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Total Mercury Concentrations in Coastal Areas of Thailand: A Review

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ABSTRACT Thailand has recognized mercury (Hg) as one of the most hazardous metals and considers this metal as a national concern. This article reviews the existing data on the total mercury concentrations in seawater, sediments and marine organisms in coastal areas of Thailand beginning in 1974 to 1999. The purpose of this article is to assess the degree of mercury contamination in Thai coastal environments. The mercury standards/guidelines from both Thailand and other countries are also included. In general, the situation of mercury contamination in Thai coastal areas is still within a safe level, except a few samples exceeding the standard have been collected in some areas.

KEYWORDS: mercury, seawater, sediment, marine organisms, coastal area.

INTRODUCTION

Thailand is situated in the tropical moonsoon belt of Southeast Asia. The country is bounded in the north, west and east by mountain ranges and in the south by the South China Sea and the Andaman Sea, with a total coastline of approximately 2,600 kilometers. The Gulf of Thailand (Fig 1) is an enclosed sea in the southwestern part of the South China Sea, covering an area of approximately 350,000 km^2, with an average water depth of 55 meters and a maximum of 84 meters. The Gulf is divided into two portions: the Upper Gulf and Lower Gulf. The Upper Gulf located at the innermost area is an inverted-U shape[1], which has a coastline of 700 kilometers from Prachaub-Kiri-Khan Province to Rayong Province.[2] The Upper Gulf is very shallow with an average depth of 15 meters, whereas the Lower Gulf includes a relatively deep part with an average depth of 55 meters.[1] In coastal areas, many developments with high rates of industrialization and urbanization have taken place, thereby changing the landuse pattern and deteriorating natural resources and the aquatic environment. Numerous industries located along the coast discharge their wastes into the Upper Gulf causing water quality deterioration with major pollutants from organic wastes. In some locations, the Upper Gulf has been faced the problems from heavy metals (including mercury) discharged by industries.[2] In particular, Map Ta Phut Industrial Estate established in 1989 in Rayong Province along the east coast has developed as a national heavy metal center, including a gas separation plant, oil refineries and petrochemical and chemical plants. Laem Chabang Industrial Estate was established in 1987 in Chonburi Province for medium-sized and non-polluting industries with

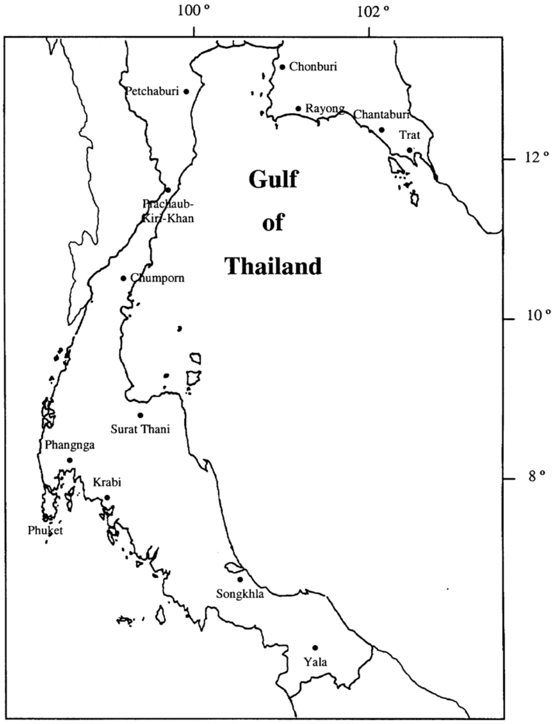

Fig 1. Map showing the Gulf of Thailand.

three petroleum refineries being located nearby the Estate. In addition, there has been an increase in the number of platforms for oil and gas exploration and production in the Gulf of Thailand.[3] The water quality deterioration in the Upper Gulf is partly due to wastes from the rivers because there are four major rivers draining into the Upper Gulf, namely the Chao Phraya, the Mae Klong, the Ta Chin and the Bangpakong Rivers.

