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Study of the Phytoplankton Diversity with Respect to Water Quality Index in Damalia Abandoned Coal Mine Pit Lake, Raniganj Coalfield, West Bengal, India

***Abstract*: In the open cast coal mining like that in Raniganj coalfield (RCF) after completion of coal extract a pit is produced which is subsequently restored by groundwater and contiguous surface runoff. The current study encompasses the assessment of seasonal Phytoplankton Diversity and calculates the Phytoplankton Species Diversity Index ($\bar{H}$) in respect of the Water Quality Index in Damalia pit lake in RCF from 2019 to 2020. In the pit, Cyanophycean members were found most abundant followed by Zygnematophycean members. $\bar{H}$ values are 1.889615, 1.749925 and 2.170007 in the pre-monsoon, monsoon & post-monsoon respectively, having Phytoplankton density 118600 - 131366.7 /litre. As per Wilhm and Dorris (1966) and Staub et al., (1970) yardstick in all seasons the pit lake was polluted and WQI varied from 97.6991 to 105.08 viz., unfit for any kinds of utilizes. To conclude the pit lake may be treated mechanically or through bio-remediation for utilisation of it for diverse purposes by the local communities (Figure 1).**

Key words: Phytoplankton density; Phytoplankton Species Diversity Index ($\bar{H}$); Pit lake; Raniganj coalfield (RCF); Water Quality Index

Coal is one of the extensive and prime energy resources. Succeeding coal extraction from surface cut mine an abandoned pit lake (locally called Khadan) is created in the RCF area. RCF is the oldest and major coal mining area in India. The physical and chemical property of a pit lake is very distinct and extraordinary compared to the other water bodies[1-3]. The Phytoplankton is a satisfactorily bio-monitoring tool to determine any contamination and its status of an aquatic system hence they are utilized for the rating of water samples with various kinds of adulterants[4,5]. Contrastingly the WQI could be an adequate appliance for the comparison of various sources of water bodies' water quality and it furnishes a common conception of the feasible water-related problems in a particular region. The WQI is very much contractive and important to relate the tendency of water quality with management and strategy of water quality[6,7]. Therefore, it is worthy to research the seasonal phytoplankton community and their role in the aquatic ecosystems and water quality to contribute to a theoretical basis for abandoned coal mine lake's ecological restoration, management and sustainability.

Abandoned coal mine pit lakes are relatively uncharted in the RCF. In conformity with the proposition, the authors are eager to investigate the various aspects of Pit Lake in the RCF region of an optimal strategy of these aquatic landscapes. Specifically, the objectives of the current study include: a) To explore the seasonal phytoplankton biodiversity and biomass b) determine the season wise Phytoplankton SDI ($\bar{H}$) c) reckon the seasonal WQI of the studied pit lake & d) recognize the pollution status with the aid of Phytoplankton SDI ($\bar{H}$) and WQI.

***Material and Methods*: Study Area:** Damalia pit lake is situated in Damalia village which is in Tirat gram panchayat, Raniganj block of Paschim Bardhaman in West Bengal, India (Figure 2) and coordinal extension is 23.36.32N, 87.04.00E. The pit lake is Opposite L shaped, length 650m & 710m, width 220m & 140m, depth 19m – 24m and last coal extracted in 1989.

Phytoplankton Collection, Documentation, Preparation of Permanent Slide and Preservation: Phytoplanktons were collected from the studied pit lake. Collection was carried out during the study period in three different seasons (Pre-monsoon, Monsoon & Post Monsoon) to study the variation and establish the effects of mines contamination on phytoplankton. The Drop Count Procedure was come after as numerical representation of phytoplankton and its densities were calculated as organisms per litre.

Observations and Identifications: Microscopic analysis from the permanent slides were done under Olympus GB microscope and Digital images were also captured utilizing Leica D series microscope with QWin software and CARL ZEISS Axiostar plus transmitted-light microscope with Axio Vision LE software version 4.8.2. Afterwards phytoplankton identification was done using standard literature and monographs[8-10].

