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# Water Quality Assessment of Natural Springs in Udhampur District and Application of Iron Nanomaterial as a Remedial Step

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**ABSTRACT**
This study investigates the water quality of natural springs in the Udhampur District by analysing the physicochemical properties of water samples from Mongu Di Bowli (a natural spring) and Pittan Barh Bowli (a natural spring) near the Devika River. Over the year 2021, several parameters such as temperature, pH, dissolved oxygen, total dissolved solids, alkalinity, hardness, calcium, chloride, fluoride, nitrate, sulphate, and phosphate mostly remained within acceptable limits. However, elevated levels of magnesium (Mg), boron (B), nitrite ($NO_3^-$), and, in some instances, phosphate ($PO_4^{3-}$) were noted, necessitating attention. The evaluated Water Quality Index (WQI) of 82 for Mongu Di Bowli and 68.2 for Pittan Barh Bowli both fall under the "good" category, indicating that the water is generally safe for consumption but may require treatment to fully comply with established standards. This comprehensive assessment underscores the need for continuous monitoring and improvement measures to mitigate identified water quality issues, ensuring human health and environmental sustainability in the Udhampur District. Strengthening environmental regulations, implementing advanced water treatment processes, and enhancing community engagement are pivotal to sustaining water quality. It suggests that anthropogenic activities, such as the discharge of untreated effluents, agriculture waste, and domestic wastewater, are the primary contributors to groundwater pollution. This study explores porous iron-based nanomaterials with a 0.32 cm3/g pore volume, highlighting their effectiveness in removing impurities from water. The nanomaterials' enhanced adsorptive capacities are attributed to their specific physical and chemical properties. This research offers a promising solution to contemporary water pollution challenges and underscores the potential application of these nanomaterials in sustainable water treatment.

**Keywords:** Water Quality, Udhampur District, Physicochemical Properties, Water Quality Index (WQI), Groundwater Pollution, Nanomaterials, Sustainable Water Treatment

## 1. INTRODUCTION

The quality of water resources is a very important parameter for establishing or planning any project in any region of a nation. Groundwater contamination is a serious concern due to anthropogenic activities and unplanned urbanization[1]. Groundwater is one of the primary sources for survival activities such as drinking, domestic purposes, industrial uses, agriculture, and electricity generation. People in India use water for drinking purposes from springs in different regions, such as Jammu and Kashmir, Himachal Pradesh, Uttarakhand, and Punjab[2]. The springs contain water that naturally flows out of the ground and have spiritual importance. Natural springs in the Udhampur region are a main source of fresh water for drinking purposes and need to be protected from contamination.

It has been reported that variation in groundwater quality in physicochemical parameters is influenced by anthropogenic activities with an increasing population[3]. These natural springs are under constant threat, might result in ecological imbalance, and need effective management to study the quality of the water.

As per the recent reports published in The Tribune on September 5, 2023, hundreds of fish have died in local nullahs at Battal Ballian, Dudhar, and Barrian in Udhampur district due to excessive water pollution allegedly caused by discharge from some units at the local Battal Ballian Industrial Area. There are many factors responsible for water pollution, such as the discharge of untreated effluents, pesticides from agricultural sources, and domestic activities. Various reports have been dedicated to showing the deteriorating quality of groundwater due to increasing industrial and wastewater pollution [4].

The variation in the concentration of physicochemical parameters like total hardness, dissolved oxygen, chemical oxygen demand, chloride, sulphate, nitrate, iron, and inorganic ions poses a serious threat not only to groundwater but also to spring water. The variation in the concentration of physicochemical parameters like total hardness, dissolved oxygen, chemical oxygen demand, chloride, sulphate, nitrate, iron, and inorganic ions poses a serious threat not only to groundwater but also to spring water[5]. Water contamination may increase the risk of water-borne diseases due to contamination and the potential health hazards [6]. The study on groundwater and river water not only provides a way to conserve them but also adopts a holistic model for the life of society.

The Indian Government launched many projects related to water management in 2019 under the Jal Jeevan Mission (JJM) Abhiyan and the National Water Mission. It is our fundamental right to have clean and pure water. However, it is vulnerable to contamination from natural and anthropogenic sources, leading to adverse health effects in humans and ecological imbalances[7].

Spring water provides a cost-effective option for potable water throughout the Himalayan region. The quality of spring water alters from spring to spring, which results in different uses of springs by users, such as recreational, domestic, industrial, and agricultural usages[8]. Spring water quality depends on several factors, such as the interaction of the water with the geology of the area, the composition of minerals present in an aquifer, rock-water interactions, products of weathering, the topography of the surrounding area, climatic conditions, and anthropogenic activities [9].

Due to a growing population and unplanned development, springs have been adversely affected, which leads to the depletion of this major water resource in the whole Himalayan region[10]. The Indian government has started many projects, such as Namami Gange or wastewater recycling projects, to monitor river water quality and take steps to overcome this problem. This prompts us to contribute our research work associated with water pollution.

Undertaking research on the water quality of natural springs (bowlis) in Udhampur, Jammu and Kashmir is essential in order to address environmental conservation, resource management, and public health concerns in a comprehensive manner.

The present research aims to evaluate the physicochemical assessment of groundwater in a specific region near the Devika River in Udhampur district of J&K UT, aiming to understand the overall water quality and identify potential sources of contamination. The results were compared with the drinking water specifications of WHO and IS 10500, 1991 (reaffirmed in 1993), [11] including the latest amendments of BIS (IS 10500: 2012), WHO (2008), and the latest CPCB (Central Pollution Control Board) standards.

This study examined various biotic and abiotic sources of contamination that can adversely affect the water quality in Bowlis in the district of Udhampur. This study would be helpful in developing and implementing pollution prevention strategies in the contaminated areas of the Udhampur district.

## 2. MATERIALS AND METHODS

### 2.1 Study Area

Udhampur is the district headquarters and was named after Raja Udham Singh, the eldest son of Maharaja Gulab Singh, the founder of Dogra rule in Jammu and Kashmir. Udhampur is situated between 32° 34' and 39° 30' North Latitude and 74° 16' and 75° 38' East Longitude [12].

