J. Mountain Res. P-ISSN: 0974-3030, E-ISSN: 2582-5011
Vol. 19(2), (2024), 33-42
DOI: https://doi.org/10.51220/jmr.v19-i2.5

Water Quality Assessment of Natural Springs: A Case Study of Jakholi Block, Rudraprayag, Uttarakhand

Vikas Rawat[1] • Anjali Naik[1] • Mahabir Singh Negi[1]

[1]*Department of Geography, H. N. B. Garhwal University, Srinagar Garhwal, Uttarakhand-246174, India*

*Corresponding Author's Email: vikasrawat0102@gmail.com

Received: 20.7.2024; Revised: 16.9.2024; Accepted: 17.9.2024

Abstract: This research aimed to evaluate the water quality of natural springs in five villages—Badhani, Gaithana, Ghegad Khal, Tuneta, and Kanda—located in the Jakholi block of Uttarakhand, India. A water quality testing kit was used to analyze key parameters, including pH, turbidity, total hardness, chloride, iron, residual chlorine, nitrate, and fluoride. The Water Quality Index (WQI) was calculated following the method proposed by Brown et al. (1970). The results indicated that the water quality in Badhani, Gaithana, and Kanda was excellent, with WQI scores of 17.72, 6.02, and 17.34, respectively, confirming the water's suitability for drinking. In Tuneta and Ghegad Khal, the water quality was categorized as good, with WQI scores of 26.28 and 44.57. However, the assessment of Ghegad Khal revealed concerns related to high total hardness and a low water discharge rate, highlighting an urgent need for management strategies to address the social and economic impacts on the community.This study underscores the importance of regular monitoring and maintenance of natural springs to ensure safe drinking water for rural populations. It also calls for the implementation of effective conservation and sustainable management strategies for spring-water resources.

Keywords: Himalaya Spring • Water Quality Indexing • Physio-chemical parameters • Water Scarcity

Introduction

Natural water springs have become increasingly important in meeting the growing demand for drinking water in the world (ICIMOD, 2009). These are vital sources of fresh water for many people living in Uttarakhand, both in urban and rural areas. Springs are often relied upon for drinking, domestic, and agricultural purposes, but it's important to note that the water may not always be safe for consumption without proper treatment (Tripaty et al. 2005, Negi et al. 2022). Spring is a geological feature where water from an aquifer runs to the surface of the earth, typically at the intersection of the ground surface and impermeable rocks. The occurrence of springs depends on numerous factors, including the lithology, porosity, and permeability, the hydro-geomorphology of the area, the slope of the surface, and precipitation (Tripathi et al. 2015). Aspects, such as the location, source and amount of discharge, geological structure, topography, type and the direction of water movement within the aquifer, recharge zone, water chemistry parameters, vegetation cover and human use can be used for the classification of the natural springs (Agarwal et al. 2016, Wekesa et al. 2022). Even though they are essential, these vital sources have not received adequate concern, which has resulted in their perilous condition. The available evidence indicates that the state of springs is of concern, as there has been a decrease in their discharge and quality, leading to an escalation of water scarcity. Over a million springs in the Indian Himalayan Region are now either seasonal or dried up. (NITI Aayog 2018, Dimri et al. 2021). Uttarakhand has over 3,000 natural springs, of which approximately 400 are utilized for domestic purposes. However, the utilization of these springs has been affected due to climate change, urbanization, and reckless human activities. Therefore, natural spring assessment studies have become essential in Uttarakhand to quantifying the quality and quantity of these resources (Singh et al. 2013). One such case study was conducted by several researchers in the Tons Valley region of Uttarakhand, where natural springs play a important role in meeting the water needs of the local inhabitants (Jain et al. 2010, Mandoli et al. 2018). The study reported that the natural spring water was highly alkaline and had a total dissolved solids (TDS) concentration higher than the BIS limits. Similarly, another study assessed the water quality of the springs in Chamba district, Uttarakhand. The study reported poor water quality in nearly half of the natural springs tested and called for the development and implementation of management strategies to conserve and protect these water resources in the district. Anthropogenic activities and the impression of climate change on spring water has resulted in its poor quality (Narsimha et al. 2019, Chauhan et.al. 2020). Numerous seasonal springs within the state have been observed to possess physiochemical and bacteriological parameters that surpass the permissible limits approved by the Indian standards, rendering them unsuitable for drinking purposes. (Jain et al. 2010, Tyagi 2013).

