

Effect of domestic sewage on sand beach meiofauna at Goa, India

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Abstract

Meiofauna of a sewage-polluted sandy beach, where sand alone constituted $> 90\%$, was surveyed. Nematodes dominated the fauna numerically at all stations, followed by harpacticoid copepods. Most of the animals were confined to the top 5 cm of the sediment. A seasonal pattern was observed in the distribution of the fauna. There were significant spatial and temporal variations in mean meiofauna density, attributed to organic discharge via sewage and prevailing environmental conditions in the study area.

Introduction

Domestic sewage, which contains mainly household wastes and human excreta, is rich in various nutrients and organics. O'Sullivan (1971) has reviewed the polluting effect of sewage on the marine environment.

Macrobenthos has been extensively used for pollution studies (Reish, 1973; Pearson & Rosenberg, 1978). However, meiofauna, in which many species have a short life span, is also well suited for pollution monitoring (Gray & Ventilla, 1971; Gowing & Hulings, 1976; Heip, 1980). In the present paper the distribution of the meiobenthic fauna of a sandy beach affected by the discharge of domestic sewage in Goa is reported.

Material and methods

Mandovi estuary, which opens into the Arabian Sea near Panjim on the west coast of India (Fig. 1), receives about 1 300 million litres of urban runoff annually (Anonymous, 1978). During the present study a section of beach of the estuary, receiving domestic sewage through a 'nullah', was sampled.

Meiobenthic samples were collected from 3 stations along a decreasing gradient of sewage pollution, station 1 being at the discharge point and station 3 furthest away toward the seaward side. Sampling was done during the premonsoon (February – May), monsoon (June – September) and postmonsoon (October – January) from February 1980 to January 1981. Each station was

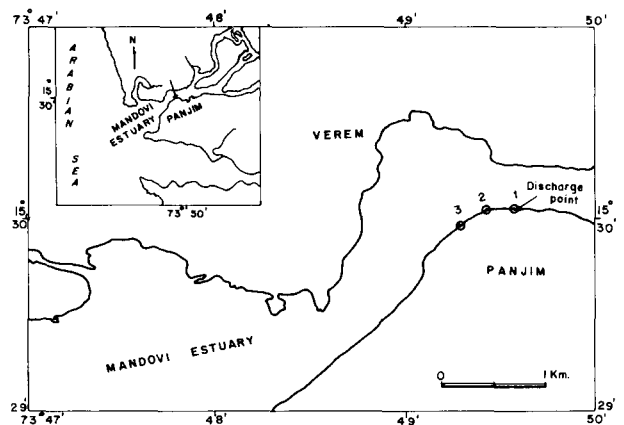


Fig. 1. Map showing location of station in the Mandovi estuary, Goa, India.

sampled three times in each season at approximately 5-week intervals and replicate samples were collected each time with a hand core (inner diameter 4.5 cm; length 10 cm). The core was divided into two 5 cm sections which were preserved in 5% buffered formalin containing Rose Bengal. From this, meiofauna was extracted and counted following Gowing & Hulings (1976).

Sediment temperature was measured *in situ*. Interstitial water was analysed for salinity, oxygen and nutrients following Strickland & Parsons (1965). Organic carbon of the sediment was determined by the method of ElWakeel & Riley (1956). Sediment from each station was analysed at 0.5 ϕ intervals and mean grain size (MZ ϕ) and sorting ($\delta I\phi$) were calculated after Folk (1968).

Statistical analysis

Comparison of stations and seasons with respect to mean meiofaunal density were made using one- and two-way analysis of variance. The Raw data were transformed to \log_{10} in order to stabilize the variance.

Results

Table 1 shows seasonal data (average) on physical and chemical environmental factors of the sed-

iment. Sediment pH did not show any appreciable change in the three seasons at the three sampling sites. High sediment temperature was recorded in premonsoon (Feb. – May) at all the sites. Maximum fluctuation in sediment temperature was 6.4 °C at station 1. The sediment was mainly composed of medium to fine sands (> 90%) which were well sorted at all stations. The organic matter content of the sediment showed high values at station 1 and lowest values at station 3. In general, the organic content showed low values in monsoon and high values in pre- and post-monsoon (Oct. – Jan.).

