

Ecology and Diversity of Algae in Godavari River, Near Bhadrachalam, Telangana

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ABSTRACT

A study evaluated Godavari River algal ecology and diversity. Three sites took monthly water and algal samples from the Godavari River at Bhadrachalam from February 2022 to January 2024. Analysis of water and wastewater samples included physico-chemical parameters. At stations I and II, the river had low pH, carbonates, bicarbonates, chlorides, dissolved oxygen, phosphates, and total hardness. However, station III near the effluent channel had high bicarbonates, chlorides, organic matter, total hardness, and phosphates. Phycological factors were evaluated for quantitative and qualitative benthic and planktonic organism assessments. *Cymbella aspera*, *Synedra ulna*, *S. tabulata*, *Achnanthes minutissima*, *Navicula bacillum*, *Gomphonema montanum*, *Merismopedia punctata*, *M. glauca*, *Oscillatoria formosa*, *Cosmarium variolatum*, *Coelastrum cambricum*, *Oedogonium* species, and *Spirogyra* species were common in the water of the Godavari River prior to waste management. *Euglena polymorpha*, *Gomphonema parvulum*, *Scenedesmus quadricauda*, *Nitzschia obtusa*, *Nitzschia palea*, *N. hungarica*, *N. acicularis* var. *closterioides*, *N. thermalis*, *Oscillatoria chalybea*, *O. ornata*, *Synedra tabulata*, *Scenedesmus quadricauda*, *Pandorina morum*, and *Nitzschia* are common in the water of the Godavari River before waste. *Oscillatoria chalybea*, *O. ornata*, and *Nitzschia obtusa* flourished in the effluent channel. In conclusion, the river has many species and diversity.

Key words: Ecology, Diversity, Water quality and River Godavari

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INTRODUCTION

Water is priceless, the bitterness of which is experienced by virtually every generation and every nation. A drop of moisture in the desert is worth its weight in gold. Freshwaters are, perhaps, the most vulnerable habitats and thus most likely to be changed by the activities of man [1]. Water pollution becomes a severe problem with industrialization of nations coupled with rapid acceleration in population growth. Industrialization leads to urbanization and domestic wastes from the rapidly expanding towns and wastes from industrial processes are all poured treated/untreated into the nearest inland waters [2]. Thus, lakes act as sinks for many of the products of human activity in their catchments, while the rivers are the naturally provided drains for the removal of waste to sea, making the effluents of some towns, the water supplies of other towns in downstream [3]. For this reason alone, it is important that the effluent discharge into a water course is of high quality and the degree of pollution is such that the self-purifying capacity of the river is not impaired [4].

The Western Ghats is the main watershed in the Indian Peninsula. Major rivers of the Peninsula such as the Godavari, the Krishna, the Mahanadi and the Cauvery flow eastwards on the plateau and drain into the Bay of Bengal. These rivers have built large deltas at their mouths. The peninsular rivers differ from the Himalayan rivers in flow patterns due to differences in climatic regimes. The regimes of peninsular are controlled by monsoon as they are rainfed whereas the regimes of Himalayan rivers are dependent on the pattern of water supply both from snow-melt and rainfall. The River Godavari, the largest of the Peninsular rivers, rises at Triambak in Nasik district of Maharashtra, enters Andhra Pradesh in Adilabad district and joins the Bay of Bengal near Antarvedi after traversing a distance of 1.465 kms. The drainage basin extends over 312,812 sq.kms., of which, 50 per cent lies in Maharashtra. Besides Maharashtra, it is shared by Madhya Pradesh, Karnataka, Orissa, Telangana and Andhra Pradesh. Its principal tributaries

include Pravara, Purna, Manpra, Penganga, Wainganga, Wardha, Pranhita, Indravati, Maner, Kinnerasani and Sabari. The Godavari flows at a low level until May. It has a double maxima-one in May-June and the other in July-August. After August there is a sharp fall in discharge although the volume of flow in October and November is higher than in any of the months from January to May.