This study endeavors to analyze the water quality of specifically chosen springs located within the Jakholi block villages, thereby facilitating the identification of underlying factors contributing to health-related concerns among the rural population. To achieve this objective, personal interviews were conducted and a water quality index for the springs was developed.

Study Area

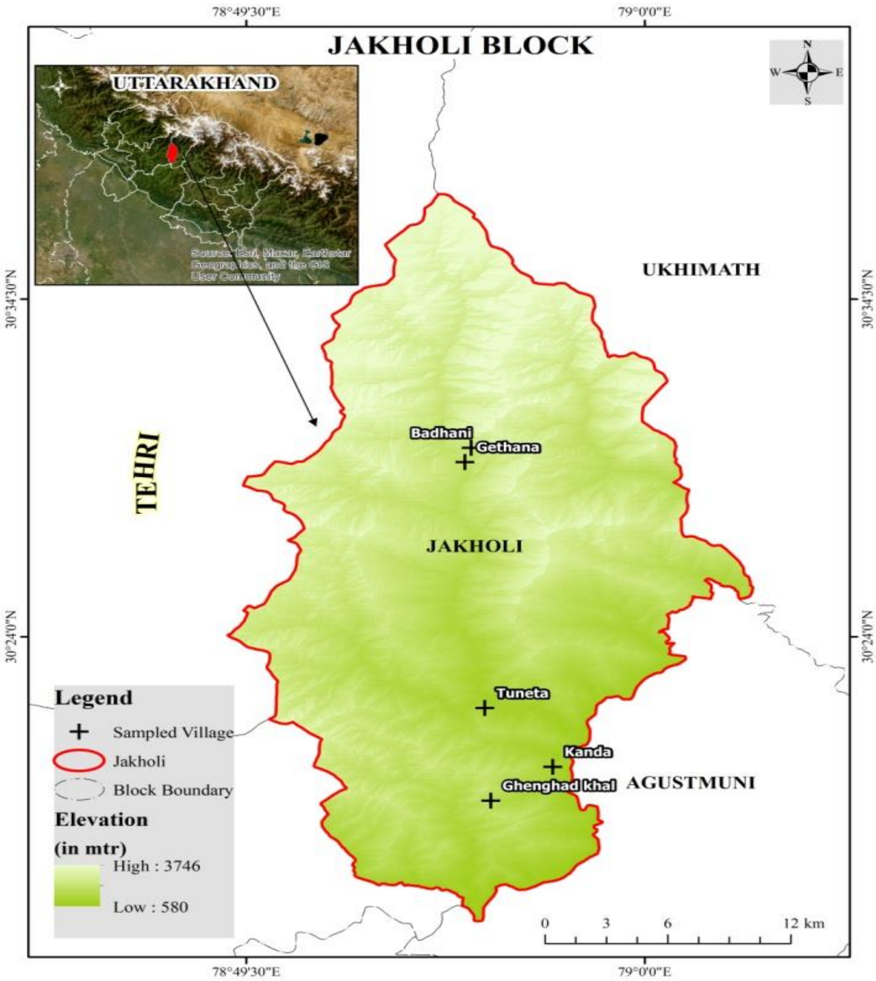
The Jakholi block, located in the Rudraprayag district of Uttarakhand, can be geographically located between the coordinates of 30° 37'N to 30° 15'N and 79° 03' to 78° 50'E, encompassing an area of 497 square kilometers. It is bounded by the Rudraprayag block in the south and Ukhimath block in north (Singh et al. 2017, Chauhan et al. 2023). The geographical elevation varies from 800 to 3400 meters and the average rainfall in the region ranges from 1850-2000 mm annually (Singh et al. 2013). The prominent river that traverses through this block is the *Lastar Gad*, while the *Mandakini River* delineates its geographical boundary with the Ukhimath block. According to the district handbook 2011, this block includes 133 villages with 74,759 expected populations and there are 16,117 households. The selection of five villages namely Badhani, Gaithana, Ghegar Khal, Kanda, and Tuneta has been elected for the water quality assessment of natural springs.

