



Some desmid flora of Ajodhya hills and forest area in relation to physicochemical parameters of water bodies of Baghmundi (Purulia district, West Bengal)

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Abstract

Physicochemical parameters and morphotaxonomic studies of desmid flora were conducted in five lentic water bodies of Ajodhya hills and forest area of Baghmundi, Purulia, West Bengal. 17 parameters of five water bodies (surface water) were analyzed followed by APHA (2017) and morphotaxonomic studies of collected algal samples were done with the help of standard literatures, monographs etc. A total of 31 taxa were identified based on morphotaxonomical attributes. The genera with higher number of species were *Closterium* Nitzsch ex Ralfs (17), *Cosmarium* Corda ex Ralfs (10) in addition with *Micrasterias* C. Agardh ex Ralfs (1), *Penium* Breb. ex Ralfs (1), *Staurastrum* Meyen Ralfs (1) and *Euastrum* Ehren. Ex Ralfs (1). Our study was revealed that desmid flora was dominant which was indicating the oligotrophic nature of water. All species are being reported for the first time from Ajodhya hills and forest area of Baghmundi, Purulia, West Bengal. This study contributes to the knowledge of the biodiversity of this region providing support for future ecological studies and biomonitoring. Rich diversity of desmid shows that water bodies of this hilly region has still undisturbed and need protection.

Keywords: Habitat, Fresh Water, Morphotaxonomical, oligotrophic

Introduction

The desmids are single-celled green algae which can form only in the fresh water having low level of calcium and magnesium with slightly acidic pH (Lee, 2008). Although molecular techniques have been very useful in elucidating taxonomic relationships, the traditional methodology of morphometric analysis still provides important taxonomical data (Stastny & Kouwets, 2012).

Water bodies of Ajodhya hills and forest area have not been explored for green algal flora, only fragmentary report is available. Wallach (1860), Turner (1892), Biswas (1925), Plantar (1993), Mukherjee & Srivastava (1993), Mallick & Keshri (2004), Pal *et al.* (2019) have reported desmid flora from some other part of Purulia district and other districts of West Bengal. Till date no record of desmid flora of this region has been recorded. This is the first attempt to study the desmids of the water bodies mentioned above. Desmids constitute an integral part of fresh water bodies specially the tropical oligotrophic water bodies as found in the study and rich variety of desmids are encountered. In the present study altogether 6 genera of desmids have been recorded. The present paper deals with 31 taxa which have been studied morphotaxonomically.

Present study area includes five water bodies namely Upper dam (SITE-I), Lower dam (SITE-II), Marble lake (SITE-III), Kestobazar lake (SITE-IV), and Murguma dam (SITE-V) which have been selected for the present study. Upper and Lower dam are mainly used for hydro-electric power project, Marble lake adds to aesthetic beauty of the tourist, the lake was created by cutting stones when constructing the upper and lower dam. Kestobazar lake is an impoundment used by local people for various purposes and Murguma dam is being used for irrigation and drinking purposes. These serene water bodies make the place an attractive tourist spot. All the dams are source of fish fauna. The details of 5 water bodies are given below-

Materials and method

1. Water analysis

Three consecutive years (2020, 2021 and 2022) observations and analysis water quality from the five different surface water bodies of Ajodhya hills have been done. The physicochemical parameters were analysed according to the method of APHA (2017). At each site, water samples were collected at five different locations for monitoring. Samples results of those five locations have been recorded.

A total of 17 parameters were studied. These are – water Temperature, pH, Alkalinity, Phosphate, Nitrate, Chloride, Dissolved Oxygen, Chemical Oxygen Demand, Calcium, Sodium, Silicate, Potassium, Magnesium, TDS, TSS, Biological Oxygen Demand and Turbidity.

2. Morphotaxonomic part

Five water bodies were selected for the collection of samples of desmids along with other algal flora for three consecutive years. Monthly collection of samples from surface water were made and five collection sites were chosen for each water body namely Site-I, Site-II, Site-III, Site-IV, and Site-V.

The samples were brought to laboratory and examined under Levenhuk Biological Microscope (Magnification 40x to 1200x) and photographic analysis of objectives were performed with Microscope Digital Camera (Model No. SCMOS00350KPA, TOUPCAM) for morphotaxonomical studies. Both fresh and preserved (4% formalin) samples were studied and micro measurement was taken. Identification was made following The Fresh Water Algal Flora of British Isles, A Monograph of British Desmidiaceae Vol.-I&II, Algae of the Western Great Lake Area, Fresh Water Algae of Eastern India, Algal Flora of Jharkhand and other relevant literatures.

