

ASSESSMENT OF THE IMPACT OF DEVELOPMENTAL ACTIVITIES ON ESTUARINE ENVIRONMENTS OF MANDOVI AND ZUARI RIVERS OF GOA ALONG THE WEST COAST OF INDIA.

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Abstract: This paper discusses physico-chemical and biological data for EIA as regards construction of two jetties in the estuarine environments of Mandovi and Zuari rivers of Goa. Multivariate statistical techniques (Factor analysis) applied to physico-chemical data in water and sediments separately over different tidal periods, indicated a total of 6 factors each explaining 91% of the total variance during high tide and 84% of the total variance during low tide in Mandovi. Similarly, in Zuari, altogether 4 factors explained 78% of the total variance during low tide and 6 factors explained 83% of the total variance during high tide. In sediments, a total of 2 factors explained 73% of the total variance in Mandovi and 3 factors explained 95% of the total variance in Zuari river irrespective of tides. Observed increases in ammonia, PHc, Hg, etc in these rivers suggested contamination from domestic waste /organic matter, boat traffic and ship building activities. Though, jetty construction would disturb bed sediments and increase trace metals, micronutrients and organic load, increasing oxygen demand of riverine water, the resultant spring tide currents in NE-SW direction with a maximum speed of 1.08 ms^{-1} in Mandovi and in E-W direction Zuari with a maximum speed of 0.97 ms^{-1} , as observed from MIKE 21 HD model, in construction area of these estuaries would flush the contaminants out to the sea minimizing the impact due to construction..

Keywords: Mandovi River; Zuari River; physico-chemical parameters; environmental impact assessment; multivariate statistical analyses.

INTRODUCTION

Increasing population increases the developmental activity; however, the need of the hour is sustainable development. Instances have shown that urbanization dramatically transforms coastal marine environments and alters their environmental conditions. Recognition of the impacts of developmental activity on the riverine or coastal marine environment is therefore one of the important issues in modern times (Ashantha et, al 2004). Consequences arise due to the introduction of pollutants of physical, chemical and biological origin, resulting from various anthropogenic activities common to urban areas, which exert detrimental impact on aquatic organisms and alter the characteristics of ecosystem. (Hall & Ellis, 1985; House et al, 1993).

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One of the gradually developing states along the west coast of India is Goa. It lies between 15°48'00"-14°53'54" N and 74°20'13"- 73° 40'33"E, occupies an area of 3,702 km² and has a population of 13, 43,998 as per 2001 census. This small state with a coastal stretch of 102 km has a large scope for development because of its rich natural resource.

Besides agriculture and fishing, it is one of the well known tourist destinations in the world. Of the 7 rivers of Goa, the Mandovi and Zuari are the two major rivers and are called the life line of Goa. They originate at Bhimgad and Hermad-Barshen respectively in the Western Ghats and after traversing a long distance join the Arabian Sea. Both the rivers are connected by Cumbarjua canal. The river Mandovi receives more fresh water due to the input from number of tributaries compared to Zuari, which is more saline.

Tourism being one of the major industries in Goa, infrastructural facilities is highly necessary and one of the facilities required was the construction of jetties in the estuarine environments of these rivers for conducting cruises and for various other purposes like the berthing of vessels etc. This required the EIA reports and this task was assigned by the Government of Goa to the National Institute of Oceanography through its organization - Goa State Infrastructure Development Corporation (GSIDC) Ltd. in 2007. In view of this, the physico-chemical and biological studies were carried out at in Mandovi and Zuari rivers to understand the impact of jetty construction on the surrounding environment. The present studies were carried out at various selected locations from mouth towards upstream, which also included the construction sites, in these two rivers during high tide and low tide and the observations have been explained in the text of the paper.

