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ALGAE AS BIOINDICATORS AND HYPERACCUMULATOR OF HEAVY METALS IN FRESHWATER SPRINGS

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Abstract

This study investigates the water quality of freshwater springs in villages surrounding Srinagar, Uttarakhand, with a focus on assessing algal diversity and their role as bioindicators of organic pollution. As these natural springs serve as vital water sources in hilly regions where conventional water supply systems are often unavailable, understanding their quality is crucial for public health and environmental sustainability. The research evaluates seven physicochemical parameters: pH, dissolved oxygen, carbon dioxide, alkalinity, hardness, nitrate, and chloride. While most parameters adhered to WHO and BIS standards, hardness exceeded the desirable limit at Gorsali spring. Algal diversity was analyzed, revealing high species diversity and highlighting *Phormidium* as a common genus across all sites. The Palmer index indicated significant organic pollution at Kothar Spring, necessitating targeted remediation efforts. The study also examined the accumulation of heavy metals, including aluminum, barium, copper, magnesium, manganese, nickel, lead, uranium, and zinc, in water and algal samples. Notably, barium exceeded permissible limits at Kamleshwar Spring, and uranium surpassed limits at Gorsali spring. Algae demonstrated a pronounced ability to absorb heavy metals, with concentrations of aluminium and lead in algae being up to 1,000 times higher than in water. These findings underscore the importance of algae in natural water purification processes and highlight potential health risks associated with metal accumulation. The study emphasizes the need for continued monitoring and implementation of effective strategies to protect these crucial water resources, particularly through improved sanitation practices and pollution control measures.

Keyword: Water Quality, Himalayas, Uttarakhand, Water Pollution, Drinking Water

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Introduction

Water is essential for the survival of all living organisms, yet only a small fraction of the Earth's water—2.7%—is freshwater, and much of even this is not easily accessible. As the global population grows, the scarcity of freshwater resources becomes more acute, with the world's population consuming about 4 trillion metric cubeswater annually (Worldometer). In India, the annual water consumption is approximately 581 trillion litres, with 89% used for agriculture (Dhawan, 2017). Rapid urbanization and population growth have intensified the demand for water, often exceeding the available supply. This has resulted in significant challenges, particularly in rural areas where clean water access is limited. In many Indian states, especially in regions like Uttarakhand, water supply systems are often not available in hilly areas, forcing people to rely on natural water sources like springs. Even when water supply systems are available, many people prefer spring water for drinking, believing it to be purer. Thus, assessing the quality of these water sources is crucial.

Algae are a vital component of every aquatic ecosystem, serving as primary producers and bioindicators of water quality. They respond rapidly to changes in the physio-chemical properties of water, making them highly sensitive to environmental shifts (Gökçe, 2016). Algae are particularly important for their ability to purify water by removing pollutants such as heavy metals (Alp et al., 2012), which can be present in spring water due to the unique geography and terrain of the Himalayan region. Their capacity to absorb high concentrations of heavy metals makes algae crucial for maintaining water quality in natural environments. This study aims to evaluate the water quality of freshwater springs in villages around Srinagar, Uttarakhand, by assessing algal diversity and examining their role as bioindicators of organic pollution. Additionally, the research investigates the capacity of algae to accumulate heavy metals, highlighting their importance in natural water purification processes. Through this study, we aim to better understand how algal communities contribute to maintaining the health of aquatic ecosystems.

Materials and Methods

Study Area

Srinagar is a town located at an elevation of 1,840 feet along the banks of the Alaknanda River in the Pauri district of Uttarakhand, India. Positioned at latitude of 30.22°N and a longitude of 78.78°E, the town had a population of 20,115 according to the 2011 census. Srinagar experiences hot summers with temperatures rising up to 45°C and cold winters with lows reaching 2°C. The surrounding vegetation is primarily mixed deciduous forest. For this study, five freshwater springs were selected for sampling based on the local population's reliance on these water sources. Three of these springs are located near the highway and town, while two are situated in nearby villages within a 5-kilometer radius of Srinagar (Table 1).

