

## Algae as Bio-monitors for Damodar River Water Pollution

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### ABSTRACT

Damodar is an important tributary of Ganga river basin and cater the needs of industries and growing human population in the eastern part of India. Assessment of algal diversity was carried out to understand the impact of coal mining and allied industrial activities on the ecological condition of Damodar river basin. Surface water and algal samples were collected in the summer (2009) from ten sites along the Damodar River. Bio-monitoring of algal diversity showed high organic pollution load in the Damodar River. These observations were confirmed by statistical analysis. Algal community analysis and multivariate analysis showed influence of organic pollution in the river. Cluster analysis (CA) identified the similarity and dissimilarity among sampling sites and discriminate the reference site from rest of the impacted sites in the Damodar river basin.

**Key words:** Damodar River, bioindicators, Saprobic and Diversity index, Cluster Analysis.

### INTRODUCTION

Population pressure, urbanization, industrialization by a long way, added up the huge amount of waste which is toxic and non-toxic to the aquatic ecosystems. These Pollutants alters the physico-chemical quality of water which eventually upset the biotic components of the aquatic system. Physico-chemical analyses show different concentrations of chemical pollutants, but they do not reflect its effect on ecological condition of water, as they do not integrate ecological factors<sup>17</sup>. Biomonitoring and bioindicational methods are useful alternative for assigning the ecological changes of aquatic ecosystems as biological communities shows overall effects of chemical, physical and geomorphological characteristics of water<sup>39</sup>

Algae being a primary source of food in aquatic food web, therefore even small changes in the in the algal community can show a wide alteration tropic status of any aquatic system<sup>34</sup> Therefore, algae can be used as important bio-indicators in the monitoring of streams and rivers<sup>19</sup>. A wide verity of

work has been done by various researchers, using algae as bioindicator for biomonitoring of rivers to see the effect of water pollutants on biota.<sup>21, 3, 33, 14, 35.</sup>

The effect of pollution on algal species can be evaluated by using diversity index (H') and Saprobic index (S). Several researchers have used the S for the evaluation of water quality<sup>4, 5</sup>. Bioindicators and biotic indices have been adopted as technical standards in Germany<sup>11</sup> and in Austria<sup>26</sup>. These methods have also been used in Europe for more than a decade<sup>16</sup>

Damodar River flows through mineral rich areas of the eastern India. Therefore mining is one the most significant industry in this region. Water from Damodar River and its tributaries are mainly used to meet the ever growing urban water demand, industrial activities and agricultural requirements. The important factors that pose threat to the water quality of Damodar River are, coal mines, washeries, coke oven plants, Thermal Power Plants, Steel Plants and sponge iron industries etc.

Impact of Industrial effluent and domestic waste on Damodar River is well documented by <sup>40</sup>. Physico-chemical assessment and bio-monitoring has been conducted only in the lower stretch of Damodar river i.e the stretch falling in the West Bengal, <sup>10, 9</sup>. A systematic study on assessment including bio-monitoring throughout the stretch affected by mining and allied industrial activity is lacking. Therefore present work was undertaken to study the effect of anthropogenic activities on algal assemblage in relation to its water quality. We tried to implement the two bioindicational and statistical methods, which represent some new approaches in water quality and algal diversity analysis of Damodar River.

### Study area

Damodar River basin area extends from 22045' N to 24030' N and 84045' to 88000' E. The length and catchment area of Damodar river is 542 km and 23,170 km<sup>2</sup>, respectively. It flows through the industrial cities mainly Ramgarh, Bokaro, Dhanbad, Asansol, Durgapur, Bardwan and Howrah, before joining the lower Ganga (Hooghly estuary). The Damodar river is fed by number of tributaries at different reaches; the major ones are the Bokaro, Konar, Jamunia, Garga, Katri and Barakar (Figure 1). The basin is characterized by tropical climate with the annual rainfall of about 127cm <sup>10</sup> most of which occurs during monsoon.

### MATERIAL AND METHODS

Damodar river water samples were collected from ten different sites during the summer. These locations were downstream to different mines and industrial discharges between Patratu to Durgapur covering 300 km of river stretch (figure 2, table 1).

