Chapter IV

# DISCUSSION

## Water

The concentration of lead and mercury in the water samples from each station for the January collections are shown in Table 1a and for May collections in Table 1b. The concentration of lead both the dissolved and the particulate fractions for the January collections is shown in Figure 5. The particulate fraction showed the locational variation, and indicated a maximal value at station VIII, located in an area of heavy cross-river transportation at low tide. The values then decreased to the same level as the background value for station IX. The dissolved fraction increased slightly from station IX to station VI, and became lower at stations IV+V and III. It showed approximately the same order through stations II and I. The combination of soluble and particulate fractions indicated the total lead concentration, illustrated graphically in Figure 5. The trends of the curve are similar to that of the particulate fraction, with an abrupt increase at station VIII, and then a decrease through all the other stations. The lead concentration for the May collections are shown graphically in Figure 7 for the dissolved, particulate and total fractions. The trends of the three forms are approximately the same as those for the January collections, but the values were a little higher at station V, II and then decreased from the higher level at station VIII. The trends are not so smooth in the stations down the river as are those of the January collections. The soluble fraction did not show any

significant variation in values around the nine stations. A nearly-straight line can be observed in the graphic illustration of the dissolved fraction. The total lead concentration showed a similarity in graphic characteristics to that of the particulate fractions. The sudden increase of lead at some stations downstream might be caused by the introduction of lead into the water through the waste disposal from domestics and industry located along the river. However, the information on this matter is still limited, if the information is available, the situation can be better understood. The lead values of both the dissolved and the particulate forms are considerably higher than those found by others. The particulate in American water ranged from 0.06-0.09 µg/l and the soluble was 0.06-0.09, giving total values of 0.12-0.18 µg/l. From the same authors the total lead concentration varied from 0.65-4.7 µg/l in the Juan de Fuca Strait (Schell and Barnes, 1973, Goldberg et al., 1971). Turekian (1971) also reported the same value of lead in sea water (0.03 ppb). Those values detected in the samples collected from the Gulf of Thailand during the Third Pollution Survey ranged from 3.0-6.0 ppb. If these values are for the dissolved fraction only, the detected concentration of the dissolved fraction from the Chao-Praya River of the two collections is at a similar level. Lead, however, is ubiquitous in the aquatic environment and is absorbed through the disposal of industrial and domestic wastes, atmospheric fallouts, and most notably through the decay products of radioactive elements. The domestic effluents from the city of Pittsburg give 0.075 mg/l of lead to the receiving water (Davis III and Jacksaw, 1975). The leaded gasoline exhausts from boats can contaminate certain samples

as can be verified from the high values of lead concentration found from stations located in areas of urbanization and heavy water-transportation. Lead contamination through the absorption of leaded-gasoline exhausts from water-transportation might be a significant cause of pollution; especially in surface water.

Particulate, dissolved and total mercury, from the two collections are shown in table 1a (the January collections) and in table 1b (the May collections). The variation in the mercury concentration in the water from the January collections is shown in Figure 6. The mercury concentration showed some interesting trends. There are high values at station III and IV+V for the January collections, especially for the dissolved fractions. The dissolved fractions showed higher values than the particulate fractions at every station. The dissolved fractions showed uniform trends at stations IX and VIII with a drop at station VII, then the concentration increased continuously and reached a peak at station III. From station III the particulate mercury decreased downward all the way to station I in the gulf. The station IV+V is the combination of stations IV and V which is located in an area of heavy industrialization of Prapadaeng District which possilby gives rise to the high concentration of mercury.

The total concentration of mercury for the January collections was approximately the same as that of the dissolved fraction. The particulate fraction showed high values at stations IX, VII, VI with the highest peak occuring at station IV+V. It then decreased through stations III, II and I.

The results of the mercury concentration in the water samples for the January collections cannot be readily compared to those of the May collections since the latter showed an obvious pattern of mercury distribution along the study area. The surface water of the May collections gave the highest peak for the dissolved fraction at station VI, then decreased to station III, and again abruptly increased at station II before decreasing again through the remainder of the area. The particulate fraction for the May collections showed higher concentration than that of the January collections and the values are comparatively high at stations VI, V and IV. And the rest was nearly the same as those of the January collections. Stations I, II and III located in the gulf and the river channel gave low mercury concentration for the particulate form. The trend of the total mercury was approximately the same as that of the dissolved fraction.

