# Evaluating Spring Water Potability Using Water Quality Indices: A Case Study of Takoli Gad Watershed, Uttarakhand

**Bhawna Siwach[1*] • Meenakshi Soliyal[1] • Gaurav[2] • Mohan Singh Panwar [1]**

*[1]Department of Geography, School of Earth Science, H.N.B. Garhwal University, Srinagar, Utttarakhand-246174*
*[2]Department of Geography, Indraprastha College for Women, Delhi University, New Delhi*

[*]Corresponding Author Email Id: siwachbhawna99@gmail.com

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**Abstract:** Natural springs are vital sources of freshwater, particularly in mountainous regions like the Garhwal Himalayas. However, concerns about spring water quality, driven by both natural processes and anthropogenic activities, have prompted the need for systematic water quality assessments. This study examines the drinkability of spring water across six villages within the Takoli Gad watershed, Uttarakhand, by analyzing key physico-chemical parameters such as total electrical conductivity (EC), dissolved solids (TDS), pH, nitrate levels, and many other indicators. Water samples were assessed against BIS and WHO guidelines to determine compliance with potable water standards. Using Water Quality Indices (WQI) to categorize the water from the springs, revealing considerable variability. Springs like Jirno Dhaara and Cham Dhaara exhibited excellent water quality (WQI < 25), while others such as Amoli and Dangchoura fell into the "very poor" category (WQI > 90). The findings of the study suggest the need for targeted water management strategies, including treatment of springs with suboptimal water quality to ensure safe drinking water for local communities. Furthermore, the study shows effects of geochemical and environmental factors, such as aquifer rock composition and anthropogenic pressures, on water quality. These insights contribute to a broader understanding of spring sustainability effected by climate change and increasing human activity.

**Keywords**: Spring Water • Physicochemical parameters • Water Quality Index • Statistical analysis • Watershed • Permissible limits • Uttarakhand • Drinking water

## Introduction

Groundwater is a vital resource for human life, serving as a principal supply for both irrigation and drinking water. Its quality has a direct effect on public health and agricultural productivity. Globally, over 66% of the population relies on groundwater (Adimalla and Li 2019). Springs, which are natural outflows of groundwater, hold a significant role in the hydrological cycle and have long served as reliable sources of freshwater, particularly in mountainous areas. Evaluating the quality of spring water is essential, as it provides critical insights into the condition of the underlying groundwater systems and their vulnerability to contamination from both natural and human-induced factors (Valdiya & Bargariya 1991).

In the Himalayan region, including areas such as Garhwal, springs are a foundational component of local water supply networks, supporting domestic use, irrigation, and ecosystem functions (Das & Sen et al 2021). However, recent years have witnessed substantial changes in both the volume and quality of spring water, raising significant concerns regarding their long-term viability. These shifts are frequently linked to increased human activity and variations in climatic patterns (Pant & Rawat 2015). Numerous springs have either dried up, become seasonal, or show noticeably reduced discharge (Valdiya & Bargariya 1991).

Himalayan springs are primarily recharged by groundwater aquifers, which in turn rely on precipitation and snowmelt. The physico-chemical characteristics of spring water are indicative of aquifer health and recharge mechanisms (Dhakal et al., 2014). Key parameters—such as total dissolved solids (TDS), electrical conductivity (EC), pH, and concentrations of major ions like calcium, magnesium, and bicarbonates—offer insights into the geological composition, the nature of water-rock interactions, and the residence time of water underground (Joshi 2006). These indicators are crucial for the sustainable management of springs in areas dependent on groundwater.

Groundwater pollution, particularly where spring water is used without treatment, presents a growing risk. Natural geochemical influences such as rock weathering and soil leaching affect water chemistry (Jal Shakti 2019), while anthropogenic activities—such as deforestation, agricultural practices, urban growth, and tourism—introduce pollutants like nitrates, phosphates, and heavy metals into the groundwater system (Valdiya & Bargariya 1991). Continuous monitoring of spring water's physico-chemical properties is necessary to maintain its potability and protect ecological integrity in fragile mountain ecosystems (Conboy & Goss 2000). Recent research has increasingly emphasized the significance of these properties for identifying environmental trends, evaluating hazards, and informing conservation strategies in sensitive regions such as the Himalayas (Ansari et al 2018).