MATERIAL AND METHODS

The sampling stations were selected from mouth towards upstream of Mandovi and Zuari rivers with a wide range of catchments and surface water types (rivers, streams, tributaries). These rivers drain the major rural, agricultural, urban and minor industrial areas of Goa and discharge into the Arabian Sea (Fig.1). The main pollutant loads include sewage and domestic wastewaters, agricultural runoff, animal husbandry and minimum industrial effluents. Surface and bottom water samples were collected from 8 locations in Mandovi and from 10 locations in Zuari as shown in Fig.1, using Niskin water samplers. Water quality parameters DO, BOD and nutrients were analysed using standard methods as given by Strickland and Parsons (1979), APHA (1992) and Grasshoff (1999) The pre-concentration of Pb and Cd metals was done by chelating them with ammonium pyrrolidine dithiocarbamate (APDC), followed by extraction in methyl isobutyl ketone (MIBK). Total phosphorous and total nitrogen in sediments were analysed as per the spectrophotometric method used for the analyses of dissolved inorganic phosphate and nitrate in water (Grasshoff, 1999).

Hydrodynamics

Self recording current meters (RCM – 9 MK II, Aanderaa Co., Norway) deployed over 15 days for recording at every 10 minute interval at selected locations in both the rivers showed resultant spring tide currents in NE-SW direction (maximum speed 1.08 ms⁻¹) in Mandovi and in E-W direction Zuari, with a maximum speed of 0.97 ms⁻¹, based on MIKE 21 HD model. Vertical profiles of temperature and salinity were obtained from different locations using portable SBE 19

SEACAT Profiler (Sea-Bird Electronic, Inc., USA). MIKE21 hydrodynamic model was used for understanding tidal elevations along open boundaries. A large-scale model with $200 \times 200 \text{ m}^2$ grid was used to simulate the currents and water level variations between the coastal stations.

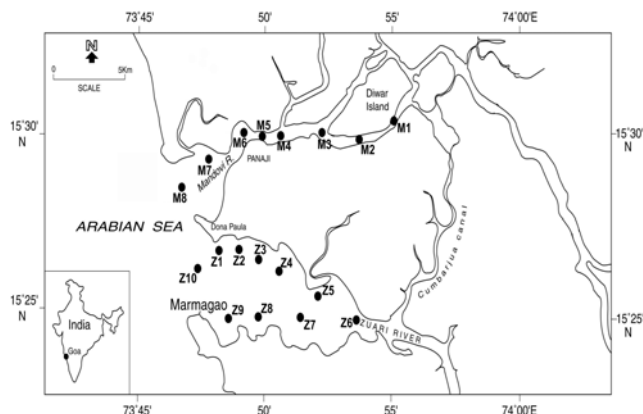
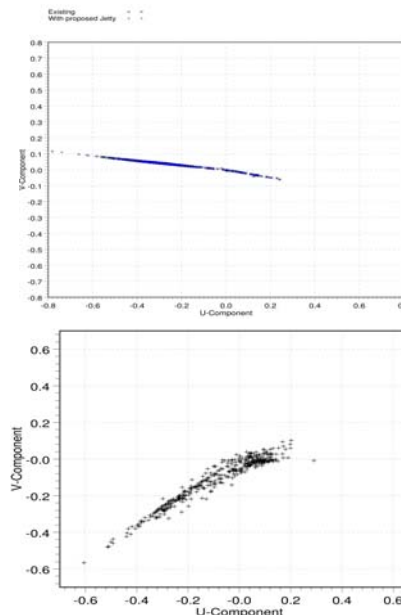


Fig. 1. Map Showing location of sampling stations in Mandovi and Zuari rivers of Goa.

Fig. 2. Resultant current velocity and direction in (a)Mandovi river and (b)Zuari river.

(b)



MULTIVARIATE STATISTICAL ANALYSIS

Principle Component Analysis (PCA)

The data collected was subject to multivariate statistical analysis to understand the influence of various parameters on the environment. Multivariate statistical approaches such as the PCA or the Factor analysis have been widely used for deriving the significance of specific parameters within the data generated (Vega et al., 1998; Helena et al., 2000; Simenova et al., 2003; Singh et al., 2004, Wunderlin et al, 2001 and Richman,1986). A varimax rotation of different varifactors with factor loading was evaluated using eigen value greater than 1 and sorted by the results having values greater than 0.4, based on significant influence (Sahu et al., 1998, Panigraphy et al., 1999 and Rath et al., 2000). The factor loading was classified as per Liu et al (2003), who categorized the factor loadings as “strong”, “moderate” and “weak” corresponding to absolute loading values of >0.75 as “strong”, of $0.75-0.5$ as “moderate” and of $0.50 - 0.40$ as “weak”.