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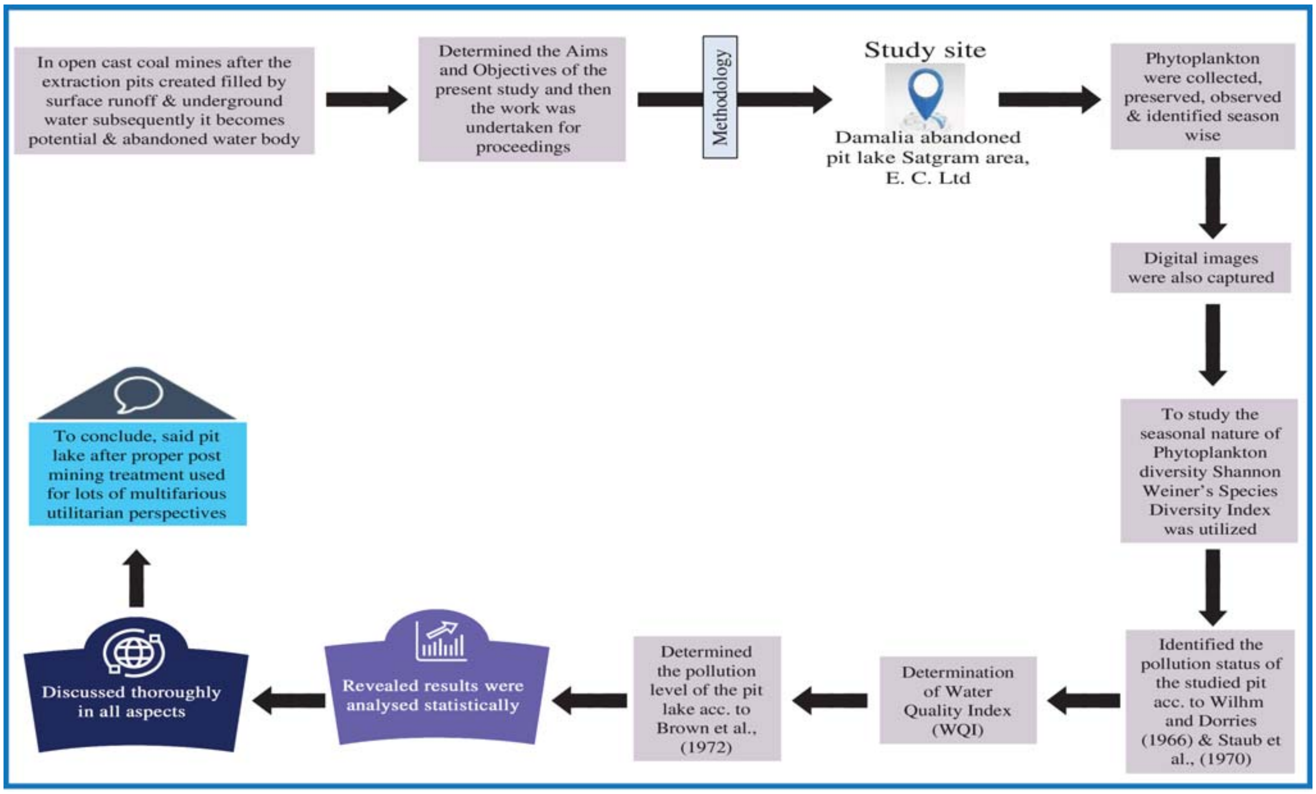

Figure 1. Diagrammatic representation of the present study.

Investigation of Phytoplankton Species Diversity Index: To study the seasonal nature of Phytoplankton diversity of abandoned pits Shannon Weiner's SDI ($\bar{H}$) was employed.

The formula is:

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

Determination of the Pollution Status: The specified relationship in between Phytoplankton SDI ($\bar{H}$) and pollution measure of a water body was exercised[11-12].

Determination of Water Quality Index (WQI): Subsequently WQI was also calculated by Weighted Arithmetic Index method[13]. The Maximum permissible limit as per ISI as S_n was considered for analysis of WQI.

1st Step

Calculate the unit Weight (Wn) factor for each parameters by using the formula

$$Wn = \frac{K}{Sn}$$

Where, $$K = \frac{1}{\frac{1}{S1}+\frac{1}{S2}+\frac{1}{S3}+.....+\frac{1}{Sn}} = \frac{1}{\sum \frac{1}{Sn}}$$

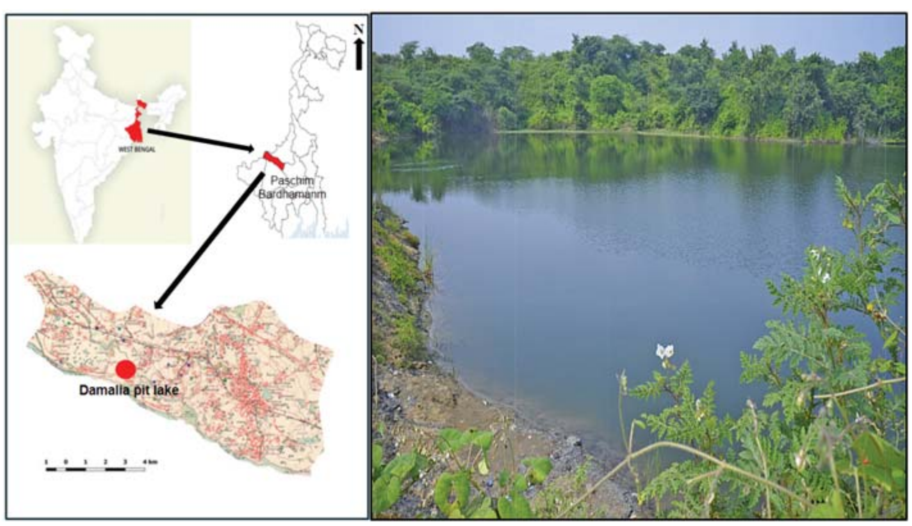

Figure 2. Geographical map of Damalia village where the studied abandoned pit lake is located and the said abandoned pit lake, RCF

Sn = Standard desirable value of the nth parameters

On summation of all selected parameters unit weight factors, Wn=1(unity)

