°14′48.1" E	Govt. Tube-well water	1038 ft
Sarai (SS3)	29°53′40.30" N; 78°06′02.63" E	Ganga canal water	909 ft.

resources based on certain parameters. The Weighted Arithmetic Mean Index method was used for calculating the Water Quality Index (Brown *et al.*, 1970). In this method, firstly, we select the parameters, then calculate their relative weight with the help of standards provided by BIS. Relative weight (W_i) is calculated by the inverse proportionality to recommended standard value (S_n) for the corresponding parameter, by equation 1.

$$Wi = A/Yi \quad (1)$$

where,

W_i= n^{th} parameter's relative (unit) weight

Y_i= n^{th} parameter's standard permissible value

A= constant of proportionality

The next step is calculating the quality rating scale by using equation 2.

$$Qi \frac{Oo-Oi}{Os-Oi} \times 100 \quad (2)$$

where,

Q_i is the quality rating of i^{th} parameter for an overall of n water quality parameters

O_O is the observed value of different parameters from the laboratory analysis

O_i is the ideal value of the quality parameter from the standards

O_n is the WHO recommended standard for different parameters

Lastly, overall WQI is calculated by combining W_i and Q_i (Eq. 3)

$$\text{Water Quality Index (WQI)} = \Sigma Wi\ Qi/\Sigma Wi_1 \quad .. (3)$$

The permissible limit of WQI for drinking purposes is well illustrated in Table 3 and the score is taken out of 100.

Table 2. Status of water as per Water Quality Index (Brown *et al.*, 1970)

Status of Water Quality	Quality Index Level of Water
Water not suitable for drinking	>100
Very poor quality of water	76-100
Poor quality of water	51-75
Good quality of water	26-50
Excellent quality of water	0-25

Results and Discussion

Tabulation of the average and the standard deviation value for the year 2018-19 of all the selected

Table 3. The seasonal (Mean ± S.D.) values of all the selected physicochemical parameters in different water sources

Parameters/	SS1			SS2			SS3		
Season/Sites	Summer	Monsoon	Winter	Summer	Monsoon	Winter	Summer	Monsoon	Winter
pH	7.76±0.18	8.18±0.07	7.26±0.17	6.95±0.13	7.55±0.13	7.20±0.14	7.95±0.19	8.37±0.05	7.98±0.22
TDS (mg/L)	274.00±21.60	251.50±20.47	249.50±43.40	141.88±27.85	145.01±45.64	102.18±8.48	385.75±28.65	350.25±63.02	332.75±16.46
EC (µS/cm)	408.96±32.24	375.37±30.55	372.39±64.78	211.76±41.57	216.43±68.12	152.50±12.66	575.75±42.76	498.88±94.05	496.64±24.57
Hardness (mg/L)	182.00±45.69	213.02±12.70	162.50±16.84	94.96±12.21	129.40±38.03	90.98±7.23	300.02±9.74	242.82±45.56	258.66±50.47
Calcium (mg/L)	50.46±12.61	101.13±10.73	40.58±8.11	31.12±7.98	66.86±29.36	32.26±3.68	141.24±22.08	119.78±17.05	98.76±57.32
Magnesium (mg/L)	32.10±12.85	27.30±4.58	29.75±3.66	15.58±1.85	15.26±8.82	14.33±1.44	38.74±7.12	54.42±9.99	39.02±16.33
Chloride (mg/L)	12.82±3.83	26.79±9.48	11.01±2.13	17.04±7.78	17.75±11.03	15.27±8.86	20.66±4.09	22.29±2.36	23.77±7.89
Sodium (ppm)	2.97±0.11	2.79±1.26	2.03±1.24	1.22±1.19	2.90±1.57	1.90±1.16	5.48±0.58	6.38±0.12	5.55±0.58
Potassium (ppm)	0.24±0.03	0.39±0.10	0.30±.02	0.25±0.04	0.49±0.32	0.20±0.07	0.74±0.08	0.81±0.25	0.49±0.23
Sulphate (mg/L)	57.16±2.56	65.89±2.10	54.74±2.64	54.43±1.12	57.55±1.71	51.58±2.67	76.33±6.59	82.91±3.03	78.83±4.06
Nitrate (mg/L)	8.65±0.66	12.35±0.88	9.03±1.32	1.69±1.13	3.89±0.30	3.90±0.46	12.29±3.86	17.85±1.98	17.77±1.09

physicochemical parameters such as pH, total dissolved solids (TDS), electrical conductivity (EC), hardness, calcium (Ca), magnesium (Mg), chloride (Cl), sodium (Na), potassium (K), sulphate (SO_4), and nitrate (NO_3) of three seasons i.e., summer, monsoon, and winter for three water sources are well depicted in Table 4.