Result and discussion

1. Water analysis

The Temperature ranges from 08 – 35°C. pH value ranges from 6.8 to 8.1. Diversity of alkalinity was found. The value of alkalinity ranges from 84-112 ppm. Phosphate value ranges from 1.30 – 4.5 mg/L. Nitrate concentration ranges from 0.150 – 0.60 ppm. Chloride content varies from 12 ppm – 27 ppm. Dissolved oxygen ranges from 5.3 to 7.1 ppm., Biological Oxygen Demand ranges from 2.1mg/l to 6.2 mg/l, Chemical Oxygen Demand varied from 2.9mg/l to

5mg/l, Turbidity ranges from 0.35 to 0.80 NTU, calcium (hardness) varied from 48 mg/l to 71 mg/l, sodium value varied from 3.2 mg/l to 4.2 mg/l, potassium value varied from 1.2 mg/l to 1.7 mg/l, magnesium hardness value ranges from 45 mg/l to 61 mg/l, total solids value ranges from 79 mg/l to 118 mg/l. (Dey and Sharan,2022) [12].

The average results (2020,2021 and 2022) of water quality of 17 parameters have been done according to seasons (pre-monsoon, monsoon and post-monsoon) and given in below tables (I, II and III)-

Table 1: Water analysis (pre-monsoon season)

Sl No.	Parameter	Different Sites				
		Site- I	Site- II	Site- III	Site- IV	Site- V
1	Water Temperature (°C)	27	25	25	23	33
2	pH	7.3	7.5	7.3	6.9	6.9
3	Alkalinity (ppm)	97	93	108	102	103
4	Phosphate (mg/L)	1.17	1.6	1.8	1.6	2.0
5	Nitrate (mg/L)	0.43	0.15	0.40	0.28	0.39
6	Chloride (ppm)	20	15	26	17	24
7	Dissolved Oxygen (ppm)	5.5	6.5	6.0	6.2	6.5
8	Chemical Oxygen Demand (COD)	3.8	3.3	3.5	4.0	3.5
9	Calcium (Mg/L) Hardness	58	65	62	66	68
10	Sodium (mg/l)	82	80	86	80	79
11	Silicate (mg/L)	5	8	10	11	9
12	Potassium (mg/L)	69	75	78	72	76
13	Magnesium(mg/l)	97	99	98	96	95
14	TDS (mg/L)	497	494	500	495	497
15	TSS (mg/L)	135	139	143	134	139
16	Biological oxygen demand (ppm)	3.9	3.0	3.6	3.3	5.7
17	Turbidity (NTU)	0.43	0.55	0.47	0.79	0.70

Table 2: Water analysis (monsoon season)

Sl No.	Parameter	Different Sites				
		Site- I	Site- II	Site- III	Site- IV	Site- V
1	Water Temperature (°C)	32	39	33	32	35
2	pH	8.2	8.3	6.9	7.4	7.1
3	Alkalinity (ppm)	112	86	116	108	107
4	Phosphate (mg/L)	1.1	1.3	2.1	1.2	2.6
5	Nitrate (mg/L)	0.39	0.13	0.15	0.19	0.15
6	Chloride (ppm)	24	20	29	27	26
7	Dissolved Oxygen (ppm)	5.6	5.4	5.1	5.1	4.9
8	Chemical Oxygen Demand (COD)	2.9	2.11	3.3	2.10	2.9
9	Calcium (Mg/L) Hardness	47	61	60	66	63
10	Sodium (mg/l)	85	85	78	85	82
11	Silicate(mg/L)	6	11	7	12	11
12	Potassium (mg/L)	73	77	73	73	79
13	Magnesium(mg/l)	100	97	98	100	95
14	TDS (mg/L)	502	497	499	597	497
15	TSS (mg/L)	141	133	142	134	137
16	Biological oxygen demand (ppm)	3.3	3.0	3.3	3.4	5.8
17	Turbidity (NTU)	0.50	0.62	0.50	0.76	0.72

Table 3: Water analysis (post -monsoon season)

Sl No.	Parameter	Different Sites				
		Site- I	Site- II	Site- III	Site- IV	Site- V
1	Water Temperature (°C)	15	19	19	19	21
2	pH	6.9	6.9	7.3	6.9	7.2
3	Alkalinity (ppm)	90	94	98	104	98
4	Phosphate (mg/L)	1.29	1.2	1.3	2.2	1.8
5	Nitrate (mg/L)	0.51	0.21	0.58	0.41	0.58
6	Chloride (ppm)	18	14	16	10	21
7	Dissolved Oxygen (ppm)	5.8	6.9	6.8	7.1	6.9
8	Chemical Oxygen Demand (COD)	5.1	4.4	4.5	4.0	4.6

9	Calcium (Mg/L) Hardness	69	64	68	72	69
10	Sodium (mg/l)	86	80	85	84	79
11	Silicate(mg/L)	8	8	11	8	12
12	Potassium (mg/L)	72	77	73	75	76
13	Magnesium(mg/l)	99	98	97	99	99
14	TDS (mg/L)	488	495	502	497	502
15	TSS (mg/L)	135	138	138	137	141
16	Biological oxygen demand (ppm)	3.9	3.3	3.6	3.5	6.3
17	Turbidity (NTU)	0.36	0.56	0.44	0.79	0.76

Morphotaxonomic part

Collected specimens were identified by standard literatures (Each species case is given in its brackets). They are unicellular having 'semi cells' joined each other by 'Isthmus'. Each semi cell contains one or more axial or parietal chloroplast with different shape and single or more pyrenoids. Cell wall having diverse ornamentation patterns which may be smooth, sinulate, verrucate, undulate, crenulate, striated, granulate etc. Reproduction occurs by conjugation with amoeboid non-flagellate gametes forming thick-walled various ornamented zygospores.