Badhani: The village of Badhani has a total land area of approximately 56.4 hectares (ha). The population of the village is 424 individuals, comprising 183 males and 241 females, as per the latest census data. The literacy rate of the village is 63.44%, with a higher proportion of literate males (75.41%) compared to females (54.36%). The village has a total of 88 residential units. Geographically, the village is situated at an elevation of 2017 meters above mean sea level (MSL), with a specific spatial location defined by coordinates 30.295230° latitude and 78.552812° longitude.

Gaithana: The village of Gethana is situated in the Jakholi block of Rudraprayag district, Uttarakhand, India, at an elevation of 1892 meters above mean sea level (MSL). The village's geographical coordinates are 30.291382° latitude and 78.551568° longitude, indicating a specific spatial location. The village's total land area is approximately 146.72 hectares (ha). The population of Gethana is 768 individuals, comprising 335 males and 433 females, as per the latest census. The literacy rate of the village is 59.77%, with a higher proportion of literate males (69.85%) compared to females

(51.96%). The village has a total of 157 residential units.

Ghegar khal: The village's location is situated at the geographic coordinates of 30°19'33.38"N and 78°57'15.50"E, with an elevation of 997 meters above mean sea level. The village is situated at a distance of 22 kilometers from Rudraprayag and 35 kilometers from the sub-district headquarters of Jakholi. It occupies a total geographic area of 145.04 hectares. Based on the 2011 census, the village has a population of 1,084 individuals, comprising 453 males and 631 females.



Source: Survey of India

Fig. 1: Location and Extent of Study Area

Kanda: The Kanda Village is situated at the geographical coordinates of 30°19'58.15" N and 78°57'35.43" E at an altitude of 1051 meters. It is linked to the district headquarter Rudraprayag and sub-district headquarter Jakholi, situated 26 kilometers and 22 kilometers away, respectively. The entire geographical area of the vill age is 113.13 hectares. Village Kanda is home to 625 people, with 270 males and 355 females. The literacy rate in Kanda is 65.28%, with 75.19% of males and 57.75% of females. There are roughly 132 households in the village of Kanda.

Tuneta: Tuneta village is located between 30°21'46.67"N and 78°55'47.59"E, at the altitude of 1062 m from msl. This village is home to 371 people, distributed among 91 families. Of the total population, 161 are male and 210 are female, resulting in a sex ratio of

DOI: https://doi.org/10.51220/jmr.v19-i2.5

1304, which is higher than the average sex ratio of Uttarakhand (963). The village has 60 children aged 0-6 years, with a child sex ratio of 875, which is lower than the state average of 890.

Research Methodology

For the current research study, in the month of June samples of water were gathered from each village and subjected to analysis via a water quality testing kit. After the testing of different physio-chemical parameters a water quality index (WQI) has been calculated for the natural springs. The method used for the preparation of index was given by Brown et al in 1965. The utilization of the WQI is a reliable method for evaluating the quality of water samples for human consumption. (Brown et al. 1970, Tyagi et al. 2013, Dutta et al. 2022). It is a method for quantifying water quality conditions across the state. It involves the selection of parameters, significance of parameters, quality function and combination through a mathematical equation (Jordana et al. 2004, Fish et al. 2020, Chhimwal et al. 2022). The parameters included in the present work for the indexing are pH, Turbidity, Total Hardness, Chloride, Iron, Residual Chlorine, Nitrate and Fluoride. All mentioned parameters were compared with the standard limits suggested by the Bureau of Indian Standards. Mentioned below are some formulas which have been used for the indexing of the water quality.

$$WQI=\sum_{n=1}^{n} W_nQ_n / \sum_{n=1}^{n} W_n$$

$$Q_n= 100[(V_n-Vio) / (S_n-Vio)$$

$$W_n = k/S_n$$

In the equation, Qn represents the quality grade assigned to the nth parameter of water quality. Wn denotes the entity weight allotted to the nth parameter. Variable n encompasses all the water quality parameters under consideration. Vn stands for the expected value of the nth parameter recorded at a specific sampling station. Sn indicates the average permitted value for the nth parameter. Additionally, Vio represents the ideal value for the nth parameter, which is typically 7 for pH and 0 for all parameters.

