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Comparative study on Phytoplankton Distribution and Bioaccumulation of Heavy Metals in *Microspora* sp. of Chromite Contaminated Damsal nala of Sukinda Valley, Odisha, India

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Abstract

Damsal nala of Sukinda Valley of Odisha is accumulating drainage water coming from adjacent different chromite mines. A comparative study on seasonal distribution of phytoplankton community and heavy metals' bioaccumulation in Microspora sp. of Damsal nala was carried out during the year 2009 - '10, '10 - '11 and '11 - '12 in the present study. A total number of 8 species of phytoplankton was recorded from Damsal nala in the upstream region including six species of green algae (Chlorophyceae), one species of Bacillariophyceae and one of blue green algae (Cyanophyceae), whereas only three species belonging to a single family of Chlorophyceae were recorded from downstream region of Damsal nala. The abundance of phytoplankton community was found in the order of Microspora sp. > Zygnema sp. > Oscillatoria sp. > Spirogyra sp. > Navicula sp. > Ulothrix sp. > Mougeotia sp. > Oedogonium sp. and Microspora sp. > Oedogonium sp. > Mougeotia sp. in the upstream and downstream regions respectively. The concentration of three heavy metals, like total chromium, lead and cadmium in Microspora sp. of upstream region of Damsal nala ranged from 0.24 to 0.79 g kg^{-1}, 0.033 to 0.047 g kg^{-1} and 3.00 to 4.66 mg kg^{-1} respectively during the entire period of study. But the concentration of heavy metals in Microspora sp. collected from downstream region of Damsal nala ranged from 30.11 to 36.11 g kg^{-1}, 0.047 to 0.063 g kg^{-1} and 6.93 to 7.66 mg kg^{-1} for total chromium, lead and cadmium respectively during the study. The degree of heavy metal accumulation in Microspora sp. was found in the order of Cr > Pb > Cd and Cr >> Pb > Cd in the upstream and downstream regions of Damsal nala respectively. Microspora sp. can be used as phytoremediator due to its property of accumulation of high amount of chromium and lead and could be used as a natural filter media for the removal of these metals.

Keywords: Chromite mining, Damsal nala, Enrichment Factor, Heavy metal, *Microspora* sp., Phytoplankton distribution, Phytoremediation, Sukinda valley.

Introduction

The Sukinda Valley of Odisha is distinguished for its comprehensive chromite ore reserves. Its production has been augmented since last thirty years because of its towering demand. Damsal nala, the key surfacewater source of this province, is incessantly receiving toxic effluents discharging from number of adjacent chromite mines simultaneously. Phytoplankton constitutes the foundation layer of the food web in aquatic ecosystem and represent one of the most direct and profound indicator to pollutants entering into the reservoirs. Phytoplankton in the rivers or streams is mainly represented by algae and they appear to be ubiquitous in flowing water capable of photosynthesis. Some of the phytoplankton has been found to be the efficient indicators of water quality in riverine system. Metal content of algae increases with its age[1]. *Chlorella vulgaris* (Chlorophyceae) bioaccumulated hexavalent chromium maximally at an ambient concentration of 300 ppb; growth and phosphorilation (energy assimilation process) were decreased at higher concentrations, even for a short span of time[2]. Plants can bioaccumulate chromium in high amount[3]. Organisms, dwelling in water, can uptake and assimilate different toxic metals and thereby express metal toxicity[4]. Some researchers have examined the extent of metallic elements of diverse aqua systems together with bottom sediment as well as inhabitant fishes of Damsal Nala of Sukinda Valley[5-11]. But no study has been reported on the distribution of phytoplankton community of chromium contaminated Damsal nala till date. Study on the naturally available hyperaccumulating algae is also very scanty. To enlighten these areas the present work has aimed to study the seasonal distribution of phytoplankton community in uncontaminated upstream and contaminated downstream sites of Damsal nala of Sukinda Valley region on a comparative basis. Bioconcentration of heavy metals, namely chromium, lead and cadmium in *Microspora* sp. only, in particular due to availability and order of accumulation, was accessed to find out its suitability as phytoremediatior. The study of Enrichment Factor (EF) was also helpful to evaluate the extent of human interference.