The holy Devika River in Udhampur is surrounded by numerous natural springs (bowlis) that contribute to its scenic landscape [12]. In the present study, we have studied two natural springs or bowls, the water of which has been used for drinking and other domestic purposes for ages.

**Sampling Site-1(SA 1) Mongu Di Bowli:** This bowlli is located near Devika Ghat, and it is named Mongu Di Bowli, the Bowli, after the name of a pious gentleman named Mongu who constructed it in the year 1941.

**Sampling Site-2 (SA 2) Pittan Barh Bowli:** The location of this particular bowli is in the Pittan Barh region of Udhampur, in close proximity to the banks of the Devika River. The water sourced from this particular bowl is regarded as being of high quality and is utilised by the local community for both potable and bathing reasons.


**Figure 1: Location map & GPS images of the study area**

### 2.2 Sample Collection

During the year 2021, the water samples (six grab samples from each spring were collected on the same day at a 1-hour interval and then mixed to form composite samples) from the two sites (bowlis), which are near the shores of the Devika River, were collected in pre-cleaned polyethylene bottles with a 2-litre capacity as per the standard procedure and analysed for physical and chemical parameters by following the standard procedures (APHA, 2005)

### 2.3 Water Quality Index Calculation

The suitability of the studied water samples was examined by comparing them with BIS (IS 10500:2012) and WHO (2008) standards for drinking water. To get an overall view of the water quality of the studied natural springs (bowlis), the weighted arithmetic index method was used. This method is one of the common approaches used for calculating the Water Quality Index (WQI). This method assigns weights to different parameters based on their importance. It is a flexible approach that allows customization according to local conditions and priorities. Weighted arithmetic indices are widely used in research and can be adapted to specific environmental concerns[14]. WQI is computed to turn compound water quality data into easily understandable instructions that can be used by the public[15]. The most convenient weighted arithmetic water quality index method is adopted[16]. Hence, WQI is a convenient and capable tool that provides us with an easy-to-understand water quality indicator depending on a few major parameters. In the present investigation, for calculation of WQI, specified standards for drinking water were used BIS (IS 10500: 2012) and WHO (2008). The WQI was computed using three steps:

In the first step, weight (Wi) was given to every selected parameter depending on its relative importance in the overall water quality for drinking purposes.

In the second step, the relative weight of chemical parameters is calculated by using the following equation:

$$W_i = w_i / \sum_{i=1}^{n} W_i$$

*Where,* $W_i$= relative weight
$w_i$= weight of each parameter
n = number of parameters

In the 3rd step, qi (quality rating scale) is calculated by using equation.
$qi = (C_i/S_i) \times 100$
Where, qi= quality rating scale
$C_i$= concentration of each chemical parameter in water sample in mg/L
$S_i$= Indian drinking water standard for each chemical parameter in mg/L

Finally, for WQI, the sub-index (SI) is determined for each chemical parameter as-
$SI_i = W_i \times q_i$
$WQI = \Sigma SI_i - n$
*Where,* SIi= sub-index of $i^{th}$ parameter
$W_i$= relative weight of $i^{th}$ parameter
$q_i$= rating based on the concentration of $i^{th}$ parameter
n = number of chemical parameters

The WQI range is divided into five categories[17]:
Good Water Quality (50-100)
Poor Water Quality (100-200)
Very Poor Water Quality (200-300)
Water Unsuitable for Drinking (>300)

### 2.4 Analytical Methods used for Physicochemical Analysis:

The water quality of groundwater, including temperature, pH, dissolved oxygen, total dissolved solids, total alkalinity, total hardness, calcium, chloride, magnesium, boron, fluoride, nitrate, nitrite, sulphate, and phosphate, was analysed using various methods and instruments.

**Table 1: List of parameters, time gap between sampling and testing, methodology, and instrumentation used.**

| S.No. | Parameter | Time between Sampling and Testing | Methodology or Instrumentation Used for Testing |
|---|---|---|---|
| 1. | pH | Immediately or within 12 hours of sampling | Water and Soil Analysis Kit, Cat. No. IE-WS08, INSIF INDIA |
| 2. | Dissolved Oxygen | Immediately or within 12 hours of sampling | Water and Soil Analysis Kit, Cat. No. IE-WS08, INSIF INDIA |
| 3. | Total Dissolved Solids | Within 12 hours of sampling | Water and Soil Analysis Kit, Cat. No. IE-WS08, INSIF INDIA |
| 4. | Total Alkalinity | Within 12 hours of sampling | Titrimetric Method (titration against EDTA solution) |
| 5. | Total Hardness, Calcium, Magnesium | Within 48 hours of sampling | Titrimetric Method (titration against EDTA solution) |
| 6. | Chlorides | Within 48 hours of sampling | Argentometric Titration |
| 7. | Boron | Within 2 days of sampling | Colorimetric Method |
| 8. | Fluoride | Within 2 days of sampling | Colorimetric Method |
| 9. | Nitrate | Within 12 hours of sampling | Double-Beam UV-Visible Spectrophotometer, Type 2203, SYSTRONICS |
| 10. | Nitrite | Within 12 hours of sampling | Double-Beam UV-Visible Spectrophotometer, Type 2203, SYSTRONICS |
| 11. | Sulphate | Within 3-4 days of sampling | Gravimetric Method |
| 14. | Phosphate | Within 3-4 days of sampling | Colorimetric Method |

## 3. RESULTS AND DISCUSSION

### 3.1 Data Analysis and Interpretation:

The experimental values for all the physico-chemical parameters are tabulated in tables 2 and 3 and were compared with standards as prescribed by different agencies, including BIS (IS 10500: 2012), WHO (2008), and the latest CPCB standards (IS:10500, WHO). The interpretation of the data has been made with the help of statistical tools. The results of the physicochemical analysis of water compare the measured parameters with national and international standards or guidelines, highlighting any variations or deviations from acceptable limits. Interpret the implications of these findings for water quality and potential sources of contamination. Data collected was analysed using the PIVOT table-chart tool using Microsoft® Excel® 2019 MSO (Version 2308 Build 16.0.16731.20182), 64-bit. and compared against BIS (IS 10500:2012) and WHO (2008) standards for drinking water.