RESULTS

Physical aspects: Current Pattern, Temperature, Salinity

Current vectors in Mandovi River indicated a maximum spring tide elevation of 2.33m, with a maximum current speed of 1.11 m/s. The u-component varied from -0.64 to 0.43 ms^{-1} , whereas, the v-component of the current indicated predominant currents in north-south direction (Fig.2a), with current components varying from -0.96 to 1.02 ms^{-1} . Similarly in Zuari, the water level variation indicated a maximum water level of 2.33m during spring tide and 1.4m during neap tide. The maximum current speed observed during spring tide was 0.97 m/s. The u-component of the current indicated predominant currents in an east-west direction (Fig.2b), with current

components varying from -0.71 to 0.29 m/s near the construction area. The v-component varied from -0.66 to 0.10 m/s.

Chemical Aspects: Water and sediment Quality

Variations in water quality parameters in both the rivers during high tide and low tide are depicted in Table-1. In sediment, the total phosphorous (TP), total nitrogen (TN), indicate higher values of TP (30 – 330µg/g; av. 118.7 µg/g) and TN (40-440 µg/g; av. 195.5 µg/g) in Mandovi relative to those in Zuari, with TP (4.35 – 13.46 µg/g; av. 7.59 µg/g) and TN (55.53 – 253.9 µg/g; av. 148.63 µg/g) remaining slightly lower. Trace metals - Pb (24 to 87 ppm), Cd (0.01 to 0.03 ppm) and Hg (74 to 900 ηg g⁻¹) indicate higher values for Hg in the upstream of Mandovi in clayey and organic rich sediments. In Zuari, the trace metals show Pb to vary from 3.38 – 23.51 ppm (av. 13.51 ppm), Cd from 0.04 – 0.16 ppm (av. 0.07 ppm) and Hg to vary from 80 –530 (av.186 ηgg⁻¹) during high tide. During low tide, the Pb varies from 7.67 – 33.14 ppm (av. 15.4 ppm), Cd from 0.1 – 0.8 ppm (av. 0.2 ppm) and Hg from 143 –236 (av.198 ηgg-1), with high values in the bay region and towards the mouth as compared to the estuarine region.

Table 1. Physico-chemical parameters during high tide and low tide of Mandovi and Zuari. Units: Temp(⁰C),Salinity(psu),pH(pH unit),TSS,DO,BOD(mgI⁻¹),PO4-P,NO2-N,NH3-N,NO3-N,SiO4-Si(□moll-1), PHC, Phenol (□g/l),

Zuari River							Mandovi river					
High tide				Low tide			High tide			Low tide		
	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.
Temp	31.8	29.0	30.5	25.0	23.5	24.8	29.0	28.0	28.7	29.0	28.3	28.6
pH	8.2	8.1	8.1	7.9	7.6	7.7	7.8	7.3	7.7	7.8	7.3	7.6
Salinity	32.4	14.3	20.3	28.0	12.0	9.6	31.1	14.1	23.2	31.1	7.8	20.6
DO	7.4	4.2	5.9	7.7	5.2	6.6	7.2	6.5	6.8	7.1	6.7	6.9
BOD	1.6	0.1	0.9	1.2	0.2	0.6	1.3	0.0	0.7	1.4	0.4	0.9
TSS	21.0	3.1	11.0	103.2	1.4	24.9	NC	NC	NC	NC	NC	NC
PO4	1.1	0.4	0.7	4.3	0.7	1.7	0.4	0.1	0.3	0.4	0.2	0.3
NO2	2.1	0.1	0.6	1.7	0.2	0.7	2.2	0.2	0.7	2.5	0.3	1.1
NO3	4.6	0.3	1.4	4.0	0.4	1.9	2.8	0.1	1.0	4.5	1.1	2.3
SiO4	9.6	2.7	5.2	23.0	1.0	10.2	19.9	3.5	10.2	30.9	6.3	15.7
NH3	41.2	3.3	9.8	5.1	0.9	2.2	5.3	1.0	2.5	18.5	1.0	5.2
PHc	13.2	3.9	8.6	11.2	6.6	8.0	14.4	2.7	7.7	10.9	3.8	7.1
Phen.	6.5	0.0	3.3	10.0	2.1	4.9	5.3	0.2	3.3	3.7	0.9	2.0
Pb	0.2	0.0	0.1	NC	NC	NC	0.2	0.0	0.1	2.8	0.7	1.1
Cd	0.2	0.1	0.1	NC	NC	NC	0.4	0.0	0.1	0.2	0.1	0.1
Hg	62.5	37.5	43.8	69.0	31.0	49.4	36.0	11.0	22.3	320.0	30.0	140.0
TP	1.0	0.4	0.6	2.0	0.5	1.0	1.2	0.5	0.8	2.4	0.7	1.2
TN	24.7	12.3	19.5	29.0	11.3	20.8	27.4	17.8	22.0	31.8	13.3	24.2

