Prakriti- The International Multidisciplinary Research Journal
Year 2026, Volume-3, Issue-1 (Jan-Jun)

Water Quality Assessment of Springs in the Middle Himalayas: A Case Study of Banjar Block in Himachal Pradesh

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ARTICLE INFO

Key words: Himalayan Springs, Spring Water Quality, Sustainable Development, Water Contamination, Weighted Arithmetic Water Quality Index

doi:10.48165/pimrj.2026.3.1.3

ABSTRACT

Springs in the Himalayan region are significant for domestic, agricultural, and ecological needs, yet they face declining flows, seasonal variability, and potential contamination from urbanisation, tourism, and climate change. Limited studies exist on water quality in the Middle Himalayas. The present study focuses on assessing water quality in springs of Banjar Block, Kullu Valley, Himachal Pradesh, where high relief and monsoonal turbidity make surface water unreliable, emphasising the reliance on springs and Bawdis. This study aims to assess the suitability of these sources for domestic use by evaluating their physical, chemical, and bacteriological parameters. Nineteen water samples have been collected from perennial springs using purposive sampling and analysed in government laboratories for 11 key parameters following the BIS IS 10500 methods. The Weighted Arithmetic Water Quality Index (WAWQI) was computed, assigning weights based on health and usability priorities. The study highlights that no E. coli or total coliforms were found, indicating that the water quality is excellent at all springs. The average values of the study reflect a TDS of 153.03 mg/L, total hardness of 68.29 mg/L, turbidity of 0.22 NTU, and a pH of 7.6. The results of all parameters fall within the permissible limits of the BIS standard. It is evident from the study that the water quality index, ranging from 10.81 to 20.18, is identified as “Excellent” and these pristine, untreated waters support safe domestic use for mountain people. However, in the face of mounting challenges, community conservation and spring shed management are necessary for sustainable Himalayan development.

Introduction

Springs are a vital lifeline for millions in the Himalayan region, serving as the primary source of water for drinking, domestic, and agricultural needs in both rural and urban communities. Most water supply systems in these areas rely on springs, underscoring their critical role in sustaining life (Gupta et al., 2018). Water quality assessment is essential not only to evaluate the quantity of available water but also to ensure its suitability for consumption, agriculture, industry, and ecological support (Chapman & Sullivan, 2022). Access to freshwater resources is crucial for sustainable socioeconomic development globally (Thakur et al., 2018). Springs, where aquifer water emerges at or near the surface, and Bawdis,

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traditional ponds for storing temporary spring water, are integral to the Himalayan water system (Meroz et al., 2024). Although no official count exists, India is estimated to have around 2 million springs, with nearly half of the perennial ones having dried up or become seasonal, leading to acute water shortages in approximately 8,000 villages (Barman et al., 2022; Rana & Gupta, 2009). Approximately 60–70% of the Himalayan population relies directly on springs to meet their domestic and livelihood needs (Verma & Jamwal, 2022). Springs also contribute to the base flow of many rivers in the region. In the Indian Himalaya, 64% of irrigated areas are fed by springs (R. K. Singh & Govind Ballabh Pant National Institute of Himalayan Environment (GBP-NIHE), 2021). Their revival and management are critical for the sustainable growth of the Himalayan region.

In Kullu Valley, data from the Department of Irrigation and Public Health (IPH) confirm that springs are the primary source of drinking water (Thakur et al., 2018). With climate change intensifying water scarcity, springs are increasingly vital for meeting domestic water demands in the middle Himalayas (Bhat et al., 2022). Water quality assessments, which analyse physical, chemical, and bacteriological parameters, are crucial for identifying pollution sources, monitoring contamination, and ensuring water safety. This ensures water remains safe and reliable for human and ecological needs.