2nd Step

Calculate the Sub-Index (Qn) value by using the formula

$$Q_n = \frac{(V_n - V_0)}{(S_n - V_0)} * 100$$

Where,

V_n = mean connection of the nth parameters

S_n = Standard desirable value of the nth parameters

V_0 = Actual value of the parameters of the pure water (generally V_0= O2 for most parameters except for pH)

$$QpH = \frac{[(VpH - 7)]}{[(8.5 - 7)]} * 100$$

3rd Step

Combining 1st Step & 2nd Step, WQI is calculate as follows

$$WQI = \frac{\sum WnQn}{\sum Wn}$$

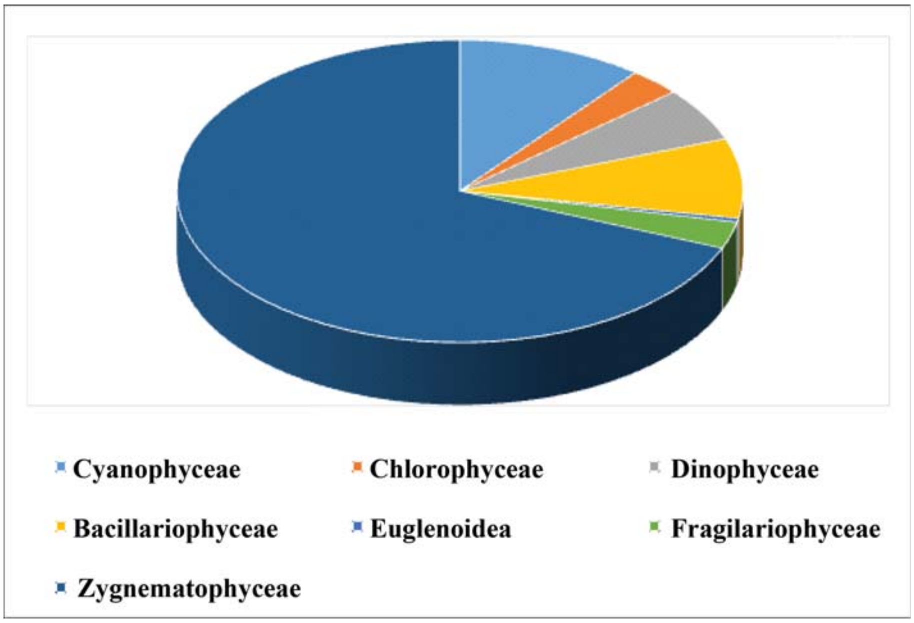

Figure 3. Consolidated season wise abundance of different classes of phytoplankton of Damalia pit lake, RCF (2019-2020)

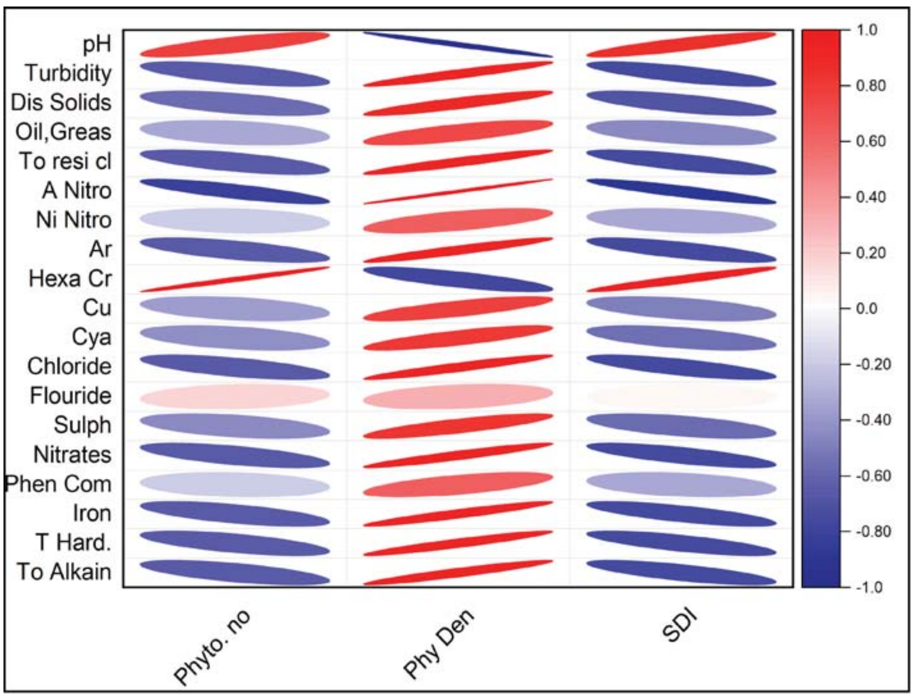

Figure 4. Seasonal correlation matrix among Phytoplankton number, Phytoplankton Density, Phytoplankton SDI ($\bar{H}$) and Limnological parameters considered for WQI calculation of Damalia pit lake

Discussion: In 1774, first was colliery commenced in the RCF, Bengal province of India. John Sumner and Suetonius Grant Heatly of the British East India Company (close to Ethora, currently in Salanpur community growth block) initiated coal mining from very beginning. 1820 onwards Alexander & Co. undertook constant mining activities. In 1835, the collieries were acquired by Prince Dwarkanath Tagore and the field was led by Carr Tagore & Company. Afterward, in 1973 all non-coking coal mines were nationalized and placed under the Coal Mines Authority of India. In 1975, the private collieries of RCF were included under Eastern Coalfields Limited, a subsidiary of Coal India Limited[14-16]. In this context, it is worth mentioning that coal mining is the distinct fundamental industry that contributes to economic growth and the primary source of energy, coal has become essential to meet the energy demand of a country. But after completion of coal extraction from the surface cut mine, a pit is created then it is refilled by groundwater and contiguous surface runoff.

