Risk Assessment Studies
Report No. 31

Mercury in Fish and Food Safety

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EXECUTIVE SUMMARY

The Centre for Food Safety (CFS) has conducted a study to measure the levels of total mercury (tHg) and methylmercury (MeHg), and the ratio of MeHg to tHg in different fish species available for consumption in Hong Kong. On the basis of levels measured and reported in commonly consumed fish species health advice was formulated.

Mercury is present widely in the environment from natural sources and human activities. It accumulates in the food chain particularly in fish mainly in the organic form as MeHg. Concerns regarding MeHg in food are related to its potential to affect the nervous system, particularly in the developing foetus. In 2003, the Joint Food and Agriculture Organization/World Health Organization Expert Committee on Food Additives (JECFA) adopted a lower Provisional Tolerable Weekly Intake (PTWI) of 1.6 µg/kg bodyweight (bw) for MeHg. The levels of tHg and MeHg in fish depend on their species, living environments, feeding patterns and ages. Therefore, longer-living fish and fish at the top of the food chain such as large predatory fish tend to accumulate higher levels of mercury.

<u>Study on Mercury in Fish and Food Safety</u>

Sampling was carried out from April to August 2007. Total mercury and MeHg levels were analysed in 280 samples including 266 whole fish and 14 canned fish. Laboratory analysis was conducted by the Food Research Laboratory of the CFS. All samples of whole fish were identified for their species by the Agriculture, Fisheries and Conservation Department (AFCD).

Results

The range for tHg and MeHg of all samples were 3 – 1370 µg/kg and 3 - 1010 µg/kg, with the median of 63 µg/kg and 48 µg/kg respectively. Two hundred and seventy-seven samples (99%) contained tHg and MeHg below 500 µg/kg . Three samples of alfonsino (species: *Beryx splendens*) were found to contain tHg and MeHg at levels higher than 500 µg/kg (tHg: 609 – 1370 µg/kg; MeHg: 509 – 1010 µg/kg). The ratios of MeHg to tHg in the different fish species ranged from 0.46 to 0.99.

Mercury intake in an individual depends on the consumption amount as well as the mercury level in the food. Together with data used for the risk assessment study "Dietary exposure to Mercury of Secondary School Students" in 2004, dietary exposure of secondary school students to methylmercury was estimated, and was below the PTWI for the average consumer (31-41% of PTWI). However, the estimated dietary exposure for the high consumer (95^{th} percentile exposure level) may exceed the PTWI (94% - 106% of PTWI).

Conclusion and recommendation

Results of this study showed that most of the fish available in the Hong Kong market contained relatively low levels of tHg and MeHg, while a small proportion contained higher levels. The amounts of MeHg relative to total mercury in different fish species varied considerably. For the high consumers among secondary school students, the estimated dietary exposure to methylmercury may exceed the PTWI and therefore their risk of adverse effects due to MeHg cannot be excluded.

Advice to consumers

1. Maintain a balanced diet. Avoid overindulgence of food items.
2. Fish contain many essential nutrients, such as omega-3 fatty acids and high quality proteins. Moderate consumption of a variety of fish is recommended.
3. Pregnant women, women planning pregnancy and young children when selecting fish species in their diet should avoid eating large predatory fish and the types of fish which may contain high levels of mercury such as shark, swordfish, marlin, alfonsino and tuna (especially bigeye and bluefin species).

Advice to the trade

1. Obtain food supplies from reliable sources.
2. Maintain proper records to enable source tracing when required.
3. Inform customers the types of fish sold, served and used in fish products.

Risk Assessment Studies –

Mercury in Fish and Food Safety

OBJECTIVES

1. The study aims to

(i) measure the levels of total mercury (tHg) and methylmercury (MeHg) in different fish species available for consumption in Hong Kong,

(ii) determine the ratio of MeHg to tHg in the different fish species, and

(iii) formulate health advice based on the measured and reported levels in commonly consumed fish species.

BACKGROUND

2. Mercury (Hg) is a naturally-occurring element on the earth's crust. It enters the environment by both natural sources and human activities. Natural processes such as volcanic activity, erosions and weathering contribute to the presence of mercury in the water, soil and the atmosphere. Mercury may be present as environmental contaminants due to human activities such as mining, fossil fuel combustion, and industrial emissions, direct application of fertilizers and fungicides and disposal of solid waste, including batteries and thermometers, to landfills. Mercury that is present in water, ocean sediment and rocks of sea bed

can be taken up by aquatic organisms and bio-accumulates at progressively higher levels of the food chain, particularly in longer-living and predatory fish.

3. Mercury exists in three forms, namely metallic (elemental), inorganic and organic mercury. The forms can be altered under certain conditions.[1] Mercury can be oxidized to inorganic mercury with the presence of organic matters in water, and can be converted back to the elemental metallic mercury in certain industrial effluent. The inorganic mercury can also be converted to methylated form by microorganisms especially in aquatic systems. Methylmercury is the organic form present predominantly in fish.

Sources of Exposure

4. Contamination of food from natural sources and human activities, dental amalgam and occupational exposure in agriculture and manufacturing sectors are possible routes of exposure to mercury. Dietary intake is the main source of human exposure to mercury.

5. In food, mercury can exist in inorganic form and the more toxic organic forms such as MeHg in fish. Fish and other seafood products are the main source of MeHg, and large predatory species such as tuna and swordfish tend to accumulate relatively higher levels. Mercury is also present in other foods mainly in inorganic form. Dietary inorganic mercury is of little toxicological concern.

Toxicity and Health Effects

6. The health effects of mercury exposure depend on its chemical form, the route of exposure (inhalation, ingestion or skin contact), and the level of exposure. Elemental mercury from dental fillings does not generally pose a health risk. Inorganic mercury can cause kidney failure and gastrointestinal damage, whereas, organic form, which combines with carbon, also known as MeHg, can quickly enters and accumulate through the aquatic food chain. Organic mercury compounds are more harmful than inorganic mercury to human health.

Kinetics and metabolism

7. Methylmercury in the human diet is rapidly and almost completely absorbed from the gastrointestinal tract (up to 95%).[2] Methylmercury are more easily absorbed than inorganic mercury salts.[3] Methylmercury distributes in the bloodstream to all tissues.[4] The highest MeHg levels in humans are generally found in the kidneys, but the target organ of MeHg is the central nervous system.

