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Physicochemical, Radiological and Biological Assessment of Hot Spring Water in Gaya District, Bihar, India

Amrendra Kumar¹, Dr. S.P. Singh²

Department of Chemistry, Patliputra University, Patna, India¹

Department of Chemistry, A.N. College, Patliputra University, Patna, India²

ABSTRACT: Hot springs are important geothermal resources that possess therapeutic, ecological, and socio-economic significance. The present study evaluates the physicochemical, radiological, and biological characteristics of hot spring water collected from selected geothermal sites in Gaya district, Bihar, India. Water samples were analysed for temperature, pH, electrical conductivity (EC), total dissolved solids (TDS), alkalinity, hardness, dissolved oxygen (DO), chloride, sulphate, nitrate, fluoride, and trace metals using standard APHA methods. Radiological analysis included measurements of gross alpha and gross beta activities, while biological assessment involved total coliform and bacterial load determination. The observed temperature ranged from 35–45.5°C, indicating geothermal influence. The pH values showed slightly acidic nature. Elevated sulphate and TDS concentrations suggest significant mineral dissolution from surrounding rocks. Gross alpha and beta activities remained within WHO permissible limits. Biological analysis indicated low microbial abundance due to elevated temperatures, although occasional coliform contamination was observed near bathing zones. The study concludes that the hot spring waters are moderately mineralized and generally suitable for therapeutic applications, but treatment is recommended before potable use. The findings provide baseline scientific data useful for environmental monitoring and sustainable utilization of geothermal resources in Bihar.

KEYWORDS: Hot springs, physicochemical analysis, radiological assessment, microbial analysis, geothermal water, Gaya Bihar.

I. INTRODUCTION

Hot springs are naturally occurring geothermal discharges characterized by elevated temperature and dissolved mineral content. Such geothermal systems are often associated with tectonic activities and deep groundwater circulation. India possesses numerous geothermal provinces distributed mainly along tectonic belts, including Bihar, Jharkhand, Himachal Pradesh, Uttarakhand, and Jammu & Kashmir.

The hot springs located in the Gaya region of Bihar are traditionally used for religious bathing and therapeutic purposes. Despite their socio-cultural importance, systematic scientific investigations concerning physicochemical, radiological, and biological quality remain limited. Earlier studies from Bihar mainly focused on groundwater quality and pond ecosystems rather than geothermal systems.

Thermal waters may contain elevated concentrations of dissolved minerals, radionuclides, and microbial communities influenced by subsurface geological interactions. Long-term consumption of untreated geothermal water may lead to health risks due to excessive fluoride, sulphate, or radionuclide concentrations. Therefore, integrated assessment of physicochemical, radiological, and microbiological parameters is essential.

The present study aims to:

1. Assess the physicochemical characteristics of hot spring waters in Gaya district.
2. Determine radiological activity levels in the water.
3. Evaluate biological contamination and microbial status.
4. Compare observed values with WHO and BIS drinking water standards.



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II. STUDY AREA

The study was conducted in selected hot spring zones situated near Gaya district, Bihar, India. The region lies within the Indo-Gangetic geological setting characterized by fractured rocks and geothermal manifestations. The springs are frequented by pilgrims and local residents throughout the year.

The climate of Gaya is tropical with high summer temperatures and moderate rainfall. Geological formations in the region consist mainly of granite, gneiss, quartzite, and metamorphic rocks which contribute dissolved minerals into groundwater systems.



III. MATERIALS AND METHODS

3.1 Sample Collection

Water samples were collected from four major hot spring outlets during pre-monsoon season using sterilized polypropylene bottles. Samples for microbiological analysis were preserved separately under refrigerated conditions.



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Sampling Sites

Sites	Name
T ₁	Sanak Kund
T ₂	Sanandan Kund
T ₃	Sanat Kund
T ₄	Kumar Kund

3.2 Physicochemical Analysis

The following parameters were measured according to APHA standard procedures:

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

3.3 Radiological Analysis

Gross alpha and gross beta activities were measured using low background radiation counting techniques. Results were expressed in Bq/L.

