International Journal of Environnemental Sciences 13 (4) (2024) **103-112**

Content is available at: CRDEEP Journals
Journal homepage: http://www.crdeepjournal.org/category/journals/ijes/

International Journal of Environmental Sciences
(ISSN: 2277-1948) (Scientific Journal Impact Factor: 6.043)

UGC Approved-A Peer Reviewed Quarterly Journal

Full Length Research Paper

Assessment of Physicochemical Parameters of Spring Water of the Indian Himalayan Region: A Case Study of Maharaja Valley, Kullu

Rakesh Kumar Singh[1]
Scientist-F, G.B. Pant National Institute of Himalayan Environment, Himachal Pradesh Regional Centre, Mohal, Kullu – 175126, Himachal Pradesh, India

ARTICLE DETAILS

Corresponding Author:
Rakesh Kumar Singh

Key words:
Spring, Water, Physicochemical, Maharaja Valley, Indian Himalayan Region (IHR)

ABSTRACT

In the mountain villages where there is no piped water supply, spring water serves as the sole source of drinking water. Himachal Pradesh, nestled in the pristine Himalayas of India, is renowned for its breath-taking landscapes and abundant natural resources. Mountain springs are the main source of water for the rural households in the region. Around 60% of the population is entirely dependent on spring water due to limited availability or inaccessibility of the alternative surface water sources. As the demand for clean and safe drinking water grows, it becomes crucial to assess the quality of spring water in Himachal Pradesh. Therefore, in this study, we have assessed physico-chemical properties such as pH EC total dissolved solid (TDS), hardness, chloride, sodium, potassium, nitrate, sulphate of 10 spring samples from different altitudinal sites of Maharaja valley region in Kullu district of Himachal Pradesh. Analytical results were compared with prescribed BIS potability2012 parameters for drinking purposes. Overall results for the assessed parameters are within the permissible limits for most of the sites with few exceptions for locations. S1, S2, and S3,showed high magnesium content (108.2378 to183.1601) more than BIS permissible limit of 100mg/L. and S3 showed high EC i.e., 456µS/cm which is more than permissible limit of 400 µS/cm. A correlation matrix has been created to analyse and observe the significance of the factors on spring water quality assessment. The value of 0.98 indicates high positive correlation between EC and TDS. The drinking water quality index ranged from 15.64 to 49.39, indicating that the majority of valley springs have excellent to good water quality. Hence the spring waters in the study area are safe for drinking as well as for irrigation. Overall, the study suggests that the water in Kullu Valley is generally good, but there are concerns about anthropogenic interventions and the need for treatment prior to drinking.

1. Introduction

Water is of paramount importance on our planet. It is a fundamental requirement for the survival, growth, and reproduction of organisms, including humans, animals, and plants. It's a necessity for basic body functions like the breakdown of food, circulation, temperature regulation, and waste removal. Drinking an adequate amount of clean water is essential to prevent dehydration and maintain overall well-being. As per WHO(World Health Organization., 2011), the total volume of water on Earth is approximately 1400 million billion litres. Most of this water is seawater i.e., 97% which is not suitable for drinking without desalination. However, fresh water accounts for 3% of the world's water supply, with approximately 2% trapped in polar ice caps and glaciers, rendering it inaccessible for immediate use.

Freshwater is a precious resource worldwide, and its availability is closely linked to the Indian Himalayan Region (IHR) as a significant source of drinking water. The region's abundant glaciers, rivers, and lakes contribute to the overall freshwater reserves, which are essential for sustaining ecosystems and meeting the water needs of communities. Around 50 million

[1]Author can be contacted at: *Scientist-F, G.B. Pant National Institute of Himalayan Environment, Himachal Pradesh Regional Centre, Mohal, Kullu – 175126, Himachal Pradesh, India*
Received: 20-October-2024; Sent for Review on: 25-October-2024; Draft sent to Author for corrections: 12-November-2024; Accepted on: 16-November-2024; Online Available from 17-November-2024
DOI: 10.13140/RG.2.2.18251.91685

people who live in the Himalayas depend on natural resources for their basic needs such as drinking water, food, and shelter. (Bhat et al., 2022; Gupta & Kulkarni, 2017). Fiver million springs have been identified in India, with three million springs being registered in the IHR. (Bhat et al., 2022; Gupta & Kulkarni, 2017). Mountain springs, also known as Dharas in the local language, are natural flows of groundwater from various aquifers, in most cases unconfined (Tambe et al., 2012). When water pressure induces a natural flow of groundwater to the earth's surface, springs emerge. As the rainwater flows into or "recharges" the aquifer, it exerts pressure on the already present water. This pressure forces water through the aquifer's cracks and tunnels, and this water naturally flow to the surface in places that are called springs. Area from where spring water originate is called as orifice (Verma & Jamwal, 2022). It is a high-quality perennial freshwater source for remote communities (Bhat et al., 2020). Mountain springs are the region's primary supply of water for rural households. Due to the low availability or inaccessibility of alternate surface water sources such as rivers, streams, and supplies to the region's households, around 60% of the population is fully reliant on spring water (Tambe et al., 2012). A growing concern is emerging as many springs are drying out globally at an alarming rate. Many springs are experiencing a decline in their flow or completely drying out. This situation has been observed in various regions, from arid landscapes to mountainous areas. According to NITI Aayog , roughly 50% of the springs in the IHR are drying up, which has directly impacted the livelihoods of millions of people who rely on natural spring water for various purposes (Gupta & Kulkarni, 2017). Regardless of being one of the main sources of clean drinking water, springs may contribute to a variety of waterborne diseases when contaminated here could be several anthropogenic and natural factors that contribute to the spring water contamination (Thakur et al., 2018). This study will help in assessing the water quality and potability of Maharaja Valley's springs. The study's objectives include: providing a thorough understanding of the water quality parameters, identifying potential sources of contamination if any, and suggesting appropriate actions for preserving or enhancing water quality. This investigation will serve as the basis for further research in this region as well as other Himalayan tourist hotspots.

