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Research article

EVALUATION OF MARINE WATER QUALITY WITH RESPECT TO BIOLOGICAL ENVIRONMENT DUE TO DISCHARGE OF TREATED WASTEWATER AT OUTFALL LOCATION ON THE ESTUARINE ZONE OF RIVER NARMADA, GUJARAT

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ABSTRACT: Studies were carried out for the evaluation of marine water quality with respect to primary and secondary productivity i.e. phytoplankton and zooplankton and benthic flora and fauna in estuarine zone of river Narmada to assess the water quality and bio-aesthetic value of the water body. The results revealed that an average counts for phytoplankton, zooplankton and zoobenthos were found to be 2800 Number/ml, 450 Number/ml and 220 Number/m^2 respectively. Among the major taxonomic groups, Chlorophyceae and Bacillariophyceae were the most dominant phytoplankton species. Based on the study of zooplanktons, it appeared that the area is mostly preferred by Rotifera and Cladocera followed by Copepoda and Protozoa. The SWD index ranged between 0.06-2.00 and 0.72-2.00 for phytoplankton and zooplankton respectively indicating moderate productivity of the water body whereas the SWD index (2.234) for zoobenthos indicated better productivity in sediment.
Key words: Pollution, Estuary, Planktons, Diversity index, Sediment

INTRODUCTION

The biota of an ecosystem when measured quantitatively and qualitatively gives an insight into the conditions existing in aquatic ecosystem [1],[2]. In natural and unpolluted streams the flora and fauna is represented by a high number of taxa, most of them with relatively small populations. A progressive decrease in the number of individual of each taxa is generally observed with an increase in pollution. Taking into account of both the number of taxa present and their abundance relative to one another, the diversity in populations of organisms is a measure of pollution. The diversity is directly correlated with the stability of ecosystem [3].

Biological species viz., phytoplankton and zooplankton specific for a particular environmental condition are the best indicators of environmental quality. Phytoplankton are chlorophyll bearing suspended microscopic organism consisting of algal cells which are representatives from all major taxonomic phyla, the majority of members belong to Chlorophyceae, Cyanophyceae and Bacillariophyceae. Their unique ability to fix inorganic carbon to build up organic matter through primary production makes their study a subject of prime importance. The quality and quantity of phytoplanktons, and their seasonal successional patterns have been successfully utilised to assess the quality of water and its capacity to sustain heterotrophic communities. On the other hand, Zooplanktons are microscopic free swimming animal components of aquatic ecosystem represented by a wide array of taxonomic group, of which the members belonging to Protozoa, Rotifera, Cladocera and Copepoda are most common and often dominate the entire consumer communities. They constitute an important link between primary producers and consumers of higher order in aquatic food webs [4].

The nature and quality of biological species in a water body is dependent on various physico-chemical characteristics of water such as pH, conductivity, nutrients, BOD, alkalinity etc. and also on the type of water body such as lentic and lotic system. Thus the quality and quantity of planktons obtained in any water body is an indicator of the physico-chemical quality of water as well as the type of water body. The estimation of plankton community structure in water bodies is thus helpful to assess and enumerate the aquatic ecosystem.

Several studies have been undertaken to assess the water quality in terms of phytoplankton, zooplankton and benthic flora and fauna. Phytoplankton aids the primary productivity and food chain of aquatic ecosystems. Any disturbance in their community structure directly decreases its productivity [5], [6].