8. Methylmercury in the body is relatively stable. It is only slowly transformed to other forms of mercury (e.g. to inorganic mercury by microflora in the intestines). It readily crosses the blood-brain barrier and the placenta. The half life of MeHg in the human body is about 44 -80 days.[5] Methylmercury is excreted from faeces, urine, hair and breast milk. However, the transport of MeHg from blood to milk is less efficient than transport across the blood-brain and blood-placenta barriers. Therefore, MeHg exposure to offspring through lactation is lower than exposure during pregnancy. In addition, both animal experiment and the Iraqi poisoning cases indicated that breast-fed was at less risk than the foetus,

since most of the brain development has already occurred.[2, 5]

Acute toxicity

9. Acute toxicity is often a result of occupational exposure, and that from dietary exposure is rare. Acute effects include increased occurrence of lymphocytic aneuploidy, discolouration of front surface of lens of the eyes, insomnia, tremors and hyperexcitability.[6] For MeHg, the acute LD50 (the lethal dose administered that kills half of the experimental animals) in rodents treated orally is between 10-40 mg/kg body weight (bw).[2]

Chronic toxicity

10. Neurotoxicity is the effect of greatest concern. The symptoms were mainly in the nervous system, such as difficulty with peripheral vision or blindness, sensory disturbances, incoordination, impairment of walking and slurred speech. Recent studies indicate that lower dose exposure to mercury may have effects on the cardiovascular and immune systems, In rodent, MeHg reduced mast cell function and at higher doses, decreased spleen and thymus cell activity. The JECFA committee considered that available evidence for the potential cardiotoxicity of MeHg was not conclusive.[2]

Developmental and nervous system toxicity

11. Both data from human and experimental animals, such as rats, mice, guinea pigs, hamsters and monkey indicated that MeHg causes subtle to severe neurologic effects which depends on dose and individual susceptibility. In

non-human primates, adverse effects in neurological, sensory and motor functions resembling symptoms seen in humans have been observed. These studies also supported that the developing foetus is more sensitive than adults.[2,7]

12. In pregnant women, MeHg can cross the placenta into the foetus and build up in the foetal brain and other tissues. In addition, infants may be exposed to MeHg through breast milk. A child's developing nervous system is particularly susceptible to MeHg and which can cause a decrease in Intelligent Quotient (IQ), lack of coordination, blindness and seizures in children. In the recent report published in 2007, the JECFA committee considered that concerning infants and children age up to about 17 years, available data do not allow firm conclusions to be drawn regarding their sensitivity compared to that of adults. While it is clear that they are not more sensitive than the embryo or foetus, they may be more sensitive than adults because significant development of the brain continues in infancy and childhood.[8]

13. In adults, extreme exposure can lead to personality changes, tremors, changes in vision, deafness, loss of muscle coordination and sensation, memory loss and intellectual impairment.

Mutagenicity and reproductive effects

14. Methylmercury appears to be clastogenic and causes chromosome damage. Environmental Protection Agency (EPA) of the United States has classified MeHg as being of high concern for potential human germ cell mutagenicity.

15. The shorter term studies in rodents, guinea pigs and monkeys indicated that MeHg had consistent reproductive deficits effects. Increased frequencies of abortions, resorptions and malformations, and reduced offspring viability have been observed in pregnant female rodents following treatment with MeHg.

Carcinogenicity

16. The carcinogenic effects of MeHg in animals were observed in the presence of profound damage to the kidney. The International Agency for Research on Cancer (IARC) evaluated mercury and mercury compounds in 1993. It considered methylmercury compounds as possibly carcinogenic to humans (Group 2B) and considered metallic and inorganic mercury compounds as not classifiable as to their carcinogenicity to humans (Group 3).[9]

Poisoning in human

17. High intake of methylmercury may cause poisoning like Minamata disease and the cases in Iraq (poisoning caused by intake of seed wheat treated with MeHg fungicide).[2] There is a long latent period before early symptoms of MeHg poisoning including paraesthesia, malaise and blurred vision emerge. Constriction of the visual field, deafness, dysarthria and ataxia may develop at a later stage, finally can lead to death. The patient may partly recover from the symptoms in a less severe case or may fall into a coma as a result of severe case. Damages to the central nervous system are highly localized and affect mostly sensation, vision and hearing.

Interactive effects with other substances

18. It has been reported that ethanol increases the toxicity of MeHg in experimental animals, whereas vitamin D and E, thiol compounds, selenium, copper, and possibly zinc are antagonistic to the toxic effects of mercury.

Safety Assessment for Mercury in Fish

19. The level of MeHg in fish is of particular concern worldwide because it can cause adverse effect to the nervous system, especially the developing brain. In 2000, JECFA set a PTWI of 3.3 µg/kg bw for the general population, but highlighted that the foetus and infant might be at a greater risk of toxic effects.[10] In 2003, this PTWI was reduced to 1.6 µg/kg bw following further risk assessment. This value was considered to be sufficient to protect the developing foetus, which are the most sensitive to MeHg.

20. In 2006, the JECFA Committee confirmed the PTWI of 1.6 µg/kg bw, based on the most sensitive toxicological end-point (developmental neurotoxicity) in the most susceptible species (humans). In addition, the Committee considered that intakes of up to about 2 times higher than the existing PTWI of 1.6 µg/kg bw would not pose any risk of neurotoxicity in adults. In the case of women of childbearing age, intake should not exceed the PTWI, in order to protect the foetus. At present, the Committee could not identify a level of intake higher than the existing PTWI that would not pose a risk of developmental neurotoxicity for infants and children.[8]

21. At present, Codex guideline levels for MeHg are set at 1 mg/kg for

large predatory fish and 0.5 mg/kg for all other fish.[11] In view of the possibility that some consumers will exceed the PTWI, even if fish contain mercury at the guideline levels, JECFA has considered it necessary to explore how mercury exposure can be further reduced.

22. In the JECFA meeting held in 2006, the Committee evaluated the impact of current Codex guideline levels for MeHg in fish on exposure and risk. The Committee concluded that the setting of guideline levels for MeHg in fish may not be an effective way of reducing exposure for the general population, and noted that advice targeted at population subgroups that might be at risk from MeHg exposure could provide an effective method for lowering the number of individuals with exposures greater than the PTWI.[12]

Reported levels of mercury in fish overseas

23. Since the revised PTWI of JECFA was adopted in 2003, national food authorities have issued consumer advisories on the consumption of different fish species based on the levels of mercury detected in them. The types of fish that have been reported to contain high levels of mercury include shark, swordfish, marlin, alfonsino, orange roughy, pike, tilefish and king mackerel. Some species of tuna such as bigeye, bluefin and albacore have been reported to contain higher levels of mercury. In addition, MeHg, which is the toxic form of mercury, can contribute to a high percentage of the tHg content and are present at higher levels in some types of fish than in others.

