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VARIATIONS IN COMMUNITY STRUCTURE OF PHYTOPLANKTON IN RELATION TO PHYSICO-CHEMICAL NATURE OF HIGHLY TURBID SEAWATER

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Abstract: The highest concentration/count of TSS, DO, NH_4-N total Nitrogen, PO_4-P total Phosphorus and total count of phytoplankton were highest at different stations and transects of Alang and Piram where turbidity caused by the TSS is very high. However, pH, salinity, DO, BOD, NO_3-N, total phosphorus, total no. of phytoplankton genera as well as total count of phytoplankton were highest at control site (Poshitra) where seawater is very clear. Similarly the salinity, NO_2-N and generic diversity of phytoplankton were also maximum at Mahuva where seawater is least turbid as compared to Alang. However, the concentration/count of DO, NO_3-N, total Phosphorus and generic diversity of phytoplankton in the different stations and or transects were lowest at Alang, whereas the concentration of salinity and BOD were lowest at Piram. Similarly, pH, and the concentration of total Nitrogen were lowest in the different stations and or transects of Mahuva. The concentration of TSS, DO, BOD, NO_2-N, NH_4-N and PO_4-P were lowest at Poshitra. Forty nine genera of phytoplankton were recorded from different transects respectively. Twenty genera were common to different transects. *Celoneis, Climacodium, Grammatophora, Rhabdonema, Skeletonema, and Synedra* was observed only at *Poshitra,* while *Oxytoxum* was recorded only from Mahuva. Similarly, *Podocystis* and *Surirella* were observed only at Piram. In general, *Coscinodiscus* gave the highest count of phytoplankton, as compared to other species at all four transects. However, *Surirella* gave highest count at Alang where *Coscinodiscus* was sub-dominant. The similarity index indicated that all transects were more or less similar. However, the Mahuva was slightly more similar than the others, where turbidity of seawater was very high. It may be concluded that turbidity of seawater has significantly reduced the total number of genera as well as total count of phytoplankton at Alang and Piram, where seawater is highly turbid, as compared to control site where seawater is very clear.

Key words: Physico-chemical, Turbidity, Seawater, Phytoplankton

INTRODUCTION

The present paper deals with physico-chemical nature of highly turbid seawater and its effects on the growth and species diversity of phytoplankton. The Gulf of Cambay has very high tidal amplitude (11.64m) and tide is semidiurnal. The close end of the gulf is narrow and has shallow depth. The big perennial rivers-Narmada, Mahi, Tapti and Sabarmati in addition to other seasonal rivers discharge huge quantity of fresh water in the gulf. The slope of the intertidal coast is flat. Therefore huge quantity of silt and clay has accumulated in the gulf, which is frequently churned due to semidiurnal and high amplitude of tide in the gulf. This causes very high turbidity in the gulf. The turbidity continuously decreases as the gulf widens to Arabian Sea. The Piram and Alang are situated near the close end of the gulf and have very high turbidity.

However, at Mahuava it is least turbid as it is situated near the open end of the gulf. Poshitra has quite clear seawater as it is near to Okha which receives clear seawater from the open coast of Arabian Sea. The growth and species diversity of photosynthetic organisms like phytoplankton are severely affected if the water is turbid. Total suspended solids in the seawater are very high as the light penetration is significantly attenuated. This results in the reduced growth of phytoplankton (De *et al*., 1994; Snow, *et al*., 2000). The literature search, including internet search, did not reveal any published work on the effect of highly turbid seawater on the growth of phytoplankton although some work is available on the effect of low turbidity / low suspended solid on the growth of marine phytoplankton (De *et al*., 1994; Snow, *et al*., 2000). Therefore, it was desirable to study the effect of high turbid seawater and physio-chemical parameters of seawater in *in situ* condition on growth and generic diversity of marine phytoplankton.

