

Chemical Oceanography of Harbour & Coastal Environment of Visakhapatnam (Bay of Bengal): Part II—Nature & Composition of Sediments

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Harbour and coastal sediments of Visakhapatnam are predominantly silty-sand and sand-silt-clay respectively. High concentration levels of organic matter (OM), total phosphorus (TP), Fe, Zn, Mn, Pb, Cu, Co, Ni and Cd are observed in the inner harbour sediments due to the influx of industrial effluents and domestic sewage. On the other hand, there is no enrichment of Ca and Mg in the harbour when compared with the coastal sediments. Significant positive correlation is observed between finer fraction of the sediment, OM, TP and metals indicating their common association. However, Mn showed negative correlation with all these constituents.

Several geochemical aspects of the shelf sediments of Visakhapatnam have been reported¹⁻⁸. Though several reports are available on hydrography⁹, chemical¹⁰ and biological aspects of pollution¹¹⁻¹³, no detailed investigation on the nature and geochemical aspects of the sediments of this region has been reported. The present paper deals with the chemical composition and effects of industrial and domestic pollutants on the distribution of some major and trace elements of the harbour sediments.

Materials and Methods

The area of investigation and station locations are same as reported¹⁴. Sediment samples were collected at 7 stations in the harbour during monsoon (Sept.), postmonsoon (Dec.) and premonsoon (May) of 1983-84. Coastal sediments from 4 stations were collected during postmonsoon (Dec. 1983). The samples were dried at 70°C. A portion of the sample was subjected to grain size analyses for the separation of sand, silt and clay fractions. The sand fraction was sieved with $\frac{1}{2}\phi$ interval and the clay fraction was subjected to pipette analysis¹⁵. The cumulative frequency curves were drawn and the mean size was computed from the data¹⁶. The ratios of sand, silt and clay were calculated and the texture of the sediment was determined based on the nomenclature of Shepard¹⁷. Organic carbon (OC) was determined by the direct wet oxidation method¹⁸ and the organic matter (OM) was calculated¹⁹ by multiplying with a factor of 1.724.

Total phosphorus (TP) was estimated following the method of Rochford²⁰. Metals were determined by atomic absorption spectrophotometer (Schimadzu AA-640-12) after digestion of the sediment²¹ with HF and HClO₄. The values reported are the average of duplicate determinations of the bulk sediment samples.

Results and Discussion

Textural studies (Table 1) indicate that silty-sand was the predominant mode in the harbour and sand-silt-clay in the coastal region. The sediment transportation was mainly by littoral and tidal currents from coastal to harbour region. An increase in OM was observed during Sept. at all stations in the harbour followed by a decrease in Dec. Highest OM was recorded at st 3 which is the main navigational channel of the harbour, handling large quantities of bulk and general cargo. Extensive marsh vegetation, sewage in the upstream and the effluents from nearby molasses installation also account for high OM at this station. The domestic sewage from the city is contributing significantly to high OM at st 5.

TP was high in May and relatively low in Sept. (Table 1). Highest TP was observed at st 2 which can be attributed to the discharge of effluents from the fertilizer plant. The phosphate may get incorporated in the sediment mainly through biological activity^{22,23}. Lower TP values in Sept. are due to its leaching²⁴ from the sediment to the overlying waters because of heavy

Table 1—Texture and Chemical Characteristics of Harbour and Coastal Sediments of Visakhapatnam

