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Assessment of certain Anthropogenic Interventions and their Impacts along the Indian Coastline

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Abstract

Coastal anthropogenic activities such as sand mining, disposal of untreated or partially treated sewage and industrial effluents from selected centres along Indian coastline and their possible impacts impairing the coastal environment are discussed with the data collected for two year period from eight maritime states of India. Destruction of macro benthos due to large scale sand mining along the Malabar coast was estimated to show an average of 2760 m^{-2} day^{-1} equivalent to 10.42 g m^{-2} day^{-1} (wet weight) registering maximum during the post monsoon season. Non biodegradable objects such as polythene carry bags, ropes and sachets were recovered in considerable quantities from the beaches (0.145-9.8 g m^{-2}) as well as from the fishing grounds (32-85 g $haul^{-1}$). The domestic sewage disposed to Visakhapatnam inshore area registered appreciable density of toxic algal species such as *Gonyalux fragilis, Peridnium depressum* and *Porocentrum gracile.* Annual average of mercury in soft tissues of crab *Portunus sanguinolentus* was found in very high levels from Veraval (2.90 ppm) followed by Tuticorin (2.39 ppm), Visakhapatnam (1.83 ppm) and Cochin (1.77 ppm). However, arsenic levels were very high in all the tissue samples collected from Tuticorin, Mandapam, Chennai and Visakhapatnam.

Key words: Anthropogenic interventions, Indian coast, sand mining, habitat destruction, sewage disposal, heavy metal pollution

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Introduction

Coastal environment is constantly stressed from anthropogenic activities and other developmental programmes. Improper and excessive use of natural resources for short term economic benefits has resulted in long term environmental degradations. Changes in macrobenthic community structure especially of *Mactra veneriformis* due to sea wall construction along the west coast of Korea (Young & Woo, 1998), influence of aliphatic and polyaromatic hydrocarbon plume on the water quality of the Venezuela coast (Jaffe et al., 1995), increase in metal load in sediments within the Montevideo Harbour, Uruguay (Pablo et al., 2004), rise in the elements in estuarine sediments of Hugli estuary, India due to the differential discharge of untreated effluents from industries, agriculture and domestic sewages (Sarkar et al., 2004) and massive fish kill in Karapad Bay, Tuticorin due to very high levels of ammonia contamination (Asha et al., 2009) are few examples. In this communication, some anthropogenic activities along the peninsular Indian coast and their impacts on coastal environment are enlisted using data collected during June 2007 – December 2009. The impact of urban and domestic sewage, port and harbour related activities, mangrove destruction, industrial as well as thermal effluents and sand mining along the maritime states of India was studied.

Materials and Methods

Parameters such as CO_2, BOD, TSS, NH_3, NO_3, primary productivity and quantity of plastics and other non-biodegradable materials were monitored monthly using standard procedures (APHA, 1998; Strickland & Parsons, 1968; Parsons et al., 1984). Sampling was made from 32 stations at eight coastal centres of India (Fig. 1).

