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Mini review: Thermal algae of India with special reference to Jharkhand

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Abstract : The present paper deals with the current status of thermal algae in India and also enumerating the phyco-resources of two unexplored thermal springs of Jharkhand.

Keywords : Thermophlic algae, India, Jharkhand

INTRODUCTION

Thermal springs are specialized habitats characterized by high temperature of water and sulphur emission. The thermal aquatic environment provides special situations for studying the distribution of algae in natural temperature gradients. In India, about 131 thermal springs are documented so far which are located in geologically active regions of Assam, Bihar, Gujarat, Haryana, Himachal Pradesh, Jammu & Kashmir, Jharkhand, Maharashtra, Meghalaya, Odisha, Tripura, Uttarakhand, Sikkim and West Bengal but very little attention has been paid to their biotic components, except Kirtikar (1886)[1], Drouet (1938)[2], Parukutty (1939)[3], Gonzalves (1947)[4], Prasad and Srivastava (1965)[5], Thomas and Gonzalves (1965a-g)[6-12], Vasishta (1968)[13], Pattanaik and Rao (1972)[14], Patel (1974)[15], Rao & Pattanaik (1975)[16], Jana (1973,1978)[17-18], Prasad et. al., (1984)[19], Hazarika and Gogoi (1985)[20], Singh and Sharma (1986)[21], Adhikary and Sahu (1987)[22], Jha and Kumar (1990)[23], Patralekh (1990)[24], Jha (1992)[25], Adhikary (2006)[26], Yadav and Singh (2009)[27], Bharadwaj et. al. (2010)[28], Mongra (2012)[29] and Kumar et.al. (2013)[30], Roy et.al. (2015)[31]. The present status of the documentation of thermal algae from different hot springs of India is presented in Table 1. Structurally, hot springs in India have two principal components, i.e. the Main tank or the source and the outer channels which are sometimes converted to bathing tanks, prepared for touristic purposes. The average temperature in the main tank varies within 50–110ºC and exhibit limited microbial diversity whereas the diversity increases with the down flow with lowering of temperature. Cyanobacteria are the integral part of the micro-biota of main tanks whereas occurrence of eukaryotic algae is observed with lowering of temperature in the outflow.

While studying the 'Algal flora of Jharkhand' under the approved action plan of Botanical Survey of India, the author came across two thermal springs from Dumka (24º22"36.48' N and 87º12"11.16' E) and Hazaribagh (24º08"58.92' N and 85º38"42.60' E). The former one is remotely located and maintained by the local people only and devoid of any sort of anthropogenic and touristic influences, but the later one is major touristic attraction for religious purposes. The primary goal of the present work was to determine differences in community composition of high temperature phototrophic mats distributed across thermal spring. So, the algal flora of these hot springs were documented for the first time

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emphasizing on the colonization and mat formation by cyanobacteria at different temperature gradients.

A total of 63 samples were collected from different sites of the hot springs. Thick cyanobacterial mats were collected directly from their substratum and planktonic algae collected using plankton net and fixed with Lugol's iodine on the spot for immobilization of the cells to facilitate microscopic examination during August, 2013 and April, 2014. Each sample was assigned with a field number with date of collection and preserved in 4% formalin solution along with 3-4 drops of glycerine. GPS data of the habitat were also recorded. The algal samples were studied under the Olympus CX41 compound microscope and photomicrographs were taken under Olympus C–7070 camera. In this study Fritsch system (1935, 1945) of classification is followed.The specimens are deposited in CAL. For the identification of algal species relevant literature (Desikachary, 1959; Komárek & Anagnostidis, 2008 a, b)[32,33,34] were followed.

