J. Mountain Res. P-ISSN: 0974-3030, E-ISSN: 2582-5011 DOI: https://doi.org/10.51220/jmr.v18i2.20
Vol. 18(2), (2023), 181-190

Water Quality Assessment of Alaknanda River in the Srinagar Valley, Garhwal Himalaya, India

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Received: 02.08.2023; Revised: 15.12.2023; Accepted: 16.12.2023

Abstract: In the Himalayas, most of the towns are located near the bank of rivers and streams. River water is supplied for drinking and other purposes. However, a scientific analysis of drinking water quality is essential for the vital rivers that feed thousands. In this work, we assess the drinking water quality Alaknanda River at Srinagar, Garhwal Himalaya. The water quality index (WQI) is estimated based on 11 physical parameters that are compared with the World Health Organization (WHO) and the Bureau of Indian Standard (BIS). Water samples were collected at Srinagar pump station and tested Jal Sansthan Department Srinagar from Dec. 2017 to June 2018. An average pH of 7.83 is estimated of river water while other parameter averages, such as TDS (137.16), Chloride (2.52), Total hardness (94.38), Calcium (30.17), Magnesium (4.72), Total alkalinity (80.47), Nitrate (0.51), Sulphates (23.18), Fluoride (0.34) and Iron (0.10), are within desirable limits. The analysis reveals that the raw water of the Alaknanda River is experiencing a high concentration (213.4) of Coliform because of the occasional pre-monsoon rainfall which increased the sediment runoff in the river water and human activities. Month-wise water quality index (WQI) was also calculated that shows that December and January water is under good quality (<50), Feb to March water quality is good (50 to 75) and May and June water quality is not useful for drinking. Rainy season river water is highly polluted by flood sediments without purification.

Key words: Alaknanda • water quality • parameter • assessment • drinking water

Introduction

Water is an essential natural resource for life of human beings, animals and plants. Water is responsible for every activity in the human body. Water is most abundant physical substance and transparent liquid on the earth. In many part of our country safe and sufficient water supply is a crucial issue in rural and many urban areas. In the mountain areas springs, streams and river are the reliable and finite source of water for various purposes. Water is basic elements of social and economic development.

Mountain water resources are indispensable for drinking, irrigation, energy production, industrial development, municipal water supply, management of resources, conservation of environment and source of streams and rivers. In the Himalayan Mountain, region water has religious values and important source of freshwater for the local people. Glaciers, springs and seepage (locally known as Dhara, Naula, Kund, Paniyar and Tal) water are the major sources of mountain streams and rivers which are locally known as *Gad, Gadheras.* Each and every village and its hamlets are located near the springs and most of the towns are located near the water features or river banks. But since the last few decades, it is noticed that people face an acute shortage of water during summer. They are sometimes compelled to reduce water consumption and face social conflicts (Negi and Joshi, 1996). The spring are drying or becoming seasonal and reducing their water discharge due to the low intensity

of regional rainfall. Glaciers are receding and melting before summer season. As a result streams and rivers reducing summer discharge water on the Himalayan Mountains (Prakash A., 2020). With the rapid expansion of urbanization and tourism activities in the mountains, the river's water is being polluted and unhygienic. At present management and conservation of the springs and rivers is the matter of vigorous worrying in the inhabited area of the mountains. Another facet of the problem is a landslide, flash flood, soil erosion, instability of hill slope and associated catastrophic losses in the adjoining area caused by instance rainfall during the rainy season (Negi and Joshi, 1996). The previous studies indicate that deforestation, land-use changes, a decline of rainfall, etc are the major causes of diminishing discharge of the rivers in the mountain during summer.