DISCUSSION

Mandovi River

PCA of water quality parameters from Mandovi indicates that during high tide a total of 6 factors each explain 91% of the total variance, while during low tide, they explain 84% of the total variance.

High tide account for 33.6% of the total variance and is associated with strong positive loadings of nitrite, DIN, nitrate, silicate and ammonia, with moderate positive loading of TN, followed by strong negative loading of pH and moderate negative loadings of temperature and lead. In this factor, the nutrients (nitrite, nitrate, ammonia, silicate and DIN) correlate significantly positively with each other suggesting a common source but they correlate negatively with pH. Their negative correlation with pH indicates that at higher pH, the nutrients get decreased. In a tide dominated river, the pH of water increases during high tide due to the incursion of coastal seawater, while the riverine water has a lower pH. This suggests that the riverine water brings in nutrients from the surrounding catchment areas into the Mandovi River.

Factor 2 explains 48% of the total variance and is associated with strong positive loadings of TP and DOP, moderate positive loading of DO and weak positive loading of BOD, followed by a weak negative loading of Phenol. There is no significant correlation between any other parameters except that between TP and DOP. This suggests addition of phosphogenic material to the estuarine water, which may be a weathering product of the river. So, phosphatic material addition may be the terrestrial weathering input to the river.

Factor 3 explains 62% of the total variance and is associated with strong positive loadings of PO₄ and DIP, with a weak positive loading of NH₃. A significant positive correlation between PO₄ and DIP is coupled with a weak addition of NH₃ suggesting the influx of waste discharges through weathering products.

Factor 4 explains 73% of the total variance and is associated with a strong positive loading of DON and moderate positive loadings of TN and Phenol. TN is significantly correlated with organic form of nitrogen content. However, the moderate positive loading of phenol suggests industrial outfall, which is very prominent along the coastal regions and is being brought into the river during high tide. **Factor 5** explains 82% of the total variance and is associated with a moderate positive loading of PHc, weak positive loadings of Temperature and DO followed by strong negative loading of Hg and a weak negative loading of phenol. The DO does not correlate significantly either with phenol, PHc or Hg but indicates a negative trend with phenol and Hg. So also, the phenol does not correlate well with PHc but it correlates significantly with Hg. This suggests a common origin of these two parameters, the source of which could be industrial, particularly from ship break yards present along the river bank. However, the positive loading of PHc indicates its contamination in this river which is due to large barge and other boat traffic in the river.

Factor 6 explains 91% of the total variance and is associated with a moderate positive loading of BOD, strong negative loading of cadmium and a moderate negative loading of lead. BOD does not correlate well with Cd or Pb suggesting that organic matter or sewage is not the source of these metals in the river.

LOW TIDE

Factor 1 account for 25% of the total variance and is associated with strong positive loadings of nitrite, nitrate and silicate, with moderate positive loadings of DIN and BOD, followed by strong negative loading of pH and moderate negative loading of DON. pH correlates significantly negatively with nitrite, nitrate, silicate and BOD, which suggests the input of these constituents during low tide from riverine sources. Furthermore, the significant positive correlation of BOD with nitrite, nitrate and silicate suggests the addition of nutrients to Mandovi river from organic matter or sewage discharges.

Factor 2 explains 43.8% of the total variance and is associated with strong positive loadings of DOP, TP and NH₃, with moderate positive loading of DIN and a weak positive loading of BOD, with a weak negative loading of DON. The NH₃ correlates significantly positively with TP, DIN and DOP but negatively with DON, whereas BOD correlates significantly positively with DIN. This suggested the input of inorganic nutrients by riverine waters from upstream.