Methodology

Water and algae samples were collected from five sampling sites (Figure 1). Water samples were obtained in sterilized, clean high-density polyethylene bottles. The physio-chemical parameters of the spring water, including pH, dissolved oxygen, carbon dioxide, alkalinity, hardness, nitrate, and chloride, were measured using standard protocols outlined by the American Public Health Association (APHA) and were subsequently compared with the guidelines set by the Bureau of Indian Standards (BIS) and the World Health Organization (WHO) for potable water. Algal samples were washed with distilled water and preserved in formalin. Identification was conducted under a research microscope, and the level of organic pollution was assessed using Palmer's Algal Genus Index. Half of the algal samples from each site were air-dried at 90°C in separate Petri dishes. To analyse heavy metal content, 500 mg of dried algae from each sample was digested with 25 ml of Analar grade nitric acid in a digestion tube until the solution evaporated to dryness. After cooling, 20 ml of Millipore water was added to each tube, and the content was filtered using 0.45 µm filters. The digested algal samples, along with water samples, were analysed for heavy metal concentrations using mass spectrometry at the University Science Instrumentation Centre

(USIC) at Hemvati Nandan Bahuguna Garhwal University (HNBGU) in Srinagar, Garhwal, Uttarakhand.

Table-1. Description of Sampling Sites

S. No.	Sampling Sites	Site Code	Coordinates	Description
1	SSB Spring	SN1	30°13’19” N 78°46’18” E	The location is a residential area with about 150 households, situated just 100 meters from the national highway.
2	Kamleshwar Spring	SN2	30°13’19” N 78°46’43” E	Located just 20 meters from the national highway, this area combines residential and commercial spaces, including approximately 100 households and 40 shops.
3	Kothar Spring	SN3	30°13’11” N 78°47’37” E	It is located within a 100-meter radius of the national highway, in a residential area with approximately 100 nearby households.
4	Barkot Spring	SN4	30°14’18” N 78°48’59” E	The spring is situated 2.5 kilometres from Srinagar town in Barkot village, having a population of over 300 people who rely on this spring for their drinking water.
5	Gorsali Spring	SN5	30°14’19” N 78°47’41” E	Located 2.5 kilometres from Srinagar, Gorsali village is home to more than 300 residents who depend on this spring for their drinking water supply

Figure-1. Sampling Sites

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RESULTS AND DISCUSSION

Physio- Chemical Parameters

This study assessed seven physicochemical characteristics: pH, dissolved oxygen, carbon dioxide, alkalinity, hardness, nitrate, and chloride. Water quality is influenced by various human activities, as well as the geography, topography, and geology of a region. Practices such as dumping garbage, human waste, washing clothes, and bathing can pollute water and lead to disease. Therefore, assessing the quality of drinking water sources is crucial to maintaining or improving their safety. The values for pH, chloride, alkalinity, and nitrate were within the desirable limits set by WHO and BIS, ranging from 6.9 to 7.2, 29.8 to 45 mg/L, 31 to 47 mg/L, and 3.7 to 6.25 mg/L, respectively. Hardness was within the desirable limits at four sites, except for SN5, where it was 202 mg/L, slightly exceeding the desirable limit of 200 mg/L but still within the permissible range. Although WHO does not specify strict minimum values for dissolved oxygen and carbon dioxide, the observed concentrations ranged from 2.8 to 8.4 mg/L and 0.66 to 1.4 mg/L, respectively(Figure 2).Spring water, which is continuously flowing, interacts with many substances that can dissolve in it, altering its physicochemical properties. For example, contact with salts and lime can contribute to water hardness, while interactions with soil minerals, domestic waste, and human waste can increase chloride content, thereby affecting water salinity.