Materials and Methods

Description of the study area: Sukinda Valley region is situated in the Jajpur district of Odisha. The total area is restricted in the south-western quadrant of topo-sheet no. 73G/12 and 73G/16 and is placed between latitude 21^{0}0’54.04” to 21^{0}3’53.1”N and longitude 85^{0}43’28.51” to 85^{0}52’14.55”E. Sukinda Valley is embraced by Daitari hill range on one side and the Mahagiri hill range on the other side. The entire drainage of the area flows towards NW (North-West) and finally joins Damsal nala which after originating from Daitari hill ultimately meet the major river, Bramhani. Damsal nala is perennial in nature. Most of the mine drainage is becoming a burden to it. For comparison and convenience, the study area was demarcated into two regions, *e.g*., upstream (relatively less polluted) and downstream (heavily polluted due to drainage). Two villages, namely Kansa and Jargi Sahi of Kansa panchayet situated in the upstream region and four villages namely Kolorangi (of Ransol panchayet), Rangamatia (of Chingudipal panchayet) and Ghagiasai and Chirgunia (of Kaliapani panchayet) *etc*., situated in the downstream region were selected as study sites. The detailed description and exact geographic locations of all these sampling stations are recorded in Table-1.

Collection, preservation and identification: Phytoplankton sample was collected randomly by plankton net through hauling process in three consecutive seasons (winter, summer and monsoon) during 2009 - '10, '10 - '11 and '11 - '12 respectively. Each phytoplankton sample was immediately fixed with Lugol's iodine solution. The identification of phytoplankton sample was performed as per standard guidelines[12-14].

Analysis of heavy metals: Heavy metals, particularly Cr, Pb and Cd in *Microspora* sp. were extracted following the digestion method[15] and estimated by Atomic Absorption Spectrophotometer (AAS) (Model: GBC AVANTA 932).

Enrichment Factor (EF): Enrichment Factor was reckoned following standard methods[16-17].

Results and Discussion

Phytoplankton distribution: Phytoplankton, the primary producer of an aquatic ecosystem, having great ecological significance in food chain maintains proper equilibrium between biotic and abiotic components of an aquasystem and reflects the overall environmental condition of any aquatic body. They have a short span of life and respond quickly to sharp environmental changes. Seasonal (winter, summer and monsoon) variations in distribution of phytoplankton community observed from six different sampling sites of upstream as well as downstream regions of Damsal nala for the three consecutive years *viz*., 2009 - ’10, ’10 - ’11 and ’11 - ’12 and presented in Tables 2-4.

The total number of 8 species of phytoplankton was recorded during the present span of study from the two sampling sites of Damsal nala in the upstream region which includes six species of green algae (Chlorophyceae), one species of Bacillariophyceae and one species of blue green algae (Cyanophyceae). Present study revealed that *Microspora* sp. was the most abundant as well as dominant species followed by *Zygnema* sp., *Oscillatoria* sp., *Spirogyra* sp., *Navicula* sp. and *Ulothrix* sp., whereas, *Mougeotia* sp. and *Oedogonium* sp. were less abundant species in the upstream region of Damsal nala. The availability of phytoplankton showed seasonal variations in the upstream region and the degree of availability was found in the order of summer > winter > monsoon during 2009 - ’10 and winter > summer > monsoon during 2010 - ’11 as well as 2011 - ’12.

Table-1
Details of sampling stations

District	Region	Panchayet	Village	Sampling station		Latitude	Longitude
				Name	Code		
Jajpur	Upstream	Kansa	Kansa	Damsal nala water	C_1	21^{0}3’53.1”N	85^{0}52’14.55”E
			Jargi Sahi	Damsal nala water	C_2	21^{0}3’49.7”N	85^{0}51’30.8”E
	Downstream	Kaliapani	Chirgunia	Damsal nala water	D_1	21^{0}2’14.75”N	85^{0}44’53.05”E
			Ghagiasai	Damsal nala water	D_3	21^{0}1’59.95”N	85^{0}44’33.75”E
		Chingudipal	Rangamatia	Damsal nala water	D_2	21^{0}2’13.25”N	85^{0}44’47.41”E
		Ransol	Kolorangi	Damsal nala water	D_4	21^{0}0’54.04”N	85^{0}43’28.51”E