Water is fundamental to life, but not all water on Earth is suitable for human use. The potability of water, determined by its Water quality. That is defined by its physical appearance (colour, odour, and taste), chemical properties (pH, turbidity, hardness, alkalinity, total solids, and the presence of metallic or non-metallic salts), and biological properties, which are critical for sustainable development (Gaur et al., 2022). Poor water quality can harm human health, necessitating thorough assessments for domestic water planning. In the Banjar Block of Kullu Valley, high absolute relief (Fig. 2) and deep gorges make water collection challenging, as most freshwater originates from high Himalayan streams that flow through these deep gorges. Seasonal variations, particularly high turbidity and siltation during monsoons, degrade surface water quality, leaving springs and Bawdis as the most reliable sources for drinking and domestic use. The growing tourism industry in the region has further increased demand for these water sources. However, studies on the water quality of springs and Bawdis in the Himachal Himalayas remain limited, despite their importance. In the Kullu region of Himachal Pradesh, mountain springs are the primary source of water for rural settlements (Alam & Shivani, 2019). These natural water sources are referred to as "Jairu", "Bai", "Nalu", and "Bawdi" in the study area. The people from these rural areas use these springs for daily needs, such as drinking, laundry, cleaning utensils, bathing, and some irrigation purposes (Fig. 1). Most settlements in the region are situated on mountain slopes and ridges, where access to natural water resources is a prerequisite for survival. In the monsoon and winter seasons, only springs provide suitable water for domestic use. The importance of these resources in the mountainous region sparks academic interest in assessing the quality of water in these sources.

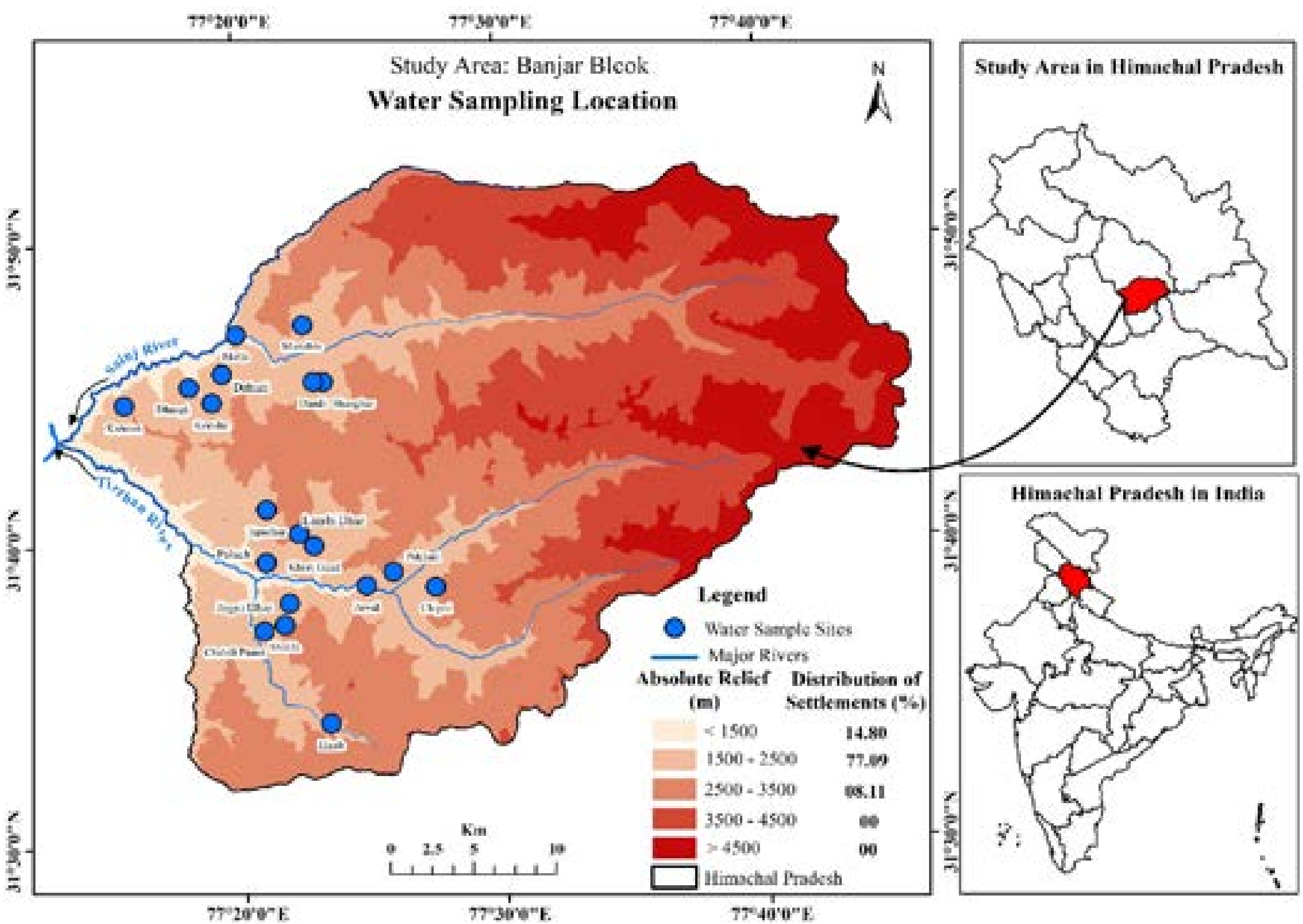
The objective of the study is to evaluates the water quality of springs and Bawdis in Banjar Block by examining their physical, chemical, and bacteriological features to determine their suitability for domestic use. The ongoing decline in water quality, caused by urbanisation and industrialisation, highlights the importance of such assessments in ensuring safe and sustainable water resources for the region's communities.