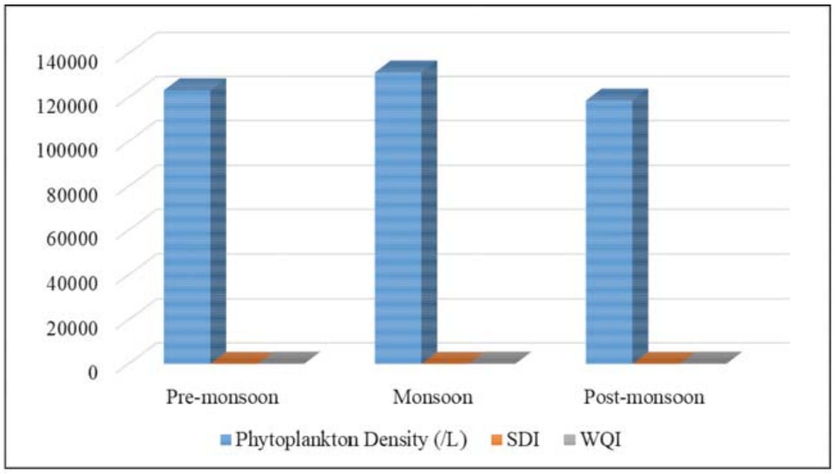

Figure 5. Seasonal compression among Phytoplankton Density, Phytoplankton Species Diversity Index ($\bar{H}$) and WQI of Damalia pit lake

Plate 1: Selective representatives of Phytoplankton in Damalia RCF

Consequently, it explodes as a potential and abandoned water body. Pit lakes are significant aspects of mine closure. Nevertheless, depending upon certain attributes of which water quality is the key, pit lakes often also present opportunities to afford notable regional welfare [17-18].

Phytoplankton is well known as a veritable bio-monitor of water contamination that can alter the phytoplankton community of a water body. In the present study from the considered pit lake a total of 31 phytoplankton species were recorded under 7 classes (Figure 3). Zygnematophycean members were found most abundant followed by Cyanophycean members. *Ceratium hirundinella*, *Chroococcus limneticus*, *Coelastrum microporum*, *Cosmarium canadense*, *Cymbella* sp., *Fragillaria* sp., *Glenodinium penardiforme*, *Gomphonema* sp., *Gymnodinium* sp., *Lepocinclis fusiformis*, *Microcystis pulverea*, *Mougeotia* sp., *Navicula* sp., *Rhopalodia* sp., *Spirogyra* sp., *Trachelomonas dybowskii*, *Ulnaria unla* were noted plentifully. Seasonal habitat of phytoplankton was demonstrated in Table 1. and photographic plates of selected representatives of phytoplankton were cited in Plate 1. *Ceratium hirundinella* is well known to cause difficulty in drinking water purification. Commonly freshwater dinoflagellates are distinguished in organically polluted waters having dead animal remains or blood, pus cells etc. This is owing to mesotrophic nature of algae. Presence of *Ceratium hirundinella*, *Peridinium* sp. and *Gloeodinium penardiforme* is an indication and the situation may also be panicky. A significantly higher total cell density of phytoplankton was

Table 1. Season wise habitat of Phytoplankton in respect of pit lake

Sl. No.	Phytoplankton taxa	Class	Pre-monsoon	Monsoon	Post-monsoon
1	*Amphora ovalis*	Bacillariophyceae	P	P	P
2	*Anabaena* sp.	Cyanophyceae	A	A	P
3	*Ceratium hirundinella*	Dinophyceae	P	P	P
4	*Chlorosarcina* sp.	Cyanophyceae	A	P	A
5	*Chroococcus limneticus*	Cyanophyceae	P	P	P
6	*Coelastrum microporum*	Chlorophyceae	P	P	P
7	*Cosmarium canadense*	Zygnematophyceae	P	P	P
8	*Cosmarium obtusatum*	Zygnematophyceae	A	A	P
9	*Cosmarium biretum*	Zygnematophyceae	A	P	P
10	*Cymbella sp.*	Bacillariophyceae	P	P	P
11	*Encyonema sp.*	Bacillariophyceae	P	A	P
12	*Fragillaria sp.*	Fragilariophyceae	P	P	P
13	*Glenodinium penardiforme*	Dinophyceae	P	P	P
14	*Gomphonema sp.*	Bacillariophyceae	P	P	P
15	*Gymnodinium sp.*	Dinophyceae	P	P	P
16	*Gyrosigma sp.*	Bacillariophyceae	P	A	P
17	*Gloeocystis ampla*	Chlorophyceae	A	A	A
18	*Glaucocystis nostochinearum*	Glaucophyceae	A	A	A
19	*Hantzschia sp.*	Bacillariophyceae	A	A	A
20	*Lepocinclis fusiformis*	Euglenoidea	P	P	P
21	*Microcystis pulverea*	Cyanophyceae	P	P	P
22	*Mougeotia sp.*	Zygnematophyceae	P	P	P
23	*Navicula sp.*	Bacillariophyceae	P	P	P
24	*Oedogonium sp.*	Chlorophyceae	P	A	P
25	*Peridinium sp.*	Dinophyceae	A	P	P
26	*Pinnularia sp.*	Bacillariophyceae	A	A	P
27	*Rhopalodia sp.*	Bacillariophyceae	P	P	P
28	*Spirogyra sp.*	Zygnematophyceae	P	P	P
29	*Trachelomonas dybowskii*	Euglenoidea	P	P	P
30	*Trachelomonas volvocina*	Euglenoidea	A	A	A
31	*Ulnaria unla*	Fragilariophyceae	P	P	P

