**RESEARCH ARTICLE**

Diatom Flora of Kalath and Khirganga Thermal Springs of Himachal Pradesh, India

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**ABSTRACT**

Diatoms are fascinating group of microorganisms; abundant in all aquatic habitats. They are used as reliable environmental indicators. In the present study diatoms flora of Kalath and Khirganga thermal springs of Kullu district, Himachal Pradesh were examined for the first time. Water temperature for these springs range between 39-48°C with neutral to slightly acidic pH. Total eighteen taxa of diatoms (Bacillariophyceae) reported during study belonging to seven genera. Diatom species of Nitrogen heterotrophic- *Nitzschia* and *Gomphonema* dominated in these thermal springs. It indicates water of these springs is rich in nitrogen due to pollution. Present study adds twelve new taxa to the algal flora of Himachal Pradesh.

**Keywords:** Thermal spring, Diatoms, Kullu.

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**Conflict of interest:** None

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**Materials and Methods**

Random sampling technique has been applied in the algal collection procedure. Samples were collected in 2018 from Kalath (lat. 32.1856 and long. 77.1856) and Khirganga (lat. 31.993 and long. 77.5096) thermal springs, Kullu district, Himachal Pradesh. Temperature and pH of water was measured in each case with the help of Mercury Celsius thermometer and portable pH meter on the site respectively. The algal samples were preserved in 4% formalin solution and submitted in Phycology research lab, University of Lucknow. Slides were prepared of the Patrick and Reimer (1966) and mounted in DPX (Destyrene Phthalate Xyloil). Microscopic studies were made by Nikon Labophot microscope E-400 with H-II photomicrographic attachment (Plate 1A-D).

**Morphological identification**

Taxonomical identifications were done by comparing each of the taxon with monographs of Hustedt (1930), Foged (1981), Gandhi (1999) and Karthick *et al.* (2013). Identifications were confirmed by cross-checking with the Algal database and morphological characters.
related research papers, journals. Diatom taxa reported in the present investigation have been arranged according to Hendey (1964).

**RESULTS**

1. *Diatoma vulgaris* Bory (Pl. 2, Fig. A)
Tiffany, L. H., and Britton, M. E., 1952, pg. 230, pl. 61, fig. 686.  
*Description*: Valves elliptical-lanceolate, narrowed slightly towards the rounded poles; with very narrow pseudoraphe; valve length 15 µm and breadth 4 µm; trans apical ribs, 7 in 10 µm.

*Locality*: River side outflow on NH-3 near River Beas, Kalath, Kullu.  
*Collection number*: HP/KU/KL/S5.

2. *Navicula cryptocephala* Kützing (Pl. 2, Fig. D)
Kuetzing, F.T., 1849, pg. 75; Gandhi, H.P. 1999, pg. 35, Pl. II, fig. 70.  
*Description*: Valves linear-lanceolate with constricted produced somewhat capitates ends; raphe thin, straight median with distinct central nodules; striae lineate, short in central area, radiate in the middle becoming convergent towards apices; valve length 24 µm, breadth 5 µm; striae 16-17 in 10 µm.

*Locality*: Near bathing pool area, Khirganga.  
*Collection number*: HP/KU/KH/S13.
3. *Navicula zanoni* Hustedt (Pl. 2, Fig. E)
Hustedt, 1949, pg. 92, pl. 5, fig. 1-5; Gandhi, H. P., 1959a, pg. 127, pl. II, fig. 48.  
*Description:* Narrowly lanceolate with narrowed, constricted, produced acutely rounded ends; raphe thin and straight; axial area is narrow, with circular central area; valve length 22 µm, breadth 5 µm; striae 20 in 10 µm.  
*Locality:* Bathing pool in Shiv temple, Khirganga, Kullu.  
*Collection number:* HP/KU/KH/S12.

4. *Caloneis gracilis* H.P. Gandhi ex Karthik (Pl. 2, Fig. C)
Gandhi, H. P., 1999, pl. 1, fig. 16 a-b.  
*Description:* Valves linear in the middle delicately convex, ends broadly rounded; raphe thin and straight with central pores distinctly and distantly placed and terminal fissures curved; apices narrow, linear lanceolate; valve length 40 µm, breadth 7 µm; striae 18 in 10 µm.  
*Locality:* Parvati Thermal water Kunda, Khirganga, Kullu.  
*Collection number:* HP/KU/KL/S11.