Mercury is recognized as one of the most toxic pollutants in the coastal environment and is a national pollutant in Thailand. Mercury and its compounds are widely used in a variety of industrial and agricultural applications. Thailand has further developed with a rapid expansion of industrialization, urbanization and use of pesticides in agriculture anticipated. These activities will substantially increase the degree of heavy metal pollution, which will subsequently have a direct impact on the quality of life of the people in the coastal areas.

Here the existing data on the total mercury concentrations in seawater, sediments and marine organisms in coastal areas of Thailand are reviewed. The data are taken from various studies undertaken by government and private agencies available since 1974, in order to document the past and present status of mercury contamination in Thai coastal environments.

MERCURY CONCENTRATIONS IN SEAWATER

Heavy metal monitoring in Thailand began more than twenty years ago. There have been many studies on heavy metal concentrations in seawater. However, there are not many papers reporting studies of mercury compared to other heavy metals during the past twenty-five years. Considering the data obtained from several reports beginning in 1974 (Table 1), it can be observed that higher mercury concentrations in Thai coastal water were found in the early period, especially from 1979 to 1986, than in recent years. The highest mercury concentration reported (386 μg L^{-1}) was found in the areas of Bangpakong to Bang Pra in 1981[4], whereas in the Upper Gulf, a concentration of 342 μg L^{-1} was found in 1979[5] and a concentration of 203 μg L^{-1} found during 1983 to 1986[6]. The high mercury concentrations found in the past were probably due to some errors in methodology, measurement and sample collection. Utoomprurkporn et al[7] discovered that heavy metal concentrations in seawater reported for the Gulf of Thailand were apparently decreasing by as much as 500 times from 1979 to 1985, which is likely due to improvement in analytical techniques and methodology, rather than a decrease in the discharge of heavy metals into the Gulf. This improvement may account for the decrease in mercury and other heavy metals concentrations indicated in recent studies compared to previous studies.[1] Therefore, a decrease in mercury concentration has been observed since 1986. In general high mercury concentrations are occasionally observed in some coastal areas, however, the overall situation is still within a safe level, except at some locations and during some sampling periods as reported by Chongprasith and Wilairatanadilok.[3]

Recently, Thailand has faced the problem of increasing mercury concentrations in the coastal areas as a result of industrial activities and also in the Gulf due to oil and gas activities. Chongprasith and Wilairatanadilok[3] reported that total mercury in coastal waters has been monitored along the entire Thailand coastline by the Pollution Control Department since 1997, covering 218 sampling sites. Specific areas, such as industrial estates in Map Ta Phut and Laem Chabang, where elevated mercury concentrations were found have been monitored more extensively. The results showed that mercury concentrations ranged from <0.01 to 0.54 μg L^{-1} with an average of 0.032 μg L^{-1} during the periods from 1997 to 1998; mostly in compliance with the National Coastal Water Quality Standard for mercury of 0.1 μg L^{-1}. They also reported total mercury concentrations found in the areas adjacent to the Map Ta Phut Industrial Estate and the Laem Chabang Industrial Estate. Results of the mercury concentrations in the area from the former location ranged from 0.01 to 0.48 μg L^{-1} with an average of 0.057 μg L^{-1} during the periods from 1995 to 1998 whereas those from the latter ranged from <0.01 to 0.16 μg L^{-1} with an average of 0.064 μg L^{-1}during the periods from 1995 to 1996. High mercury concentrations were detected in the Map Ta Phut area especially in 1995-1996. They also reported high mercury concentrations in the areas around natural gas platforms and in the inner Gulf of Thailand ranging from <0.01 to 0.51 μg L^{-1} during the periods from 1995 to 1998 with a peak in 1995, then decreasing in the following years. This was possibly due to the release of mercury from discharged water produced from oil and gas activities. In addition, results reported by EVS Environment Consultants[8] showed that mercury concentrations in the Gulf of Thailand and around the Industrial Estates on the east coast in 1998 were below the National Coastal Water Quality Standard for mercury

Table 1. Total mercury in water and sediments in coastal areas of Thailand.