A total of three species belonging to a single family, Chlorophyceae was recorded from the four different sampling sites of Damsal nala in the downstream region. The study confirmed that the *Microspora* sp. was the most abundant species followed by *Oedogonium* sp. and *Mougeotia* sp. The availability of phytoplankton varied seasonally in the downstream region and the degree of availability was found in the order of winter > summer > monsoon throughout the entire period of study. Some researchers studied on phytoplankton population in sewage fed river of Mahanadi, Odisha and reported 25 species of phytoplankton of three groups, *viz*., Chlorophyceae, Bacillariophyceae and Myxophyceae with seasonal fluctuations[18]. Distribution, occurrence and density of phytoplankton species are depended on various physicochemical parameters of the aquatic environment[19]. A hydrobiological survey in Damodar river basin was carried out and 39 species of phytoplankton of four groups, *viz*., Chlorophyceae, Bacillariophyceae, Cyanophyceae and Euglenophyceae were reported with distinct seasonal variations[20].

Metallic Bioconcentration in *Microspora* sp.: Algae are considered as an important component of aquasystem because they act as primary producers in one hand and on the other hand they serve as a very good filter media for accumulating heavy metals. The heavy metal concentration of *Microspora* sp. collected from chromite contaminated Damsal nala (upstream and downstream regions) was recorded during the study period in Table-5.

Table-2
Seasonal variations in phytoplankton distribution of Damsal nala during the year 2009 - '10

Season	Family	Phytoplankton species	Sampling site					
			Upstream region		Downstream region			
			C_1	C_2	D_1	D_2	D_3	D_4
Winter	Chlorophyceae	*Microspora* sp.	+	+	+	+	+	+
		Mougeotia sp.	-	-	+	+	-	-
		Oedogonium sp.	+	-	+	+	+	-
		Zygnema sp.	-	-	-	-	-	-
		Spirogyra sp.	-	-	-	-	-	-
		Ulothryx sp.	+	-	-	-	-	-
	Bacillariophyceae	*Navicula* sp.	-	+	-	-	-	-
	Cyanophyceae	*Oscillatoria* sp.	-	+	-	-	-	-
Summer	Chlorophyceae	*Microspora* sp.	-	+	+	-	+	-
		Mougeotia sp.	+	-	+	-	-	-
		Oedogonium sp.	-	-	-	+	-	-
		Zygnema sp.	+	+	-	-	-	-
		Spirogyra sp.	+	-	-	-	-	-
		Ulothryx sp.	-	-	-	-	-	-
	Bacillariophyceae	*Navicula* sp.	-	+	-	-	-	-
	Cyanophyceae	*Oscillatoria* sp.	-	+	-	-	-	-
Monsoon	Chlorophyceae	*Microspora* sp.	-	+	+	-	-	-
		Mougeotia sp.	-	-	-	-	-	-
		Oedogonium sp.	-	-	-	-	-	-
		Zygnema sp.	-	-	-	-	-	-
		Spirogyra sp.	-	-	-	-	-	-
		Ulothryx sp.	-	-	-	-	-	-
	Bacillariophyceae	*Navicula* sp.	-	-	-	-	-	-
	Cyanophyceae	*Oscillatoria* sp.	-	-	-	-	-	-

[+ = Present] and [- = Absent]

Table-3
Seasonal variations in phytoplankton distribution of Damsal nala during the year 2010 - '11