Some qualitative and quantitative studies at different places in running waters have indicated a definite correlation with the intensity of pollution [7],[8] and [9]. Zooplankton is known not only to form an integral part of the lotic community but also contribute significantly to the biological productivity of fresh water ecosystem [10],[11].
Nutrients from anthropogenic pollution can degrade water quality and alter the balance of marine food webs lying at the base of the trophic pyramid, plankton quickly respond to nutrient changes in the water, which can have repercussions throughout both pelagic and benthic food webs, and thus they serve as a good bio-indicator of water quality [12].
Benthos were dominated more in the sediment depth of 4-6mm and decreased progressively in the deeper layers showed patchy dispersion, related to the availability of food and predation [13]. Setty, 1976 reported the observed abundance of Foraminifera population in polluted water of Cola Bay, Goa. Higher value of benthos count may be due to the nutrient enrichment of organic contents [14]. Enrichment of coastal waters due to riverine flow and land runoff also seems to be one of the factors contributing to richness of fauna in near shore regions. The availability of food and the associated chemical changes influence the population dynamics [15].
In early November 2009, studies have been carried out on sediment pollution, water pollution, and plankton abundance at four shoreline sites in the San Francisco Bay. Results revealed that the sediment phosphorus and water phosphates were strongly correlated with one another, but soluble nitrates remained relatively constant at low levels. The daytime plankton abundance showed a positive trend with soluble phosphate which indicates that nitrogen is quickly taken up by plankton, making nitrogen the limiting factor for them [12].
With a view to evaluate the impact on marine environment arising due to the discharge of treated effluent from Final Effluent Treatment Plant (FETP) setup to received treated wastewater generated from Ankleshwar, Jhagadia and Panoli industrial estates at Bharuch in CETP, on the estuarine zone of river Narmada, the study has been undertaken on biological estuarine water quality including benthic macro, meo and micro flora and fauna.

MATERIAL AND METHODS

Studies were carried out on phytoplankton, zooplankton and zoobenthos to examine the water and sediment quality of the Narmada estuary region. In the present study, 10 sampling locations were identified in the estuarine zone of river Narmada near village Bhadbhut and village Ambetha (Fig.1). For Phytoplankton and Zooplankton analysis, water samples were collected from each sampling location at surface level in high and low tide conditions as per the standard method [16]. Thus, a total of 20 water samples were collected to establish diversity index to assess biological quality. All the analysis and estimations were carried out as per the procedure described in the Standard Methods [16]. Heavy metals were determined by ICP using JY-24 Model of Jobin Yvon, France.
Phytoplankton, mostly the unicellular organisms are either multicellular or colonial.

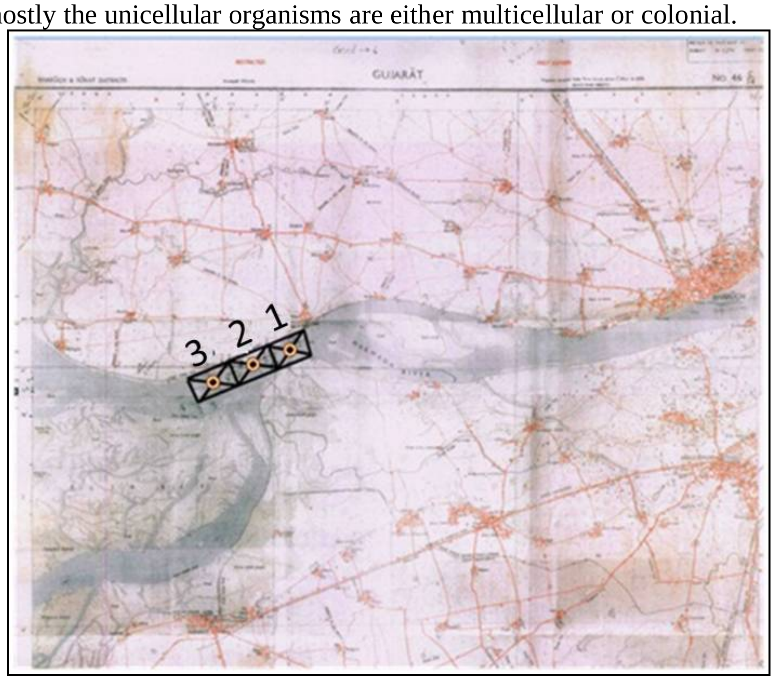

Fig.1: Study Area Map

1: Upstream of Outfall Location	**2: Outfall Location**	**3: Downstream of Outfall Location**