5. *Pinnularia macra* H.P. Gandhi (Pl. 2, Fig. B)
*Description:* Ends strongly constricted, broadly capitate and rounded; raphe thin and straight with central pores unilaterally inclined and terminal fissures curved; axial area is more or less lanceolate, central area large, rhomboid; valve length 21 µm, breadth 3 µm; striae 18 in 10 µm.  
*Locality:* River side outflow on NH-3 near River Beas, Kalath, Kullu.  
*Collection number:* HP/KU/KL/S5.

6. *Gomphonema lagenula* Kützing (Pl. 2, Fig. F)
*Description:* Valves linear-lanceolate, with rounded to sub-rounded apices; central area broad; raphe thick; striae are distinctly placed, thick; valve length 22 µm, breadth 6 µm; striae 17 in 10 µm.  
*Locality:* Parvati Thermal water Kunda, Khirganga, Kullu.  
*Collection number:* HP/KU/KL/S11

7. *Gomphonema parvulum* (Kützing) Kützing (Pl. 2, Fig. G)
Foged, N., 1981, pg. 645, pl. 10, fig. 17.  
*Description:* Valves small, linear, lanceolate-clavate with slightly constricted produced rounded apex and gradually attenuated rounded base; raphe thin, median straight, with distinct central nodules, having an isolated puncta on opposite side; striae linear, radiate and slightly distinctly placed in middle; valve length 13 µm, breadth 6 µm; striae 16 in 10 µm.  
*Locality:* Main bathing pool, Kalath, Kullu.  
*Collection number:* HP/KU/KL/S3.

8. *Rhopalodia gibba* (Ehrenberg) O. Müller (Pl. 2, Fig. H)
*Description:* Cells in girdle view broadly linear with median inflation and rounded poles; valves broadly lunate with straight ventral sides and recurved acute poles; valve length 27 µm, breadth 4 µm; costae 8-9 in 10 µm alternating with 3-4 rows of alveoli 11-12 in 10 µm.  
*Locality:* Bathing pool in Shiv temple, Khirganga, Kullu.  
*Collection number:* HP/KU/KH/S12.

9. *Rhopalodia gibberula* (Ehrenberg) O. Müller (Pl. 2, Fig. I)
Hustedt, 1930, pg. 391, fig. 742; Karthick, B., Hamilton, P.B. & Kociolek, J.P., 2013, pl. 107  
*Description:* Cell-wall elliptical with flat ends in girdle view; valve length 29 µm and breadth 7 µm; costae 3-4 in 10 µm, alternating with rows of alveoli 15-16 in 10 µm.  
*Locality:* River side outflow on NH-3 near River Beas, Kalath, Kullu.  
*Collection number:* HP/KU/KL/S5.

10. *Rhopalodia musculus* (Kützing) O. Müller (Pl. 2, Fig. J&K)
*Description:* Valves semi-elliptical, strongly convex along the dorsal margin, tapering to narrow rounded ends; raphe is located in the canal along the dorsal margin; valve length 30 µm, breadth 6 µm; costae 4-5 in 10 µm; striae in 10 µm.  
*Locality:* Bathing pool in Shiv temple, Khirganga, Kullu.  
*Collection number:* HP/KU/KH/S13.

11. *Nitzschia allansonii* Cholnoky (Pl. 2, Fig. L)
Cholnoky, 1958, pg. 257, fig. 24-27; Gandhi, H.P., 1999, pg. 197, pl. 6, fig. 190.


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12. *Nitzschia alpina* Hustedt (Pl. 3, Fig. A)
Hustedt, F., 1942, pg. 124-197, 225-280; fig. 60-65.
*Description*: Valves linear to lanceolate, bluntly rounded to rostrate apices; fibulae equidistant; valve length 14 µm, breadth 4 µm; striae 20 in 10 µm.
*Locality*: River side outflow on NH-3 near River Beas, Kalath, Kullu.
*Collection number*: HP/KU/KL/S4.

13. *Nitzschia amphibia* Grunow (Pl. 3, Fig. B)
*Description*: Valves short, linear-lanceolate with slightly constricted produced, sub-rostrate ends; carinal dots big, rounded; median two slightly placed apart; striae coarse, very slightly elongated; median two somewhat distinctly placed; striae very fine, lineate, delicate, parallel throughout the valve; valve length 40 µm, breadth 5 µm; striae 20 in 10 µm.
*Locality*: Bathing pool in Shiv temple, Khirganga, Kullu.
*Collection number*: HP/KU/KH/S12.

14. *Nitzschia capitellata* Hustedt (Pl. 3, Fig. C)
Hustedt, F., 1938, pg. 474, pl. 41, fig. 26 & 27.