After identification systematic parts are given below-

Systematic enumeration

Class: Chloropyceae

Order: Zygnematales

Family: Desmidiaceae

Genus: *Closterium* Nitzsch ex Ralfs

1. *Closterium abruptum* West (plate.1, Fig.a&i)

(John et al.2011^[17], p.618, pl.154S; Prescott et al.1975, p.25, pl.18, f.9-12; Sharan et al. 2010, p.495-499; Keshri et al.2013, No.2, p.37-44)

Date of collection: 01.08.2022

Place of collection: site- I, III

Collection No.: P.D 251

2. *Closterium acerosum* Ralfs (plate.1, fig.b.)

(John et al.2011^[17], p.620, pl.154E; Habib.2005(Keshri&Kargupta, 2005.Glimpses of Indian Phycology, p.75-85)

Date of Collection: 03.09.2022

Place of Collection: site-I, V

Collection No.: P-. D 255

3. *Closterium acutum* Brébisson in Ralfs (plate.1, Fig.c.)

(Aquino et al.2016^[2], p.669-688, f.38; Carter et al.1904^[4] (vol-I), p.177, pl. XXIII, f.9-14)

Date of collection: 08.12.2022

Place of collection: site- Site-I, II, V

Collection No.: PD250

4. *Closterium closterioides* var.*intermedium* (J.Roy&Bisset)Ruzick (plate.1, Fig.d.)

(Shakmatov et al.2019, p.12, f.2,2; John et al.2011^[17], p.622, pl.153A)

Date of collection: 01.09.2022

Place of collection: Site-I, II, V

Collection No.: P.D 260

5. *Closterium costatum* Corda ex Ralfs (plate.1, Fig.e.)

(Shakmatov et al.2019, p.12, f.3; John et al.2011^[17], p.623, pl.154Q)

Date of Collection: 03.09.2022

Place of Collection: site-I, II

Collection no.:P.D 257

6. *Closterium diana* Ehren. ex Ralfs (plate.1, Fig.f.)

(West,W and W,G.,S.,1994,Vol.1,p.130,pl.15, Fig.1-6; GuptaR.K.2021,(BSI),P.86)

Date of collection: 03.08.2022

Place of collection: Site- I, V

Collection No.: P.D 252

7. *Closterium ehrenbergii* Menegh ex Ralfs (plate.1, Fig.g.)

(Prasad&Misra,1992 p.116, fig.5; John et al.2011^[17], p.625, pl.154B)

Date of collection: 11.01.2020

Place of collection: Site-I

Collection No.:P.D 120

8. *Closterium moliniferum* (Bory)Ehrenb.var. *moliniferum* Die Infus (plate.1, Fig.h.)

(Oliviera et al.2013, p.125, f.43; Das &Adhikary,2014. p.92, pl.6, f.3; Gupta,R.K. 2021.p.87)

Date of collection: 02.08.2022

Place of collection:Site- I,II,V

Collection No.: P. D254

9. *Closterium stirgosum* Brébisson (plate.1, Fig.j.)

(Das &Adhikary,2014. p.93, pl.6, f.8; West et al.1905(vol.II),P.165,Pl.XXI,f.6,7)

Date of collection: 02.08.2022

Place of collection:site-Site I,II

Collection No.:P.D 256

10. *Closterium tumidulum* Gay (plate.1, Fig.k.)

(Das&Adhikary.2014, p.93, pl.6, f.10)

Date of collection: 03.09.2022

Place of collection: site- I, V

Collection No.:P.D 253

Genus: *Cosmarium* Corda ex Ralfs (Plate-2, Fig.a)

1. *Cosmarium birectum* Ralfs

(John et al.2011^[17], p.669, pl.164Q)

Date of collection: 12.12.2020

Place of collection: site- I,

Collection No.:P.D 179

2. *Cosmarium botrytis* Meneghini ex Ralfs (Plate-2, Fig.b)

(John et al.2011^[17], p.647,669, pl.164B)

Date of collection: 01.08.2022

Place of collection: site- I, II, V

Collection No.:P.D 278

3. *Cosmerium circulare* Reinsch var. *messikomeri* Krieger et Gerloff (Plate-2, Fig.c)

(Mishra et al. 2008, p.180, pl.1, f.7)

Date of collection: 05.08.2021
Place of collection: site- III, V
Collection No.: P.D 165

4. *Cosmarium contractum* var. *ellipsoideum* (Elfving) West Et G.S. West

(West *et al.* 1905(vol.II),p.171,LXI)
Date of collection: 04.09.2022
Place of collection: site- I, II, V
Collection No.: P.D 280