The density of phytoplankton is higher than that of zooplankton. Therefore, representative water sample of about 100 ml concentrated sample was collected from the water body in clean, good quality of plastic bottles. These samples were preserved by adding Lugol's Iodine solution (1 ml per 100 ml of water sample). Some phytoplankton organisms are unicellular whereas others are multicellular or colonial. Therefore, Lackey Drop Counting procedure was adopted to enumerate these algae. The Lackey Drop (Microtransect) method is a simple method of obtaining counts of considerable accuracy with samples containing a dense plankton population. The diversity was calculated for each community by Shannon Wiener Diversity Index (SWDI). The proportion is obtained by dividing the number of individuals of species by total number of individual in a sample.

Zooplankton density is always lesser than phytoplankton density. Therefore, around 20-50 L water was passed through plankton net (mesh size 64 micron) to concentrate zooplankton. The zooplankton thus collected and preserved immediately with an appropriate quantity of buffered formalin (5%) solution. The entire water was centrifuged, decanted and concentrated to make 1 ml total volume for observation under S-R (Sedgwick-Rafter) counting cell. The zooplankton were observed and counted under the microscope using 10 x magnifications.

Sediment samples were collected using Van-veen dredge grab sampler. One set of grab sample was collected from each location to account for the variability. The sediment was sieved through a 0.5 mm mesh size sieve and benthos retained in the sieve were collected in a polythene bottle and preserved in 5% buffered Rose-bengal formaldehyde solution. Samples were processed in the laboratory for estimation of total benthic population. Before analyzing the sediment samples in the laboratory, they were protected in aluminum foils and preserved immediately at low temperature for preventing decomposition and degradation of hydrocarbon content in them. Standard methods have been followed for the analysis of sediment samples. The chemical characteristics of sediment were determined by preparing sediment extract in distilled water in the ratio of 1:1. Sediment samples were analyzed for their physico-chemical characteristics of texture, ash content, volatile matter, calcium, magnesium, sodium, potassium, chloride, sulphate, nitrogen, phosphorus and heavy metals. It was observed that the grain size varies from 118µm to 392µm with an average of 237µm.

Benthos is an organism that inhabits the bottom of an aquatic body. Many of them are sessile while some creep over burrows in the mud. The quality and quantity of the animals found at the bottom are related to the nature of substrate and to the depth. The diversity was calculated for each community by Shannon Wiener Diversity Index (SWDI) as given in phytoplankton analysis. The organisms were identified with the help of available reference [17], [18] and [19].

RESULTS AND DISCUSSION:

The productivity is more in open sea, which is due to turbulence in water. This is called upwelling phenomena observed more in summer. The count as number of organism per ml of coastal water varied between 200-5400 Numbers. Chlorophyceae and Bacillariophyceae were found to be the dominant groups present. SWD Index varies between 0.06-2.00 indicating low to moderate productivity of water body (Table 1). The phytoplankton species identified are shown in Table 2. The zooplankton species/groups, its population dynamics and community composition at each sampling location are shown in Table 3. The count of number of organisms per m^3 of coastal water varied between 200-700 Numbers. Rotifera and Cladocera were found to be the dominant groups present indicating pollution (Table 4). The SWD index varies between 0.72-2.00, which indicates moderate productivity.

The physico-chemical characteristics of sediment such as texture, ash content, volatile matter, calcium, magnesium, sodium, potassium, chloride, sulphate, nitrogen, phosphorus and heavy metals are presented in Tables 5 to 9. The sediment texture diagrams is given in Fig.2 from the results it was observed that sediment texture was sandy with low organic matter. Nutrient in terms of nitrogen and phosphorus was also found to be low. Heavy metals like cadmium, chromium, and lead were found below detectable levels at monitored locations whereas iron, manganese and zinc were found to vary in the range 4827-9527 mg/kg, BDL-133 mg/kg and 10.1-28.3 mg/kg respectively. The data reveal that the sediments which are basically sandy type are free from pollution in the study region (Fig. 2).