The water quality status was assessed according to Table 1, using the calculated value obtained from the weighted arithmetic WQI.

Table 1: WQI Range with Status

WQI level	Water Quality Classification
More Than 100	Unsuitable for Drinking
76-100	Very Poor
51-75	Poor
26-50	Good
0-25	Excellent

Source: Brown et.al. 1970.

Results And Discussion

The table presented below exhibits the parameters and their respective units as well as the values obtained from water quality testing of five villages – Badhani, Gethana, Kanda, Tuneta, and Ghegar Khal, during the month of May. The parameters evaluated here are pH, turbidity, total hardness, chloride, iron, residual chlorine, nitrate, and fluoride.

i) Badhnai ii) Gethana iii) Ghegar Khal iv) Kanda v) Tuneta

Fig.3: Natural Springs of Sampled Village

Table 3: Water Quality Indexing of Badhani Village

Parameter	BIS Standards (Sn)	1/Sn	Σ1/Sn	K=1/(Σ1/Sn)	Unit weight (Wn=k/Sn)	Ideal Value	Observed Value	Vn/Sn	Quality Rating (Qn=Vn/Sn*100)	WnQn
pH	8.5	0.118	9.682	0.103	0.012	7	7.300	0.2	20	0.243
Turbidity	5	0.2	9.682	0.103	0.021	0	2	0.4	40	0.826
Total Hardness	200	0.005	9.682	0.103	0.001	0	30	0.15	15	0.008
Chloride	250	0.004	9.682	0.103	0.000	0	20	0.08	8	0.003
Iron	0.3	3.333	9.682	0.103	0.344	0	0.1	0.333	33.33	11.476
Residual Chlorine	0.2	5	9.682	0.103	0.516	0	0	0	0	0
Nitrate	45	0.022	9.682	0.103	0.002	0	0	0	0	0
Fluoride	1	1	9.682	0.103	0.103	0	0.5	0.5	50	5.164
										17.720

Table 4: Water Quality Indexing of Gethana Village

Parameter	BIS Standards (Sn)	1/Sn	Σ1/Sn	K=1/(Σ1/Sn)	Unit weight (Wn=k/Sn)	Ideal Value	Observed Value	Vn/Sn	Quality Rating (Qn=Vn/Sn*100)	WnQn
pH	8.5	0.118	9.682	0.103	0.012	7	7	0.000	0.000	0.000
Turbidity	5	0.2	9.682	0.103	0.021	0	2	0.400	40.000	0.826
Total Hardness	200	0.005	9.682	0.103	0.001	0	105	0.525	52.500	0.027
Chloride	250	0.004	9.682	0.103	0.000	0	40	0.160	16.000	0.007
Iron	0.3	3.333	9.682	0.103	0.344	0	0	0.000	0.000	0.000

Residual Chlorine	0.2	5	9.682	0.103	0.516	0	0	0.000	0.000	0.000
Nitrate	45	0.022	9.682	0.103	0.002	0	0	0.000	0.000	0.000
Fluoride	1	1	9.682	0.103	0.103	0	0.5	0.500	50.000	5.164
										6.024