Water pH, which measures its acidity or alkalinity, is a key quality metric. It is influenced by environmental factors such as $CO_2$ absorption, geological interactions, and biological activity like respiration and photosynthesis (Jeelani et al 2011). In mountainous areas, bedrock and soil types further modulate pH. For instance, carbonate-rich formations raise pH due to calcium carbonate dissolution (Ford et al 2007), whereas granite or silicate rocks typically produce more acidic water. Similarly, EC, an indicator of dissolved ion concentration, reflects water quality and can rise due to mineral weathering or human interference like runoff and sewage (Jeelani et al 2014). High EC levels in the Garhwal Himalaya often point to human-related impacts (Joshi 2006). TDS also reveals aquifer composition, while major ions like calcium, magnesium, sodium, bicarbonate, and chloride offer further geochemical context. For instance, dominance of calcium-bicarbonate indicates interaction with carbonate rocks, while elevated sodium-chloride may indicate pollution from agriculture or domestic waste (Joshi B.K 2003).

Despite their importance, Himalayan springs face numerous threats to sustainability. Climate change is a significant challenge, altering recharge dynamics through changing temperatures and precipitation (Dhakal et al 2014). The region is experiencing irregular rainfall, extended dry periods, and reduced snowfall, all contributing to declining spring flows (Jal Shakti 2019). Extreme weather events like floods and landslides further disrupt recharge zones and increase sedimentation in spring catchments (Chinnasamy & Prathapar 2016).

Human activities exacerbate spring degradation. Agricultural intensification introduces nitrates and phosphates into aquifers (Ansari et al 2018), while tourism adds pollutants via unmanaged waste (Hamza et al 2017). Urban development in recharge areas further disturbs groundwater flow, causing many springs to dry up (Jeelani 2008). Compounding these threats is the lack of effective governance. Water management policies in India largely overlook springs, resulting in fragmented and inadequate stewardship (Joshi 2006). In addition, the absence of comprehensive hydrological data hampers strategic planning. This situation calls for an integrated water resource management approach that balances environmental conservation with community needs (Joshi B.K 2003).

**Study Area**

The Garhwal Himalaya is known for its many clean springs, which are important freshwater sources for local communities. These springs, found along roads, provide drinking water to nearby villages. This study took place in the Takoli Gad watershed in Uttarakhand, India. The watershed is located between 30°14’ and 30°23’ N latitude, and 78°37’ and 78°46’ E longitude, covering an area of about 13,143.18 hectares. The region is part of the Tehri Garhwal district in Uttarakhand.

