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Assesment of seasonal phytoplankton diversity of abandoned coal pits in Harabhanga village, Raniganj, West-Bengal with reference to pollution status caused by heavy metals

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Abstract
Coal mining is one of the core industries that contributes to the economic development of a country but deteriorates the environment in certain ways. In the process of mining, huge amount of water is discharged on surface to facilitate the mining operation. The discharged water often contains high load of TSS, TDS, hard and heavy metals, which contaminate the surface and ground water. Sometimes it is acidic in nature and pollutes the water regime. The water is mainly rain water and mine discharge. The investigation was carried out to determine the pollution status caused by heavy metals of abandoned open cast mine pits through the assessment of phytoplankton diversity. The investigated sites were abandoned Harabhanga pit and Damalia pit in Harabhanga Village, Raniganj, West Bengal. The seasonal limnological study with respect to heavy metals was targeted to get uncommon biomass & algal biodiversity variation. Diatoms, followed by pollution indicator forms like *Scenedesmus*, *Oscillatoria*, *Euglena*, *Phacus* etc. were noted. The Damalia pit was found richer in comparison. Interestingly Dinoflagellate genera like *Peridinium* & *Gymnodinium* were noted. Although diatoms were recorded, dominant genera were *Trachelomonas*, *Anabaena*, *Microcystis* & *Oscillatoria*. Harabhanga pit represented a different composition of diversity having *Merismopedia* & *Oscillatoria* among blue greens, *Melosira* & Melosira among diatoms, *Euglena* & *Lepocinlis* among Euglenophytes and *Coelastrum*, *Closterium* & *Lacunastrum* among green algae. Most of the genera are pollution tolerant but some Prasinophytes are found in all water bodies. After this work it was found that rainy season is the most affective time in terms of heavy metals contamination, so phytoplankton diversity is high. The same status continues in post-monsoon season due to retention of the same metal substances in the pit water bodies. The lower rate of contamination in pre-monsoon season or dry hot summer months due to lack of surface runoff or other contaminations phytoplankton diversity appeared higher.

Keywords: biomass, heavy metal, limnology, monsoon, open cast mine pit, phytoplankton diversity, pollution indicator

Introduction

In coal mining area, the surrounding environment of coal mining is adversely affected as destruction of total ecology, atmosphere, land, human health and water system (Dhar, 1993 [6]; Ripley *et al*., 1996 [23]; Peplow and Edmonds, 2002 [19]; Younger, 2004) [32]. After completion of coal extraction in open cast mining process a pit lake is formed, due to fill up by surface runoff and groundwater discharge. Thereafter the pit lake becomes a water body, locally known as Khadan. (Ghosh, 2012 [11]; Tiwary and Dhar, 1994 [29]; Ghosh *et al*., 2005) [10].The surrounding upper surface of pit soil contaminates the pit water. The soil commonly consists of toxic chemicals, pollutants, heavy metals etc (Ghose, 2001 [8]; Dutta and Agrawal, 2002 [7]; Ghose, 2004 [8]; Mercuri *et al*., 2005 [17]; Maiti, 2007 [15]; Sheoran *et al*., 2010 [24]; Stoertz *et al*., 2002 [28]; Johnson, 2003 [13]; Pagnanelli *et al*., 2004 [18]; Razo *et al*., 2004; Marin-Guirao *et al*., 2005; Maiti, 2007 [15]; Bhuiyan *et al*., 2010 [2]; Das and Chakrapani, 2011) [3]. In Raniganj coalfield area of West Bengal the pit water bodies contain high concentration of metals like Pb, Cu, Zn, Co, Cr, Fe,Mn, Cd, etc., that pollute pit ecosystem (De and Mitra, 2002 [4]; Singh *et al*., 2009 [1]; Das and Chakrapani, 2011) [3]. The heavy metal pollution is a serious problem in local, regional, and global level (Kudo and Miyahara, 1991) [14]. Phytoplankton is a satisfactory bio-monitoring tool to identify any environmental condition or change of a water body ecosystem (Ghosh and Keshri, 2011) [12].The aim of this present study is to detect through phytoplankton diversity how the coalmine abandoned pits are polluted by heavy metals in Raniganj coalfield area with respect to seasonal variation.