Study Period	Location	Total Mercury: Water ($\mu g\ L^{-1}$)	Total Mercury: Sediment ($\mu g\ g^{-1}$ dry wt)	Reference
	Gulf of Thailand			
1975-1976	Upper Gulf	0.01 - 0.11	-	9
1977	Upper Gulf	0.02 - 2.00	-	9
1975-1976	Upper Gulf	0.467	-	10
1979	Upper Gulf	1.54 - 12.0	0.049 - 0.268	11
1981	Upper Gulf	nil - 1.58	nil - 0.28	4
1982	Upper Gulf	nil - 0.40	0.01 - 0.26	
1978	Upper Gulf	0.01 - 0.29	0.1 - 0.13	5
1979	Upper Gulf	0.27 - 342	0.0 - 0.24	
1980	Upper Gulf	0.2 - 1.0	0.0 - 1.2	
1981	Upper Gulf	0.25 - 4.25	0.01 - 0.14	
1983-1986	Upper Gulf	0.2 - 203.0	-	6
1995-1998	Gulf of Thailand (Natural gas platforms and in the inner Gulf)	< 0.01 - 0.51 (0.046)	0.006 - 0.121	3
1998	Gulf of Thailand	ND - 3.000	0.05 - 2.8	8
	River Mouths and Coastal Areas			
1974	Bang Pra Coast Chonburi	0.015 - 0.019	0.003 - 0.069 (wet wt)	12
1976	Chao Phraya Estuary	0.216 ± 0.280	0.012 - 0.264	13
1978-1979	Estuarine areas			11
	- Mae Klong	0.12 - 10.10	0.036 - 0.885	
	- Ta Chin	0.12 - 6.40	0.071 - 0.746	
	- Chao Phraya	0.94 - 8.20	0.079 - 1.860	
	- Bangpakong	0.55 - 12.96	0.069 - 0.299	
1980	Estuarine areas			14
	- Mae Klong	0.03	-	
	- Ta Chin	0.25	-	
	- Chao Phraya	0.74	-	
	- Bangpakong	0.30	-	
1980	Estuarine areas			15
	- Mae Klong	-	0.23 ± 0.1	
	- Ta Chin	-	0.67 ± 0.1	
	- Chao Phraya	-	2.80 ± 0.4	
	- Bangpakong	-	0.52 ± 0.2	
1981	Bangpakong Estuary to Bang Pra	nil - 386	nil - 0.80	4
1977-1981	Bangpakong Estuary	4.60	-	16
	Ang Sila	6.50	-	
	Bang Saen	16.30	-	
	Bang Pra	2.10	-	
	Si Racha	1.30 ± 6.20	-	
	Pattaya	0.35 ± 0.54	-	
1979-1980	Estuarine areas			17
	- Bangpakong	0.10 - 1.22 (0.30 ± 0.20)	0.000 - 0.038 (0.014 ± 0.014)	
	- Mae Klong	0.08 - 1.25 (0.38 ± 0.30)	0.006 - 0.046 (0.014 ± 0.011)	
	- Ta Chin	0.10 - 0.50 (0.24 ± 0.09)	0.006 - 0.038 (0.017 ± 0.009)	
	- Petchburi	0.08 - 0.88 (0.27 ± 0.19)	0.004 - 0.015 (0.007 ± 0.044)	
	- Pranburi	0.08 - 0.82 (0.28 ± 0.17)	0.006 - 0.038 (0.014 ± 0.011)	

Table 1. Cont'd.