The hydrochemistry of the river is depending upon the lithological structure, rock weathering, and slope, topography of the spring catchment area, climatic changes, and anthropogenic activities in addition to precipitation. The assessment of river water quality is very necessary from the human health and ecological point of view (Boyd 2015). The WHO report indicates that about 80 percent of diseases in the human population are caused by drinking water (CPCB, 2009). Although the river water is freshwater causes of water quality declination are several pollutants that come from the leaching of rocks, sewage and human waste nearby river and agricultural waste (Pathak B. et al, 2021). Due to the fast growth of the urban population, the process of urbanization, construction of the hydroelectric project, diversion of river water in small canal, ecological changes around Srinagar valley of Garhwal Himalaya, it is observed that the Alaknanda River water is being polluted (Sharma et al, 2014). CPCB (2009) prescribed that the TSS and COD values were observed above the prescribed criteria limit of 10 mg/L for drinking purpose for Alaknanda River (Sharma et al, 2019). Increasing anthropogenic pressure around Srinagar town is a big contribution to pollution. Joshi et al (2006) define the contents of toxic elements of the Nainital lake water by EDXRF. The water quality of the reservoir of Lambagar and Supana Dams (Srinagar) in Alaknanda valley was carried out by Rawat et al, (2019). Recently Nainital lake water quality measurement and analysis was also assessed by Pathak et al (2021) which shows that lake water is highly polluted and is not suitable for drinking without purification. Bhandari and Bisht, (2022) assess the water quality of springs in the Srinagar valley of Garhwal Himalaya.

Study Area

Srinagar town is located in the lower Alaknanda valley of Garhwal Himalaya (30^0 13' 12" N Latitude and 78^0 46' 76" longitude) at the average height of 650m. The Srinagar Town is situated at the left bank of the river (Fig. 1). River water, and natural springs are the primary sources of water for domestic and productive purposes in the valleys of the Himalaya region (Valdiya et al 1996). Approximately 14 thousand households in Srinagar town and surrounding villages (Census 2011), along with a significant number of pilgrims and tourists, rely on water from rivers and springs. The Alaknanda River flows in the centre in a bow-shaped meander (Fig. 1). The valley is drained by the Alaknanda River which rises from the Satopant Glacier. Geologically the valley falls in the Lesser Himalaya of Garhwal which consists of Chandpur phyllite, quartzite, Marora limestone, and Kilkileswar-Chamdhar metabasic rocks (Rawat et al, 2019). Out of that North Almora Thrust, Kirtinagar fault and numerous longitudinal and transverse faults and lineaments are found in the Srinagar valley through which different small order drainage streams rise (Sati et al, 2005, 2007).

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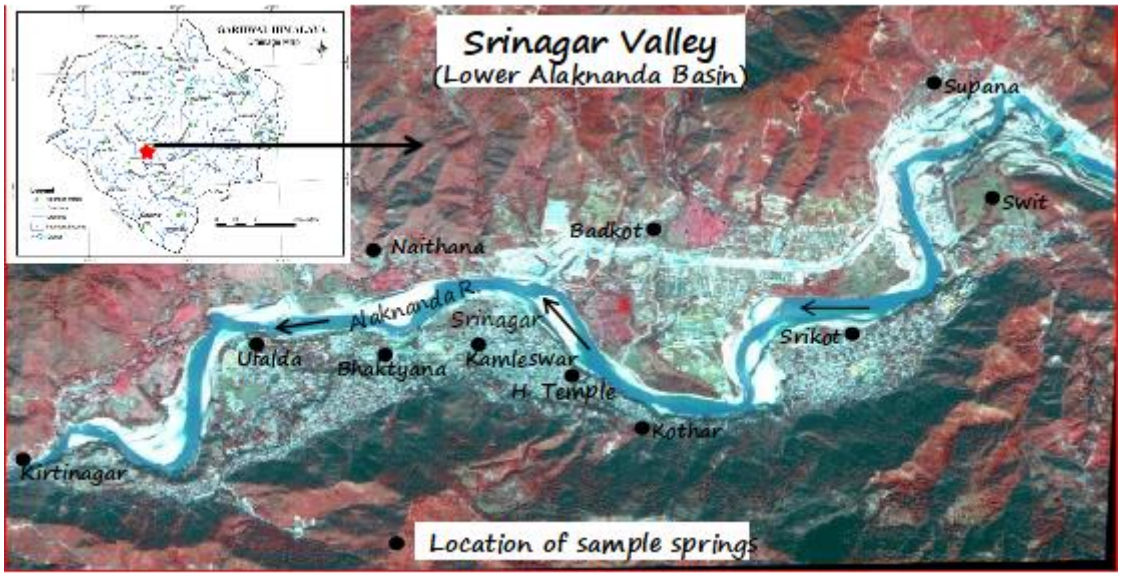

Figure 1. Location Map of Srinagar Valley

Objective

The objective of this study is to investigate the quality of drinking water supplied from the Alaknanda River in Srinagar Township. The

Research Methodology

For the assessment of water quality of Alaknanda River in Srinagar valley samples have been taken every month of the year (2022) in polypropylene bottles. The water samples are analysed for 12 chemical and 2 biological parameters (Table 1). The physical-chemical characteristics of the samples are tested and analysed in the Jal Nigam Laboratory of Srinagar Garhwal.