**Table 1: Comparative study of physicochemical properties of water samples from Mongu Di Bowli/Spring near the Devika River in Udhampur District in the year 2021 with the standards for drinking water set by BIS (IS 10500: 2012) and WHO (2008)**

| Parameter | January | February | March | April | May | June | BIS/WHO/CPCB Standards (Acceptable Limits) |
|---|---|---|---|---|---|---|---|
| Water Temperature (°C) | 20.3 | 20.1 | 20.7 | 21.1 | 21.5 | 21.1 | Not specified |
| pH | 7.1 | 7.5 | 7.5 | 7.4 | 7.3 | 7.3 | 6.5 - 8.5 |
| Dissolved Oxygen (mg/L) | 6.8 | 6.8 | 6.7 | 6.7 | 6.8 | 6.8 | 6.5 - 8 mg/L |
| Total Dissolved Solids (mg/L) | 234.13 | 232.23 | 235.7 | 224.04 | 236.83 | 285.76 | 500 mg/L |
| Total Alkalinity (mg/L) | 102.1 | 102.3 | 102.1 | 102.4 | 102.5 | 102.4 | 200 mg/L |
| Total Hardness (mg/L) | 108.6 | 105.6 | 108.2 | 105.2 | 102.5 | 104.5 | 300 mg/L |
| Calcium (mg/L) | 29.62 | 29.12 | 28.43 | 28.23 | 27.24 | 27.26 | 75 mg/L |
| Chloride (mg/L) | 20.15 | 20.18 | 21.25 | 21.18 | 20.19 | 20.11 | 250 mg/L |
| Magnesium (mg/L) | 38.23 | 37.34 | 37.7 | 39.34 | 39.78 | 38.79 | 30 mg/L |
| Boron (mg/L) | 1.94 | 1.93 | 1.88 | 1.83 | 1.92 | 1.96 | 0.5 mg/L |
| Fluoride (mg/L) | 0.62 | 0.64 | 0.64 | 0.43 | 0.54 | 0.45 | 1.0 mg/L |
| Nitrate (mg/L) | 10.87 | 10.82 | 9.2 | 11.05 | 10.76 | 10.67 | 45 mg/L |
| Nitrite (mg/L) | 1.87 | 1.86 | 1.93 | 1.88 | 1.86 | 1.98 | 1.0 mg/L |
| Sulphate (mg/L) | 13.67 | 12.43 | 13.34 | 12.56 | 13.35 | 12.37 | 200 mg/L |
| Phosphate (mg/L) | 1.67 | 1.83 | 1.64 | 1.86 | 1.85 | 1.67 | 1 mg/L |

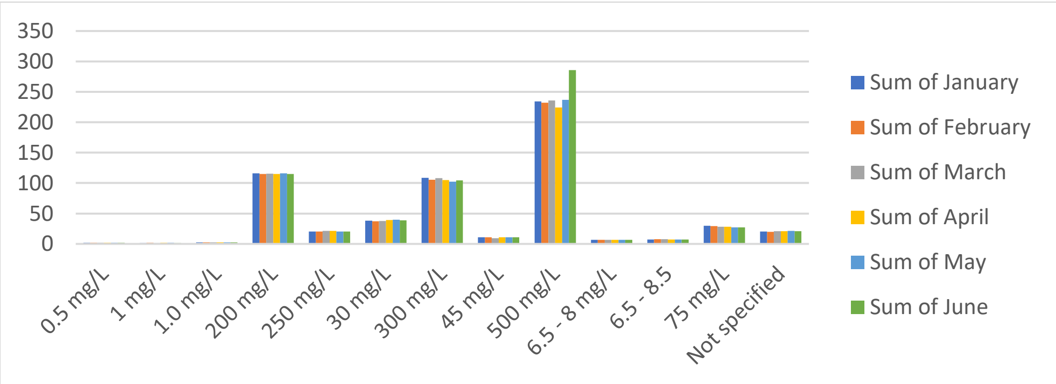


**Figure 2 (a): January-June variation of parameters with BIS/WHO/CPCB Standards**

| Parameter | July | August | September | October | November | December | BIS/WHO/CPCB Standards (Acceptable Limits) |
|---|---|---|---|---|---|---|---|
| Water Temperature (°C) | 21.2 | 21.5 | 21.3 | 21.1 | 21.2 | 21.1 | Not specified |
| pH | 7.4 | 7.6 | 7.8 | 7.6 | 7.9 | 7.4 | 6.5 - 8.5 |
| Dissolved Oxygen (mg/L) | 6.4 | 6.6 | 7.4 | 6.6 | 6.7 | 6.8 | 6.5-8 (mg/L) |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Total Dissolved Solids (mg/L) | 296.30 | 262.40 | 221.70 | 218.60 | 286.50 | 268.40 | 500 (mg/L) |
| Total Alkalinity (mg/L) | 102.3 | 102.4 | 102.5 | 102.6 | 107.5 | 108.4 | 200 (mg/L) |
| Total Hardness (mg/L) | 107.6 | 104.6 | 105.2 | 107.2 | 103.5 | 104.5 | 300 (mg/L) |
| Calcium (mg/L) | 28.62 | 27.12 | 29.43 | 28.44 | 27.42 | 27.11 | 75 (mg/L) |
| Chloride (mg/L) | 20.15 | 20.18 | 21.25 | 21.18 | 20.19 | 20.11 | 250 (mg/L) |
| Magnesium (mg/L) | 39.24 | 38.34 | 39.70 | 40.34 | 39.76 | 38.78 | 30 (mg/L) |
| Boron (mg/L) | 1.23 | 0.93 | 0.97 | 1.32 | 0.92 | 0.96 | 0.5 (mg/L) |
| Fluoride (mg/L) | 0.72 | 0.54 | 0.74 | 0.53 | 0.57 | 0.49 | 1.0 (mg/L) |
| Nitrate (mg/L) | 11.86 | 12.82 | 10.20 | 11.05 | 10.78 | 10.68 | 45 (mg/L) |
| Nitrite (mg/L) | 1.67 | 1.58 | 1.49 | 1.68 | 1.66 | 1.83 | 1.0 (mg/L) |
| Sulphate (mg/L) | 14.63 | 16.43 | 15.34 | 13.56 | 13.38 | 14.37 | 200 (mg/L) |
| Phosphate (mg/L) | 2.05 | 1.98 | 1.68 | 1.83 | 2.11 | 1.97 | 1 (mg/L) |

