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TOTAL MERCURY IN THE FOOD CHAIN OF BANG PRA COASTAL AREA, CHON BURI

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Summary

*The biological magnification of total mercury residues was found in Bang Pra coastal area, Chon Buri. Fish in the higher trophic level bore higher mercury concentrations than those in the lower trophic level. It was also found that the aged predator and scavenger such as barracuda (**Sphyraena obtusata**) and stringray (**Dasyatis zugei**) exhibited positive linear relationship between total mercury residue concentration and their size. The comparison between the total mercury residue data obtained in this investigation and the data reported in other areas of the world revealed that the total mercury in this area was in normal range. Therefore, it can be concluded that the biological magnification in the Bang Pra coastal area occurs naturally.*

Introduction

There are two sources discharging mercury into the environment: man-made and natural. The principal man-made discharges are through the application of pesticides, and in the chlor-alkali production. The principal natural discharges are through leaching and volatilization from geological formations containing significant quantities of mercury. However, the local incidence of mercury contamination caused by natural sources is very rare. Recent concern has locally focused on the discharges from the man-made sources.

Once mercury is introduced into the food chain it becomes available to all organisms of the chain. The reports of high mercury concentration in tuna and swordfish and the high trophic level in freshwater fishes suggest that mercury may be concentrated in the same manner as such organic compounds as chlorinated hydrocarbons i.e., passed through and amplified by the food chain.[1] Bang Pra coastal area in Chon Buri province is presently under agricultural development and is projected for large scale industrial development in the near future. Therefore, it was deemed necessary to survey the environmental baseline of the area prier to development. This included survey on the mercury distribution in both non-biotic and biotic marine environment.

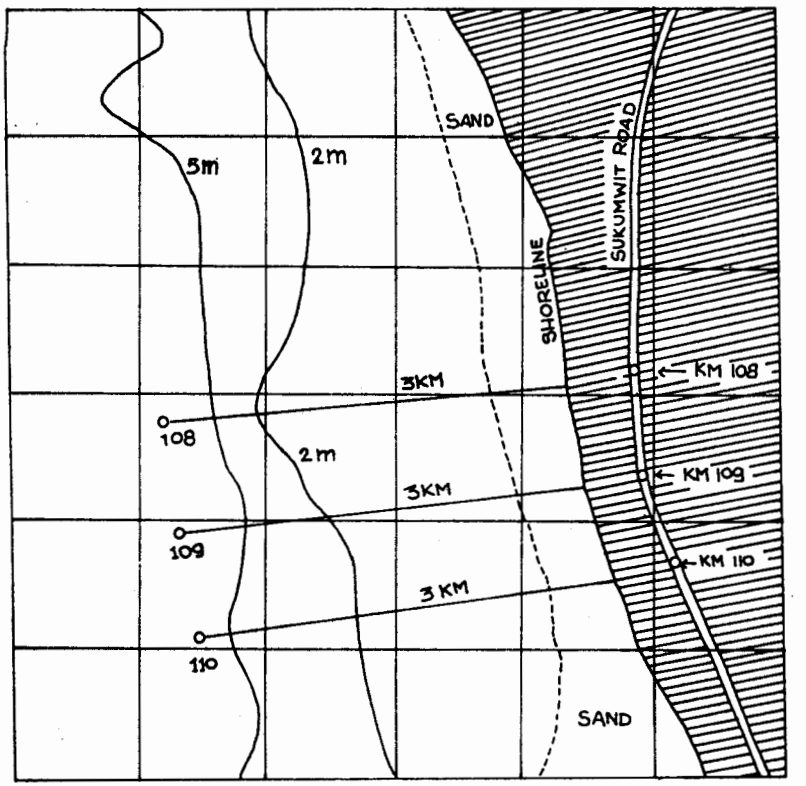

Fig. 1. Sampling stations for the total mercury residues distribution at Bang Pra, Chon Buri.