15. *Nitzschia communis* Rabenhorst (Pl. 3, Fig. D)
Grunow, 1862, pg. 561, 578, pl. 12, fig. 18.
*Description*: Valves linear with rounded apices; fibula relatively large and distinct, about 10-15 in 10 µm; striae resolved in the light microscope but very fine; valve length 28 µm, breadth 3 µm; striae 30 in 10 µm.
*Locality*: Outflow in Hotel, Kalath, Kullu.
*Collection number*: HP/KU/KL/S4.

16. *Nitzschia elegantula* Grunow (Pl. 3, Fig. E)
*Description*: Valves linear-lanceolate to lanceolate; apices rounded to sub rostrate; valve length 10 µm, breadth 3 µm; striae 18 in 10 µm.
*Locality*: Outflow in Hotel, Kalath, Kullu.
*Collection number*: HP/KU/KL/S4.

17. *Nitzschia liebethruthii* Rabenhorst (Pl. 3, Fig. F)
*Description*: Valves linear-lanceolate, with margins more or less parallel; apices attenuated, but not protracted, and narrowly rounded; central gap in the fibulae or central nodule present; fibulae distinct with a density of 10-12 in 10 µm; valve length 30 µm, breadth 4.5 µm; striae 18 in 10 µm.
*Locality*: Near bathing pool area, Khirganga.
*Collection number*: HP/KU/KH/S13.

18. *Nitzschia thermalis* (Ehrenberg) Auerswald (Pl. 3, Fig. G)
Hustedt, 1949, pg. 130, pl. 11, fig. 63-64. Gandhi, H.P., 1999, pg. 221, pl. 6, fig. 221-227.
*Description*: Valves linear with parallel edges and concave or wedge shaped narrowed, more or less protracted ends, 31 µm long and 7 µm broad; keel pointed small, rounded, and present throughout the margins of valve, 8-10 in 10 µm; striae not clearly seen in light microscope.
*Locality*: Outflow in Hotel, Kalath, Kullu.
*Collection number*: HP/KU/KL/S4.

**Discussion**

*Nitzschia, Gomphonema, Cymbella, Navicula, Pinnularia and Rhopalodia* are some common genera reported in thermal springs of India (Table 1). Diatom species of Nitrogen heterotrophic- *Nitzschia* and *Gomphonema* dominate in Kalath and Khirganga thermal springs (Table 2). It indicates water of these springs is rich in nitrogen due to pollution. Findings are supported by Bhardwaj (2012). Water temperature for these springs range between 39-48°C with neutral to slightly acidic pH. Total eighteen taxa of diatoms (Bacillariophyceae)
**Table 1:** List of Diatoms observed in thermal springs in the India.

<table>
<thead>
<tr>
<th>S.N.</th>
<th>Name of Species</th>
<th>Occurrence</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Fragilaria virescens var. briostrata, Pinnularia santapau, Cymbella ehrenbergii var. elongata, Hantzschia virgata var. lata, Surirella tenera var. indica, Synedra tabulata var. elliptica var. angusta, Diploneis hyperborea var. minor, Nitzschia sigma var. indica, Stauropeum acuta var. tenuis, Pinnularia episcopalis var. elongata, Nitzschia latestriata var. minor f. intermedia, Cyclotella comta var. irregularis, Diploneis smithii var. rhombica f. major, Surirella robusta var. splendida f. ovata, Surirella desikachariensis</td>
<td>Palli, Lasundra, Tuwa, Tooral, Rajewadi, Sav hot spring, Maharashtra</td>
<td>Thomas and Gonzalves (1965a,b,c,d,e,f)</td>
</tr>
<tr>
<td>2.</td>
<td>Navicula sp., Cyclotella sp.</td>
<td>Bakreswar thermal spring, West Bengal</td>
<td>Jana (1973)</td>
</tr>
<tr>
<td>3.</td>
<td>Fragilaria construens, Fragilaria pinnata, Navicula cryptocephala, Navicula cupistate, Navicula dicephala, Navicula variostriata, Stauropeum phoenicentron, Cymbella gastroides, Cymbella koftei, Cymbella parva, Rhopalodia gibba</td>
<td>Puga geothermal spring, Ladakh</td>
<td>Prasad et al. (1984)</td>
</tr>
<tr>
<td>5.</td>
<td>Achnanthes lanceolate var. rastrata, Caloneis silicula var. minuta, Diploneis domblittensis, Anomoeoneis brachysira var. genuine, A. sphaerophora, Navicula viridula var. rostella, Pinnularia brevissoni var. hybrid, Amphora coffeaformis var. africana var. elongatum, A. ovalis, A. veneta, Cymbella claasseniae, Gomphonema purpulum var. exilissimum, Denticula thermalis, Nitzschia. epithemioides, N. hybrid, N. philippinarum, N. sigma, N. subtilis and N. Thermalis</td>
<td>Palvani Unhavre thermal spring, Ratnagiri, Maharashtra</td>
<td>Kha (2014)</td>
</tr>
<tr>
<td>7.</td>
<td>Achnanthes lanceolata, Cocconeis striata, Navicula fluens, Navicula microsora, Navicula protracta, Navicula exilis, Halamphora veneta, Nitzschia obtuse, Nitzschia vasini, Rhopalodia gibberula, Rhopalodia opeculata, Surirella minuta</td>
<td>Tarabela, Taptapi, Deulajhari thermal spring, Odisha</td>
<td>Bhakta et al. (2016)</td>
</tr>
</tbody>
</table>