5. *Cosmarium difficile* Lutkemuller (Plate.2, Fig. e)

(John *et al.* 2011^[17], p.552, pl.162U; Das & Adhikary 2014.p.110, pl.8, f.11)
Date of collection: 04.03.2021
Place of collection: site- II
Collection No.: P.D 166

6. *Cosmarium formosulum* Hoffman (Plate.2, Fig. f)

(John *et al.* 2011^[17], p.553, pl.164D; Mishra *et al.* 2008, p.179-180, pl.1, f.11)
Date of collection: 01.09.2022
Place of collection: site-I, II, III
Collection No.: P.D 269

7. *Cosmarium granatum* Brébisson ex Ralfs (Plate.2, Fig. g)

(John *et al.* 2011^[17], p.653, pl.160V; Das & Adhikary 2014, p.111, pl.8, f.15)
Date of collection: 05.08.2022
Place of collection: site-I, V
Collection No.: P.D 272

8. *Cosmarium leave* Robenhort (Plate.2, F.h)

(John *et al.* 2011^[17], p.655, pl.162V; Das & Adhikary, 2014, p.112, pl.8, f.17)
Date of collection: 08.09.2022
Place of collection: site-I, II,
Collection No.: P.D 276

9. *Cosmarium margaritatum* (P.Lundell) Roy E.T (Plate.2,F.i)

(John *et al.* 2011^[17], p.655, pl.164L; Gupta, R.K. 2021, P.91; Das Adhikary, 2014.p.113, pl.8, f.23)
Date of collection: 03.09.2022
Place of collection: site-I, II,
Collection No.: P.D 273

10. *Cosmarium nitidulum* De Notaris (Plate.2, F. j)

(John *et al.* 2011^[17], p.197, pl. LXIV, f.1-3; Das & Adhikary, 2014, p.114, pl.8, f.26)
Date of collection: 02.08.2022
Place of collection: site- II
Collection No.: P.D 280

11. *Cosmarium obtusatum* Schimidle (Plate.2, F.k)

(Phykos.1971(vol.10), p.60)
Date of collection: 03.09.2022
Place of collection: site- II, III
Collection No.: P.D 271

12. *Cosmarium ornatum* Ralfs var. *ornatum f.ornatum* (Plate.2,F.l)

(Aquino *et al.* 2016^[2], p.674, f.21 a-c; John *et al.* 2011^[17], p.658, pl.163D)

Date of collection: 03.09.2022
Place of collection: site- I, II, V
Collection No.: P.D 270

13. *Cosmarium punctulatum* Brébisson (Plate.2, F.m)

(John *et al.* 2011^[17], p.663, pl.163S)
Date of collection: 11.07.2021
Place of collection: site- III
Collection No.: P.D 155

14. *Cosmarium pyramidatum* Ralfs (Plate.2, F.n)

(John *et al.* 2011^[17], p.666, pl.162 A)
Date of collection: 04.09.2022
Place of collection: site- I, II
Collection No.: P.D 170

15. *Cosmarium subtumidum* Nordstedt (Plate.2, F.o)

(John *et al.* 2011^[17], p.671, pl.165E)
Date of collection: 06.04.2021
Place of collection: site- V
Collection No.: P.D 144

16. *Cosmarium turpinii* var. *podolicum* Gutwinski (Plate.2, F.p)

(John *et al.* 2011^[17], p.673, pl.163L)
Date of collection: 11.07.2022
Place of collection: site- II, IV
Collection No.: P.D 288

17. *Cosmarium venustum* (Brébisson) W.Archer (Plate.2,F.q)

(Phykos, Vol.10, 1971, p.65; John *et al.* 2011^[17], p. 673, pl.162H)
Date of collection: 03.09.2022
Place of collection: site- I
Collection No.: P.D 272

Genus: *Euastrum* Ehrenberg ex Ralfs

1. *Euastrum bidentum* Nageli (Plate.3, F.a)

(Shakhmatov *et al.* 2019, p.11-12; West *et al.* 1905(vol.I),p.39,pl.XXXVII,f.16-19; John *et al.* 2011^[17], p.678,679,684,pl.167H)
Date of collection: 01.09.2022
Place of collection: site-I, II,
Collection No.: P.D 265

Genus: *Micrasterias* Agardh ex Ralfs

1. *Micrasterias apiculata* (Ehrn.) Menegh. (Plate.3, F.b)

(Levvanets *et al.* 2008; John *et al.* 2011^[17], p.688, pl.168A)
Date of collection: 11.07.220
Place of collection: site- I, II, V
Collection No.: P.D 96

Genus: *Penium* Breb. Ex Ralfs

1. *Penium spirostriolatum* J.Barker (Plate.3,F.c)

(John *et al.* 2011^[17], p.635, pl.152W)
Date of collection: 02.09.2022
Place of collection: site-I, III, V
Collection No.: P.D 264

Genus: *Staurastrum* (Mayen) Ralfs. *Staurastrum pentacerum* (Wolle) G.M.Smith (Plate.3,F.d)

(Gerrath *et al.* 1983^[15], p.141-150)
Date of collection: 01.09.2022
Place of collection: site- I, III
Collection No.: P.D 262

Discussion

Desmids display characteristics of good bioindicator. They prefer freshwater habitats with slightly acidic and respond to changes in the environment. In this study area, desmid flora increases as water quality improves and different species appear in desmid communities with changing water conditions. So, water quality plays a significant role in the distribution of desmids in the inland water. Green algae such as desmids form the base of food chain of any ecosystem. The quality of water effects the distribution of algae. Fish fauna are also dependent on the nature of food in the form of algae. In our research area (5 water bodies) no artificial food are being provided for fishes. Distribution pattern of desmids are very much dependent on the quality of water.