2. Study Area

Banjar block is located in the mid-hill region of the western Himalayan district of Kullu, Himachal Pradesh, India (Fig. 2). The study area forms part of the Lesser Himalayan alpine zone.

Figure 1. The first four images (a,b,c and d) depict community springs with tap outlets, where villagers are seen cleaning clothes and utensils, illustrating their essential function in providing easy access to drinking water, cooking, laundry, cleaning, and bathing for remote hillside homes where clean water options are scarce. Image f) shows children carrying water for domestic use, emphasising the reliance on these sources for daily household needs. Image g) features a traveller drinking water from a spring outlet, highlighting its convenience and importance for visitors in isolated areas.

It is bordered by the Great Himalayan range to the east and northeast, and the Lesser Himalayan mountains to the south and southwest. The region extends from 31° 32' to 31° 52' 49" N in latitude and from 77° 13' 28" to 77° 45' 21" E in longitude. The primary rock formations are crystalline, consisting of quartzites, phyllites, slates, and schists. The area features a complex landscape of moderate to high mountains, with elevations ranging from 910 m to 5800 m. The topography is generally rugged, characterised by narrow valleys, cliffs, and steep, barren southwestern slopes. The climate is mainly warm temperate. The area receives an average annual rainfall of 1120 mm, over 50% of which occurs during the southwest monsoon season (June–September).



In winter, western disturbances significantly contribute to precipitation, bringing rain and snow to the higher elevations of the region (Dimri et al., 2015). The valley features a diverse range of vegetation, spanning from subtropical and temperate to subalpine and alpine zones (Irfan, 2023). The area exhibits several spring sources that the inhabitants have used for a long time. Approximately 77 percent of settlements are located between 1,500 m and 2,500 m above mean sea level (Fig. 2), reflecting the mountainous environment of the study area.

Data Sources and Methodology

A total of nineteen water samples were collected from perennial springs in the study area, identified through a preliminary pilot survey and documented in a Panchayat-level database, with data validated by field surveys and corroborated by local representatives. The selection of these nineteen springs was based on purposive sampling, prioritising proximity to the water testing laboratory.