For the January samples, the lead concentration showed the had a dissolved fraction ranging from 7.49 % to 24.38 %, resulting in a mean percentage of 15.81 for the dissolved fraction of lead. The mercury concentration had a dissolved fraction ranging from 41.82 % to 99.29 % with a mean percentage of 79.53 for dissolved mercury. In May collections, the dissolved fraction of lead ranged from 4.19 % to 22.58 % with a mean percentage of 15.53 %. For mercury the dissolved fraction range from 47.92% to 97.92 % with a mean value of 84.73 %.

At many stations the total lead and mercury concentration detected in the water samples in the May collections are somewhat higher than those found in the January collections. This might be due to the dilution effects of the water in the river. Hydrographical conditions in May are

different from those in January, the rainfall is scarce, which accounts for the small volume of river water. During the January period, however, the surface runoff and late-season rainfall caused by the depression prior to the collection time produced an unusual flood condition in the river, so the river-water condition could still represent the rainy season.

The analysis of variance or F-test was applied to the mean values of the varieties of the two metals to determine whether there existed the difference in the mean values of the samples from the two collections. The F values obtained from calculation and the Variance Analysis Table are shown below

| | | $F_{(calculated)}$ | $F_{(7,8)\ \alpha .05}$ |
|---|---|---|---|
| Lead | Dissolved fraction | 2.216 | 3.50 |
| | Particulate fraction | 0.690 | |
| | Total fraction | 0.760 | |
| Mercury | Dissolved fraction | 1.320 | 3.50 |
| | Particulate fraction | 1.080 | |
| | Total fraction | 1.360 | |

As it can be seen from the table above that there is no statistical difference in particulate, dissolved and total lead and mercury for the January and May collections regarding the analysis of variance.

Sediment

The total concentration of lead in the sediment cores are showned in table 2 and indicates the amount of lead remaining in each layer of

sediment core. The lead profiles at each station are shown in Figure 9-16 inclusive. The lead content in the top sediment layer varied from station to station.

Station I which was in the inner gulf, is an area which is slightly contaminated, having a value of 0.556 ppm of lead residue in its sediment (on the wet weight basis). The lead content at station I was similar to that of stations VIII and IX in spite of the fact that station IX is a thinly populated area. This was a similar amount to that of stations IV+V and VI which had values of 0.532 and 0.565 ppm respectively. On the other hand, stations IV+V and VI (which are located in the river course) are heavily contamianted areas, largely as a result of the industrial and domestic activities of the Bangkok Metropolitan Area.

Stations II and III (located at the outer bar of the river mouth) cover the area reported by the Port Authority of Thailand as one with a heavy sedimentation of the particles swept along by the Chao-Praya River. Dredgings have been regularly operated there during the past years to remove the sediment blanket in the channel and to prevent it from hintering water-transportation in and out of the Bangkok harbour. Another major cause of such sedimentation is that the coastal shallow water is used as a fishery ground and fishing gear employed in this area can cause disturbances to the sedimentation layers. The extent to which sedimentation disturbances are caused in this way is rather difficult to assess. These fishing and dredging activities can be considered as the causes which have produced the type of sedimentation indicated in the profiles of the mentioned area.

The lead profile at station III showed a high lead residue which supported the assessment of the situation by the Port Authority.

Station VII, VIII and IX did not show any dramatic variation in the lead content, and station IX (which is about 65 km from the river mouth) can be considered as having representative background values for lead and mercury residues. Station IX is located in the river course about 2 km beyond the city of Nonthburi. At this station, the inhabitation is scarce. At station VIII, the lead value in the top layer of the sediment increased to 0.326 ppm and the value then decreased to 0.303 ppm at station VII. Going down along the river, passing the Bangkok Metropolitan Area, the surface lead can be compared as follows: the values at station VIII and VII were about 2 times that of station IX, the values at stations VI and IV+V were about 3 times that of station IX, stations III and II showed high values-about 15 and 11 times those of the background respectively. Station I, which is in the sea, had 3 times more lead content than that taken as the background value. These figures indicated the possible high sedimentation of the lead-contaminated particles along the river bottom down the river through the urban area, and showed the dramatic increase towards the river mouth - especially in the river channel at the outer bar of the river, where the downriver fresh water with a sediment load meets the saline water, causing both the chemical and physical changes and resulting in the sedimentation of the suspended particles.

