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Limnological Studies of Thermal Springs of Bihar, India

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In the two thermal springs Bhimbandh (63–39°C) and Rishikund (46–31°C) located in Munger district, Bihar the temperature at the source of emergence as well as at other points was constant throughout the year. With the fall of temperature, the *p*H, dissolved O_2 and alkalinity increased, whereas the silicate content declined. Some rare gases like helium and argon were also discharged alongwith hot water at the source. At temperature above 60°C only blue-green algae and bacteria were recorded. The species diversity was very limited in this range. Green algae and diatoms were recorded only at lower temperatures. Below 46°C the frequency of blue-greens declined and these totally disappeared below 41°C. Chlorophyceae and Bacillariophyceae appeared below this temperature. Protozoans, nematodes rotifers, and insects species were recorded between 38 and 45°C while fishes were found below 45°C.

Key Words: Limnological survey, Rare gases, Thermal springs

Introduction

In recent years considerable attention has been paid to the ecological aspects of thermal springs notably by Gonzalves 1947, Thomas et al. 1965, Prasad & Srivastava 1965, Vashist 1967, Patel 1974 who have studied the taxonomy of thermophilic algae. Jana (1977, 1978), Jana and Sarkar (1982), Saha et al. (1978) as well as Saha and Datta Munshi (1979) have studied some limnological aspects of thermal springs. However, very little work is known in the thermal springs of Bihar which lie mainly in the Southern belt of the state. It is hoped that the present limnological account of two hot springs Bhimbandh and Rishikund located in Munger district of Bihar would fill this gap. The study was conducted from October, 1981 to September, 1983.

Materials and Methods

The algal samples were collected at monthly intervals and preserved in 4% formalin. Their frequency was measured by species count method using haemocytometer. Physico-chemical analysis of water was carried out by the methods recommended by APHA (1975). Total bacterial density was measured by plate count method using nutrient agar and total coliform bacteria were determined by multiple tube dilution technique using MacConkey's broth of single and double strength (APHA 1975). Further, IMViC and other biochemical tests were done according to Sirockin and Cullimore (1969) and Starr et al. (1981). Free carbon-dioxide, dissolved O_2, bicarbonate alkalinity were measured at the locations while Na, K, Ca, Mg, SiO_2 and phosphate phosphorus were determined in the laboratory. Samples of rare gases were sent to Bhabha Atomic Research Centre, Variable Energy Cyclotron Centre, Calcutta for analysis. The objective of estimating the gases was to ascertain as to how the water reaches such a high temperature, below the earth crust. Their presence shows that heat is generated due to radioactive substance like K_{40}.

Bhimbandh and Rishikund thermal springs are situated in the reserve forest area of Kharagpur hill range of Munger district (lat. 25°.3′N, long. 86°25′E). At Bhimbandh hot water comes out from numerous mountain fissures and it forms a stream which subsequently joins a cold stream (figure 1). The water of the stream cools down slowly and develops a gradient from 63 to 39°C along a stretch of about 1.5 Km. The bed of the stream is covered with pebbles having profuse algal deposition over it. The temperature at Rishikund ranges from 46 to 31°C within a distance of about 100 meter (figure 2). The base is mostly stony except in *Kund* (main source) which is muddy at the bottom. Algal growth is quite luxuriant. Six spots at intervals of temperature variation of 5°C were selected at Bhimbandh which had a temperature gradient from 63 to 39°C. Similarly four spots were selected at Rishikund which had a temperature gradient from 46–31°C.

