Cadmium occurs in the earth's crust at concentrations between 0.1 and 0.5 µg g⁻¹, whereas the average level in natural waters is 0.4 µg l⁻¹. Also it has been well documented that Cd is closely associated with the behaviour of Zn in its geochemistry (Alloway, 1990). Cadmium is a byproduct from the smelting of zinc sulfide ore minerals, (0.2 - 0.4 % Cd is present in sphalerite and wurtzite, substituting for some amount of the Zn.) The world production of Cd increased considerably from 11,000 tonnes in 1960 to 19,000 tonnes in 1985 (Nriagu, 1988). The FAO / WHO recommended maximum human intake of Cd as 70 µg day⁻¹ (Fassett, 1980). The United States Environmental Protection Agency has recommended a maximum allowable concentration of Cd(II) as 6.3 µg l⁻¹ in freshwater and 59 µg l⁻¹ in marine waters. Toxicologically, excess of this metal in potable waters may cause hypertension. In the human body, the critical organ is the kidney where one third of this metal is found to accumulate. There is no known mechanism for controlling Cd levels in humans, which may therefore accumulate following intake. This fact together with its relatively longer half-life (10-30 days) in biological systems makes Cd
one of the most toxic metals (Craig, 1986). It is also now known that the itai-itai disease in Japan was directly linked to excessive cadmium exposure.

Considerable evidence is now available on the behaviour of Cd in the aquatic environment (Duinker and Nolting, 1978; Jouanneau et al., 1983; Elbaz-Poulichet et al., 1987; Huynh-Ngoc et al., 1988; Windom et al., 1988 & 1991; Paulson et al., 1989; Kuwabara et al., 1989; George, 1989; and Forstner et al., 1990). All these studies revealed the preference of Cd to remain in the dissolved phase (75 to 90%) rather than in the particulate phase. In this context, the low charge density of Cd and that the concentration of Cd in the environment being controlled by weak ion-exchange reactions, this metal is significantly enriched in the water column (Martin and Whitfield, 1983). In freshwater, 90% of the cadmium appears as Cd(II) cationic species, but in the marine zones, anionic and neutral chlorocomplexes predominate. The stability of Cd-humic complexes has been reported to be far less compared to Cd-Chlorocomplexes and hence the very little organophilic nature of cadmium. Unlike copper, the particulate-associated Cd is found to be replaced by Na+ ions when it comes into contact with seawater. In order to have a better insight into the behavioural picture of Cd during estuarine mixing, a speciation approach has been adopted in the present study.

As far as the Cochin estuary is concerned, the major point sources are the zinc smelter and a fertilizer industry on the banks of Periyar river; urban runoff from vast agricultural expanse of Periyar river basin contributes significantly to non point inputs.

II. Results:

Chelex 100 Labile Metal (CLM)

The monthly distribution of different fractions of Cd is shown in Fig. 4.1; on an average 29% of the total cadmium is
Fig. 4.1 Monthly distribution of cadmium fractions at Stations 1 to 6
(D-December 1988 to N-November 1989)
found to be present as the CLM form. In freshwater, the content of this metal was negligibly small and indicated low terrestrial inputs. Similar are the values at other downstream Stations during times of high river discharge. Analysing the features at Stations 4 & 5, binodal peaks have been noted. This feature is also translated further downstream (Stations 1 to 3) albeit with lower magnitude. Content-wise, the CLM fraction varied from near detection limit in July 1989 at Station 6 to 1.99 µg l\(^{-1}\) in November 1989 at Station 4. Exceptionally high values were recorded in November 89 at Stations 3, 4 & 5 and in May 1989 at Station 5. Considerably low concentrations occurred during monsoon and was the highest during postmonsoon at all Stations except at Station 6, where it was high during premonsoon (Fig. 4.2a). The seasonal changes showed a gradual decrease towards the marine side. The premonsoon period coinciding with predominant tidal excursions define conditions conducive for sustainable concentrations within the estuary, longitudinally.