Algal samples were obtained by dragging a bottle across the water surface to collect the floating community <sup>7</sup>. Uniform sized stones or pebbles covered with algal mass were scraped carefully with a scalpel and brush <sup>4</sup>. Samples were preserved using 4% of formalin <sup>15</sup>. Three replicate slides were prepared for each sample and cells were measured by drop count method <sup>15</sup>. Counting and identification of species, was done using the digital microscope (Olympus Bx 60 fitted with digital

camera). Identification of algae was done with help of standard keys in Standard books and monographs <sup>32, 1, 6, 42, 8, 29</sup>.

### Statistical analysis

Biodiversity indices were calculated using following formula:

$$H' = \sum [pi (\ln pi)], \quad 37 \quad \dots(i)$$

Where, pi= proportion of each species in the sample.

$$\text{Saprobic Index} : S = \sum s.h / \sum h, \quad 27 \quad \dots(ii)$$

Where, s = value of each species according to Liebmann's list of indicator organisms <sup>20</sup>

H = frequency of each species found.

Cluster Analysis (CA) was also conducted to find out the (dis)similarity between the sampling sites <sup>12</sup>. The levels of (dis)similarity at which observations are merged used to construct a Dendrogram. To perform CA, an agglomerative hierarchical clustering (AHC) was used in combination of the Ward's linkage method and Euclidean distances as a measure of (dis)similarity. All the statistical analysis was performed using XLSTAT version 6.05.2014.

### RESULTS AND DISCUSSION

Algal species composition of Damodar River during the sampling period is given in Table 3. A total of 71 species belonging to 9 phyla were identified during summer season in the Damodar River. Phytoplankton was observed high during summer season, supported by finding of different researchers, <sup>18, 36</sup>. Chlorophyta and Bacillariophyta were the richest taxonomic group with 27 and 21 species respectively, followed by Cyanophyta (12 species) and Euglenophyta (4 species), Heterokontophyta (3 species), Charophyta (2 species), Rhodophyta and Cryptophyta with 1 species each.

Damodar River at Moonidih (Site6) showed maximum number of species during the study period. 27 species were found at site6 followed by site5 and site7 with 24 and 18 species respectively. Maximum number of Cyanophyta (6 species) and Chlorophyta (9 species) was found at site5. Maximum number of Bacillariophyta (11 species) was found at site 6. All the sites were subjected to some form of pollution; hence the species distribution was strongly biased

towards those that are tolerant of heavy or slightly elevated level of pollution. Among Cyanophyceae, species of *Oscillatoria* showed maximum occurrence. Among Chlorophyceae, species of *Spirogyra*, *Cladophora* and *Oedogonium* species showed maximum occurrence. Among Bacillariophyta, *Synedra ulna*, species of *Gonphonema*, *Nitzschia* and *Navicula* showed maximum occurrence.<sup>30, 28, 15</sup> <sup>24</sup> has shown that species of *Oscillatoria*, *Euglena*, *Nitzschia*, *Navicula*, *Synedra*, *Fragilaria*, *Closterium*, *Microcystis* and *Scenedesmus* are species present in the organically polluted water with high pollution indicative values. Similar genera are also found in the present study. *Stigeoclonium* is considered to be a pollution (organic and heavy metal) tolerance species by<sup>22, 13</sup> which is also recorded in the present study at site 6.

The saprobic index (S), which was based on the specific saprobic zone of algal species used in this study, distinguished the levels of water quality conditions in the Damodar River. The sampling

stations along the stretch of Damodar River can be classified, on the basis of physico-chemical characteristics as well as the specific tolerance of algal species (S) as clean, moderate and highly polluted. The physico-chemical values and saprobic condition can be related, and S values provide an excellent refinement of the general picture obtained by chemical analysis<sup>23</sup>. The S calculated for each of the sampling sites that reflects organic pollution, varies from 1.18 to 2.14 (figure 3). The amplitude of variation falls in the rank of the Oligosaprobic to  $\hat{a}$ -mesosaprobic, showing polluted water quality. Minimum S was calculated for Urimari which was the least disturbed area. The S value started increasing down the river, peaking at Bhurkunda (site 2) (2.14) d/s to Nalkari river (tributary of Damodar River) carrying effluent from Patratu Thermal Power Plant. Next peak value was observed at Damodar River d/s to Konar (site 3). This sampling site falls at the d/s to the tributaries that, apart from carrying industrial effluent may also carry large amount of domestic discharge from the residential area through which