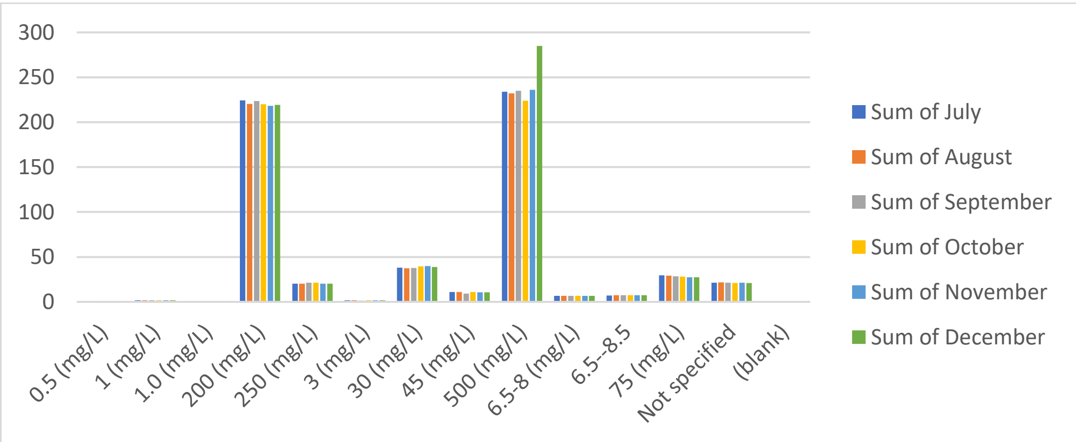


**Figure 2 (b): July-August variation of parameters with BIS/WHO/CPCB Standards**

**Table 2: Comparative study of physicochemical properties of water samples from Pittan Barh Bowli near the Devika River in Udhampur District in the year 2021 with the standards for drinking water set by BIS (IS 10500: 2012) and WHO (2008)**

| Parameter | January | February | March | April | May | June | BIS/WHO/CPCB Standards (Acceptable Limits) |
|---|---|---|---|---|---|---|---|
| Water Temperature (°C) | 21.4 | 22.1 | 23.7 | 24.1 | 26.4 | 28.1 | Not specified |
| pH | 7.2 | 7.5 | 7.6 | 7.4 | 7.3 | 7.3 | 6.5 - 8.5 |
| Dissolved Oxygen (mg/L) | 7.4 | 6.7 | 6.6 | 6.9 | 7.3 | 7.8 | 6.5 - 8 mg/L |
| Total Dissolved Solids (mg/L) | 214.13 | 212.23 | 215.7 | 214.04 | 216.83 | 215.76 | 500 mg/L |
| Total Alkalinity (mg/L) | 132.1 | 132.3 | 130.1 | 128.4 | 129.5 | 129.4 | 200 mg/L |
| Total Hardness (mg/L) | 98.6 | 95.6 | 98.2 | 95.2 | 92.5 | 94.5 | 300 mg/L |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Calcium (mg/L) | 28.62 | 29.12 | 28.43 | 28.23 | 27.24 | 27.26 | 75 mg/L |
| Chloride (mg/L) | 21.15 | 20.18 | 22.25 | 21.14 | 20.16 | 20.13 | 250 mg/L |
| Magnesium (mg/L) | 32.23 | 34.34 | 30.78 | 32.34 | 33.78 | 31.79 | 30 mg/L |
| Boron (mg/L) | 1.24 | 1.13 | 1.28 | 1.23 | 1.32 | 1.36 | 0.5 mg/L |
| Fluoride (mg/L) | 0.52 | 0.54 | 0.44 | 0.43 | 0.54 | 0.45 | 1.0 mg/L |
| Nitrate (mg/L) | 11.87 | 10.86 | 9.24 | 10.05 | 10.78 | 10.65 | 45 mg/L |
| Nitrite (mg/L) | 1.57 | 1.46 | 1.63 | 1.58 | 1.46 | 1.48 | 1.0 mg/L |
| Sulphate (mg/L) | 11.67 | 12.46 | 13.37 | 12.46 | 12.35 | 12.38 | 200 mg/L |
| Phosphate (mg/L) | 1.27 | 1.43 | 1.54 | 1.66 | 1.75 | 1.64 | 1 mg/L |