MATERIAL AND METHODS

The river Godavari, the largest of the Peninsular rivers, rises in the Nasik district of Maharashtra, enters Andhra Pradesh State and joins the Bay of Bengal near Antarvedi after traversing a distance of 1465 km. The river provides large quantities of fresh water to Bhadrachalam Paper Boards for processing of the paper and in turn receives enormous quantities of liquid wastes. Water and algal samples were collected from three sampling sites along the course of the river near Bhadrachalam town at monthly intervals for a period of two years. Samples were collected in the river before the entry of wastes (Station I), at the point of entry of wastes (Station II) and at 1 km after the entry of wastes into the river (Station III). Effluents were also collected just before their discharge into the river. Samples were analyzed for selected variables by following the standard procedures [5]. For the collection and analysis of algae, the technique of Blum, J.L. 1956 & 1957 [6 & 7] was followed, described in detail by Venkateswarlu et al. [8]. Four or five uniformly sized pebbles (2 x 2 in) coated with brown or green scum were collected from the habitat in a wide-mouthed bottle containing 250 ml of water. The pebbles were scraped carefully with a scalpel and a brush. The samples were preserved in 4% formaldehyde solution and the final volume of sample was reduced to 50 ml by sedimentation. The concentrated material was used for frequency measurements and species identification.

In Telangana a large number of industries (large, medium and small scale) including Pesticides, Rayon, NTPC, Paper and Pulp mills are located on the banks of the River Godavari. To meet the water needs, they draw large quantities of water and let out the factory wastes into the river in the downstream in enormous quantities. One of such big industries is the Bhadrachalam Paper Boards with an annual turnover of Rs 6 crores. It is located on the right bank of the River Godavari near Bhadrachalam town in Khammam district of Telangana. It draws the required water from the river in the upstream and releases the liquid wastes in the downstream at Burgampad town through an open channel of about 5 km length. 3 Sampling sites were selected along the river course and they are characterized as follows.

SAMPLING STATIONS

Station 1: Site I is near the bridge located across the river near Bhadrachalam town, 100 meters above which is the water pumping station to meet the drinking needs of the town. Here the substratum was more silty than sandy. Huge rocks were found in the river bed. Very little human disturbance was found here because of more depth of the river (8-10 ft.). Water was confined to a large channel in the river towards the town side in most of the months in a year. The water was relatively clean and was selected as an index of pure water.

Station II: This is located in the downstream near Burgumpad town where the industrial effluents from Bhadrachalam Paper Boards join the river waters. It is located about 3 Km from station I along the course of the river. The flow was greater than at station 1. The bottom was sandier and with huge rocks. Pebbles were found rarely due to complete clogging up of the bottom by organic detritus discharged through paper board effluents. Adjacent soil or silt was completely water logged. The water was confined to a part of the river (towards opposite side of Bhadrachalam town). This site was selected to see the effects of paper mill effluents on river water and algal composition.

Station III:

It is about 1 Km distance from the point of entry of effluents. Here the water is subjected to human disturbances because the water is drawn some times for agricultural purposes. The substratum consists of a large number of pebbles with huge stones here and there. The rate of flow is much higher than that at the other two stations. This site was selected to study the degree of dilution of effluents.

RESULTS AND DISCUSSION

Water and effluent samples were analyzed for carbonates, bicarbonates, chlorides, dissolved oxygen, organic matter, ammonia, nitrates, nitrites, silicates, phosphates, total hardness, calcium, magnesium, total solids, dissolved solids and suspended solids by following the standard procedures (Table:1).

pH and temperature were recorded in the field itself. Quantitative as well as qualitative estimations of both benthic and planktonic organisms were taken into consideration under phyecological parameters. In the river Godavari, at station 1, the average pH was around 8.5. Bicarbonates ranged between 82 and 214 mg/L, while chlorides were present in the range of 14-36.5 mg/L. Dissolved oxygen was always above 6.0 mg/L. Organic matter attained a maximum of 2.56 mg/L. Total solids have not exceeded 600 mg/L.

At station II, the average pH was 7.6. Carbonates reached a maximum of 16.2 mg/L. Bicarbonates were quite high (87.8- 307.4 mg/L) and chlorides fluctuated between 38.2 and 216.9 mg/L. Dissolved oxygen was present in the range of 1-8.8 mg/L with an average of 4.0 mg/L. Very high organic matter content (avg. 18 mg/L) was recorded. Total solids were recorded in quite high concentrations (900-2500 mg/L). Calcium and magnesium were in the ranges of 18.7-112.3 and 8.7-68.2 mg/L respectively. At station II, Bicarbonates attained a maximum of 274.5 mg/L. Chlorides were in the range of 12.7-129 mg/L. Organic matter reached a maximum of 28.1 mg/L. Silicates were recorded in the range of 0.51-10.2 mg/L. The effluents were characterized by the presence of high organic matter, dissolved and suspended solids and very low dissolved oxygen.