2. Problem statement & objectives

Indian Himalayan region is renowned for its abundant freshwater resources, including numerous springs that serve as crucial water sources for local communities. However, the quality of spring water in this region remains largely unexplored and poses potential risks to human health and ecosystem sustainability. Therefore, there is an urgent need for a comprehensive assessment of spring water quality in the Indian Himalayan region to understand the presence of contaminants, assess potential health hazards, and formulate effective management strategies. By conducting a comprehensive assessment of the spring water quality in the specific location, this case study aims to:

1. To carry out the physico-chemical analysis of the springs in the villages of Maharaja Valley of Kullu district by using the drinking water parameters.
2. To calculate the Water Quality Index of the combined dataset for the evaluation of the current status of quality of spring waters.
3. Analysis and interpretation of various chemical constituents present in the spring water, including ions.

These findings will contribute to evidence-based decision-making, facilitate the implementation of appropriate water treatment measures, and ensure the long-term availability of safe and clean drinking water for communities in the Indian Himalayan region.

3. Study area

Study area lie in Maharaja Valley of district Kullu, Himachal Pradesh. The District is bounded by Pir-Panjal range in the north; Bara Bhangal in the Northwest; the Greater Himalayas in the eastern boundary and Dhauladhar Range in the southwest. Kullu district is characterized by its diverse topography, ranging from high-altitude mountain ranges to deep valleys. As much as 70% of the land area in Kullu is covered with fresh vegetation. The district is influenced by several significant geographical features, including the Beas River, and numerous glacial streams originating from the surrounding mountains. These features contribute to the hydrological network and affect the water quality and availability of the springs. The climate in the region is cool and dry, and the annual rainfall is 1405mm. Most of the rainfall, about 57 percent, occurs from June to September. (Sharma et al., 2021).

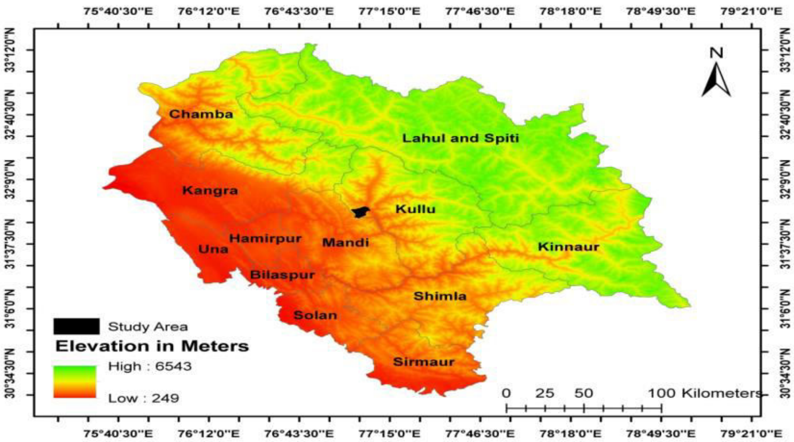

Fig 1: Digital Elevation Model(DEM) of the study area in Himachal Pradesh

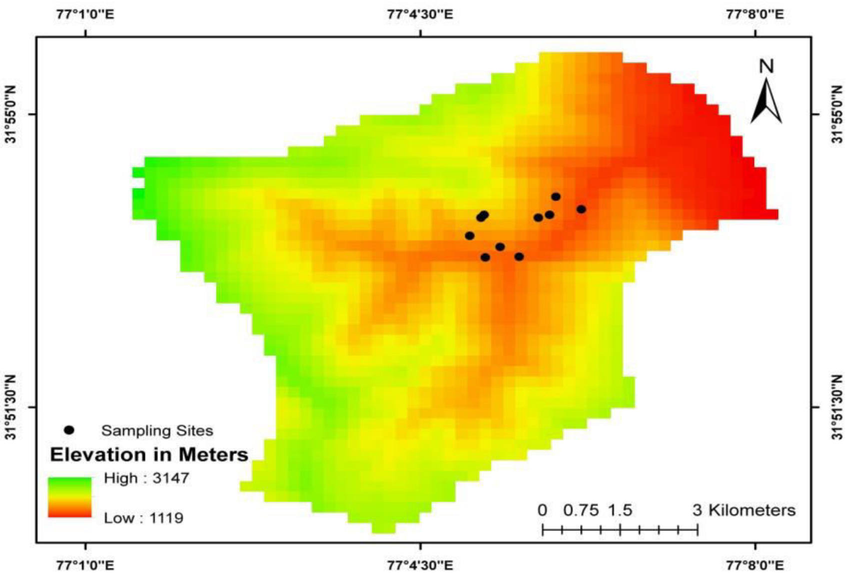

Fig 2: Study Area Map of Maharaja Valley in Kullu district

To carry out the investigation, 10 springs locations have been identified. The selected villages are under the Khadiyar Gram Panchayat of Kullu district. Field surveys and water sampling was carried out in the month of June. The villages were given unique Spring ID for easy identification. The details of the springs IDs are given below:

Table 1: Study Area Coordinates

Spring ID	Location	Coordinates	
		Latitude	Longitude
S1	**Khalogi I**	31.89861111	77.09000000
S2	**Khalogi II**	31.89666667	77.08611111
S3	**Muthal I**	31.89611111	77.08555556
S4	**Muthal II**	31.89611111	77.08555556
S5	**Kareri**	31.8925	77.08361111
S6	**Dohranala I**	31.88818611	77.08631111
S7	**Pahnala I**	31.89027778	77.08888889
S8	**Dohranala II**	31.88833333	77.09222222
S9	**Buragran I**	31.89777778	77.10305556
S10	**Buragran II**	31.89764722	77.10310833

4. Methdlogy

4.1 Sampling Site Selection

Total of 10 spring water samples were collected in in sterile Polyethylene bottles. The sampling was conducted in the month of June. The collected water samples will be tested for its suitability as per the standards provided by Bureau of Indian Standards (Bhavan et al., 2012) and World Health Organization(World Health Organization., 2011).

4.2 Sample Collection Requirements

For collecting the water samples, we require HDPE High Density Polyethylene Bottle, stopwatch, pH meter, Compass, Tissue**,** measuring cylinder and distilled water (APHA, 2017). Spring water samples were collected from 10 study sites, at the point of emergence in an air tight high-density polyethylene bottles (HDPE) of one litre capacity. After rinsing with the same water, the samples were collected. This process was repeated for all the sites. Using a GPS system, the latitude, longitude, and altitude of all sampling sites, as well as the source, were recorded during sample collection.

4.3 Water Quality Parameters Analysis

Physico- chemical parameters Temperature, pH, and electrical conductivity (EC), as well as TDS, were measured on-site using a handheld portable metre. The remaining parameters were analysed by the method given below:

Table 2: Instrumentation used for the physico-chemical analysis

S.No	Parameter	Reagents/ Instrumentation
1.	**pH** **Temperature** **EC** **TDS**	Calibrated portable pH/EC/TDS/Temperature Meter was used on-site for the calculation
2.	**Calcium**	Titration method using standardised solution of Ethylene diaminetetra acetic acid (EDTA)

3.	**Magnesium**	Titration method using standardised solution of Ethylene diamine tetra acetic(EDTA)
4.	**Total Hardness**	Titration method using standardised solution of Ethylene diamine tetra acetic acid (EDTA)
5	**Sodium**	Flame photometry is commonly used technique
6.	**Potassium**	Flame photometry is commonly used technique
7.	**Chloride**	Potassium chromate is titrated with silver nitrate
8.	**Nitrates**	UV visible spectrophotometer Used sulphanilic acid, N-1-naphthylethylene Diamine dihydrochloride sodium acetate solution ,
9.	**Sulphates**	UV–VISspectroscopy at specific wavelength of 420 nm.

4.4 Calculations

4.4.1 Statistical Analysis

Pearson's correlation coefficient is a statistical measure of the strength of a two-variable linear relationship. The correlation matrix for all chemical components of all spring samples was generated (Sharma et al., 2021). A correlation coefficient number close to -1 or 1 denotes the strongest negative or strongest positive association between two variables, whereas a value close to 0 denotes no linear relationship between variables.

4.4.2 Water Quality Index

The Water WQI is a tool used for evaluating the quality of water based on physical, chemical, and biological factors that are combined into a single value ranging from 0 to 100. The WQI provides a single number that expresses the overall water quality at a certain location and time. The index is a unit less number ranging from 1 to 100, where a higher number indicates better water quality (Brown et al., 1972). WQI is commonly used for detection and evaluation of water pollution and may be defined as a reflection of composite influence of different quality parameters on overall quality of water(Horton, 1965). Water quality index was calculated by weighed index method to get a picture on the quality of spring water.Various scientists have employed weighted arithmetic water quality index method to check the purity of water. The calculation of WQI was made in 4 steps(Brown et al., 1972). According to this WQI method the classification of WQI is given in (Table 3.)

Step 1

Collect all the data physicochemical data for the calculation of WQI

Step 2

Calculate unit weight (Wt) factors for each parameter

Where, $Wn = \frac{K}{Sn}$

Where K is the constant of proportionality

And $K = \frac{1}{\sum \frac{1}{Sn}}$

Sn= Standard desirable value of n^{th} parameters

Unit weight factors Wn=1 (unity)

Step 3

Calculate Sub index (Qn) value by-

$$Qn = \frac{(Vn - Vo)}{(Sn - Vo)} \times 100$$

Vn= Estimated concentration of n^{th} parameter in sample water

Sn=Standard permissible value of n^{th} parameter

Vo=Ideal value of n^{th} parameter in pure water

Generally Vo=0 for most of the parameter except for pH

$$Q_{pH} = \frac{V_{pH}}{8.5 - 7} \times 100$$

Step 4

Calculate Water quality index by using formula,

Overall $WQI = \frac{\sum Wn * Qn}{\sum Wn}$

The WQI values (Table 3.) ranges from 10 to 100, with higher numbers indicating poor water quality.

Table 3: Water quality Index (WQI) and status of water quality.

