

Heavy metal concentrations in seawater and sediments of Gulf of Mannar and Palk Bay, southeast coast of India

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An investigation was carried out to delineate the levels of heavy metals both in the seawater and sediments from the Gulf of Mannar and Palk Bay. The data, obtained during the year 1995 revealed that Cd could not be detected in the waters of Kanyakumari. However, at other stations the levels of Cd were in the order of Arumuganeri > Tuticorin > Thondi > Mandapam. In contrast, Pb levels were found to be maximum at Kanyakumari and minimum at Arumuganeri, while Hg was found to be maximum at Arumuganeri and minimum at Mandapam. Cd levels were found to decrease towards sea from the coast at Tuticorin. However no definite trend was observed at Mandapam and Thondi. Unlike Cd, Pb showed seaward increasing trend at Thondi transect. However, no definite trend was evident for other transects as seen for Cd. Bottom waters showed higher concentration of Cd and Pb as compared to those in surface water. Hg did not show any trend in its distribution. Data on sediments showed that Cd registered maximum levels at Arumuganeri (4.33 ppm) while Kanyakumari exhibited the minimum (0.4 ppm). Similarly the levels of Pb were found to be minimum (1.15 ppm) at Kanyakumari. In conclusion, among the transects studied, Arumuganeri appeared to be polluted.

Gulf of Mannar was once famous for its 'Oriental Pearls' since ancient times throughout the world. For the last several decades pearl fishing has unfortunately become rare/almost nil. There are two questions to be answered, whether the pearl resources are depleted by over-fishing or whether the conducive environment has been affected by the industrial establishments on the coastal areas. In this respect, the environmental studies in the Gulf of Mannar becomes significant in addition to other demanding reasons.

Distribution of nutrients in the water of Gulf of Mannar has been studied by Gnanasekaran *et al.*¹ Studies on the levels of heavy metals in seaweeds of this environment have also been made². However, literature on the concentration of heavy metals in seawater and sediments is not available for this region barring the work of Ganesan & Kannan³ who reported only the levels of Mn and Fe in Tuticorin coast. Therefore, it has become imperative to take-up an investigation on the levels of heavy metals particularly toxic elements like Cd, Pb and Hg in the Gulf of Mannar and Palk Bay.

Materials and Methods

Fifteen stations were selected from 5 transects in the Gulf of Mannar and Palk Bay (Fig.1). Three stations were fixed on a line perpendicular to the coast of every transect with 5 km distance between them. Seawater and sediment samples were collected once during the year 1995 using van Dorn water sampler

and van Veen grab respectively. Water samples, each 1 litre, were filtered through membrane filters of 0.45 μ pore size, acidified and stored until extraction in pre-cleaned polyethylene containers. Sediment samples were oven dried at 110°C and ground to a fine powder using agate mortar and pestle. Cadmium and lead in both seawater and sediment samples were analyzed. But Hg was analyzed only in seawater. APDC-MIBK pre-concentration procedure⁴ was adopted for the extraction of heavy metals from seawater, while sediment sample was subjected to wet acid digestion⁵. The extracts were suitably diluted with 0.1 N HNO₃ and aspirated into an atomic absorption spectrophotometer.

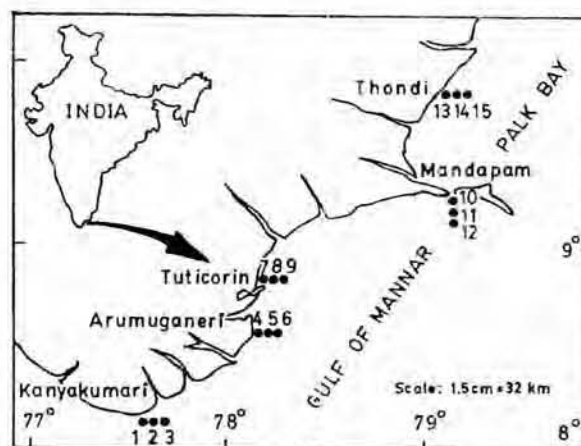


Fig. 1 — Map showing the transect in the Gulf of Mannar & Palk Bay

meter (GBC 906 AA). Mercury in seawater was determined by cold vapour technique using Mercury analyzer (MA5800E) following standard procedure⁶. Sediment textural analysis was made by screening known quantity of sediment through different sieves⁷.

Results and Discussion

The concentrations of heavy metals in seawater and sediment are presented in Tables 1 and 2. The percentage of sediment texture is given in Table 3.

Cadmium—The results showed that cadmium was found to be below the detection limit (BDL) at all stations in Kanyakumari transect (sts.1,2,3), while Arumuganeri waters recorded as high as 2.8 ppb of Cd at st.5. At Tuticorin transect, Cd levels varied from 0.34 to 0.7 ppb with seaward decreasing trend. On the contrary, a higher concentration of Cd (0.8 ppb) was observed at Mandapam transect (st.12). In the present study, vertical distribution revealed surface minimum and bottom maximum of Cd at all the stations excepting the stations 6 and 11.