Season	Family	Phytoplankton species	Sampling site					
			Upstream region		Downstream region			
			C_1	C_2	D_1	D_2	D_3	D_4
Winter	Chlorophyceae	*Microspora* sp.	+	+	+	+	+	+
		Mougeotia sp.	-	-	+	+	+	+
		Oedogonium sp.	-	-	+	+	+	+
		Zygnema sp.	+	+	-	-	-	-
		Spirogyra sp.	+	-	-	-	-	-
		Ulothryx sp.	+	-	-	-	-	-
	Bacillariophyceae	*Navicula* sp.	-	+	-	-	-	-
	Cyanophyceae	*Oscillatoria* sp.	-	+	-	-	-	-
Summer	Chlorophyceae	*Microspora* sp.	-	+	+	+	-	-
		Mougeotia sp.	-	-	-	-	+	-
		Oedogonium sp.	-	-	-	+	-	-
		Zygnema sp.	-	-	-	-	-	-
		Spirogyra sp.	-	-	-	-	-	-
		Ulothryx sp.	-	-	-	-	-	-
	Bacillariophyceae	*Navicula* sp.	-	-	-	-	-	-
	Cyanophyceae	*Oscillatoria* sp.	+	+	-	-	-	-
Monsoon	Chlorophyceae	*Microspora* sp.	-	+	+	-	-	-
		Mougeotia sp.	-	-	-	-	-	-
		Oedogonium sp.	-	-	-	-	-	-
		Zygnema sp.	+	-	-	-	-	-
		Spirogyra sp.	-	-	-	-	-	-
		Ulothryx sp.	-	-	-	-	-	-
	Bacillariophyceae	*Navicula* sp.	-	-	-	-	-	-
	Cyanophyceae	*Oscillatoria* sp.	-	-	-	-	-	-

[+ = Present] and [- = Absent]

Table-4
Seasonal variations in phytoplankton distribution of Damsal nala during the year 2011 - '12

Season	**Family**	**Phytoplankton species**	**Sampling site**					
			Upstream region		**Downstream region**			
			C_1	**C_2**	**D_1**	**D_2**	**D_3**	**D_4**
Winter	Chlorophyceae	*Microspora* sp.	+	+	+	+	+	+
		Mougeotia sp.	+	-	+	+	-	+
		Oedogonium sp.	-	+	+	+	+	-
		Zygnema sp.	+	+	-	-	-	-
		Spirogyra sp.	+	-	-	-	-	-
		Ulothryx sp.	+	-	-	-	-	-
	Bacillariophyceae	*Navicula* sp.	-	+	-	-	-	-
	Cyanophyceae	*Oscillatoria* sp.	-	+	-	-	-	-
Summer	Chlorophyceae	*Microspora* sp.	-	+	+	-	-	+
		Mougeotia sp.	-	-		-	-	+
		Oedogonium sp.	-	-	-	+	-	-
		Zygnema sp.	+	-	-	-	-	-
		Spirogyra sp.	+	-	-	-	-	-
		Ulothryx sp.	-	-	-	-	-	-
	Bacillariophyceae	*Navicula* sp.	-	-	-	-	-	-
	Cyanophyceae	*Oscillatoria* sp.	-	+	-	-	-	-
Monsoon	Chlorophyceae	*Microspora* sp.	-	+	+	-	-	-
		Mougeotia sp.	-	-	-	-	-	-
		Oedogonium sp.	-	-	-	-	-	-
		Zygnema sp.	-	+	-	-	-	-
		Spirogyra sp.	-	-	-	-	-	-
		Ulothryx sp.	-	-	-	-	-	-
	Bacillariophyceae	*Navicula* sp.	-	-	-	-	-	-
	Cyanophyceae	*Oscillatoria* sp.	-	+	-	-	-	-

[+ = Present] and [- = Absent]

Table-5
Year-wise and seasonal analysis of chromium (g kg^{-1}), lead (g kg^{-1}) and cadmium (mg kg^{-1}) in *Microspora* sp. of Damsal nala