Organically Bound Metal (OBM)

The OBM fraction generally showed an increase in content towards the saline region. The minimum concentration observed was 0.1 µg l\(^{-1}\) at Station 6 in October 1989 and maximum was 2.33 µg l\(^{-1}\) at Station 5 in May 1989 (Fig 4.1). Yet another high value was also recorded at Station 5 in December 1988. Here too the metal levels were comparatively low at Station 6 in the freshwater zone, which is relatively free of pollution. The bound metal in association with the organic phase retains one half or more of Cd than the CLM fraction. Quantitatively this refers to more abundance (increasing down estuary), consistent with higher biological activity in the estuarine zones. This phase of the metal revealed 1) that through December 1988 to August 1989, the relative proportions at each Station was on the decrease and 2) that coinciding with the times of higher biological productivity, the OBM content also simultaneously peaked. The magnification in the content was 2 to 3 times more between values in July-August to those in February-March. From Fig. 4.2a it can be observed that the
Fig. 4.2 Seasonal variation of cadmium fractions
a) absolute values b) percentages
seasonal OBM fraction was comparatively low during monsoon at all Stations except Station 6 where it was almost uniform during all seasons. Additionally, the monsoonal OBM values were similar at Station 3, 4, 5 & 6 but enhanced at Stations 1 & 2. During postmonsoon, the values were increasing steadily from Station 6 to Station 1 (freshwater to seawater), but this feature was inconsistent during premonsoon.

Particulate Exchangeable Metal (PEM)

The distribution of particulate exchangeable metal (depicted on a logarithmic scale) for the year 1988-89 is shown in Fig. 4.1. The general trend of PEM was a decrease towards the lower estuarine regions (from Station 5 to 1). The values of the PEM fraction varied in the range 0.73 μg g⁻¹ in May 1989 at Station 1 and 160.49 μg l⁻¹ at Station 5 in December 1988. The lower values of PEM were detected in May at Stations 1, 2 & 3 and relatively high values at Stations 4, 5 & 6 again in May 1989. The monthly distribution observed at Station 4 showed recurring values during the first four months of collection and thereafter, except May, the next 5 collections recorded similar, but lower, values compared to the previous collections. Noticeably, peak concentrations occurred in the month of May as stated above. Yet another feature was the gradually decreasing values at Stations 1, 2 & 3 from February to May and increasing values from May to August. Stations 1 & 2 exhibited values ranging from ≈ 1.0 μg g⁻¹ to > 10 μg g⁻¹ which is a marginal change compared to changes in the upper reaches of the estuary (Station 4, 5 & 6 - 3.5 μg g⁻¹ to 160.5 μg g⁻¹). The PEM levels were low during monsoon and indicated the presence of a mid-estuarine maximum (Fig. 4.2a). During premonsoon and postmonsoon, a sharp decrease was noted from Station 5 to Station 1. An exceptionally high averaged value was recorded at Station 5 during postmonsoon. The seasonal changes presented in the figure revealed, remarkable Station-wise variation - quantitatively a ten times decrease towards the marine region. The exchangeable Cd in the particulate phase hence tended to diminish progressively in its spatial distribution than in its systemized temporal variation.
Total Particulate Metal (PTM)

The total particulate-associated cadmium was estimated by strong acid treatment and it revealed significant contributions from the terrestrial regions to the aquatic environments. At Station 6, since March 1989 to the end of the study, the inputs detected were \( \approx 10 \, \mu g \, g^{-1} \) with an exceptionally high value in May 1989. The commencement of the study in December 1988 followed by analyses in January and February 1989 indicated marginal content of this fraction in the freshwater zone. The adjacent downstream Stations (Stations 4 & 5) contained appreciably high quantities with values, at times, more than 100 \( \mu g \, g^{-1} \), mostly related to influence of anthropogenic inputs. There has been considerable reduction in the concentration in the distributional trends towards the saline regions; values at Stations 1 & 2 varied from a minimum of 2.8 \( \mu g \, g^{-1} \) to slightly more than 11 \( \mu g \, g^{-1} \). Station 3 in the mid-estuarine region indicated a gradual decrease from the start of the year up to May and thereafter recorded a progressive increase. The overall behavioural pattern, irrespective of season, was a general decrease towards the lower estuarine region.

However the seasonal results presented (Fig 4.2a) illustrates, more explicitly the decrease in the content of total particulate cadmium from Station 5 to 1. Station 6 in the freshwater zone exemplified the true character of a terrestrial waterway in that the content of not only this fraction but other species estimated in this study also exhibited low metal values. Similar to the distribution of PEM, PTM values too were low at Stations 1 to 6 during monsoon whereas the decrease during premonsoon season commenced from Station 5 onwards. The profile of postmonsoon distribution was not smooth because of the hike at Station 3.