Study Period	Location	Total Mercury Water (μg L⁻¹)	Total Mercury Sediment (μg g⁻¹ dry wt)	Reference
1992-1993	Bangpakong River	0.10 - 0.12	-	18
1983-1984	East Coast of the Upper Gulf	nil - 85	0.01 - 0.14	19
1987-1990	Aquaculture areas			20
	- Bangpakong River mouth to Ang Sila	< 0.2 - 0.6	-	
	- Chantaburi toTrat	< 0.2 - 0.5	-	
1987-1988	- Bangpakong River mouth to Ang Sila	-	0.1 - 1.5	20
	- Chantaburi toTrat	-	0.1 - 1.2	
1990	Ban Phe Bay, Rayong	0.0006 - 0.0024 (0.0015)	-	21
1992-1993	Aquaculture areas			22
	- Bangpakong River mouth to Ang Sila	ND - 0.48	-	
1992	Coast of Trat	0.0006 - 0.0448 (0.014)	-	23
1993	East Coast (Chonburi-Trat)	0.02	-	24
1994	East Coast (Chonburi-Trat)	ND - 0.0861 (0.0188)	-	25
1995	East Coast (Chonburi-Trat)	< 0.001 - 0.096	-	26
June 1997-July 1998	Entire Coast of the Gulf of Thailand and the Andaman Sea	< 0.01 - 0.54 (0.032)	-	3
March -April 1998	Entire Coast of the Gulf of Thailand and the Andaman Sea	-	0.047 - 2.135 (0.136)	3
March 1999	Bangpakong River Estuary (0-10 cm depth)	-	0.12 - 0.48	27
	Industrial Estate			
	Petrochemical Complex site, Chonburi	0.3 - 22.0 (5.58 ± 5.23)	0.0262 - 0.2845	28
1977-1981	Map Ta Phut	0.60 ± 0.20	-	16
1987-1990	Industrial areas			29
	- Laem Chabang	<0.2 - 0.7	-	
	- Map Ta Phut	<0.2 - 0.8	-	
1987-1988	- Laem Chabang	-	0.1 - 1.4	29
	- Map Ta Phut	-	ND - 1.2	
1992-1993	Laem Chabang	ND - 0.26	-	22
	Map Ta Phut	ND - 0.76	-	
1995-1998	Map Ta Phut Industrial Estate, Rayong	0.01 - 0.48 (0.057)	<0.005 - 0.134	3
1995-1996	Laem Chabang Industrial Estate, Chonburi	<0.01 - 0.16 (0.064)	-	3
1996-1998	Laem Chabang Industrial Estate, Chonburi	-	<0.005 - 0.032 (0.016)	3
April 1998	Laem Chabang	-	<0.005 - 0.139	8
	Map Ta Phut	0.01 - 0.02	<0.005 - 0.037	
June-July 1998	Laem Chabang	0.01 - 0.02	0.024 - 0.037	
	Map Ta Phut	0.01 - 0.03	<0.005 - 0.156	8
	Standard/Guideline			
Canadian Water Quality Guideline for Protection of Aquatic Life		0.1	-	30
World Average Value for Seawater		0.05	-	31
Thai Water Quality Criteria for Protection of Freshwater Animals		0.5	-	20

Table 1. Cont'd.

Study Period	Location	Total Mercury Water ($\mu g\ L^{-1}$)	Total Mercury Sediment ($\mu g\ g^{-1}$ dry wt)	Reference
Thai Surface Water Quality Standard		2.0	-	20
Thai Coastal Water Quality Standard		0.1	-	20
ASEAN Marine Water Quality Criteria				32
- For protection of aquatic life		0.16	-	
- For protection of human health from seafood consumption		0.04	-	
- For protection of human health from recreational activities		21	-	
World average value for marine sediment		-	0.3	33
Clean ocean sediment		-	0.1-1.0	34
Average shale		-	0.4	35
Earth's crust		-	0.08	31
Average crustal abundance		-	0.08	36
Sediment Quality Standard for the State of Washington		-	0.41	37
Draft Interim Canadian Marine Sediment Quality Guideline		-	0.13	38
Draft Interim Canadian Freshwater Sediment Quality Guideline		-	0.174	38
Sediment Quality Guidelines for				
- Florida		-	0.13 - 0.7	MacDonald (1994) [8]
- Australia and New Zealand		-	0.15 - 1	ANZECC (1998) [8]
- Hong Kong		-	0.5 - 1	HKGS (1998) [8]

ND = Non-detectable

of 0.1 $\mu g\ L^{-1}$ (with the exception of only one sample in the Gulf exceeding the standard), and the average mercury concentrations appeared to be elevated along the southern Gulf.