Table: 1

Water Quality Parameters: Methods of Analysis and Permissible Limits as per BIS IS 10500

Analysis	Method of Analysis	Permissible Limit as per BIS
Calcium (as Ca)	EDTA Titrimetric Method	200
Chloride (as Cl)	Argentometric	1000
Colour	Visual Comparison Method	15
E. Coli	MPN	No Relaxation
Fluoride as (F)	Sodium 2-(parasulphophenylazo) -1,8 - dihydroxy -3,6-naphthalene desulphonated (SPADNS) method	1.5
Free Residual Chlorine	Orthotolidine Method	1
Iron as (Fe)	Phenanthroline method or as per IS 15303: 2002 Electrothermal atomic absorption/ Spectrophotometer Method	1
Nitrate (as NO3)	Colorimetric Method	45
Odour	Threshold Water Test	Agreeable
pH	Electrometric Method	No Relaxation
Sulphate (as SO4)	Turbidimetric Method	400
TDS	Gravimetric Method	2000
Total Alkalinity (as Calcium Carbonate)	Titration Method	600
Total Arsenic (As As)	Silver diethyldithiocarbamate (SDDC) method using a Visible Spectrophotometer	0.01
Total Coliform	MPN	No Relaxation
Total Hardness (as CaCO3)	EDTA Titrimetric Method	600
Turbidity	Nephelometric method	5

Source: Methods Adopted by Laboratory Jal Shakti Bibhag Govt. of Himachal Pradesh

Due to the lack of preservatives at the facility, the entire analytical process was completed within a six-hour window. Samples were collected in pre-cleaned 500 ml borosilicate glass bottles during the pre- and post-monsoon seasons, when turbidity levels were minimal, and subsequently analyzed at the laboratories of the Jal Shakti Subdivision in Banjar and Kullu, Government of Himachal Pradesh. Table 1 outlines the methodology for assessing various physicochemical parameters. Eleven parameters, selected for their significance to health and usability, were assigned weights reflecting their priority (5 for E. coli and Total Coliform due to pathogenic risks, 4 for Free Residual Chlorine, pH, and Turbidity for disinfection and stability, 3 for Total Dissolved Solids, Total Alkalinity, and Total Hardness for taste and scaling, and 2 for Calcium, Chloride, and Magnesium for nutritional impact, summing to 37), and the Weighted Arithmetic Water Quality Index (WAWQI) was computed through a three-step process: (1) Quality Rating (Q_i) calculated using specific formulas tailored to each parameter,

$$Q_i = \frac{V_i - V_0}{S_i - V_0} \times 100$$

V_i = *Observed Value of the Parameter*, V_0 = *Ideal Value of the Parameter*

S_i = *Standard Permissible Value*

(2) Sub-Index determined as: Sub Index$_i$ = And

$$W_i = Weight\ Assigned\ to\ the\ Parameters$$

(3) WQI derived as:

$$WQI = \frac{\sum(Q_i \times W_i)}{\sum W_i}$$

The results were categorised into quality classes: 0–25 (Excellent), 26–50 (Good), 51–70 (Poor), 71–90 (Very Poor), and >90 (Unsuitable).

Results and Discussion

Physicochemical Composition of Spring Water

The physical and chemical composition of spring water is shown in Table 2. Table 2 displays the water quality parameters of springs and bawdis (traditional water wells or stepwells) in the Banjar Block. The parameters tested across 19 sampling sites in various Panchayat include calcium (as Ca), chloride (as Cl), E. coli, free residual chlorine, magnesium (as Mg), pH, total dissolved solids (TDS), total alkalinity (as calcium carbonate), total coliform, total hardness (as CaCO3), and turbidity. The study finds that all samples from the Banjar Block show no presence of E. coli and total coliform bacteria, indicating the absence of microbial contamination and compliance with safe drinking water standards for these indicators. Free residual chlorine is also not detected in any sample, implying these are natural, untreated water sources without disinfection. The pH values range from 6.8 to 8.3, with an average of 7.6, indicating neutral to slightly alkaline water suitable for drinking. TDS levels vary widely, ranging from 50.8 mg/L to 290 mg/L, with an average of 153.03 mg/L; most sources fall within the freshwater category (below 500 mg/L). Total hardness averages 68.29 mg/L, ranging from 17.7 mg/L (very soft) to 173 mg/L (moderately hard). Turbidity remains low, averaging 0.22 NTU and reaching a maximum of 0.7 NTU, which is well within the limits for safe drinking water. Calcium and magnesium are at moderate levels, contributing to hardness, while chloride levels are low, averaging 13.63 milligrams per litre. Overall, these water sources appear clean and naturally mineralised, with minimal turbidity and no bacterial contamination, although local geological factors may cause differences between sites. The subsequent part explains the parameters at the individual level.