Percentage Abundance of Cd Species

The seasonal Station-wise abundance of metal species is shown in Fig. 4.2b. The percentage abundance of CLM fraction
varied between 18 and 48%. The Stations 2, 3, 4 & 5 indicated a higher Cd-CLM abundance during postmonsoon period. Remarkably the end member Stations (Stations 1 & 6) showed no seasonal variation in the relative percentages. The premonsoonal behaviour of CLM, percentage-wise, exhibited a higher abundance at Station 4, which smoothened off to either sides of the river. Considering the contribution of OBM fraction, this form of dissolved metal predominated the other two fractions in this estuary. In contrast to the CLM fraction, the OBM percentages maximised at the end member Stations whereas the mid-estuarine abundance is about two-third's that of Stations 1 & 6. Within the seasons, none of the Stations showed any significant variations. The PTM percentage contribution was mainly noticed at Stations 3, 4, 5 & 6. The content was appreciably lower in the lower estuarine reaches and seasonally these two Stations besides, Station 6, exhibited only mild variations.

Station 6 in the riverine zone proportionally contained more OBM fraction followed by PTM and CLM. The Stations downstream of Station 6 were manifested by rather three equally contributing fractions with the OBM fraction alone being slightly on the higher side. The seasonal differences were explicitly significant during post monsoon period. Within Stations 1 & 2 the OBM fraction appeared to be the principal form of the metal (60 to 70%) followed by the CLM fraction (22 to 26%) and to a lesser extent the PTM fraction (8 to 14%). The fourth fraction PEM which is represented here as a part of the total metal estimated (accounted within the PTM fraction analytically) exhibited predominance at Stations 5 & 6 (12 to 20%). At both these locations, the postmonsoonal abundance far surpassed the premonsoon contribution.

**Correlation Studies**

The results of the intercorrelation studies among the four fractions of cadmium as well as between these fractions and various environmental parameters studied are given below.
Among the different fractions of cadmium the PEM and PTM showed excellent positive correlations with each other ($r = 0.78$). The CLM fraction showed positive correlations with OBM ($r = 0.43$), PEM ($r = 0.34$) and PTM ($r = 0.34$). Against environmental parameters, the OBM fraction showed significant positive correlation with salinity ($r = 0.51$) and DOC ($r = 0.35$). The PEM fraction showed significant negative correlation with salinity ($r = -0.52$), pH ($r = -0.52$) and suspended solid load ($r = -0.49$). The PTM fraction too showed similar negative correlations with pH ($r = -0.39$) and SS ($r = -0.44$).

III. Discussion

The behavioural patterns of cadmium species during estuarine mixing are dealt with in detail hereunder. Available literature on the behaviour of cadmium (Windom et al., 1988; Jouanneau et al., 1990, Elbaz-Poulichet et al., 1991) highlights the hydrophilic nature in the environment but a comprehensive analysis of the various fractions of cadmium was lacking in earlier studies.

i. Spatial and Seasonal Variation.

From Figs. 4.1 and 4.2a it was observed that all the four fractions of Cd studied were considerably low in amounts at Station 6. This sampling site is in the freshwater zone and relatively unpolluted since all the industrial effluent outfalls are downstream of Station 6. Noticeably all fractions of Cd indicated a rapid increase in concentration at Station 5. This is because of the anthropogenic inputs from the fertilizer industry and the zinc smelter factory situated 200m upstream of Station 5. Craig (1986) and Alloway (1990) have reported that both these industries are potential sources of Cd contamination. Paul and Pillai (1983a) also have reported higher values of Cd in the industrial zone of Periyar river. The mid-estuarine region of this tropical water body is a very active zone in modifying the fractions of metals. The absolute values of these fractions are subjected to high variability giving rise
to interspecies transformations. In the case of cadmium this aspect is well defined for OBM and PTM fractions. A direct reasoning for the above variability would be dependent on two important aspects - the tidal excursions and the bioactivity resulting from the ecosystem manifestations. The behaviour of Cd-CLM fraction appears to be influenced by estuarine ionic conditions whereas Cd-OBM was influenced more by organic detritus. The general diminution observed for Cd-PEM and Cd-PTM in the lower estuary points to a decrease in the metal adsorptivity or in the ability to retain the metal by interfacial processes. The real time variability is hence subjected to environmental modifications arising mainly out of chemical processes.