The high values of the lead residues in the urban area might be due mainly to the consumption of the leaded-fuel in water transportation. The introduction of this metal through industrialization is also a possible

cause. The nearer we get to the urban area, the more the lead content in the soil increased (Bogden et al., 1975), and this lead pollutants eventually find their way into the water. Paint chips and marine paints also give rise to lead contamination in water. The Third Pollution Survey in the Gulf of Thailand (9-11 April, 1974) reported that the range of lead content in the sediments was from 0.15-3.03 ppm. Welch and Dick (1975) reported that the lead contamination in surface soil along the highway related to the distance from the highway. The finding was similar to that of Minerau and Favara (1975): the uncontaminated soil of Colorado has been reported as 22.9±4.4 ppm, while soil samples taken 15 m away from the highway (examined to a depth of about 5 cm) increased within 100 m of the highway.

The total concentration of mercury in the surface layers at each station also showed a similar variation. At station IX the value was quite low, but increased at station VII to about 0.329 ppm. The range of the mercury content did not show a wide discrepancy with the 0.237 value obtained at station II. Such discrepancy as there was, was probably due to the introduction of mercury into the river environment through the city's activities. Nevertheless, the surface values of mercury at station were still within an acceptable limit and were not very different from the normal mercury value value given for the earth's crust. This is also true of the lead content at each station in the top layer. (Rankama and Sahama, 1960). They also reported lead values of 0-20 ppm and mercury values of 0.3 ppm in the earth's crust as being the normal limit.

The lead and mercury profile at station I in Figure 9 did not show any significant variation in the mercury content. But for lead, the profile showed the highest peak at the second layer determined and then gradually decreased.

The profile at station II in Figure 10 showed the mercury content peak at the $20^{th}$ - cm layer of the core and then decreased downward. Lead showed the highest value in the surface layer then decreased continuously.

The profiles of lead and mercury at station III in Figure 11 showed a similar variation for the two metals. The highest peak of lead appeared in the first 10-cm portion of the core and then decreased down-ward, whereas the mercury content fluctuated with depth: but in neither case did the values represent extremes.

Station IV+V in Figure 12 also showed a similar profiles for the lead and mercury content in the sediment. The highest peak was on the first 10-cm portion of the core, and then decreased typically as did those of the sediment profiles recorded in other studies. There was not any clear sign of gross contamination by foreign lead in any layer of the sediment cores which were studied, but the mercury content was highest at the 10-cm layer of the core. This might be due to the deposition of high mercury-load particles on the river bottom because this station is located in the area of intense industrialization that might give rise to the artificial inputs of lead and mercury into the river.

Station VI in Figure 13 showed similar trends for the lead and mercury content as those of station IV+V.

Station VII in Figure 14, the lead content was nearly uniform throughout the various layers of the core. The highest peak for mercury content appeared at the first 10-cm portion of the core with an abrupt drop in value to the previous range of the sediment in the core, which might be caused by contamination from the nearly oil refinery.

Station VIII in Figure 15 did not show any significant variation for either the lead or mercury content, though sharp peaks still existed. These peaks probably occured as a result of an irregular contamination of some sort, and there may well be several causes which would account for them. They might also be due in part to long-term contamination.

For station IX in Figure 16, the lead content did not vary from that given in the typical sediment profiles, while mercury fluctuated in peak height but showed no significant variation.