Factor 3 explains 55.4% of the total variance and is associated with strong positive loadings of PO₄ and DIP, with a weak positive loading of Cd. The PO₄ correlates well with DIP, while there is no significant correlation between PO₄ and Cd, which suggests that these two elements have different source of origin. The strong loading of PO₄ suggests input from terrestrial weathering products.

Factor 4 explains 65% of the total variance and is associated with a strong positive loading of Pb and Hg, with a moderate negative loading of Phenol. Pb correlates well with Hg but they do not correlate well with phenol. This suggests a common source for these metals, which indicates metal contamination in Mandovi river.

Factor 5 explains 74.8% of the total variance and is associated with a strong positive loading of TN, moderate positive loadings of PHc and DON with a weak negative loading of Cd. TN correlates well with PHc suggesting a common source and their dominance indicates contamination from PHc and nitrogenous materials.

Factor 6 explains 84% of the total variance and is associated with a strong positive loading of temperature and DO and a weak negative loading of Phenol. This suggests that well oxygenated water coming from the upstream regions is devoid of phenols.

Zuari River

Water quality data of Zuari, subjected to PCA indicate that during high tide a total of 6 factors explain 83% of the total variance while during low tide a total of 4 factors explain 78% of the total variance.

High tide:

Factor 1 account for 16% of the total variance and is associated with moderate loadings of silicate and Hg, with a weak positive loading of nitrite, followed by strong negative loading of pH and a moderate negative loading of NO₃. The interrelationship shows only significant positive correlation of Hg with

NO₃ indicating a common source. **Factor 2** explains 31.3% of the total variance and is associated with strong positive loading of PHc, moderate positive loading of NO₂ and moderate negative loading of DO with weak negative loading of Hg. All these parameters show no significant relationship with each other, however, the strong positive loading of PHc suggests contamination by PHc in Zuari. **Factor 3** explains 46% of the total variance and is associated with strong

High tide							Low tide						
RCM	1	2	3	4	5	6	RCM	1	2	3	4	5	6
NO2	0.98						NO2	0.94					
NO3	0.97						NO3	0.91					
SiO4	0.87						SiO4	0.91					
NH3	0.85		0.44				pH	-0.89					
TN	0.55			0.74			DON	-0.53	-0.50			0.53	
DIN	0.97						BOD	0.55	0.45				
TEMP	-0.74				0.42		DIN	0.67	0.67				
pH	-0.95						NH3		0.82				
Pb	-0.55					-0.54	TP		0.92				
TP		0.94					DOP		0.92				
DOP		0.93					PO4			0.89			
DO		0.54			0.41		Cd			0.40		-0.47	
BOD		0.49				0.68	DIP			0.89			
Phenol		-0.49		0.61	-0.42		Pb				0.79		
Cd						-0.82	Hg				0.74		
Hg					-0.91		Phenol				-0.55		-0.52
PHc					0.65		PHc					0.67	
DON				0.91			TN					0.80	
PO4			0.98				DO						0.75
DIP			0.98				temp						0.80
Eigen Value	6.7	2.9	2.8	2.2	1.8	1.8	Eigen Value	5.1	3.6	2.3	2.0	1.9	1.8
% Variance	33.6	14.4	13.9	10.9	9.2	9.0	% Variance	25.6	18.2	11.6	9.8	9.6	9.1
Cum.%	33.6	48.1	61.9	72.9	82.1	91.0	Cum.%	25.6	43.8	55.4	65.2	74.8	83.9

positive loadings of BOD and temperature, moderate positive loading of DO and weak positive loading of NO₃. There is no good correlation among these parameters, however, the strong positive loading of BOD suggests organic matter or sewage contamination in Zuari river.

Table 2. Factor loadings of variables during high tide and low tide in Mandovi River.

Factor 4 explains 60% of the total variance and is associated with strong positive loadings of NH₃ and

Phenol, moderate positive loading of TSS and weak negative loading of temperature. No good correlation is observed between each of these parameters; however, the strong positive loading of NH₃ suggests ammonia contamination, which could be due to the release from sewage or waste discharges into the river.