Thus, most of the factors analyzed showed that their concentrations increased by more than 100% from Station I to Station II. However, at Station-III most of these factors decreased by less than 50% thus recording low rate of dilution.

Certain heavy metals like Cd, Cr, Pb, Co, Ni, Cu, Zn, Fe and Mn were also estimated in the effluents and in the river waters as well.

In the effluents of Bhadrachalam Paper Boards, chromium fluctuated between 60 and 210 mg/L whereas cobalt was observed up to a maximum of 60 mg/L. Zinc attained a maximum of 2000 mg/L, while manganese was observed with an average of 270 mg/L. After the entry of effluents into the river cadmium attained a maximum of 2 mg/L and no significant dilution was recorded in the lead concentration. Nickel and zinc showed considerable dilution with their averages being 37 and 280 mg/L respectively. At Station III, there was significant dilution in the concentrations of various heavy metals. The average value of cadmium was 1 mg/L. Chromium fluctuated between nil and 80 mg/L and lead ranged between nil and 30 mg/L. Nickel was recorded in the range of nil to 40 mg/L, whereas zinc attained a maximum of 1100 mg/L.

The results of various physico-chemical factors were compared with the standards stipulated for drinking purposes by various National and International organizations like WHO & ISI. Before the entry of effluent into the river waters the important factors like pH, dissolved oxygen, oxidizable organic matter, nitrates, dissolved and suspended solids are within the permissible limits assigned for drinking water purposes. However, after the entry of wastes, there was a considerable change in the water chemistry. At Stations II & III, various chemical factors like dissolved solids, suspended solids and organic matter are found to exceed the permissible limits and dissolved oxygen is below the required levels.

In the effluents, certain factors like dissolved solids, suspended solids, iron exceeded the limits of Minimum National Standards stipulated for the discharge of industrial wastes into the inland waters.

Algae:

In the river Godavari, the percentage composition of diatoms is greater at stations I and III than at station II. At the latter station blue- greens constitute the majority of benthic populations. The prevalence of Cyanophyceae at station II, is the result of their tolerance to low DO and their ability to utilise the organic matter for metabolism. The main components of Chlorophyceae are chlorococcales and desmids along with luxuriant growths of Oedogonium sps, Spirogyra sps. Except some chlorococcales, desmids, Oedogonium sps and Spirogyra sps are sensitive to heavy pollution as is evident by their disappearance at station II. The occurrence of euglenoid-flagellates in considerable number at the highly polluted station indicates their preference for high organic matter. Manikya Reddy and Venkateswarlu (1985) [9] called those organisms which can adjust to poorly aerated waters as adjustors. In contrast, the organisms at station I, which are less tolerant to formation of nutrient and DO gradients are called regulators [10].

The algae recorded in the river Godavari, can be categorized into 4 groups on the basis of their abundance at sampling stations. Each group of algae is abundant under specific environmental conditions

Group I: It includes those organisms that prefer exclusively station 1. This category of organisms comprises *Cymbella aspera*, *Navicula bacillum*, *Caloneis silicula*, *Achnanthes minutissima*, *Euastrum spinulosum*, *S. acutiformis* *Oscillatoria formosa*, *Merismopedia glauca*, *Oedogonium sp.* and *Spirogyra sp.*, *Coelastrum cambricum* (Plate:1).

Group II: It comprises organisms which are abundant at station II. They are *Nitzschia obtusa var. scalpelliformis*, *N. palea*, *N. thermalis*, *N. hungarica*, *N. acicularis*, *Achnanthes exigua*, *Cyclotella meneghiniana*, *Oscillatoria chalybea*, *O. ornata*, *O. animalis*, *O. angustissima*, *Pandorina morum*, *Stigeoclonium tenue*, *Pediastrum simplex*, *Scenedesmus perforatus* and *S. dimorphus*.

Group III: It includes those organisms which are common at all the three stations like *Synedra ulna*, *S. acus*, *S. tabulata*, *Scenedesmus quadricauda* and *S. armatus*.