The values of surface mercury fall in the range previously recorded by others, Schell and Barnes (1973) found 0.262-2.800 ppm in the sediments of Lake Union and Lake Washington; Potter et al. (1975) found 30 ppb in the sediments of Lake Powel. Klein and Goldberg (1970) reported the mercury concentration in dried sediments off the Californian coast as 0.02-1.0 ppm. The values reported by the Hydrographic Department, Japan, from a survey made during 1972-1973 in Tokyo bay, Osaka bay and Ise bay were 0.12-0.72 ppm, 0.31-0.63 ppm and 0.21-0.34 ppm respectively, whereas the legal dumping area showed only 0.01-0.02 ppm. From report on the Third Pollution Survey in the Gulf of Thailand (9-11 April, 1974) it was noted that the bottom sediment showed a mercury content ranging from 0.000 ppm in some certain stations to 2.4-23.4 ppm in others.

Schell and Barnes (1973), Edington (1976) and Lindberg et al.(1974) suggested that a study of the sediment core profile is an excellent indicator of the past history of both lead and mercury input to the aquatic environment as a result of manmade activities. There are obvious differences in the profiles from core to core, but the general trends which they exhibited indicate some similarity of sedimentation development over the whole area. A discrepancy in the magnitude of the concentration of lead and mercury was also observed from station to station, like that found by Schell and Barnes (1973). Lindberg et al., (1974) who studied the autropogenic causes of mercury contamination from the Everglade cores. They also found that mercury residues varied with the depth of the sediment. The deposition of the sediment in each layer of a given core also influences the amount of metals residues in each layer, a fact already reported by Swedish authors (Eric et al., 1975) Linberg et al., 1974).

Biota

Only some economically important species of fish, prawn, and molluscs have been investigated for total residues of lead and mercury in the muscle. The results of this study are shown in table 4 (for the January collections) and table 5 (for the May collections). From the samples collected in January at stations I, II and III, it was clear that Scatophagus argus, Carnx malan, Epinepherus tauvina, Sepia sp. and Loligo sp. all showed a positive linear relationship between the total mercury residue in the muscle and the weight and length of the specimens. This phenomena has already been mentioned by many authors (Schell and Barnes, 1973, Smith et al., 1976 and Potter et al., 1975). However, such a rela-

tionship with the lead residue was not clearly established in the case of the samples examined.

The fish samples at station IV+V, where industrialization is believed to give rise to the high accumulation of total lead and mercury, whowed a linear positive relationship in Pangasius pangasius, Kryptoterus bleekeri, Puntius gonionotus, Pluntioplites proctozysron, and Pangasius nasatus.

The lead and mercury residues found in the muscle of the seagulls representing the top of the food chain did not show obvious relationship to body weight and length as those found in the fish and some of the molluscs. However, the absolute values of both lead and mercury in each organism were high as compared to those of the same trophic level previously detected. Although the migratory habits of these marine birds are very well known as compared to most of the other birds, their feeding habits, the availability of food and their constant movements over a large area, make it difficult to draw conclusion regarding the results obtained on the total lead and mercury residues in each organism.

The fish and mollusc samples collected during May collections were analysed for lead and mercury residues in the muscle and the results are shown in table 5. The trends of total lead and mercury concentration were similar to those of the January collections, and the pattern of the mercury residue indicated with reasonable certainty a positive linear relationship between the mercury content in the muscle with the weight and length of the following species: Caranx malan, Scomberomerus commersoni, Loligo sp. Polynemus sp., Puntius gonionotus, Mystus nemerus, Kryptoterus bleekeri,

Notopterus notopterus and Ambasis wolffi. The other samples examine showed a variation in the lead content from sample to sample, but this variation was not so noticeable among the similar species.

Figure 17a and 17b showed positive linear relationship between lead and mercury residues in biota muscle with length.

A comparison of the total lead and mercury residues in the biota muscle, according to the trophic level in the food chain, is shown in Figure 18. The samples were selected from two collections. For the first collection, made in January, it was found that the mercury in the third trophic level was at the lowest, but it was quite close to that of the fourth level. The fifth level species, however, produced the maximal values for mercury residue in the muscle. Thus the positive accumulation of mercury in the muscle was related to the trophic level in the food chain. The same set of organisms showed the highest lead residues in the third trophic level, whereas those of the fourth and fifth level both showed magnitudes similar to each other. At the same time, there was some doubt as to the validity of the results obtained. The fish samples of third trophic level consisted of only one species, Puntius gonionotus, which has specific habits with respect to feeding on aquatic plants. So the positive accumulation of lead according to the trophic level in the food chain cannot be clearly established in this case because results concerning a single species did not lend themselves to a reliable general interpretation.