Study Area

The present study sites are the abandoned coal pits named Harabhanga pit and Damalia pit situated in Harabhanga village which is located in Tirat gram panchayat, Raniganj block of Paschim Barddhaman district in West Bengal, India.
Harabhanga pit is geographically located at 23039’52’’ N lat and 87001’44’’ E long, length 450m, width 140m, average mean depth 9-16m and Damalia pit lake at $23^0$36' 32" N Lat and $87^0$04' 00" E Long, length 650-710m,width 140-220m, average mean depth 19-24m. The both pits’ altitude is 88.45 mt. from MSL and is part of Satgram area in Eastern Coalfield Ltd.

Fig 1: Satellite View of 2 pits

Fig 2: Harabhanga pit

Fig 3: Damalia pit

Materials and Methods

The primary samples i.e., Phytoplankton were collected from both pits in pre-monsoon (March -May), post-monsoon (September- November) and monsoon (June- August) between 9 to 10 am in 500 ml amber colour bottle and fixed with Lugol's iodine solution in 100 : 1 ratios. The supernatant part was pipetted out and the sample being concentrated to 5 ml for analysis. Drop Count method (Trivedy and Goel, 1984) [30] was followed for numerical representation of phytoplankton and the phytoplankton densities are calculated as organisms per litre. Identification of phytoplankton were done using standard literature and monographs (Turner 1892 [33], Anand 1998 [1], Desikachary 1959 [5], Prescott 1962 [20], Smith 1950) [27] Simultaneously water samples were collected from the both study sites of three consecutive seasonal phases (pre-monsoon, monsoon and post-monsoon seasons). Then these were brought to the laboratory for analysis by using APHA 23rd Edition, 1060. Parameters like As, Pb, Cr, Cu, Zn, Se, F, Mn were considered for analysis. So many statistical methodologies were used in this study to explore the actual result. Arithmetic mean, ANOVA, frequency distribution (bar or comparative bar) were used. Standard protocols and methodologies were maintained during sampling and analysis of the mine water. Whereas Correlation statistics was performed by using SPSS statistical software version 16.0 for analysing the data set to get better result. To identify the seasonal nature of Phytoplankton diversity in two pits Shannon Weiner's Species Diversity Index (SDI) was applied. This is the most suitable statistical tools to determine the phytoplankton species diversity in different time scale or in different area or condition. The formula used for Shannon Weiner's Species Diversity index:

$$H = -\sum_{i=1}^{s} pi \ln pi$$

Where, H = Shannon-Weiner species diversity index (SDI); $P_i = n_i/N$ (n_i = Number of individuals in species i species and N= total number of individuals of all the species in the quadrate).

Data Analysis

In the present work, the water samples were collected from 2 coal mine pits for analysis of heavy metals.

Harabhanga, Damalia abandoned pits are in Satgram area of E. C. Ltd. So many types of heavy metals, i.e. As, Pb, Cr, Cu, Zn, Se, F, Mn were taken into consideration for the study.

In monsoon season, due to rainfall high amount of heavy metals passed through the surface runoff and contaminated the pits water bodies. As a result, the water quality was deteriorated massively. But, the rate of contamination was reduced in pre-monsoon and in post-monsoon seasons due to low amount of rain fall. Among the heavy metals concentration, Lead (Pb) was very high in all seasons in respect of other heavy metals, but its level was maximum in monsoon season in both pits.

Permissible limit as per MoEF (Ministry of Environment and Forest).

Schedule-VI standard was the scale of consideration for measuring the magnitude of heavy metals concentration in different season.