Mercury Concentrations in Sediments

Sediment is considered to be a good indicator of metal pollution because it serves as a source as well as an ultimate sink of many pollutants in the aquatic environment, thus providing the best assessment of pollutant distribution. As a result, mercury in sediments has received increasing attention in recent years. From the existing data, there are two areas found to have very high mercury contamination in sediments (>1.0 $\mu g\ g^{-1}$ dry weight). The first area is the Upper Gulf particularly in the Chao Phraya area in 1978-1979, as reported by Polprasert et al[11], in 1980 reported by Menasveta and Cheevaparanapiwat[15] and in 1998 reported by EVS Environment Consultants.[8] Another area is near the industrial estates of the east coast in 1987 reported by the Pollution Control Department[29] (see Table 1). A decrease in sediment mercury concentrations was observed in recent studies by Chongprasith and Wilairatanadilok[3] and EVS Environment Consultants[8] compared to the early studies, especially near the industrial estates of the east coast. However, the concentrations detected in some stations were still higher than some sediment quality standards. Since Thailand does not have a sediment quality standard at the present time, some sediment mercury guidelines and standards of other countries and some natural background values have been used to evaluate the sediment mercury problem in Thailand. Among various guidelines and standards, the lower value of mercury is 0.13 $\mu g\ g^{-1}$ dry weight belonging to the Canadian Marine Sediment Quality Guideline (interim draft)[38] and the Sediment Quality Guideline for Florida[8] (Table 1). Also, there are two natural background values of mercury: average shale value (0.4 $\mu g\ g^{-1}$ dry weight) of Turekian and Wedepohl [35] and average crustal abundance (0.08 μg g^{-1} dry weight) of Taylor.[36] Therefore, the lowest value is of average crustal abundance (0.08 μg g^{-1} dry weight). Chongprasith and Wilairatanadilok[3] compared their results with the value of 0.08 μg g^{-1} dry weight (mercury level in unpolluted sediment) and found that higher mercury concentrations were detected, especially from stations near river mouths, probably due to accumulations from anthropogenic discharges to rivers. In addition, they also found relatively high mercury levels in the sediments around the Map Ta Phut Industrial Estate (<0.005 – 0.134 μg g^{-1} dry weight), but relatively low concentrations around the Laem Chabang Industrial Estate (<0.005 – 0.032 μg g^{-1} dry weight). EVS Environment Consultants[8] recommended use of guidelines from three jurisdictions: Florida (USA), Hong Kong and Australia-New Zealand, which were considered appropriate for tropical marine coastal habitat and reported that the overall sediment mercury concentrations in the Map Ta Phut, Laem Chabang and Oil Terminals areas did not exceed the sediment quality guidelines, except for some stations at Map Ta Phut and in the Upper Gulf, especially in the Chao Phraya area.

According to those reports, the recently observed slight elevation of mercury contamination in sediments in the Upper Gulf and near the industrial estate in the east coast might indicate of industrially-related pollution. However, sediments can accumulate metal levels in excess of average crustal abundance for several reasons other than accumulation from anthropogenic inputs, and there are regional differences in natural background levels used including standards or guidelines from other countries due to geological and other differences. Use of reference background values obtained from the literature or use of standards and guidelines from other countries should be noted in the interpretation of pollution assessment, because different background values or standards will give different conclusions of the degree of anthropogenic influences. Moreover, total mercury concentrations alone in sediments cannot provide reliable information for pollution assessment in the area, as the bioavailability and toxicity of mercury and other heavy metals depend very much on the speciation of the heavy metals.[39, 40] For example, recently Thongra-ar[27] reported that the Bangpakong River sediments has not been polluted with mercury or has only been minimally polluted with mercury, even though the highest mercury concentration of 0.94 μg g^{-1} dry weight was found in the top 2 cm of the sediments. This is because the major chemical form of mercury existing in the sediments is morethan 90% in the residual fraction, which is within the crystalline lattices of minerals and is the least available form; the elevated mercury concentration detected was largely due to natural or lithogenic rather than anthropogenic inputs. Therefore, the speciation of mercury in sediments should be evaluated in order to know its mobility and potential bioavailability to aquatic life. However, a sediment quality standard in Thailand should be established urgently.