MATERIALS AND METHODS

Two liters of surface seawater were collected at different height of the tide from Mahuva (21° 01' to 21° 05'N Lat and 71° 52'E Long), Piram (21° 29' to 21° 34'N Lat and 72° 20' to 71° 35'E Long), Alang (21° 18' to 21° 22'N Lat and 72° 10'to 72° 15'E long) and Poshtra (22° 25' to 22° 30' N Lat and 69° 11' to 69° 14'E long) during Nov-Dec 2009 and Jan-Feb 2010 using Nansen water sampler, Poshitra has quite clear water (Control) whereas the other three transects have different degree of turbidity due to the presence of suspended solid. The samples were collected from the shoreline, 1 km (Station-1), 5 km (Station-2) and 10 km (Station-3) at each transects. However, for the phytoplankton studies 100 L of surface seawater were collected at different height of the tide from the above said transects and they were filtered through 20μ mesh plankton net. The collected phytoplankton's were kept in 250 ml Seawater and preserved with 4% formalin and Lugol's iodine for further studies in the laboratory. The physico-chemical parameter, enumeration and identification of different species of phytoplankton were performed as per the method described (Tewari *et al*., 2001). Only the mean data for different tidal amplitude for each station is presented in the tables. The generic diversity was calculated as per the under mentioned formula (Shannon & Weaver, 1949).

Shanon index of general diversity = - "(ni/N)* log (ni/N) or, - " Pi log Pi. Where ni = Importance value for each genera, N= Total of importance values, Pi = Importance probability for each species = ni/N. The similarity index (S) was calculated by using the formula (ICMAM, 1998).

S = (2C/a+b)*100 where C= Number of species common at any two stations. a = Number of species at one Station and b =Number of species at the other station.

RESULTS AND DISCUSSION

The physico-chemical characteristics of seawater at different transects viz. Poshitra, Mahuva, Alang and Piram are presented in Table-1. The total suspended solids at different stations were always minimum at Poshtra (Control) and maximum at Alang. The total suspended solid ranged from 45.64 at station III of Poshitra to 583.3 mg L^{-1} at Station II of Alang. The similar trend was observed by mean total suspended solid as it varied from 54.50 at Poshitra transect to 559.54 mg L^{-1} at Alang transect. Total suspended solids showed the trend: Alang > Piram > Mahuva > Poshitra.

The pH varied in a very narrow range throughout different transect and stations. It was minimum (7.8) at station – I of Mahuva and maximum (8.20) at all stations of Poshitra. The DO ranged from 4.14 at station –II of Alang to 5.22 μ mol L^{-1} at station-I of Poshitra. Average dissolved oxygen of different transect did not show significant difference as it ranged from 4.24 at Alang transect to 4.74 μ mol L^{-1} at Poshitra transect. However, the water of all transects were well aerated. The Biochemical Oxygen Demand was quite low at all transects and stations as it varied from 1.04 at station –II to 2.34 μ mol L^{-1} at station-I for both of Poshitra transects. However, average BOD ranged from 1.22 at Piram to 1.54 μ mol L^{-1} at Poshitra.

The Salinity at Mahuva, Alang, and Piram were comparatively low as it varied between 31.52 at Station-I of Piram to 33.59 ‰ at station-III of Mahuva. However, the salinity at Poshitra was significantly high at different stations (37.31 to 37.55 ‰).

The concentration of NO_3-N ranged from 1.51 at station- III of Alang to 4.67 μmolL^{-1} at station-II of Poshitra. Similar trend was shown by average NO_3-N (1.62 at Alang to 3.70 μ mol L^{-1} at Poshitra). The concentration of NO_3-N showed the trend: Poshitra > Mahuva > Piram > Alang. The concentration of NO_2-N ranged from 0.02 at station-III of Poshitra to 0.59 μ mol L^{-1} at station-III of Mahuva. Similar trend was shown by average concentrations of NO_2-N (0.15 at Poshitra to 0.49 μ mol L^{-1} at Mahuva). The concentration of NO_2-N followed the trend: Mahuva > Alang > Piram > Poshitra. The concentration of NH_4-N ranged from 0.52 at station-IV of Poshitra to 1.18 μ mol L^{-1} at the stations-I and II of Piram. However, the average concentration of NH_4-N was least (0.76 μ mol L^{-1}) at Mahuva while highest (1.14 μ mol

Table 1. Physico-chemical analysis of seawater at Poshitra, Mahuva, Alang and Piram transects during 2009-10