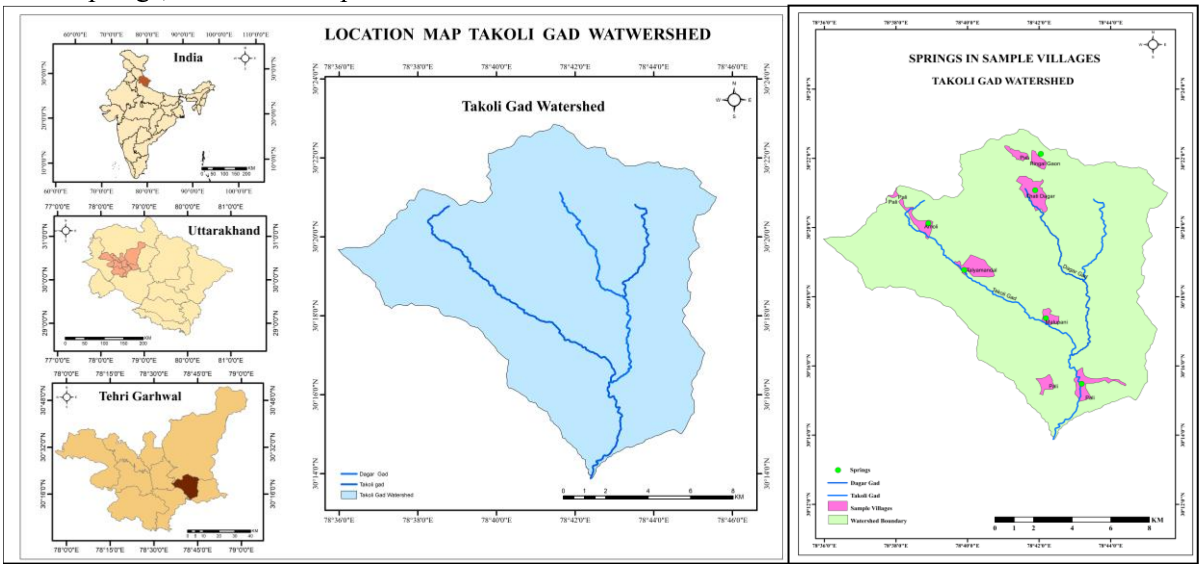


Figure 1: Location Map of Takoli Gad Watershed and Natural Water Springs in Takoli Gad Watershed (Source: Prepared by Author in QGIS)

The Takoli Gad watershed is located in the inner Garhwal Lesser Himalayas and is characterized by a mature and gently sloping topography. Originating from the eastern slope of Chandrabadni Peak at 2,278 meters, the Takoli Gad river flows down to meet the Alaknanda River at Juyal Garh (605 meters). The watershed supports diverse vegetation, including Tropical Dry Deciduous forests, Warm Temperate or Sub-Tropical Himalayan flora, and Cool Temperate or Moist Himalayan species. Prominent tree species include Banj, Burans, Chir, Deodar, Ralkher, Kharas, Moru, and Mukkut.

Climatically, the region transitions from cold temperate in the north to tropical and sub-tropical in the south. Winters bring sub-zero temperatures to northern and northwestern areas, while southern regions remain warmer and more humid. Occasional snowfall occurs in some villages. Temperatures vary seasonally, with summer peaks of 35°C and winter lows of 1.8°C between December and January. Annual precipitation averages 123.6 cm, with most rainfall during the monsoon (July–September). Winter rains, caused by Western Disturbances, are common in valleys, while higher altitudes may receive snowfall.

Understanding the watershed’s hydrology and climate is critical for sustainable resource management, especially amid rising climatic variability and human water demands. Studies emphasize the ecological importance of such watersheds in sustaining biodiversity and ecosystem services (Singh J.S., 2006). Additionally, climate-topography interactions significantly influence species distribution and habitat resilience (Dhakal et al., 2014). Ensuring long-term sustainability requires integrated conservation practices to protect natural springs and the communities that depend on them.

## Material and Methods

### Study Area Selection

This study was conducted in the Takoli Gad watershed, located in Uttarakhand, India. The selection of sample villages was carried out based on their varying elevations within the watershed, which ensured a representative distribution of natural springs across different altitudinal gradients. Six villages were selected, each containing one natural spring, which were chosen for in-depth investigation (Table 1)

Table 1: Sampling locations of Takoli Gad watershed

| Sl. No. | Village Name | Spring Name | Spring ID | Latitude | Longitude | Height (in Metres) |
|---|---|---|---|---|---|---|
| 1 | Amoli | Amoli | S1 | 30°20'7.19" N | 78°38'54.4" E | 1272 |
| 2 | Malupani | Malupani | S2 | 30°17'22.66" N | 78°42'21.42" E | 1169 |
| 3 | Pali | Dangchoura | S3 | 30°15'29.01" N | 78°43'11.39" E | 641 |
| 4 | Ringol | Jirno Dhaara | S4 | 30°19'14.01" N | 78°38'16.98" E | 1642 |
| 5 | Talyamandal | Talyamandal | S5 | 30°19'29.67" N | 78°39'16.09" E | 1230 |
| 6 | Thati Dagar | Cham Dhaara | S6 | 30°21'4.66" N | 78°41'53.47" E | 1314 |

(Source: Primary Field Work)

### Sampling & In-Situ Water Quality Testing

Physico-chemical parameters of the natural springs were assessed using a portable water testing kit. Testing was conducted directly at the spring sites to avoid any potential alterations in water quality during sample transport and to ensure the accuracy of the data. This approach minimized the chances of errors arising from time delays and environmental exposure.