pH

pH can be defined as the logarithmic value of hydrogen ions in the negative. It can be expressed on a scale ranging between 0-14. At SS1, pH value was observed maximum in monsoon season (8.18±0.07) and minimum in the winter season (7.26±0.17); SS2 have a maximum value of pH in monsoon (7.55±0.13) and minimum in summer (6.95±0.13); SS3 have maximum value in monsoon (8.37±0.05) and minimum value in summer (7.95±0.19) (Table 3). The water at all the sites was within the permissible limit as described by BIS (2012) standards i.e., 6.5-8.5. While at SS2, a slightly acidic pH was recorded during summer, which indicates an increase in the concentration of CO_2 in the respective waterand also the weathering processof the underlain geology (Gupta *et al*., 2017). The high-value pH at SS3 during monsoon was may be due to the sewage and agricultural runoff in the adjoining river canal. When consumed by humans before prior treatment can cause several human disorders such as irritation in the eyes, skin roughness, irritation in mucous membrane and gastrointestinal regions, etc.

Total Dissolved Solids (TDS: mg/l)

The presence of inorganic constituents and a small ratio of organic components in water is described by TDS concentration. At SS1,maximum TDS was observed in summer (274.00±21.60) mg/l and minimum in winter (249.50±43.40) mg/l; at SS2 maximum in monsoon (145.01±45.64) mg/l and minimum in winter (102.18±8.48) mg/l and SS3 maximum in summer (385.75±28.65) mg/l and minimum in winter (332.75±16.46) mg/l (Table 3). The higher concentration of TDS at SS3 during the summer season was due to the geological activities, anthropogenic interferences viz. the agricultural run-off, domestic waste discard, industrial discharge, etc. Rusydi, (2018) similarly reported the elevated concentration of TDS in different types of water resources. When the water with high TDS is consumed daily can cause a laxative effect. Even the person can suffer from kidney and cardiovascular diseases that were reported by Sasikaran *et al*. (2012).

Electrical Conductivity (EC: mg/l)

EC is the concentration of dissolved ions that can carry current in the water system. At SS1, maximum in summer (408.96±32.24) µS/cm and minimum in winter (372.39±64.78) µS/cm; SS2 maximum in monsoon (216.43±68.12) µS/cm and minimum in winter (152.50±12.66) µS/cm; SS3 maximum in summer (575.75±42.76) µS/cm and minimum in winter (496.64±24.57) µS/cm (Table 3). Electrical conductivity at SS1 in summer and winter and SS3 in summer are above the permissible limit as described by BIS (2012) i.e., 300 µS/cmmay be due to the sedimentation and dissolution process (Upadhyaya and Chandrakala, 2014).

Table 4. Water Quality Index (WQI) of all the sampling sites (SS1, SS2, and SS3)

Parameters/	Summer			Monsoon			Winter		
Monsoon	WQI	WQI	WQI	WQI	WQI	WQI	WQI	WQI	WQI
pH	9.70	10.38	9.22	8.82	9.58	9.14	10.09	10.63	10.13
TDS	6.52	5.98	5.94	3.37	3.45	2.43	9.18	7.96	7.92
Calcium	4.80	9.63	3.86	2.96	6.36	3.07	13.45	11.41	9.40
Magnesium	7.64	6.50	7.08	3.70	3.63	3.41	9.22	12.96	9.29
Chloride	0.61	1.27	0.52	0.81	0.84	0.73	0.98	1.06	1.13
Sodium	0.14	0.01	0.09	0.06	0.14	0.09	0.26	0.30	0.26
Potassium	0.11	0.18	0.14	0.01	0.03	0.01	4.54	4.93	4.69
Sulphate	3.28	3.92	3.26	14.39	15.22	13.64	3.25	4.72	4.70
Nitrate	2.28	3.26	2.38	0.80	1.85	1.85	0.35	0.38	0.23
WQI	WQI= 35.10	WQI= 41.29	WQI= 32.51	WQI= 35.10	WQI= 41.29	WQI= 32.51	WQI= 51.34	WQI= 54.36	WQI= 47.77

*OV: Observed value; WQI: Water quality index

Hardness (mg/L)

Hardness can be defined based on the presence of cations and anions such as calcium, magnesium, carbonates, chlorides, and bicarbonates in the water. At SS1, maximum in monsoon (213.02±12.70) mg/l and minimum in winter (162.50±16.84) mg/l; SS2 maximum in monsoon (129.40±38.03) mg/l and minimum in winter (90.98±7.23) mg/l; SS3 maximum in summer (300.02±9.74) mg/l and minimum in monsoon (242.82±45.56) mg/l (Table 3). According to the World Health Organization (WHO), different limits indicate the hardness of water viz., if the hardness value ranges between 0-40, the water is considered to be hard; 40-100 indicates that the water is fairly hard; 100-300 as hard and 300-500 as very hard. Mostly the hardness in all the sites of the study area ranges from fairly hard to hard. It may be due to the increase in the concentration of the salts with the increasing temperature that results in more evaporation. At site SS3, during the summer season, hardness is maximum and falls under the category of hard water may be due to the addition of detergents from the sewer pipes into the canal. When the canal water is consumed barely without any prior treatment can cause stomach infection and even can produce crystals of calcium oxalate in the urinary tract of humans. Though hardness does not affect the body severely but creates irritation when utilized in household activities (Dey *et al*., 2021).