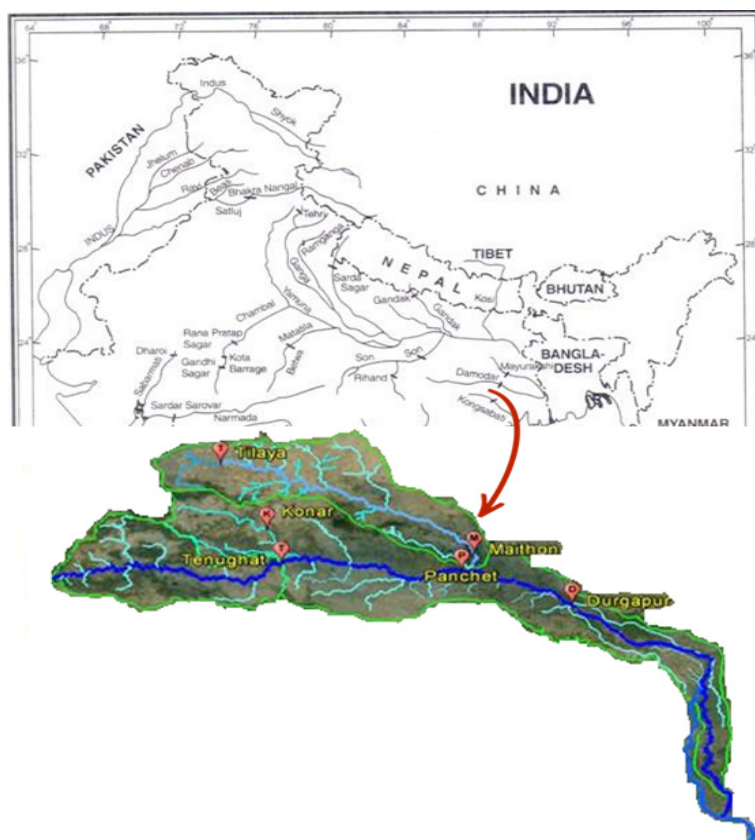
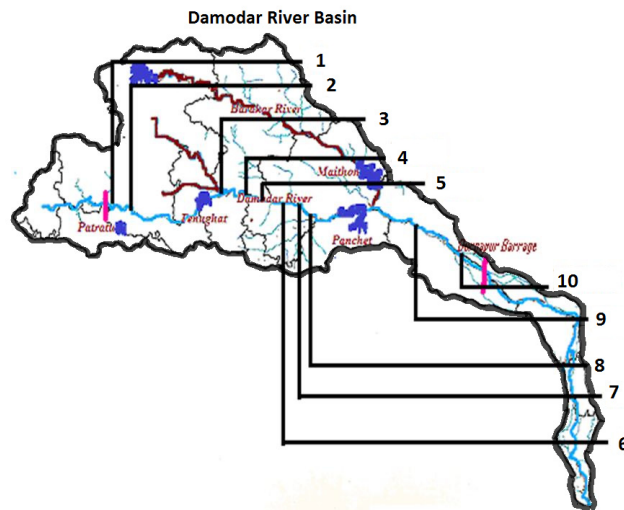


Fig. 1: Study area location map

they passes and ultimately drains into Damodar River. The S value increases at Moonidih (site 6) and Mohalbani (site 7). May be because these sampling sites fall under wide industrial and residential area. S value at Burnpur (DR9) and at Durgapur (site 10) showed lower saprobic values i.e. 1.73 and 1.7 respectively.