P: Present; A: Absent

In the present study from the considered pit lake a total of 31 phytoplankton species were recorded.

detected during the monsoon season (131366.7cells/l), while the lowest in post-monsoon (118600cells/l). The Phytoplankton SDI ($\bar{H}$) varied significantly (1.749925-2.170007), with the highest value recorded during the post-monsoon season. As per the yardstick[11,12] for the year 2019-2020 in all seasons the studied pit lake was polluted but the highest pollution was noted in monsoon (Table 2-4, 8).

Determination of WQI is very utilitarian to assess the quality of the water as well as in water quality management. WQI of the studied pit waters in different seasons of the study period are exercised (Table 3-7) and ranged from 97.699 to 105.079. The Highest WQI value was recorded in monsoon. Figure 4 and 5 show the season wise correlation among the Phytoplankton number, Phytoplankton Density, Phytoplankton SDI ($\bar{H}$) and

Table 2. Determination of the SDI ($\bar{H}$) of Pre-monsoon

Sl.	Taxa	1st drop	2nd drop	3rd drop	Total	Average (ni)	Total average (N)	Species Diversity Index ($\bar{H}$)	Phytoplankton Density (/L)	$\bar{H}$
1.	*Cosmarium canadens*	1	1	2	4	1.333333	1232.333	0.01066		
2.	*Chroococcus limneticus*	24	18	32	74	24.66667	1232.333	0.112945		
3.	*Ceratium hirundinella*	0	0	2	2	0.666667	1232.333	0.005871		
4.	*Rhopalodia* sp.	11	5	8	24	8	1232.333	0.047177		
5.	*Ulnaria unla*	19	7	13	39	13	1232.333	0.069273		
6.	*Cymbella* sp.	36	22	32	90	30	1232.333	0.130491		
7.	*Encyonema* sp.	2	3	0	5	1.666667	1232.333	0.012889		
8.	*Mougeotia* sp.	772	858	983	2613	871	1232.333	0.353852		
9.	*Gyrosigma* sp.	1	0	0	1	0.333333	1232.333	0.003206		
10.	*Amphora ovalis*	34	25	18	77	25.66667	1232.333	0.11633		
11.	*Coelastrum microporum*	24	32	16	72	24	1232.333	0.110663	123233.3	1.88962
12.	*Lepocinclis fusiformis*	2	1	4	7	2.333333	1232.333	0.017126		
13.	*Navicula* sp.	4	3	2	9	3	1232.333	0.021136		
14.	*Gomphonema* sp.	6	5	2	13	4.333333	1232.333	0.028664		
15.	*Spirogyra* sp.	32	20	27	79	26.33333	1232.333	0.118561		
16.	*Fragillaria* sp.	35	28	43	106	35.33333	1232.333	0.146921		
17.	*Microcystis pulverea*	95	88	139	322	107.3333	1232.333	0.30669		
18.	*Gloeodaenium penardiforme*	5	0	0	5	1.666667	1232.333	0.012889		
19.	*Hantzschia* sp.	13	17	22	52	17.33333	1232.333	0.086526		
20.	*Gymnodinium* sp.	18	25	21	64	21.33333	1232.333	0.101308		
21.	*Trachelomonas dybowskii*	2	3	2	7	2.333333	1232.333	0.017126		
22.	*Oedogonium* sp.	24	8	0	32	10.66667	1232.333	0.05931		