Table 1: Showing season wise heavy metal concentration in 2 Pits

Heavy Metals	Pre-monsoon		Monsoon		Post-monsoon		Permissible Limit as per MoEF Schedule-VI Standard
	Harabhanga pit	Damalia pit	Harabhanga pit	Damalia pit	Harabhanga pit	Damalia pit	
Arsenic (As) (mg/lt.)	0.013	0.016	0.04	0.03	0.011	0.01	0.2
Lead (Pb) (mg/lt.)	0.053	0.054	0.06	0.07	0.04	0.05	0.1
Hexavalent Chromium (Cr) (mg/lt.)	0.001	0.001	0.002	0.003	0.001	0.001	0.1
Total Chromium (Cr) (mg/lt.)	0.12	0.1	0.3	0.25	0.095	0.1	2
Copper (Cu) (mg/lt.)	0.011	0.01	0.02	0.02	0.01	0.01	3
Zinc (Zn) (mg/lt.)	0.011	0.01	0.025	0.02	0.017	0.01	5
Selenium (Se) (mg/lt.)	0.01	0.01	0.02	0.02	0.01	0.01	0.05
Fluoride (F) (mg/lt.)	0.016	0.015	0.022	0.02	0.01	0.01	2
Manganese (Mn) (mg/lt.)	0.011	0.01	0.013	0.01	0.01	0.01	2