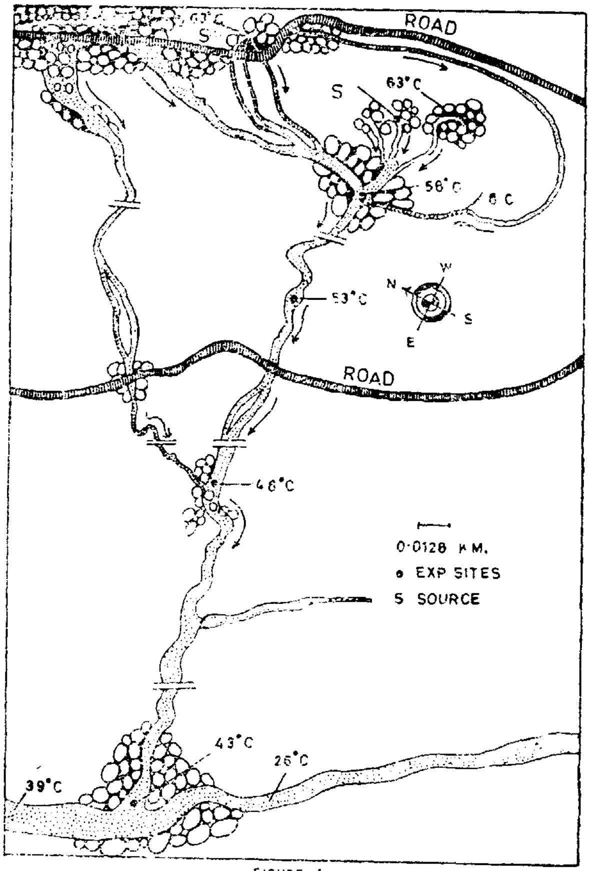

Figure 1 Map showing different temperature gradients of Bhimbandh Thermal Spring.

Results and Discussion

A consistency in temperature at the source was observed (tables 1 & 2). Seasonal variations did not have any effect on water temperature at the source. At other points it was very negligible (±1°C) as also reported for several other thermal springs too. However, in few thermal springs like Sitakund (India), Geyser (Iceland) and Tsukiji Shokan (Japan) the temperature is known to vary on some occasions even during different hours of the day (Barth 1950, Uzamasa 1965). Both the thermal springs were acidic with low *p*H ranges i.e., 3.9–6.8 and 5.0–6.7 respectively (figures 3 & 4). The rise in *p*H along the thermal gradient was

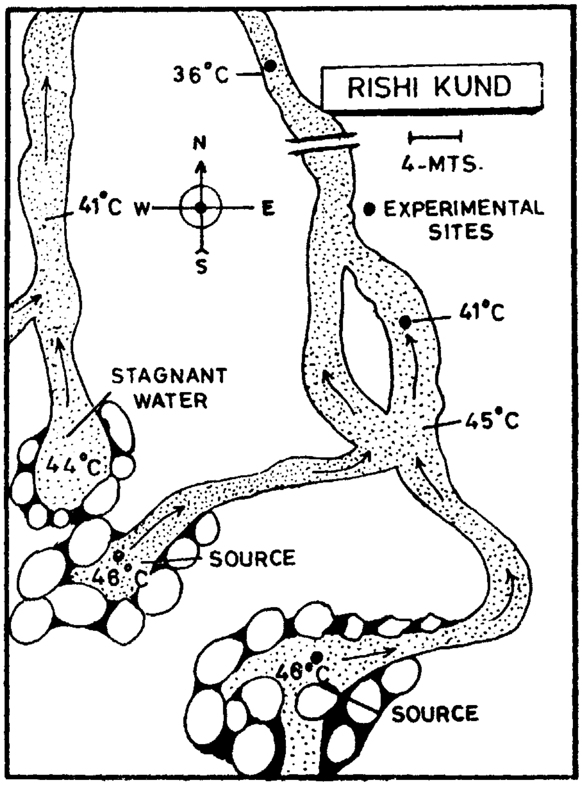

Figure 2 Map showing experimental sites of Rishikund thermal spring with thermal gradient