	TSS (Mg L^{-1})	pH	Salinity (%)	DO (µmol L^{-1})	BOD (µmol L^{-1})	NO_3-N (µmol L^{-1})	NO_2-N (µmol L^{-1})	NH_4-N (µmol L^{-1})	TN (µmol L^{-1})	PO_4-P (µmol L^{-1})	TP (µmol L^{-1})
Ps-1	66.05±2.30	8.20±0.00	37.33±0.00	5.22±0.01	2.34±0.03	2.02±0.02	0.16±0.04	0.98±0.03	88.42±1.39	0.30±0.01	7.92±0.16
Ps-2	51.83±1.70	8.20±0.01	37.55±0.16	4.44±0.04	1.04±0.06	4.67±0.33	0.27±0.06	0.82±0.07	81.45±0.79	0.57±0.03	7.80±0.04
Ps-3	45.64±0.37	8.20±0.00	37.31±0.04	4.58±0.04	1.25±0.16	4.40±0.23	0.02±0.01	0.55±0.08	75.99±1.97	1.02±0.01	7.88±0.40
Ps-4	46.3±1.58	8.21±0.00	37.26±0.01	4.29±0.08	1.14±0.01	4.11±0.05	0.01±0.00	0.52±0.07	77.33±034	1.03±0.01	7.92±0.03
Mh-1	351.38±22.28	7.80±0.48	33.58±0.04	4.68±0.13	1.31±0.10	2.37±0.09	0.39±0.04	0.65±0.10	70.97±2.91	2.58±0.06	7.30±0.36
Mh-2	271.51±0.99	8.16±0.01	33.54±0.06	4.64±0.03	1.29±0.28	2.49±0.09	0.50±0.05	0.79±0.06	76.72±3.09	2.33±2.33	7.45±0.43
Mh-3	169.36±1.29	8.15±0.00	33.59±0.06	4.60±0.08	1.36±0.08	2.60±0.10	0.59±0.06	0.84±0.01	75.16±5.31	2.71±0.37	7.84±1.15
Al-1	544.93±6.08	8.12±0.01	33.19±0.01	4.33±0.28	1.21±0.07	1.71±0.06	0.17±0.01	0.85±0.19	84.89±2.01	2.30±0.06	7.06±1.08
Al-2	583.30±46.88	8.12±0.00	33.40±0.09	4.24±0.02	1.22±0.03	1.65±0.14	0.17±0.01	0.89±0.10	78.04±1.33	2.44±0.16	7.66±0.33
Al-3	550.38±5.98	8.12±0.01	33.21±0.16	4.25±0.02	1.32±0.02	1.51±0.01	0.28±0.03	1.03±0.01	80.72±0.86	2.35±0.01	7.52±0.76
Pm-1	344.97±27.39	8.14±0.01	31.52±0.02	4.81±0.01	1.23±0.05	2.24±0.18	0.30±0.02	1.18±0.03	90.60±1.70	2.73±0.24	8.43±0.05
Pm-2	280.41±12.40	8.12±0.00	31.64±0.040	4.51±0.07	1.10±0.01	2.09±0.13	0.21±0.01	1.18±0.11	87.74±1.14	2.76±0.22	7.19±0.31
Pm-3	362.44±7.83	8.12±0.01	31.73±0.06	4.58±0.06	1.34±0.18	1.77±0.21	0.10±0.01	1.07±0.01	85.77±1.11	2.55±0.01	7.45±0.97

L^{-1}) at Piram. The variation of NH_4-N followed the trend: Piram > Alang > Poshitra > Mahuva. The concentration of Total Nitrogen (TN) in seawater ranged from 70.97 at station-I of Mahuva to 90.60 µ mol L^{-1} and station-I of Piram. Similar trend was exhibited by average concentration of TN at these transects (74.28 at Mahuva to 88.03 µ mol L^{-1} at Piram). The concentration of TN followed the trend: Piram > Poshitra > Alang > Mahuva.

The concentration of PO_4-P ranged from 0.30 at station-I of Poshitra to 2.76 µ mol L^{-1} at station-II of Piram. Similar trend was shown by average concentration of Phosphate at these transects (0.63 at Poshitra to2.68 µ mol L^{-1} at Piram). The concentration of PO_4-P followed the trend: Piram > Mahuva > Alang > Poshitra. The concentration of Total Phosphate (TP) ranged from 7.06 at station-I of Alang to 8.43 µ mol L^{-1} at station of Piram. However, the lowest average concentration of TP was at Alang (7.41 µ mol L^{-1}) but the highest concentration was observed at Poshitra (7.87 µ mol L^{-1}). The variation of TP showed the trend: Poshitra > Piram > Mahuva > Alang (Table-1).

The above said results indicate that highest concentration of average NO_2-N, NH_4-N,TN were observed where the seawater has considerable degree of turbidity due to total suspended solid. However, the NO_3-N, and TP were highest at Poshitra where seawater is quite clear. The lowest average concentration of NO_2-N and PO_4-P were observed at Poshitra while NO_3-N, NH_4-N, TN and TP were lowest at Alang and Mahuva where seawater had considerable degree of turbidity due to suspended solids.