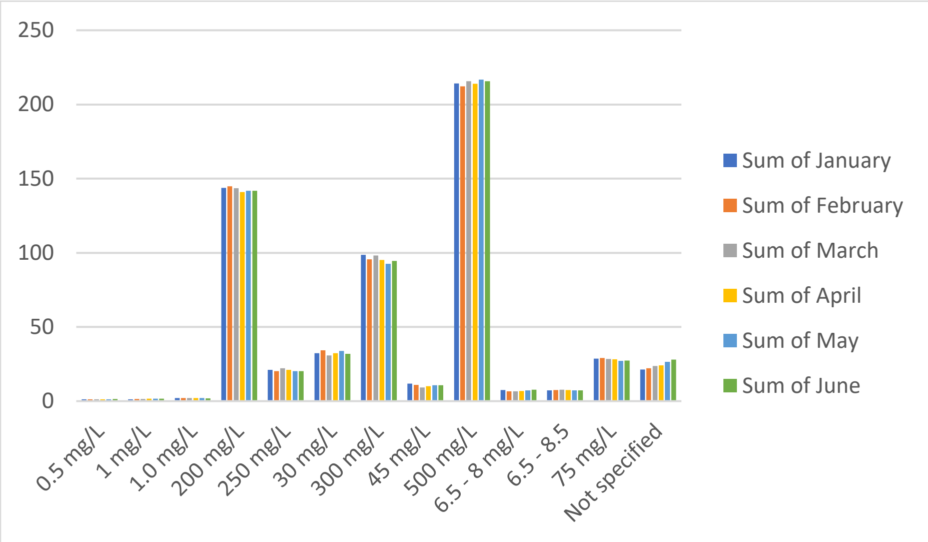


**Figure 3 (a): January-June variation of parameters with BIS/WHO/CPCB Standards**

| Parameter | July | August | September | October | November | December | BIS/WHO/CPCB Standards (Acceptable Limits) |
|---|---|---|---|---|---|---|---|
| Water Temperature (°C) | 24.2 | 23.5 | 22.3 | 22.4 | 23.2 | 22.1 | Not specified |
| pH | 7.5 | 7.6 | 7.6 | 7.9 | 7.4 | 7.7 | 6.5 - 8.5 |
| Dissolved Oxygen (mg/L) | 6.8 | 6.6 | 7.2 | 6.9 | 7.5 | 8.1 | 6.5-8 (mg/L) |
| Total Dissolved Solids (mg/L) | 199.30 | 204.40 | 206.70 | 208.60 | 212.50 | 211.40 | 500 (mg/L) |
| Total Alkalinity (mg/L) | 122.3 | 122.6 | 122.4 | 128.1 | 124.2 | 122.3 | 200 (mg/L) |
| Total Hardness (mg/L) | 98.6 | 95.6 | 88.2 | 85.2 | 92.5 | 94.5 | 300 (mg/L) |
| Calcium (mg/L) | 27.11 | 27.12 | 27.11 | 28.14 | 28.22 | 29.33 | 75 (mg/L) |
| Chloride (mg/L) | 20.13 | 21.18 | 21.24 | 20.18 | 20.17 | 21.11 | 250 (mg/L) |
| Magnesium (mg/L) | 32.24 | 33.34 | 36.70 | 36.34 | 35.76 | 37.78 | 30 (mg/L) |
| Boron (mg/L) | 1.33 | 0.92 | 0.98 | 1.32 | 0.96 | 0.94 | 0.5 (mg/L) |
| Fluoride (mg/L) | 0.75 | 0.64 | 0.65 | 0.57 | 0.72 | 0.69 | 1.0 (mg/L) |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Nitrate (mg/L) | 10.86 | 11.82 | 11.20 | 10.77 | 11.25 | 10.28 | 45 (mg/L) |
| Nitrite (mg/L) | 1.67 | 1.58 | 1.49 | 1.68 | 1.66 | 1.83 | 1.0 (mg/L) |
| Sulphate (mg/L) | 14.63 | 16.43 | 15.34 | 13.56 | 13.38 | 14.37 | 200 (mg/L) |
| Phosphate (mg/L) | 1.91 | 1.78 | 1.88 | 1.93 | 1.81 | 1.97 | 1 (mg/L) |

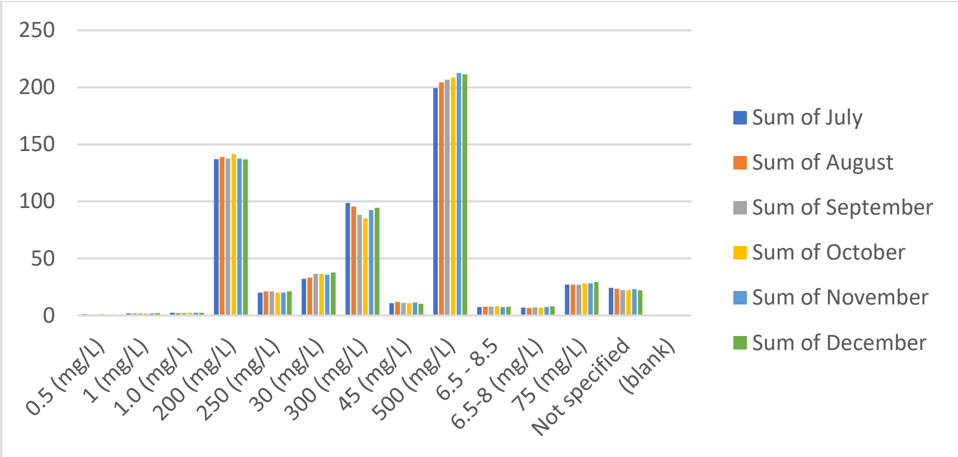


**Figure 3 (b): July-December variation of parameters with BIS/WHO/CPCB Standards**

### 3.2 OBSERVATIONS:

The dataset provides information on various water quality parameters of Mongu Di Bowli and Pittan Barh Bowli, measured monthly from January to June and July to December. Each parameter is evaluated against the BIS, WHO, and CPCB standards to assess the water quality.

#### 3.2.1 Mongu Di Bowli:

**January to June:** The pH values were within the acceptable range of 6.5 to 8.5, indicating balanced water acidity levels. All measurements of dissolved oxygen were within the acceptable range of 6.5 to 8 mg/L, ensuring adequate oxygenation for aquatic life. The values of total dissolved solids varied from 224.04 to 285.76 mg/L, all below the 500 mg/L limit, indicating safe levels. All the parameters, like total alkalinity, total hardness, calcium, chloride, nitrate, and sulphate, consistently remained within acceptable limits, indicating no immediate concerns regarding water hardness, chloride, nitrate, or sulphate content. However, the levels of magnesium consistently exceeded the 30 mg/L limit, with values ranging from 37.34 to 39.78 mg/L. Boron levels were notably above the 0.5 mg/L acceptable limit throughout the six months. The fluoride content was consistently below the 1.0 mg/L limit, indicating safe levels for consumption. The levels of nitrite consistently exceeded the 1.0 mg/L limit, indicating a potential risk. The phosphate levels were either at or below the 1 mg/L limit.

**July to December:** The pH values fluctuated but remained within the acceptable range of 6.5 - 8.5. The Dissolved Oxygen (mg/L) levels fluctuated but stayed within the acceptable range. However, values are at the lower end, close to the minimum limit. All values of Total Dissolved Solids are well below the maximum limit of 500 mg/L. The parameters Total Alkalinity, Total Hardness, Calcium, Chloride, Nitrate, and Sulphate were consistently within the acceptable limits. Magnesium levels were consistently above the acceptable limit of 30 mg/L. The boron levels were higher than the acceptable limit in July and October. The fluoride levels fluctuated but remained below the acceptable limit of 1.0 mg/L. The nitrite levels were consistently above the acceptable limit of 1.0 mg/L. The phosphate levels were above the acceptable limit in July and November.