Determination of Water Quality Index (WQI): The water quality index has been calculated on the basis of Pathak et al (2021), Anuradha et al (2021), Rawat et al (2019), and Sharma et al (2014). A total 11 parameters are considered and each parameter is given a definite assigned weightage according to its relative importance (Table 1). The relative importance assigned from 1 to 5 on overall quality of water. The higher numbers (5) are given to those parameters which are more affective to quality of water while lower numbers are given to those which are least affective. The relative weight calculated as the following method-

authors aim to analyze the hydro-chemical characteristics of the Alaknanda River water used for drinking purposes.

$Wr = Wa \sum Ni=1Wi$

Where,

Wr = Relative weight

Wa = Weight of each parameter

N = Number of parameters

Here Wa represents the assigned waitage, N is number of parameter and Wr is relative weight for each parameter which is calculated as per formula (Table 1). After calculated relative weight of the all parameters, Quality Rating Scale (Qi) is calculated dividing the concentration of selected parameters (Ci) divided by its standard value (Si) as suggested by WHO and BIS as per formula-

$Qi = Ci/Si*100$

Where,

Qi = Quality rating scale

Ci = Concentration of each chemical parameter in water sample in mg/L

Si = Indian drinking water standard for each chemical parameter in mg/L

The Q value of pH parameter is calculated differently by using formula given by Pathak et al (2021). The ideal value (Vi) of pH is 7

guided by WHO and BIS has been used for the calculation of Q.

Q = Ci-Vi/Si-Vi*100

After calculating of the selected parameters, the Sub-Indices (Si) are calculated as a product of relative weight (Wr) and Quality Rating Scale (Qi). In the end the Water Quality Index is sum of all indices (Pathak et al 2021, Rawat et al 2019, Ramakrishanaih et al 2009, Yadav et al 2010). Finally WQI has been calculated by the following formula-

pH: According to the WHO and BIS guidelines, the desired pH range is between 6.5 and 8.5. Water samples for pH measurement were collected from the Alaknanda River near the pump station in Srinagar Valley. The maximum pH value of 8.2 was recorded in the month of April, while the minimum pH value of 7.5 was recorded in June. It is noteworthy that all the water samples from each month fall within the acceptable pH limit.

SIi = Wr*Qi

WQI = ∑ SIi-N

Where,

SIi= Sub-index of ith parameter

Wi= Relative weight of ith parameter

Qi= Rating based on the concentration of ith parameter

N = number of chemical parameters

Results of the Study

Turbidity: As per the WHO and BIS guidelines, the permissible limit for turbidity is 1. However, the 12-month data of water samples shows turbidity ranging from 1.75 to 43.85, which exceeds the permissible limit by a significant margin. The months of June, July, and August record the highest turbidity levels, whereas October, November, and December show the lowest turbidity levels (Table 2).

Table 1: Weightage and relative weightage of each parameter

S.No	Parameter	WHO Standard (Desirable Limit)	Bureau Indian Standard (Desirable Limit)	Weight (Wa)	Relative Weight (Wr)
1.	PH	6.5-8.5	6.5-8.5	4	0.1111111111
2.	Turbidity	1.0	1.0	5	0.1388888889
3.	TDS	500-1000	500	4	0.1111111111
4.	Chloride	250	250	3	0.0833333333
5.	T. Hardness	500	300	2	0.0555555556
6.	Calcium	100	75	2	0.0555555556
7.	Magnesium	50	30	2	0.0555555556
8.	Alkalinity	200	200	2	0.0555555556
9.	Nitrate	50	45	1	0.0277777778
10.	Sulphate	250	200	4	0.1111111111
11.	Fluoride	-	1	2	0.0555555556
12.	Iron	0.3	0.3	5	0.1388888889
	Total			**36**	