The results on qualitative and quantitative estimation of different genera of phytoplankton are depicted in Table 2-5. Forty nine genera of phytoplankton were recorded from all four transects comprising 38, 29, 34 and 30 genera at Poshitra, Mahuva, Alang and Piram transects respectively. The maximum number (38) was observed in control site and the least at Mahuva (29) Table 2&3. Twenty genera were common to all four transects. However, *Celoneis, Climacodium, Grammatophora, Rhabdonema, Skeletonema* and *Synedra* were observed only at Poshitra while *Oxytoxum* was recorded only from Mahuva. Similarly *Podocystis* and *Surirella* were observed at Alang whereas *Exuviella* and *Ornithocercus* were observed only at Piram (Table 4 and 5). It seems that the six genera recorded only from Poshitra prefer clear seawater whereas *Podocystis* and *Surirella* can grow well in highly turbid seawater at Alang.

The total count of phytoplankton at Piram ranged from 328 at the station-III to 354 No. L^{-1} at station-I, while for Alang it varied from 361 at station-III to 1191 No. L^{-1} at station-I. Similarly at

Table 2. Qualitative and quantitative estimation of phytoplankton at Poshitra during 2009-10

Genera	Ps-1	Ps-2	Ps-3	Average
		(Phytoplankton count No.L-1)		
Amphiprora	6	5.5	3	4.83
Asterionella	5.5	2	3	3.5
Bacilliaria	8	12	6.5	8.83
Biddulphia	126	164	39	109.83
Celoneis	3	1.5	6.5	3.67
Ceratium	6	2	5	4.33
Chaetoceros	29.5	22.5	27.5	26.5
Climacodium	0	1	0	0.33
Climacoshpenia	16.5	27	11	18.17
Cocconeis	0	0	1	0.33
Coscinodiscus	240	265	175	227
Dinophysis	5.5	10.5	1	5.67
Ditylium	189	221	92	167
Fragillaria	10.5	14	6	10.17
Grammatphora	3.5	0	0	1.17
Guinardia	4	1.5	3	2.83
Gymnodinium	1.5	1	2.5	1.67
Gyrosigma	6	10	18	11.33
Lauderia	3	0	1	1.33
Leptocylindrus	16	24	4.5	14.83
Licmophora	1	0	0	0.33
Melosira	13	13	4.5	10.17
Navicula	11	5.5	13	9.83
Nitzschia	94	43	63	66.67
Oscillatoria	3	2	1	2
Peridinium	3.5	5	5.5	4.67
Phaeocystis	2.5	5	1	2.83
Pleurosigma	15.5	19.5	15.5	16.83
Rhabdonema	17.5	5	1	7.83
Rhizosolenia	43.5	47	37	42.5
Skeletonema	6.5	6.5	1	4.67
Stauroneis	8.5	16.5	4.5	9.83
Stephanopyxis	70.5	37.5	31.5	46.5
Synedra	2.5	1.5	1	1.67
Thalassionema	19.5	22	5	15.5
Thalassiosira	25	29	9	21
Thalooassiothrix	25	12	43	26.67
Triceratium	4.5	3	2	3.17
Total Count No. L^{-1}	1046	1058	645.5	916.49
Total No. of Genera	36	34	35	35
Generic Diversity	0.89	0.83	0.88	0.88
Similarity Index				

Table 3. Qualitative and quantitative estimation of phytoplankton at Mahuva during 2009-10

Genera	Mh-1	Mh-2	Mh-3	Average
	(Phytoplankton count No.L-1)			
Asterionella	0	0	1	0.33
Bacilliaria	4	10	34.5	16.2
Biddulphia	23	52	40	38.3
Ceratium	31.5	34	24.5	30
Climacoshpenia	4	4.5	1	3.2
Coscinodiscus	59	55	79	64.5
Dinophysis	3.5	3.5	3.5	3.5
Ditylium	55	28	16	33
Fragillaria	17	25	7	16.5
Guinardia	0	1	0	0.33
Gymnodinium	12	1	1	4.8
Leptocylindrus	17.5	26.5	16.5	20.2
Licmophora	0	0	1	0.33
Melosira	9	10	19	12.7
Navicula	28	27	15	23.3
Nitzschia	9.5	19	19.5	16
Oxytoxum	1	0	0	0.33
Peridinium	8	20	36	28
Phaeocystis	0.5	13.5	5.5	9.8
Pleurosigma	0	11.5	27	13.2
Prorocentrum	0	0	7.5	2.5
Protoperidinium	0	5.5	0	5.2
Rhizosolenia	0.5	14	12	11.5
Stauroneis	0.5	3.5	1	2
Stephanopyxis	9.5	49.5	8	25.7
Thalassionema	0.5	4	18	8.2
Thalassiosira	0	0	1	0.33
Thalassiothrix	0	19	25	18.2
Triceratium	0	2	1	1.3
Total count No. L^{-1}	67	436	422	409.3
Total No. of Genera	4	24	26	24.67
Generic Diversity	0.19	1.22	1.2	1.25
Similarity Index	7.61			