of silicate remained unaltered at Tantloi and Bakreswar. Silicate concentration however, declined with the fall of temperature both at Bhimbandh and Rishikund. A steep rise in the population of diatoms and Rhizopods at 41°C was the main reason for the fall in silica concentration at lower temperature which had an inverse relationship with the population of diatoms. The phosphate level also declined down the stream both at Bhimbandh and Rishikund suggesting its utilization in the formation of dense algal mats at lower temperatures. Castenholtz (1969) also recorded a fall in phosphate level down the stream at Hunter's hot spring (USA). Brock et al. (1969), accompanied by a fall in the level of CO_2. At the source free CO_2 was maximum in both the streams. Rapid fall in free CO_2 down the stream may be attributed to increased periphytonic algae and their photosynthetic activity. Dissolved O_2 at the source was very low both at Bhimbandh and Rishikund. Its concentration increased with the fall of temperature along the stream. This is because of greater diffusion and solubility of atmospheric O_2 at lower temperatures and also due to high photosynthetic activity. This observation supports the findings of Hubbs (1967). Bicarbonate alkalinity was lower near the source at both the places and gradually increased along with the rise of *p*H. Jana and Sarkar (1982) found that the value

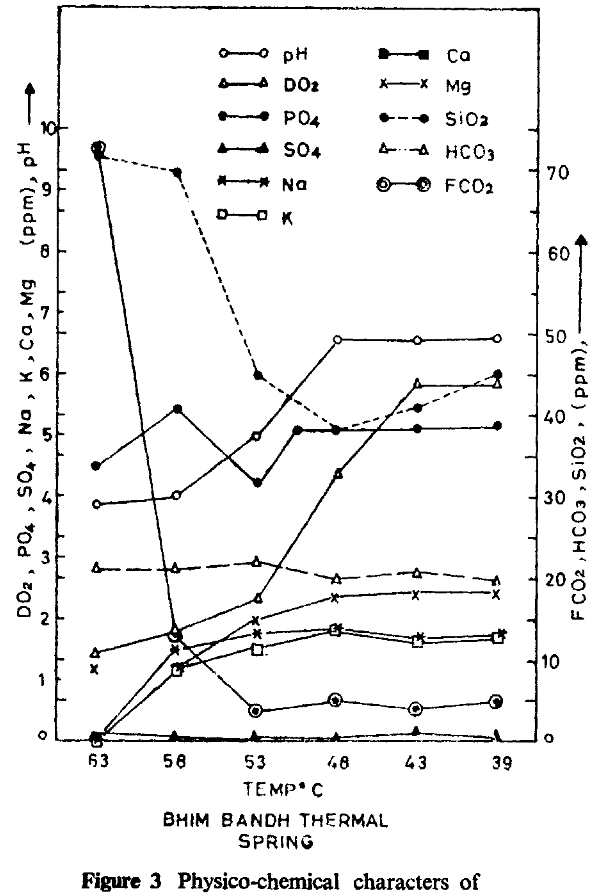

Figure 3 Physico-chemical characters of Bhimbandh thermal spring

Table 1 *Gas analysis at thermal springs of Bhimbandh and Rishikund*

Sources	Temperature at source	Atmospheric temp.	Helium	Argon	Nitrogen %	Oxygen %	Carbon dioxide %
Bhimbandh	63°C	23·5°C	55×10^{-4}	1·2	65·2	6·0	27·6
Rishikund	46°C	24°C	31×10^{-4}	1·3	73·1	5·2	20·4

Table 2 *Distribution of biota in different portions of the effluent channel of Bhimbandh*