Calcium (Ca: mg/L)

It is one of the essential elements that are important for the proper growth of the bones both in humans and animals. Usually, it is found in all sources of water due to its high solubility and abundance in rock material. At SS1,themaximum value of calcium was observed in monsoon i.e. (101.13±10.73) mg/l and minimum in winter (40.58±8.11) mg/l; at SS2 maximum in monsoon (66.86±29.36) mg/l and minimum in summer (31.12±7.98) mg/l and SS3 maximum in summer (141.24±22.08) mg/l and minimum in winter (98.76±57.32) mg/l(Table 3). The calcium value at SS1 in monsoon, SS3 in summer and winter were above the permissible limit of BIS (75 mg/l) which was because of weathering of rocks. The continuous consumption of calcium via water for a longer period may lead to the formation of kidney stones and faster calcification of vessels when vitamin D is not properly managed. Kamboj and Aswal (2015) and Bhutiani *et al.* (2018) foundthe similar pattern of calcium concentration.

Magnesium (Mg: mg/L)

The concentration of magnesium is usually found to be lesser than that of calcium due to its lesser dissolution of magnesium-rich compounds and also due to the presence of a high proportion of calcium in the earth's crust. According to BIS (2012) standards, the permissible limit of magnesium in water is 30 mg/l. At SS1,maximum in summer i.e. (32.10±12.85) mg/l and minimum in monsoon i.e. (27.30±4.58) mg/l; SS2 maximum in summer (15.58±1.85) mg/l and minimum in winter (14.33±1.44) mg/l; SS3 maximum in monsoon (54.42±9.99) mg/l and minimum in summer (38.74±7.12) mg/l (Table 3). The increased concentration of magnesium was observed at SS3 due to exploration weathering of rocks and some of the anthropogenic activities such as mining, sedimentation load, runoff mixing, etc.

Chloride (Cl: mg/L)

It is one of the essential elements that is required by plants and animals for fulfilling their metabolic activities. Chlorides act as an indicator of a heavy load of pollution either through sewage mixing or agricultural runoff. Though chloride ion is less harmful it changes the taste of the water and even the floral vegetation gets affected. At SS1, maximum in monsoon (26.79±9.48) mg/l and minimum in winter (11.01±2.13) mg/l; SS2 maximum in monsoon (17.75±11.03) mg/l and minimum in winter (15.27±8.86) mg/l; SS3 maximum in winter (23.77±7.89) mg/l and minimum in summer (20.66±4.09) mg/l (Table 3). A higher concentration of chloride at SS1 during monsoon was due to the natural processes such as the channel of water fleeting through the natural salt formations in the earth. Similarly, anthropogenic interferences in the form of sewage and small industrial mixing results in the chloride elevation. The higher concentration of chloride at SS3 during the winter season was also due to the discharge of sewage effluent from the nearby treatment plants, the agricultural runoff from the adjoining fields, etc.

Sodium (Na: ppm)

Sodium is one of the essential nutrients that is required for the proper functioning of plants and is also crucially involved in enhancing soil productivity and yield. In humans, it is required in the sodium-potassium pump mechanism of glucose transport. At SS1, maximum in summer (2.97±0.11) ppm and minimum in winter (2.03±1.24) ppm; SS2 maximum in monsoon (2.90±1.57) ppm and minimum in summer (1.22±1.19) ppm; SS3 maximum in monsoon (6.38±0.12) ppm and minimum in summer (5.48±0.58) ppm (Table 3). The higher concentration of sodium at all the sites was due to the discharge of sewage and industrial effluents in the water channel, weathering of sodium-containing rocks (Tiwari *et al.,* 2017). Due to the intake of higher concentration of Na via water, several health issues arouse viz., hypertension, renal problems, congenital cardiac disease, etc. (Kamboj *et al.*, 2016).