Table 5: Water Quality Indexing of Ghegar Khal Village

Parameter	BIS Standards (Sn)	1/Sn	Σ1/Sn	K=1/(Σ1/Sn)	Unit weight (Wn=k/Sn)	Ideal Value	Observed Value	Vn/Sn	Quality Rating (Qn=Vn/Sn*100)	WnQn
pH	8.5	0.118	9.682	0.103	0.012	7	7	0.000	0.000	0.000
Turbidity	5	0.2	9.682	0.103	0.021	0	2	1.000	100.000	2.066
Total Hardness	200	0.005	9.682	0.103	0.001	0	75	0.375	37.500	0.019
Chloride	250	0.004	9.682	0.103	0.000	0	20	0.080	8.000	0.003
Iron	0.3	3.333	9.682	0.103	0.344	0	0.1	0.333	33.333	11.476
Residual Chlorine	0.2	5	9.682	0.103	0.516	0	0.1	0.500	50.000	25.821
Nitrate	45	0.022	9.682	0.103	0.002	0	4	0.089	8.889	0.020
Fluoride	1	1	9.682	0.103	0.103	0	0.5	0.500	50.000	5.164
										44.56

Table 6: Water Quality Indexing of Kanda Village

Parameter	BIS Standards (Sn)	1/Sn	Σ1/Sn	K=1/(Σ1/Sn)	Unit weight (Wn=k/Sn)	Ideal Value	Observed Value	Vn/Sn	Quality Rating (Qn=Vn/Sn*100)	WnQn
pH	8.5	0.118	9.682	0.103	0.012	7	7	0.000	0.000	0.000
Turbidity	5	0.2	9.682	0.103	0.021	0	1.6	0.320	32.000	0.661
Total Hardness	200	0.005	9.682	0.103	0.001	0	50	0.250	25.000	0.013
Chloride	250	0.004	9.682	0.103	0.000	0	40	0.160	16.000	0.007
Iron	0.3	3.333	9.682	0.103	0.344	0	0.1	0.333	33.333	11.476
Residual Chlorine	0.2	5	9.682	0.103	0.516	0		0.000	0.000	0.000
Nitrate	45	0.022	9.682	0.103	0.002	0	4	0.089	8.889	0.020
Fluoride	1	1	9.682	0.103	0.103	0	0.5	0.500	50.000	5.164
										17.341

Table 7: Water Quality Indexing of Tuneta Village

Parameter	BIS Standards (Sn)	1/Sn	Σ1/Sn	K=1/(Σ1/Sn)	Unit weight (Wn=k/Sn)	Ideal Value	Observed Value	Vn/Sn	Quality Rating (Qn=Vn/Sn*100)	WnQn
pH	8.5	0.118	9.682	0.103	0.012	7	7.5	0.340	34.000	0.413
Turbidity	5	0.2	9.682	0.103	0.021	0	2	0.400	40.000	0.826
Total Hardness	200	0.005	9.682	0.103	0.001	0	44	0.220	22.000	0.011

Chloride	250	0.004	9.682	0.103	0.000	0	40	0.160	16.000	0.007
Iron	0.3	3.333	9.682	0.103	0.344	0	0.2	0.667	66.667	22.952
Residual Chlorine	0.2	5	9.682	0.103	0.516	0	0	0.000	0.000	0.000
Nitrate	45	0.022	9.682	0.103	0.002	0	1.9	0.042	4.222	0.010
Fluoride	1	1	9.682	0.103	0.103	0	0.2	0.200	20.000	2.066
										26.284