Water Quality Level	Water quality Status
0-25	Excellent water quality
26-50	Good water quality
51-75	Poor water quality
76-100	Very poor water quality
>100	Unsuitable for drinking

Source: (Bhutiani et al., 2019; Chatterjee & Raziuddin, 2007)

5. Results& discussion

5.1 Overall Results

We have created a spring inventory for the site-wise comparison of the water quality parameters. Our results indicate that all 10 spring sites are suitable for drinking. Our data has similar results to studies that have been carried in the other villages of Kullu district. As per Table 4, the pH for all 10 locations were in the range of 05.99 -7.22. The minimum pH range was for S10 shows the minimum pH range i.e. 5.99, the value is slightly acidic in nature. Highest value of pH was recorded in S4,the value is above neutral, which indicates a slightly alkaline or basic nature. Electrical conductivity (EC) was found to lie in the range of 143.7 µS/cm to 456 µS/cm with an average of 285.44 µS/cm indicating low to moderate mineral content. TDS values showed variation in range between 111.3mg/l to 335.1mg/l with an average of 205.

Table 4: Site-wise results of the parameters analysed

Parameter Recorded	Permissible Limits As per BIS	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
Discharge Rate	**s/ml**	24.67	-	-	15.26	37.93	4.99	2.90	2.00	2.32	2.72
Temperature	**° Celsius**	17.5	14.1	18.9	19	18.8	16.6	18.9	17.2	17.9	18.5
pH	**6.5-8.5**	7.08	7.13	6.32	7.22	7	7.07	7.08	6.66	6.63	5.99
EC	**400µS/cm**	325.7	187.7	456	178.5	364.1	143.7	254.9	159.3	192.8	300.7
TDS	**500mg/l**	245.9	153.4	335.1	130.8	268	111.3	158.8	121.6	145	223.3
Calcium	**200mg/l**	62.23	41.21	27.75	33.642	51.30	34.48	34.48	30.27	33.64	2.52
Magnesium	**100mg/l**	108.2	108.9	183.1	79.588	24.27	8.23	17.47	17.59	6.804	43.18
Sodium	**200mg/l**	0.9	1.3	1.6	1.8	1.8	2.1	2	2.1	2.4	2.5
Potassium	**12mg/l**	2.7	4	3.9	4.6	4.2	4.3	5.2	4.6	4.6	5.2
Chloride	**250mg/l**	1.42	0.426	0.284	0.71	0.994	0.284	0.142	0.142	0.284	0.284
Nitrate	**45mg/l**	8.38	11.65	8.38	1.35	3.47	3.06	2.66	1.71	1.84	3.88
Sulphate	**400mg/l WHO 500mg/l**	9.47	11.78	15.67	11.57	20.22	6.66	10.34	6.45	8.25	11.42
WQI		18.13	22.89	43.16	24	15.64	15.92	19.55	25.19	25.94	49.39

5.2 Parameter Wise Results

5.2.1pH

The term pH stands for potential of hydrogen and it quantifies the concentration of hydrogen in a solution. According to BIS (Bhavan et al., 2012)and WHO(World Health Organization., 2011), the ideal pH range for drinking water is between 6.5 and 8.5. The ideal range ensures that the water is neither too acidic nor too alkaline. Our results show that the pH for all 10 locations ranges between 5.99 -7.22. S10 shows the minimum pH range i.e., 5.99, the value is slightly acidic in nature. Highest value of pH was recorded in S4; the value is above neutral, which indicates a slightly alkaline or basic nature.

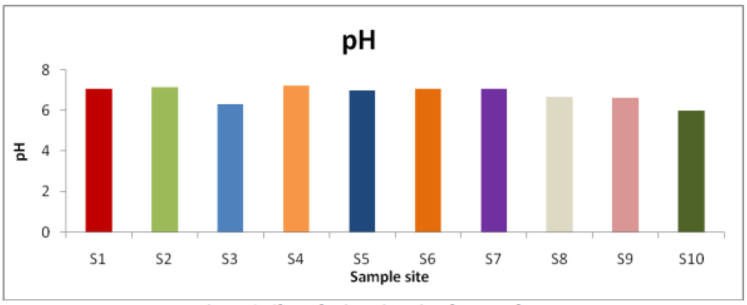

Fig 3: Chart depicts site wise the pH values

5.2.2Electrical Conductivity

Electrical conductivity is a measure of solutions ability to conduct electric current. It is a critical parameter in water quality study since it offers information about the mineral and dissolved ions or salts that are present in the water (Barakat et al., 2018). Higher level of dissolved ions generally results in increased electrical conductivity. BIS acceptable limit for EC is 400µS/cm. Our sites electrical conductivity (EC) was found to be in the ranges of 143.7µS/cm to 456µS/cm with an average of 285.44µS/cm indicating low to moderate mineral content. Minimum value was found at S6, which represents moderate level of ions and maximum EC values were recorded at S3 representing higher concentration of dissolved ions in water. However, there are potentially higher levels of conductivity (> 400µS cm^{-1}) found in the spring S3, which are more than the limit possibly due to contamination (Fig.4). High EC in water may be caused by aquifer material leaching and dissolving, as well as mixing of saline sources. (Hem, 1985; Hounslow, 1995; Thakur et al., 2018).