### Parameters Assessed

The water quality parameters assessed were Electrical Conductivity (EC), pH, Ammonia, Total Dissolved Solids (TDS), Temperature, Chloride, Sulphate, Total Hardness, Total Alkalinity, Fluoride, Residual Chlorine, Nitrate, and Turbidity. These parameters were selected as they are key indicators of water quality and are commonly used to assess the potability and safety of drinking water.

### Water Quality Standards

The results of the physico-chemical testing were compared against permissible limits as prescribed by the BIS and the WHO guidelines. This comparison allowed for an assessment of whether the water from the springs met national and international drinking water quality standards.

Table 2: Physico-chemical parameters for analyzing Spring water

| Sl. No. | Parameter | Units | BIS Standards (2012) Requirement Acceptable - Allowable limit in the absence of an alternative source | WHO Standards (2011) Allowable limit in the absence of an alternative source |
|---|---|---|---|---|
| 1 | Color (Hazen unit) max | - | 5 to 15 | - |
| 2 | Taste | - | Fine | - |
| 3 | Odour | - | Fine | - |
| 4 | pH | - | 6.5 to 8.5 - No relaxation | <8.0 – No relaxation |

| | | | | |
|---|---|---|---|---|
| 5 | Temperature | $^0$C | 25 | - |
| 6 | Electrical Conductivity | µS.cm$^{-1}$ | 1500- | - |
| 7 | Total Dissolved Solids | mg.l$^{-1}$ | 500 to 2000 | 600 to 1000 |
| 8 | Total Hardness | mg.l$^{-1}$ | 200 to 600 | 100 to 500 |
| 9 | Total Alkalinity | mg.l$^{-1}$ | 200 to 600 | - |
| 10 | Nitrate | mg.l$^{-1}$ | 45 to No relaxation | 50 |
| 11 | Chloride | mg.l$^{-1}$ | 250 to 1000 | 250 |
| 12 | Sulphate | mg.l$^{-1}$ | 200 to 400 | 250 to 1000 |

(Source: Bureau of Indian Statistics & World Health Organization)

**Water Quality Index (WQI) Calculation**

Horton introduced the WQI in 1965 and later modified by Brown in 1970 with a version closely resembling Horton's index. To assess the suitability of spring water for human use, we employed the weighted arithmetic water quality index method. This approach is commonly used in water quality evaluations, as highlighted in the studies by Adimalla and Venkatayogi (2018).

The Water Quality Index (WQI) simplifies complex data by combining multiple parameters like pH, dissolved oxygen, and TDS into a single value reflecting overall water quality. Using a weighted arithmetic method, each parameter is assigned a weight based on its importance to health and environmental safety. This approach provides a clear classification of water quality, from "excellent" to "unsuitable for drinking," and helps identify key pollutants, making it a useful tool for water resource management. The calculation of the WQI formula:

$$\mathbf{WQI = \sum QiWi / \sum Wi} \qquad 1)$$

$$\mathbf{Qi = 100 * Vn/Si} \qquad 2)$$

$$\mathbf{Wi = K / Si} \qquad 3)$$

$$\mathbf{K = 1 / (\sum 1/Si)} \qquad 4)$$

Here,

Qi= Overall quality rating Scale

Wi= Unit weight for each parameter

Vn= Particular parameter's estimated concentration in water sample (except pH)

Vo= Ideal value for that particular parameter (for all value Vo=0, except pH=7.0)

K= Proportionality constant

Si= Standard value of a particular parameter (different according to different organizations)

The assigned weight for physicochemical parameters is determined by their relative importance in overall drinking water quality, with values ranging from a maximum of 5 to a minimum of 1 (Tyagi et al 2013).