Lowest number of desmids taxa were found in Murguma and Kestobazar dam. Certain portion of these water bodies are used by few local people of the neighbouring for various purposes like washing clothes, utensils, bathing, domesticated livestock washing etc. and these boarder areas have been avoided for collection. The collections were made from the undisturbed part of areas. Maximum number of taxa (21) were found in Upper dam followed by Lower dam (19), undisturbed part of Murguma dam (14), Mable lake (2). Maximum number of taxa were collected in the month of September.

The occurrence of diverse desmid flora is further supported by oligotrophic nature as reported by the authors previously.

All the desmids studied in the present paper have shown resemblance with type specimens as mentioned in the literatures.

Conclusion

Desmids are diverse group of microscopic algae that could serve as bioindicators, live in clear, unpolluted water and most of them prefer to water that is low in nutrients and slightly acidic (Mager,2022). This study contributes to the knowledge of the biodiversity of this hilly region providing support for future ecological studies and biomonitoring. Rich diversity of desmids show that water bodies of these hilly areas are still undisturbed and need protection for preservation of algal biodiversity.

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Conflict of interests

No conflict of interest.

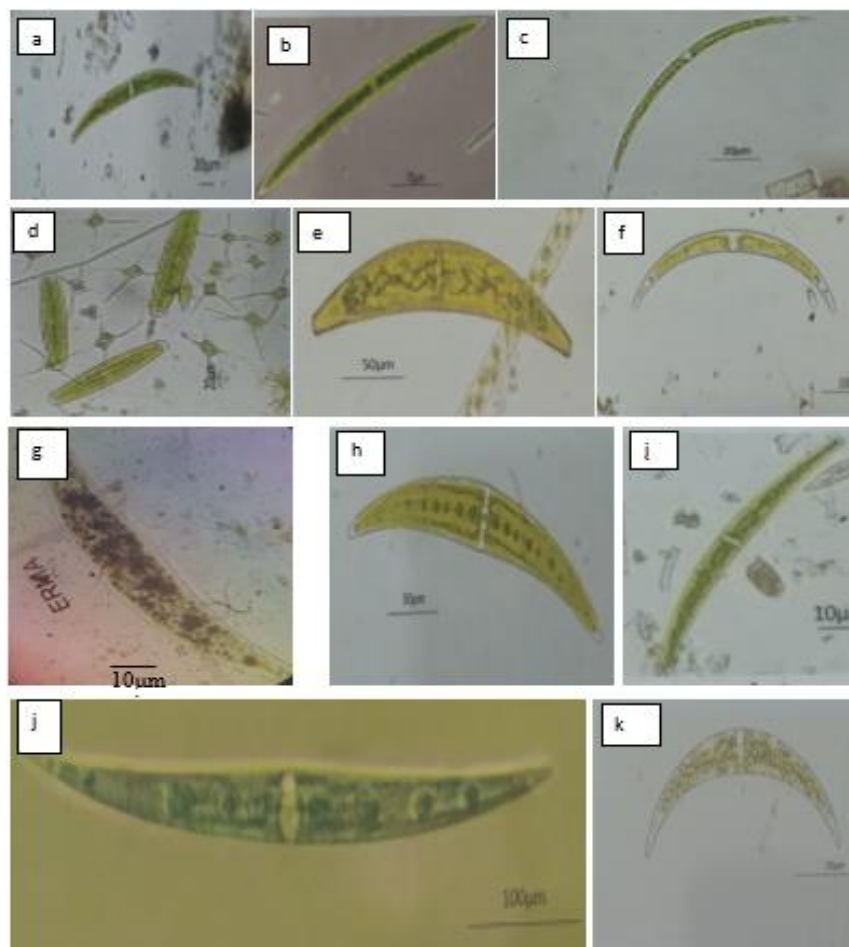


Plate.1. Micro-photograph of Desmid taxa from study area. (a):*Closterium abruptum* West; (b):*Closterium acerosum* Ralfs;(c):*Closterium acutum* Brebs in Ralfs;(d):*Closterium closterioides* var.*intermedium* (J.Roy&Bisset)Ruzick;(e):*Closterium costatum* Corda ex Ralfs;(f):*Closterium diana*e Ehren. ex Ralfs;(g):*Closterium ehrenbergii* Menegh ex Ralfs;(h):*Closterium moliniferum* (Bory)Ehrenb.var. *moliniferum* Die Infus; (i): *Closterium abruptum* West;(j):*Closterium stirgosum* Breb.:(k): *Closterium tumidulum* Gay