Group IV: It covers those organisms which are common at station III. Interestingly enough, they are a combination of organisms that come under Groups I and II. These include *Cymbella aspera*, *N. denticula var. Curta*, *N. amphibia*, *Cocconeis placentula*, *Nitzschia obtusa var. scalpelliformis*, *Gyrosigma acuminatum*

and *Pleurosigma angulatum*, *Surirella robusta*, *Pinnularia biceps*, *Achnanthes lanceolatum*, *Gomphonema sphaerophorum*, *G. parvulum*, *Nitzschia acicularis*, *Oedogonium sp.*, *Spirogyra sp.*, *Cosmarium variolatum*, *C. menghinii*, *C. granatum* (Table:2).

Based on these groups it is possible to assign indicator value to these algae. Group I indicate the clean and uncontaminated nature of their environment, as they are very sensitive to pollution. These organisms can be termed as 'Response indicators' as they respond quickly to environmental perturbations.

Group II forms the highly polluted nature of the habitat. These organisms can be harnessed to treat the pollutants biologically. These can be called as 'utilization indicators' as they thrive well in polluted environments by assimilating the pollutants.

Group III algae, show some peculiarities. Though they are common to all stations, they exhibit interesting variations in their abundance. *Synedra ulna* and *Synedra tabulata* are very abundant at stations I and III. But they show their token presence at station II, being reduced considerably in number. Here mere presence or absence of these algae cannot determine the pollution status of the habitat, rather, it is their abundance/percentage composition of the total algae would be helpful in this type of studies.

Group IV comprises algae that inhabit station III, which shows the confluence of algae of stations I and II. *Nitzschia obtusa*, *Nitzschia acicularis* are very abundant at station II, occasional at station III and completely absent at station I. This shows their indicator value of heavy pollution, but they can tolerate mild pollution as well. Here also, it is their abundance/percentage composition which is important rather than their presence/absence. *Achnanthes minutissima*, *Navicula rhynchocephala* are more common at stations I and III. but the former is more abundant at station-I. whereas the latter prefers station III environment. *Achnanthes minutissima* though occurs in recovery zones of pollution, prefers habitats free of any contamination.

In contrast, *Navicula rhynchocephala* forms large communities in mildly polluted zones. Similarly, the occurrence of *Gomphonema sphaerophorum* and *G. parvulum*, *Surirella robusta* and *Navicula popula* to *capitata* in considerable numbers indicates their preference to zones of mild pollution. Further, the occurrence of *Nitzschia obtusa* var. *scalpelliformis*, *Nitzschia acicularis*, along with *Cosmarium variolatum*, *C. granatum* and *Achnanthes minutissima* indicates the mixed nature or mild pollution of the habitat. *Pleurosigma* and *Gyrosigma* are more common in habitats free of pollution than that of mildly polluted ones [9].

The present investigations reveal that the effluents discharged do not comply with the standards stipulated by various National and International Organisations. The suspended solid content in wastes is several times higher than the permitted levels. As a result of discharges from the paper mills, there is an increase of more than 100% in the concentrations of several factors analysed, Fe and Mn levels are above the permissible levels of potable waters. The percentage dilution is not sufficient even after 1 km from the point of confluence. The rate of persistence of every metal is high. The colour of the effluents is objectionable and causes aesthetic pollution. Hence it is necessary to ensure that effluent discharges are of high quality and the degree of pollution is such that the self-purifying capacity of the river is not disturbed. The waste water must be subjected to preliminary treatment before its release into natural environments. In the present case it is highly necessary to dilute the effluents at least by 50% because most of the factors show less than 50% dilution in the river stretch of 1 km so that their discharges into the river would not cause any disturbances in the ecosystem.

The effluents in the present study cannot be utilised as such for irrigation as is practised because of the presence of high TDS, SO_4^{2-} , and chlorides and they may affect the soil properties due to their accumulation in the soil. The soil texture gets affected due to the deposition of lignin on the surface of the soil. Further the continuous use of liquid wastes may lead to accumulation of heavy metals in the soil [11].

CONCLUSIONS

Phycological factors Mainly 4 groups of benthic algae were recorded in the river These are Bacillariophyceae, Chlorophyceae, Cyanophyceae and Euglenophyceae. Of the 4 groups, Bacillariophyceae dominated the other groups constituting about 61% before the entry of effluents. Cyanophyceae became dominant over other groups representing about 67% of total algae at Station II. At Station-III, again Bacillariophyceae became dominant. Only 2 groups of algae namely Cyanophyceae and Bacillariophyceae could be recorded in the effluent channel.