The biological production potential of the study area was evaluated based on the qualitative and quantitative data on organisms representing different trophic levels. The phytoplankton cell counts and zooplankton standing stock population cover the productivity at primary and secondary levels respectively and the benthic fauna reflect on benthic productivity. The results are shown in Tables 10 and 11. A cumulative evaluation of all these parameters covering different stations is expected to give a general scenario on the resource potential of the estuarine system.

The macrobenthic and meiobenthic population was found to be more in the downstream region near the coastal area and indicated the coastal influence on the productivity in the form of phytoplankton and zooplankton. The diversity index (2.234) indicates the better productivity in sediment region. The dominant species were Bivalvia and Nematoda.

Table 1: Estuarine Water Quality – Biological Parameters (Phytoplankton) (Narmada Estuary)

S.No	Sampling Location			Phyto-plankton Number/ml	% Composition					Shannon Wiener Diversity Index
					Chlor-ophyceae	Bascill-ariophyceae	Cyano-phyceae	Eugleno-phyceae	Dino-phyceae	
Estuary Water of River Narmada near Bhadbhut										
1.	$21^0$41’5.9”N	HT	S	1550	70	8	15	4	3	0.066
	$72^0$51’25.5”E	LT	S	4200	59	20	11	5	5	0.722
2.	$21^0$40’42.2”N	HT	S	1500	49	10	30	6	5	0.133
	$72^0$50’39.8”E	LT	S	5000	60	10	22	5	3	0.558
3.	$21^0$40’4.0”N	HT	S	1570	67	6	25	-	2	0.269
	$72^0$49’49.7”E	LT	S	4500	68	8	22	2	-	0.464
4.	$21^0$39’45.8”N	HT	S	1500	62	15	23	-	-	0.259
	$72^0$49’1.1”E	LT	S	4300	54	24	17	5	-	0.387
5.	$21^0$39’11.7”N	HT	S	2000	57	15	17	7	4	0.162
	$72^0$48’21.7”E	LT	S	5400	65	15	20	-	-	0.524
Estuary Water of River Narmada near Ambetha										
6.	$21^0$38’59.7”N	HT	S	600	1	80	3	5	14	1.156
	$72^0$33’2.5”E	LT	S	520	2	82	2	2	12	1.500
7.	$21^0$39’35.7”N	HT	S	640	-	83	2	-	15	1.890
	$72^0$34’11.4”E	LT	S	200	1	84	2	-	13	1.570
8.	$21^0$40’12.8”N	HT	S	680	2	84	2	-	12	1.792
	$72^0$35’32.5”E	LT	S	240	-	86	1	-	13	1.573
9.	$21^0$40’24.8”N	HT	S	540	1	86	3	-	10	1.702
	$72^0$36’52.9”E	LT	S	260	2	90	-	-	8	1.783
10.	$21^0$40’12.5”N	HT	S	730	-	87	2	-	11	1.893
	$72^0$38’41.9”E	LT	S	250	2	95	-	-	3	2.00

Ranges of Shannon Wiener Diversity Index

<1: Indicate maximum impact of pollution or adverse factor HT: High Tide
1-2: Indicate medium impact of pollution or adverse factor LT: Low Tide
>2: Indicate lowest or no impact of pollution or adverse factor S: Surface

Table 2: List of Identified Phytoplankton Species (Narmada Estuary)

Chlorophyceae	Bacillariophyceae	Cyanophyceae	Euglenophyceae	Dinophyceae
Scenedesmus sp.	*Navicula* sp.	*Gomphosphaeria* sp.	*Euglena* sp.	*Ceratium* sp.
Chorella sp.	*Nitzschia* sp.	*Oscillatoria* sp.	*Phacus* sp.	*Protoperidinium* sp.
Chlorococcum sp.	*Synedra* sp.	*Chroococcus* sp.		
Ankistrodesmus sp.	*Cyclotella* sp	*Raphidiopsis* sp.		
Cosmarium sp.	*Cymbella* sp.			
Chlamydomonas sp.	*Gyrosigma* sp.			
Closteridium sp.	*Skeletonema* sp.			
Miractinium sp.				
Tetraedron sp.				