Unlike in seawater, the Cd concentration in sediment was found to be maximum in near shore and minimum in offshore in all the transects excepting Tuticorin (st.8) where offshore exhibited maximum value. Thus, sediment samples showed a decreasing trend towards offshore indicating anthropogenic input. Of all the transects investigated, Arumuganeri recorded higher Cd concentration (4.33 ppm) followed by Tuticorin (3.95 ppm), Mandapam (3.6 ppm), Thondi (2.9ppm) and Kanyakumari (1.0 ppm).

Among the 5 transects investigated Arumuganeri transect exhibited higher Cd concentrations in both

seawater (st.5) and sediment (st.4). This could be attributed to the discharge of industrial effluents from chloralkali chemicals unit as the st.4 situated at the point of effluent discharge. In the present study, it could be noted that Cd in seawater and sediment shows rather conflicting results which can however be rationalized in terms of sediment texture. In all the transects nearshore sediments were characterized by very fine sand with higher Cd concentration as compared to offshore where the sediment texture was coarse in nature with lower Cd concentration. This observation lends support to the views of Satyanarayana *et al.*⁸ who reported that accumulation of metals and stability is more in fine grain sand. The lower Cd concentration recorded in the nearshore waters of Arumuganeri, Mandapam and Thondi transects could be explained that Cd would have adsorbed onto particulate matter or faecal pellets and settled down quickly as the column depth is very low, which resulted in enrichment of Cd in sediment. There was a small increase of Cd in seawater at st.5 as compared to st.4 though the latter station is located very close to the site of effluent discharge. Presumably this might be due to the release of sedimentary Cd to the overlying water due to the very coarse nature of sediment or the dissolved Cd would remain in the water column itself which is further evidenced by lower Cd concentration in sediment at st.5. Similar to Arumuganeri transect offshore waters showed relatively higher Cd levels as compared to nearshore waters in Mandapam (st.12) and Thondi (st.15). The levels of Cd observed in the present study are in general higher when compared to those

Table 1 — Heavy metal concentration in seawater (ppb)

Transects	St.no	Cd		Pb		Hg	
		S	B	S	B	S	B
Kanyakumari	1.	BDL	—	48.6	—	BDL	—
	2.	BDL	BDL	86.7	62.8	BDL	BDL
	3.	BDL	BDL	71.37	52.25	BDL	BDL
Arumuganeri	4.	1.6	2.5	1.2	1.4	1.76	0.94
	5.	2.3	2.8	2.1	2.5	2.05	1.96
	6.	2.2	0.8	0.5	2.5	1.25	1.05
Tuticorin	7.	0.46	0.7	1.38	1.86	1.63	0.93
	8.	0.48	0.44	1.62	2.3	1.21	1.37
	9.	0.38	0.34	0.56	2.54	1.63	1.29
Mandapam	10.	0.42	0.64	12.45	13.15	0.32	0.13
	11.	0.36	BDL	18.18	10.68	0.28	0.69
	12.	0.6	0.8	1.4	2.8	BDL	0.93
Thondi	13.	0.7	0.14	1.28	3.0	0.48	0.70
	14.	0.1	0.24	1.65	2.4	0.10	0.28
	15.	0.68	0.68	2.64	3.94	0.21	0.19

S — Surface, B — Bottom, BDL — Below detection limit.

reported^{9, 10} for the western Bay of Bengal. The concentrations off Arumuganeri transect which are among the highest observed in the present study (0.8-2.8 ppb) are however, smaller than those reported for Cochin estuary¹¹ (1.8-4.2 ppb). The range reported for Andaman Sea¹² (0.5-2 ppb) is matching with the range of the present study. The Cd concentration observed in sediment of the present study (0-4.33 ppm) is found to be much higher when compared to those reported for the sediments of Karnataka coast¹³ (0-2.13 ppm).

Lead—The concentration of Pb in seawater varied from 0.5 ppb (Arumuganeri) to 86.7 ppb (Kanyakumari). Lead concentration in seawater increased towards offshore in all the transects excepting few stations (sts. 6,9,12). Like Cd, bottom water showed higher Pb concentration as compared to that of the surface at most of the transects except at few stations at Kanyakumari.