Calcium (Ca)- Calcium is an important component of drinking water. The concentration of calcium can significantly impact water quality. Very low or very high concentrations of calcium (Ca) in drinking water have been empirically linked to problems with corrosion, scaling, or water taste (Kozisek, 2020). Table 2 presents the calcium concentrations in drinking water from springs in the Banjar block. The data shows that calcium levels vary from a minimum of 3.2 mg/L to a maximum of 31.2 mg/L, with an average concentration of 14.84 mg/L across the Banjar block.

Chloride (Cl^-) Chloride is present in natural water in the form of sodium, calcium, and magnesium salts. The water flows through the soil layer containing chloride, which leads to the dissolution of salt deposits and other chloride-containing sediments in water (Hong et al., 2023). It is evident from Table 2 that results range from a low of 3.9 mg/L at Chhaluli Pani (Chehni) to a high of 27.4 mg/L at Lambidhr (Kalwari), with an average of 13.63 mg/L. The comparatively low averages indicate limited human impact on these springs.

Magnesium (as Mg)- Magnesium is a significant parameter to determine water quality. Magnesium, together with calcium (Ca2+), plays a crucial role in controlling muscle contraction, including the tension of smooth muscles.

Table 2

Banjar Block: Water Spring/Bawdi Quality Parameters

Sampling Site (Panchayat)	Parameters Tested									
	Calcium (as Ca)	**Chloride (as Cl)**	**E. coli**	**Free residual Chlorine**	**Magnesium (As Mg)**	**pH**	**TDS**	**Total Alkalinity (as Calcium Carbonate)**	Total coliform	Total Hardness (As CaCO3)	Turbidity
Hirab (Sajwar)	4.8	4.9	0	0	2.8	6.99	55.3	20	0	23.6	0.05
Chhaluli Pani (Chehni)	4	3.9	0	0	2.8	6.8	52.1	20	0	21.7	0.05
Kaunsha (Dushahar)	22.4	13.7	0	0	7.9	8.08	219.9	85	0	88.7	0.1
Khori Gaad (Kalwari)	31.2	22.21	0	0	9.1	8.2	222.2	87	0	90	0.5
Dehuri (Banogi)	25.7	16.6	0	0	13.1	8.1	258.7	115	0	118.2	0.1
Pekhari (Nohanda)	5	10.1	0	0	13.3	8.3	112.9	27	0	112.2	0.3
Kanon (Kanoun)	19.2	9.8	0	0	8	8	180.4	75	0	80.8	0.1

Jawal (Kandidhar)	15	23.4	0	0	17.3	8.1	201.6	51.2	0	78.9	0.7
Manhara (Shensher)	20.1	13.13	0	0	11.2	7.52	188.2	75	0	70.93	0.6
Palach (Palach)	20.3	7.9	0	0	7.8	7	173.4	88.9	0	24.4	0.2
Dhaugi (Dhaugi)	23.4	21.21	0	0	17.2	7.77	188.2	150	0	134.94	0.2
Dandi (Shanghar)	28.3	8.08	0	0	11	8.04	98.1	80	0	24.22	0.3
Shanghar (Shanghar)	7	21.21	0	0	13	7.26	176.2	85	0	57.09	0.2
Matla (Suchaihn)	8	23.23	0	0	3.7	7.66	290	175	0	173	0.4
Chipni (Tung)	22	11.7	0	0	11.3	7.39	77.5	25	0	31.5	0.1
Shalda (Kothi Chehni)	4	6.8	0	0	3.3	6.9	59.6	20	0	23.6	0.05
Lambidhr (Kalwari)	13.6	27.4	0	0	13.2	7.9	233.7	95	0	98.5	0.1
Jogni Dhar (Kothi Chehni)	3.2	5.9	0	0	2.4	6.8	50.8	15	0	17.7	0.05
Tipudhar (Chanon)	4.8	7.8	0	0	3.8	7.2	68.8	25	0	27.6	0.1
Average	14.84	13.63	0	0	8.29	7.6	153.03	69.16	0	68.29	0.22
Min.	4	3.9	0	0	2.4	6.8	50.8	15	0	17.7	0.05
Max.	31.2	27.4	0	0	17.3	8.3	290	175	0	173	0.7

