



# **Hydrogeochemical and Physicochemical Evaluation of Thermal Waters of Rajgir Kunds, Bihar, India**

**Amrendra Kumar, Dr. S.P. Singh**

Department of Chemistry, Patliputra University, Patna, Bihar, India

Department of Chemistry, A.N. College, Patliputra University, Patna, Bihar, India

**ABSTRACT:** Rajgir Kunds, situated in Nalanda district of Bihar, represent one of the most prominent geothermal spring systems in eastern India. These thermal springs are geologically associated with tectonic fractures and fault-controlled geothermal activity in the Rajgir hill ranges. The present study focuses on the physicochemical characterization of hot spring waters of Rajgir Kunds with special emphasis on temperature, pH, electrical conductivity, total dissolved solids, alkalinity, hardness, chloride, sulphate, calcium, magnesium, sodium, potassium, dissolved oxygen, and silica concentration. Water samples from major kunds such as Brahmakund, Suryakund and Saptadhara were analyzed using standard analytical methods. The findings reveal that the spring waters are neutral to slightly alkaline in nature with moderate mineralization and elevated temperature ranging between 42°C and 64°C. The hydrochemical facies indicate dominance of bicarbonate and alkaline earth metals. The study highlights the geological significance, therapeutic value, and environmental concerns associated with the Rajgir geothermal system. Continuous monitoring and sustainable conservation strategies are essential for preserving the ecological and cultural importance of these thermal waters.

**KEYWORDS:** Rajgir Kunds, geothermal springs, hydrogeochemistry, thermal water, physicochemical parameters, Bihar.

## **I. INTRODUCTION**

Hot springs are naturally occurring geothermal discharges in which groundwater emerges at elevated temperatures due to subsurface heating processes. These springs are commonly associated with tectonic faults, volcanic regions, and geothermal gradients. India possesses several thermal spring systems distributed across the Himalayan region, central India, and eastern India. Among these, the Rajgir hot springs of Bihar are scientifically important because of their geological setting and therapeutic significance.

Rajgir, an ancient historical town in Nalanda district, is surrounded by quartzitic hill ranges belonging to Precambrian rock formations. The thermal springs emerge through fractures and joints developed within these rocks. Rajgir Kunds are culturally and religiously important and attract thousands of pilgrims and tourists every year. The water is traditionally believed to cure skin disorders, arthritis, and rheumatic diseases.

Physicochemical studies of thermal waters provide valuable information regarding hydrogeochemical evolution, rock-water interaction, geothermal reservoir characteristics, and environmental quality. The present study attempts to evaluate the physicochemical nature of Rajgir thermal springs and assess their suitability for human use.

## **II. OBJECTIVES**

The major objectives of the study are:

1. To determine the physicochemical properties of Rajgir hot spring water.
2. To analyze hydrochemical characteristics and mineral composition.
3. To evaluate the suitability of thermal water for bathing and domestic purposes.
4. To understand the geological controls responsible for thermal activity.
5. To examine environmental concerns affecting Rajgir Kunds.





#### IV. MATERIALS AND METHODS

Water samples from different kunds were collected in sterilized polyethylene bottles during field investigation. Standard procedures recommended by APHA (American Public Health Association) were followed for physicochemical analysis.

##### Parameters Studied

The following parameters were analyzed:

- Temperature
- pH
- Electrical Conductivity (EC)
- Total Dissolved Solids (TDS)
- Total Hardness
- Total Alkalinity
- Chloride
- Sulphate
- Calcium
- Magnesium
- Sodium
- Potassium
- Dissolved Oxygen (DO)

##### Instruments and Techniques

Parameter	Method Used
pH	Digital pH meter
EC	Conductivity meter
TDS	Gravimetric method
Calcium & Magnesium	EDTA titration
Chloride	Argentometric titration
Sulphate	Spectrophotometric method
Sodium & Potassium	Flame photometry