TDS (Total Dissolved Solids): The permissible limit of TDS is less than 500mg/L according to the guidelines of the Bureau of Indian Standards (BIS), while the World Health Organization (WHO) suggests a range between 500 to 1000 mg/L. In this study, the authors have adhered to the BIS guidelines. Thus, all 12 months' water samples for TDS fall within the range of 136.66 to 142.67 mg/L. The average value of TDS measured is 136.34 mg/L. The highest TDS value is recorded in June, while the lowest is in January. These findings indicate that the TDS levels throughout all months are lower than the desired limit, making the water suitable for drinking purposes in the Srinagar valley.

Chloride: According to BIS guidelines, water with a chloride concentration of 250mg/L is recommended for drinking purposes. Generally, chloride is not harmful to humans. It can find its way into surface water from various sources, including rocks containing chloride and agricultural runoff. Typically, the chloride levels in water samples range from 1.6 to 4 mg/L. The highest chloride concentration is observed in water samples during September and November (4mg/L), while the lowest levels are recorded in May and April (refer to Table 2).

Table 2: Results of the assessment of water quality Parameters of Alaknanda River at Srinagar Garhwal Himalaya

S.No	Month	PH	Turbidity	TDS	Cl	T.H	Ca	Mg	ALK	Ni	Sul	F	Iron
1	Jan	7.79	2.42	131.66	3.16	98	32.0	4.37	84.0	0.26	22.33	0.32	0.05
2	Feb	7.62	2.60	133.66	3.13	88	31.2	3.40	76.0	0.36	26.66	0.29	0.09
3	March	7.91	2.81	137.49	2.46	96	32.0	3.89	82.0	0.76	22.33	0.33	0.05
4	April	8.20	3.03	141.33	1.80	100	32.0	4.86	88.0	1.17	18.0	0.38	0.02
5	May	7.91	10.52	136.00	1.60	92	28.8	4.86	76.0	0.37	24.33	0.41	0.31
6	June	7.50	43.85	142.67	2.20	88.67	23.2	7.29	73.0	0.30	30.0	0.31	0.20
7	July	7.78	33.67	136.0	3.50	92	30.4	3.89	80.0	0.36	14.0	0.36	0.08
8	August	7.75	27.18	132.0	3.50	88	29.6	3.40	76.0	0.24	18.0	0.31	0.05
9	Sep	7.65	2.16	132.0	4.0	92	29.6	4.37	76.0	0.32	19.0	0.28	0.02
10	Oct	7.85	1.75	136.0	3.5	92	29.6	4.37	72.0	0.28	18.0	0.33	0.07
11	Nov	8.12	1.65	140.0	4.0	96	28.8	5.83	80.0	1.12	20.0	0.35	0.05
12	Dec	7.83	1.91	137.33	3.3	98	32.0	4.37	84.0	0.40	18.66	0.36	0.04
Average		7.83	11.13	136.34	3.01	93.39	29.9	4.57	78.9	0.49	20.94	0.34	0.09

Water Hardness and Its Nutritional Benefits: Hardness in water is primarily caused by the presence of dissolved mineral compounds, with calcium and magnesium being the main contributors. Interestingly, both calcium and magnesium offer significant benefits to human health. The hardness of water is typically measured and expressed in milligrams per liter (mg/L). Magnesium, in particular, is a crucial nutrient for human beings, playing various vital roles in the body. According to the guidelines set by the Bureau of Indian Standards (BIS), the permissible total hardness of water is up to 300 mg/L. Upon analyzing the present water samples, the recorded hardness levels range from 88 to 100 mg/L, with an average value of 93.39 mg/L (Table 2). The highest hardness value was obtained from the April sample, while the lowest values were recorded in February and August. Fortunately, all the recorded hardness values fall under the permissible limit, making the water suitable for drinking and other purposes.

Calcium: Calcium is a nutrient that all human beings need. Calcium is crucial for bone health and is found abundantly in the human body. About 99 percent of bones and teeth of the human body are built by calcium. As per the BIS guidelines, the desirable limit of calcium is 75mg/L and 100 mg/L by WHO. The calcium in the collected water samples varies from 23.2 to 30.4 (Table 2). Te average measured value of the calcium is 29.9. The mostly maximum amount of calcium is observed in the months of January, March, April and December.