Diversity Index showed wide variation during summer (figure 3). High  $H'$  is observed at

the middle stretch of Damodar River. Damodar River at Phusro (site 5) showed maximum value (2.61) followed by Moonidih (site 6) (2.40) and Mohalbani (site 7) (2.04). Lower  $H'$  values was observed at Kargali (0.79) followed by Konar (1.05) and at Bhurkunda (1.45). Sampling site like Urimari (site 1) shows good algal diversity with low saprobic value. Maximum diversity was observed at site 6 (1.98). Sampling site 5, 6, 7 showed moderated pollution with high  $H'$ . Most probably, the occurrence of



**Fig. 2:** location map showing sampling site from Patratu to Durgapur barrage

**Table 1: Location of water sampling stations in the river**

Sampling site code	Name of sampling Site	Description of Sampling Site
Site1	Urimari	Location falls near to the origin point of Damodar River.
Site2	Bhurkunda	Downstream (D/s) to the confluence of Nalkari River, carries the effluent discharged from the Patratu Thermal Power Plant.
Site3	Konar	D/s to the confluence of Konar River pouring the effluent from Bokaro Thermal Power Plant.
Site4	Kargali	D/s to the confluence of Kargali River carries the effluent from Kargali coal washery.
Site5	Phusro	D/s to an industrial area.
Site6	Moonidhi Kapat ghat	D/s to effluent discharge from the Moonidih coal washery.
Site7	Mohalbani ghat	D/s to effluent discharge from an industrial area
Site8	Domgarh ghat	D/s to effluent discharge from Patherdih, Sudamdih and Chasnalla coal washery.
Site9	Burnpur	D/s to the confluence of Burnpur steel plant effluent
Site10	Durgapur Barrage	D/s to the confluence of mixed effluents from Industries at Durgapur.

**Table 3: Presence, absence and distribution of algal specie during the study period at different sampling locations of Damodar River**

Phytoplankton during summer	Sampling Site									
	1	2	3	4	5	6	7	8	9	10
Cyanophyta										
<i>Oscillatoria princes</i>			*	*	*		*			
<i>Oscillatoria splendid</i>					*					
<i>Oscillatoria irrigua</i>						*	*			
<i>Oscillatoria tenuis</i>	*							*		
<i>Oscillatoria chlorine</i>							*			
<i>Chroococcus</i> sps.		*			*					
<i>Chroococcus limneticus</i>					*					
<i>Sytonema</i> sps.			*							
<i>Anabaena</i> sps.					*					
<i>Lyngbya</i> sps						*				
<i>Oocystis</i> sps.					*	*				
<i>Microcystis</i> sps.						*	*	*		
	<b>1</b>	<b>1</b>	<b>2</b>	<b>1</b>	<b>6</b>	<b>4</b>	<b>4</b>	<b>2</b>	<b>0</b>	<b>0</b>
Chlorophyta										
<i>Characium</i> sps.	*						*			
<i>Spirogyra</i> sps 1	*	*								
<i>Spirogyra</i> sps 2					*		*			
<i>Spirogyra</i> sps 3				*				*		
<i>Spirogyra singularis</i>		*								*
<i>Spirogyra jogensis</i>	*	*					*		*	*
<i>Ulothrix</i> sps.1						*				
<i>Ulothrix</i> sps.2						*				
<i>Cladophora glomerata</i>	*		*		*	*			*	*
<i>Zygnema</i> sps.					*					
<i>Microspora</i> sps.						*	*			
<i>Mougeotia scalaris</i>					*					
<i>Oedogonium</i> sps.				*	*	*			*	*
<i>Geminella interrupta</i>	*									
<i>Hydrodictyon</i> sps.					*		*			*
<i>Hydrodictyon reticulatum</i>						*				
<i>Scenedesmus</i> sps.						*				
<i>Scenedesmus linearis</i>								*		
<i>Scenedesmus dimorphus</i>		*								
<i>Coleochaete</i> sps.			*							
<i>Stigeoclonium</i> sps.						*				
<i>Chaetophora incrassate</i>							*			
<i>Monostroma</i> sps.				*						*
<i>Volvox</i> sps					*					
<i>Pandorina morum</i>					*					
<i>Phacus longicauda</i>							*			
<i>Kirchneriella lunaris</i>					*					