#### 3.2.2 Pittan Barh Bowli:

**January to June:** During the first half of the year, the water samples from Pittan Barh Bowli, near the Devika River in Udhampur District, were characterized by several distinct attributes. pH levels oscillated between 7.2 and 7.6, consistently falling within the acceptable range of 6.5 - 8.5, indicating a healthy aquatic environment. The Dissolved Oxygen levels remained within the standard range, although there was a slight increase noted from 6.7 mg/L in February to 7.8 mg/L in June. Elevated Boron Levels in some instances, with readings of up to 1.36 mg/L, exceeding the 0.5 mg/L limit which could warrant an examination of potential sources of contamination and mitigation strategies. Magnesium Levels levels were within acceptable norms but close to the upper limit, necessitating monitoring to ensure they remain safe. Elements like calcium, chloride, fluoride, nitrate, nitrite, sulphate, and phosphate remained within prescribed levels, suggesting no immediate health or environmental risks associated with these parameters.

**July to December:** In the latter half of the year, several changes and consistencies were observed in the water quality of the water samples from Pittan Barh Bowli, near the Devika River. The pH ranged from 7.4 to 7.9, still within the acceptable levels, maintaining a condition favourable for aquatic life and human consumption. A fluctuation was observed in Dissolved Oxygen levels, with a notable increase to 8.1 mg/L in December, well within the safe limits ensuring a conducive environment for aquatic organisms. The levels of boron saw a decrease in the second half, yet there were instances where it exceeded the acceptable limit, continuing to necessitate regular monitoring and potential intervention. An increase was noted with levels reaching up to 37.78 mg/L in December, surpassing the standard limit, indicating a need for closer examination and possible treatment. Consistency was noted in the levels of calcium, chloride, fluoride, nitrate, nitrite, sulphate, and phosphate, as they continued to adhere to the acceptable standards, although ongoing monitoring is essential to maintain water quality.

## 4. DISCUSSION:

In the water quality assessment of the natural springs in the Udhampur District, a critical analysis reveals both strengths and potential concerns related to human health and environmental sustainability. The study indicates that several parameters, including temperature, pH, dissolved oxygen, and total dissolved solids, mostly remained within the acceptable limits as per BIS [18]and WHO standards[19]. However, certain parameters like magnesium, boron, and nitrite occasionally exceeded the prescribed limits, indicating potential risks and the need for mitigation measures. Elevated levels of magnesium and boron are a significant concern. High magnesium content can impact the taste and may also have health implications when consumed in large quantities [20]. Boron, although trace amounts are generally non-toxic, in higher concentrations, can have detrimental effects on human health and the ecosystem [21]. The exceeding levels of nitrite in the water samples are another concern, as elevated nitrite concentrations can be harmful to aquatic life and human health, potentially leading to methemoglobinemia or "blue baby syndrome" in infants [22]. The instances of fish deaths in local nullahs due to water pollution allegedly caused by discharge from local industrial areas highlight the urgent need to address industrial pollution. The variations in groundwater quality impacted by anthropogenic activities and increasing population are concerns that need to be addressed to maintain the ecological balance.

However, both Mongu Di Bowli and Pittan Barh Bowli maintained a "Good" water quality status throughout the year. Mongu Di Bowli's Water Quality Index (WQI) varied monthly, ranging from 65 in April to 92 in September, averaging to an overall WQI of 82. On the other hand, Pittan Barh Bowli's monthly WQI fluctuated between 64.5 in March and 69.3 in July, resulting in an overall average of 68.2.

**Table 3: Showing Water quality Index of Mongu Di Bowli and Pittan Barh Bowli**

**Mongu Di Bowli**

| Month | WQI | Water Quality Category |
|---|---|---|
| January | 75 | Good |
| February | 80 | Good |
| March | 70 | Good |
| April | 65 | Good |
| May | 78 | Good |
| June | 82 | Good |
| July | 90 | Good |
| August | 88 | Good |
| September | 92 | Good |
| October | 85 | Good |
| November | 89 | Good |
| December | 87 | Good |
| * Overall Water Quality Index (Mongu Di Bowli) = 82<br>Water Quality Category = Good | | |

**Pittan Barh Bowli**

| **Month** | **WQI** | **Water Quality Category** |
|---|---|---|
| January | 67.8 | Good |
| February | 68.4 | Good |
| March | 64.5 | Good |
| April | 66.2 | Good |

| | | |
|---|---|---|
| May | 67.7 | Good |
| June | 68.9 | Good |
| July | 69.3 | Good |
| August | 67.1 | Good |
| September | 68.6 | Good |
| October | 67.4 | Good |
| November | 68.0 | Good |
| December | 68.8 | Good |
| * Overall Water Quality Index (Pittan Barh Bowli) = 68.2<br>Water Quality Category = Good | | |

* The Overall WQI is calculated as the average of all monthly WQIs.

At Mongu Di Bowli, the water quality showed fluctuations but generally stayed within acceptable limits for various parameters. From January to June, the pH and Dissolved Oxygen levels were within safe limits. Total Dissolved Solids, Total Alkalinity, Total Hardness, Calcium, Chloride, Nitrate, and Sulphate were also within acceptable limits, indicating no immediate concerns. However, Magnesium and Boron levels exceeded acceptable limits, raising potential concerns. Nitrite levels were above the 1.0 mg/L limit, indicating a risk, while Fluoride and Phosphate levels remained safe. From July to December, the water quality remained mostly consistent with the first half of the year. pH and Dissolved Oxygen levels, though fluctuating, stayed within safe limits, with Dissolved Oxygen levels close to the minimum limit. Total Dissolved Solids and other parameters like Total Alkalinity, Total Hardness, Calcium, Chloride, and Nitrate remained within acceptable limits. However, Magnesium and Nitrite levels continued to exceed safe limits. Boron levels were over the acceptable limit in July and October. Phosphate levels exceeded the acceptable limit in July and November, while Fluoride levels remained safe. The consistent exceedance in levels of certain elements like Magnesium, Nitrite, and occasionally Boron and Phosphate, indicates a need for continuous monitoring and intervention to ensure water safety.