Magnesium: Magnesium is a chemical element that plays numerous crucial roles in the human body, including energy production, nerve function, and muscle support. The concentration of magnesium in the water samples ranges from 3.4 to 7.29. The annual average value of the magnesium is 4.57. According to the BIS guidelines, the acceptable magnesium level in normal water is 30, and all the monthly water samples in this study fall within the recommended BIS range. The highest concentration of magnesium (7.29) was observed in the samples collected

in June, while the lowest concentration was recorded in March. It is worth noting that all the measured and recorded samples of magnesium in the study area fall within the permissible limit, which indicates that the magnesium content in the water is safe for consumption and other purposes.

Alkalinity: Alkalinity refers to the water's capacity to neutralize acid. It is measured by considering bicarbonates, carbon dioxide, hydroxide ions, and carbonates present in the water. When mixed with drinking water, alkalinity helps protect health. According to WHO and BIS standards, the desirable limit of alkalinity is around 200 ppm (Table 1). The alkalinity levels in the 12-month water samples vary from 72 to 88 ppm. The annual average alkalinity value for the Alaknanda River water in Srinagar is approximately 78.9 ppm. It is noteworthy that the highest alkalinity is observed in the samples taken in April, followed by January and December. Conversely, the lowest alkalinity is measured in the water samples of September. After analyzing all 12 months' samples, it is concluded that Alaknanda River water is suitable for drinking purposes due to its alkalinity falling within the acceptable range.

Nitrate: Nitrates are a set of compounds that are soluble in water salt-containing ions. Excess Nitrate in water is a source of fertilizer for aquatic plants and algae. According to BIS the desirable limit of nitrate in water is 45. Table 2 reveals that the maximum amount of nitrate is found 1.17 in the water sample of April followed by November (1.12) while the minimum nitrate is observed in the month of August (0.24). The average value of the nitrate is about 0.49. A low amount of nitrate in all the samples indicates the continuous flow of water.

Sulphate: Sulphate is basically a chemical compound that is composed of sulphur and oxygen atoms. Sulphate minerals tend to be delicate and are found near the Earth's surface on different kinds of sedimentary rocks. Many kinds of bacteria which thrive near oxygen and water are found on these mineral sites. Infect a large community of bacteria even live without oxygen by reducing sulphate to sulphide. According to WHO and BIS, the desirable limit of alkalinity is about 200 ppm (Table 1). All the water samples are tested and found under the desirable limit. The range of sulphate is from 14 to 30ppm. The average value of the sulphate is measured 20.94ppm.

Fluoride: Fluoride is a chemical substance that can be found in water. It represents the anion of fluorine with a -1 electrical charge. Fluoride can be present in any compound, whether organic or inorganic. The fluoride content in the water samples ranges from 0.29 to 0.41. The highest fluoride concentration was recorded in the sample from May (0.41), followed by April (0.38), and the lowest magnesium fluoride concentration of 0.29 was observed in February. The average value of all the water samples is 0.35. According to BIS guidelines, the permissible limit for fluoride is 0.1, and all the water samples fall below this limit, making them safe for drinking.

Iron: In most water samples, iron exists in its oxidized form due to the presence of oxygen. Iron is a mineral that plays a crucial role in body growth and development. The iron content in the collected water samples varies from 0.02 to 0.31. The highest iron concentration was observed in May, while the lowest iron levels were found in April and September, followed by June. Table 2 shows that all the iron samples are close to the desirable limit (0.3).

Table 3. Comparison of Water Quality Index (WQI) for Alaknanda River using the scales proposed by Yadav et al (2010) and Ramakrishnaiah et al (2009).