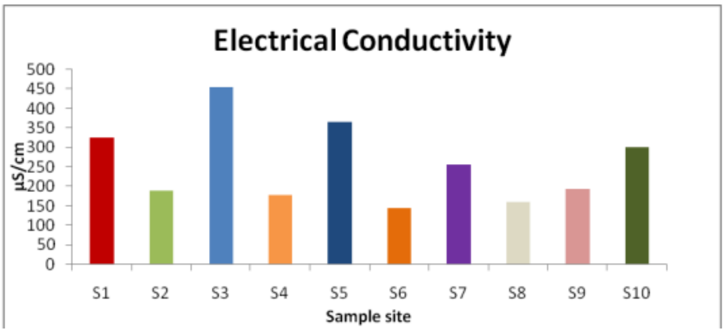

Fig 4: Site wise rates of Electrical Conductivity

5.2.3Total Dissolved Solids

It is used for determining the concentration of inorganic and organic substances that are dissolved in water. It represents combined content of all ions and other dissolved substances in water. It is typically measured in mg/lor ppm. Acceptable TDS level can vary depending upon intended use of water. According to BIS the permissible limit for TDS in drinking water is 500 mg/l respectively. These limits ensure that water is safe for consumption and does not pose any health risk.Fig.5 shows the values variation in range between111.3mg/l to 335.1mg/l with an average of 205. Maximum TDS is at S3 and minimum at S6.

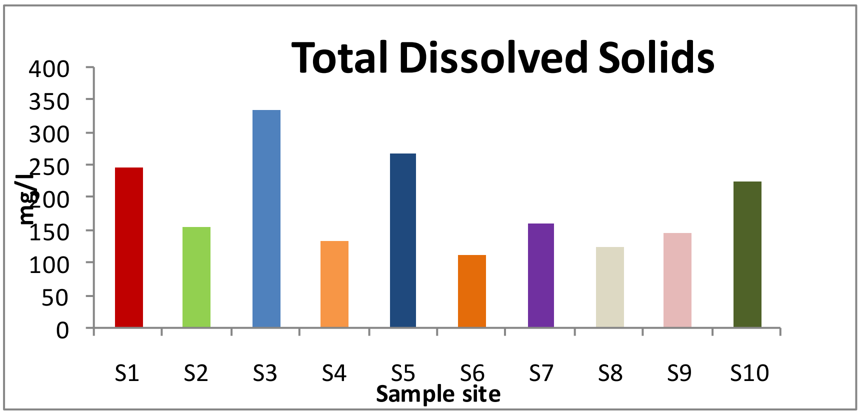

Fig 5: Site-Wise TDS value

5.2.4Cation and Anion Analysis

Piper plot, also known as the Piper trilinear diagram or Piper trilinear diagram, is a graphical representation, which was used for the visualization and interpretation of the hydrochemical composition of spring water samples in terms of cation and anions. Typical cations include calcium (Ca2+), magnesium (Mg2+), sodium (Na+), and potassium (K+). Common anions include bicarbonate (HCO3-), chloride (Cl-), sulfate (SO42-), and nitrate (NO3-). The concentrations of cations and anions are converted into milli equivalents per liter (meq/L) by dividing the concentration (in mg/L or ppm) by the respective ion's equivalent weight. The resulting Piper plot showed the relative proportions and classification of the water samples based on their dominant cation-anion compositions.

5.2.4.1 Cation Analysis

- **Calcium:** It is occurring naturally in water. It may dissolve from rocks such as marble, calcite, dolomite, gypsum, limestone and fluorite. Calcium is water hardness predictor, given that it can be found in water as Ca^{2+} ions. According to BIS the acceptable limit for calcium is 200mg/l.The value showed variation in range between 2.52315 to 62.2377[Fig. 6].

- **Magnesium:** The primary source of magnesium in spring water is the natural geological formations through which water flows. As water moves through the rocks and soil, it can dissolve mineral and trace elements, including magnesium, from the surrounding environment .Common mineral that contributes to the magnesium content in the spring water include dolomite, magnetite and various magnesium bearing silicate minerals. According to BIS the permissible limit for magnesium is 100mg/l.The value of magnesium showed variation in range between 6.804 to 108.9953.All the values were within permissible limit of BIS i.e., 200mg/l except S1,S2,S3 [Fig.6].

- **Sodium:** Presence of sodium in spring water can be due to anthropogenic and geological formation i.e .from rock and soil, salt deposits, agricultural activities such as application of fertilizers or irrigation with sodium rich water, can lead to increased sodium levels. According to BIS the acceptable limit for calcium is 200mg/l .The value of sodium showed variation in range from 0.9 to 2.5 [Fig 6.].

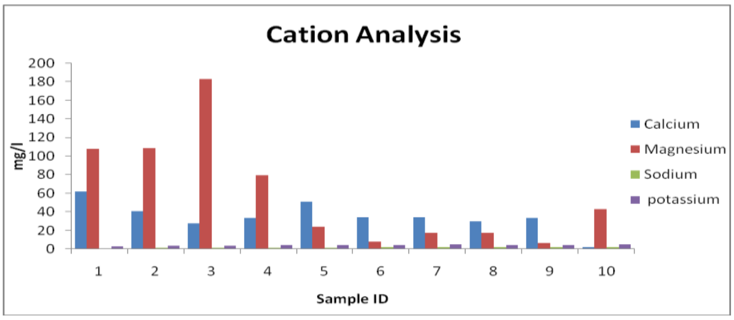

Fig 6: Bar Chart depicts site-wise cation analysis of spring water

- **Potassium**: Potassium in spring water is present due to weathering of rocks .As water moves through rock and soils, it can dissolve potassium containing minerals. Potassium rich minerals such as Feldspar, micas and certain clay minerals contribute to rich potassium content in spring water. Organic matter such as decaying vegetation can also release potassium in water. According to BIS the acceptable limit for potassium is 12mg/l.The value of potassium show variation in range between 2.7 to 5.7[Fig.6.].