Factor 5 explains 72.6% of the total variance and is associated with strong positive loadings of Pb and Cd, and a weak positive loading of TSS. There are no good correlations between these parameters but the strong positive loadings of Pb and Cd suggests trace metal contamination, which could be from ship yards and the Port activities in the river, where painting and scrapping etc takes place. **Factor 6** explains 83% of the total variance and is associated with a strong positive loading of salinity and a moderate positive loading PO₄. Both these parameters are not significantly correlated with each other and therefore, the strong loading of phosphate suggests phosphatic contamination, probably from organic wastes in high salinity waters of Zuari.

Low tide

Factor 1 accounts for 29.6% of the total variance and is associated with strong positive loadings of NO₂, SiO₄, PO₄; moderate positive loading of Phenol, weak positive loading of Hg and moderate negative loading of pH. All these parameters do not correlate significantly with each other, however, the strong positive loadings of nutrients indicates riverine additions from upstream. **Factor 2** explains 49% of the total variance and is associated with strong positive loadings of DO and BOD and moderate negative loading of Hg. This factor also does not show good correlations between each of these parameters and the strong positive loadings of DO and BOD suggests well oxygenated waters with some organic waste. **Factor 3** explains 63.7% of the total variance and is associated with moderate positive loading of NO₃ and moderate negative loadings of NH₃ and pH. is factor also does not show good correlations between each of these parameters but the strong positive loading of NO₃ suggests addition of nitrogenous compounds to the river. **Factor 4** explains 78% of the total variance and is associated with strong positive loading of TSS, moderate positive loading of temperature, weak positive loading of NH₃ and a weak negative loading of Phenol. There are no good correlations between each of these parameters, but the strong positive loading of TSS suggests turbulent conditions which resuspend the settled sediments increasing the TSS in water, which is partly associated with NH₃.

In Mandovi river, total 2 factors explain 73% of variation in sediments, while in Zuari, 3 factors explain 96% of variation. Factor 1 in Mandovi explains 41.6% of the variation and shows strong positive loadings of TP and Cd and moderate positive loading of TN, with no good correlation between them. Similarly, Factor 2 explains 73% of the variation and shows strong positive loadings of Pb and Hg, with no good correlation between them. However, their strong positive loadings indicate contamination by these parameters. In Zuari, the Factor 1 explains 54% of variation and indicates strong positive loadings of OC, Pb, TP and TN, with no good correlation among them. Factor 2 explains 77.5% of the variation and indicates strong positive loading of Cd and moderate positive loading of TN, with no good correlation between them. Factor 3 explains 96% of the variation and indicates strong positive loading of Hg. All this indicates that they are independent of any other parameter during deposition in sediments.

The impacts which may arise due to jetty constructions in these two rivers mostly involve chemical and biological ones. The chemical impacts envisage water quality changes due to variation in dissolved oxygen content, the release of micronutrients, trace metals, halogenated hydrocarbons, petroleum hydrocarbons and organic compounds from un-oxidised bed sediments during digging by machinery for piling into the riverine area. The re-suspended sediment particles can increase oxygen demand to inhibit growth and reproduction capacity of some organisms posing environmental problems. Since, the DO of water in these rivers is at a saturation or super saturation level, the good flushing rate in these areas will maintain oxygen levels sufficiently high and minimize the problem for fish survival.

Table 3. Factor loadings of variables during high tide and low tide in Zuari River.

High tide								Low tide				
RCM	1	2	3	4	5	6		RCM	1	2	3	4
pH	-0.90							NO2	0.94			
SiO4	0.74							SiO4	0.85			
NO3	-0.53		0.50					PO4	0.83			
Hg	0.59	-0.48						Phen	0.68			-0.46
NO2	0.45	0.68						pH	-0.65		-0.66	
PHc		0.95						Hg	0.44	-0.73		
DO		-0.66	0.53					DO		0.96		
BOD			0.87					BOD		0.85		
Temp			0.75	-0.57				NO3			0.72	
NH3				0.86				NH3			-0.71	0.41
Phenol				0.79				TSS				0.76
TSS				0.63	0.42			Temp				0.55
Pb					0.91			Eigen Value	3.6	2.4	1.7	1.7
Cd					0.77			% Variance	29.6	19.7	14.4	14.4
Salinity						0.78		Cum.%	29.6	49.3	63.7	78.1
PO4						0.74						
Eigen Value	2.6	2.5	2.4	2.2	2.0	1.7						
% Variance	16.0	15.3	14.9	14.0	12.4	10.4						
Cum.%	16.0	31.3	46.2	60.2	72.6	83.0						