Potassium (K: ppm)

Potassium is the vital element that is required for the proper functioning of plants and humans in the form of nutrients. At SS1,maximum in monsoon (0.39±0.10) ppm and minimum in summer (0.24±.03) ppm; SS2 maximum in monsoon (0.49±0.32) ppm and minimum in winter (0.20±0.07) ppm; SS3 maximum in monsoon (0.81±0.25) ppm and minimum in winter (0.49±0.23) ppm (Table 3). At SS1 and SS2 the maximum value of potassium was reported in monsoon due to several factors such as slower weathering of rocks that contains the potassium content. It is the chemical decay of sylvite i.e., potassium chloride and silicates that is responsible for the addition of potassium in the water bodies. At site SS3, the agricultural runoff containing the potassium component and breakdown of animal and the solid waste materials are mainly responsible for the elevation in the potassium component in the canal water. A similar trend of potassium variation was observed by Kamboj *et al*. (2018) and Saha *et al*. (2019). Due to the excessive ingestion of potassium in the body, the problem of the nervous system and digestive system arises in humans (Tiwary, 2001).

Sulphate (SO_4: mg/l)

The high concentration of sulphate in the water bodies may be due to the oxidation of pyrite and the drainage from different sources such as sewage treatment plants, solid waste treatment plants, mine drainage, etc. (Meride and Ayenew, 2016). The permissible limit of sulphate according to BIS (2012) is 200 mg/l. At SS1,maximum in monsoon (65.89±2.10) mg/l and minimum in winter (54.74±2.64) mg/l; SS2 maximum in monsoon (57.55±1.71) mg/l and minimum in winter (51.58±2.67) mg/l; SS3 maximum in monsoon (82.91±3.03) mg/l and minimum in summer (76.33±6.59) mg/l (Table 3). The changing trend of sulphate at different sampling sites may be due to both natural (deposition, mineralized sulphate dissolution, oxidation of sulphide minerals) and anthropogenic sources (such as sewage treatment plants, solid waste treatment plants agriculture runoff, etc.).

Nitrate (NO_3: mg/l)

Nitrogen is fundamental for all living things, however undeniable degrees of nitrate in drinking water can be hazardous to wellbeing, particularly for newborn children and pregnant ladies. At SS1, maximum in monsoon (12.35±0.88) and minimum in summer (8.65±0.66) mg/L; SS2 maximum in winter (3.90±0.46) mg/l and minimum in summer (1.69±1.13); SS3 maximum in monsoon (17.85±1.98) mg/l and minimum in winter (12.29±3.86) mg/l were recorded (Table 3). According to WHO the maximum permissible limit of nitrate is 5 mg/l. In the present study except for site SS2, other sites have nitrate content beyond the permissible limit due to some natural and anthropogenic activities such as oxidation of nitrogenous that is present in the rocks, use of agriculture supplement in the adjoining land that gets flushed out with the spring water flow, etc. (Elisante and Muzuka, 2017).Continuousintake of water with a high concentration of nitrate can lead to several human health problems such ashypothyroidism, thyroid cancer, diarrhea, repeated diarrheal infections, stunted growth in humans, etc. (Magram, 2010).

Water Quality Index (WQI)

At SS1, the water quality index rating for the three seasons i.e., summer, monsoon, and winter was observed as 35.10, 41.29, and 32.51. WQI scores of SS2 were 34.96, 41.131, and 34.38 and at SS3 it was 51.34, 54.36, and 47.775 (Table 4). The values obtained were compared with the described criteria by Brown *et al.,* (1970) illustrated in Table 2. It was observed that in all the seasons at SS1, water was found of good quality (26-50) and can be easily consumable by the populace living in the nearby areas. At SS2 also, in all the season's water was found to be of good quality (26-50). At SS3 it was observed that in summer and monsoon the water quality falls in the poor category (i.e., 51-75) and is not suitable for domestic and drinking purposes while in winter seasons good quality of water was observed (i.e., 26-

50). It was due to the release of sewage from the small metalwork industries also and solid waste treatment plant at the vicinity of the canal. Even the agricultural runoff and anthropogenic activities are responsible for the alteration in the water quality.

Conclusion

This study concluded that the water quality of the water resources in the lower Shivalik Himalaya region, Uttarakhand, India ranged from good to poor quality. At sampling sites SS1 and SS2, the water resources were within the good range as depicted from WQI values and can be recommended for domestic use and drinking purposes directly. Whilst, sampling site SS3 showed a slight fluctuation in the WQI values which indicated that it had water quality under the poor category among two seasons i.e., summer and monsoon. From the findings, it was observed that the negative changes in water quality were due to natural and human interference. This study suggested the appropriate treatment strategies should be adopted before utilizing these waters for domestic and drinking purposes. Since direct consumption of water can cause several health problems in humans, as well as disturb the aquatic life inhabiting inside local water. We recommend that regular monitoring and proper management plans should be adopted to prevent contamination of water bodies in this area.

Conflict of Interest

The author declares that there is no conflict of interest.

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