**Statistical Analysis**

Data from the in-situ measurements was collected and processed in Microsoft Excel for statistical analysis. A correlation matrix was generated to assess the link among the physico-chemical parameters. Analysis correlation helped in identifying significant interactions between the variables, providing insights into potential factors for contamination or natural processes affecting water quality in the watershed.

**Correlation Matrix**

A correlation matrix is a statistical tool used to assess the connection between pairs of variables within a dataset. This matrix displays each variable's correlation coefficient in a table format, where a value of 1 indicates a strong positive relationship, and 0 represents no relationship. Negative values suggest an inverse relationship between variables, while values closer to 1 or -1 indicate stronger associations. Correlation matrices are commonly used in data analysis to identify patterns and dependencies among variables.

## Results and Discussion

### Physico-Chemical Properties

The water quality of 6 natural springs within the Takoli Gad watershed was evaluated based on several physico-chemical parameters. The springs assessed were Amoli, Malupani, Dangchaura, Jirno Dhaara, Talyamandal, & Cham Dhaara. The results are presented in Table 3.

The pH of springs ranged from 6.5 (Thati Dagar) to 8.6 (Amoli), indicating slightly acidic to slightly alkaline conditions. Springs like Thati Dagar may have minor acidity, while Amoli shows alkaline tendencies. All values, except Amoli, fall within or near BIS permissible limits (6.5–8.5). Onsite water temperature measurement is crucial, as transporting samples can introduce errors due to temperature changes (Delpla et al., 2009). Temperature affects various physico-chemical properties like dissolved oxygen, pH, and conductivity, impacting water quality assessment (Dumaru et al., 2021).

In-situ temperature testing ensures more accurate results. Temperatures varied from 22.4°C (Thati Dagar) to 25°C (Malupani), showing a stable thermal profile within the permissible limit. Electrical Conductivity (EC), indicating ionic content, ranged from 160 µS/cm (Talyamandal) to 576 µS/cm (Ringol), all below the permissible 1500 µS/cm, suggesting low ion concentrations and good water purity.

Table 3: Different Values of Parameters Tested in Natural Springs of the Study Area

| Sl. No. | Parameters | Permissible Limit (PL) | Amoli (S1) | Malupani (S2) | Pali (S3) | Ringol Gaon (S4) | Talya mandal (S5) | Thati Dagar (S6) |
|---|---|---|---|---|---|---|---|---|
| 1 | **Spring Name** | - | Amoli | Malupani | Dang chaura | Jirno Dhaara | Talya mandal | Cham Dhaara |
| 2 | **Spring ID** | - | S1 | S2 | S3 | S4 | S5 | S6 |
| 3 | **Color** | Agreeable | No Color | No Color | No Color | No Color | No Color | No Color |
| 4 | **Odor** | Agreeable | Odor less | Odorless | Odor less | Odor less | Odor less | Odorless |
| 5 | **Taste** | Agreeable | Taste less | Tasteless | Taste less | Taste less | Taste less | Tasteless |
| 6 | **pH** | 6.5-8.5 | 8.6 | 8.1 | 8.56 | 6.8 | 7.92 | 6.5 |
| 7 | **Temperature (°C)** | 25 | 23.8 | 25 | 23.4 | 23.2 | 24 | 22.4 |
| 8 | **EC (µS.cm) (Conductivity)** | 1500 | 339 | 473 | 365 | 576 | 160 | 316 |
| 9 | **TDS (mg/l)** | 500-2000 | 240 | 336 | 269 | 316 | 327 | 342 |
| 10 | **Total Hardness (mg/l)** | 200-600 | 210 | 165 | 225 | 90 | 225 | 120 |
| 11 | **Nitrate (mg/l)** | 45 | 5 | 5 | 15 | 5 | 5 | 5 |
| 12 | **Alkalinity (mg/l)** | 200-600 | 350 | 300 | 250 | 175 | 250 | 275 |
| 13 | **Chloride(mg/l)** | 250-1000 | 60 | 40 | 20 | 80 | 80 | 60 |
| 14 | **Sulphate (mg/l)** | 200-400 | 100 | 100 | 200 | 200 | 200 | 200 |
| 15 | **Acidity** | 200 | 350 | 300 | 250 | 175 | 250 | 275 |