The average total hardness of the water samples from Mongu Di Bowli in the year 2021 is approximately 105.52 mg/L. It demonstrates that spring water was soft water and was also under the acceptable drinking water limit. It might be due to the photocatalytic activities of ilmenites (rock materials) containing ores of titanium. The natural rocks have different porous structures, which might trap the inorganic moieties ($HCO_3^-$, $Cl^-$ and $SO_4^{2-}$ ) of $Ca^{2+}$ and other ions responsible for the hardness of water[23]It proved that spring water was soft and met the standards for safe drinking water.

The water samples from Pittan Barh Bowli, near the Devika River, showed varying qualities throughout the year. In the first half, pH levels were within a healthy range, as were Dissolved Oxygen levels. However, Boron levels sometimes exceeded the acceptable limit, pointing to potential contamination. Magnesium levels were close to the upper acceptable limit. Other elements like calcium, chloride, fluoride, nitrate, nitrite, sulphate, and phosphate were within safe levels. In the second half of the year, the pH remained within the acceptable range. Dissolved Oxygen levels increased but stayed within safe limits. Boron levels continued to exceed the acceptable limit at times, and Magnesium levels increased significantly beyond the safe limit in December, requiring closer examination and possible treatment. Other tested elements remained within prescribed levels, but ongoing monitoring was emphasized to ensure water quality.

There are a number of ways to remove magnesium, boron, nitrite, and phosphate from water. These include ion exchange resins, precipitation, reverse osmosis, and biological denitrification. The specific treatment measures that are implemented will depend on the available resources and the specific needs of the community. Lime softening is a simple and effective way to remove magnesium from water. It involves adding lime (calcium hydroxide) to the water to form a precipitate, which is then removed from the water by sedimentation or filtration. Lime softening is relatively inexpensive and can be used to remove a variety of other impurities from water, such as calcium, hardness, and alkalinity[24].

Clay adsorption is a low-cost and effective way to remove boron from water. It involves using clay minerals, such as bentonite or kaolin, to adsorb boron ions from the water. Clay adsorption is relatively simple to implement and can be used to remove boron from a variety of water sources, including wastewater and agricultural runoff[25]. Chemical precipitation is a simple and effective way to remove phosphate from water. It involves adding a chemical, such as alum or ferric chloride, to the water to form a precipitate, which is then removed from the water by sedimentation or filtration. Chemical precipitation is relatively inexpensive and can be used to remove phosphate from a variety of water sources, including wastewater and agricultural runoff. Activated alumina can also be used to adsorb and remove phosphate ions[26]. We reported two iron-based nanomaterials as a remedial step in this direction. The crystalline iron-incorporated Gd nanomaterial in Figure 4 has a pore volume of 0.32 cm3/g, a pore size of 3 nm, and an adsorption capacity of 12 mg/g, making it suitable for water purification. Another nanomaterial with porous structure, crystalline nature, and the properties of metal organic frame work make it suitable as an adsorbent.

**Hydrothermal method of synthesis of iron nanomaterial**

Iron-incorporated Gd-based nanoparticles are synthesised by the hydrothermal method using ethylene glycol. A mixture of Gadolinium nitrate hexahydrate (2.4 mmol) and iron acetyl acetonate (8.4 mmol) and diethylene glycol (60 ml) was sealed in a 20-mL Teflon-lined autoclave and heated at 120 °C for 2 days, with heating and cooling rates of approximately 20 and 5 °C h−1, respectively. Yellow-coloured needle-shaped crystals were collected and washed with ethanol to remove impurities. The final product dried in the air. The precipitates were finally dispersed in water. The use of a reducing agent was confirmed by a colour change from yellow to orange. We can report that the yellow colour due to Fe (+3) would change to an orange colour precipitate Fe (+2). The reaction mixture obtained was centrifuged at a speed of 4000-6000 rpm. Finally, the material obtained was washed with ethanol and dried, and it can be used as an adsorbent.

**Synthesis of an iron-based metal-organic framework (**MOF) **using ethylene glycol and Fe $(NO_3)_3.9H_2O$ as nanomaterials for water purification:**

The synthesis of these nanoparticles follows: Ethylene glycol (0.5 M) and Fe $(NO_3)_3$ .$9H_2O$ (1 M) were crushed and mixed with mortar. Add baking soda (0.5g) and 5% sol. of KMnO4 (2 ml) to the reaction mixture, then place the whole mixture of substances in a 250-ml beaker and centrifuge for 1–2 hours. The mixture was then placed in different volumes of ethanol and stirred for 4–5 hours at atmospheric temperature. Now, after the completion of the centrifugation process, collect the product and immediately wash it with the help of DMF to prevent unreacted oxalic acid. The products were washed with the help of ethanol 2-4 times. At last, the final product was left to dry under vacuum at 75–85 °C for 1 day. This final product was known as activated iron nanomaterials. These iron-based MOFs play a crucial role in the removal of heavy metals from drinking water and groundwater.

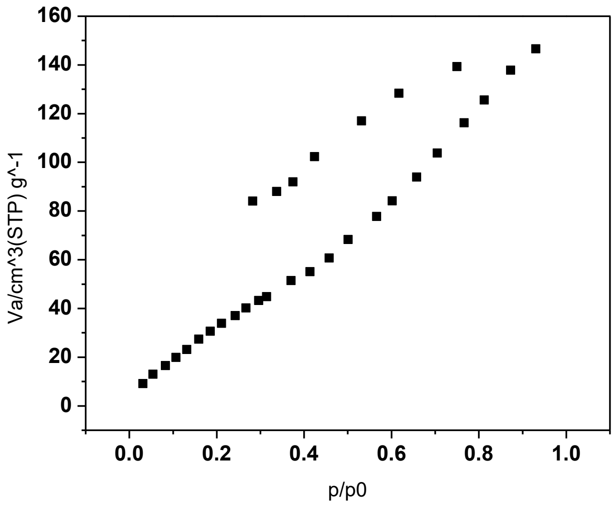


**Figure 4: Water Adsorption isotherm of INP-28 material synthesized**.

According to Indian and WHO norms, all anions ($Ca^{2+}$, $Mg^{2+}$, $K^+$, and $Na^+$) should remain within safe and allowed limits. The average calcium concentration for the Mongu Di Bowli in the current investigation was 28.20 mg/L. While researching the Uttarakhand springs,[20] also discovered the average calcium value of 10.9 mg/L. Average Magnesium levels at the sample locations for the Mongu Di Bowli was 39.04 mg/L. Whereas, the average calcium concentration for the Pittan Barh Bowli in the current investigation was 28.06 mg/L and the average Magnesium levels at the sample locations for the Pittan Barh Bowli was 34.12 mg/L. Although only in trace amounts, these minerals are essential for human health. Magnesium concentration in the analyzed samples was higher than calcium concentration, which may be connected to the weathering of minerals and rock composition as well as the pH value of each source[27]