Station	Depth (m)	Texture	Sand:silt: clay	Mean size (φ)	Conc. (%)					Conc. (ppm)							
					OM	TP	Ca	Mg	Fe	Mn	Zn	Pb	Cu	Cd	Co	Ni	
1	10	SS	A 35:41:24	6.9	7.27	0.50	0.54	2.52	5.88	467	9152	155	112	30	29	19	
			B 70:17:13	4.2	5.79	0.51	0.16	2.52	6.32	544	7384	173	117	41	14	41	
			C 56:23:21	5.3	6.20	0.68	0.24	3.56	6.64	559	6000	81	103	56	61	44	
			D 54:27:19	5.5	6.42	0.56	0.31	2.87	6.28	523	7512	136	111	42	35	35	
2	10	SSC	A 21:59:20	7.0	6.55	0.97	0.24	1.76	6.23	353	6760	763	140	36	32	41	
			B 56:26:18	5.6	4.14	1.29	0.04	2.36	6.48	359	6088	832	146	45	13	59	
			C 14:44:42	8.6	4.82	1.98	0.12	3.04	6.70	364	3800	244	92	81	75	93	
			D 30:43:27	7.1	5.17	1.41	0.13	2.39	6.47	359	5549	613	126	54	40	64	
3	10	SS	A 54:32:14	4.3	18.71	0.43	0.76	1.56	6.56	425	6200	162	127	24	12	30	
			B 82:17:1	2.9	9.82	0.54	0.08	2.48	6.98	586	6160	356	129	25	7	49	
			C 75:14:11	3.9	12.77	0.63	0.48	3.20	7.04	631	4792	122	103	32	40	74	
			D 70:21:9	3.7	13.77	0.53	0.44	2.41	6.86	547	5717	213	120	27	20	51	
5	6	SSC	A 39:22:39	7.3	11.41	0.30	0.36	2.48	3.81	356	12880	236	134	22	14	34	
			B 27:39:34	7.8	8.96	0.55	0.28	2.56	6.19	394	10700	305	154	55	8	48	
			C 26:36:38	7.8	9.39	0.57	0.32	3.36	6.27	412	9136	122	77	63	57	67	
			D 31:32:37	7.6	9.92	0.47	0.32	2.80	5.42	387	10905	221	122	47	26	50	
6	13	SS	Outer harbour														
			A 30:42:28	7.0	8.32	0.15	0.96	2.52	3.56	303	6720	81	54	4	11	30	
			B 54:38:18	4.7	3.57	0.44	0.28	3.16	6.84	485	6560	407	100	24	8	41	
			C 70:24:6	4.2	3.62	0.89	0.52	3.36	7.64	567	4380	61	34	32	14	52	
7	15	SS	D 51:35:14	5.3	5.17	0.49	0.59	3.01	6.01	452	5887	183	63	20	11	41	
			A 59:26:15	5.8	3.80	0.13	0.64	2.24	3.68	329	5100	61	26	5	12	26	
			B 80:11:19	4.0	2.43	0.21	0.32	3.24	6.68	539	5020	142	57	6	7	44	
			C 72:19:9	4.9	2.77	0.25	0.36	3.28	7.21	556	2920	41	25	16	14	48	
8	18	S	D 70:16:14	4.9	3.00	0.20	0.44	2.92	5.86	475	4347	81	36	9	11	39	
			A 75:16:9	5.2	2.76	0.11	0.56	2.24	3.56	382	3160	41	17	3	11	22	
			B 71:22:7	3.8	2.12	0.13	0.36	3.28	6.15	608	2920	61	40	4	7	30	
			C 84:12:4	4.2	1.76	0.18	0.48	3.32	6.84	639	1380	41	18	8	12	44	
9	50	SSC	D 77:17:6	4.4	2.21	0.14	0.47	2.95	5.52	543	2487	48	25	5	10	32	
			Coastal region														
			B 43:32:25	8.2	1.42	0.02	1.41	3.50	5.20	417	112	80	40	ND	14	35	
			B 35:40:25	8.9	1.48	0.04	0.22	3.06	5.28	429	108	64	36	ND	8	30	
12	45	SS	B 50:31:19	7.4	1.47	0.04	1.02	2.80	4.08	382	64	64	32	ND	8	20	
			B 32:33:35	8.8	1.27	0.06	1.38	3.04	4.32	398	80	136	44	ND	6	23	

A = monsoon (Sept.), B = postmonsoon (Dec.), C = premonsoon (May), D = average, OM = organic matter, TP = total phosphorus, ND = non-detectable, S = sand, SS = silty sand, SSC = sand silt clay

influx of fresh water followed by turbulence and intense circulation in monsoon.