Source: Sample collected by the scholar and tested in the laboratory of Jal Shakti HP Government

A lack of it could result in cramps, irregular heartbeat, hypertension, nervousness, mood swings, sleep disorders, and improper functioning of the nervous system or endocrine glands (Barloková et al., 2017). The study shows that the minimum level is 2.4 mg/L at Jogni Dhar (Kothi Chehni), the maximum is 17.3 mg/L at Jawal (Kandidhar), and the average is 8.29 mg/L. These levels are generally low, aligning with the soft water profile observed in many sites.

pH- pH, as a fundamental parameter, plays a significant role in determining the chemical characteristics of water (Dewangan et al., 2023). pH measures the water's acidity or alkalinity on a scale of 0 to 14, with a pH of 7 being neutral. Drinking water ideally falls between 6.5 and 8.5 to avoid corrosion or scaling issues. The study reveals that the pH ranges from a minimum of 6.8 at Chhaluli Pani (Chehni), Jogni Dhar (Kothi Chehni), and others to a maximum of 8.3 at Pekhari (Nohanda), with an average of 7.6. The slightly alkaline average indicates balanced, non-corrosive water suitable for consumption.

TDS (Total Dissolved Solids)- TDS quantifies all inorganic and organic substances dissolved in water, affecting taste and indicating overall mineralisation; levels below 500 mg/L are typically acceptable for drinking. Table 2 presents the minimum value of 50.8 mg/L at Jogni Dhar (Kothi Chehni), the maximum value of 290 mg/L at Matla (Suchaihn), and the average value of 153.03 mg/L. Most sites have low TDS, indicating that the water is fresh and low in minerals, likely from these springs.

Total Alkalinity (as Calcium Carbonate)- Alkalinity measures the water's ability to buffer acids, primarily from bicarbonates, helping stabilise pH and prevent corrosion; it is expressed as equivalent $CaCO_3$. Table 2 reveals that the values range from a minimum of 15 mg/L at Jogni Dhar (Kothi Chehni) to a maximum of 175 mg/L at Matla (Suchaihn), with an average of 69.16 mg/L. This moderate average supports the observed stability of pH levels across the different sites.

Total Hardness (as $CaCO_3$)- Hardness is primarily due to calcium and magnesium ions, which affect soap efficiency and cause scale buildup in high amounts. It's calculated as equivalent to $CaCO_3$, with levels below 60 mg/L considered soft. The minimum is 17.7 mg/L at Jogni Dhar (Kothi Chehni), the maximum is 173 mg/L at Matla (Suchaihn), and the average is 68.29 mg/L. Overall, the water is soft to moderately hard, with variability likely.

Turbidity- Turbidity indicates the cloudiness from suspended particles like sediment or organic matter, which can harbor pathogens or affect disinfection; it's measured in NTU, with <1 NTU ideal for drinking water. The table shows that the values are low, ranging from a minimum of 0.05 NTU at several sites (e.g., Hirab, Chhaluli Pani, Jogni Dhar) to a maximum of 0.7 NTU at Jawal (Kandidhar), with an average of 0.22 NTU. These clear waters suggest minimal particulate matter, enhancing safety and aesthetics.