Table 3. Determination of the SDI ($\bar{H}$) of Monsoon

Sl.	Taxa	1st drop	2nd drop	3rd drop	Total	Average (ni)	Total average (N)	Species Diversity Index ($\bar{H}$)	Phytoplankton Density (/L)	$\bar{H}$
1.	*Cosmarium canadens*	3	2	4	9	3	1313.667	0.020038		
2.	*Chroococcus limneticus*	22	38	36	96	32	1313.667	0.130551		
3.	*Mougeotia* sp.	984	1069	856	2909	969.6667	1313.667	0.323333		
4.	*Rhopalodia* sp.	3	6	5	14	4.666667	1313.667	0.028906		
5.	*Ulnaria unla*	27	13	17	57	19	1313.667	0.088392		
6.	*Cymbella* sp.	19	25	12	56	18.66667	1313.667	0.087204		
7.	*Ceratium hirundinella*	1	0	0	1	0.333333	1313.667	0.003031		
8.	*Peridinium* sp.	32	27	21	80	26.66667	1313.667	0.114132		
9.	*Coelastrum microporum*	16	8	32	56	18.66667	1313.667	0.087204		
10.	*Lepocinclis fusiformis*	4	2	3	9	3	1313.667	0.020038		
11.	*Navicula* sp.	3	0	4	7	2.333333	1313.667	0.016229	**131366.7**	**1.749925**
12.	*Gomphonema* sp.	9	7	11	27	9	1313.667	0.049255		
13.	*Spirogyra* sp.	32	27	19	78	26	1313.667	0.112001		
14.	*Fragillaria* sp.	18	28	34	80	26.66667	1313.667	0.114132		
15.	*Microcystis pulverea*	85	112	94	291	97	1313.667	0.277596		
16.	*Gloeodaenium penardiforme*	6	4	3	13	4.333333	1313.667	0.027194		
17.	*Chlorosarcina* sp.	24	29	18	71	23.66667	1313.667	0.104394		
18.	*Gymnodinium* sp.	18	27	22	67	22.33333	1313.667	0.099935		
19.	*Trachelomonas dybowskii*	3	2	4	9	3	1313.667	0.020038		
20.	*Cosmarium biretum*	3	0	1	4	1.333333	1313.667	0.010093		
21.	*Amphora ovalis*	4	2	1	7	2.333333	1313.667	0.016229		

Table 4. Determination of the SDI ($\bar{H}$) of Post-monsoon

Sl.	Taxa	1st drop	2nd drop	3rd drop	Total	Average (ni)	Total average (N)	Species Diversity Index ($\bar{H}$)	Phytoplankton Density (/L)	$\bar{H}$
1.	*Mougeotia* sp.	789	669	875	2333	777.6667	1186	0.399246		
2.	*Chroococcus limneticus*	34	28	40	102	34	1186	0.146906		
3.	*Cosmarium canadens*	2	5	3	10	3.333333	1186	0.023819		
4.	*Rhopalodia* sp.	7	4	2	13	4.333333	1186	0.029582		
5.	*Ulnaria unla*	3	9	7	19	6.333333	1186	0.040312		
6.	*Cymbella* sp.	27	19	33	79	26.33333	1186	0.121965		
7.	*Encyonema* sp.	0	2	0	2	0.666667	1186	0.006069		
8.	*Pinularia* sp.	4	1	2	7	2.333333	1186	0.017686		
9.	*Ceratium hirundinella*	0	2	0	2	0.666667	1186	0.006069		
10.	*Gyrosigma* sp.	2	0	1	3	1	1186	0.00861		
11.	*Peridinium* sp.	27	21	18	66	22	1186	0.106707		
12.	*Coelastrum microporum*	64	32	48	144	48	1186	0.187262		
13.	*Lepocynclis fusiformis*	0	2	1	3	1	1186	0.00861	**118600**	**2.170007**
14.	*Navicula* sp.	1	2	1	4	1.333333	1186	0.011014		
15.	*Gomphonema* sp.	7	5	2	14	4.666667	1186	0.031437		
16.	*Spirogyra* sp.	33	58	43	134	44.66667	1186	0.178168		
17.	*Fragillaria* sp.	13	8	17	38	12.66667	1186	0.069944		
18.	*Microcystis pulverea*	117	135	77	329	109.6667	1186	0.317618		
19.	*Anabaena* sp.	18	19	15	52	17.33333	1186	0.089099		
20.	*Gloeodaenium penardiforme*	8	6	4	18	6	1186	0.038585		
21.	*Amphora ovalis*	2	0	4	6	2	1186	0.015534		
22.	*Cosmarium obtusatum*	27	21	23	71	23.66667	1186	0.112688		
23.	*Gymnodinium* sp.	9	26	7	42	14	1186	0.075602		
24.	*Trachelomonas dybowskii*	6	9	1	16	5.333333	1186	0.035062		
25.	*Oedogonium* sp.	22	0	26	48	16	1186	0.083803		
26.	*Cosmarium biretum*	0	1	2	3	1	1186	0.00861		

Prepared seasonal Phytoplankton SDI of selected pit lake are presented in the Table 2 - 4.

Limnological parameters considered for WQI calculation of considered pit lake from 2019 to 2020. The outcomes showed that Phytoplankton SDI ($\bar{H}$) and WQI analyses collectively prove that Damalia pit lake is the most polluted water body and the water sample fall under the very much poor water category, unfit for drinking & other motives and treatment is needed before any utilizes (Table 8).

Conclusion: In RCF area after fulfilment of surface cut coal extraction the pits formed get transformed into a potential water body that is much contaminated owing to mining and anthropogenic activities etc. and by means of requisite post-mining strategy, planning and implementation using bioremediation or mechanical treatment from local and Government authorities the said pit lake may be used for lots of multifarious utilitarian perspectives and sustainability of the said area.