**Table 2:** List of Diatoms observed in two thermal springs.

<table>
<thead>
<tr>
<th>S.N.</th>
<th>Name of species</th>
<th>Kalath</th>
<th>Khirganga</th>
<th>Water temperature (°C)</th>
<th>Water pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Diatoma vulgare</td>
<td>++</td>
<td>-</td>
<td>40</td>
<td>6.8</td>
</tr>
<tr>
<td>2.</td>
<td>Pinnularia macra</td>
<td>++</td>
<td>-</td>
<td>40</td>
<td>6.8</td>
</tr>
<tr>
<td>3.</td>
<td>Caloneis gracilis</td>
<td>-</td>
<td>+</td>
<td>48</td>
<td>6.6</td>
</tr>
<tr>
<td>4.</td>
<td>Navicula cryptocephala</td>
<td>-</td>
<td>+</td>
<td>41</td>
<td>6.6</td>
</tr>
<tr>
<td>5.</td>
<td>Navicula zanonii</td>
<td>-</td>
<td>+</td>
<td>41</td>
<td>6.5</td>
</tr>
<tr>
<td>6.</td>
<td>Gomphonema parvulum</td>
<td>+</td>
<td>-</td>
<td>43</td>
<td>6.8</td>
</tr>
<tr>
<td>7.</td>
<td>Gomphonema lagenula</td>
<td>-</td>
<td>+</td>
<td>48</td>
<td>6.6</td>
</tr>
<tr>
<td>8.</td>
<td>Rhopalodia gibberula</td>
<td>++</td>
<td>++</td>
<td>40</td>
<td>6.8</td>
</tr>
<tr>
<td>9.</td>
<td>Rhopalodia musculus</td>
<td>+++</td>
<td>+++</td>
<td>39</td>
<td>6.7</td>
</tr>
<tr>
<td>10.</td>
<td>Rhopalodia gibba</td>
<td>-</td>
<td>+</td>
<td>43</td>
<td>6.7</td>
</tr>
<tr>
<td>11.</td>
<td>Nitzschia alpine</td>
<td>+++</td>
<td>-</td>
<td>40</td>
<td>6.8</td>
</tr>
<tr>
<td>12.</td>
<td>Nitzschia alansonia</td>
<td>-</td>
<td>+</td>
<td>48</td>
<td>6.6</td>
</tr>
<tr>
<td>13.</td>
<td>Nitzschia amphibia</td>
<td>++</td>
<td>-</td>
<td>40</td>
<td>6.8</td>
</tr>
</tbody>
</table>
reported during study belonging to seven genera. Diatom flora of these thermal springs were studied first time. Species richness increases with decrease in temperature (Table 2). Genus Rhopalodia mainly found at higher altitudes (2000-3250 m) were recorded in Kalath and Khirganga at 39 to 48°C. Mandal and Sarkar (2015) also reported Rhopalodia sp. from Bakreswar thermal spring at 35 to 48°C. Diatoms are critical components of thermal spring ecosystems. They are sensitive to nutrient pollution, making them a potentially useful indicator of ecosystem change. Their species composition and biomass were affected by water quality and habitat alteration and can be informative indicators of environmental condition. Present study adds twelve new taxa to algal flora of Himachal Pradesh viz., Navicula zanoni, Caloneis gracilis, Pinnularia macra, Gomphonema lagenula, Rhopalodia gibberula, R. musculus, Nitzschia allansonii, N. alpine, N. communis, N. elegantula, N. liebenthruithii, N. thermalis.

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References