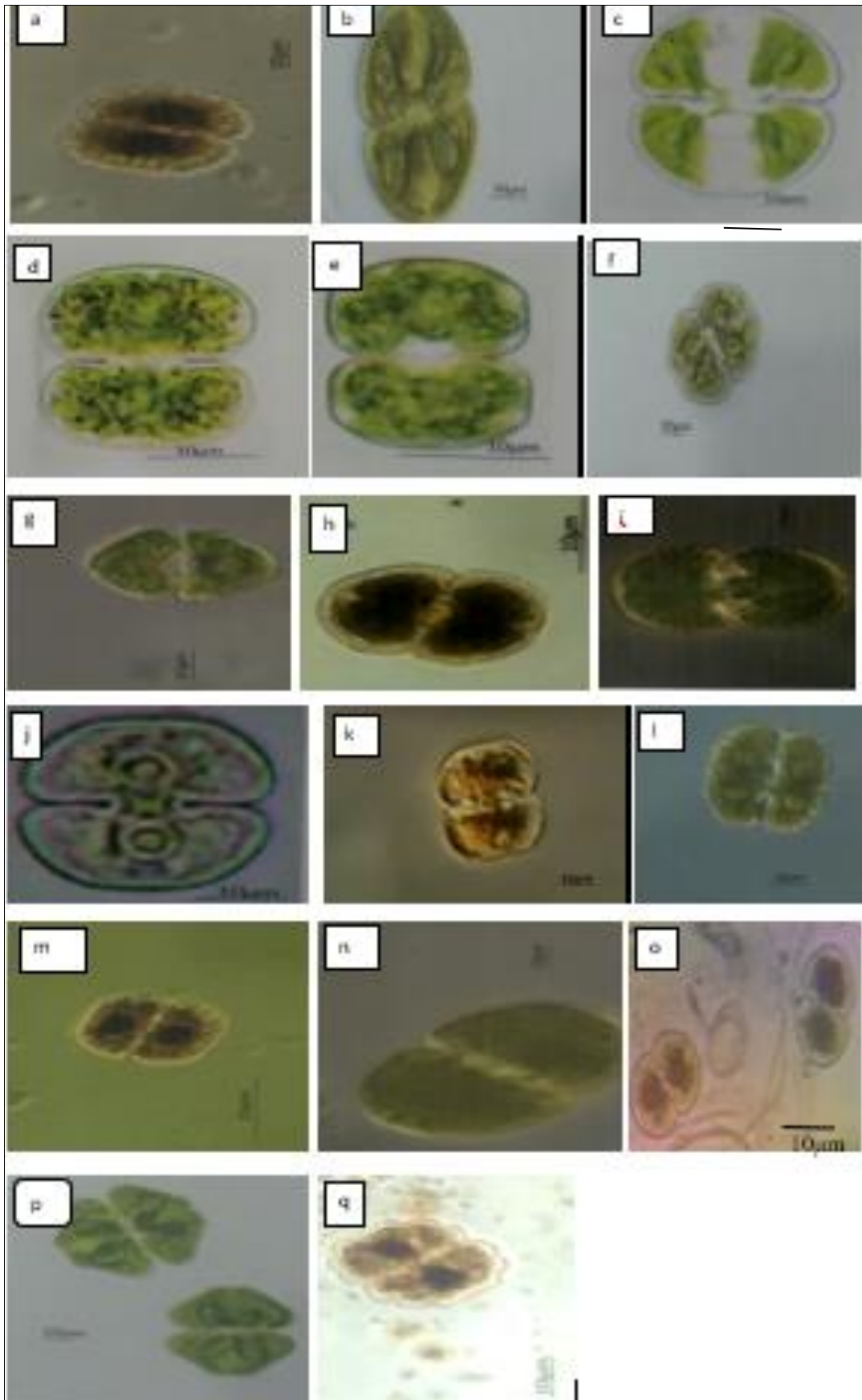


Plate.2. Micro-photograph of Desmid taxa from study area.(a):*Cosmarium birectum* Ralfs;(b):*Cosmarium botrytis* Meneghini ex Ralfs;(c):*Cosmarium circulare* Reinsch var.*messikomeri* Kriegeret Gerloff;(d):*Cosmarium contractum* var.*ellipsoideum* (Elfv.)West Et G.S West;(e):*Cosmarium difficile* Lutkemuller;(f):*Cosmarium formosulum* Hoffman;(g):*Cosmarium granatum* Breb.Ex Ralfs;(h):*Cosmarium leave* Robenhorst;(i):*Cosmarium margaritatum* (P.Lundell)Roy E.T;(j)*Cosmarium nitidulum* De Not.:(k)*Cosmarium obstusatum* Schmidle;(l):*Cosmarium ornatum* Ralfs var. *ornatum f.ornatum*;(m):*Cosmarium punctulatum* Breb.:(n):*Cosmarium pyramidatum* Ralfs;(o):*Cosmarium subtumidum* Nordstedt;(p):*Cosmarium turpinii* var. *podolicum* Gutwinski;(q):*Cosmarium venustum* (Breb.)W.Archer