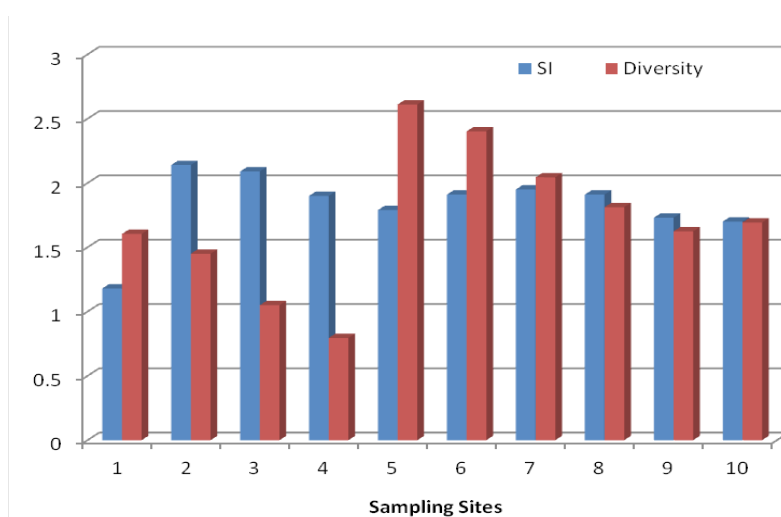
	5	4	2	3	9	8	7	2	3	6
Bacillariophyta										
<i>Nitzschia sigmoidea</i>	*				*					*
<i>Nitzschia palea</i>					*	*	*			
<i>Nitzschia vermicularis</i>					*					
<i>Nitzschia elongate</i>					*					
<i>Nitzschia flexoides</i>						*				*
<i>Nitzschia sps</i>										*
<i>Synedra acus</i>						*			*	*
<i>Synedra ulna</i>	*	*	*		*	*		*	*	*
<i>Cymbella aspera</i>	*					*				*
<i>Cymbella sps</i>								*		
<i>Fragilari sps.</i>						*				
<i>Gomphonema truncatum</i>	*					*			*	*
<i>Gomphonema parvalum</i>						*			*	*
<i>Gomphonema ventricosum</i>									*	
<i>Melosira sps</i>						*			*	*
<i>Navicula Capita</i>		*								
<i>Navicula subtilissima</i>							*			
<i>Navicula rhynchocephala</i>							*			
<i>Navicula sps</i>					*	*		*		*
<i>Cyclotella sps</i>					*					
<i>Cyclotella meneghiniane</i>						*				
	4	2	1	0	7	11	3	3	6	10
Euglenophyta										
<i>Euglena gracilis</i>							*			
<i>Euglena elastic</i>							*			
<i>Euglena acus</i>								*		
<i>Euglena sps</i>				*		*				
	0	0	0	1	0	1	2	1	0	0
Rhodophyta										
<i>Adouinella violacea</i>						*				
	0	0	0	0	0	1	0	0	0	0
Charophyta										
<i>Netrium sps</i>								*		
<i>Closterium sps</i>					*		*			
	0	0	0	0	1	0	1	1	0	0
Heterokontophyta										
<i>Cocconeis sps</i>	*									
<i>Gyrosigma sps</i>						*				
<i>Pinnularia sps</i>							*	*		
	1	0	0	0	0	1	1	1	0	0
Cryptophyta										
<i>Chroomonas sps</i>						*		*		
	0	0	0	0	0	1	0	1	0	0
Protozoa										
<i>Arcella discoides</i>					*					
	0	0	0	0	1	0	0	0	0	0
<i>Total no.of species in the study area</i>	11	7	5	5	24	27	18	11	9	10

**Table 3: Variance decomposition for the optimal classification**

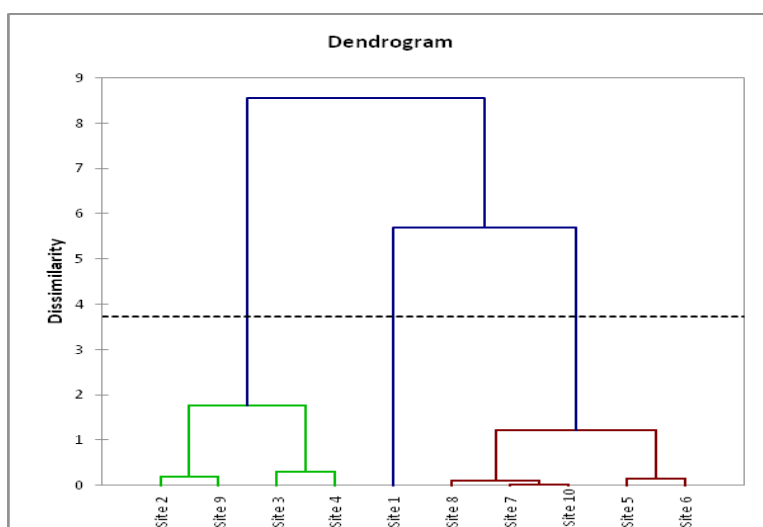
	Absolute	Percent
Within-class	0.134	33.25%
Between-classes	0.270	66.75%
Total	0.404	100.00%