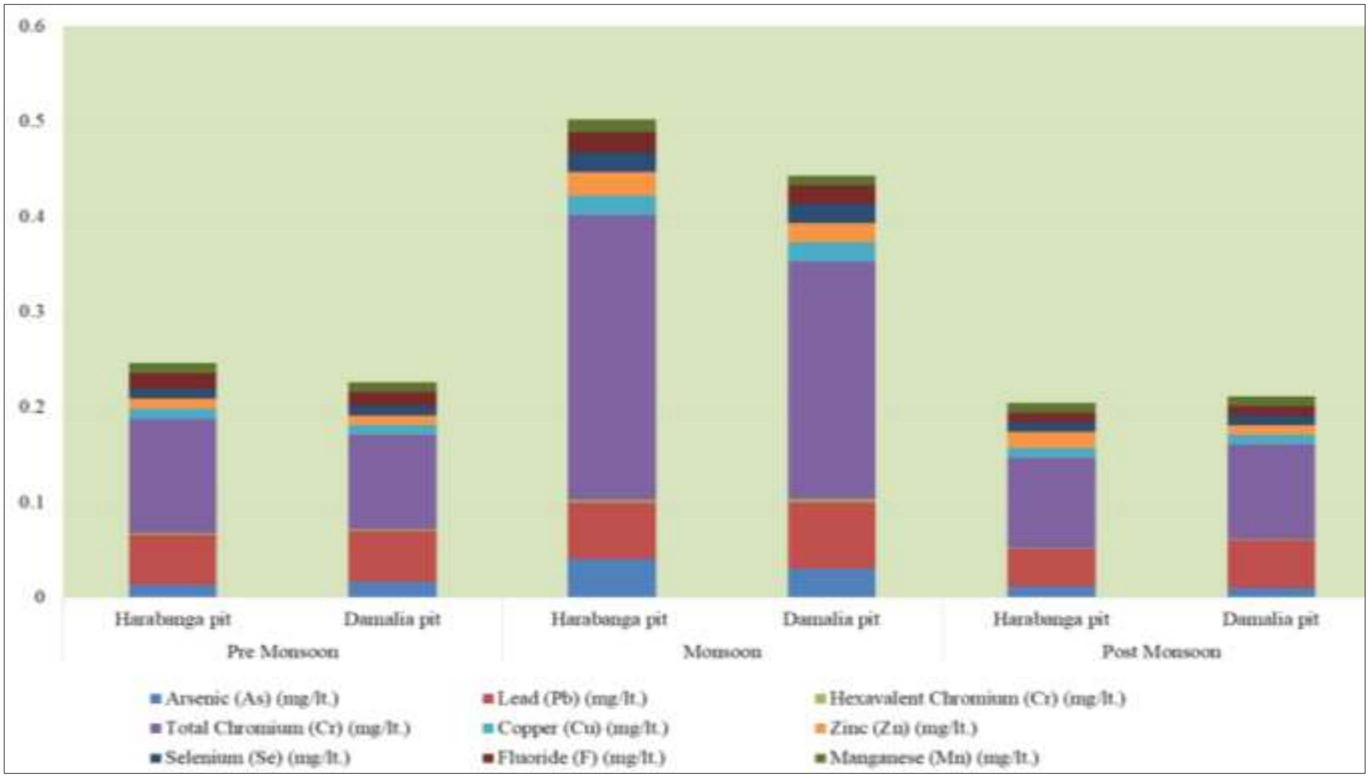

Fig 4: Showing season wise heavy metal concentration in 2 Pits

The samples were collected during three different seasons from 2 pits in the impactful season with respect to heavy metal concentration in those pits' water to find out the main controlling factor of it.

Table 2: Two way ANOVA for showing Season wise and pit wise variation of significant levels of heavy metals concentration

ANOVA						
Source of Variation	***SS***	***df***	***MS***	***F***	***P-value***	***F crit***
Within the Properties	0.10819938	7	0.01546	13.8587	1.3E-07	2.35926
Within the Season	0.00853435	4	0.00213	1.91296	0.13603	2.71408
Error	0.03122925	28	0.00112			
Total	0.14796298	39				

Notes: SS = Sum of Squares, df = Degree of Freedom, MS = Mean Sum of Squares, F_{obs} = Observed F, P- value = Probability, F_{crit} = Critical F.

From ANOVA on monsoon data regarding season wise and pit wise heavy metals concentration (Table 2), it is shown that there is significant difference in terms of both cases, i.e. different heavy metals and Seasonal variation in pits (Fobs>Fcrit).

ANOVA on post-monsoon data (Table 2) represents the same condition like pre-monsoon time, like significant difference in respect of different heavy metals (Fobs>Fcrit) but among seasons and in terms of pits, there is no significant difference (Fobs<Fcrit). Rather, it is also found that the significance level is higher in all post-monsoon months.

Table 3: Phytoplankton taxa in the 2 pits under seasonal variation

Sl No.	Materials	Class	Pre-monsoon		Monsoon		Post-monsoon	
			Harabhanga pit	Damalia pit	Harabhanga pit	Damalia pit	Harabhanga pit	Damalia pit
1	*Microcystis sp*	Cyanophyceae	1	8	1	9	2	14
2	*Merismopedia sp*	Cyanophyceae	6	2	8	2	13	2
3	*Melosira sp*	Cyanophyceae	8	1	9	1	15	2
4	*Anabaena sp*	Cyanophyceae	1	7	1	9	2	13
5	*Oscillatoria sp*	Cyanophyceae	11	12	11	13	14	16
6	*Scenedesmus sp*	Chlorophyceae	6	7	8	8	13	15
7	*Coelastrum sp*	Chlorophyceae	8	1	10	2	14	1
8	*Closterium sp*	Chlorophyceae	12	1	13	4	17	2
9	*Lacunastrum sp*	Chlorophyceae	11	1	13	2	14	1
10	*Euglena sp*	Euglenophyceae	11	5	12	5	16	7
11	*Phacus sp*	Euglenophyceae	5	6	8	8	14	10
12	*Trachelomona sp*	Euglenophyceae	1	5	2	7	1	7
13	*Lepocinlis sp*	Euglenophyceae	8	1	12	1	14	1
14	*Peridinium sp*	Dinophyceae	1	8	1	8	2	13
15	*Gymnodinium sp*	Dinophyceae	1	10	3	11	5	16
16	Unideentified	Prasinophyceae	11	11	13	13	16	14
17	Diatoms	Bacillariophyceae	16	18	19	21	23	26