4.1. Summary of Water Quality Assessment in Sampled Villages

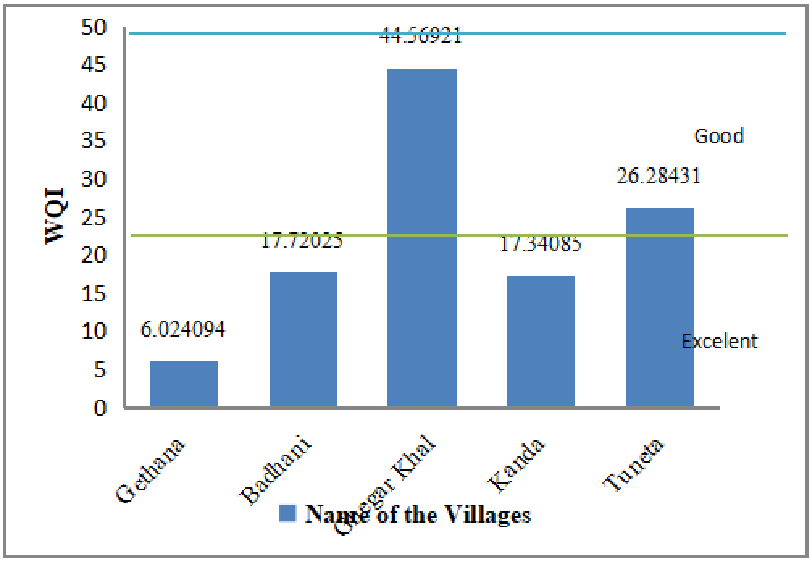


Fig. 4: Graph presenting the WQI of villages

Badhani Village

The evaluation of the spring water quality in Badhani village, conducted through a weighted water quality index resulting in a score of 17.72025, indicating excellent quality, shows positive outcomes across diverse parameters. With a pH level of 7.3, the water demonstrates near-neutrality, ideal for consumption. Additionally, its low turbidity of 2 signifies clarity, while a moderate total hardness of 30 indicates acceptable mineral content. Chloride levels at 20 fall within safe limits, as does the minimal iron content at 0.1 mg/L. The absence of residual chlorine suggests natural purity, and the lack of nitrate contamination ensures safety, particularly for vulnerable groups. Furthermore, the fluoride content of 0.5 mg/L provides dental benefits without surpassing recommended limits. Overall, these findings affirm the suitability of Gethana's spring water for domestic use and consumption, underscoring the importance of continued monitoring to maintain water quality standards. There are three natural sources of spring water located in different palace among them two are seasonal and one is perennial, which is depression type spring and majority of population are dependents on it.

Gethana Village

The water quality assessment of Gethana village's spring water, calculated through a weighted water quality index and yielding a score of 6.024094, requires scrutiny against the Bureau of Indian Standards (BIS) benchmarks. While the pH level of 7 falls within the permissible range of 8.5, the turbidity level of 2 suggests commendable clarity, meeting the BIS standard of 5. However, the observed total hardness of 105 exceeds the BIS threshold of 200, indicating relatively softer water. Chloride levels at 40 remain below the BIS limit of 250, ensuring safety. Notably, the absence of iron aligns with BIS regulations, but the fluoride content of 0.5 mg/L falls short of the 1 mg/L standard. No residual chlorine or nitrate is detected, meeting respective BIS standards of 0.2 mg/L and 45 mg/L. Although Gethana's spring water generally meets quality standards, attention to total hardness and fluoride levels may be warranted for sustained compliance and community well-being.

Ghegar Khal Village

After completion of the quality indexing, as outlined in Table 3, for Ghegar Khal village, it has been determined that the water quality is deemed to be at an exceedingly unsatisfactory level with a calculated value of 96.27, thereby rendering it unviable for consumption. The result shows that the pH value of the water in Ghegar Khal falls within the permissible limit; however, the turbidity observed is much lower (2) compared to the allowed limit of 5. The total hardness (300) exceeds the BIS accepted limit of 200 denoting the concentration of dissolved calcium and magnesium ions. Chloride is observed to be within the standard limit in Ghegar Khal (40). The concentration of iron observed in the test is found to be lower (0.1) than the maximum BIS limit of 0.3, indicating no contamination of iron in the water. The residual chlorine concentration of 0.3 is more than the lower permitted limit of 0.2. The nitrate concentration of 4 is well below the BIS acceptable limits (45). The concentration of fluoride (0.5) is also lower than the allowed limit of 1, suggesting no contamination of fluoride. Except for residual chlorine and total hardness, each parameter is under the accepted limit set by BIS. The presence of residual chlorine in drinking water serves as an indicator of minimal bacteria and virus presence. A higher concentration of residual chlorine compromises the deprivation of the water quality. However, the total hardness may be affected by the infiltration of impurities that may seep through the bedrock into the aquifer. Not only the quality is concern but also the issue of water scarcity is affecting the people of this village as in summers this spring discharges very less amount of water.