5.2.4.2Anion Analysis

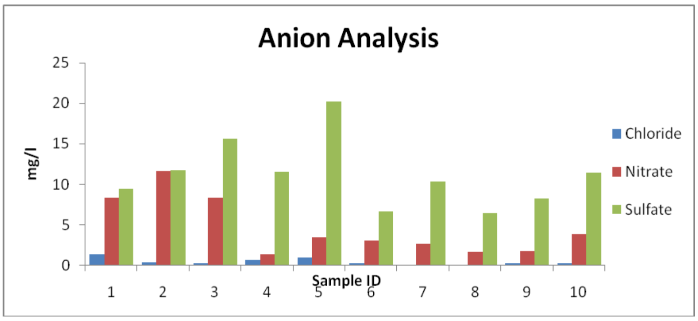

Fig 7: Bar Chart depicts site-wise anion analysis of spring water

- **Chloride:** Source of chloride contamination in water is due to water passing through geological formations can dissolve chloride containing minerals. Common chloride rich minerals include halite rock salt. Also human activities can introduce chloride into spring water e.g. industrial processes, wastewater discharges and agricultural practices. According to BIS the acceptable limit for Chloride 250 mg/l. Value of chloride in spring water varies in range from 0.994 to 1.42 .[Fig.7]
- **Nitrate:** The nitrate based fertilizer is the primary source of high nitrate level in the water source. The fertilizers leach into the soil and also to the springs. According to BIS the acceptable limit for Nitrate is 45mg/ll. The value of nitrate in spring water varies in range from1.71 to 11.65. [Fig.7]
- **Sulphate**: Sulphate in water is due to the weathering of rock containing sulphur e.g gypsum and certain sulphide minerals can contribute to sulphate content in spring water .Also human activities like mining, smelting and agricultural activities such as application of fertilizer containing ammonium sulphate can potentially lead to elevated sulphate level. According to BIS the acceptable limit for sulfate is 400mg/l .The value of sulphate in spring water lies in range from 6.45 to 20.22. [Fig.7]

5.3 Statistical Analysis

The Pearson correlation coefficient is a statistical measure of the strength of two variables' linear relationship. A correlation matrix for all of the parameters examined is shown. in Fig.8. A correlation coefficient values close to -1 or 1 denotes the strongest negative or strongest positive association between two variables, whereas a value close to 0 denotes no linear relationship between the variables (Sharma et al., 2021).

Parameters	pH	EC	TDS	Calcium	Magnesiun	Chloride	Sodium	Potassium	Nitrate	Sulfate
pH	1									
EC	-0.4056	1								
TDS	-0.4212	0.98869	1							
Calcium	0.7506	0.07232	0.09155	1						
Magnesium	-0.1193	0.58662	0.63396	0.11987	1					
Chloride	0.40914	0.32562	0.36958	0.73601	0.2589522	1				
Sodium	-0.5062	-0.3061	-0.3501	-0.7527	-0.670875	-0.6897	1			
Potassium	-0.3118	-0.3198	-0.3998	-0.7522	-0.560245	-0.747	0.86129	1		
Nitrate	0.03636	0.38601	0.45702	0.2983	0.7568598	0.27799	-0.7446	-0.6358487	1	
Sulfate	-0.0624	0.73534	0.73401	0.15833	0.3653882	0.34911	-0.2282	-0.1053339	0.2509	1

Fig 8: Correlation coefficient matrix for the parameters

The value of 0.98 indicates high positive correlation between EC and TDS. This means that if EC increases TDS also increases. TDS signifies the presence of rich soluble minerals in water and directly reciprocal with the conductivity. It denotes the dissolving of limestone in the incoming resource water. Correlation coefficient of 0.73 between Ca and Cl^- represents moderately strong positive linear relationship between two variables. It reflects lithogenic factor influencing the water chemistry. The high positive Ca loading has been attributed to natural processes such as weathering of rock minerals. (Sharma et al., 2021). Correlation of –0.74 between Cl^- and K^+ represent a moderately strong negative linear relationship. Correlation coefficient of 0.86 between Na+ and K+ represent positive linear relationship between two variables

5.4 Water Quality Index of Study Sites

WQI was calculated to assess the suitability of spring water quality for consumption. (Bhat et al., 2022; Gebrehiwot et al., 2011). At the study sites, WQI of the springs ranged from 15.64 to 49.39. Springs with ID,S5, S6, S1, S7, S2, S4, S8, and S9 WQI ranged from 0 to 25, suggesting that the water quality is excellent. However water quality of S3 and S10 is from 26-50 indicating good water quality. 80 percent of spring showed the excellent water quality, 20 percent of springs showed good water quality. This indicates that water is safe, clean and meets or exceeds the regulatory standards of drinking water. The water is suitable for drinking purposes, agricultural practices and irrigation practices. There are potential benefits for drinking this pristine water resource e.g. essential for maintaining healthy bodily functions as it is source of natural mineral content calcium and magnesium and source of natural antioxidant. It is also important to consider the variations in the WQI values depending on their location.