The seasonal features depicted in Fig. 4.2a indicate an overall decrease towards the lower reaches of the estuary (Stations 5 to 1) with the exception that OBM fraction of Cd behaves oppositely. As far as Cd behaviour in estuaries is concerned, it is generally accepted that the mobilization processes from the particulate matter occur when river water mixes with seawater leading to the formation of highly stable and soluble Cd-chlorocomplexes (Elbaz-Poulichet et al., 1987). Similar results have been reported in the lower part of the Scheldt estuary (Salomons and Kerdijk, 1986); in the Elbe estuary (Duinker et al., 1982) and in the Changjiang estuary (Edmond et al., 1985). In the case of Cochin estuary, seasonal or otherwise, the PEM and PTM fractions decrease towards the seaward end. Hence, if the net mass has to be balanced, an increase on the Cd-CLM and Cd-OBM may have to be visualized. Relatively, only the OBM fraction exhibits this feature whereas CLM does not. The diminution in the content of CLM is appropriately compensated by the increase of values in the OBM fraction. However mass balance compensation and decompensation need not be strictly adhered to. The complexation of the mobilized Cd-CLM by free organic ligands in the estuarine region is well documented (Jouanneau et al., 1990; Bilinski et al., 1991).

The seasonal features indicate generally lower values in
monsoon for the PEM and PTM fractions. In this context, the suspended particulate matter consists of two types of particles, one is the finer texture with high metal content (in suspension) and the other consists of coarser particles with higher settling velocity and lower metal content. The exchangeable and the total particulate Cd values were plotted against the suspended solids (SS) load seasonally (Fig. 4.3a, b & c and 4.4a, b & c). These plots indicate that the metal content varies inversely with increase in the amounts of the SS load. The premonsoon decrease is sharp for the PEM fraction as the amount of SS increased to near 20 mg l\(^{-1}\) and there was low association of PEM at values greater than this. The monsoonal pattern show no consistent trend but may be surmised as a general decrease in moderately changing conditions of suspended loads. During postmonsoon, the values of PEM and PTM are limited to around 30 \(\mu g\) g\(^{-1}\) and 160 \(\mu g\) g\(^{-1}\) respectively at SS content < 5 mg l\(^{-1}\) which gradually lowers to values <10 \(\mu g\) g\(^{-1}\) in turbid waters (> 10 mg l\(^{-1}\)). During monsoon, the high energy inputs due to increased river discharge cause a resuspension of bottom sediments with low metal content and the percentage of this resuspended particles will be considerable, accounting for the observed lower values in PEM and PTM fractions during monsoon. Alternatively the decrease in content towards the high salinity region for PEM and PTM are sharp during both premonsoon and postmonsoon. This relates to the high residence time of particles in the estuary during the low discharge condition by which time particulates undergo physical and chemical changes resulting in species transformations.