organic matter, especially during drier months at these stations, favored certain species that can thrive in the environment. As a result, sufficient sensitive species remain together with increasing numbers of tolerant species, to maintain a fairly high  $H'$  in the population. Increase in  $H'$  under moderate stress in the present study has also been supported by <sup>2, 31, 41, 38, 25, 14</sup>.

Ten sampling sites were assessed using cluster analysis to determine the correspondence



**Fig. 3: Spatial variation of Saprobic and Diversity index along the stretch of Damodar river**



**Fig. 4: Dendrogram from agglomerative hierarchical clustering of sampling sites using Biotic indices results for Damodar river**

between the sampling sites on the basis of biotic indices (figure 4). The final dendograms exhibit a compact visualization of the dissimilarity matrix that classifies the ten sampling site into three statistically significant clusters. Cluster/class 1, 2 & 3 corresponds to relatively low pollution, moderate pollution and high pollution region of the river respectively.

Spatial cluster analysis based on Saprobic and Diversity Index generated a dendogram which is shown in figure 4. With regards to the dendogram the ten sampling sites were grouped into three clusters. Cluster 1 includes sampling site 1 corresponding to low pollution; Cluster 2 includes Sampling site 2-4 and 9 showing moderate pollution, whereas cluster 3 includes sampling site 5-8 and 10 corresponding to high pollution. The variance decomposition for the optimal classification values were 33.25% for within class variation and 66.75% for between class variations (table 3). Biotic indices clustering separated the reference site 1 from the other sampling sites indicating that the reference site was relatively clean in terms of water quality. Cluster analysis done using biotic indices classified site 2 as moderately and site 5 & 10 to be highly polluted site (figure 4).

The above observations classify Damodar River into three zones. Patrattu to Tenughat as zone 1; Tenughat to Panchet as zone 2 and Panchet to Durgapur as zone 3. Zone 1 falls into relatively polluted zone as comparatively less industrial activity in this region; Zone 2 falls into highly polluted zone as it is an intensive and active coal mining & allied industrial zone with high population; Zone 3 falls into moderately polluted zone, may be because of dilution factor of the pollutants in Panchet dam and Barker River, one of the main tributary that joins Damodar River upstream to sampling site 9 (Burnpur).

## CONCLUSION

Physico-chemical, bacteriological and phytoplankton community analysis were carried out to understand the overall ecological health of Damodar River at ten sampling sites affected by mining and allied industrial activities from Patrattu to Durgapur during summer. The study depicted that Damodar River is affected by point and non point pollution sources from coal mines, allied industries and surrounded residential areas. A total of 71 algal species were indentified during the study period. The major taxonomic divisions in Damodar River were dominated by Chlorophyceae followed by Bacillariophyceae, Cyanophyceae and Euglenophyceae. Saprobitic index showed that water quality of the Damodar River water falls between oligosaprobic to â-mesosaprobic zone. S ranged from 1.18 to 2.14 during the study period. Urimari (Site1) was found to be the only site where water quality falls under oilgosaprobic zone and have high diversity the in the upper stretch of the river which shows minimum stress level. The entire sampling site down the stretch falls under â-mesosaprobic zone, with few sampling site showing high diversity. Multivariate technique was useful in providing support to the data obtained by biotic indices. Cluster analysis showed sampling site 5, 6, 7, 8, and 10 to be organically polluted. On the basis of present study, it is concluded that biological study using algal community should be used to get the overall picture of ecological health of river, as it provide an integrated measurement of water quality as experienced by the aquatic biota, and therefore offers a useful addition to physico-chemical water quality monitoring strategies. It is also found that algal community study are very helpful in indicating sources and degree of pollution as well as discriminating reference site from the impacted sites of the study area. Therefore it is preferable and recommended to use algae for water quality monitoring that will support sound management decision regarding Damodar River water quality.

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