Materials and Methods

Sample Collection

The samples for total mercury analysis were collected in the marine environment of Bang Pra coastal area. It is between Km. 108 and 110 of Sukhumvit highway (Fig. 1). Fish samples were collected from the catch of other trawl. The trawling was done once every month from August to December, 1974. The species of fish samples ranged from the lower trophic level to higher trophic levels. Plankton samples were collected by a plankton net. Zooplankton samples were collected by a net that had mesh size (0.09 mm) large enough to allow phytoplankton to pass through but not zooplankton. Samples of seawater and sediment were collected in three stations (108,109, and 110; see Fig. 1) three kilometers from the shoreline. In each station, samples of seawater were collected at mid depth. A petersen grab was used for sediment collection. All of the samples were preserved in a freezer at a temperature of approximately–20°C. For assay the fish were thawed and dissected with a stainless steel knife and a portion of muscle was used for total mercury determination. The seawater and sediment were thawed and quantitatively analysed for the total mercury.

Total Mercury Determination

The total mercury residue in the samples was determined by the flameless atomic absorption technique. The Mercometer Model 2006–1 (Anti-Pollution Technology Corporation, Holland, Michigan) of the Department of Marine Science, Chulalongkorn University was used for measuring the mercury concentration. The details of the method are as follows. The size of seawater sample for each determination was 180 ml; fish muscle, 0.1–2.0 g (wet); sediment, 0.5–2.0 g (wet). The sample was weighed into a 250 ml Pyrex digestion bottle. Twenty ml of 1:1 concentrated redistilled HNO_3 and concentrated reagent grade H_2SO_4 were added to the sample. All nonaqueous samples were predigested in open containers with this concentrated acid solution at 95 $\pm$ 2 °C for 20 min or until digest was clear. Ten ml of saturated $K_2S_2O_8$ solution and 50 ml of distilled water were added with swirling to all nonaqueous samples. The sample containers were loosely capped with ground glass stoppers and digested at 95 $\pm$ 2 °C for 2 in a water bath. After removal from the water bath the samples were cooled to room temperature and quantitatively transferred with distilled water into a 500 ml 3-neck distillation flask. Twenty ml of reducing solution (20 g $NH_2OH.HCl$, 20 g NaCl, 33 g $SnCl_2.2H_2O$, 1 g hydrazine sulfate, and 9 ml concentrated H_2SO_4 diluted to 1 l) was added; the bubbler gas dispersion tube was inserted in one neck and the others plugged with ground-glass stoppers. The solution was swirled gently for 30 s. After swirling, bubbling with purified air which had had mercury vapour removed, was commenced.

Results

The samples comprised of two major of living things; plankton and nekton (fish). All of them, however, could be classified into four trophic levels based on the length of food chain, i.e., first, second, third and fourth trophic level. Therefore

plankton and zooplankton were considered as the representatives of the first and second trophic level. Plankton is the composite samples of many species of phytoplankton and zooplankton. Zooplankton is also a composite species. The third trophic level comprised of 5 omnivorous species, namely, *Loligo* sp., *Sepia* sp., *Leiognathus elongathus*, *Sillago maculata*, and *Aetobatus* sp. of these 5 species, *L. elongathus* was the dominant species of the study area.

The fourth trophic level comprised of five species, namely, *Saurida elongata*, *Trichirus haumela*, *Ophicephalus striatus*, *Dasyatis zugei*, *Pseudotriacantus strigillifer* and *Sphyraena obtusata*. It should be noted that although *O. striatus* is not a marine species, it is also listed in this trophic level. This is because they were fed with marine trash fish which mostly are fish in the third trophic level. The samples of *O. striatus* was obtained from a fish pond of Salaya, Nakorn Pathom province. It should be noted that every species of fish that is used for total mercury residue determination were commercial species.

The result of total mercury residue analysis revealed that seawater had the lowest mercury concentration. The mercury concentrations in seawater of the three stations did not very greatly. They ranged from .015 to .018 μg/l (ppb) (Table 1).

The mercury residue in the first and second trophic level (phytoplankton and zooplankton) was higher than the seawater content. The mercury residue in six samples of plankton and three samples of zooplankton were the same: 1 ppb (Table 2).