S.NO	Month	WQI	Remark	
			Yadav et al (2010)	**Ramakrishanaiah et al (2009)**
1.	Jan	40.01	Good quality	Excellent quality
2.	Feb	38.02	Good quality	Excellent quality
3.	March	43.77	Good quality	Excellent quality
4.	April	50.01	Good quality	Excellent quality
5.	May	77.41	Very poor quality	Good quality
6.	June	155.6	Unsuitable for drinking	Poor quality
7.	July	127.39	Unsuitable for drinking	Poor quality
8.	August	106.86	Unsuitable for drinking	Poor quality
9.	Sep	33.91	Good quality	Excellent quality
10.	Oct	39.68	Good quality	Excellent quality
11.	Nov	45.38	Good quality	Excellent quality
12.	Dec	39.19	Good quality	Excellent quality
	Average	54.77	Poor quality	Good quality

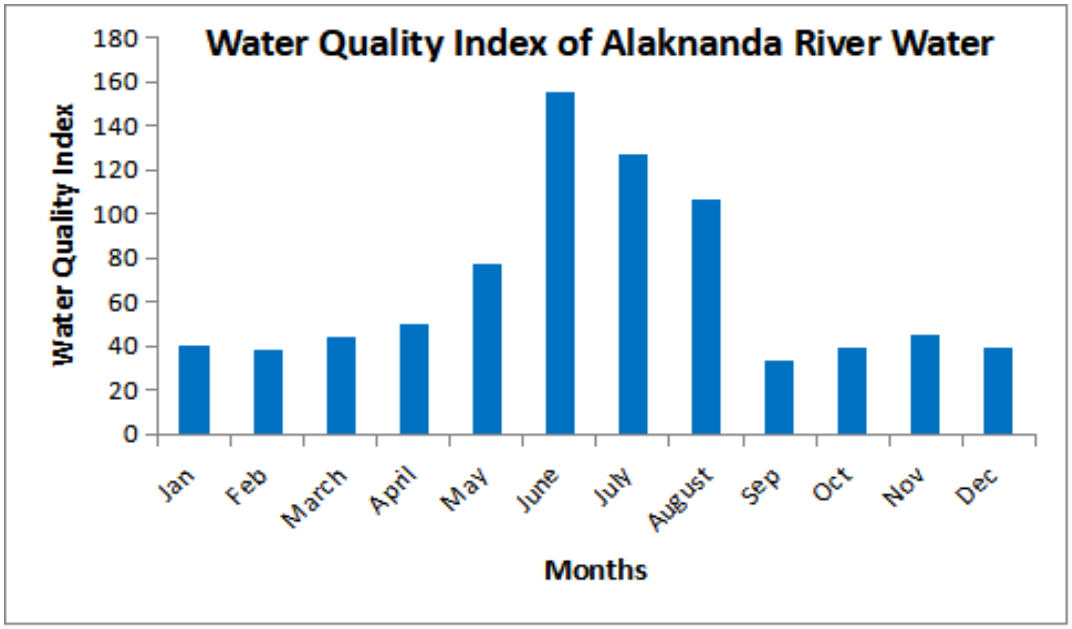

Figure 2. Water quality Index

Table 3. Seasonal Distribution of the WQI

Season	WQI	Remark	
		Yadav et al (2010)	Ramakrishanaiah et al (2009)
Summer	51.49	Poor Quality	Good Quality
Rainy	76.96	V. Poor Quality	Good Quality
Winter	40.65	Good Quality	Excellent Quality