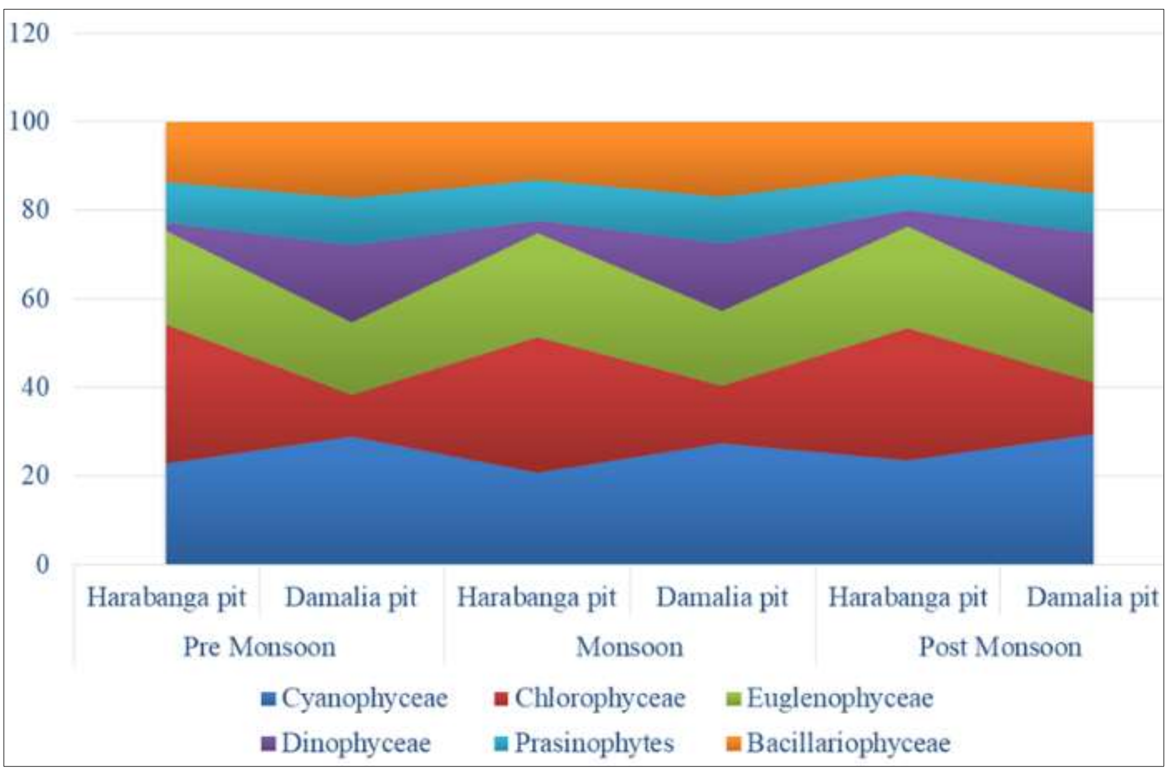

Fig 5: Percentage of Phytoplankton classes in the 2 study sites over seasonal variation

Season wise and pit wise phytoplankton diversity was also calculated using Shannon Weiner's Species Diversity Index, which is very common index for measuring phytoplankton diversity in various aspects of any kind of water body. In the both abandoned pits more or less 17 Phytoplankton species were observed during various seasons. These were *Microcystis* sp., *Merismopedia* sp., *Melosira* sp., *Anabaena* sp., *Oscillatoria* sp., *Scenedesmus* sp., *Coelastrum* sp., *Closterium* sp., *Lacunastrum* sp., *Euglena* sp., *Phacus* sp., *Trachelomona* sp., *Lepocinclis* sp., *Peridinium* sp., *Gymnodinium* sp., Diatoms (Table No. 3) and categorised under 6 algal classes (Table No 4). But their amount was varied during various seasons.