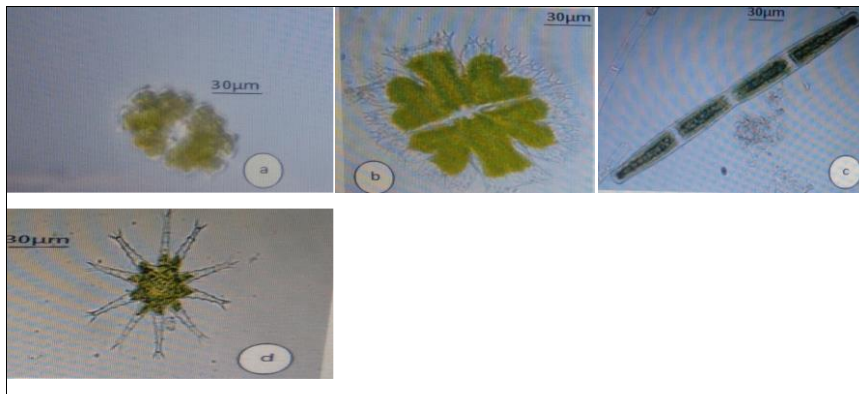


Plate 3: Micro-photograph of Desmid taxa from study area. (a):*Euastrum bidentum* Nageli;(b):*Micrasterias apiculata*(Ehrn.)Menegh. ;(c):*Penium spirostriolatum* J.Barker;(d):*Staurastrum pentacerum*(Wolle)G.M.Smith

References

1. APHA. "Standard methods for the examination of water and wastewater. American public health association," 23rd Edition, 2017, Washington, USA
2. Aquino CAN, Bueno NC, Servat LC, Bortolini, JC. "New records of *Cosmarium* Corda ex Ralfs in lotic environment adjacent to the Iguaçu National Park, Paraná State, Brazil. *Hoehnea*", 2016;43:669-688
3. Biolo S, Bueno NC, Siqueira NS, Moresco C. "New records of *Cosmarium* Corda ex Ralfs (Desmidiaceae, Zygnematophyceae) in a tributary of the Itaipu Reservoir, Paraná, Brazil". *Acta Botanica Brasilica*, 2013;27: 1-12.
4. Carter N, West GS, West W. "A monograph of British Desmidiaceae, vol.-I(Reprint), Legare street Press an imprint of creative media partners, 1904.
5. Das SK, Adhikary SP. "Freshwater algae of Sikkim", *J. Indian Bot. Soc.*, 2010;89:169-184.
6. Das D, Keshri, JP. "Desmids from Manmecho (Mamencho) Lake, Eastern Himalaya. I." *NeBio*, 2012;3(2):37-44.
7. Das D, Keshri JP. "Coccal green algae from Betang-cho lake (a high-altitude lake in Eastern Himalaya)", *Indian Hydrobiol*, 2012;15:171-182.
8. Das PR, Santra SC. "Diatoms of Senchal lake, Darjeeling", *Phykos*, 1982;21:99.
9. Das D, Keshri, JP. "Desmids from Manmecho (Mamencho) Lake, Eastern Himalaya. I." *NeBio*, 2012::3:37-44.
10. Das D, Keshri JP. "Desmids of Khechiperi Lake, Sikkim Eastern Himalaya". *Algological Studies*, 2013;143:27-41.
11. Debnath M, Mandal DK. "Some interesting desmids of Birbhum district, West Bengal, India". *Wesleyan J. Res.*, 2012;4(1):56-60.
12. Dey P, Sharan L. "Physicochemical properties of different water bodies of Ajodhya, Baghmundi block, Purulia, W.B., India," *Paripex Indian Jr. of Reseach*, 2022;11(1):26-38
13. Dhande JS, Jawale AK. "Genus *Cosmarium* Corda from Hartala Lake district, Jalgaon, Maharashtra" *Intl. Res. J.*, 2009;2(7):196-198.
14. "EIA Report for Turga pumped Storage Project, West Bengal (Previously known as Purulia Pumped Storage Extension Project on Turga Nala) WBSEDCL, Govt. of West Bengal, 2016, 1-2.
15. Gerrath JF. Polymorphism in the desmid *Staurastrum pentacerum*(Wolle) G.M.Smith.Br." *Phycel J.*, 1983;18:141-150.
16. Gupta RK. *Algal flora of Jharkhand*, BSI, Kolkat, 2021.
17. John DM, Whitton, Broke AJ (Eds). "The fresh water algal flora of the British Isles: an identification guide to fresh water and terrestrial algae," Cambridge University Press, Cambridge, 2011.
18. Kant S, Gupta P. "Algal flora of Ladakh", Scientific Publishers, India, 1998.
19. Keshri JP, Ghosh AK, Ghosh S, Roy S, Chakraborty A. Fresh water planktonic algae from oligotrophic habitat of West Bengal with special remarks on taxonomy and ecology". *Journal of Environmental Biology*, 2017;38:1441-1447.
20. Keshri JP, Kargupta AN. "Glimpses of Indian Phycology P. Sarma Felicitation". Bishen Singh Mahendra Pal Singh, Dehradun, India, 2005:75-85.
21. Levants AA, Taylor JC, Rensburg L Van. "Morphology of *Micrasterias apiculata* (Desmidiaceae, Chlorophyta) from Magaliesberg, South Africa", Gabrone conference, 2008, 38.
22. Magner, Mollie. Desmid communities and environmental conditions of New England wetlands." Ph. D. Thesis. Assumption University, 2022;38:11-12-14.
23. Mallick P. Studies on the desmid flora of Bankura and Purulia Districts West Bengal India". Ph.D. Thesis. Shodhganga <http://hdl.handle.net/10603/64025:2006>
24. Misra PK, Misra P, Shukla M, Prakash J. "Some Desmids from Garhwal Region of Uttarakhand, India", *Algae*, 2008;23:177-186.
25. Mukherjee D, Srivastava DN. "Some desmids of Purulia (West Bengal)", *J. Indian Bot. Soc.*, 1993;72:293-297.
26. Munshi JD, Munshi JD. "Fundamentals of Limnology", Daya Pub. House, New Delhi, 2015.
27. Nandi C, Bhowmik S, Gorain PC, Pal R. New and Rare Records of *Cosmarium* (Desmidiaceae, Zygnematales) from India", *Phytomorphology*, 2019;69(1-2):41-49.
28. Pal UC, Santra SC. "Algal flora of Mednapore. Desmidiaceae". *Phykos*, 1993;32:3-1-2.
29. Pandey UC, Pandey DC. "Addition to the algal-flora of Allahabad-V" Desmids. *Phykos*, 1980;19:161-170.
30. Pandey UC, Habib UC, Gangwar FC, Shukla HM. A contribution to our knowledge of desmids from Bareilly", 1981;26:86-94.