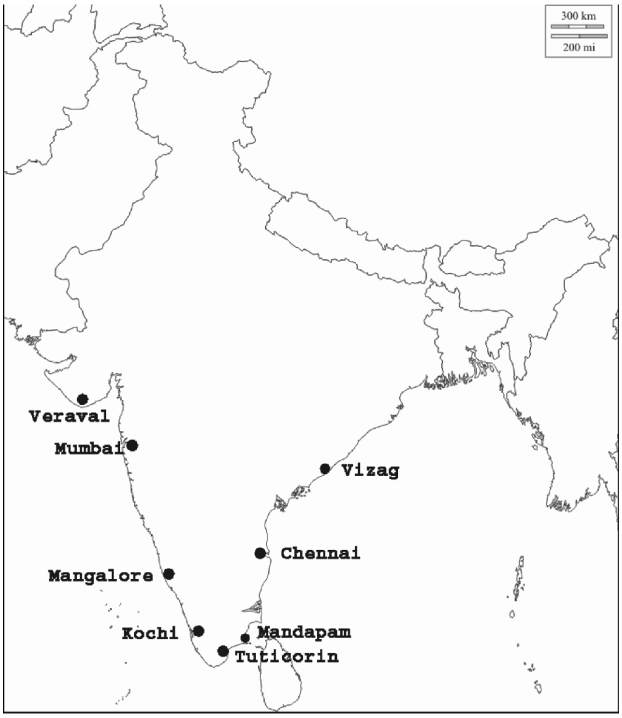

Fig. 1. Map showing the study sites along the Indian coast

Water samples in duplicate, preferably in the morning hours were collected using a clean plastic bucket from two outfall sites (sewage/industrial effluent disposal or port area) and one comparatively cleaner area (reference site, 9-10 km away from the impact locations). Upon collection, samples were transferred to clean polythene bottles kept in an ice box. Sea surface temperature (SST) was measured *in situ* with a bucket thermometer (0.5^{o}C accuracy). The hydrogen ion concentration (pH) and salinity of the water was also measured *in situ* using multi parameter meter (WTW LF320, Germany).

CO_2 sequestration studies were carried out using cleaned fronds of seaweeds weighed (0.5 g) accurately and incubated with 300 ml of CO_2 enriched seawater (5-25 mg l^{-1}) after determining the initial O_2 and CO_2 in airtight, thick and clear polythene bags in light and dark condition under a column of water (40-50 cm) for two hours. After the incubation in light and dark, 100 ml water samples from each bag were drawn gently using a large hypodermic syringe into separate glass bottles (100 ml) and subjected to CO_2 determination (Dye, 1958) and another 100 ml for determining dissolved oxygen using Winkler's reagent. Gross primary production (GPP) was calculated for each species from their oxygen production values multiplied with a factor of 0.536/PQ, where PQ was 1.25 (Westlake, 1963).

Data on mangrove destruction were collected from the destruction sites with the help of revenue department officials and social forest department. Data on plastic debris from beaches and trawl grounds were collected gravimetrically from 1 m^2 quadrates along line transects in beaches and from trawling vessels after each haul and were quantified after washing the mud and debris. Number of canoes engaged in sand mining was estimated weekly through local enquiry from the estuaries and corroborated by visual counting on monthly basis. Destruction of benthic organisms due to sand mining was assessed monthly by counting the benthic organisms from sediment samples collected from the sand mining areas using a vanVeen grab. The sand samples from five grab operations (0.075 m^2 x 5) were pooled together and sieved through sieves of 2000 μ, 1000 μ and 500 μ with excess water. The benthic fauna retained in each sieve were collected in a beaker, decanted and recorded the wet weight. The samples were transferred into a measuring jar, made up the volume to 100 ml by adding a few drops of Rose Bengal stain and preserved with 10 ml of 4% formalin. The benthic organisms were later sorted, their numbers counted by groups and multiplied for a square metre area.

Water samples were filtered through 0.45 μ GF/D filters and Hg and As (ppm) were determined once in three months from water samples by using anode stripping voltametry technique (VA757 Computrace, Metrohm, Switzerland). Determination of Hg and As from sediment and tissue samples was also done on quarterly interval. Metals from tissue and sediment samples were extracted using acid digestion procedure (Dalziel & Baker, 1984). The metals extracted from the tissue and sediments were detected on a Perkin Elmer AAS (Model 2380) in an air-acetylene flame. Statistical analyses were carried out using SPSS 12 software (SPSS Bangalore, India).

Results and Discussion

Nearly 185-210 dugout canoes were being engaged daily (192 on an average) for sand mining from Kadalundi, Murad, Korapuzha and Azhikal estuaries. The activity caused considerable destruction of eggs and larvae of fishery resources besides benthic organisms (Table 1). The destruction of macro benthos due to large scale sand mining along the Malabar coast was estimated to show an average of 2760 m^{-2} day^{-1} equivalent to 10.42 g (wet weight) m^{-2} day^{-1} registering maximum during the post monsoon season.

Table 1. Destruction of benthic organisms due to sand mining in estuaries along Malabar coast (Values are mean ± Std. Dev)

Season	Wet weight ($g\ m^{-2}\ day^{-1}$)	Number ($No.\ m^{-2}\ day^{-1}$)
Pre monsoon	11.39 ± 2.41	1270 ± 84
Monsoon	1.25 ± 0.29	491 ± 33
Post monsoon	18.63 ± 4.51	6518 ± 120