The mercury residue concentration in the third trophic level was higher than the first and second trophic level. The concentration within the species and among the five species did not differ greatly (Table 2). The average mercury concentration of the second trophic level was 7.1 ppb.

Most mercury residue concentration of the fourth trophic level was higher than of the third trophic level. There was, however, great differences within species and among the five species (Table 2). In considering the data of *Dasyatis zugei*, the simple linear regression analysis was used. The result reveals a positive linear relation between the size of fish (weight) and the mercury concentration; the mercury residue concentration in fish body increased as their size increased (Fig. 2). *Sphyraena obtusata* also exhibits the same pattern of mercury concentration. Among the five species of the fourth trophic level. *Saurida elongatus* has the lowest mercury

TABLE I TOTAL MERCURY IN THE SEAWATER OF BANG PRA COASTAL AREA.

Station	Sample No.	Total Hg Concentration, μg/l
108	1	.018
	2	.019
109	1	.015
	2	.018
110	1	.019
	2	.019

TABLE II TOTAL MERCURY RESIDUES IN THE BIOTA OF BANG PRA COASTAL AREA.

Names	Trophic levels	Sample No.	Length cm	Weight g	Total Hg conc. ng/g	Mean total Hg conc. of each species, ng/g
Composite species (Phyto-and zooplankton)	I + II	1	–	–	1.0	1.0
		2	–	–	1.0	
		3	–	–	1.0	
		4	–	–	1.0	
		5	–	–	1.0	
		6	–	–	1.0	
Composite species (Zooplankton)	II	1	–	–	1.0	1.0
		2	–	–	1.0	
		3	–	–	1.0	
Loligo sp.	III	1	–	25	8.0	7.5
		2	–	32	7.0	
Sepia sp.	III	1	–	55	6.0	6.0
Leiognathus elongathus	III	1	6.0	3	9.0	6.0
		2	6.0	5	4.0	
		3	6.5	5	5.0	
		4	7.5	8	8.0	
		5	10.0	15	6.0	
		6	10.5	17	4.0	
Sillago maculata	III	1	10.0	8	9.0	6.0
		2	10.0	12	3.0	
		3	10.0	10	6.0	
		4	13.0	20	9.0	
		5	14.0	34	3.0	
		6	15.0	37	6.0	
Aetobatus sp.	III	1	57.0**	2400	10.0	10.0
Saurida Elongata	IV	1	12.0	17	3.0	6.5
		2	15.0	32	2.0	
		3	16.0	35	5.0	
		4	26.5	170	16.0	
Trichirus haumela	IV	1	27.0	14	11.0	14.0
		2	29.0	17	17.0	
*Ophicephalus striatus**	IV	1	19.0	50	32.0	27.8
		2	22.0	90	28.0	
		3	25.5	150	26.0	
		4	31.0	280	25.0	
		5	33.5	412	28.0	
Dasyatis zugei	IV	1	8.5**	17	6.0	16.0
		2	14.5	115	9.0	
		3	21.8	300	13.0	
		4	22.8	500	12.0	
		5	24.5	470	17.0	
		6	25.8	500	16.0	
		7	34.0	1500	39.0	
Pseudotriacantus Strigillifer	IV	1	9.3	10	35.0	31.5
		2	12.5	27	28.0	
Sphyraena obtusata	IV	1	19.0	43	2.0	32.3
		2	27.5	105	38.0	
		3	83.0	2600	57.0	

* From Salaya Fish Ponds
** Disc Length

TABLE III TOTAL MERCURY RESIDUES IN SEDIMENT SAMPLES OF BANG PRA COASTAL AREAS.

Station	Sample No.	Total Hg Concentration, ng/g (wet)
108	1	54
	2	69
109	1	17
	2	15
110	1	3
	2	4

residue concentration. The mercury residue concentration of this species is somewhat the same as the mercury concentration in the third trophic level. Nevertheless, the average mercury residue concentration of the fourth trophic level was 20.9 ppb.