The algal population in the presently surveyed thermal springs of Jharkhand comprises 21 taxa of Cyanophyceae *viz.Chroococcus minor*, *Lyngbya martensiana*, *Microcoleus acutissimus*, *Oscillatoria acuminata* f. *tenuis*, *O.chlorina*, *O.formosa*, *O.geminata*, *O.okenii*, *O.princeps*, *O.pseudogeminata*, *O.tenuis*, *O.subbrevis*, *Phormidium subincrustatum*, *P.laminosum*, *P.tenue*, *Spirulina labyrinthiformis*, *Aphanocapsa thermalis*, *Calothrix thermalis*, *Mastigocladus laminosus*, *Aphanothece saxicola* and *Scytonema stuposum*; 7 taxa of Bacillariophyceae *viz. Cymbella turgida*, *Diploneis subovlis*, *Pinnularia subcapitata*, *Synedra tabulata* var. *obtusa*, *Naviculamutata*, *Nitzschia sigma* and *Rhopalodia gibberula*; 3 taxa of Euglenophyceae *viz. Euglena acus*, *Phacus caudatus*, *Strombomonas ovalis* and only 2 Chlorophycean taxa, i.e. *Cosmarium compressa* and *Oedogonium globosum*. these thermal springs, forming several thick colorful mats. In the course of studying, the mats were categorized on the basis of temperature gradients and their texture, colour and thickness. The types of mats and their cyanobacterial components were reported on basis of temperature gradients are presented in Table 2.

Cyanobacteria are highly thermal resistant and well known for their adaptability in different thermal environments causing a distinct diversity pattern. In the present work, while studying the total algal diversity of these extreme aquatic habitats, the dominance of cyanobacterial members over the other algal groups was distinctly observed. Though some coccal green algae and diatoms were also found associated with the mat at the outer channels, at low temperature, i.e. 45-50°C, their occurrence was scanty with the increasing temperature. A similar pattern of distribution was also observed for cyanobacteria as well. In the lower temperature gradient, a thin slimy mat was observed composed of only coccal cyanobacterial species *viz*., *Gloeocapsa gelatinosa*, *Chroococcus minutus, Chroococcus minor, Synechococcus lividus* and *Aphanocapsa thermalis*. The later two species had a wide range of distribution in the thermal waters around the globe, even recorded from higher temperature ranges like 70-100 °C (Castenholtz, 1969; Meeks and Castenholtz, 1978)[35,36]. The absence of these forms in the upper gradients could be related to the limnological parameters and will provide an interesting scope for further studies. On contrary to the diversity at lower temperature range, the thick colorful mats at the high temperature gradients lack any coccal form and composed of mostly filamentous forms of both heterocystous and non-heterocystous types. Occurrence of species like *Calothrix thermalis* and *Mastigocladus laminosus* proved a distinctiveness of species diversity in thermal waters irrespective of their locality and environmental trophic status. The change in colour and thickness of the mat in increasing temperature is due to the excessive secretion of extra-cellular polysaccharides by the organisms and accumulation of different mineral ions in them. *Oscillatoria princeps* and *Phormidium laminosum* are the only two species exhibiting the maximum range of thermo-tolerance from 51-87 ºC. This interesting distributional pattern of cyanobacteria in different temperature gradients showed that temperature specificity plays an important role in occurrence of species. The result incorporated on the basis of only one survey in the said area, further surveys will yield many more algal taxa, and if study will be conducted in various seasons and that will illustrate much information about the biological diversification.

Table 1: Present status of documentation of thermal algae from hot springs of India