E. coli, Free Residual Chlorine, and Total Coliform- These three parameters are all zero at every sampling site. This uniformity suggests excellent microbiological quality and no need for or presence of active disinfection in these natural spring sources: E. coli, A specific type of coliform bacteria used as an indicator of recent fecal contamination from human or animal waste, which could signal the presence of pathogens causing diseases like gastroenteritis. The complete absence (0 counts) across all sites indicates that there is no such contamination, making the water safe from this perspective without requiring treatment for E. coli-related risks.

Table 3

Banjar Block: Water Quality Index of Selected Springs

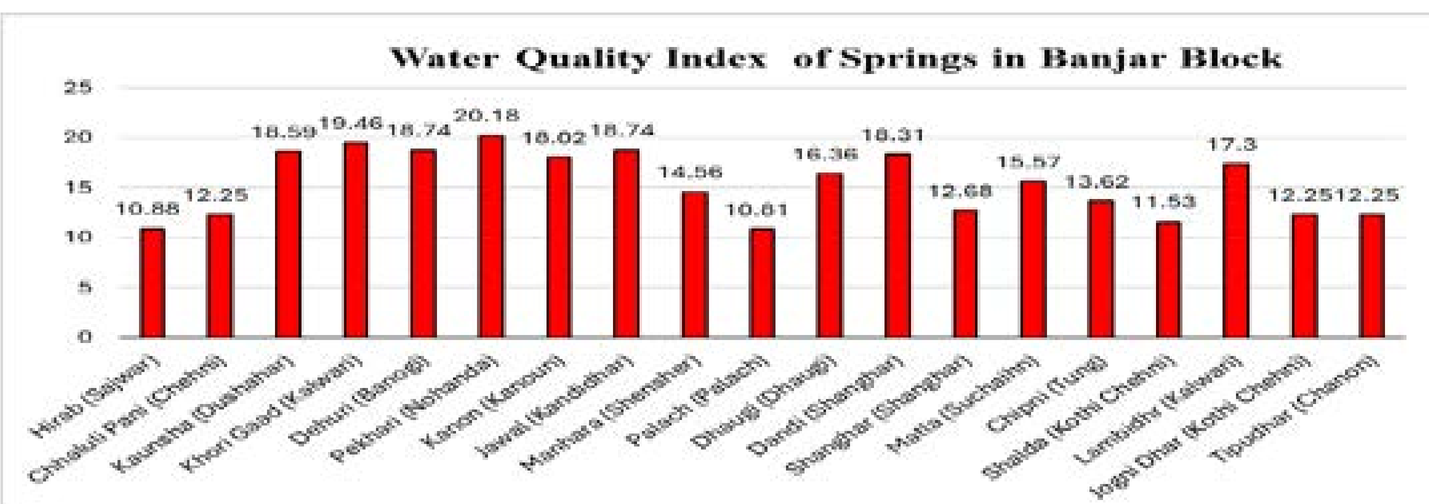
Water Source	Sum Sub-Index	WQI	Classification
Hirab (Saiwar)	402.67	10.88	Excellent
Chhaluli Pani (Chehni)	453.33	12.25	Excellent
Kaunsha (Dushahar)	688	18.59	Excellent
Khori Gaad (Kalwari)	720	19.46	Excellent
Dehuri (Banogi)	693.33	18.74	Excellent
Pekhari (Nohanda)	746.67	20.18	Excellent
Kanon (Kanoun)	666.67	18.02	Excellent
Jawal (Kandidhar)	693.33	18.74	Excellent
Manhara (Shensher)	538.67	14.56	Excellent
Palach (Palach)	400	10.81	Excellent
Dhaugi (Dhaugi)	605.33	16.36	Excellent
Dandi (Shanghar)	677.33	18.31	Excellent
Shanghar (Shanghar)	469.33	12.68	Excellent
Matla (Suchaihn)	576	15.57	Excellent
Chipni (Tung)	504	13.62	Excellent
Shalda (Kothi Chehni)	426.67	11.53	Excellent
Lambidhr (Kalwari)	640	17.3	Excellent
Jogni Dhar (Kothi Chehni)	453.33	12.25	Excellent
Tipudhar (Chanon)	453.33	12.25	Excellent