(Source: Primary Fieldwork)

Total Dissolved Solids (TDS), which affect taste, hardness, and potability, ranged from 240 mg.l$^{-1}$ (Amoli) to 342 mg.l$^{-1}$ (Thati Dagar), well within the permissible range (500–2000 mg.l$^{-1}$), indicating minimal dissolved salts. Total hardness, reflecting calcium and magnesium levels, ranged from 90 mg.l$^{-1}$ (Ringol) to 225 mg.l$^{-1}$ (Malupani and Pali). Though some values approach the upper permissible limit (200–600 mg.l$^{-1}$), most springs remain suitable for domestic use.

Nitrate levels ranged from 5 to 15 mg.l$^{-1}$, well below the 45 mg.l$^{-1}$ limit, suggesting low nitrogen pollution and no major contamination risks (Hameed et al 2018). Alkalinity, indicating buffering capacity, was highest in Amoli (350mg.l-1) and lowest in Ringol (175 mg.l$^{-1}$), both below the permissible range (200–600 mg.l$^{-1}$). This points to varying acid-neutralizing capacity among springs.

Chloride ranged from 20 mg.l$^{-1}$ (Pali) to 80mg.l-1 (Ringol), while sulphate levels were consistently high (100–200 mg.l$^{-1}$). Both remained within permissible limits (chloride: 250–1000 mg.l$^{-1}$; sulphate: 200–400 mg.l$^{-1}$), suggesting no major contamination from industrial or agricultural sources.

**Water Quality Index of different Natural Springs**

WQI was calculated for each spring to assess overall water quality by analyzing parameters like TDS, EC, pH, chloride, nitrate, sulphate, and alkalinity. This index categorizes springs from excellent to poor, indicating whether the water is safe for drinking or needs treatment. The results provide key insights for managing local freshwater resources.

Table 4: Water Quality Index of Different Natural Springs

| Village Name | Spring Name | Water Quality Index | Water Quality Category |
|---|---|---|---|
| **Amoli** | Amoli | 88.5632 | Very Poor water Quality |
| **Malupani** | Malupani | 72.68005 | Poor water Quality |
| **Pali** | Dangchoura | 92.32102 | Very Poor water Quality |
| **Ringol** | Jirno Dhaara | 20.49074 | Excellent water Quality |
| **Talyamandal** | Talyamandal | 65.63872 | Poor water Quality |
| **Thati Dagar** | Cham Dhaara | 9.586723 | Excellent water Quality |

(Source: Primary Field Work)

In Table 4, the values of the prepared index ranged between 9.586723 to 92.32102. Amoli and Dangchoura recorded WQI values over 90, categorizing them as "Very Poor" in terms of water quality. This indicates that these springs may pose a risk for human consumption without treatment. Malupani and Talyamandal had WQI values of 72.68 and 65.64, respectively, placing them in the "Poor" water quality category, which suggests that while the water is not ideal for drinking, it can be used with some level of treatment. Jirno Dhaara and Cham Dhaara were the best in terms of water quality, with WQI values of 20.49 and 9.59, respectively. Both are classified as having "Excellent" water quality, making them safe for direct consumption. (Figure 2)