According to the above analysis, it can be concluded that there is a biological magnification of mercury residues in Bang Pra coastal area (Fig. 3). Fish of higher trophic level bear higher mercury residue than those in the lower trophic level. The mercury content in the sediment samples of the three stations varies greatly. The range of variation was 3 to 69 ppb. However, it should be noted that the data did not exhibit great variation within each station. The highest mercury residue was detected in the samples from station 108 followed in decreasing order the samples from station 109 and station 110.

Discussion and Conclusion

The biological magnification of the total mercury residue was found in Bang Pra coastal area, Chon Buri. Fish in higher trophic level bore higher mercury residue than those in the lower trophic level. This suggests that mercury may be concentrated in the same manner as such organic compounds as chlorinated hydrocarbons, i.e., passed through and amplified by the food chain. The concept appears correct when considering the data presented by Johnels *et al.*,[2] Johnels and Westermark[3], Dustman *et al.*,[4] Jernelov[5], and Scott and Armstrong.[6] However, Knauer and Martin[7] concluded from their investigation that there was no biological magnification of mercury residue in the three lower trophic levels (phytoplankton, zooplankton, and anchovy) in the uncontaminated Central Pacific region. Their conclusion may be inaccurate, since only the total mercury (inorganic + organic) amplification is taken into consideration. If the amplification of organic mercury is considered, biological amplification may occur, because 33–100 percent of the total mercury in phytoplankton is inorganic, compared with 0–25 percent in anchovy. According to Matida *et al.*,[8] less than 2 percent of inorganic mercury, but 33–48 percent of organic mercury can be taken up by fish.

In general the total mercury residue in all investigated samples from Bang Pra coastal area were low. Mercury residues values of this study are comparable to the values that were reported by Huschenbeth and Harms.[9] The comparison between