Table 5: Water quality index of springs of Maharaja Valley

Sample ID	WQI
S1	18.13
S2	22.89
S3	43.16
S4	24
S5	15.64
S6	15.92
S7	19.55
S8	25.19
S9	25.94
S10	49.39

The spring water analysis in Maharaja Valley of Kullu district region has revealed significant insight regarding its quality and suitability for various applications, with minimal level of contaminants and pollutants. Springs of the region generally meet the acceptable standards for various parameters like pH, TDS, Hardness, Na, K, CL, sulphate nitrate. pH showed value within the optimal range which indicate that water is not too acidic and not too alkaline in nature and water is safe for human consumption. TDS value also range within permissible limit indicating water is relatively free from excessive dissolved solids, calcium, nitrate, sulphate, chloride is within acceptable range of BIS. The value of EC for S3 is above the acceptable limit of 400µS/cm i.e., 456µS/cm indicating higher concentration of dissolved mineral such as calcium magnesium sodium potassium and in some cases excess EC indicate pollution and contamination of spring water resource. The value of Magnesium for S1, S2, and S3 is above the permissible limit of 100mg/l i.e., 108.2378,108.9953,183.1 respectively. Some samples have 700µScm−1 EC, which can be linked to domestic sewage, inorganic fertilizer inputs, and extended host rock water contact (Bhat et al., 2020; Jeelani, 2010; Kumar et al., 1997).This indicates that spring water is influenced by geologic characteristics of the region such as dolomite and limestone. (Bhat et al., 2020; Coward et al., 1972; Jeelani, 2007)The distance travelled by water from its source to the spring can also affect the magnesium content. When compared to spring water analysis from the Jammu and Kashmir Valley's Baramulla district, the lithology is characterised by limestone and sedimentary terrain, which contributes Ca2+ and Mg2+ ions to the solution. (Bhat et al., 2020; Coward et al., 1972; Jeelani, 2007). The concentration of sulphate was between 3 mg/l to 52 mg/l, which is within the WHO's limits. The sulphate content in the water can be increased by contamination from mines, mills, landfills, sewage, and other manmade sources (Shigut et al., 2017).

6. Conclusion

This study was limited to a few locations and one season. Therefore, to better understand the water quality in the Kullu Valley, more samples from different villages and seasons should be considered. Further research and data collection may be needed to confirm the results. Future studies could consider increasing the sample size to include a larger number of springs across different villages to improve the accuracy and generalizability of the results. The current study's findings revealed that the water quality in all springs was suitable for human consumption. However, recent findings on springs indicate that the water supplies are vulnerable to anthropogenic alteration and should be treated before drinking. Our findings can guide policy decisions and interventions for the protection and conservation of spring water resources. Strategies such as watershed management, land-use planning, and pollution control measures can be implemented based on the assessment results to maintain and enhance water quality.

The assessment of spring water quality in Himachal Pradesh is important for ensuring that local residents have access to clean and safe drinking water. By employing comprehensive testing methods, identifying potential contaminants, and implementing preventive measures, the preservation of this invaluable resource is safeguarded. Continued monitoring, public awareness, and sustainable water management practices are vital for the well-being of communities and the long-term conservation of the pristine spring water that graces the Himalayan region of Himachal Pradesh. Further studies in this area could provide a better knowledge of the specific factors influencing spring water. Implementing the same will ensure the long-term management of these neglected freshwater springs.

7. References

APHA. (2017). *Standard Methods for the Examination of Water and Waste Water* (23rd Edition).

Barakat, A., Meddah, R., Afdali, M., & Touhami, F. (2018). Physicochemical and microbial assessment of spring water quality for drinking supply in Piedmont of Béni-Mellal Atlas (Morocco). *Physics and Chemistry of the Earth, Parts A/B/C*, *104*, 39–46. https://doi.org/https://doi.org/10.1016/j.pce.2018.01.006

Bhat, S. U., Dar, S. A., & Hamid, A. (2022). A critical appraisal of the status and hydrogeochemical characteristics of freshwater springs in Kashmir Valley. *Scientific Reports*, *12*(1). https://doi.org/10.1038/s41598-022-09906-2

Bhat, S. U., Mushtaq, S., Qayoom, U., & Sabha, I. (2020). Water Quality Scenario of Kashmir Himalayan Springs—a Case Study of Baramulla District, Kashmir Valley. *Water, Air, and Soil Pollution*, *231*(9). https://doi.org/10.1007/s11270-020-04796-4

Bhavan, M., Shah, B., & Marg, Z. (2012). *B U R E A U O F I N D I A N S T A N D A R D S*.

Bhutiani, R., Ahamad, F., & Ram, K. (2019). Assessment of suitability of ground water quality in and around Laksar, Haridwar, Uttarakhand on the basis Water Quality Index (WQI). *Environment Conservation Journal*, *20*, 41–46. https://doi.org/10.36953/ECJ.2019.1008.1207

Brown, R. M., Mccleiland, N., Deiniger, R., & Connor, M. (1972). Water quality index—crossing the physical barrier. *Intl Conf on Water Poll Res, Jerusalem, Vol 6*, 787–797.

Chatterjee, R. P. ,&Raziuddin, M. (2007). STUDIES ON THE WATER QUALITY OF A WATER BODY AT ASANSOL TOWN, WEST BENGAL. *Nature Environment and Pollution Technology*, *6*(2), 289–292.