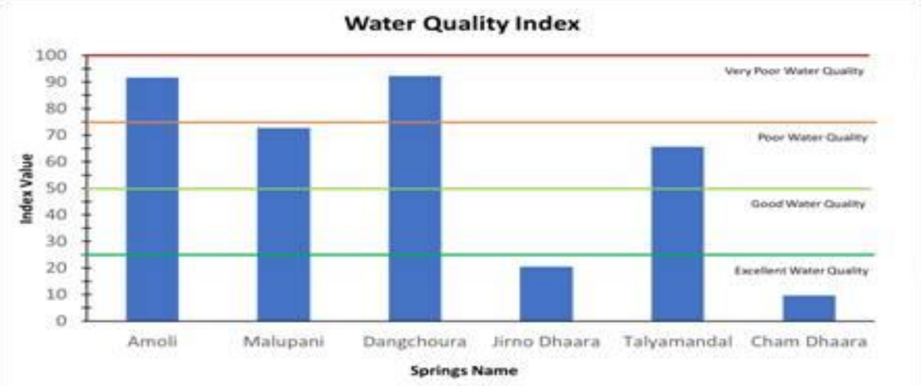


**Figure 2: Water Quality Index of Different Natural Springs**

(Source: Primary Field work)

**Correlation Among Physico-Chemical Parameters**

The correlation analysis (Table 5) provides insights into the relationships between different water quality parameters: Positive and strong correlation was observed between Hardness and pH (0.874), suggesting that as pH increases, so does the hardness of the water. This could be due to the presence of dissolved bicarbonates or carbonates. Temperature showed a moderate positive correlation with Ph (0.628) and a negative correlation with sulphates (-0.681), indicating that higher temperatures may coincide with lower sulphate concentrations. Electrical Conductivity (EC) displayed a strong negative correlation with hardness (-0.878), suggesting that high conductivity values do not necessarily imply high hardness levels, potentially due to the nature of the dissolved ions.

Table 5: Correlation Among Physicochemical Parameters

| Parameter | pH | Temp °C | EC | TDS mg.l-1 | Hardness mg.l-1 | Alkalinity mg.l-1 | Chlorides mg.l-1 | Nitrate mg.l-1 | Sulphate mg.l-1 |
|---|---|---|---|---|---|---|---|---|---|
| **pH** | 1 | 0.628506 | -0.60374 | -0.68837 | 0.874205 | 0.54675 | -0.52697 | 0.445763 | -0.52283 |
| **Temp °C** | 0.628506 | 1 | -0.31495 | -0.0134 | 0.413233 | 0.340452 | -0.18987 | -0.13124 | -0.6818 |
| **EC** | -0.60374 | -0.31495 | 1 | 0.27017 | -0.87813 | -0.30426 | -0.07205 | -0.12861 | -0.00952 |
| **TDS mg.l-1** | -0.68837 | -0.0134 | 0.27017 | 1 | -0.52894 | -0.40353 | 0.307846 | -0.42886 | 0.320204 |
| **Hardness mg.l-1** | 0.874205 | 0.413233 | -0.87813 | -0.52894 | 1 | 0.490832 | -0.37928 | 0.447214 | -0.20203 |
| **Alkalinity mg.l-1** | 0.54675 | 0.340452 | -0.30426 | -0.40353 | 0.490832 | 1 | -0.31707 | -0.13969 | -0.77302 |
| **Chlorides mg.l-1** | -0.52697 | -0.18987 | -0.07205 | 0.307846 | -0.37928 | -0.31707 | 1 | -0.76827 | 0.220863 |
| **Nitrate mg.l-1** | 0.445763 | -0.13124 | -0.12861 | -0.42886 | 0.447214 | -0.13969 | -0.76827 | 1 | 0.316228 |
| **Sulphate mg.l-1** | -0.52283 | -0.6818 | -0.00952 | 0.320204 | -0.20203 | -0.77302 | 0.220863 | 0.316228 | 1 |

(Source: Primary Field Work & MS Excel)

**Conclusion**

The water quality of the natural springs in the Takoli Gad watershed varies significantly across the different locations. Springs like Jirno Dhaara and Cham Dhaara exhibit excellent water quality, while others, particularly Amoli and Dangchoura, fall into the very poor category. Factors such as high alkalinity, hardness, and deviations in pH likely contribute to these poor rankings. The correlation analysis suggests that water quality parameters are interconnected, with pH and hardness being particularly influential. Based on these findings, certain springs may require treatment before use for drinking purposes. The excellent quality springs, however, could be prioritized for direct consumption by local populations.

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