The mean values for lead and mercury in each trophic level from the January and May collections shown in Figure 18 produced a broad view

of the lead and mercury residues in the organisms belonging to each trophic level in the food chain. No significant variations were observed in this category.

From the analysis of variance or F-test for the these trophic levels of biota ( 3rd, 4th and 5th level) from the collections in January and May, the results are as follows:

| | | F(calculated) | F $\alpha$ .05 |
|---|---|---|---|
| Lead | 3rd trophic level | 2.889 | $F_{(2,5)}$ 6.61 |
| | 4th trophic level | 0.512 | $F_{(2,34)}$ 4.13 |
| | 5th trophic level | 0.023 | $F_{(2,37)}$ 3.11 |
| Mercury | 3rd trophic level | 2.180 | $F_{(2,5)}$ 6.61 |
| | 4th trophic level | 0.686 | $F_{(2,34)}$ 4.13 |
| | 5th trophic level | 0.701 | $F_{(2,37)}$ 3.11 |

It is also can be concluded that there is no statistical difference in the three trophic levels of the biological samples from the two collections.

If the species are more available the results might be more clearly interpreted.

The concentration factor (C.F.) for the mercury residuesin the species studied ranged from 55 (in Scomberomerus commersoni) to 3580 (in Epinopherus tauvina), taken as an aggregate value without regard to particular seasons, localities and trophic levels. For lead, the C.F. values

fall within a range of the order of 100, also taken as an aggregate value. However, the over-all C.F. for each individual trophic level cannot be easily assessed' due mainly to the discrepancies in the feeding habits of different species. Some species restricted themselves to a particular geographical area, while others are migratory. So the biology of each species involved needed to be fully understood. In addition, the different levels of lead and mercury content in the water and sediment at each station also play a significant role in the susceptibility of given organism to accumulate each of the metals.

A correlation between the length of the sampled species and the total lead and mercury residues in the muscle was totally inconclusive since only a limited number of species were studied and only a few of the organs in the specimens were examined.

One possible explanation for the high lead content in Puntius gonionotus may be found by considering its diet and feeding habits. Fish can accumulate mercury in tissue either directly from water or from the food provided through the food chain. In fact the available data indicates that most of the mercury content is ingested from the surrounding water (Eric et al., 1975). The mercury residues detected in the species examined for the present study are low as compared to those found by others. The analyses of fish samples from La Grando river in northern Quebec, Canada by Eric et al., (1975) showed that the fish contained not more than 1 ppm of mercury residue in their tissue. Fonselius (1970) found that Swedish pike, perch and vendance have a mercury content ranging from 0.03-0.20 ppm. Bertine and Goldberg (1972) studied the changes in composition

of trace amounts of mercury in the shells of mussels and clams from the Belgian coast and other European regions between 1869-1971, and found that human activities can not be held responsible for the biocontamination of mercury. A similar conclusion was drawn after the mercury biocontamination study concerning the food chain of the Bang Pra Coastal Area, namely that the bioamplification of mercury there, occurred naturally (Menasveta, 1975). Though the mercury residues in the organisms examined here have a comparatively low concentration, the lead values showed that there was a high concentration of the metal in certain species. The acceptable limit given by WHO is only 0.05 ppm, but a value of 0.5 ppm is widely accepted in the United States and Sweden.

The results of this study support the view that the accummulation of mercury in the muscle of organisms happens naturally in the food chain. Though fish are frequently used as monitors in studying the pollutional effects of heavy metals in the aquatic environment with the aim of protecting man's health, it need to be borne in mind that, on considering the food chain, only certain species can satisfy some of the major requirements for accurate prognesis. Tolerance to the pollutants, restricted geographical areas, water masses, ecological niches and specializaed feeding habits are also important factors in tracing the kinetics of lead and mercury pollutants in the trophic web. The study of birds and seagulls can only indicate the real level of lead and mercury residues in the aquatic environment, if the detailed feeding history and other factors concerning their ecological niches are known..