Source: Calculated by the Author

Free Residual Chlorine: Represents the amount of chlorine remaining in the water after disinfection, which kills bacteria and maintains safety during distribution. The zero levels here imply that these springs are not chlorinated, and any potential disinfectants have entirely dissipated or were never added. **Total Coliform:** A broader group of bacteria indicating possible environmental contamination or regrowth in water systems, though not all are harmful. Zero counts everywhere to confirm the absence of these indicators, supporting the overall bacteriological safety of the water and suggesting a low risk of waterborne illnesses from microbial sources.

Water Quality Index-

Table 3 presents the Water Quality Index (WQI) for springs in the Banjar Block, calculated based on the sum of sub-indices derived from various water quality parameters tested at the 19 previously detailed sampling sites. Each entry includes the water source name, the sum sub-index value, the corresponding WQI score, and a classification category. The study reveals that all sources are classified as "Excellent," indicating superior overall water quality that is suitable for drinking and other uses without any health concerns.



WQI values range from a minimum of 10.81 at Palach (Palach) to a maximum of 20.18 at Pekhari (Nohanda), with an implied average around 15-16 based on the distribution, reflecting low levels of pollutants and balanced chemical composition across the sites. The sum sub-indices vary from 400 to 746.67, which are normalised to produce the WQI. This emphasises that even the highest sub-index sums still yield excellent ratings due to the weighting and scaling in the index methodology.

Figure 3 complements this by presenting a bar chart visualization of the WQI values for each spring, with bars ordered by site and labeled with precise scores atop each, illustrating the variability while underscoring the uniformity in excellence; for instance, sites like Pekhari show taller bars near 20, while lower ones like Hirab and Palach hover around 10-11, collectively demonstrating no instances of degradation and affirming the pristine nature of these natural water resources in the Banjar Block.

Conclusion:

The present study assessed the water quality of 19 perennial springs and Bawdis in the Banjar Block of Kullu Valley, Himachal Pradesh. The main objective of the study was to analyse physicochemical and bacteriological parameters of spring water to evaluate their suitability for domestic use. In the rural Himalayas, springs and Bawdi serve as crucial water sources for communities, providing essential water for drinking and household use. The analysis was conducted in accordance with the Weighted Arithmetic Water Quality Index (WAWQI) and the BIS IS 10500 criteria. All of the sites in the study have consistently good-quality water. Important results highlight the absence of faecal contamination and pathogenic hazards, as evidenced by the absence of microbial contamination and zero E. coli and total coliform levels in each sample. Free residual chlorine was undetectable, confirming these as untreated natural sources. The analysis of physicochemical parameters reveals that the results were well within acceptable limits. The average pH was 7.6 (neutral to slightly alkaline), the total hardness was 68.29 mg/L (indicating soft to moderately hard water), the TDS was 153.03 mg/L (suggesting fresh, low-mineral water), and the turbidity was a low 0.22 NTU, ensuring safety and clarity. Without producing scale or taste problems, the moderate levels of dissolved salt, including calcium, magnesium, and chloride, helped to maintain balanced mineralisation. The water quality assessment (WQA) rated all springs as "Excellent" (scoring 10.81–20.18), as the report makes clear. Their good potability and low pollution influence from anthropogenic or geological forces are reflected in this.

The findings show that the spring water in the study area is suitable for household usage. This is essential for maintaining the rural population in the face of water scarcity brought on by weather extremity. The ongoing urbanisation, tourism, and potential drying trends pose threats and need proactive conservation practices. Regular monitoring, community participation in protection initiatives, including waste management and reforestation and incorporating springs into regional water strategies are among the recommendations. To improve resilience, future studies might focus on climatic impacts, trace metals, or seasonal fluctuations. Ultimately, preserving these resources is crucial for sustainable socioeconomic development in the Middle Himalayas, ensuring safe access to water for future generations and supporting the health of the ecosystem.

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