In the river Godavari, before the entry of waste, the river water was characterized by the frequent occurrence of *Cymbella aspera*, *Synedra ulna*, *S. tabulata*, *Achnanthes minutissima*, *Navicula bacillum*, *Gomphonema montanum*, *Merismopedia punctata*, *M. glauca*, *Oscillatoria formosa*, *Cosmarium variolatum*, *Coelastrum cambricum*, *Oedogonium* species and *Spirogyra* species. At Station II, dominant growths of *Nitzschia obtusa*, *Nitzschia palea*, *N. hungarica*, *N. acicularis* var. *closterioides*, *N. thermalis*, *Oscillatoria*

chalybea, *O. ornata*, *Gomphonema parvulum*, *Synedra tabulata*, *Scenedesmus quadricauda*, *Pandorina morum*, *Euglena polymorpha* could be observed throughout the period of investigation. At Station III, *Nitzschia obtusa*, *Synedra ulna*, *S. tabulata*, *Navicula rhynchocephala* var. *amphicerus*, *N. rhynchocephala* var. *genuina*, *Gomphonema sphaerophorum*, *Gomphonema montanum*, *Nitzschia punctata* and *Surirella robusta* and *Oscillatoria chalybea*, were recorded in good numbers. In the effluent channel, luxuriant growths of *Oscillatoria chalybea*, *O. ornata* and *Nitzschia obtusa* were observed.

To find out the relative importance of various physico-chemical variables and heavy metals on the growth and development of various groups of algae Multiple Regression Analysis has been made. Certain mathematical equations were derived for better prediction of variation in algal number in unknown samples.

Table:1 Comparison of the present data with BIS and ISI standards

S.NO.	Physico-chemical Parameters	Station-I	Station-II	Station-III	BIS (2003)		ISI 10500:2012	
		Average	Average	Average	P	E	A	P
1	Temperature	28.2	26.9	26.88				
2	pH	8.4	8.3	8.3	5	25	6.5-8.5	No relaxation
3	CO ₃ ²⁻	20.2	18.3	17.39				
4	HCO ₃ ⁻	169.1	187.8	290				
5	Cl ⁻	64.4	91.5	177.93	250	1000	-	-
6	DO	8.4	8	8.3	6			
7	BOD	0.1	8	12	3			
8	OM	10.5	8	11.51				
9	COD	2.5	3.3	2.96	-	10		
10	TH	172.8	189.4	166	300			
11	Ca ²⁺	105.5	29.7	36.83	75	200	75	200
12	Mg ²⁺	31.4	29.7	31.52	30	100	30	100
13	SO ₄ ²⁻	37.9	39.2	39.83	200	400	200	400
14	PO ₄ ³⁻	0.1	0.2	0.12				
15	SiO ₂	2.8	2.6	2.79				
16	NO ₃ ⁻	1.4	1.82	1.47	45	45	45	No relaxation
17	NO ₂ ⁻	0.04	0.07	0.04				
18	TS	800	1100	2200				
19	TDS	352.5	468.7	450.17	500		500	
20	Iron	2	2.5	2.7				
21	Nickel	82	110	190				
22	Chromium	110	160	270				

The free-floating phytoplankton in the river Godavari was constituted by five group and Bacillariophyceae, Cyanophyceae, Chlorophyceae, Euglenophyceae and Dinophyceae. Bacillariophyceae was predominant at Stations I and III, whereas it was Cyanophyceae which was dominant at Station II. Chlorophyceae occupied the third position at all the stations. However, it was more diversified at Station-I. The greatest heterogeneity in Euglenophyceae could be seen at Station II and *Trachelomonas* species constituted the bulk of populations.

The algae in the river Godavari, can be classified into 4 categories depending on their presence or absence at different stations. The group 1 includes those organisms present exclusively at Station I. The group II represents the organisms which are present at station II. The group III comprises of organisms present at Station III. The group IV includes the organisms which are present at all the three stations.

Thus, both physico-chemical and phycological factors indicate that the river Godavari is being polluted by the discharge of wastes of the Bhadrachalam Paper Boards up to a distance of at least 1 km in the river course. The organisms grouped under category I and II can be utilized as biological indicators of pollution and the organisms classified under category II can be suggested in the biological treatment of paper mill wastes, due to their withstanding capacity to the effects. These indicators appropriately be named as 'Response' and 'Utilisation' indicators. It has been suggested that the liquid wastes discharged by Bhadrachalam Paper Boards can be reutilised for processing of the paper with dilution.