Table 2 — Heavy metal concentration in sediment (ppm)

Transect	St. no.	Cd	Pb
Kanyakumari	1.	1.0	3.25
	2.	0.4	4.05
	3.	0.4	1.15
Arumuganeri	4.	4.33	9.45
	5.	1.25	4.20
	6.	BDL	BDL
Tuticorin	7.	2.1	40
	8.	3.95	23
	9.	BDL	BDL
Mandapam	10.	3.6	13.6
	11.	2.3	24
	12.	1.15	36
Thondi	13.	2.9	15.85
	14.	1.55	20.1
	15.	2.0	8.85

BDL = Below Detection Limit

In sediment, Pb concentration was found to vary from 0 to 40 ppm, the high value being at Tuticorin transect (st.7). At Tuticorin and Arumuganeri transects, Pb concentration in sediment was found to decrease with increasing distance from shore; but such trend could be seen only beyond 5 km off Thondi and Kanyakumari. On the contrary to the above, Pb concentration was found increasing towards offshore in Mandapam transect.

Among the 5 transects studied Kanyakumari transect exhibited higher Pb concentration in seawater but not in sediment. Kanyakumari being the tourist town, the surface enrichment of Pb would probably be by atmospheric input of automobile emission. Though the nature of sediment was very fine, low Pb concentration could be observed in the sediment. Therefore, the higher concentration in seawater and lower concentration in sediment could be explained that Pb easily forms complex with particulate matter¹⁴. According to Venugopal *et al.*¹⁵ trace metals are associated with colloidal and fine matter in suspension, which resulted in lower concentration in sediment. On contrary to the above observation higher Pb concentration in sediment and lower concentration in surface water were observed in Tuticorin (st.7) and Mandapam (st.12) where the sediment texture was very fine. Lead is known to form colloids in seawater, and such colloids would have settled down after gaining weight by adsorbing onto surface of planktonic debris which consequently resulted in higher concentration in sediment. Since the sediment is very fine in nature the Pb fixed in the lattice between the fine sand grains would remain unaffected by physical processes like turbulence, current etc.

Comparison of the present results with those reported earlier, revealed that the present values

Table 3 — Percentage of soil texture in the Gulf of Mannar

St. no	Depth (m)	Granule (> 2 mm)	Very coarse sand (> 1 mm)	Coarse sand (> 0.5 mm)	Medium sand (> 0.25 mm)	Fine sand (> 0.12 mm)	Very fine sand (> 0.06 mm)	Silt & clay (< 0.06 mm)
1	2	0.75	1.15	3.25	24.25	28.75	40.80	1.05
2	20	1.15	2.27	3.64	26.25	30.15	35.81	0.73
3	35	2.58	4.21	6.24	36.05	29.67	21.25	Nil
4	1.5	0.64	0.82	2.48	6.24	64.50	24.82	0.50
5	8	1.25	3.64	61.25	31.36	2.5	Nil	Nil
6	11	2.42	3.85	56.45	36.75	0.53	Nil	Nil
7	3	1.23	2.05	8.42	17.29	30.06	25.45	15.5
8	7	1.19	1.92	6.62	23.41	40.50	20.28	6.05
9	10	3.05	7.35	26.45	41.64	21.39	0.12	Nil
10	5	0.15	0.525	0.85	6.125	28.15	59.17	5.03
11	7	0.45	1.17	3.45	6.25	32.45	52.78	3.45
12	8	0.25	0.77	1.75	5.56	31.86	54.82	4.99

observed in Tuticorin, Arumuganeri and Thondi are comparable with those of the values reported for coastal water of western Bay of Bengal⁹ and Andaman Sea¹². However, the values recorded in Kanyakumari (48.6-71.37 ppb) and Mandapam (1.4-18.18 ppb) are much higher when compared to those values reported for western Bay of Bengal⁹ (2.34-3.89 ppb). The observed values in sediment of Mandapam and Thondi are comparable with those observed in the sediment of Thane creek¹⁶. However, the Pb concentration reported for the sediments of Cork harbour¹⁷ are much higher than the values of present study.

Mercury—Like Cd, Hg also could not be detected at any of the stations studied in Kanyakumari transect. However, a maximum of 2.05 ppb of Hg was observed in Arumuganeri followed by 1.63 ppb in Tuticorin, 0.93 ppb in Mandapam and 0.7 ppb in Thondi waters. Mercury concentration seems to increase from Palk Bay (Thondi) to northern region of Gulf of Mannar and further increasing towards southern Gulf of Mannar (Arumuganeri). These levels are in general higher when compared to those reported elsewhere^{9,10}. Chloralkali plants and pulp and paper manufacturing units discharge large quantities of mercury as mercury compounds through their effluents in the southern region of Gulf of Mannar. The higher Hg concentration recorded in the Arumuganeri coastal waters could be due to the discharge of such effluents. The Ministry of environment and forest has stipulated general standard limit of 10 ppb of mercury for effluents to be discharged into the coastal area¹⁸. The present value is 5 times lower than the limit.

Based on the results it could be understood that the effluents discharged from the chloralkali plants are the prime source of Hg in the Gulf of Mannar. Increase in the concentration of Cd in sediments of Arumuganeri, Tuticorin and Mandapam and that of Pb in Tuticorin and Mandapam transects is evident in the present study.

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