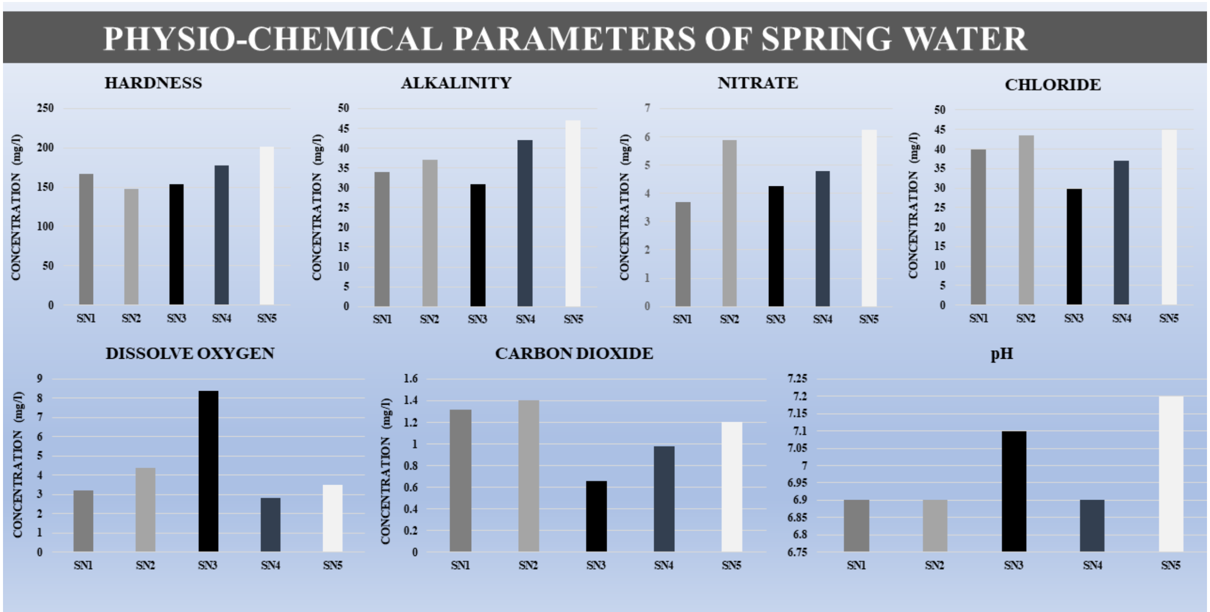

Figure-2. Physio- Chemical Parameters Monitored in the Study

Algal Diversity

The study identified 26 algal genera from the classes Chlorophyceae, Bacillariophyceae, and Cyanophyceae. The most abundant were Chlorophyceae (green algae), followed by blue-green algae and diatoms. Notable green algae included *Spirogyra* and *Cladophora*, while *Oscillatoria* and *Phormidium* were common among the blue-green algae. Diatoms such as *Fragillaria*, *Gomphonema*, *Cosmarium*, and *Amphora*was also prevalent. *Phormidium* was found across all sampling sites, whereas *Microspora*, *Mougeotia*, and a few others were rare, appearing at only one location. Species diversity was highest at SN3 and lowest at SN2 and SN4. (Table 2).

The algal samples were evaluated for pollution indicators using Palmer's index (Palmer, 1969). Out of the 20 genera listed in the index, 9 were identified at the study sites (Table 2). Taxa with a minimum of 50 cells were considered significant. The Palmer index scores were 11 for SSB Spring, 1 for Kamleshwar Spring, 21 for Kothar Spring, 9 for Barkot Spring, and 6 for Gorsali Spring. These scores indicate high organic pollution at Kothar Spring, while Kamleshwar, Barkot, and Gorsali Springs showed low to moderate pollution levels.

Table-2. Algal Diversity and Palmer Index Score of Springs

ALGAE	SN1	SN2	SN3	SN4	SN5
Acrochaetiaceae					
Audouinella	-	-	+	-	+
Chlorophyceae					
Chlorella	-	-	+3	+3	-
Cladophora	+	+	+	-	+
Microspora	+	-	-	-	-
Mougeotia	-	+	-	-	-
Oedogonium	-	+	-	+	+
Spirogyra	-	-	-	+	+
Tribonema	-	-	+	-	-
Ulothrix	-	-	-	+	-
Volvox	-	-	+4	-	-
Bacillariophyceae					
Amphora	+	+	+	-	-
Cosmarium	+	+	-	+	+
Cymbella	-	-	+	-	-
Diatoma	+	+	-	-	-
Fragillaria	+	-	+	-	+
Gomphonema	+1	-	-	-	+1
Navicula	-	-	+3	-	-
Nitzchia	+3	-	+3	-	-
Pinnularia	+	-	-	-	-
Rhopalodia	+	-	-	-	-
Synedra	+2	-	+2	-	-
Tabellaria	-	-	-	-	+
Cyanophyceae					
Anabaena	-	-	+1	+1	-
Lyngbya	-	+	-	-	+
Oscillatoria	+4	-	+4	+4	+4
Phormidium	+1	+1	+1	+1	+1
Total score	**11**	**1**	**21**	**9**	**6**

Heavy Metals

Nine elements, aluminium, barium, copper, magnesium, manganese, nickel, lead, uranium, and zinc were analysed in water and algal samples. The concentrations of aluminium, copper, manganese, nickel, lead, and zinc in the water samples were well below both BIS and WHO limits for drinking water and were even undetectable in some cases (Figure 3). However, the concentration of barium exceeded the permissible limit of 0.7 mg/L at site SN2, reaching 0.89 mg/L. Similarly, uranium levels surpassed the allowable limit of

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0.03 mg/L at site SN5, reaching 0.04 mg/L. Magnesium concentrations exceeded the desirable limit of 30 mg/L at sites SN1, SN2, and SN4, measuring 41.1, 41.9, and 53 mg/L, respectively, although they remained within the permissible limit, 100 mg/L (Figure 3). The elevated concentration of barium at site SN2 could be attributed to natural mineral deposits, while uranium at SN5 may be linked to geological formations rich in uranium-bearing minerals. Localized pollution sources, such as agricultural runoff or industrial discharges, could also contribute to the presence of these elements at these specific sites.