24. Since the levels of mercury in fish is closely related to their species, JECFA considered a need to gather data for individual fish species from different

regions and to compare the levels of MeHg with tHg in the different fish species.

Local Situation

25. Food and Environmental Hygiene Department (FEHD) has been aware of the concern of mercury in food, and has conducted two risk assessment studies in the past. In 2002, a risk assessment study “Dietary Exposure to Heavy Metals of Secondary School Students” which aimed to determine dietary exposure of secondary school students to three heavy metals, namely arsenic, cadmium and mercury.[13] In 2004, FEHD conducted a follow-up study “Dietary Exposure to Mercury of Secondary School Students” to assess whether there were any risk to the health of secondary school students resulting from the dietary exposure to mercury.[14] The food group “fish” was identified as the main dietary source of tHg and MeHg. The analysis was conducted to determine tHg and MeHg levels for the fish types mainly in the form of “composite sample”.

26. In Hong Kong under the Food Surveillance Programme, analyses for mercury in food were determined in the form of total mercury but not methylmercury. Individual data on the levels of tHg and MeHg in local fish at the species level were not available currently. In view of the above, it is considered necessary to investigate the levels of tHg and MeHg in the different species of edible fish commonly consumed by the local population so that advice to the public on the selection of fish in the diet can be formulated.

SCOPE OF STUDY

27. Fish species analysed were confined to those commonly consumed in

Hong Kong where whole fish was available for species identification. Different types of canned tuna fish available in the market were also sampled and analysed since tuna are known to contain high mercury levels but are rarely imported as whole fish into Hong Kong.

METHODS

Sampling and identification of species

28. Fish species commonly consumed in Hong Kong were sampled including marine fish and freshwater fish:

- Local fish from wet markets and other fish-selling premises
- Imported fish
- Canned fish: different species of canned tuna available in the market

29. Fish sampling was carried out by Health Inspectors of CFS from April to August 2007.

30. Fish samples were sent to the Food Research Laboratory (FRL) for analysis. Fish samples from the same batch were collected and sent to AFCD for species identification. Photographic records were made for all samples in order to verify their identities.

31. Length (which correlates to the age of the fish) and weight of each fish were recorded at the laboratory when they were received. The samples were

separated into edible portion including skin and flesh, and stored at -20 °C until they were analysed.

Laboratory analysis

32. Determination of tHg and MeHg was carried out in the FRL. Samples were analysed individually. A control standard was run with each analysis. The limit of detection was 2 μg/kg for both tHg and MeHg.

33. For tHg, homogenized fish sample was digested by concentrated nitric acid at 95°C for 2 hours. Then hydrogen peroxide was added and the mixture was kept at 95°C for another 1 hour. After dilution, the digestate was analysed by the Flow Injection Mercury Analyzer equipped with amalgam preconcentration system.

34. For MeHg, homogenised fish sample was extracted with 50% concentrated hydrochloric acid by sonication for 3 hours. After centrifugation, the extract was derivatised with sodium tetraphenylborate. Finally, the MeHg derivative was detected by Gas Chromatograph-Mass Selective Detector, operating in the Selective Ion Monitoring mode.

RESULTS

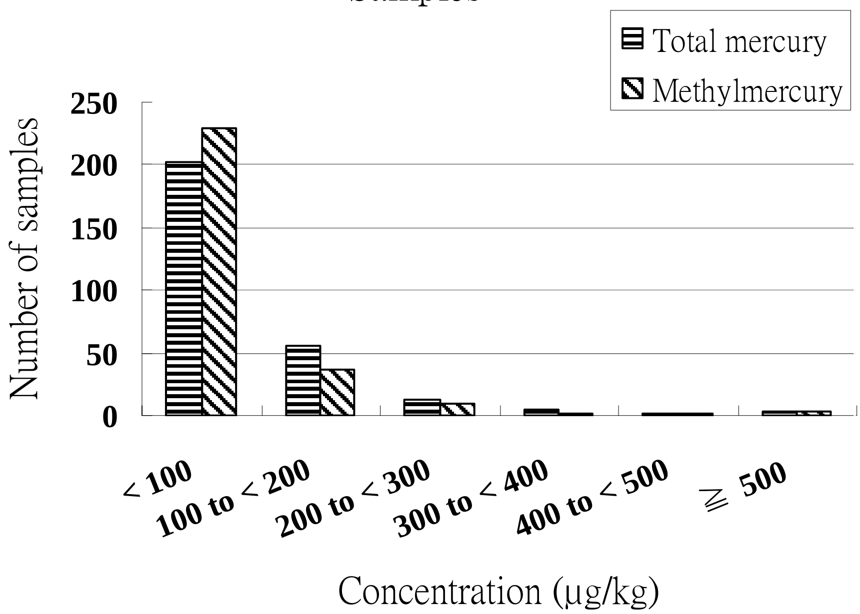
35. Two hundred and eighty samples were identified for their species and analysed for the levels of tHg and MeHg. This included 266 samples of whole fish

(89 species) and 14 samples of canned fish (3 types of tuna: skipjack tuna, yellow fin tuna, albacore tuna).

36. Total mercury and MeHg were detected in all of the 280 samples. The range for tHg and MeHg levels of all the samples were 3 – 1370 µg/kg and 3 - 1010 µg/kg respectively. , The median tHg and MeHg for all samples were 63 µg/kg and 48 µg/kg respectively. The distribution curves of total mercury and methylmercury concentrations in fish samples are illustrated in Figure 1. The mean concentrations and range of tHg and MeHg for each fish species are listed in Annex 1. Local whole fish samples tested (224 samples) contained MeHg at levels ranging from 3 - 349 µg/kg, with median MeHg at 45 µg/kg. Imported whole fish samples (42 samples) contained MeHg at levels ranging from 21 - 1010 µg/kg with median MeHg at 80 µg/kg.

37. Two hundred and seventy-seven fish samples (99%) contained tHg and MeHg at levels below 500 µg/kg. Only three samples of imported alfonsino (species: *Beryx splendens*) were detected with mercury levels higher than 500 µg/kg. These 3 samples contained tHg at levels from 609 µg/kg to 1370 µg/kg and MeHg at levels from 509 µg/kg to 1010 µg/kg. The mean ratios of MeHg to tHg in the different fish species ranged from 0.46 to 0.99 (Annex 1).