Table 3: Estuarine Water Quality – Biological Parameters (Zooplankton) (Narmada Estuary)

S. No.	Sampling Location			Zooplankton Number/m^3	% Composition of Groups				Shannon Wiener Diversity Index
					Protozoa	Copepoda	Cladocera	Rotifera	
Estuary Water of River Narmada near Bhadbhut									
1.	$21^0$41’5.9”N	HT	S	400	10	10	30	50	0.92
	$72^0$51’25.5”E	LT	S	700	14	19	23	44	1.00
2.	$21^0$40’42.2”N	HT	S	300	5	15	25	55	0.81
	$72^0$50’39.8”E	LT	S	600	8	16	35	41	1.05
3.	$21^0$40’4.0”N	HT	S	500	-	10	30	60	0.72
	$72^0$49’49.7”E	LT	S	600	5	15	15	65	1.73
4.	$21^0$39’45.8”N	HT	S	400	9	10	36	45	1.00
	$72^0$49’1.1”E	LT	S	600	6	10	10	74	1.06
5.	$21^0$39’11.7”N	HT	S	400	-	-	20	80	1.00
	$72^0$48’21.7”E	LT	S	500	2	8	20	70	1.20
Estuary Water of River Narmada near Ambetha									
6.	$21^0$38’59.7”N	HT	S	700	4	19	33	44	1.56
	$72^0$33’2.5”E	LT	S	300	5	15	40	40	2.00
7.	$21^0$39’35.7”N	HT	S	600	-	10	45	45	1.50
	$72^0$34’11.4”E	LT	S	400	-	5	45	50	1.00
8.	$21^0$40’12.8”N	HT	S	700	10	20	30	40	1.84
	$72^0$35’32.5”E	LT	S	200	-	-	50	50	1.50
9.	$21^0$40’24.8”N	HT	S	500	5	15	25	55	1.50
	$72^0$36’52.9”E	LT	S	200	6	10	10	74	0.99
10.	$21^0$40’12.5”N	HT	S	700	10	10	30	50	1.20
	$72^0$38’41.9”E	LT	S	300	14	19	23	44	0.92

Ranges of Shannon Wiener Diversity Index

1: Indicate maximum impact of pollution or adverse factor

1-2: Indicate medium impact of pollution or adverse factor

>2: Indicate lowest or no impact of pollution or adverse factor

HT: High Tide

LT: Low Tide

S: Surface

Table 4: List of Identified Zooplankton Species

Protozoa	Copepoda	Cladocera	Rotifera
Arcella sp.	*Nauplius* sp.	*Daphnia* sp.	*Keratella* sp.
Difuzia sp.	*Cyclops* sp.	*Moina* sp.	*Brachionus* sp.
	Diaptomus sp.	*Ceriodaphnia* sp.	*Filinia* sp.
		Alona sp.	

Table 5: Sediment Sampling Locations

S. No.	Sampling Location	Short form
1.	Upstream of Outfall Location	UOL
2.	Outfall Location	OL
3.	Downstream Outfall Location	DOL

Table 6: Physical Characteristics of Sediment

S.No.	Sampling Locations	Total sand	Silt	Clay	Texture	Moisture %	Volatile matter %	Ash %
		(%)						
1.	UOL	90.8	0.38	8.8	Sandy	22.56	5.6	70.8
2.	OL	94.1	2.31	3.6	Sandy	21.33	5.2	72.8
3.	DOL	95.1	1.90	2.1	Sandy	20.39	5.4	73.8

Table 7: Chemical Characteristics of Sediment

S. No.	Sampling Locations	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	SO_4^{2-}	Cl^{-}
		g/kg					
1.	UOL	6.45	1.13	2.6	1.2	9.53	12.9
2.	OL	3.93	10.9	5.8	2.8	10.2	13.9
3.	DOL	0.93	1.22	4.9	2.5	10.1	17.3