Mercury Concentrations in Marine Organisms

Mercury incorporated into the food chain can adversely affect human health through seafood consumption. The effects of mercury toxicity are well known after the Minamata incident in Japan between 1953 and 1961.[32] Therefore, mercury concentrations in marine organisms have often been used as a means of assessing biological impact of mercury of marine environment and its impact on human health. From the existing data (Table 2), the total mercury concentrations in marine organisms are mostly within Thai national standard for food consumption (0.5 μg g^{-1} wet weight). Exceptions include of a few samples exceeding the standard collected in some areas, especially in the vicinity of the oil and gas platforms in the Lower Gulf of Thailand. For example, from two recent studies conducted by Windom and Cranmer[41], only a single lizard fish *Saurida tumbil*, caught near the gas production platform in the Gulf, exceeded 0.5 μg g^{-1} wet weight and Chongprasith and Wilairatanadilok[3] found only two of the samples exceeded the standard.

Mercury concentrations in marine organisms can be differentiated among species depending on feeding and habitat of the organisms. Windom and Cranmer[41] reported that pelagic fish, eg cobia and treadfin bream, collected near the platform had lower total mercury concentrations than lizard fish, which is probably the most pronounced bottom feeder and had the highest mercury concentrations of all fish species collected. Similarly, Chongprasith and Wilairatanadilok[3] also reported that demersal fish had higher mercury concentrations than pelagic fish. And among various marine organisms (fish, crab, shrimp and scallop), the average mercury concentrations in fish were low, crabs tended to have higher concentrations than other organisms, while the lowest mercury concentrations were found in scallops.

Table 2. Total mercury in marine organisms of Thai water.

Study Period	Location	Marine Organisms	Total Mercury ($\mu g\ g^{-1}$ wet wt)	Reference
1972	Inner Gulf	Fish and shellfish	0.03 - 0.08	51
	Rayong area	Fish and shellfish	<0.01 - 0.10	
	Songkhla area	Fish and shellfish	0.01 - 0.04	
	Phuket area	Fish and shellfish	<0.01 - 0.07	
1973-1986	Gulf of Thailand	Fish	0.001 - 0.810	52
	and Andaman Sea	Shellfish	0.001 - 0.188	
1974	Bang Pra Coast,	3rd trophic level fish	0.003 - 0.010	12
	Chon Buri	4th trophic level fish	0.002 - 0.057	
1975	Andaman Sea	Predacious species		53
		- tuna	0.026 - 0.234	
		- shark	0.057 - 0.478	
1976	Chao Phraya River Estuary	Fish and shellfish	0.009 - 0.205	54
1976-1977	Inner Gulf	3rd trophic level fish	0.002 - 0.130	43
		4th trophic level fish	0.010 - 0.650	
1976-1977	Inner Gulf	Pelagic fish	0.0103 - 0.154	42
			(0.043 ± 0.029)	
		Benthic fish	0.0015 - 0.653	
			(0.043 ± 0.091)	
		Composite plankton	0.002 - 0.0045	
			(0.00295 ± 0.0007)	
1980-1981	Gulf of Thailand	Clam	0.01 - 0.04*	55
		Cockle	0.01 - 0.05*	
		Mussel	0.01 - 0.02*	55
1982-1983	Inner Gulf	Bivalve molluscs	0.001 - 0.041	56
1979-1980	Estuarine areas			17
	- Mae Klong	Fish	0.016 - 0.145	
			(0.042 ± 0.046)	
		Shrimp	0.007 - 0.217	
			(0.051 ± 0.082)	
		Mollusc	0.010 - 0.042	
			(0.032 ± 0.013)	
1979-1980	- Ta Chin	Fish	0.015 - 0.112	17
			(0.050 ± 0.034)	
		Shrimp	0.007 - 0.054	
			(0.031 ± 0.018)	
		Mollusc	0.037 - 0.055	
			(0.043 ± 0.008)	
1979-1980	- Bangpakong	Fish	0.002 - 0.162	17
			(0.032 ± 0.040)	
		Shrimp	0.007 - 0.144	
			(0.046 ± 0.059)	
		Mollusc	0.028 - 0.059	
			(0.043 ± 0.010)	
1979-1980	- Petchburi	Mollusc	0.022 - 0.042	17
			(0.033 ± 0.008)	
1979-1980	- Pranburi	Fish	0.003 - 0.045	17
			(0.012 ± 0.010)	
		Shrimp	0.016 - 0.026	
			(0.021 ± 0.007)	
1980	Estuarine areas			15
	- Mae Klong	Green mussel	0.07 ± 0.04*	
		Mullet	0.04 ± 0.03*	
	- Ta Chin	Green mussel	0.09 ± 0.03*	
		Mullet	0.07 ± 0.04*	
	- Chao Phraya	Green mussel	0.21 ± 0.06*	
		Mullet	0.15 ± 0.06*	
	- Bangpakong	Green mussel	0.09 ± 0.04*	
		Mullet	0.08 ± 0.03*	
	-Hua Hin, Intertidal	Green mussel	0.04 ± 0.03*	