Table 3: Season wise Phytoplankton Diversity (H) of study sites

Materials	Pre-monsoon				Monsoon				Post-monsoon			
	Harabhanga pit		Damalia pit		Harabhanga pit		Damalia pit		Harabhanga pit		Damalia pit	
	N	H		H	No of species individual	H	No of species individual	H	No of species individual	H	No of species individual	H
Microcystis sp.	1		8		1		9		2		14	
Merismopedia sp.	6		2		8		2		13		2	
Melosira sp.	8		1		9		1		15		2	
Anabaena sp.	1		7		1		9		2		13	
Oscillatoria sp.	11		12		11		13		14		16	
Scenedesmus sp.	6		7		8		8		13		15	
Coelastrum sp.	8		1		10		2		14		1	
Closterium sp.	12		1		13		4		17		2	
Lacunastrum sp.	11	2.57	1	2.52	13	0.03	2	0.19	14	0.04	1	0.21
Euglena sp.	11		5		12		5		16		7	
Phacus sp.	5		6		8		8		14		10	
Trachelomona sp.	1		5		2		7		1		7	
Lepocinlis sp.	8		1		12		1		14		1	
Peridinium sp.	1		8		1		8		2		13	
Gymnodinium sp.	1		10		3		11		5		16	
Prasinophytes	11		11		13		13		16		14	
Diatoms	16		18		19		21		23		26	

N = No of species individual; H = Shannan Winner Index

Table No 3. Shows that the highest phytoplankton diversity (H) was found in pre-monsoon season in both abandoned pits.