Figure 1: Distribution Curve of Total Mercury and Methylmercury Concentrations in Fish Samples



Number of samples = 280

LOD for total mercury = 2 μg/kg

Mean total mercury = 91 μg/kg

Median total mercury = 63 μg/kg

LOD for methylmercury = 2 μg/kg

Mean methylmercury = 72 μg/kg

Median methylmercury = 48 μg/kg

38. Levels of tHg and MeHg in all canned tuna samples were below 500 µg/kg (see Table 1). These include three different types of tuna fish, namely skipjack, yellowfin and albacore. Among the three different types of tuna tested, albacore tuna (canned) had the highest average mercury content with mean tHg of 263 µg/kg and mean MeHg of 205 µg/kg. However, the largest variations in tHg and MeHg levels were found in canned skipjack tuna with total mercury levels ranging from 37 - 469 µg/kg and 27-430 µg/kg respectively.

Table 1: The mean of tHg and MeHg concentrations (µg/kg) and the ratio of MeHg to tHg in different types of tuna fish

Type of tuna fish	No.	tHg (range)	MeHg (range)	MeHg/tHg (range)
Albacore (canned)	5	263 (236 – 301)	205 (185 – 229)	0.78 (0.74 – 0.81)
Yellowfin (canned)	5	114 (39 – 201)	85 (27 – 153)	0.74 (0.69 – 0.79)
Skipjack (canned)	4	163 (37 – 469)	142 (27 – 430)	0.79 (0.72 – 0.92)
*Skipjack (whole fish)	3	143 (128 –166)	128 (110 -146)	0.90 (0.86 – 0.96)

**Katsuwonus pelamis*

Exposure assessment

39. In this study, the larger number of fish species studied and the detection of total mercury and methylmercury for individual fish sample allowed a better estimation of the levels of mercury in fish and hence estimation for exposure than in previous study. In order to assess the complete dietary exposure to methylmercury, we took reference from the risk assessment study "Dietary Exposure to Mercury of Secondary School Students" conducted in 2004 for the dietary exposure for other food sources (regarding the details for the detection of methylmercury and the exposure estimates in the 2004 study, please refer to the published report). Since the majority of food items other than fish and seafood were not found to contain methylmercury in the 2004 study, the dietary exposures for methylmercury were estimated taking into account the upper bound and lower bound values and are presented in range. The upper bound estimate was calculated by assigning analytical values below LOD as the value of LOD whereas the lower bound estimate was calculated by assigning analytical values below LOD as zero. LOD for methylmercury was 1 µg/kg at that time.

40. Assuming intake of fish containing MeHg at the median MeHg level (48 µg/kg) obtained in this study, the dietary exposures to MeHg for average secondary school students and high consumers were estimated to be 0.58 µg/kg bw/week (lower bound of 0.50 µg/kg bw/week to upper bound of 0.66 µg/kg bw/week), and 1.61 µg/kg bw/week (lower bound of 1.51 to upper bound of 1.69 µg/kg bw/week) respectively. The mean of the exposures of all the students was used to represent the average dietary exposures, whereas the 95^{th} percentile of the exposure level was used to represent the exposure for high

consumers.

41. For the average consumer, the estimated dietary exposure to MeHg was below the PTWI of 1.6 µg/kg bw/week (31 – 41 % of PTWI) and therefore average consumers among secondary school students would be unlikely to experience major toxicological effects of methylmercury.

42. However, for the high consumer, the estimated dietary exposures to MeHg may exceed the PTWI (94 – 106 % of PTWI). Hence, the risk to adverse effects of methylmercury cannot be excluded.

DISCUSSION

43. In our study, tHg and MeHg were detected in all the samples tested. On the whole, mercury levels in fish samples were relatively low with median for tHg and MeHg at 63 µg/kg and 48 µg/kg respectively.

44. Mercury can accumulate in some fish species more than others. Level of mercury in fish depends on their species, ages, mercury levels in living environment and food sources. Mercury levels are related to its accumulation in the food chain and mainly concentrated in the muscle tissue.[15] Therefore, larger, longer-living fish and predatory fish contain higher levels of mercury. In addition, mercury levels in fish may be increased due to mercury pollutions present in the environment where the fish lived.

45. It may be noted that in the same *Seriola lalandi* species, significantly

different mercury levels were found in the samples from different regions. The results were shown in Table 2. This may be due to their different living environments as well as the different ages.

Table 2: The mean of tHg and MeHg concentrations (μg/kg) and the ratio of MeHg to tHg in *Seriola lalandi* species from 2 different regions

Seriola lalandi	No.	Weight (g)	Length (cm)	tHg (range)	MeHg (range)	MeHg/tHg (range)
Region A	3	4920-4948	74-76 (TL)	219 (210 – 230)	192 (186 – 200)	0.88 (0.87 –0.89)
Region B	3	3025-3535	67-70 (TL)	31 (29 – 34)	23 (21 – 27)	0.76 (0.72 –0.79)

TL: Total length

46. In this study, fish were sampled based on the availability of whole fish in the market. Some imported fish that contained high levels of mercury were not available as whole fish and were therefore not included in the sampling and analyses in this study. Therefore, in order to advise the consumer to limit the intake of those kinds of fish, the fish reported with high levels of mercury from other countries are summarised in Table 3.

Table 3: Fish reported with high tHg levels overseas

Type of fish	tHg (µg/kg)	Reference
Swordfish	970 - 1820	16,17,18,19,20
Shark	540 - 1500	17, 19, 20
Marlin	1100 - 1430	18, 19, 20
Tilefish	1450	17
King mackerel	730	17
Alfonsino	670	20
Orange roughy	600	19
Tuna	400	19
Bluefin tuna	730	20
Bigeye tuna	639 - 740	17, 20
Albacore tuna	350	17
Yellowfin tuna	286 - 325	17
Skipjack tuna	167 -205	17

47. Of these fish species, only whole fish of alfonsino and skipjack tuna were available for sampling, identification and analysis. Our results showed high tHg levels (range: 609 -1370µg/kg) and MeHg levels (509 - 1010 µg/kg) in alfonsino (*Beryx splendens*) which is consistent with overseas study.[20]

48. It has been reported that mercury levels are often lower in canned tuna than in fresh tuna due to the species of tuna and the smaller-sized fish (usually less than 1 year old) used. In this study, mercury levels in all canned tuna samples were below 500 µg/kg. However, the difference in mercury levels between canned tuna and fresh tuna was not apparent. This might be due to the small sample size of fresh and canned tuna studied, and the large variations in mercury levels found between individual samples of canned tuna. It should be noted that wide variations were found in canned skipjack tuna samples where tHg levels of individual samples ranged from 37 – 469 µg/kg. It is likely that the canned fish samples were made from fishes of very different age, size, and living environments.