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Table 5. Determination of the WQI of Pre-monsoon

Parameters	Maximum permissible limit (as per ISI) Sn	1/Sn	Σ1/Sn	K=1/(Σ1/Sn)	W1= K/Sn	Ideal Value V0	Mean Conc. Value (Vn)	Vn/Sn	Vn/Sn* 100=Qn	WnQn	WQI
PH. Value	8.5	0.11765	409.3592026	0.002442842	0.000287393	7	6.77	-0.15333333	-15.33333	-0.0044067	
Turbidity NTU	5	0.2	409.3592026	0.002442842	0.000488568	0	0.01	0.004	0.4	0.000195427	
Dissolved Solids (mg/I)	500	0.002	409.3592026	0.002442842	4.88568E-06	0	125	0.266	26.6	0.000129959	
Oil and Grease (mg/I)	0.01	100	409.3592026	0.002442842	0.244284236	0	0.0013	0.1	10	2.442842359	
Total residual chlorine (mg/I)	0.2	5	409.3592026	0.002442842	0.012214212	0	0.001	0.005	0.5	0.006107106	
Ammonical Nitrogen (mg/l)	0.1	10	409.3592026	0.002442842	0.024428424	0	3.4	37.1	3710	90.6294515	
Nitrite Nitrogen (mg/I)	0.1	10	409.3592026	0.002442842	0.024428424	0	0.0013	0.015	1.5	0.036642635	
Arsenic (mg/I)	0.05	20	409.3592026	0.002442842	0.048856847	0	0.0013	0.03	3	0.146570542	
Hexavalent Chromium (mg/I)	0.05	20	409.3592026	0.002442842	0.048856847	0	0.0012	0.02	2	0.097713694	**104.978**
Copper (mg/I)	0.05	20	409.3592026	0.002442842	0.048856847	0	0.0011	0.02	2	0.097713694	
Cyanide (mg/I)	0.05	20	409.3592026	0.002442842	0.048856847	0	0.0013	0.02	2	0.097713694	
Chloride (mg/l)	250	0.004	409.3592026	0.002442842	9.77137E-06	0	13.9	0.058	5.8	5.66739E-05	
Flouride (mg/l)	1.5	0.66667	409.3592026	0.002442842	0.001628562	0	0.001	0	0	0	
Sulphates (mg/I)	150	0.00667	409.3592026	0.002442842	1.62856E-05	0	0.0011	7.33333E-06	0.000733	1.19428E-08	
Nitrates (mg/I)	45	0.02222	409.3592026	0.002442842	5.42854E-05	0	0.0011	2.44444E-05	0.002444	1.32698E-07	
Phenolic Compounds (mg/l)	0.005	200	409.3592026	0.002442842	0.488568472	0	0.0011	0.2	20	9.771369434	
Iron (mg/l)	0.3	3.33333	409.3592026	0.002442842	0.008142808	0	0.72	2.033333333	203.3333	1.655704265	
Total Hardness (CaCO3) (mg/l)	300	0.00333	409.3592026	0.002442842	8.14281E-06	0	33.9	0.107666667	10.76667	8.76709E-05	
Total Alkainities (CaCO3) (mg/l)	300	0.00333	409.3592026	0.002442842	8.14281E-06	0	32.6	0.106666667	10.66667	8.68566E-05	

Table 6. Determination of the WQI of Monsoon

Parameters	Maximum permissible limit (as per ISI) Sn	1/Sn	Σ1/Sn	K=1/(Σ1/Sn)	W1= K/Sn	Ideal Value V0	Mean Conc. Value (Vn)	Vn/Sn	Vn/Sn* 100=Qn	WnQn	WQI
PH. Value	8.5	0.11765	409.359	0.00244	0.000287393	7	6.56	-0.22666667	-22.66667	-0.00651425	
Turbidity NTU	5	0.2	409.359	0.00244	0.000488568	0	0.02	0.004	0.4	0.000195427	
Dissolved Solids (mg/I)	500	0.002	409.359	0.00244	4.88568E-06	0	133	0.262	26.2	0.000128005	
Oil and Grease (mg/I)	0.01	100	409.359	0.00244	0.244284236	0	0.0018	0.1	10	2.442842359	
Total residual chlorine (mg/I)	0.2	5	409.359	0.00244	0.012214212	0	0.0013	0.005	0.5	0.006107106	
Ammonical Nitrogen (mg/l)	0.1	10	409.359	0.00244	0.024428424	0	3.8	37	3700	90.38516727	
Nitrite Nitrogen (mg/I)	0.1	10	409.359	0.00244	0.024428424	0	0.0015	0.013	1.3	0.031756951	
Arsenic (mg/I)	0.05	20	409.359	0.00244	0.048856847	0	0.0015	0.028	2.8	0.136799172	
Hexavalent Chromium (mg/I)	0.05	20	409.359	0.00244	0.048856847	0	0.0011	0.022	2.2	0.107485064	**105.08**
Copper (mg/I)	0.05	20	409.359	0.00244	0.048856847	0	0.0013	0.02	2	0.097713694	
Cyanide (mg/I)	0.05	20	409.359	0.00244	0.048856847	0	0.0021	0.02	2	0.097713694	
Chloride (mg/l)	250	0.004	409.359	0.00244	9.77137E-06	0	14.8	0.0592	5.92	5.78465E-05	
Flouride (mg/l)	1.5	0.66667	409.359	0.00244	0.001628562	0	0.0012	0	0	0	
Sulphates (mg/I)	150	0.00667	409.359	0.00244	1.62856E-05	0	0.0014	7.33333E-06	0.0007333	1.19428E-08	
Nitrates (mg/I)	45	0.02222	409.359	0.00244	5.42854E-05	0	0.0014	2.44444E-05	0.0024444	1.32698E-07	
Phenolic Compounds (mg/l)	0.005	200	409.359	0.00244	0.488568472	0	0.0012	0.2	20	9.771369434	
Iron (mg/l)	0.3	3.33333	409.359	0.00244	0.008142808	0	0.76	2.466666667	246.66667	2.008559273	
Total Hardness (CaCO3) (mg/l)	300	0.00333	409.359	0.00244	8.14281E-06	0	34.3	0.114333333	11.433333	9.30994E-05	
Total Alkainities (CaCO3) (mg/l)	300	0.00333	409.359	0.00244	8.14281E-06	0	33.6	0.112	11.2	9.11994E-05	