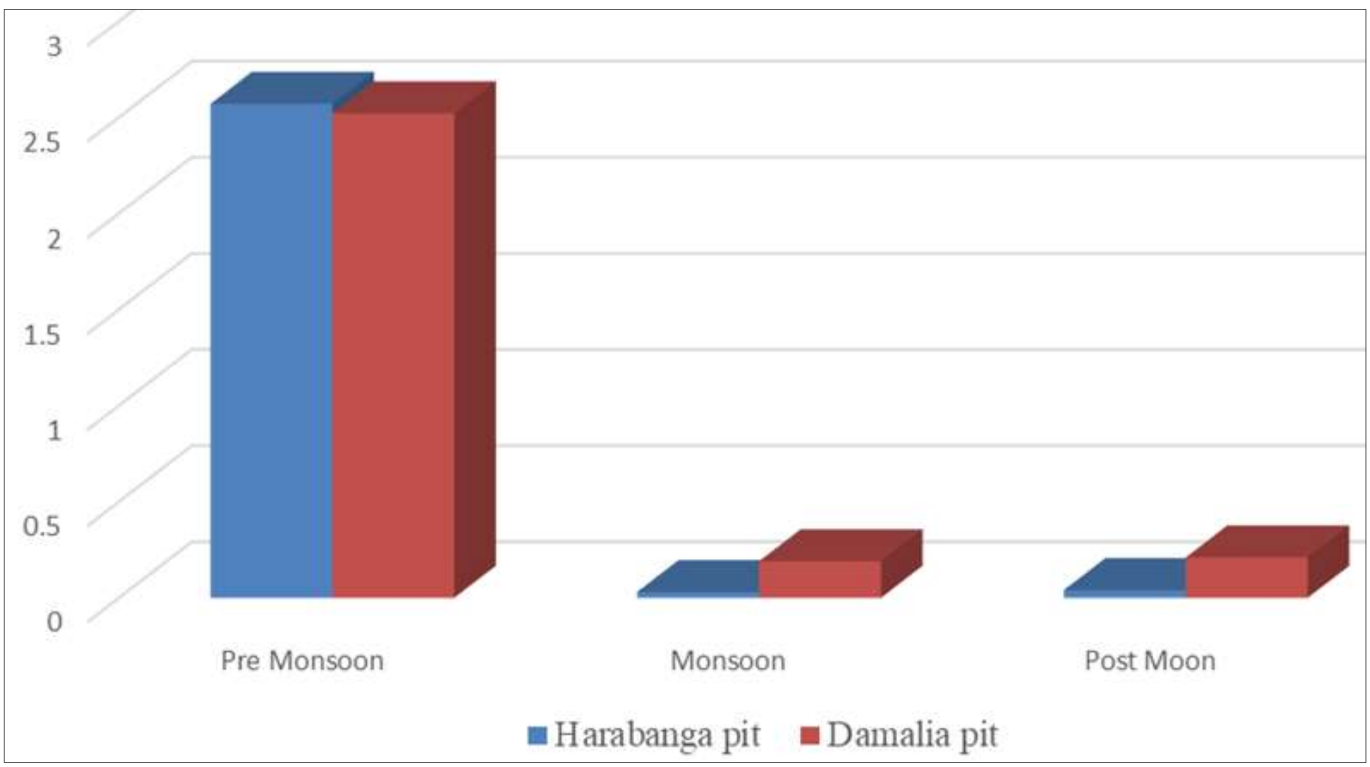

Fig 6: Bar graph of Phytoplankton diversity (H) of 2 study sites

In respect of phytoplankton diversity (Figure No 6.) in both abandoned pits were highest in the pre-monsoon season. It was also observed that in pre-monsoon the phytoplankton diversity of Harabhanga pit was slightly greater than Damalia pit plankton diversity where as in monsoon and post-monsoon season Damalia pit diversity was greater than Harabhanga pit phytoplankton diversity. In respect of season wise phytoplankton diversity following comparison was revealed.
Pre-monsoon: Harabhanga pit > Damalia pit
Monsoon: Harabhanga pit < Damalia pit
Post-monsoon: Harabhanga pit < Damalia pit

Discussion

West Bengal is a state where the atmosphere is fully controlled by the tropical monsoon. Out of three seasons, i.e. summer (March-May), Rainy (June-September) and winter (October-February) *viz*., Pre-monsoon, Monsoon and Post-monsoon respectively the monsoon is dominant over the others. In summer, huge amount of water is evaporated over the sky of Arabian Sea and the Bay of Bengal. Trade wind move towards land mass i.e., impact of Coriolis force as the high pressure belts are prevailing at Indian land mass. Then dense cloud is formed and huge amount of rainfall occurs throught the gangetic plain land. As a result of intensive rainfall, large volume of rain water flows as a surface runoff. This runoff water is contaminated with heavy metals and pollutants (both biotic and abiotic) etc. So the water bodies are also contaminated by the surface run off. For the determination of pollution level phytoplanktons are used as (Ghosh *et al*. 2012 [11], Ghosh & Keshri 2011) [12] very important indicators for biomonitoring of an inland waterbody (Sicko-Goad *et al*., 1977) [25]. In the present study the abandoned coal mine pits selected are in Raniganj coalfield area. These are filled with mines surface runoff as well as ground water. The water actually recharge during monsoon (June-September) through rain water, surface drainage and contaminated water. These pits are too deep in nature. Due to season wise variation of contamination, phytoplankton diversity is also varied. In the present study the % of phytoplankton composition had been studied as per seasonal variation through out the year show that members of Cyanophyceae 22.881, 20.833, 23.589 in Harabhanga pits & 28.846, 27.419, 29.375 in Damalia pit and Chlorophyceae were leastest 31.355, 30.555, 29.743 in Harabhanga pit & 9.615, 12.903, 11.875 in Damalia pit for pre-monsoon, monsoon, post-monsoon respectively (Table No. 4). Seasonal Phytoplankton density (H) values were maximum in premonsoon season in the both mine pits (Table No 3).In Harabhanga pit & Damalia pit the species diversity in pre-monsoon are 2.57 & 2.52 in monsoon are 0.03 & 0.19 and in post-monsoon 0.04 & 0.21 respectively. As per Wilhm & Dorries (1966) both mine pits are less polluted in premonsoon season but heavily polluted in monsoon and post-monsoon season. Wilhm & Dorris (1966) proposed the specific relationship between species diversity and pollution level of a water body as, species diversity value> 3=clean; 1.3=moderately polluted and < 1=heavily polluted. On the other hand Staub *et al*. (1970) proposed another scale of pollution in respect of phythplanktonspecies diversity value 3.5-4.5=slight pollution; 2.0-3.0=light pollution; 1.0-2.0=moderate pollution and 0.0-1.0 = heavy pollution *viz*, as per the above refrection is also satisfied. In monsoon and post-monsoon surface soil parameters are also splaming the key factors to the nature of contamination. It may be stated that, as rainy season is the most affective time in terms of heavy metals contamination so phytoplankton diversity are was also noted high. The same status continues in post-monsoon season due to retention of the same metal substances in the pit water bodies. But there is lower rate of contamination in pre-monsoon dry hot summer months due to lack of surface runoff or other contaminations.Therefore in summer high phytoplankton diversity was observed. On the other hand in pre-monsoon season the phytoplankton diversity of Harabhanga pit is more than Damalia pit *viz*., the Harabhanga pit water is less polluted than Damalia pit but in monsoon and post-monsoon the phytoplankton diversity of Harabhanga pit is less then Damalia pit *viz*., Harabhanga pit water becomes more polluted in rainy season due to surface runoff contamination. There remains loose soil surrounding this pit and this situation prevails during post-monsoon season too.