Table 8: Nutrient and Organic Contents of sediment

S.No.	Sampling Locations	Organic Matter (%)	Total Nitrogen	Total Phosphorus
			g/kg	
1.	UOL	3.08	2.28	0.08
2.	OL	3.18	2.10	0.09
3.	DOL	3.28	3.90	0.12

Table 9: Heavy Metals in Sediment

S.No.	Sampling locations	Cd	Cr	Cu	Pb	Fe	Mn	Zn	Ni
		mg/kg							
1.	UOL	0.4	4.6	6.6	BDL	9337.0	133.3	16.6	10.3
2.	OL	BDL	BDL	10.6	BDL	9527.0	64.3	28.3	BDL
3.	DOL	BDL	BDL	BDL	BDL	4827.0	BDL	10.1	BDL

BDL: Below Detectable Limit

Table 10: Analysis of Benthic Flora and Fauna in the Study Area

S.No	Sampling Location	Total Zoobenthos/m^2		Percent Composition in Groups					Shannon Weaver Diversity Index
		Macro-benthos	Meio-benthos	Forami-nifera	Nema-toda	Roti-fera	Bivalvia	Gastro-poda	
1.	UOL	40	ND	-	-	-	100	-	0.0
2.	OL	ND	80	-	99.80	-	-	0.20	0.02
3.	DOL	400	5.5960	57.06	28.5	14.27	0.17	-	2.234

ND: Not Detected

Table 11: Macrobenthic and Meiobenthic Species Identified Within Study Area

S.No	Species
Groups Studied	
1.	*Nematoda*
2.	*Rotifera*
3.	*Foraminifera*
4.	*Bivalvia*
5.	*Gastropoda*
Macrobenthos	
1.	*Bivalve larva*
2.	*Gastropod larva*
Meiobenthos	
1.	*Textularia*
2.	*Globigerina*
3.	*Nematod larva*

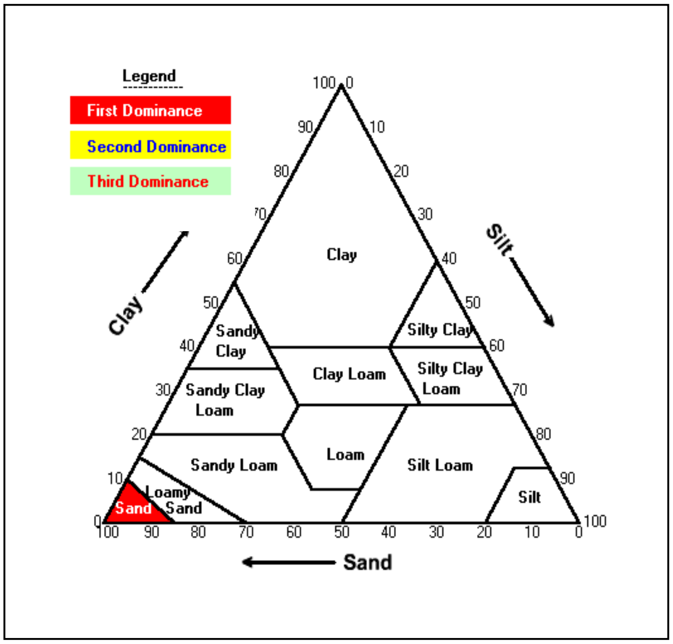

Fig.2: Sediment Texture Diagram

CONCLUSION

Higher counts of phytoplankton, zooplankton and zoobenthos in the water body are the indication for healthy productivity. The phytoplankton, zooplankton SWD index indicated moderate productivity of water body. Physico-chemical analysis of sediments depicted that the sediments which are basically sandy type are free from pollution. From the results it can be concluded that, there is insignificant impact due to the discharge of FETP effluent on the biological environment on estuarine zone of river Narmada as enough dilutions was available, moreover the high currents due to shallow depth, upwelling and shifting of aquatic and benthic flora and, fauna due to high tides and low tides maintaining the water body biologically intact.

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