3.4 Biological Analysis

Microbial examination included:

- Total Plate Count (TPC)
- Total Coliform Count
- Presence of thermophilic bacteria

Standard membrane filtration and nutrient agar techniques were used.

IV. RESULTS AND DISCUSSION

4.1 Physicochemical Characteristics

Table 1. Physicochemical Parameters of Hot Spring Water

Parameter	T ₁	T ₂	T ₃	T ₄
Temperature (°C)	45.5	35	35	45.5
pH	6.04	6.8	6.8	6.06
EC (µS/cm)	66.8	58.5	79.5	81.8
TDS (mg/L)	70	60	60	70



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Total Hardness (mg/L)	80	64	82	80
Alkalinity (mg/L)	130	130	130	122
DO (mg/L)	3.8	4.2	4.6	3.8
Chloride (mg/L)	20	27	21	22
Sulphate (mg/L)	178	162	150	175
Nitrate (mg/L)	4.1	5.3	6.0	4.5
Fluoride (mg/L)	1.2	1.0	0.9	1.1
Iron (mg/L)	0.21	0.18	0.14	0.22
Sodium ion (mg/L)	6.76	5.98	6.23	6.99
Potassium ion (mg/L)	2.26	1.21	2.04	2.50

The elevated temperature confirms geothermal origin of the waters. Slight alkalinity is attributed to dissolution of carbonate-bearing minerals. Similar hydrogeochemical trends have been observed in Indian geothermal systems and groundwater studies from Bihar.

Higher TDS and EC values indicate moderate mineralization caused by prolonged rock-water interaction. Sulphate enrichment may originate from sulphur-bearing geological formations.

Low dissolved oxygen concentrations are typical in thermal waters because oxygen solubility decreases with increasing temperature.

4.2 Radiological Characteristics

Table 2. Radiological Parameters

Parameter	T ₁	T ₂	T ₃	T ₄	WHO Limit
Gross Alpha (Bq/L)	0.18	0.15	0.12	0.19	0.5
Gross Beta (Bq/L)	0.42	0.38	0.34	0.40	1.0

The measured radioactivity levels remained below WHO permissible limits, indicating negligible radiological risk for external exposure and short-term bathing activities.

Natural radionuclides in geothermal waters are generally associated with uranium and thorium decay products dissolved from basement rocks.

4.3 Biological Characteristics

Table 3. Biological Parameters

Parameter	T ₁	T ₂	T ₃	T ₄
Total Plate Count (CFU/mL)	42	88	96	41
Total Coliform (MPN/100 mL)	Nil	6	11	Nil
Thermophilic Bacteria	Present	Present	Moderate	Present



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Microbial abundance was relatively low because elevated temperature restricts growth of many pathogenic organisms. However, increased coliform count near bathing zones suggests anthropogenic contamination from tourist activities. Previous studies on Indian hot springs also reported thermophilic microbial diversity adapted to high-temperature environments.

V. ENVIRONMENTAL AND HEALTH IMPLICATIONS

The study indicates that geothermal waters in Gaya are moderately mineralized and generally safe for external therapeutic use. However:

- Elevated sulphate may produce laxative effects upon prolonged consumption.
- Low DO and moderate microbial contamination reduce potable suitability.
- Radiological parameters remain within acceptable limits.

Proper sanitation around bathing zones is necessary to minimize microbial contamination.

VI. CONCLUSION

The present investigation provides a comprehensive assessment of physicochemical, radiological, and biological properties of hot spring waters in Gaya district, Bihar. The thermal waters exhibited slightly alkaline pH, moderate mineralization, low dissolved oxygen, and safe radiological characteristics. Biological contamination was minimal at source points but increased in public bathing areas.

Overall, the hot spring waters are suitable for recreational and therapeutic purposes after regular monitoring. However, disinfection and treatment are recommended before drinking use. Future studies should include seasonal variation, heavy metal assessment, and molecular characterization of thermophilic microorganisms.

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