Mahuva it ranged from 422 at station-III to 439 No. L^{-1} at station-II. While at Poshitra it varied from 645 at station-III to 1058 No. L^{-1} at station-II. The total count of phytoplankton showed the trend: Poshitra > Alang > Mahuva > Piram.

The lowest average count (0.33 No.L^{-1}) was shown at all transects by *Climacodium, Cocconeis and Licmophora* at Poshitra; *Asterionella, Guinardia, Licmophora Oxytoxum* and *Thalassiosira* at Mahuva; *Cocconeis, Corethron* and *Staureneis* at Alang and *Lauderia at* Piram. In general, *Coscinodiscus* gave highest count of phytoplan-kton as compared to other genera at all four transects. The count of *Coscinodiscus* ranged from 15.76% at Mahuva to 49.0% at Piram out of total count of these genera at four transects .However; the *Surirella* gave highest count (301.7 No.L^{-1}) at Alang where Coscinodiscus was subdominant. The total number of genera at different transects followed the trend: Poshitra > Alang > Piram > Mahuva.

Table 4. Qualitative and quantitative estimation of phytoplankton at Alang during 2009-10

Genera	Al-1	Al-2	Al-3	Average
		(Phytoplankton count No.L-1)		
Bacilliaria	90	28	10	42
Biddulphia	31.5	34	20.5	28.7
Campylodiscus	6	5.5	3	4.8
Ceratium	2.5	6.5	4	4.3
Climacoshpenia	9	5	3	5.7
Coscinodiscus	195	143	178	172
Cocconeis	0	0	1	0.33
Corethron	0	0	1	0.33
Dinophysis	11	5	4	6.7
Ditylium	1	2.5	0	1.2
Fragillaria	41	27	7	25
Gymnodinium	8	5	4.5	5.8
Gyrosigma	0	0	5	1.7
Lauderia	1	2	1	1.3
Leptocylindrus	3	40	9	17.3
Licmophora	12	1	1	4.7
Melosira	0	4	13.5	5.8
Navicula	11	8.5	1	6.8
Nitzschia	9	4	4.5	5.8
Noctiluca	1	3	0	1.3
Oscillatoria	11	3	1	5
Peridinium	3.5	6	2.5	4
Phaeocystis	16	5	10.5	10.5
Pleurosigma	1	4	0	1.7
Podocystis	10	8.5	4	7.3
Prorocentrum	12	1	0	0.7
Protoperidinium	1	1	0	0.7
Rhizosolenia	6	8	9	7.7
Stauroneis	0	0	1	0.33
Stephanopyxis	8	2	2	4
Surirella	670	177.5	57.5	301.7
Thalassiosira	0	2	1	1
Thalassiothrix	18	1	2	7
Triceratium	2.5	1	0	1.2
Total count No. L-1	1191	544	361	698.8
Total No. of Genera	27	30	28	28.33
Generic Diversity	0.73	0.96	0.87	0.87
Similarity Index	75			

Table 4. Qualitative and quantitative estimation of phytoplankton at Piram during 2009-10