Chauhan, J. S., Badwal, T., &Badola, N. (2020). Assessment of potability of spring water and its health implication in a hilly village of Uttarakhand, India. *Applied Water Science*, *10*(2). https://doi.org/10.1007/s13201-020-1159-6

Coward, J. M. H., Waltham, A. C., & Bowser, R. J. (1972). Karst springs in the Vale of Kashmir. *Journal of Hydrology*, *16*(3), 213–223. https://doi.org/https://doi.org/10.1016/0022-1694(72)90053-4

Gebrehiwot, A. B., Tadesse, N., & Jigar, E. (2011). *Application of water quality index to assess suitablity of groundwater quality for drinking purposes in Hantebet watershed, Tigray, Northern Ethiopia*.

Gupta, A., & Kulkarni, H. (2017). *Report of working group I inventory and revival of springs in the Himalayas for Water Security*.

Hem, J. D. (1985). *Study and Interpretation of the Chemical Characteristics of Natural Water Third Edition*.

Hounslow, A. W. (1995). *Water quality data analysis and interpretation*. CRC PRESS.

Jeelani, G. (2007). Hydrogeology of Hard Rock Aquifer in Kashmir Valley: Complexities and Uncertainties. In *Groundwater Dynamics in Hard Rock Aquifers: Sustainable Management and Optimal Monitoring Network Design* (pp. 243–248). https://doi.org/10.1007/978-1-4020-6540-8_19

Jeelani, G. (2010). Chemical and microbial contamination of Anantnag springs, Kashmir Valley. *Himalayan Ecology and Sustainable Development*, *5*, 1–10.

Kumar, K., Rawat, D. S., & Joshi, R. (1997). Chemistry of springwater in Almora, Central Himalaya, India. *Environmental Geology (Berlin).*, *berlin*, 150–156. https://doi.org/10.1007/s002540050174

Negi, G. C. S., & Joshi, V. (2002). Drinking Water Issues and Development of Spring Sanctuaries in a Mountain Watershed in the Indian Himalaya. *Mountain Research and Development*, *22*(1), 29–31. https://doi.org/10.1659/0276-4741(2002)022[0029:DWIADO]2.0.CO;2

Scott, C. A., Zhang, F., Mukherji, A., Immerzeel, W., Mustafa, D., & Bharati, L. (2019). Water in the Hindu Kush Himalaya. In P. Wester, A. Mishra, A. Mukherji, & A. B. Shrestha (Eds.), *The Hindu Kush Himalaya Assessment: Mountains, Climate Change, Sustainability and People* (pp. 257–299). Springer International Publishing. https://doi.org/10.1007/978-3-319-92288-1_8

Sharma, G., Lata, R., Thakur, N., Bajala, V., Kuniyal, J. C., & Kumar, K. (2021). Application of multivariate statistical analysis and water quality index for quality characterization of Parbati River, Northwestern Himalaya, India. *Discover Water*, *1*(1). https://doi.org/10.1007/s43832-021-00005-3

Shigut, D. A., Liknew, G., Irge, D. D., & Ahmad, T. (2017). Assessment of physico-chemical quality of borehole and spring water sources supplied to Robe Town, Oromia region, Ethiopia. *Applied Water Science*, *7*(1), 155–164. https://doi.org/10.1007/s13201-016-0502-4

Singh, S., Singh Negi, R., Dhanai, R., & Negi, R. (2014). A study of physico-chemical parameters of springs around Srinagar Garhwal valley, Uttarakhand Sustainable livelihood View project MGNREGA View project A study of physico-chemical parameters of springs around Srinagar Garhwal valley, Uttarakhand. In *International Journal of Engineering Development and Research* (Vol. 2). www.ijedr.org

Taloor, A. K., Pir, R. A., Adimalla, N., Ali, S., Manhas, D. S., Roy, S., & Singh, A. K. (2020). Spring water quality and discharge assessment in the Basantar watershed of Jammu Himalaya using geographic information system (GIS) and water quality Index(WQI). *Groundwater for Sustainable Development*, *10*, 100364. https://doi.org/https://doi.org/10.1016/j.gsd.2020.100364

Tambe, S., Kharel, G., Arrawatia, M. L., Kulkarni, H., Mahamuni, K., &Ganeriwala, A. K. (2012). Reviving Dying Springs: Climate Change Adaptation Experiments From the Sikkim Himalaya. *Mountain Research and Development*, *32*(1), 62–72. https://doi.org/10.1659/MRD-JOURNAL-D-11-00079.1

Thakur, N., Rishi, M., Sharma, D. A., &Keesari, T. (2018). Quality of water resources in Kullu Valley in Himachal Himalayas, India: perspective and prognosis. *Applied Water Science*, *8*(1). https://doi.org/10.1007/s13201-018-0668-z

Verma, R., & Jamwal, P. (2022). Sustenance of Himalayan springs in an emerging water crisis. *Environmental Monitoring and Assessment*, *194*(2), 87. https://doi.org/10.1007/s10661-021-09731-6

Wester, P., Mishra, A., Mukherji, A., & Shrestha, A. B. (2019). *The Hindu Kush Himalaya Assessment—Mountains, Climate Change, Sustainability and People.* Springer Nature Switzerland AG, Cham.

World Health Organization. (2011). *Guidelines for drinking-water quality.* World Health Organization.