The results of interstitial water analysis are given in Table 1. The highest salinity was observed during premonsoon, the lowest in the monsoon season (June – Sept). Comparatively lower salinity values were recorded at station 1, because of freshwater discharge through the 'nullah' along with sewage. The lowest dissolved oxygen content (0.23 ml/l⁻¹) was observed at station 1 in all seasons, which indicates a higher decomposition rate and consequent oxygen depletion than at the other two stations. The values of interstitial water PO₄-P, NO₃-N and NH₄-N were high at station 1, when compared to the other two stations. This suggests a direct influence of organic inputs at station 1. Stations 2 and 3 represented intermediate and unaffected conditions, respectively.

Table 2 gives the average meiofaunal data for each station in different seasons. The fauna was abundant in the top 5 cm layer of the sediment.

Table 1. Sediment and interstitial water quality characteristics. The values represent the mean for each season.

	Sed. pH	Sed. temp. °C	Sediment characters				Sediment organic matter (%)	Salinity (‰)	Dissolved O ₂ ml l ⁻¹	PO ₄ µg at P l ⁻¹	NO ₃ µg at N l ⁻¹	NH ₃ µg at N l ⁻¹
			Sand (%)	Mz ϕ	$\delta I\phi$							
<i>Station 1</i>												
Premonsoon	7.83	35.4	92.82	2.63	0.37	4.44	24.3	0.23	9.04	6.62	106.35	
Monsoon	8.30	29.0	94.56	2.75	0.24	3.76	4.3	0.42	8.68	7.81	19.75	
Postmonsoon	7.45	31.4	92.32	2.40	0.33	4.02	15.6	0.26	11.41	4.55	171.80	
<i>Station 2</i>												
Premonsoon	7.77	34.0	96.34	2.65	0.32	2.78	32.2	1.76	5.64	0.27	19.63	
Monsoon	7.91	31.5	97.83	2.12	0.35	2.04	4.7	1.90	2.49	5.91	12.82	
Postmonsoon	7.44	32.2	96.04	2.40	0.97	2.82	26.2	1.74	4.09	0.48	26.01	
<i>Station 3</i>												
Premonsoon	7.84	34.9	96.62	2.72	0.29	1.60	34.6	1.62	1.72	1.57	0.68	
Monsoon	8.25	31.0	98.65	1.76	0.28	0.88	6.6	2.92	0.54	2.08	1.44	
Postmonsoon	7.55	31.8	97.20	1.90	0.25	1.29	33.28	2.45	0.78	0.51	4.07	

Table 2. Meiofauna density per 10 cm² area for all stations in each season. Numbers are average of 6 counts.

Faunal group	Station 1		Station 2		Station 3	
	0-5 cm	5-10 cm	0-5 cm	5-10 cm	0-5 cm	5-10 cm
<i>Premonsoon</i>						
Nematoda	523	275	1065	595	1284	518
Harpacticoida	99	0	476	38	495	0
Polychaeta	47	28	87	55	44	19
Oligochaeta	57	48	198	44	20	9
Archiannelida	10	10	114	28	22	0
Turbellaria	47	14	52	24	46	18
Gastrotricha	0	0	18	0	34	10
Kinorhyncha	0	0	17	0	22	0
Tardigrada	0	0	29	0	12	7
Bivalvia	0	0	0	0	17	0
<i>Monsoon</i>						
Nematoda	65	40	94	44	60	60
Harpacticoida	14	0	32	0	39	0
Polychaeta	0	0	14	8	26	11
Oligochaeta	44	14	60	45	16	0
Archiannelida	0	0	9	0	0	0
Turbellaria	0	0	25	0	13	12
Gastrotricha	14	13	16	24	15	7
Kinorhyncha	0	0	0	0	0	0
Tardigrada	0	0	0	0	24	9
Bivalvia	0	0	0	0	0	0
<i>Postmonsoon</i>						
Nematoda	240	36	1184	188	1112	138
Harpacticoida	19	0	276	0	234	12
Polychaeta	24	2	272	66	188	34
Oligochaeta	110	45	129	18	50	14
Archiannelida	24	14	180	48	26	6
Turbellaria	16	7	34	26	38	12
Gastrotricha	0	14	10	0	62	22
Kinorhyncha	0	0	12	0	36	8
Tardigrada	0	0	15	0	22	10
Bivalvia	0	0	0	0	12	0

Nematodes were the most dominant group, constituting 50 to 70% of the total fauna. They were consistently found in the entire length of the core at all stations. Harpacticoid copepods were next in abundance, followed by oligochaetes, polychaetes and archiannelids. Other important groups were turbellarians and gastrotrichs. The maximum number of faunal was observed at station 3. Faunal density was highest at station 2, while station 1 was impoverished both in faunal density and in the occurrence of faunal groups (taxa). There was seasonal variation in the distribution of meiofauna at all stations. Maximum density was during premonsoon and minimum density in the monsoon season.