State	Name of Hot Springs	Organisms	References
Assam (2)	Nambor, Garampani	Cyanophyceae (9) Chlorophyceae (2)	Parukutty (1939), Hazarika & Gogoi (1985)
Bihar (22)	Rajgir, Saptadharakund, Brahma kund, Bhimandhkund, Surajkund, Chandramakund, Bhimbandh, Rishikund, Rameswarkund, Dalahikund, Tantloikund, Ganga –Jamuna, Anantrikhi, Rikhi, Kashyapakund, Vyas kund, Markundakund, Sitakund, Ganesh kund, Rama kund, Makhdumkund.	Cyanophyceae (34) Chlorophyceae (10) Bacillariophyceae (42)	Vashista (1968), Jha & Kumar (1986, 1990), Sinha & Chaubey (1986), Jha (1992), Kumari (1995), Yadava & Singh (2009), Patralekh (1990)
Gujarat (18)	Tuwa, Unai, Lasundra and 15 unnamed	Cyanophyceae (61) Bacillariophyceae (55)	Thomas & Gonzalves (1965), Vashista (1968), Patel (1974)
Haryana (1)	Sona	Cyanophyceae (34)	Vasishta (1968)
Himachal Pradesh (28)	Manikaran, Vashist, Tattapani, Baijnath, Kalath, Kasaul, Wayward, Geyser, Ramachandra, Khir – Ganga, Tatwani, Tatapani, Manimahesha and 16 unnamed	Cyanophyceae (72)	Vasishta (1968), Singh & Sharma (1986), Mongra (2012), Kumar& al. (2013)
Jammu & Kashmir (3)	Puga, Changchenmo river, Kyam	Cyanophyceae (12) Bacillariophyceae (11)	Drouet (1938), Prasad& al. (1984)
Jharkhand (2)	Surajkund, Palasi	Cyanophyceae (25) Bacillariophyceae (4) Chlorophyceae (2) Euglenophyceae (2)	Present work
Maharashtra (38)	Unapdeo, Vajreshwari, Akloli, Ganeshpuri, Palli, sav, Aravali, Tooral, Rajewadi, Rajapur, Sanganeshwar, Khed, Soonapdeo, Nazardeo, Sunapden, Rama kunda, Sitakunda, Lakshmankunda, Suriyakunda, Chandra kunda, Tara kunda, Gorakhkunda, Mechindrakunda, Subhashkunda, Saraswatikunda, Bhimeshwarkunda, Ansuyakunda, Aganikunda, Dr. Kothamala'skunda and 9 unnamed	Cyanophyceae (103) Bacillariophyceae (23)	Kirtikar (1886), Gonzalves (1946, 1947), Thomas &Gonzalves (1965), Vasishta (1968), Patil & Deore (2010)
Meghalaya (1)	Jakrem	Cyanophyceae (10)	Singhood & Ramanujam (2011)
Odisha (2)	Autri, Taptapani	Cyanophyceae (9)	Pattnaik & Rao (1972), Rao & Pattnaik (1975),Adhikary & Sahu (1987)
Tripura (2)	Champak,Garampani	Cyanophyceae (3)	Reddy& al. (1985)
Uttarakhand (11)	Tapoban, Badrinath, Ringidad, Soldhar, Jamnotri, Suriyakunda, Agastakunda, Vasishtakunda, Gaurikunda and 2 unnamed	Cyanophyceae (22) Bacillariophyceae (5)	Prasad & Srivastava (1965), Vasishta (1968), Bhardwaj & Tiwari (2010), Bhardwaj & et al. (2010)
West Bengal (2)	Bakreswar, Panifala	Cyanophyceae (16) Bacillariophyceae (2) Chlorophyceae (7) Euglenophyceae (3)	Jana (1973, 1978), Debnath & al. (2009), Roy & al. (2014, 2015)

Table 2: Cyanobacterial mat types and their species composition in different thermal gradients

Temperature	Nature of mats	Cyanobacterial species composition
45 – 50 ºC	Soft, deep blue-green, 15 - 20 mm thick	*Gloeocapsa gelatinosa* Kütz., *Synechococcus lividus* J.J. Copel., *Chroococcus minutus* (Kütz.) Nägeli, *Chroococcus minor* (Kütz.) Nägeli and *Aphanocapsa thermalis* Brügger.
51 – 70 ºC	Semi leathery, deep orange, 21 – 30 mm thick	*Oscillatoria okenii* C. Agardh, *Oscillatoria princeps* Vaucher ex Gomont, *Oscillatoria fragilis* Böcher, *Oscillatoria chlorina* Kütz., *Phormidium laminosum* (C. Agardh) Gomont, *Phormidium tenue* Gomont, *Lyngbyalutea* C. Agardh ex Gomont, *Lyngbya martensiana* Menegh., *Microcoleus acutissimus* N.L. Gardner and *Pseudo anabaena schmidlei* Jaag.
71 – 87 ºC	Leathery, deep reddish orange, 31 - 50 mm thick	*Calothrix thermalis* (Schwabe) Hansg., *Calothrix fusca* (Kütz.) Bornet & Flahault, *Microcoleus acutissimus* N.L. Gardner, *Oscillatoria geminata* Schwabe, *Oscillatoria princeps* Vaucher, *Phormidium laminosum* (C. Agardh) Gomont ex Gomont and *Mastigocladus laminosus* Cohn.

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