Table 2. Cont'd.

Study Period	Location	Marine Organisms	Total Mercury ($\mu g\ g^{-1}$ wet wt)	Reference
1982-1983	Gulf of Thailand	Bivalve molluscs	<0.10 - 0.12*	57
1982-1986	Inner Gulf	Bivalve molluscs	0.001 - 0.193	58
1986-1987	Ban Don Bay, Upper South	Fish	0.008 - 0.048	59
		Shellfish	0.008 - 0.029	
1987-1988	East Coast	Fish	0.021 - 0.052	60
		Shellfish	0.003 - 0.097	
1994	Bangpakong River	Fish	0.001 - 0.017 (0.0042 ± 0.004)	61
		Shrimp	0.001 - 0.008 (0.0033 ± 0.002)	
1995	Songkhla Lake	Seaperch	0 - 0.107*	62
		Tiger prawn	0 0.015*	
		Green mussel	0 - 0.021*	
		Mud crab	0 - 0.038*	
		Seaweed, *Gracilaria fisheri*	0 - 0.069*	
1996-1997	Map Ta Phut Industrial Estate	Fish, crab and mollusc	0.029 - 1.04* (0.24)	3
June 1998	Gulf of Thailand	Fish, crab, shrimp, scallop and squid	0.023 - 1.57* (0.229)	3
1998	Gulf of Thailand	Bivalves, fish, octopus, squid, shrimp and crabs	0.03 - 0.18*	8
June-July 1998	Map Ta Phut	Mussel	0.02 - 0.043	8
	Laem Chabang	Mussel	0.008 - 0.012	
June – July 1998	River mouths along coastline	Fish, shrimp and mollusc		3
	- Rayong		0.076 - 0.170*	
	- Bangpakong		0.063 - 0.153*	
	- Chao Praya		0.041 - 0.237*	
	- Ta Chin		0.070 - 0.092*	
	- Mae Klong		0.105 - 0.175*	
	- Phetchaburi		0.045 - 0.116*	
	- Pranburi		0.047 - 0.136*	
	- Kuiburi		0.060 - 0.139*	
	- Chumphon		0.061 - 0.086*	
	- Lang Suan		0.051 - 0.152*	
	- Tapi Pumdoung		0.086 - 0.204*	
	- Pak Panang		0.058 - 0.320*	
	- Patani		0.059 - 0.153*	
	- Saiburi		0.078 - 0.199*	
	- Trang		0.092 - 0.175*	
	Standard/Guideline			
Food Containing Contaminant by the Ministry of Public Health, Thailand			0.5	3
Standard of the USA Food and Drug Administration			1.25 (dry wt.)	3
U.S. Food and Drug Administration (FDA) Action Level		Fish and shellfish	1.0	63
Western Australia Food and Drug Regulation		Fish, shellfish, fish products and canned fish	0.5	64
European Economic Community		Edible parts of marine organisms	0.7	65
Canadian consumption guideline level		Fish and marine mammal meat	0.5	66
National Environmental Protection Agency (NEPA) of China, Maximum Permissible Limit		Fish	0.3	67
Japan Permissible Level		Fish	0.4	68
Australian Food Standard, Maximum permitted concentration		Muscle tissue	0.5	69
Standard of the Ministry of Health of the State of Minnesota (USA)			0.16 (Methylmercury)	70