49. Mercury levels of all tuna samples (yellowfin, skipjack and albacore) were lower than the levels reported in the bluefin and bigeye species which were known to have higher mercury levels.[17, 20] Among the three species of canned tuna tested, the highest average levels of tHg and MeHg were detected in albacore which was consistent with overseas report (Table 3).

50. The estimated dietary exposures to MeHg for the high consumer may exceed the PTWI (94 – 106 % of PTWI). Hence, the risk to adverse effects of methylmercury cannot be excluded. Nevertheless, it should be noted that

PTWI stresses on lifelong exposure and transient excursion above PTWI may not necessarily mean harm. Consumers should bear in mind that mercury intake in an individual depends on the consumption amount as well as the mercury level in the food. Therefore moderate consumption of a variety of fish is recommended. In addition, consumers should avoid overindulgence of a small range of food items.

LIMITATIONS

51. The number of fish species and the number of samples tested for each species were limited by resources available and availability of fish during the sampling period. Ideally, more samples for each species would better reflect the mercury levels for each species.

52. The species tested were the ones available during the period of sampling, but not all the species that are available for the whole year period. Since seasonal variations in the availability of fish species are expected, some species that are commonly consumed by the population are not included in this study.

53. The methodology for collection of food consumption data may influence the accuracy of the estimates on dietary exposure. In the Food Consumption Survey conducted in 2000, it was not possible to cover every single food item, some of which might be relevant to mercury exposure. Although the food frequency questionnaire included consumption data for fish, but consumption pattern of individual fish species or other seafood species was not known. In

addition, the consumption data from vulnerable population were also not available.

CONCLUSION AND RECOMMENDATIONS

54. Results of this study showed that most of the fish commonly available in Hong Kong contained relatively low levels of tHg and MeHg, while a small proportion contained higher levels.

55. The amount of MeHg relative to total mercury in different fish species varied considerably.

56. For the high consumers among secondary school students, the estimated dietary exposure to MeHg may exceed the PTWI. Therefore, the risk of adverse health effects due to MeHg cannot be excluded.

Advice to consumers

1. Maintain a balanced diet. Avoid overindulgence of food items.

2. Fish contain many essential nutrients, such as omega-3 fatty acids and high quality proteins. Moderate consumption of a variety of fish is recommended.

3. Pregnant women, women planning pregnancy and young children when selecting fish species in their diet should avoid eating large predatory fish and the types of fish which contain high levels of mercury including shark, swordfish, marlin, alfonsino and tuna, especially some species such as bigeye and bluefin.

Advice to the trade

1. Obtain food supplies from reliable sources
2. Maintain proper records to enable source tracing when required
3. Inform customers the type of fish that is sold, served or used in fish products

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ANNEX I. Overview of fish samples collected in this study: total mercury (tHg) and methylmercury (MeHg) concentrations (µg/kg) and the ratio of MeHg to tHg (MeHg/tHg) in various fish species

	Fish species	**English Common Name(s)**	**Chinese Common Name(s)**	**No. of samples**	**Weight (g) range**	**Length (cm) range**	**Maturation size (cm)**	**Mean tHg (Range)**	**Mean MeHg (Range)**	**MeHg/tHg (Range)**
1.	*Acanthopagrus australis*	Black bream, Surf bream	白鮀	2	795- 1203	33-35(TL)	N/A	190 (104 – 276)	162 (79 – 244)	0.82 (0.76 – 0.88)
2.	*Acanthopagrus latus*	Yellowfin seabream	黃腳鮀	4	171-262	20-25(TL)	N/A	41 (34 – 48)	34 (28 – 40)	0.84 (0.76 – 0.91)
3.	*Acanthopagrus schlegeli*	Black porgy, Blackhead seabream	黑鮀,黑沙鮀	1	237-271	20-21(SL)	N/A	136	116	0.85
4.	*Anguilla japonica*	Japanese eel	日本鰻鱺,白鱔	5	680-1634	68-91(TL)	16(TL)	71 (44 – 111)	60 (40 – 94)	0.86 (0.81 – 0.91)
5.	*Ariomma indica*	Indian ariomma, Indian driftfish	叉尾	3	51-105	12-14(SL)	N/A	10 (6 – 15)	5 (4 – 6)	0.54 (0.40 – 0.67)
6.	*Aristichthys nobilis*	Bighead carp	花鰱,大頭	3	1965– 2277	55-61(TL)	50(SL)	36 (34 – 38)	29 (26 – 32)	0.81 (0.72 – 0.94)
7.	**Beryx splendens*	Splendid alfonsino	紅金眼鯛(金目鯛)	3	1384– 1394	41-44(FL)	30(FL)	1053 (609 – 1370)	827 (509 – 1010)	0.80 (0.70 – 0.86)
8.	*Branchiostegus albus*	White horsehead	金馬頭,馬頭	4	157 – 959	20-34(SL)	N/A	73 (25 – 199)	59 (16 – 165)	0.76 (0.64 – 0.83)
9.	*Cephalopholis urodeta*	Darkfin hind	白尾斑	3	74-132	16-20(TL)	N/A	94 (89 – 98)	87 (83 – 94)	0.93 (0.88 – 0.96)
10.	*Channa maculata*	Snakehead, Blotched snakehead	生魚	3	492 – 597	35–38(TL)	N/A	48 (32 – 67)	37 (28 – 51)	0.79 (0.73 – 0.88)
11.	*Choerodon schoenleinii*	Green wrasse, Blackspot tuskfish	青衣	4	1059 – 1536	37–40(TL)	N/A	95 (64 – 126)	76 (53 – 106)	0.80 (0.74 – 0.86)
12.	*Cirrhinus molitorella*	Mud carp	鯪魚	3	334-510	33-36(TL)	N/A	39 (28 – 49)	30 (20 – 35)	0.75 (0.71 – 0,83)
13.	*Clarias fuscus*	Catfish, Hong Kong catfish	塘虱	3	127-260	23-30(TL)	35(TL)	7 (6 – 9)	5 (4 – 7)	0.74 (0.72 – 0.76)
14.	**Cololabis saira*	Pacific saury	秋刀魚	3	155-190	29-31(SL)	20(SL)	56 (51 – 61)	42 (39 – 46)	0.75 (0.71 – 0.78)
15.	*Cromileptes altivelis*	Humpback grouper	老鼠班	3	253-771	27-38(TL)	N/A	101 (65 – 166)	78 (49 – 133)	0.76 (0.73 – 0.80)
16.	*Ctenopharyngodon idellus*	Grass carp	鯇魚,草魚	3	2675-3115	63-66(TL)	60(TL)	8 (5 – 14)	3 (3 – 4)	0.46 (0.29 – 0.65)