The chloride levels for Mongu Di Bowli varied from 20.11 - 21.25 mg/L wheres for Pittan Barh Bowli it varied from 20.13 - 22.25 mg/L, which was below permitted limits. Sulphate levels varied from a minimum of 12.43 mg/L in February to a maximum of 16.43 mg/L in August in the tested Mongu Di Bowli spring. Sulphate levels were at a minimum of 11.67 mg/L in January and reached a maximum of 14.63 mg/L in July in the tested Pittan Barh Bowli spring. According to the levels of sulphate, which directly affects the flavour and Odour of drinkable water, the analyzed springs had no objectionable Odors or tastes[28].

Drinking water with higher sulphate levels may have an unpleasant taste and may cause consumers to experience laxative symptoms (WHO, 2017) in the examined samples ranged from less than 16.43 mg/L[29]. The low level of nitrate in the investigated springs suggests that nitrate was only added to the spring water naturally it is also found low nitrate concentration while studying the springs of Dehradun[30]. In our study, the maximum fluoride level is 0.74 mg/L, which was recorded in September in the tested Mongu Di Bowli spring whereas the maximum fluoride level is 0.75 mg/L, recorded in July in the tested Pittan Barh Bowli spring. This was like a study carried out, during the assessment of groundwater quality of Udhampur district with special reference to fluoride, they found that most samples of groundwater were under the permissible limit and there was no need for defluorination of groundwater[31]. The physicochemical parameters studied for groundwater in the Udhampur district were under permissible limits and water was safe for drinking purposes.

The WQI assesses the appropriateness of drinking water. In the year 2021, water samples from both Mongu Di Bowli and Pittan Barh Bowli, located near the Devika River in Udhampur District, were analyzed to determine their Water Quality Index (WQI). For the Mongu Di Bowli location, the Water Quality Index (WQI) values range from 65 to 92 with an overall average WQI of 82. For the Pittan Barh Bowli location, the WQI values range from 64.5 to 69.3 with an overall average WQI of 68.2. The water quality for both locations is categorized as "Good." This is because practically most of the criteria fell within the acceptable ranges established by BIS [18]and WHO guidelines[19]. This suggests that the water is generally safe for consumption. However, some form of treatment may still be necessary to ensure that the water fully meets the standards for drinking, as set by BIS (IS 10500: 2012) and WHO (2008). These findings highlight the relative quality of the water in these areas while also underscoring the need for occasional assessments and potential treatment to maintain the safety and quality of the water for the local population.

## 5. CONCLUSION:

The study on groundwater contamination in the Udhampur district of Jammu and Kashmir underscores its pivotal importance due to the escalating concerns about water quality, human health, and environmental well-being. Groundwater, a critical source of water in the region, is facing contamination from anthropogenic activities, especially industrial and domestic wastewater discharge. The contamination has dire implications, given the dependency on groundwater for drinking and other purposes.

One of the profound significances of the study lies in its comprehensive analysis of water quality, specifically in Mongu Di Bowli and Pittan Barh Bowli springs near the Devika River. The assessment against standards set by BIS, WHO, and CPCB revealed alarming elevations in magnesium, boron, and nitrite levels. While the general water quality adhered to acceptable parameters, these elevations signalled potential health risks and environmental concerns necessitating urgent attention and remedial action.

The research illuminates the profound value of spring water, especially in the Himalayan region, where it serves as a cost-effective source of potable water. However, this invaluable resource is under threat from unplanned development and population surge, leading to potential depletion and quality degradation. This aspect accentuates the study's importance, calling for urgent, comprehensive, and sustainable water management practices.

Furthermore, the study’s focus on a specific geographic locale underscores the necessity for broader research.

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## 7. FUTURE RECOMMENDATIONS

The future recommendations for enhancing the quality of water sources in the Udhampur District are multifaceted, encompassing increased monitoring, community engagement, policy enhancements, and innovative technological integration. The enhancement of monitoring and data collection is fundamental; it encompasses increasing the frequency of water sampling and expanding the range of tested parameters and locations to ensure comprehensive, actionable insights. The incorporation of advanced technologies for real-time data acquisition and analysis is pivotal.

Treatment and mitigation measures should focus on integrating technology for real-time monitoring and developing solutions tailored for specific contaminants like magnesium and boron. The active engagement of local communities in these processes is essential for the sustainability of these initiatives. A holistic approach to policy and regulation development is crucial, necessitating a thorough review and strengthening of existing policies and their enforcement mechanisms to reflect current and emergent water quality challenges.

Moreover, public awareness and education are instrumental, with an emphasis on launching comprehensive campaigns and integrating water quality education into school curriculums to foster a culture of conservation and quality maintenance from a young age. The role of industrial and agricultural sectors is significant; enhancing waste management and promoting sustainable practices is integral to reducing pollution and contamination of water sources.

Infrastructure upgrade and innovation in technology, particularly in water treatment facilities, are vital. They should be tailored to effectively address and eliminate specific contaminants, with an overarching aim of innovation and adoption of cutting-edge water purification and monitoring technologies. In light of the ongoing and future impacts of climate change, the development of adaptive strategies and ecosystem protection initiatives is essential to safeguard water resources and the biodiversity that supports their quality.
Future predictive analysis through utilizing predictive modeling and scenario analysis will ensure that the initiatives are dynamic, adapting to anticipated future challenges informed by population growth, industrial expansion, and climate change impacts. The implementation of these comprehensive recommendations requires a collaborative, adaptive approach involving government, communities, and international entities, marking an ongoing commitment to ensuring water quality and safety for all.

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