Organisms	Temperature (°C)					
	63	58	53	48	43	39
Cyanophyceae						
Synechococcus lividus	+	+	+	—	—	—
S. elongatus	—	+	+	+	+	—
Phormidium africanum	—	+	+	+	+	—
Oscillatoria amphibia	—	+	+	+	—	—
O. germinata	—	+	+	+	—	—
Lyngbya spirulinoides	—	—	+	+	+	—
Scytonema sp.	—	—	+	+	+	—
Nostoc commune	—	—	—	+	+	+
Anabaena sp.	—	—	—	+	+	+
Mastigocladus laminosus	—	—	+	+	—	—
Chlorophyceae						
Oedogonium sp.	—	—	—	+	+	+
Spirogyra sp.	—	—	—	+	+	+
Mougeotia sp.	—	—	—	—	+	+
Ulothrix moniliformis	—	—	—	+	+	+
Closterium sp.	—	—	—	+	+	+
Cosmarium trichyderum	—	—	—	+	+	+
Bacillariophyceae						
Pinnularia sp.	—	—	—	—	+	+
Fragilaria sp.	—	—	—	+	—	—
Gomphonema sp.	—	—	—	—	+	+
Cymbella sp.	—	—	—	—	+	+
Melosira sp.	—	—	—	—	+	+
Fungi						
Chaetomium sp.	—	—	—	+	+	+
Aspergillus flavus	—	—	—	+	+	+
A. fumigatus	—	—	—	+	+	+
Curvularia lunata	—	—	—	+	+	+
Trichoderma sp.	—	—	—	+	+	+
Rhizopus sp.	—	—	—	+	+	+
Protozoa						
Arcella discoides	—	—	—	+	+	+
Euglypha sp.	—	—	—	+	+	+
Vorticella sp.	—	—	—	—	+	+

Contd.

Table 2 *contd.*

Rotifera						
Monostyla sp.	—	—	—		+	+
Brachionus sp.	—	—	—		+	+
Nematoda						
Monunchus macrostoma	—	—	—	+	+	+
Trilobus gracilis	—	—	—	—	+	+
Insecta						
Chironomous sp.	—	—	—	+	+	+
Guignotus pradhani	—	—	—	—	+	+
Pisces						
Channa gachua	—	—	—		+	+
Danio dangila	—	—	—		+	+
Amphibia						
Rana cyanophyctis	—	—	—		+	+

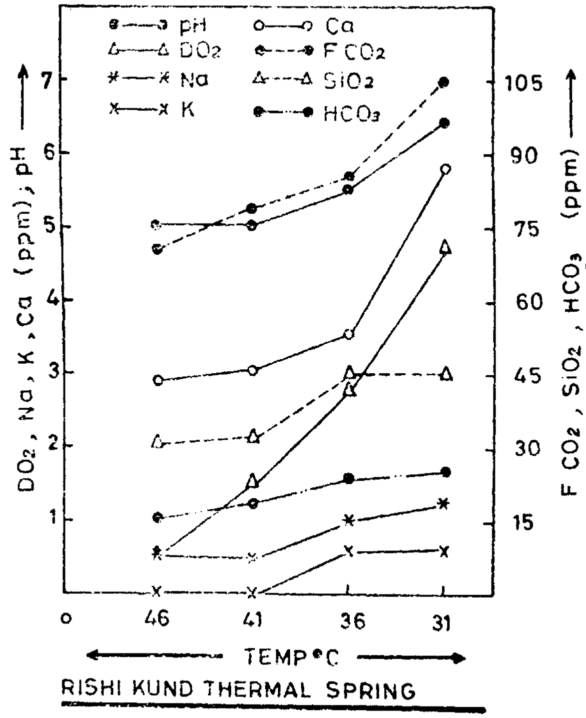

Figure 4 Physico-chemical character of Rishikund thermal spring

however, did not observe any such decrease. Sodium and potassium values also declined with the temperature gradient in both the thermal springs. Increased calcium concentration can be attributed to allochthonous sources mainly due to decomposition of leaf litter which furnishes nutrients like, Na, K, Ca, and Mg. Two rare gases, helium and argon, were found in both the thermal springs (table 1). The amount of CO_2 was fairly high (about 20%). Liberation of helium and argon at the source reflects radioactivity deep in the earth crust. These gases, which emanate along with hot water through narrow fissures, do not seem to have any effect on the organisms, firstly because they are inert and secondly because they escape to atmosphere immediately on coming to the surface.