Genera	Al-1	Al-2	Al-3	Average
	(Phytoplankton count No.L-1)			
Amphiprora	1	0.50	0	0.5
Bacillaria	34	20.00	13.5	22.5
Biddulphia	31	14.50	19	21.5
Campylodiscus	1	3.00	0	1.3
Ceratium	3.5	19.00	24	15.5
Climacoshpenia	0.5	5.00	0	1.8
Coscinodiscus	194	163.00	141	166
Dinophysis	1	3.50	7.5	4
Ditylium	1	1.50	6	2.8
Exuviella	6	3.00	2	3.7
Gymnodinium	4.5	1.50	4.5	3.5
Lauderia	0	1.00	0	0.3
Leptocylindrus	0	3.00	6.5	3.2
Melosira	2.5	7.00	11	6.8
Navicula	11	13.00	13.5	12.5
Nitzschia	21	20.00	15	18.7
Noctiluca	3.5	1.50	2	2.3
Ornithocercus	1	2.00	1.5	1.5
Oscillatoria	3.5	1.00	3	2.5
Peridinium	4.5	7.00	24	11.8
Phaeocystis	5	12.00	13	10
Pleurosigma	6.5	8.50	4	6.3
Prorocentrum	0	1.50	2.5	1.3
Protoperidinium	1.5	1.00	0.5	1
Rhizosolenia	7	2.50	4.5	4.7
Stauroneis	2.3	4.00	8.5	5
Stephanopyxis	1	2.50	0	1.2
Thalassiosira	1	4.50	1	2.2
Thalassiothrix	3.5	1.00	1	1.8
Triceratium	3.5	2.50	1	2.3
Total count No. L^{-1}	356	330.00	328	338.5
Total No. of Genera	26	29	24	26.33
Generic Diversity	0.81	0.94	0.99	0.94
Similarity Index	70.58			0.5

The total generic diversity of phytoplankton in all stations and transects were low. The generic diversity within all three stations of all transects ranged from 0.83to 0.89 at Poshitra, 1.19to 1.22 at Mahuva, 0.73 to 0.96 at Alang and 0.81 to 0.99 at Piram. However, the mean generic diversity for each transects from 0.87 at Alang to 1.25 at Mahuva. The similarity index ranged from 70.58 at Piram to 77.61 at Mahuva. The similarity index indicated that all transects were more or less similar. However, the Mahuva was slightly more similar with Poshitra than the others, where turbidity of seawater was very high.

The mean concentration for the transect as well as or variation of concentration at different stations of each transect for total suspended solid, dissolved oxygen, NH_4-N, total nitrogen, PO_4-P, total phosphorus, and total count of phytoplankton were highest at Alang and /or Piram where the turbidity caused by the total suspended solid is very high. However, the mean concentration for the transects and /or the variation of concentration of different stations of each transect for pH, salinity, dissolved oxygen, BOD, NO_3-N, total phosphorus, total number of phytoplankton genera as well as total count of phytoplankton were highest at control site i.e. Poshitra where seawater was very clear. Similarly, the values for salinity, NO_2-N and generic diversity of phytoplankton were highest at Mahuva where seawater is least turbid as compared to Alang.

The above said results indicate that the turbidity of seawater has significantly reduced the total number of genera as well as total count of phytoplankton as compared to clean seawater. However, the total count of phytoplankton at station-I of Alang was highest probably due to sufficiently higher concentration of plant nutrient at this station.

The turbidity in seawater attenuates the penetration of light through water column, therefore, affecting the growth and productivity of phytoplankton. It also alters the chemical and physical structure of seawater (COMAPS, 1998-99). The high total suspended solids which causes turbidity of seawater at Piram and Alang are caused by discharge of suspended solid loads by the perennial rivers viz., Narmada, Tapti, Mahi and Sabarmati coupled with very high tidal amplitude and semi-diurnal nature of the tide constantly keep the silt, clay and other particles in suspension. Therefore, the seawater in this region is highly turbid throughout the year. The turbidity of Mahuva is significantly reduced as the flow of the suspended solids discharge from the point of rivers to downstream up to Mahuva causes this effect. The total suspended solid load at Alang (559.54 mg L^{-1}) is more than Piram (329.27 mg L^{-1}). This is due to ship scrapping activities at Alang, which generates lots of waste materials and constant ship operation causes high turbidity in this region.

The higher salinity at Poshitra is due to enclosed nature of the area, shallow nature of the basin or arid nature of the region and absence of perennial rivers in that region. Very high concentrations of NO_3-N and TP have been observed at Poshitra. This might be due to the higher concentration of ions in seawater, the semi-arid climate and shallow nature of the basin in that region.

The *Coscinodiscus* gave the highest percentage count out of total count of phytoplankton at Poshitra, Piram, and Mahuva. However, at Alang *Surirella* gave the highest percentage count. It seems *Surirella* species can grow well in highly turbid seawater, which contains very high concentration of heavy metal and fecal pollution (Tewari *et al*., 2001). *Podocystis* and *Surirella* were recorded only from Alang and *Exuviella* and *Ornithocercus* observed only at Piram suggesting that these species can withstand very high concentration of heavy metal especially fish in such region (Nair and Subramanyan, 1955; Selvakumar, 1970; Subramanyan, 1959).

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