Ca and Mg showed relatively high values in May. In general, their values are lower in harbour than in coastal sediments (Table 1). This may be due to the absence of any carbonate contribution to the sediments other than that of biogenic origin in this area²⁵. On the average, the concentration of Fe is high in May and varied in the range 4.08-6.86%. Highest Fe was observed at st 3 which may be due to the spillage of appreciable amounts of iron ore in the form of fine dust from the adjoining ore handling plant. This is supported by the fact that a thick layer of brownish dust could be seen along the marshy area adjoining this station particularly during low tide. Mn showed relatively high concentration in May and highest being at st 3. It is interesting to note that Mn showed lowest value (359 ppm) in st 2 while other trace metals like Pb, Cu, Cd, Co and Ni recorded highest values in this station. This may be mainly due to the acidic conditions (pH 5.9 to 6.9), existing at st 2 (because of the drainage of industrial effluents) which are not favourable for its flocculation and subsequent incorporation in the sediment.

Although high concentration of Zn was observed in all stations of the harbour, it showed highest value (12,880 ppm) at st 5 in Sept. This may be due to the drainage of large quantities of domestic sewage containing considerable amounts of Zn which might be incorporated in the sediment as its sulphide²⁶. This

is in agreement with the fact that almost anoxic conditions prevail at this station particularly during low tide¹⁰.

In general, Cd, Co and Ni levels were high in May while Pb and Cu were high in Dec. Highest (average) concentrations of Pb, Cu, Cd, Co and Ni were found at st 2 (Table 1) which receives considerable quantities of effluents from zinc smelter, fertilizer plant and petroleum oil refinery.

Correlation coefficients of metals between the finer fraction of the sediment, OM and TP are shown in Table 2. Significant positive correlation was observed between finer fraction and TP, Zn, Pb, Cu, Cd, Co and Ni indicating their common occurrence with this fraction. OM showed significant positive correlation with Cu. The correlation was significant between TP and Fe, Pb, Cu, Co and Ni indicating the association of these metals with phosphorus. Positive correlation was observed between metals, significant among them were between Fe and Pb; between Zn and Cu, Cd; between Pb and Cu, Cd, Co, Ni; between Cu and Cd, Co, Ni; and between Cd and Co, Ni indicating a common source for all these metals. However, Mn showed negative correlation with all the metals indicating little chance of its occurrence among these metals.

Comparison of chemical composition of harbour (sts 1-3, 5-8) sediments with those of coastal (sts 9, 10, 12, 13) region is shown in Table 3. Concentrations of OM, TP, Fe, Zn, Mn, Pb, Cu, Cd, Co, Ni are higher in harbour compared to coastal sediments. Except Mn,

Table 2—Correlation Coefficients of Metals and Other Constituents ($P < 0.01$)

	TP	Fe	Mn	Zn	Pb	Cu	Cd	Co	Ni
Silt + clay	0.71		-0.88	0.71	0.73	0.68	0.87	0.71	0.67
OM				0.58		0.74	0.42		0.44
TP		0.75	-0.64		0.98	0.69	0.79	0.81	0.84
Fe					0.67	0.39	0.34	0.53	0.53
Mn				-0.47	-0.73	-0.40	-0.62	-0.47	-0.70
Zn						0.70	0.71	0.48	0.31
Pb						0.65	0.74	0.72	0.92
Cu							0.92	0.82	0.71
Cd								0.93	0.69
Co									0.59

Table 3—Average Concentration of Chemical Constituents in Harbour and Coastal Sediments

Chemical constituent	Inner harbour (Sts 1-3,5)	Outer harbour (Sts 6-8)	Coastal region (Sts 9,10,12,13)
OM (%)	8.82	3.46	1.41
TP (%)	0.74	0.28	0.04
Fe (%)	6.26	5.80	4.72
Ca (%)	0.30	0.50	1.01
Mg (%)	2.62	2.96	3.10
Mn (ppm)	454	490	407
Zn (ppm)	7421	4240	91
Pb (ppm)	296	104	86
Cu (ppm)	120	41	38
Cd (ppm)	43	11	ND
Co (ppm)	30	11	9
Ni (Ppm)	50	37	27

there was a general decrease of their concentration from the inner (sts 1-3, 5) to the outer harbour (sts 6-8). This is probably due to the discharge of industrial and domestic effluents into the inner harbour and their gradual dilution and dispersion into the coastal region. The relatively high value of Mn in the outer harbour is due to its accumulation from the ore jetty and subsequent incorporation in the sediment as hydrous manganese oxide. However, the concentrations of Ca and Mg decrease in the sediments from coastal to the inner harbour which may be due to the absence of significant contribution of these metals in the effluents.

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