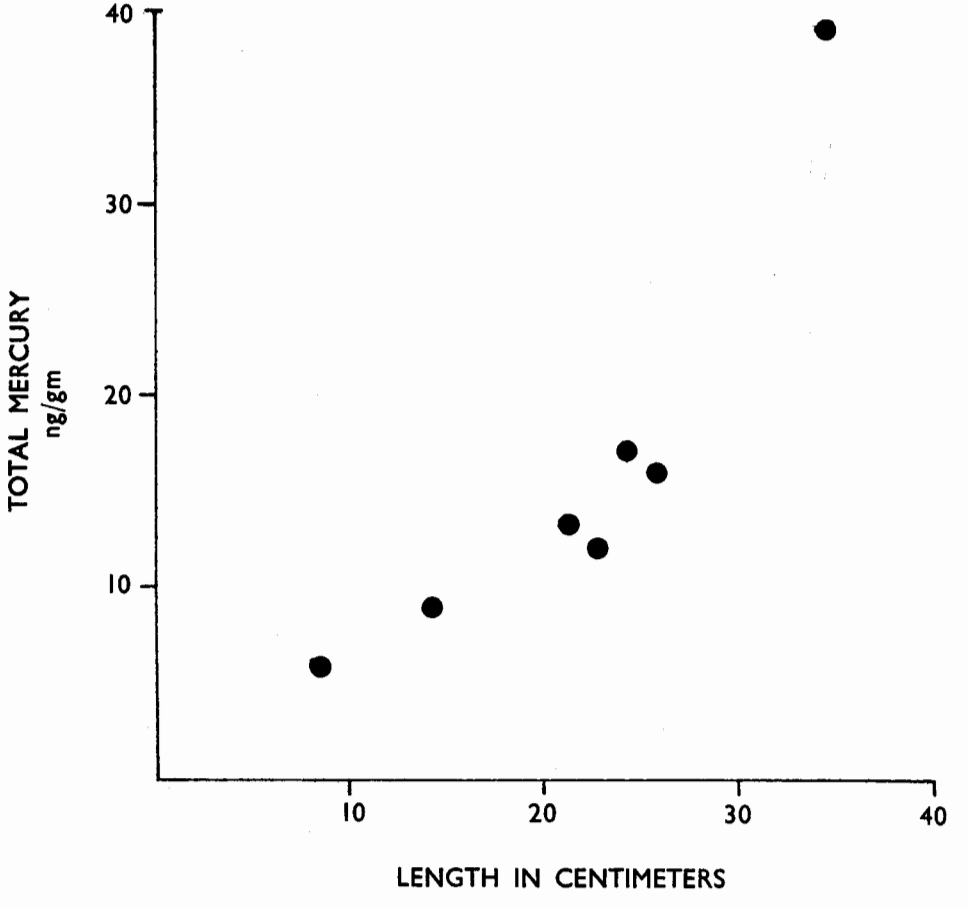

Fig. 2. Relationship between length of stingray *(Dasyatis zugei)* and total mercury residue concentration.

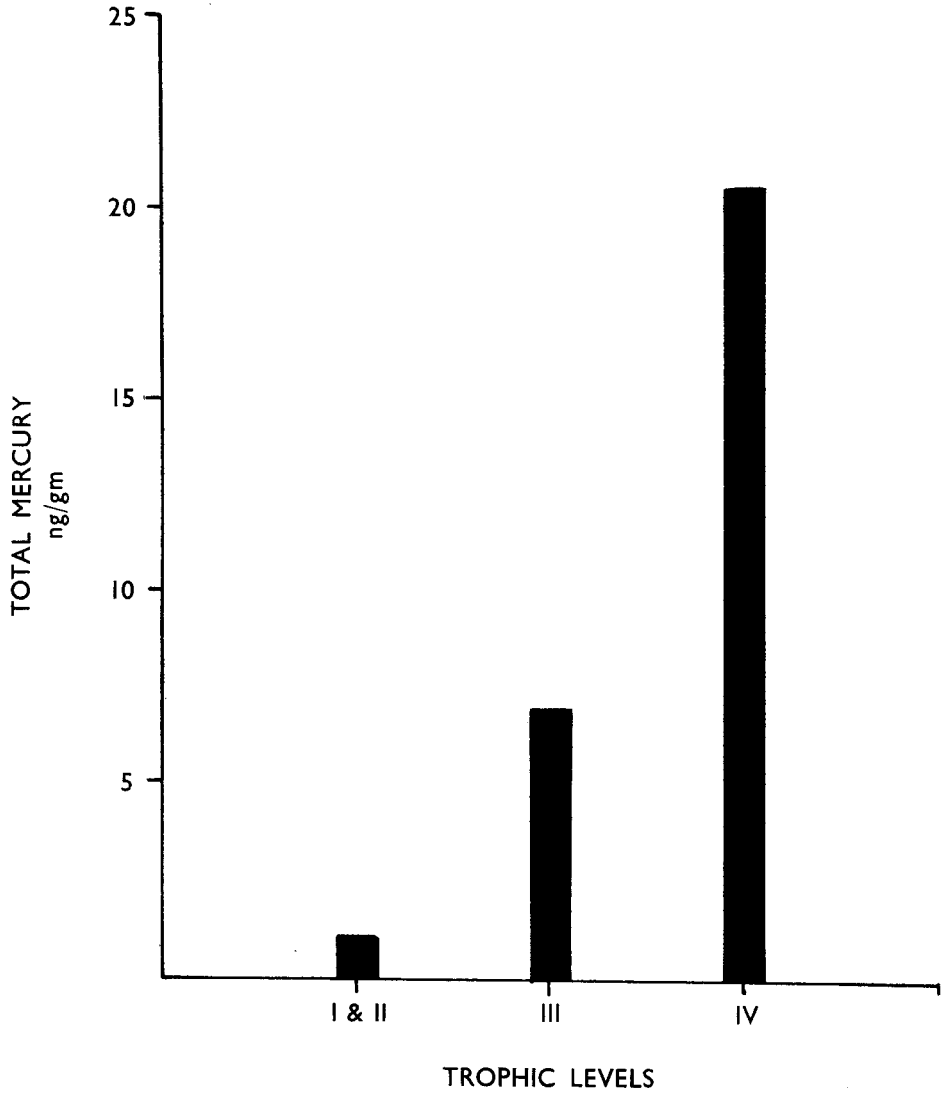

Fig. 3. Total mercury residue concentration in the three trophic levels.

the total mercury residues obtained in this investigation and the data reported in other areas of the world (Table 4) also reveals that the total mercury residues in this area is in a normal range. Furthermore, many publications by Swedish and Japanese authors make it clear that the mercury residues value under 0.2 ppm can be regarded as typical of unpolluted sea areas. Therefore, it can be concluded that the biological magnification in the Bang Pra coastal area occurs naturally.