From the trawl ground, 27 to 94 g of plastic debris per haul of one hour duration was collected from off Mandapam, 18-79 g $haul^{-1}$ from off Cochin, and 60-150 g $haul^{-1}$ from off Mangalore (Table 2). Plastic objects strewn around beaches vary from 0.145 g m^{-2} from Calicut, 2.5 g m^{-2} from Cochin, 9.8 g m^{-2} from Tuticorin, 8.7 g m^{-2} from Visakhapatnam and 7.3 g m^{-2} from Mandapam (Table 2). These plastic objects comprised largely of plastic ropes, pet bottles, sachets, milk covers and thin carry bags. The composition of non biodegradable objects collected from three different beaches along Tuticorin is given in Fig 2. Thin plastic carry bags were found to be the dominant constituent. India generates over 10 000 t of plastic waste materials daily which is almost 10% of the entire solid waste generated (Jamwal, 2010) and when they decompose, Bisphenol-A, a well known hormone disrupter which is used as a plasticizer is liberated (Ryan et al., 2010). According to the UNEP (2009), worldwide, plastic is killing a million seabirds and hundreds of thousands of marine mammals and turtles in a year.

Table 2. Plastics and non degradable objects retrieved from seashore and from fishing grounds

Location	Beaches ($g\ m^{-2}$)	Fishing grounds ($g\ haul^{-1}$)
Tuticorin	9.8 (6.0- 30.0)*	35 (25 - 85)
Mandapam	7.3 (5.4 - 24.0)	32 (27 - 94)
Visakhapatnam	8.7 (4.0 - 15.5)	65 (40 - 90)
Mangalore	4.5 (1.6 - 12.0)	85 (60 - 150)
Calicut	0.15 (0.1 - 0.4)	72 (60 - 130)
Cochin	2.5 (0.5 - 5.6)	40 (18 - 79)

*Values in paranthesis indicate the range

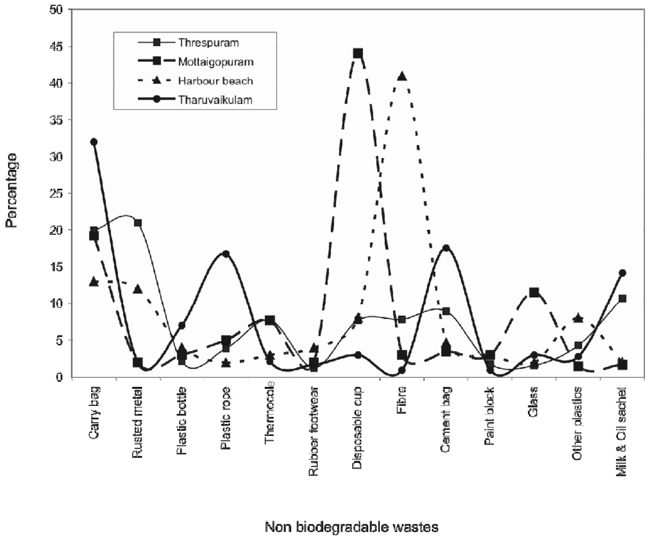

Fig. 2. Occurrence of non biodegradable waste (percentage mean) in different beaches along Tuticorin coast

Nearly 46 000 pieces of plastic inhabit per square km of the world's oceans (Ryan, 2008). Bottle caps, nylon rope pieces, pocket combs, cigarette lighters, cotton bud shafts, toys, syringes and thin carry bags are routinely found in the stomachs of dead seabirds and turtles (Moore, 2008). As per the Marine Plastic Pollution Research and Control Act (MARPOL) which came into effect on December 31, 1988, it is illegal for any vessel or land-based operation to dispose plastics or any non biodegradable objects at sea. Although the use of thin polythene bags (less than 40μ) is banned in India legally, its use is going on rampantly unchecked.

Coconut spikes suspended on long ropes employed to aggregate squid and cuttlefish by traditional fishers along the Malabar coast pose serious problems to the trawlers during off season as huge sand bags and rocks used to anchor the long ropes bearing these spikes called *kolachil* in local parlance are abandoned without leaving any buoys or indicators which obstruct trawling operations and damage the gears.

Mangroves are denuded mainly for house construction, agriculture and aquaculture. It was estimated that 0.61 ha of mangroves, mainly *Avicenia officinalis* was destructed recently near Kadalundi. However, 50 ha of mangroves are now protected at the Kadalundi Community Reserve under the Kerala Forest Department and afforestation with *Rhizophora* saplings in 15 ha area. Branches of mangrove trees especially *Avicenia officinalis* and *Rhizophora mucronata* are cut for the purposes of fire wood and timber in Kerala. It is learnt that nearly 0.81 ha of mangroves were destroyed by a non-profit society- Eco Tourism Society to develop a theme park at Pappiniserry, Kannur, Kerala violating CRZ rules (Malayala Manorama, 24 July 2010). Approximately 30-50 million post larvae of *Penaeus indicus* and *Metapenaeus dobsoni* were collected annually from Kerala mangroves in addition to fry and fingerlings of *Chanos, Etroplus, Lates* and *Mugil* sp for aquaculture alone (Kaladharan et al., 2005).