ii. Estuarine Metal Reactivity

The tropical estuaries are regions of high energy transformation sites not only in physical terms but chemically and biologically. Within this subsection the different fractions of Cd which undergo modifications are (re)viewed to identify the important mechanisms causing the above mentioned changes. As far as the particulate fractions are concerned it has already been reported that the most important mechanism
Fig. 4.3 Suspended solids – PEM plots
   a) premonsoon b) monsoon c) postmonsoon
Fig. 4.4 Suspended solids – PTM plots
(a) premonsoon  b) monsoon  c) postmonsoon
identified to be operating in the Cochin estuary is desorption (Shibu et al., 1990). To illustrate the features more clearly the salinity - PEM plots and the salinity - PTM plots for premonsoon and postmonsoon are provided in Figs. 4.5 a & b and 4.6 a & b respectively. The Figures indicate a sharp removal of particulate associated metal in the low salinity regions (< 5%). Unlike copper, the cadmium associated with particulate matter is susceptible to exchange by Na⁺ ions (Bourg, 1983) or Mg²⁺ and Ca²⁺ ions (Forstner et al., 1990). Reports from South San Francisco Bay (Kuwabara et al., 1989) and Gironde estuary (Jouanneau et al., 1990) also show a similar removal of particulate-Cd with salinity. They attributed this to the desorption followed by a stable chlorocomplex formation. In Mandovi and Zuari estuaries, George (1989) also has observed the decrease of particulate associated Cd which was accounted as "particle dilution". He also reported an increase in the two forms of dissolved Cd (labile and bound) in higher salinity regions and proved experimentally that the desorption from particulate phase cannot quantitatively account for the observed increase. The various factors such as dredging, shipping and mining activities along with remobilization from the sedimentary phase was attributed to the above result by George (1989). Forstner et al., (1990) explained the increase of dissolved Cd versus salinity gradient as a result of the formation of stable chloro-complexes and competition of alkaline earth metal ions (Ca²⁺ & Mg²⁺) for sorption sites on solid substrates. Recently Elbaz-Poulichet et al., (1991) also have reported similar behaviour of addition of Cd to the dissolved phase during etuarine mixing. In the present study, however, the CLM fraction was found to decrease towards the saline regions. This aspect is summarised as due to the high productivity in this area as revealed by the detailed seasonal studies of Gopinathan et al.,(1984) and Joseph (1989). Cadmium which gets transformed from the CLM phase to the OBM phase may finally end up (partially) in the sediments during the settling of organic detritus particles. Similar processes have been reported elsewhere too (Sharp et al., 1984; Zwolsman and Van Eck, 1990). The laboratory experiments of Slauenwhite and Wangersky (1991) also testify to the operation of the above
Fig. 4.5 Salinity - PEM plots
   a) premonsoon b) postmonsoon
Fig. 4.6 Salinity - PTM plots
a) premonsoon b) postmonsoon
process. Furthermore, the increase in the OBM content in the present study supports the above proposition. Additionally, the increase in OBM fraction can also be due to the remobilization from the sediments as a result of microbial activity stimulating Cd release by a complex process of substrate decomposition and potential organic ligand liberation and/or formation as also reported by Forstner et al., (1990) in the Elbe estuary. They also observed that the distribution patterns of total and partitioned-Cd in a sediment profile suggest the release of metals from particulates into the water media and further transfer to the biota to be controlled by the frequent downward flux of oxidized surface water by tidal action. Windom et al., (1991) did identify biological regeneration as an important process which could affect the behaviour of Cd in estuaries.

From the documented evidence (Forstner et al., 1990), it was expected that long term removal of up to 50% of the cadmium from the sediment subsurface would take place from the anoxic sedimentary sinks located a few centimeters below the sediment-water interface. This factor would be helpful in explaining the negative mass balance of Cd in this estuary which will be discussed later. The model experiments of Bilinski et al., (1991) also have shown that Cd was released from inorganic solids, into the water column at higher salinities. Kuwabara et al., (1989) found an increase of dissolvedCd with increase in suspended solids and considered the suspended particulate matter as a source for Cd in the saline region. In the present study, the CLM fraction was found to decrease sharply with increases of SS load. It may be assured that any increase in dissolved Cd is surmounted by equally vibrant increase in OBM fraction supported by remobilization from the sedimentary phase. Kuwabara et al., (1989) also found that dissolved Cd is highly correlated with POC; but in the present study no such relation was observed. The salinity–OBM plots (Fig 4.7a & b) show a broad maximum at higher salinities (20-25%). Similar broad maximum for dissolved Cd has been reported elsewhere (Elbaz-Poulichet et al., 1987; Windom et al., 1991). They attributed this to the
Fig. 4.7 Salinity - OBM plots
a) premonsoon b) postmonsoon
desorption followed by complexation with $\text{Cl}^-$ ions in estuarine waters. But CLM fraction did not exhibit any such maximum in the present study. So it can be concluded here that the broad maximum observed at higher salinities in the Cochin estuary may be the result of desorption followed by complexation with organic ligands. The increase in OBM also coincides with an increase in the DOC content (Fig 4.8 a, b & c). Significant positive correlation exists between DOC & OBM ($r = 0.35 \; p < 0.001$) considering the complete data set. Concurrently, there are other speciation studies in which only very little organic association has been reported for Cd (Florence, 1977; Hart and Davies, 1981; George, 1989).