Table 7. Determination of the WQI of Post-monsoon

Parameters	Maximum permissible limit (as per ISI) Sn	1/Sn	Σ1/Sn	K=1/(Σ1/Sn)	W1= K/Sn	Ideal Value V0	Mean Conc. Value (Vn)	Vn/Sn	Vn/Sn* 100=Qn	WnQn	WQI
PH. Value	8.5	0.11765	409.359	0.00244	0.000287393	7	6.79	-0.14	-14	-0.00402351	
Turbidity NTU	5	0.2	409.359	0.00244	0.000488568	0	0.01	0.002	0.2	9.77137E-05	
Dissolved Solids (mg/I)	500	0.002	409.359	0.00244	4.88568E-06	0	124	0.248	24.8	0.000121165	
Oil and Grease (mg/I)	0.01	100	409.359	0.00244	0.244284236	0	0.001	0.1	10	2.442842359	
Total residual chlorine (mg/I)	0.2	5	409.359	0.00244	0.012214212	0	0.001	0.005	0.5	0.006107106	
Ammonical Nitrogen (mg/l)	0.1	10	409.359	0.00244	0.024428424	0	3.5	34	3400	83.05664019	
Nitrite Nitrogen (mg/I)	0.1	10	409.359	0.00244	0.024428424	0	0.0011	0.013	1.3	0.031756951	
Arsenic (mg/I)	0.05	20	409.359	0.00244	0.048856847	0	0.0013	0.026	2.6	0.127027803	
Hexavalent Chromium (mg/I)	0.05	20	409.359	0.00244	0.048856847	0	0.0011	0.024	2.4	0.117256433	**97.6991**
Copper (mg/I)	0.05	20	409.359	0.00244	0.048856847	0	0.001	0.02	2	0.097713694	
Cyanide (mg/I)	0.05	20	409.359	0.00244	0.048856847	0	0.001	0.02	2	0.097713694	
Chloride (mg/l)	250	0.004	409.359	0.00244	9.77137E-06	0	13.9	0.0556	5.56	5.43288E-05	
Flouride (mg/l)	1.5	0.66667	409.359	0.00244	0.001628562	0	0	0	0	0	
Sulphates (mg/I)	150	0.00667	409.359	0.00244	1.62856E-05	0	0.001	7.33333E-06	0.0007333	1.19428E-08	
Nitrates (mg/I)	45	0.02222	409.359	0.00244	5.42854E-05	0	0.0011	2.44444E-05	0.0024444	1.32698E-07	
Phenolic Compounds (mg/l)	0.005	200	409.359	0.00244	0.488568472	0	0.001	0.2	20	9.771369434	
Iron (mg/l)	0.3	3.33333	409.359	0.00244	0.008142808	0	0.72	2.4	240	1.954273887	
Total Hardness (CaCO3) (mg/l)	300	0.00333	409.359	0.00244	8.14281E-06	0	33.9	0.113	11.3	9.20137E-05	
Total Alkainities (CaCO3) (mg/l)	300	0.00333	409.359	0.00244	8.14281E-06	0	32.6	0.108666667	10.866667	8.84852E-05	

Prepared seasonal WQI of studied pit lake is presented in the **Table 3 – 7.**

Table 8. Seasonal pollution status of studied pit lake

Pre-monsoon					Monsoon					Post-monsoon				
$\bar{H}$	Pollution status[11]	Pollution status[12]	WQI	Water Quality status[13]	$\bar{H}$	Pollution status[11]	Pollution status[12]	WQI	Water Quality status[13]	$\bar{H}$	Pollution status[11]	Pollution status[12]	WQI	Water Quality status[13]
1.889	Moderately polluted	Moderately polluted	104.978	Very Poor	1.749	Moderately polluted	Moderately polluted	105.079	Unfit for drinking and any kind uses	2.170	Moderately polluted	Light polluted	97.6991	Unfit for drinking and any kind uses

Table 8. In all seasons the studied pit lake is contaminated whereas the most polluted is in monsoon season

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Conflict of Interests: The present study will make the local villagers, Government and other authorities/ organisations aware of the ambient water adulteration of abandoned coal mine pit lake and in this context the authors do hereby declare that there is no conflict of interest with the above said persons and authorities / organisation. ❐

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