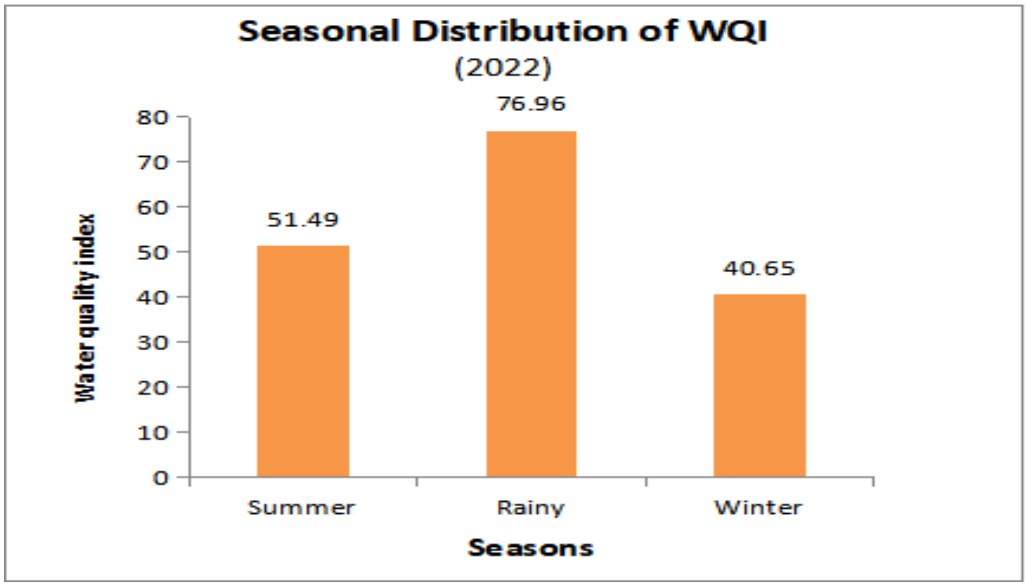

Fig 3: Seasonal distribution of WQI (2022)

Discussion

The study focuses on the water quality index (WQI) of the Alaknanda River, analyzing 11 water quality parameters in the study area. Previous works by Chatterji and Raziuddin (2002), Ramakrishnaiah et al. (2009), Varol & Davzaz (2015), and Shah et al. (2018) have also evaluated the WQI for suitability of drinking water.

Table 3 presents the WQI values, where higher values indicate poorer water quality, while lower values represent good to excellent water quality. The obtained WQI indicates that the overall water quality index of the water samples collected over 12 months ranges from 38 in February to 156 in June 2022 (Table 3 and Fig. 2). The annual average value of the WQI is estimated to be 54.8, suggesting good quality water.

According to the rating scale of Yadav et al. (2010) in Table 4, the WQI of the river ranges from unsuitable to excellent water quality. The analysis reveals that 8 months of water samples had good quality, one month (May) had very poor quality, and during the three monsoon months (June, July, and August), the water quality was unsuitable for drinking.

Similarly, according to Ramakrishanaiah et al. (2009), their WQI rating scale ranges from poor quality to excellent water quality index value. Their analysis shows that 8 months of water quality are excellent, while 3 months have poor quality, and one month (May) has good quality (Table 3).

Impact of Dam on Drinking Water Supply:

A hydro-power project has been constructed on the Alaknanda River at Supana village, diverting the river through a Chauras canal before entering the Srinagar valley. The construction of the dam and diversion of the canal have led to significant water losses, resulting in a reduction of water flow downstream, affecting both surface water sources and the recharge of groundwater. Consequently, the water pumps in Srikot, Ghasya Mahadev, Ufhalda, and Ranihat have been directly affected, leading to a decrease in water levels. To address these issues, a new system is required (Semwal 2019).

The construction of the dam has disrupted the fresh and continuous water supply, leading to the distribution of warm, polluted, and stored water to the people. This compromised water quality can result in various diseases spreading in the surrounding environment. Moreover, the reduced and fluctuating river flow during dry seasons has led to an increased concentration of pollutants downstream.

Conclusion

The present study analyzed the quality of spring water by considering various physico-chemical parameters. Water samples collected from the Alaknanda River were found to be satisfactory for drinking purposes and within desirable limits according to the Indian and WHO standards, except for EC and iron, which exceeded the permissible limit. The overall water quality index revealed that S1 has "excellent" water quality, while S2 has "good" water quality. The higher value of WQI at S2 was due to the elevated level of iron. Based on the results of the current study, the concentration of the studied physico-chemical parameters does not have detectable negative effects. In conclusion, the study suggests that the water quality of the Alaknanda River is generally good, but certain months, particularly during the monsoon season, may require additional attention and treatment before being considered suitable for drinking. Continuous monitoring and appropriate measures are essential to maintain and improve the water quality of the river. It can also be stated that anthropogenic activities are responsible for deteriorating the quality of water in the Srinagar valley near the urban centres. Pollution, encroachment, sewerage pits, and human activities near the river bed are responsible for deteriorating factors. Attention should be given by administrators, planners, local natives, as well as scientists and environmental researchers.

Acknowledgment

The authors acknowledge the Jal Nigam Office of Srinagar for providing water testing facilities. The authors also thank Prof. M.S.M. Rawat, former Head of the Chemistry Department and Ex-Vice Chancellor of Garhwal University. We also acknowledge our respective teachers, Prof. M.S. Negi and Prof M.S. Panwar for their support, help, and encouragement.

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