	Fish species	English Common Name(s)	Chinese Common Name(s)	No. of samples	Weight (g) range	Length (cm) range	Maturation size (cm)	Mean tHg (Range)	Mean MeHg (Range)	MeHg/tHg (Range)
17.	*Cynoglossus arel*	Largescale tonguesole, Tonguefish	粗鱗撻沙,撻沙	3	144-213	31-35(TL)	20(TL)	75 (51 – 98)	57 (38 – 73)	0.76 (0.74 – 0.79)
18.	*Cynoglossus bilineatus*	Fourlined tonguesole	龍脷,撻沙	3	161-290	29-34(SL)	N/A	39 (31 – 48)	28 (26 – 32)	0.74 (0.67 – 0.84)
19.	*Dentex tumifrons*	Golden tail, Yellowback seabream	波鮋	4	297-856	20-29(SL)	15(FL)	281 (156 – 374)	253 (127 -349)	0.89 (0.81 – 0.96)
20.	*Eleutheronema tetradactylum*	Fourfinger threadfin, Blind tasselfish	正種馬鮁,四指馬鮁	3	395-741	28-38(TL)	26(TL)	65 (63 – 68)	48 (47 – 49)	0.73 (0.69 – 0.78)
21.	*Epinephelus areolatus*	Areolate grouper, Green-spotted rock cod	芝麻斑,齊尾芝麻斑	3	379 - 520	28-32(TL)	N/A	66 (64 – 70)	47 (45 – 50)	0.71 (0.70 – 0.71)
22.	*Epinephelus awoara*	Yellow grouper, Banded grouper	黃釘, 黃斑,黃釘斑	3	551 - 919	33-40(TL)	N/A	118 (73 – 175)	87 (57 – 126)	0.74 (0.72 – 0.78)
23.	*Epinephelus bleekeri*	Duskytail grouper	芝麻斑	3	204 – 568	25-33(TL)	N/A	80 (50 – 100)	67 (38 – 87)	0.82 (0.76 – 0.87)
24.	*Epinephelus coioides*	Green grouper, Orange-spotted grouper, Estuary grouper	青斑	3	482 – 800	32-37(TL)	N/A	57 (37 – 81)	47 (33 – 66)	0.83 (0.77 – 0.89)
25.	*Epinephelus fasciatomaculosus*	Rock grouper, Banded reef-cod	石釘	3	62 – 368	17-29(TL)	N/A	86 (44 – 107)	63 (32 – 82)	0.72 (0.69 – 0.77)
26.	*Epinephelus hexagonatus*	Starspotted grouper	花頭梅	2	182 – 224	24-26(TL)	19(TL)	65 (51 – 78)	56 (43 – 69)	0.86 (0.84 – 0.88)
27.	*Epinephelus lanceolatus*	Giant grouper	龍躉,花尾	4	1743 -5090	45-67(TL)	N/A	51 (25 – 89)	37 (18 – 64)	0.72 (0.71 – 0.72)
28.	*Epinephelus merra*	Honeycomb grouper	花頭梅,金錢斑	1	92 – 132	19-21(TL)	11(TL)	33	30	0.91
29.	*Epinephelus quoyanus*	Longfin grouper	花頭梅,花狗斑	1	428 – 464	22(TL)	N/A	68	60	0.88
30.	*Epinephelus trimaculatus*	Threespot grouper	鬼頭斑,花鬼頭,花斑	1	286 - 337	23(SL)	N/A	76	55	0.72
31.	*Gymnothorax favagineus*	Laced moray	花鯙	1	1728	91(TL)	N/A	166	123	0.74

	Fish species	English Common Name(s)	Chinese Common Name(s)	No. of samples	Weight (g) range	Length (cm) range	Maturation size (cm)	Mean tHg (Range)	Mean MeHg (Range)	MeHg/tHg (Range)
32.	*Gymnothorax reevesii*	Reeve's moray	花鮱,泥婆	3	321 – 751	58–72(TL)	N/A	67 (33 – 99)	55 (22 – 88)	0.81 (0.71 – 0.89)
33.	*Hapalogenys nitens*	Skewband grunt, Grunt	打鐵鮀	3	467- 727	24-26(SL); 27-28(TL)	N/A	118 (68 – 214)	78 (56 – 122)	0.72 (0.57 – 0.82)
34.	*Harpadon nehereus*	Bombay duck	九肚	3	43- 97	19-23(SL)	13(TL)	17 (13 – 21)	13 (10 – 15)	0.78 (0.72 – 0.84)
35.	**Katsuwonus pelamis*	Skipjack tuna	鰹，杜仲（木魚）	3	1846 - 2007	45-47(FL)	43.5(FL)	143 (128 – 166)	128 (110 – 146)	0.90 (0.86 – 0.96)
36.	*Larimichthys croceus*	Yellow croaker, Croceine croaker, Large yellow croaker	黃花	3	381 – 457	30-32(TL)	17(TL)	44 (36 – 58)	36 (28 – 47)	0.81 (0.78 – 0.84)
37.	*Lateolabrax japonicus*	Japanese seaperch, Common sea bass, Japanese seabass	鱸魚,百花鱸,花鱸	5	387-1210	31-46(TL)	50(TL)	38 (28 – 47)	28 (20 – 35)	0.74 (0.70 – 0.81)
38.	*Lates calcarifer*	Barramundi	盲鰽	6	368- 626	31-36(TL)	29(TL)	91 (21 – 129)	77 (15 – 113)	0.82 (0.73 – 0.90)
39.	*Lethrinus obsoletus*	Orange-striped emperor	連尖	2	152 - 302	20-27(TL)	N/A	50 (21 – 78)	37 (16 – 57)	0.75 (0.73 – 0.76)
40.	*Lutjanus argentimaculatus*	Mangrove red snapper	紅鮪	5	287 - 2023	25-26(FL); 29-47(TL)	49(TL)	60 (46 – 84)	46 (36 – 62)	0.77 (0.74 – 0.80)
41.	*Lutjanus malabaricus*	Red snapper, Malabar blood snapper	紅魚	3	314 - 581	29-35(TL)	36(TL)	106 (102 – 111)	78 (72 – 86)	0.73 (0.71 – 0.77)
42.	*Lutjanus russelli*	Russell's snapper, fingermark bream	火點	3	228-500	26-31(TL)	N/A	112 (94 – 147)	87 (67 -120)	0.77 (0.71 – 0.82)
43.	*Lutjanus stellatus*	Star snapper	石蚌	3	416-609	28-31(TL)	N/A	161 (142 -190)	105 (89 – 123)	0.65 + (0.63 – 0.69)
44.	*Megalobrama terminalis*	Black amur bream	邊魚,三角魴	1	497	31(TL)	30(TL)	7	6	0.86
45.	*Micropterus salmoides*	Large mouth bass, Largemouth black bass	加州鱸,大口鱸	3	262-376	26-29(TL)	N/A	69 (62 – 82)	50 (45 – 59)	0.73 (0.72 – 0.76)
46.	*Mugil cephalus*	Grey mullet, Flathead grey mullet	烏頭	3	335-584	27-31(SL)	12(SL)	14 (6 – 21)	9 (4 – 13)	0.68 (0.61 – 0.72)
47.	*Mulloidichthys flavolineatus*	Yellowstripe goatfish	三鬚	1	136-168	25-26(TL)	12.3(TL)	42	30	0.71