Similarly, the release of phosphates and nitrates into the water from sediment particles and interstitial water can stimulate excessive phytoplankton growth. However, the concentrations of essential micronutrients do not fall within critical levels, so it will not limit production. The release of heavy metals can increase the levels of lead, cadmium and mercury in fishes, shells, oysters etc exerting significant impact on fish. Increasing turbidity will not exert any negative impact on zooplankton, though a localized and marginal change in community structure and population alterations may occur confined to the project area. Such changes are temporary and irrelevant to the overall secondary productivity.

Table 4. Correlation matrix and factor loading variables in sediments of Mandovi river.

RCM	1	2	3			
OC	0.94					
Pb	0.93					
TP	0.93					
TN	0.78	0.61				
Cd		0.99				
Hg			0.99			
Eigen Value	3.2	1.4	1.1			
% Variance	53.7	23.8	18.3			
Cum.%	53.7	77.5	95.8			
Correlation Matrix						
	Pb	Cd	Hg	TP	TN	OC
Pb	1.00					
Cd	0.43	1.00				
Hg	0.14	0.32	1.00			
TP	0.00	0.19	0.41	1.00		
TN	0.01	0.02	0.45	0.00	1.00	
OC	0.00	0.37	0.37	0.00	0.01	1.00

Table 5. Correlation matrix and factor loading variables in sediments of Zuari river

RCM	1	2			
Cd	0.82				
TP	0.92				
TN	0.67				
Hg		0.86			
Pb		0.88			
Eigen Value	2.1	1.6			
% Variance	41.6	31.4			
Cum.%	41.6	73.0			
Correlation Matrix					
	Pb	Cd	Hg	TP	TN
Pb	1.00				
Cd	0.46	1.00			
Hg	0.11	0.09	1.00		
TP	0.41	0.04	0.25	1.00	
TN	0.39	0.31	0.45	0.08	1.00

Biological community's damage normally occurs in sediments during construction in riverine areas, resulting in loss of benthic organisms, particularly the macrobenthos, as during digging of foundation for piling, the removal of sediment will result in loss of benthic diversity. Since the

benthic forms observed in the area are of normal types, their recolonization in tropical estuary is faster and hence the damage to ecology would be minimum. Besides, the sediments surrounding the project area being physically and chemically nearly the same, a rapid colonization by same type of benthic communities will restore the benthic structure. Even, the fishes exposed chronically to high turbidity may suffocate because their gills can get clogged with sediment, but their high mobility will help them to avoid the disturbed area. Overall, the study indicated no adverse impact on the surrounding environment due to the construction of jetties in both these rivers.

CONCLUSIONS

The physico-chemical data from Mandovi and Zuari rivers of Goa indicated high concentrations of NH_3 and localized high BOD, which is an indication of organic matter or domestic waste influx into the riverine system. Besides this, the high concentrations of PHc, Phenol and Hg indicate anthropogenic additions from minor industrial waste discharges, boat traffic and ship building activities along the river banks, which contaminate the riverine waters as seen from the PCA analyses of the data. The construction activity in the estuarine environments of these two rivers indicates that the disturbances to the unoxidised bed sediments will increase turbidity and suspended load, release organic matter, toxic trace elements, micronutrients and other toxic compounds into the riverine water increasing the oxygen demand of water, which will lead to proliferation of phytoplankton and affect fish production due to deteriorating water quality. However, the currents in the vicinity of construction in these two rivers as observed from current meter data indicate that the resultant spring tide currents in NE-SW direction with a maximum speed of 1.08 ms^{-1} in Mandovi and in E-W direction in Zuari with a maximum speed of 0.97 ms^{-1} based on MIKE 21 HD model, would provide sufficient flushing that will flush the contaminants out to the sea thereby minimizing the impact arising out due to the construction of these jetties.

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