Metal	Region	Year	Winter	Summer	Monsoon	Mean	Range	SD	SE
Cr	Upstream	2009 - '10	0.24	0.63	0.79	0.553	0.24 - 0.79	0.283	0.163
		2010 - '11	0.33	0.69	0.75	0.590	0.33 - 0.75	0.227	0.131
		2011 - '12	0.39	0.67	0.73	0.597	0.39 - 0.73	0.181	0.104
	Downstream	2009 - '10	30.11	34.54	36.11	33.59	30.11 - 36.11	3.11	1.79
		2010 - '11	30.45	33.36	35.66	33.16	30.45 - 35.66	2.61	1.51
		2011 - '12	31.12	34.66	34.93	33.57	31.12 - 34.93	2.13	1.23
Pb	Upstream	2009 - '10	0.033	0.041	0.042	0.039	0.033 - 0.042	0.0050	0.003
		2010 - '11	0.039	0.043	0.046	0.043	0.039 - 0.046	0.0035	0.002
		2011 - '12	0.036	0.045	0.047	0.043	0.036 - 0.047	0.0060	0.003
	Downstream	2009 - '10	0.053	0.061	0.058	0.057	0.053 - 0.061	0.004	0.002
		2010 - '11	0.054	0.047	0.063	0.055	0.047 - 0.063	0.008	0.005
		2011 - '12	0.059	0.055	0.061	0.058	0.055 - 0.061	0.003	0.002
Cd	Upstream	2009 - '10	3.00	4.12	4.43	3.85	3.00 - 4.43	0.75	0.43
		2010 - '11	3.23	4.03	4.66	3.97	3.23 - 4.66	0.72	0.41
		2011 - '12	3.21	4.15	4.55	3.97	3.21 - 4.55	0.69	0.40
	Downstream	2009 - '10	7.20	7.60	7.66	7.49	7.20 - 7.66	0.25	0.14
		2010 - '11	6.93	7.21	7.50	7.21	6.93 - 7.50	0.28	0.16
		2011 - '12	7.02	7.36	7.63	7.34	7.02 - 7.63	0.31	0.18

The total chromium concentration of *Microspora* sp. collected from upstream region of Damsal nala near Jargi Sahi village ranged from 0.24 to 0.79 g kg^{-1}, 0.33 to 0.75 g kg^{-1} and 0.39 to 0.73 g kg^{-1} during 2009 - '10, 10 - '11 and '11 - '12 respectively (Table-3). The total chromium concentration of *Microspora* sp. collected from downstream region of Damsal nala near Chirgunia village varied from 30.11 to 36.11 g kg^{-1}, 30.45 to 35.66 g kg^{-1} and 31.12 to 34.93 g kg^{-1} during 2009 - '10, '10 - '11 and '11 - '12 respectively (Table-3). The total chromium concentration in *Microspora* sp. of Damsal nala showed wide range of seasonal fluctuation in both upstream and downstream regions. Concentration of lead in *Microspora* sp. collected from upstream region of Damsal nala near Jargi Sahi village varied between 0.033 and 0.042 g kg^{-1}, 0.039 and 0.046 g kg^{-1} and 0.036 and 0.047 g kg^{-1} during 2009 - '10, '10 - '11 and '11 - '12 respectively (Table-3). Concentration of lead in *Microspora* sp. collected from downstream region of Damsal nala near Chirgunia village ranged from 0.053 to 0.061 g kg^{-1}, 0.047 to 0.063 g kg^{-1} and 0.055 to 0.061 g kg^{-1} during the period of 2009 - '10, '10 - '11 and '11 - '12 respectively (Table-3). The concentration of lead in *Microspora* sp. of Damsal nala varied in short range in upstream as well as in downstream regions. Concentration of cadmium in *Microspora* sp. collected from upstream region of Damsal nala near Jargi Sahi village fluctuated between 3.00 and 4.43 mg kg^{-1}, 3.23 and 4.66 mg kg^{-1} and 3.21 and 4.55 mg kg^{-1} during 2009 - '10, '10 - '11 and '11 - '12 respectively (Table-3). Concentration of cadmium in *Microspora* sp. collected from downstream region of Damsal nala near Chirgunia village varied from 7.20 to 7.66 mg kg^{-1}, 6.93 to 7.50 mg kg^{-1} and 7.02 to 7.63 mg kg^{-1} during 2009 - '10,'10 - '11 and '11 - '12 respectively (Table-3). The concentration of cadmium in *Microspora* sp. of Damsal nala depicted short range of seasonal variations in upstream and downstream regions.