Mercury in soft tissues of crab *Portunus sanguinolentus* was found in very high levels in Veraval (2.90 ppm) followed by Tuticorin (2.39 ppm), Visakhapatnam (1.83 ppm) and Cochin (1.77 ppm) with levels exceeding the permissible limits. Mercury in finfish, crustacean, bivalve and gastropod tissue samples registered safe levels from Chennai, Mandapam, Mangalore, Mumbai and Cochin except in the crab tissue from Cochin. However, arsenic levels were very high in all the tissue samples collected from the centres along the east coast *viz*., Tuticorin, Mandapam, Chennai and Visakhapatnam (Table 3). It could be inferred from earlier investigations (Kaladharan et al., 2006) that due to various anthropogenic activities in and around Cochin, fish tissue sampled from off Cochin was found to accumulate very high levels of lead (0.9 – 83.3 ppm) while the samples of the same species and size collected from Andaman Sea did not have detectable levels of lead.

Low levels of dissolved oxygen (0.07- 0.8 ml l^{-1}) were encountered at Threspuram coast (Tuticorin) sometimes reaching anoxic levels during July 2009, while the CO_2 levels in seawater remained higher (42 mg l^{-1}) during September 2009. However, this elevated CO_2 levels did not affect the primary and secondary productivity of this area. Dissolved CO_2 in Mandapam coast remained well below the detection levels possibly due to the extensive seagrass and seaweed beds existing there (Table 4).

In Visakhapatnam coast, the fisheries harbour and the sewage disposal sites registered higher species diversity of phytoplankton than the reference site (Table 5). The sewage disposal site registered appreciable density of toxic algal species such as *Gonyalux fragilis, Peridnium depressum and Porocentrum gracile* which occurred less conspicuously in other sites. Nearly 44 000 m^3 of domestic sewage and 440 m^3 of industrial effluents are discharged every year in the seas of India (Shindikar et al., 2000).

Table 3. Mean Mercury and Arsenic concentration (ppm) in fish tissue samples collected from eight centres during 2008-09 (Values are mean ± SD)

Species	Vizag		Chennai		Mandapam		Tuticorin		Cochin		Mangalore		Mumbai		Veraval	
	Hg	As	Hg	As	Hg	As	Hg	As	Hg	As	Hg	As	Hg	As	Hg	As
Finfish	0.43± 0.11	8.57± 2.2	0.3± 0.12	4.11± 1.8	0.41± 0.12	10.16± 3.75	0.25± 0.09	21.64± 3.37	0.43± 0.14	18.75± 3.73	0.14± 0.08	0.64± 0.11	0.21± 0.15	5.34± 1.81	1.08± 0.79	56.67± 11.62
Crab	1.83± 0.83	23.12± 4.83	ns	ns	0.59± 0.13	25.18± 6.15	2.39± 1.06	34.65± 5.94	1.77± 0.74	12.61± 3.45	0.12± 0.08	1.84± 0.3	ns	ns	2.90± 1.44	48.8± 9.97
Shrimp	0.67± 0.14	12.75± 3.35	0.52± 0.24	24.82± 4.16	0.16± 0.07	18.68± 3.98	0.21± 0.13	11.62± 3.44	0.66± 0.26	9.78± 1.29	0.14± 0.11	1.77± 0.3	0.71± 0.18	19.06± 4.84	0.09±	45.72± 10.24
Clam	1.05± 0.44	17.67± 5.17	ns	ns	ns	ns	0.70± 0.18	32.84± 8.46	ns	ns	ns	ns	ns	ns	ns	ns
Mussel	ns	ns	0.61± 0.27	60.13± 11.5	0.1± 0.11	51.74± 11.41	ns	ns	ns	ns	ns	ns	0.63± 0.23	9.82± 0.99	ns	ns
Squid	0.73± 0.27	11.72± 5.34	0.58± 0.14	35.6± 4.19	0.29± 0.09	42.08± 9.9	ns	ns	0.33± 0.12	17.03± 4.67	0.19± 0.07	1.38± 0.09	ns	ns	0.52± 0.16	56.19± 8.73
Cuttle fish	0.49± 0.17	45.56± 9.61	0.74± 0.29	35.42± 9.78	ns	ns	2.91± 0.85	39.24± 12.67	0.35± 0.19	15.51± 2.55	ns	ns	ns	ns	0.35± 0.13	53.74± 13.49

ns - No samples

Table 4. Mean water quality parameters and metals in marine sediment from eight centres during 2008-09 (Values are mean ± SD)