A one-way analysis of variance showed a highly

significant F ratio for meiofauna abundance (Table 3). When the sites were compared, the analysis showed significant differences in mean meiofaunal density. Two-way analysis of stations vs seasons revealed significant differences between stations and seasons (Table 4). The differences resulting from seasons were most significant.

Discussion

There are several environmental variables that determine the distribution of interstitial fauna (Swedmark, 1964; McIntyre, 1971). Beach stability is one important factor. The southwest monsoon,

Table 3. One way analysis of variance of total meiofauna in 10 cm core samples in different seasons (A) and different stations (B).

	Source of variation	Sum of square	Degree of freedom	Mean square	F ratio
A					
Premonsoon	Between stations	0.5954	2	0.29702	265.196*
	Within stations (residual error)	0.01676	15	0.00112	
Monsoon	Between stations	0.31457	2	0.15728	27.9857*
	Within stations (residual error)	0.08436	15	0.00562	
Postmonsoon	Between stations	1.11897	2	0.55949	451.202*
	Within stations (residual error)	0.01861	15	0.00124	
B					
Station 1	Between seasons	2.13108	2	1.06554	253.7*
	Within seasons (residual error)	0.06358	15	0.0042	
Station 2	Between seasons	3.02132	2	1.51066	786.802*
	Within seasons (residual error)	0.0289	15	0.00192	
Station 3	Between seasons	0.17548	2	1.58774	134.554*
	Within seasons (residual error)	0.17712	15	0.0118	

* Significant at $p > 0.01$

Table 4. Two way analysis of variance of stations vs Seasons for total meiofauna count.

Source of variation	Sum of square	Degree of freedom	Mean square	F ratio
Between stations	2.02895	2	1.014479	23.374*
Between seasons	8.32747	2	4.16373	91.833*
Residual error	0.18136	4	0.04534	

* Significant at $p > 0.01$

which prevails in this part of the west coast of India, causes physical changes in the beach profile and adversely affects the distribution of intertidal fauna (Achuthankutty, 1976). Although significant variations in meiofaunal density have been reported from samples collected from different sites of a beach in one day (Gray & Rieger, 1971; Hulings, 1971), the results obtained in the present study (Table 2) show seasonality. The meiofauna density, irrespective of the season, also showed striking differences between stations. This can be attributed to critical environmental conditions, other than substratum, prevailing at these sites. From Table 1, it may be inferred that the moderate supply of nutrient salts at station 2, results in a higher meiofaunal density. There was also a response gradient with distance from the source of sewage discharge. Marcotte & Coull (1974) studying meiofauna along a

transect off a sewage outlet, reported similar observations.

The major effect of sewage is that it reduces the oxygen content and stimulates the formation of hydrogen sulphide. Such conditions can be disastrous to biota (Bozzini, 1975). This is clear at station 1, where the oxygen level was low and the occurrence of a black sulphide layer below 5 to 6 cm sediment was observed. This layer was not found in the top 10 cm layer at stations 2 and 3, which were further away from the point of sewage discharge. This explains the impoverished faunal density at station 1, and confirms earlier observations by Sarma & Ganapati (1975), Gray & Ventilla (1971), and McLusky *et al.* (1981).

Recently, Raffaelli & Mason (1981) suggested that the ratio of nematodes to harpacticoid copepods could be used in monitoring organic pollu-

Table 5. Ratio of nematodes to copepods taken from total counts.

	Premonsoon	Monsoon	Postmonsoon
Station 1	8.0	7.5	14.5
Station 2	3.3	4.3	4.9
Station 3	3.3	3.0	5.0

tion, particularly of sandy beaches. They report a high nematode/copepod ratio where sewage pollution is strong. In the present study, this ratio was highest at station 1, irrespective of season, followed by station 2 and 3 (Table 5). This substantiates the suggestion by Raffaelli & Mason (1981).

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