## V. RESULTS AND DISCUSSION

Table 1: Physicochemical Characteristics of Rajgir Hot Spring Water

Parameters	Brahmakund	Suryakund	Saptadhara	WHO Permissible Limit
Temperature (°C)	64	58	42	—
pH	7.8	7.4	7.1	6.5–8.5
Electrical Conductivity (µS/cm)	420	390	310	1500
TDS (mg/L)	265	240	190	500
Total Hardness (mg/L)	138	124	110	300
Total Alkalinity (mg/L)	156	149	132	200
Calcium (mg/L)	42	39	34	75
Magnesium (mg/L)	21	19	16	30
Sodium (mg/L)	28	24	20	200
Potassium (mg/L)	8	7	6	—
Chloride (mg/L)	36	32	28	250
Sulphate (mg/L)	48	44	39	200
Dissolved Oxygen (mg/L)	4.1	4.5	5.0	5–6

## VI. INTERPRETATION OF RESULTS

### 6.1 Temperature Variation

The thermal waters exhibited high temperatures ranging from 42°C to 64°C. Brahmakund recorded the highest temperature, indicating proximity to deeper geothermal circulation zones. Elevated temperature enhances dissolution of minerals and influences hydrochemical reactions.

### 6.2 pH Characteristics

The pH values ranged from 7.1 to 7.8, indicating neutral to slightly alkaline nature of the water. Such pH conditions are common in geothermal systems dominated by silicate rock interaction.

### 6.3 Electrical Conductivity and TDS

Moderate electrical conductivity and TDS values indicate low to moderate mineralization. The dissolved solids are primarily contributed by bicarbonates, chlorides, sulphates, and alkali metals derived from rock-water interaction.

### 6.4 Hardness and Alkalinity

The thermal waters showed moderate hardness due to calcium and magnesium ions. Alkalinity values indicate the presence of bicarbonate ions formed during weathering of silicate minerals.

### 6.5 Major Ion Chemistry

#### Calcium and Magnesium

These ions originate mainly from mineral dissolution processes in quartzitic and phyllitic rocks.

#### Sodium and Potassium

The presence of sodium and potassium suggests prolonged interaction between groundwater and silicate minerals.

#### Sulphate and Chloride

Moderate sulphate concentration may be associated with geothermal sulphur-bearing compounds. Chloride concentration remained within safe limits.

### 6.6 Dissolved Oxygen

DO values were comparatively low because oxygen solubility decreases with increasing temperature. However, the observed values indicate limited organic pollution.

## VII. HYDROGEOCHEMICAL NATURE OF RAJGIR THERMAL WATER

Hydrochemical analysis indicates that Rajgir thermal waters belong mainly to the Ca–Mg–HCO<sub>3</sub> type. The chemistry is controlled by:

- Silicate weathering
- Geothermal heating
- Fracture-controlled groundwater circulation
- Ion exchange processes

Meteoric water infiltrates through fractures and joints, gets heated at depth due to geothermal gradient, and rises to the surface through tectonic conduits.

## VIII. THERAPEUTIC IMPORTANCE

Rajgir hot springs have been used for therapeutic bathing since ancient times. Local populations believe that thermal bathing helps in relieving:

- Rheumatism
- Arthritis
- Skin diseases
- Muscular pain

The therapeutic effects are mainly attributed to elevated temperature and dissolved mineral content.

## IX. ENVIRONMENTAL ISSUES

The increasing number of visitors and unplanned tourism activities have affected the environmental quality of Rajgir Kunds. Major concerns include:

- Waste accumulation around kunds
- Soap and detergent contamination
- Overcrowding
- Decline in natural discharge pathways

Proper conservation and scientific management are necessary for sustainable utilization of the geothermal resource.

## X. CONCLUSION

The physicochemical investigation of Rajgir hot spring water reveals that the thermal waters are neutral to slightly alkaline with moderate mineralization and elevated temperatures. The hydrogeochemical characteristics indicate dominance of calcium, magnesium, and bicarbonate ions derived from rock-water interaction within geothermal environments.

Most physicochemical parameters fall within permissible limits for domestic and bathing purposes. The thermal waters possess geological, medicinal, cultural, and tourism importance. However, increasing anthropogenic pressure necessitates regular water quality monitoring and implementation of conservation strategies to protect the Rajgir geothermal ecosystem.

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