	Fish species	English Common Name(s)	Chinese Common Name(s)	No. of samples	Weight (g) range	Length (cm) range	Maturation size (cm)	Mean tHg (Range)	Mean MeHg (Range)	MeHg/tHg (Range)
48.	*Nemipterus japonicus*	Japanese golden thread, Japanese threadfin bream	瓜衫	4	86-137	18-21(TL)	10.5(TL)	36 (19 – 57)	31 (16 – 49)	0.85 (0.81 – 0.88)
49.	*Nemipterus virgatus*	Golden threadfin bream, Golden thread	紅衫，長尾衫	3	124-198	17-20(FL)	15(FL)	54 (36 – 80)	41 (28 – 60)	0.76 (0.75 – 0.78)
50.	*Oreochromis niloticus niloticus*	Tilapia, Nile tilapia	金山鰂,非洲鰂	4	260-628	19-27(SL)	15(SL)	17 (3 – 33)	13 (3 – 25)	0.81 (0.72 – 1.00)
51.	*Pagrus major*	Red pargo, Japanese seabream, Red seabream	七星�llas，紅魚立，沙魚立	3	497-882	24-27(SL)	N/A	51 (36 – 59)	39 (26 – 47)	0.75 (0.72 – 0.80)
52.	*Pampus argenteus*	Silver pomfret, Butterfish, Pomfret	白鯧,粉鯧	5	77-840	12-20(SL); 38(TL)	N/A	17 (12 – 23)	11 (8 -16)	0.62 (0.50 – 0.70)
53.	*Pampus nozawae*	Swallow tail pomfret	燕尾鯧	3	189-972	23-36(TL)	N/A	24 (22 – 27)	15 (13 – 17)	0.62 (0.59 – 0.63)
54.	**Paralichthys olivaceus*	False halibut, Bastard halibut	大烏,左口,(平目)	3	1068-1239	45-49(TL)	40(TL)	48 (46 – 50)	35 (33 -37)	0.73 (0.72 – 0.74)
55.	*Parupeneus barberinus*	Dash-and-dot goatfish	三鬚	1	841	41(TL)	N/A	150	136	0.91
56.	*Parupeneus indicus*	Indian goatfish	印度三鬚,三鬚	2	211-259	25-27(TL)	N/A	188 (49 – 326)	166 (40 – 292)	0.86 (0.82 – 0.90)
57.	*Pennahia argentata*	White croaker, White chinese croaker, Silver croaker	白鰔	5	112-312	18-24(SL); 24-28(TL)	N/A	79 (40 – 112)	62 (35 – 84)	0.80 (0.75 – 0.88)
58.	*Platycephalus indicus*	Flathead, Bartail flathead	牛鰍,沙鰍	4	733-848	46-51(TL)	11.5(TL)	108 (29 – 192)	81 (21 – 146)	0.74 (0.72 – 0.76)
59.	*Platycephalus spp*	Flathead	牛鰍	1	197-249	33-35(TL)	N/A	51	41	0.80
60.	*Plectorhinchus cinctus*	Cresent sweetlips, Grunt	包公,細鱗,假細鱗	3	287-547	28-34(TL)	N/A	64 (62 – 68)	50 (49 – 52)	0.78 (0.72 – 0.83)
61.	*Plectropomus areolatus*	Squaretail coralgrouper	西星斑	2	329-618	28-36(TL)	N/A	91 (73 -108)	68 (49 – 86)	0.73 (0.67 – 0.80)
62.	*Plectropomus leopardus*	Leopard coralgrouper	東星斑	4	228-853	22-33(SL)	25(SL)	52 (40 – 75)	42 (27 – 54)	0.72 (0.68 – 0.77)
63.	*Pomadasys kaakan*	Javelin grunter	頭鱸	4	304-813	28-39	N/A	90 (63 – 165)	78 (50 – 160)	0.83 (0.76 – 0.97)