* mg/g dry weight

More importantly, there is an evidence of biomagnification of mercury through the marine food chain. Organisms of higher trophic levels have higher mercury concentrations than those in the lower trophic levels, and most fish species exhibited a positive linear relationship between total mercury concentrations and their size.[12, 42, 43] Methylmercury is the predominant form of mercury in fish[44, 45], because it is more highly bioaccumulated in fish than inorganic mercury.[46, 47] The elimination of methylmercury by fish is very slow relative to the rate of uptake, resulting in the increase of mercury concentrations in fish flesh with increasing age or body size.[48]

The impact of mercury contamination in fish on human health is of more concern and it may correlate with the frequency of mercury contaminated fish consumption, because the major source of human exposure to methylmercury is through the consumption of fish and fish products.[49] However, mercury intake in humans can be controlled by limiting the intake of mercury contaminated fish. The information about the average amount of fish daily consumed per capita and fish mean mercury concentrations can be used to estimate the daily mercury intake through fish consumption according to the following equation[50]:

Hg daily intake (μg) = fish (g) x fish Hg ($\mu g\ g^{-1}$)/ body weight (kg)

A Provisional Tolerable Weekly Intake (PTWI) established by the Joint FAO/WHO Expert Committee on Food Additives is 0.3 mg of total mercury per capita of which no more than 0.2 mg should be present as methylmercury (expressed as mercury); these amounts are equivalent to 5 μg and 3.3 μg, respectively, per kg of body weight.[44, 45] The PTWI is based on adult person weighing 60 kg. In general, people with a high fish intake or those consuming fish with a high methylmercury content can easily exceed the PTWI. Therefore, the total intake of methylmercury through fish or seafood consumption should be limited in such cases.

Estimate of Maximum Mercury Intake for Thai People

For Thai people, the fish consumption rate is approximately 13.1-18.8 kg per capita year^{-1} (Chua, 1986).[32] Assuming the fish consumption rate among Thai people is roughly 20 kg per capita year^{-1}. This level is equal to 385 g per capita week^{-1}. The maximum mercury intake for Thai people can be estimated to the PTWI by using the following equation:

Hg weekly intake (μg) = fish consumption (g week^{-1}) x fish Hg ($\mu g\ g^{-1}$)

Use of Thai national standard of total mercury for food consumption (0.5 $\mu g\ g^{-1}$ wet weight) as fish mercury concentrations, the maximum weekly intake of total mercury for Thai people is calculated as follows:

$$\text{Hg weekly intake} = 385 \times 0.5 = 192.5\ \mu g = 0.2\ mg$$

$$\text{PTWI of total Hg} = 0.3\ mg$$

Therefore, the maximum weekly mercury intake through fish consumption for Thai people is estimated to be 0.2 mg per capita. This value is equal a daily intake of 27.5 μg per capita. This suggests that if mercury concentrations in fish and other seafood in Thai waters are still within the Thai national standard, fish mercury intake will not exceed the PTWI and might not have any impact on the health of Thai people.

Conclusions

In conclusion, the existing data indicate that slight elevations in mercury concentrations are occasionally observed in coastal water and sediments in some areas, especially the Upper Gulf and near the industrial estates of the east coast. These can be attributed to discharges from industries, natural gas platforms, agriculture and untreated domestic sewage. The concentrations found in marine organisms are still within the standard for food consumption with the exception of a few samples. However, the overall situation of mercury contamination in all compartments (seawater, sediments and marine organisms) is still within a safe level.

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