IV. Transport and species transformations

The transport of Cd in different seasons is shown in Table 4.1. Similar to the observations of Hart and Davies (1981) in the Yarra river system; Windom et al., (1988) in the Bang Pakong estuary, Kuwabara et al., (1989) in the San Francisco Bay and Jouanneau et al., (1990) in the Gironde estuary, here in Cochin estuary too, Cd is transported mainly in the dissolved phase. The data analysis indicate that on an average about 19% of the total Cd is transported in the particulate phase (out of this 19% , about 54% is in the exchangeable form subjected to increase upto 70% during postmonsoon) and 81% is transported in the dissolved phase. Similar metal transport was reported from CSF and RG rivers (89% dissolved & 11% particulate; Lacerda et al., 1987), Rhine estuary (72% and 28%, de Groot et al., 1976), Yarra river system (75% and 25% , Hart and Davies, 1981). Out of the 81% dissolved cadmium transported in Cochin estuary 35% is in the CLM form and 65% in the organic form. Generally the metal transport is highly dependent on climatic conditions and associated river discharges. In the case of Cd transport, the seasonal variations in relative proportions of different fractions are not very significant.
Fig. 4.8 DOC - OBM trend plots
   a) premonsoon b) monsoon c) postmonsoon
Table 4.1

<table>
<thead>
<tr>
<th>Season</th>
<th>CLM</th>
<th>OBM</th>
<th>PEM</th>
<th>PTM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Premonsoon</td>
<td>28.88</td>
<td>52.04</td>
<td>08.38</td>
<td>19.09</td>
</tr>
<tr>
<td>Monsoon</td>
<td>22.41</td>
<td>55.46</td>
<td>11.64</td>
<td>22.14</td>
</tr>
<tr>
<td>Postmonsoon</td>
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<td>49.19</td>
<td>10.95</td>
<td>15.66</td>
</tr>
<tr>
<td>Annual average</td>
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<td>52.23</td>
<td>10.33</td>
<td>18.96</td>
</tr>
</tbody>
</table>

The transformations that are taking place in each species on transport from the UE - upper estuary (freshwater) through ME - mid estuary to the LE - lower estuary during the three seasons are shown in (Fig 4.9). Both the particulate fractions (PEM and PTM) decreased considerably from the upper estuary to the lower estuary during all the seasons. The CLM fraction showed a mid-estuarine maximum during premonsoon and postmonsoon while it increased steadily during monsoon. In premonsoon and postmonsoon the net result of estuarine mixing was a decrease of CLM fraction in the LE and during monsoon this fraction steadily increased with respect to other fractions. During postmonsoon, the decrease of CLM was considerable (33.68% - 40.65% - 21.58%). On the other hand, sharp increase of OBM fraction during postmonsoon (46.36% - 44.32% - 69.49%) was observed. During all the seasons the percentage OBM fraction was comparable in the upper and mid estuary but increased sharply in the lower estuary.

V. Mass balance

Given

\[ C_R = 1.08 \, \mu g \, l^{-1} \]
\[ C_B = 2.11 \, \mu g \, l^{-1} \]
\[ C_E = 1.67 \, \mu g \, l^{-1} \]

Flux in from the river = \( Q_R \times C_R \)
\[ = 5.61 \times 10^3 \, Kg \, Yr^{-1} \]

Flux in from the barmouth = \( Q_B \times C_B \)
\[ = 3.76 \times 10^3 \, Kg \, Yr^{-1} \]
Fig. 4.9 Seasonal Species transformations during estuarine transport
LE-lower estuary ME-middle estuary UE-upper estuary
Total Cd flux into the estuary = \((5.61 + 3.76) \times 10^3\) Kg Yr\(^{-1}\)

\[= 9.37 \times 10^3\] Kg Yr\(^{-1}\)

Flux out from the estuary = \(Q_E \times C_E\)

\[= 11.64 \times 10^3\] Kg Yr\(^{-1}\)

Mass balance for Cd = \((9.37 - 11.64) \times 10^3\) Kg Yr\(^{-1}\)

\[= -2.27 \times 10^3\] Kg Yr\(^{-1}\)

The mass balance of Cd in the Cochin estuary showed an excess of \(2.27 \times 10^3\) Kg Yr\(^{-1}\) indicating some sources of Cd. This may be the result of sewage discharges and desorption/remobilization from the sedimentary phase, both of which were not taken into account in this calculation. Windom et al., (1976), evaluated the transport of metals and concluded that estuaries did not serve as sinks for Cd and Hg but that these two metals were transported ultimately to the coastal waters. The computations performed here attributed to a source factor of about 25% added to input flux to be discharged to the nearshore waters.