Parameters	Vizag		Chennai		Mandapam		Tuticorin		Cochin		Mangalore		Mumbai		Veraval	
	OF	Ref	OF	Ref	OF	Ref	OF	Ref	OF	Ref	OF	Ref	OF	Ref	OF	Ref
CO_2 (mg l^{-1})	30.3± 4.27	0.0	0.13± 0.05	0.0	0.0	0.0	27± 8.4	3.17± 1. 5	nd	nd	nd	nd	230± 34	20± 9	nd	nd
NH_3 (mg l^{-1})	134± 20	0.14± 0.06	1.25± 0.09	0.0	2.38± 0.08	3.9± 1.07	1.0± 0.05	0.09± 0.005	24.52± 4.57	6.50± 1.12	nd	nd	nd	nd	2.84± 0.94	0.39± 0.04
Hg in water (ppm)	0.012± 0.004	0.01± 0.005	0.01± 0.004	0.01± 0.003	bdl	bdl	0.01± 0.004	bdl	0.01± 0.003	bdl	bdl	bdl	0.01± 0.004	bdl	0.02± 0.005	0.01± 0.003
As in water (ppm)	0.01± 0.001	bdl 0.003	0.06±	bdl	bdl	bdl	0.02± 0.002	bdl	0.06± 0.003	bdl	0.01± 0.002	bdl	0.02± 0.001	bdl	bdl	bdl
Hg in sediment (ppm)	1.12± 0.81	0.03± 0.01	0.25± 0.08	0.23± 0.07	0.08± 0.006	0.11± 0.09	0.32± 0.11	0.12± 0.04	6.66± 1.17	1.42± 0 09	0.29± 0.08	0.24± 0.06	3.03± 1.04	0.24± 0.09	0.23± 0.08	0.11± 0.05
As in sediment (ppm)	17.24± 6.65	2.98± 1.08	1.97± 0.74	2.23± 0.56	9.63± 1.19	3.08± 0.83	3.08± 0.95	5.65± 1.37	6.79± 1.25	12.5± 3.77	00	00	5.28± 0.91	21.7± 4.57	10.78± 2.22	5.8± 1.59

nd - Not determined; bdl- Below detection level; OF- Effluent outfall site; Ref- Reference site

There has been a 35% increase in CO_2 emission worldwide since 1990 (IPCC, 2007). Carbon fixation by photoautotrophic algae has the potential to diminish the release of CO_2 into the atmosphere. Phytoplankton, seaweeds and seagrasses are excellent carbon sequestering agents than their terrestrial counterparts (Zou, 2005). It was estimated that the seaweed biomass occurring along the Indian coasts is capable of utilizing 9052 t of CO_2 day^{-1} against emission of 365 t CO_2 day^{-1} indicating strong sequestration of 8687 t of CO_2 day^{-1} by seaweeds (Kaladharan et al., 2009). Large scale mariculture of seaweeds along the Indian continental shelf is recommended as one of the positive anthropogenic activities to sequester CO_2 that can check global warming to a larger extend.

Table 5. Phytoplankton distribution (No of cells l^{-1}) in three study sites along Visakhapatnam coast

Month and year of study	Harbour site	Sewage disposal site	Reference site
Aug 2007	52000	63000	14000
Nov 2007	27000	78000	44000
May 2008	42000	No sampling	49000
Aug 2008	156000	18000	17000
Nov 2008	42000	73000	20000
Feb 2009	34000	14000	24000
Average	58833	49200	28000

In the present communication, possible anthropogenic interventions capable of making positive and negative impacts on coastal environment are enlisted. Preliminary attempt to assess their biological and environmental impacts to the coastal fishery was also made. It is envisaged to monitor coastal anthropogenic activities which have negative impacts through systematic and extensive investigations along the peninsular coast of India.

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