Kanda Village

The water quality index value of this village is 17.34, indicating an "excellent" classification of water quality (Table 4). The outcomes reveal that the pH of water in Kanda village is lower than the BIS permissible limit of 8.5. However, the observed value of turbidity is much lower (1.6) than the allowed limit of 5. The total hardness is significantly low (50) compared to the BIS standard limit of 200, indicating the absence of dissolved calcium and magnesium ions. Chloride concentration in Kanda village is well within the standard limit (40) set by BIS. The concentration of iron observed during the water quality testing in Kanda village is lower than BIS limits, suggesting no contamination of iron in the water. The residual chlorine concentration is observed to be zero, which is below the lower permissible limit of 0.2, indicating safe drinking limits. The concentration of nitrate (4) is much lower than the accepted limit of 45 set by BIS for safe drinking water. Similarly, the fluoride concentration (0.5) is below the maximum permitted limit of 1.0. In summary, the outcome specifies that the water quality in Kanda village is excellent and well within the BIS standards for most parameters evaluated, except for the pH value. Despite the village's commendable water quality, the discharge of its spring remains dry for the majority of the month, thus rendering it insufficient for the needs of its inhabitants. Consequently, the village's residents rely on water tank vehicles dispatched by *Uttarakhand Jal Sansthan*, as well as pay for the services of car operators to transport water from neighbouring villages.

Tuneta Village

According to the results (Table 5), the pH value obtained during the testing is higher than the BIS permissible limit, suggesting slightly alkaline water. The turbidity level is found to be within permissible limits, with an observed value of 2 compared to the BIS limit of 5. The total hardness of the water in Tuneta village is quite low (44) compared to the BIS permissible limit of 200. Chloride concentration in the water is also well within the standard limit (40) set by BIS. The iron concentration (0.2) in the tested water is also lower than the BIS limit of 0.3, indicating no contamination of iron in water. The residual chlorine concentration is 0, which is below the lower permissible limit of 0.2, indicating safe drinking limits. The nitrate concentration (1.9) is well below the BIS accepted limit of 45 established for safe drinking water. Similarly, the fluoride concentration (0.2) is significantly lower than the maximum permissible limit of 1. In summary, the results show that the quality in Tuneta village meets the BIS standards for most of the parameters evaluated and is suitable for drinking purposes. The slightly alkaline pH value of the water can be managed with water treatment methods if required.

Conclusion

The water quality assessment of five villages—Badhani, Gaithana, Ghegar Khal, Kanda, and Tuneta—revealed varying levels of water quality. Ghegar Khal's water was found to be unsuitable for consumption due to high total hardness and a low discharge rate. In contrast, Badhani, Gaithana, and Kanda exhibited excellent water quality, though challenges with pH levels and water scarcity were noted. Tuneta's water quality was generally within permissible limits, making it suitable for drinking. All villages experience seasonal water variations, with abundant supply during the post-monsoon period and scarcity in the summer. Kanda village faces significant water loss due to the erosion and dismantling of reservoir tanks. The findings emphasize the need for sustainable water conservation strategies and effective management of spring water resources. The government must undertake rigorous scientific studies, particularly in mountainous areas, in collaboration with research institutes and departments, before implementing any water policies. Geological and hydrological assessments are crucial to mitigate adverse outcomes and ensure a stable water supply for local communities. Based on this analysis, appropriate measures must be taken to secure access to drinking and usable water for these rural populations.

References

Agarwal A, Arora M and Gurung RN (2016) Springs of MidWestern Himalayan (Uttarakhand) and their response. Mausam 67(2): 509-512.

Aayog, N. I. T. I. (2017). Inventory and revival of springs in the Himalayas for water security. Dept. of Science and Technology, Government of India, New Delhi.

Azam M, Prasad J and Prasad HS (2022) Evaluation of spring water quality using water quality index method for Bageshwar District, Uttarakhand, India. Environ. Conserv. J. 23(1&2): 370-379.