Myxophyceae constituted 100% population at higher temperatures (51–63°C) at Bhimbandh. At 63°C, *Synechococcus lividus* was the only alga to be encountered but at a slightly lower temperature, say 59°C, few more algae like *S. elongatus*, *Phormidium africanum*, *Oscillatoria amphibia* were recorded. The growth of these algae was most luxuriant between 55 and 50°C. Rich accumulation of algal mat at this temperature was due to total absence of herbivores. Chlorophyceae and Bacillariophyceae were also not recorded at this high temperature. At higher temperatures silicate concentration was more. Similar observations were made by Round (1970). Peterson (1920) however, recorded diatoms even at 70°C in some thermal springs of Siberia. At 46°C the frequency of blue green algae declined and members of Chlorophyceae and Bacillariophyceae made their appearance. At 41°C the blue-greens were further depleted and the green ones increased substantially. Below 41°C the growth of blue-green algae disappeared and total algal community was occupied by Chlorophyceae and Bacillariophyceae. In Rishikund no species of *Synechococcus* was recorded at 46°C which is the extreme temperature limit of this spring. Chlorophyceae and Bacillariophyceae were dominant at lower temperatures.

Total bacterial density at Bhimbandh near the source was 0.6×10^6/liter at 63°C, and MPN for coliform was 43/100 ml. Both these, however, increased with the fall of temperature (3.1×10^6/liter, MPN 223/100 ml at 51°C) and at 41°C (5.2×10^6/liter, MPN 663/100ml). *Aerobacter aerogenes* type I and II and *E. coli* type I and II were the important coliform bacteria to be encountered at lower temperatures. At higher temperatures some thermophilic bacteria like *Bacillus pasteurii*, *B. anthracis*, *Lactobacillus*, *acidiphilus* were recorded. In Rishikund thermal spring total bacterial density ranged from 2.82×10^6/liter to 4.01×10^6/litre and MPN 174/100 to 218/100 ml at 46 to 41°C. Both these thermal springs are situated in

Table 3 *Distribution of biota in different portions of the effluent channel at Rishikund*

Organisms	Temperature (°C)			
	46	41	36	31
Cyanophyceae				
Lyngbya bipunctata	+	+	+	—
Lyngbya lagerheimii	+	+	—	—
Phormidium tenue	+	+	—	—
Oscillatoria jasorvensis	+	+	—	—
Anabaena circularis	—	+	+	+
Chlorophyceae				
Oedogonium sp.	—	+	+	+
Spirogyra sp.	—	+	+	+
Cosmarium pseudoconnatum	—	+	+	+
C. westii	—	+	+	+
Fungi				
Aspergillus flavus	—	+	+	+
A. niger	—	+	+	+
Curvularia lunata	—	+	+	+
Zooplankton				
Ostracoda				
Stenocypris malcomsoni Insecta	—	+	+	+
Laccophilus anticatus	—	+	+	+
Enochrus sp.	—	+	+	+
Anisops sardia	—	+	+	—
Pisces				
Danio dangila	—	+	+	—

forests where there are large number of herbivorous animals and bacteria (specially the coliforms) appear to come in the system through faecal matter. Few members of Ascomycetes also occur in the springs. The down stream of the channel was moderately populated with protozoa, Rotifera, Nematoda, Insecta, fishes and amphibia at Bhimbandh (table 2). Altogether nine species of invertebrates and three species of vertebrates were collected during the study between 38 to 45°C. In Rishikund zooplankton were not recorded while insects were represented by *Huignotus pradhani* and *Chrinomus* larva at 40–42°C (table 3).

The species diversity in both the thermal springs declined with the rise of temperature, only the procaryotic forms (blue-green algae and bacteria) were encountered at very high temperatures. The blue-greens are unicellular, non nitrogen fixing forms referable to the genus *Synechococcus* (Brock 1967). Relationship between temperature and biota is well reflected in these thermal springs. The diversity in forms increases with the fall of temperature. In other words it could be said that with the rise of temperature the significance of the population structure becomes progressively simpler and from evolutionary point of view it could be inferred that microbes found at higher temperatures are optimally adapted to this condition nearly identical to the extremes.

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