The degree of heavy metal accumulation in *Microspora* sp. was found in the order of Cr > Pb > Cd and Cr >> Pb > Cd in the upstream and downstream regions of Damsal nala respectively. An unusual high Cr concentrations was observed in some species of algae from Narragansett Bay, Rhode Island[21] and from Puerto Rico[22] which was certainly came from chromium wastes discharged from electroplaters (in Narragansett Bay) and from other anthropogenic sources as suggested in Puerto Rico. Marked toxicity of Cr was found with respect to photosynthetic pigments, photosynthesis, nitrate reductase activity and protein content in green algae[23]. The accumulation of heavy metals in the algae (*Fucus ceranoides*) is a continuous process throughout their life span after binding on the external wall, older tissues usually contains higher levels of some heavy metals[1]. Some naturally occurring plant species, collected from the bank of chromite contaminated Damsal Nala of Sukinda Valley, were found to accumulate high level of heavy metals like Cr, Pb and Cd in their different tissues and hence can be implemented for phytoremediation purposes of the surrounding ecosystem[24].

Enrichment Factor (EF): Enrichment factor (EF) can be implemented to make a distinction between the metals originating from anthropogenic activities and those from natural procedure and to evaluate the extent of anthropogenic influence. EF value increases with the increasing contributions of the anthropogenic origins. Similarly, EF value decreases with the decreasing rate of anthropogenic contributions. The results of the estimation of enrichment factor of *Microspora* sp. (collected from Damsal nala) calculated for different heavy metals are shown in Table-6.

The EF values of total chromium in *Microspora* sp. ranged from 45.71 to 125.46, 47.55 to 92.27 and 47.85 to 79.79 during 2009 - ’10, ’10 - ’11 and ’11 - ’12 respectively. The EF values of *Microspora* sp. showed extremely high level of enrichment for total chromium throughout the entire period of study depicting extremely high level of contamination and that may be surely due to soaring anthropogenic intervention like chromite mining. The EF values of lead in *Microspora* sp. varied from 1.38 to 1.61, 1.09 to 1.46 and 1.22 to 1.64 during 2009 - ’10, ’10 - ’11 and ’11 - ’12 respectively. The EF values of *Microspora* sp. showed that the level of enrichment remained within minimal or no enrichment level for lead throughout the entire period of study and it was indicative of the fact that those were free from anthropogenic influences and the variations were probably due to the temporal as well as special difference. The EF values of cadmium in *Microspora* sp. were fluctuated between 1.73 and 2.40, 1.79 and 2.14 and 1.68 and 2.19 during the year 2009 - ’10, ’10 - ’11 and ’11 - ’12 respectively. Whereas, the EF values of *Microspora* sp. varied from minimal or no enrichment to moderate enrichment for cadmium and divulged that those were not instigated from human activities and the minimal pollution was may be owing to natural processes like weathering *etc*. The EF values of heavy metals in *Microspora* sp. were found in the order of total chromium > cadmium > lead.

Table-6
Year-wise and seasonal analysis of Enrichment Factor (EF) of *Microspora* sp. of Damsal nala

Heavy metal	Year	Winter	Summer	Monsoon	Mean
Cr	2009 - '10	125.46	54.82	45.71	75.33
	2010 - '11	92.27	48.35	47.55	62.72
	2011 - '12	79.79	51.73	47.85	59.79
Pb	2009 - '10	1.61	1.49	1.38	1.49
	2010 - '11	1.38	1.09	1.46	1.31
	2011 - '12	1.64	1.22	1.30	1.39
Cd	2009 - '10	2.40	1.84	1.73	1.99
	2010 - '11	2.14	1.79	1.89	1.94
	2011 - '12	2.19	1.77	1.68	1.88

Conclusion

Significantly less abundance of phytoplankton in the downstream region of Damsal nala might be caused due to pollution by heavy metals like chromium, lead *etc.* In general, the phytoplanktonic communities are marked as water quality indicators. So, occurrence and distribution of *Microspora* sp., *Oedogonium* sp. and *Mougeotia* sp. in the downstream region were considered as phytoindicator tolerant species confirming their ability to survive in adverse conditions and accommodate themselves in that environment. *Microspora* sp. was found to accumulate high amount of chromium and lead and could be used as a natural filter medium for the removal of chromium and lead (phytoremediation) from the waste water, particularly coming from different chromite mines.

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