The concentration of copper, manganese, and zinc in algae was over 100 times higher than in water. For aluminium and lead, the concentration was even more pronounced, being 1,000 times higher in algae(Figure 3). Although the concentration of magnesium in the algae samples was lower than in water, it was still greater compared to other absorbed metals. This may be because magnesium, not being a trace element, is present in water in quantities exceeding the absorption capacity of algae. The concentration of barium in algae was undetectable at sites SN 1, 2, and 4, but absorption was noted at sites SN 3 and 4. In the case of nickel, the concentrations in algae at sites SN 1, 2, and 5 were three times lower than in water, while at sites SN 3 and 4, the opposite was observed(Figure 3). This variation suggests that algae may selectively absorb barium and nickel. As for uranium, its concentration in algae was undetectable at all sites except SN 2. This could be due to a specific type of algae at that site with a high affinity for uranium, absent elsewhere. Despite the high uranium concentration in water at SN 5, no uptake by algae was detected, possibly indicating that the elevated uranium levels were not a consistent occurrence.

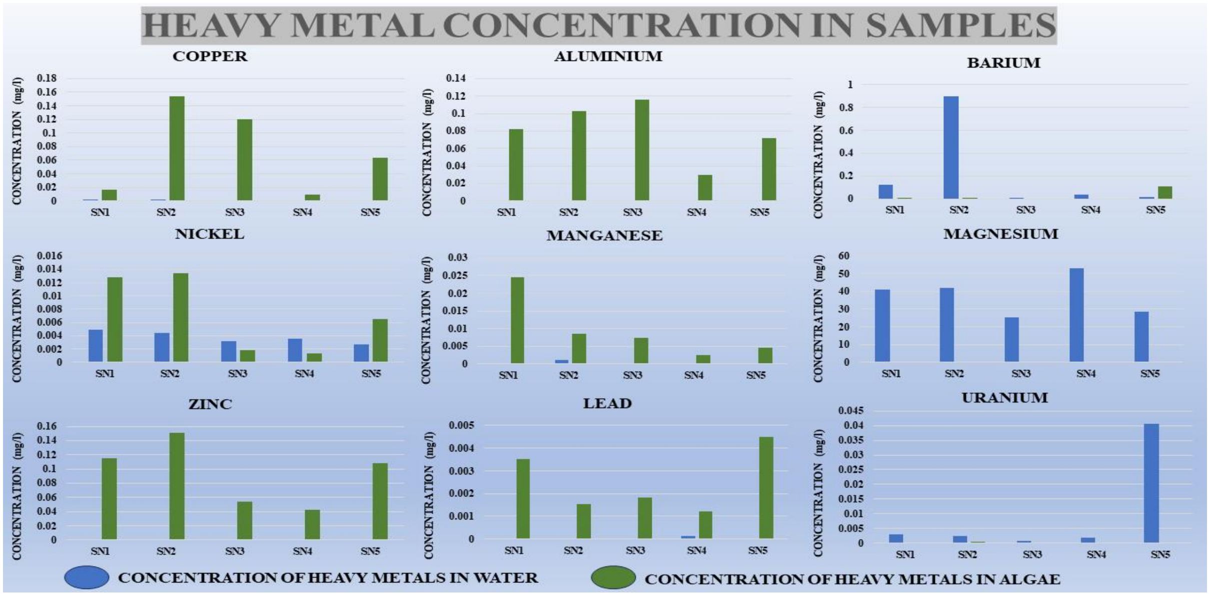

Figure-3. Heavy Metal Concentration in Algae and Water Samples

Conclusion

This study highlights the critical role that freshwater springs play in supporting the lives of those residing in hilly regions, emphasizing the need for thorough water quality assessments. The findings show that the springs are in generally good condition, as the physicochemical parameters mostly adhere to established standards. However, evaluations of algal diversity and pollution indices have pinpointed areas needing attention, particularly at Kothar Spring, where high levels of organic pollution were observed. It is essential to promote good sanitation practices to prevent further organic pollution, such as maintaining clean surroundings and properly disposing of waste. Although heavy metals in the water samples were within permissible limits except for uranium at one spring and barium at another, their accumulation in algae suggests the potential for these metals to build up in the bodies of people consuming the water, posing significant health risks. Also, the high concentration of uranium and barium even at one site is not something to be overlooked as it can cause severe health implications.A comprehensive and long-term study is recommended to better understand the overall health of these springs. To address these challenges, effective strategies must be implemented, including identifying pollution sources and controlling contamination, to ensure the protection of these vital water resources.

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