	Fish species	English Common Name(s)	Chinese Common Name(s)	No. of samples	Weight (g) range	Length (cm) range	Maturation size (cm)	Mean tHg (Range)	Mean MeHg (Range)	MeHg/tHg (Range)
64.	*Priacanthus tayenus*	Purple-spotted bigeye, Big-eye perch	長尾木棉	4	190-427	21-37(TL)	N/A	44 (31 – 56)	33 (23 – 42)	0.75 (0.73 – 0.77)
65.	*Priacanthus macracanthus*	Red bigeye, Bulls-eye perch	齊尾木棉	2	105-206	17-20(SL)	N/A	19 (18 – 19)	12 (11 – 13)	0.65 (0.61 – 0.68)
66.	*Psenopsis anomala*	Butter fish, Pacific rudderfish	瓜核鯧,藍鯧	4	56-186	14-16(TL), 17(SL)	N/A	13 (7 – 29)	10 (6 – 21)	0.75 (0.67 – 0.86)
67.	**Pseudocaranx dentex*	White trevally	長鼻水珍,木黃	3	1668-1729	47-50(TL)	28(TL)	101 (94 – 105)	84 (81 – 89)	0.83 (0.77 – 0.86)
68.	*Rachycentron canadum*	Black bonito, cobia	魚仲，懵仔	1	6874	82(TL)	70(TL)	101	100	0.99
69.	**Salmo Salar*	Atlantic salmon	三文魚	3	6186-6287	83-84(TL)	N/A	34 (31 – 39)	25 (24 – 27)	0.74 (0.69 – 0.77)
70.	**Sarda orientalis*	Striped bonito	煙仔虎,西齒(戍功)、掠齒煙	3	665-748	37-38(FL)	N/A	101 (99 – 104)	76 (73 – 81)	0.76 (0.73 – 0.78)
71.	**Sardinops sagax*	South American pilchard	沙丁魚,鰛仔	3	34-59	14-17(SL)	7(SL)	31 (31)	26 (24 -27)	0.83 (0.77 – 0.87)
72.	*Saurida elongata*	Slender lizardfish	泥釘	2	54-105	17-21(SL)	16(SL)	20 (16 – 24)	16 (12 – 20)	0.79 (0.75 – 0.83)
73.	*Saurida tumbil*	Greater lizardfish	狗棍	1	89-131	19-22(SL)	14(FL)	24	18	0.75
74.	*Scatophagus argus*	Spotted scat, Butter fish, spade fish	金鼓	3	169-390	18-23(TL)	14(TL)	34 (32 – 37)	28 (25 – 29)	0.81 (0.78 – 0.85)
75.	**Scomber japonicus*	Chub mackerel	花鮫,花鮫鱃,大口鮫, (鯖魚)	3	845-854	42-44(TL)	30(TL)	213 (161 – 262)	152 (116 – 188)	0.72 (0.71 – 0.72)
76.	*Scomberomorus commerson*	Narrow-barred spanish mackerel	竹鮫,鮫魚	1	2038	64(FL)	65(FL)	83	59	0.71
77.	*Scomberomorus guttatus*	Indo-pacific king mackerel	線鮫,泥鮫	5	888-1673	59(FL)	32.5(FL)	87 (33 – 138)	69 (18 – 112)	0.76 (0.55 – 0.89)
78.	*Sebastiscus marmoratus*	Rockfish	石狗公	3	22-89	10-17(TL)	9(TL)	33 (26 – 41)	25 (18 – 33)	0.76 (0.69 – 0.80)
79.	**Seriola dumerili*	Purple amberjack, Greater amberjack	章雄	3	2413-2650	59-62(TL)	75(TL)	113 (104 – 128)	89 (78 – 98)	0.79 (0.75 – 0.86)
80.	**Seriola lalandi*	Yellowtail kingfish, Yellowtail	黃尾鰤，章雄，	3	4920-4948	74-76(TL)	50.6(TL)	219 (210 – 230)	192 (186 – 200)	0.88 (0.87 – 0.89)

	Fish species	English Common Name(s)	Chinese Common Name(s)	No. of samples	Weight (g) range	Length (cm) range	Maturation size (cm)	Mean tHg (Range)	Mean MeHg (Range)	MeHg/tHg (Range)
	(Region A)	amberjack	（油甘魚）							
81.	**Seriola lalandi* (Region B)	Yellowtail kingfish, Yellowtail amberjack	黃尾鰤，章雄，（油甘魚）	3	3025-3535	67-70(TL)	50.6(TL)	31 (29 – 34)	23 (21 – 27)	0.76 (0.72 – 0.79)
82.	*Siganus canaliculatus*	Rabbitfish, pearl-spotted spinefoot, white-spotted spinefoot	泥鯭	3	48-93	14-19(TL)	10(TL)	14 (11 – 18)	9 (7 -12)	0.67 (0.64 – 0.69)
83.	*Sillago japonica*	Japanese sillago	沙鑽	3	36-121	17-25(TL)	N/A	133 (58 – 186)	117 (51 – 153)	0.88 (0.82 – 0.95)
84.	*Siniperca chuatsi*	Freshwater grouper, Mandarin fish	桂花魚,鱖魚	3	332-939	27-34(TL)	20(TL)	91 (82 – 102)	77 (66 – 90)	0.85 (0.80 – 0.88)
85.	**Sphyraena flavicauda*	Yellowtail barracuda, Barracudas	竹簽,(梭子魚)	3	255-382	34-40(TL)	N/A	295 (147 – 406)	216 (107 – 299)	0.73 (0.73 – 0.74)
86.	*Trachinotus blochii*	Snubnose pompano	黃鱲鯧	3	273-385	21-26(FL)	N/A	56 (48 – 72)	48 (38 – 64)	0.84 (0.79 – 0.89)
87.	**Trachurus japonicus*	Japanese jack mackerel, Atlantic horse mackerel	日本鰺,石鰺,(池魚)	3	166-207	23-29(TL)	18(TL)	64 (53 – 74)	42 (33 – 59)	0.65 (0.52 – 0.80)
88.	*Trichiurus lepturus*	Largehead hairtail, Hairtail	灰鰭牙帶,牙帶	5	749-1371	90-129(TL)	75(FL)	91 (62 – 158)	69 (49 – 122)	0.77 (0.70 – 0.81)
89.	*Trichiurus nanhaiensis*	Largehead hairtail, South China Sea hairtail	黃鰭牙帶,牙帶	1	617	85(TL)	N/A	56	42	0.75
90.	*Variola albimarginata*	White-edged lyretail	燕尾星	3	268-526	26-36(TL)	N/A	102 (80 -115)	73 (59 – 81)	0.72 (0.70 – 0.74)
91.	-	Albacore tuna (canned)	長鰭金槍魚	5	-	-	-	263 (236 – 301)	205 (185 – 229)	0.78 (0.74 – 0.81)
92.	-	Skipjack tuna (canned)	鰹、杜仲	4	-	-	-	163 (37 – 469)	142 (27 – 430)	0.79 (0.72 – 0.92)
93.	-	Yellowfin tuna (canned)	黃鰭金槍魚、黃鰭杜仲	5	-	-	-	114 (39 – 201)	85 (27 – 153)	0.74 (0.69 – 0.79)

*Imported fish; TL: total length; SL: standard length; FL: fork length; N/A: not available