31. Patel RJ. On desmids of Gujarat". J. Bombay Nat. Hist. Soc, 1969:66:414–419.
32. Patel RJ. Desmids of Gujarat, India I. Genus *Closterium* Nitzsch". Phykos, 1979:18:111–124.
33. Patil KJ, Mahajan RT, Mahajan SR. Plankton diversity of Jalgaon district, Maharashtra (India). J. Algal Biomass Util, 2012:3:71–102.
34. Phykos. "Phycological Society of India". New Delhi, 1971, 10(1-2).
35. Prakash J Kishore, S Asthana DK, Misra PK, Singh SK. "Morphotaxonomy of freshwater chlorophycean algae (Desmids) from Siddharth Nagar, U.P., India." Ecoprint, 2005:12:21–25.
36. Prasad BN, Mehrotra RK. "Desmid flora of North Indian paddy fields". New Botanist, 1977:4: 49–74.
37. Prasad BN, Misra R. Desmid flora of Sikkim-I Geophytologia, 1987:17:163–173.
38. Prasad BN, Srivastava MN, Khanna P. Diatoms of Kalimpong, West Bengal (India)", Geophytologia, 1988:18:78–86.
39. Prescott GW. Revised Edition. Algae of the western great lake area. WM. C. Brown Company Publisher, Dubuque, Low, 1962.
40. Santra SC, Pal UC. Desmid flora of Eastern Sikkim & West Bengal, 2006.
41. Sharan L, Sinha R. Biomonitoring of a fresh water habitat of Ranchi (Hatia Dam) on the basis of Nygaard's Indices", Bioscan, 2010:5:495–499.
42. Shukla SK, Shukla CP, Misra PK. Desmids (Chlorophyceae, Conjugales, Desmidiaceae) from Foothills of Western Himalaya, India" Algae, 2008:23:1–14.
43. Suseela MR, Toppo K. Enumeration of Freshwater Algal Flora of Gangtok, Sikkim, India. Geobios, 2006:33:225–232.
44. Suxena MR, Venkateswarlu V. Desmids from Andhra Pradesh, I from Pakhal Lake, Warangal". Hydrobiologia, 1968:28:49–65.
45. Toppo K, Suseela MR. *Cosmarium* diversity of Mani Pokhar pond of Jashpur district in Ahhattisgarh state. India." Ann. Forestry, 2009:17:117–124.
46. West GS, Carter N, West W. A monograph of British Desmidaceae, (Reprint), Legare street Press an imprint of creative media partners, 1905, 2-1.
47. West W. Algae of the English lake district". J Roy Microscop Soc, 1892: 8:713–748.
48. Wallich GC. Desmidaceae of Lower Bengal." An. Mag. Nat. Hist. 1860:3:184-187:273-285.
49. Wolle F. Desmids of the United States and the list of American *Pediastrum*, *morarian* Pub. Office, 1892.