Table: 2 Common and Dominant species of Algae

Group	Dominant Species
Bacillariophyceae	<i>Synedra tabulata</i>
	<i>Cocconeis placentula</i>
	<i>Mastogloia smithii</i>
	<i>Gyrosigma accuminatum</i>
	<i>Amphora ovalies</i>
	<i>Navicula rhynchocephala</i>
	<i>Cymbella affinis</i>
	<i>C. cymbiformis</i>
	<i>C. tumida</i>
	<i>Rhopalodia gibba and Nitzschia denticula.</i>
Chlorophyceae	<i>Scenedesmus acutiformis</i>
	<i>S.armatus</i>
	<i>S.perforatus</i>
	<i>Coelastrum cambricum</i>
	<i>Pediastrum boryanum</i>
	<i>P.simplex</i>
	<i>P.duplex</i>
	<i>P. tetras</i>
	<i>Cosmarium granatum and C.laeve</i>
Cyanophyceae	<i>Chroococcus turgidus, Gomphosphaeria aponia</i>
	<i>Merismopedia glauca,</i>
	<i>Oscillatoria formosa</i>
	<i>Osc.princeps</i>

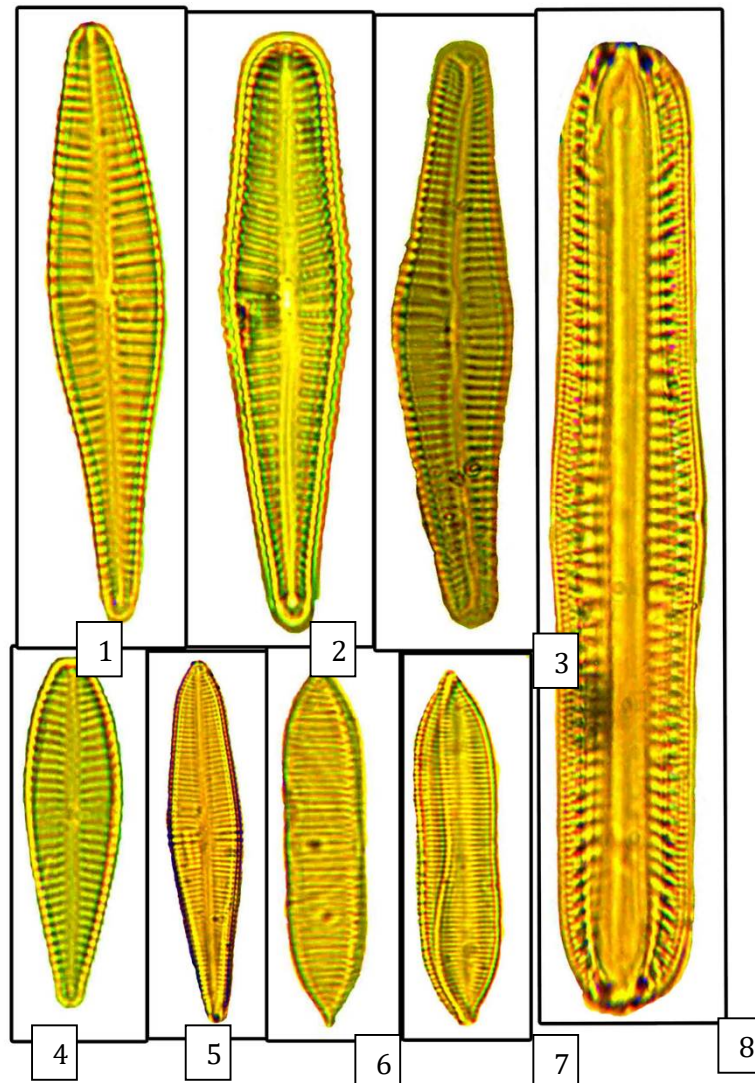


Plate 1: The algae recorded in the river Godavari.
 1) *Gomphonema constrictum* (Ehr) var. *capitatum* (Ehr) cl
 2) *G. montanum* var. *acuminatum* (Mayer)
 3) *Cymbella* sp.
 4) *G. montanum*
 5) *G. montanum* var. *turriforme*
 6) & 7) *Nitzschia tryblionella* (Hantzsch)
 8) *Rhopalodia gibba* (Ehrnberg) Muller

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