Brown E, Skougstad MW and Fishman MJ (1970) Methods for collection and analysis of water samples for dissolved minerals and gases. Washington, D.C. 173 pp.

Chauhan JS, Badwal T and Badola N (2020) Assessment of potability of spring water and its health implication in a hilly village of Uttarakhand, India. Appl. Water Sci. 10: 73.

Chauhan N (2023) An integrated study of natural springs to sustain water security: Case study of three villages from a Himalayan state of India. J. SAFER: 6-7.

Chhimwal M, Kaur S, Srivastava RK, Hagare D and Shiva Prasad HJ (2022) Water quality of springs and lakes in the Kumaon Lesser Himalayan region of

Uttarakhand, India. J. Water Health 20(4): 737-754.

Dimri D, Daverey A, Kumar A and Sharma A (2021) Monitoring water quality of River Ganga using multivariate techniques and WQI (Water Quality Index) in Western Himalayan region of Uttarakhand, India. Environ. Nanotechnol., Monitor. Manage. 15: 100375.

Dutta N, Thakur BK, Nurujjaman M, Debnath K and Bal DP (2022) An assessment of the water quality index (WQI) of drinking water in the Eastern Himalayas of South Sikkim, India. Groundwater Sustainable Dev. 17: 100735.

Fish KE, Reeves-McLaren N, Husband S et al. (2020) Uncharted waters: the unintended impacts of residual chlorine on water quality and biofilms. npj Biofilms Microbiomes.

Horton RK (1965) An index number system for rating water quality. J. Water Poll. Control Fed. 37(3): 300-306.

ICIMOD (International Center for Integrated Mountain Development) (2009) The changing Himalayas: Impact of climate change on water resources and livelihoods in the Greater Himalayas. Kathmandu: ICIMOD.

Jain CK, Bandyopadhyay A and Bhadra A (2010) Assessment of ground water quality for drinking purpose, District Nainital, Uttarakhand, India. Environ. Monit. Assess. 166: 663-676.

Jordana S and Batista E (2004) Natural groundwater quality and health. Geologica Acta 2(2): 175-188.

Maindoli SD, Singh P, Nutan MP, Chanyal PC and Gupta PK (2018) Assessment of water quality of some fresh water mountain springs in Naini lake basin of Kumaun Himalaya. Assess. 3(2).

Narsimha Adimalla and Hui Qian (2019) Groundwater quality evaluation using water quality index (WQI) for drinking purposes and human health risk (HHR) assessment in an agricultural region of Nanganur, South India. Ecotoxicol. Environ. Saf. 176: 153-161.

Negi PS, Singh R and Mishra AP (2022) An assessment of water quality of Nainital springs, Uttarakhand, India. J. Indian Assoc. Environ. Manage. 42(4): 17-23.

Singh A, Nautiyal MC, Kunwar RM and Bussmann RW (2017) Ethnomedicinal plants used by local inhabitants of Jakholi block, Rudraprayag district, western Himalaya, India. J. Ethnobiol. Ethnomed. 13: 1-29.

Singh S, Negi RS and Dhanai R (2014) A study of physico-chemical parameters of springs around Srinagar Garhwal valley, Uttarakhand. Int. J. Eng. Res. 2014-2013.

Tripathi DK, Pandey G and Jain CK (2015) Physicochemical analysis of selected springs water samples of Dehradun City, Uttarakhand, India. Int. J. Innov. Res. Sci. Tech. 2(5): 99-103.

Tripaty JK and Sahu KC (2005) Seasonal hydrochemistry of groundwater in the barrier spit system of the Chilika Lagoon, India. J. Environ. Hydrol. 13: 1-9.

Tyagi S, Kaur N, Sharma R and Purohit S (2013) Water quality assessment in terms of water quality index. Am. J. Water Resour. 1(3): 34-38.

Wekesa AM and Otieno C (2022) Assessment of groundwater quality using water quality index from selected springs in Manga Subcounty, Nyamira County, Kenya. Sci. World J. 2022(1): 3498394.