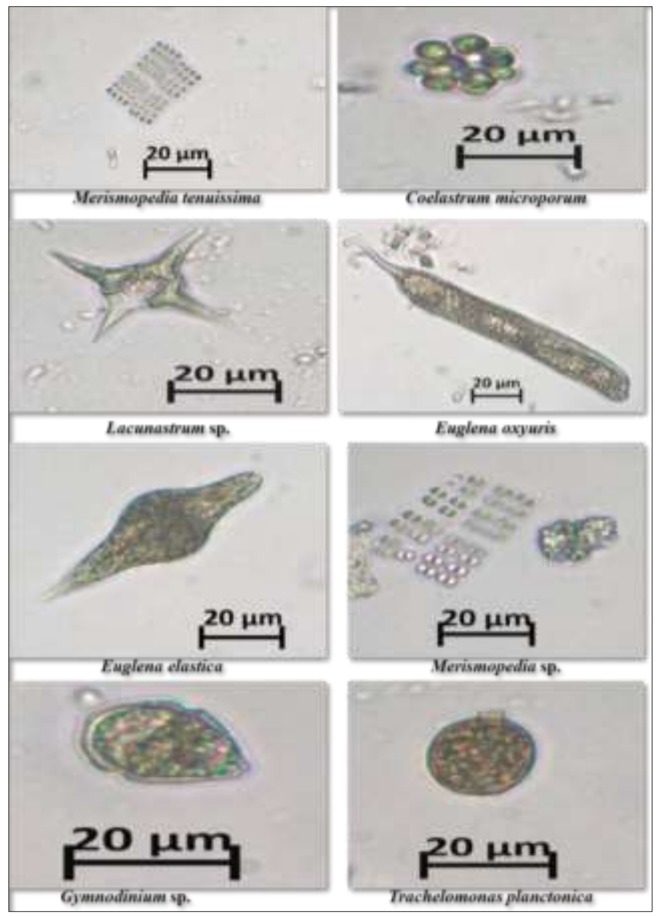

Fig 7: Sample of Phytoplanktons found in 2 study sites

Conclusion

The present findings indicate that phytoplankton diversity relates with the seasonal variation of abondoned coal mine pit water body. Low species diversity during monsoon justify that pit water is polluted by adjoining surface soil runoff with heavy metals by rain water. During post-monsoon season the process continues that way and phytoplankton diversity is also low in this season. The water quality of the mine pit under consideration is not suitable for drinking and domestic use. Proper scientific planning and processing is needed from Government or any other end to use this pit water effectively.

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