TABLE IV MERCURY CONTENT IN WATER AND FISH AS COMPLIED BY KOTHNY[10].

Water type	Concentration of Hg in water μg/l	Fish type	Concentration of Hg in fish μg/g
Rain	0.01 – 0.48	–	–
Ice prior to 1952	0.06 ± 0.02	–	–
Ice from 1960 to 1965	0.13 ± 0.05	–	–
Spring	0.05 – 0.13	–	–
Uncontaminated river water	0.01 – 0.05		
River water in U.S.A.	0.04 – 0.5	Freshwater fish	0.08 – 0.5
Ocean, Uncontaminated	0.03 – 0.27	Tuna	0.03 – 1.0
		Swordfish	1.0
		Protein, concentrated	0.3 – 0.9
Japan, Minamata Bay	1.6 – 3.6	Marine fish	9 – 24
Sweden, Lake	–	Pike	0.04 – 8.4

It was also found in this study that the aged predator and scavenger such as barracuda (*Sphyraena obtusata)* and stingray (*Dasyatis zugei)* exhibit positive linear relationship between mercury concentration and their size; this is well documented.[11, 12, 13] The increment of mercury residues in the fish with age is due to the fact that the accumulation rate is faster than the elimination and growth rate.[14]

It is very interesting to consider the mercury residue in *Saurida elongata.* This species is a carnivorous fish and is categorized into the fourth trophic level but having comparable mercury residues to the third trophic level. This consequence may be due to the age factor. Of the four fish used for mercury determination, three were in young stages. Hence the average mercury residue of this species must be low.

It was also found that mercury residue in the sediment samples in the three stations (108, 109 and 110) varied greatly. The mercury residues were highest in station 108 followed in decreasing order in station 109 and 110. This consequence may be due to the sediment composition effect. A large portion of the sediment samples of station 110 was sand, contrary to the samples from 108 in which a large portion was mud.

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บทคัดย่อ

ได้พบการเพิ่มขยายทางชีวภาพ (biological magnification) ของสารปรอท (total mercury) ในลูกโซ่อาหาร (food chain) ของบริเวณชายฝั่งทะเลบางพระ ชลบุรี ปลาที่อยู่ในชั้น อาหารที่สูงกว่า (higher trophic level) มีความเข้มข้นของสารปรอทสูงกว่าปลาและสิ่งมีชีวิตอื่น ๆ ที่อยู่ในชั้นอาหารที่ต่ำกว่า นอกจากนี้ยังพบว่าปลาชนิดที่ล่าเหยื่อ (predator) และพวกที่กินซากพืชและสัตว์ที่ตายแล้ว (scavenger) เช่นปลาสาก (*Sphyraena obtusata)* เช่นปลากระเบนหัวแหลม *(Dasyatis zugei)* มีความเข้มข้นของสารปรอทภายในตัวเพิ่มขึ้น เมื่อมีขนาดเพิ่มขึ้นอย่างไรก็ดี เมื่อได้เปรียบเทียบข้อมูลที่ได้จากการสำรวจและวิจัยครั้งนี้ กับข้อมูลต่าง ๆ ที่ได้รายงานทั่วโลกแล้วจะเห็นได้ว่า ความเข้มข้นของสารปรอทในน้ำและสิ่งมีชีวิตในบริเวณชายฝั่งทะเลบางพระ มีความเข้มข้นในพิกัดปรกติ ฉะนั้น จึงสรุปได้ว่า การเพิ่มขยายทางชีวภาพของสารปรอทในลูกโซ่อาหารของบริเวณดังกล่าว เกิดขึ้นโดยธรรมชาติ.