COMMITTEE ON TOXICITY OF CHEMICALS IN FOOD, CONSUMER PRODUCTS AND THE ENVIRONMENT

STATEMENT ON A SURVEY OF MERCURY IN FISH AND SHELLFISH

Introduction

1. We have been informed of the results of a Food Standards Agency (FSA) survey of the mercury levels in imported fish and shellfish and UK farmed fish and their products [1]. We were also informed of provisional results of blood mercury levels in 1320 adults participating in a recent National Diet and Nutrition Survey (NDNS)[2].

2. In an initial response to the estimations of mercury intake derived from the fish survey results, the FSA released a precautionary interim statement following consultation with the COT Chairman. This statement advised the general population to restrict consumption of shark, swordfish and marlin to no more than one portion a week of any of these fish. It also gave precautionary advice to pregnant women, women intending to become pregnant and children to avoid consumption of these three species of fish.

3. We were asked to consider the most appropriate safety guidelines to use in assessing the health implications of mercury in fish, and to consider possible health concerns associated with the estimated mercury intakes and blood level data provided.

Background

4. The toxicity of mercury is dependent on whether it is inorganic, elemental or organic (e.g. methylmercury). Methylmercury affects the kidneys and also the central nervous system, particularly during development, as it crosses both the blood-brain barrier and the placenta [3]. Both neuro- and nephrotoxicity have been associated with acute methylmercury poisoning incidents in humans, and neurotoxicity, particularly in the developing fetus, has been associated with lower level chronic exposures.

5. Exposure of the general population to mercury can occur via inhalation of mercury vapour from dental amalgam fillings (elemental), or through the diet (methylmercury and inorganic mercury). Methylmercury in fish makes the most significant contribution to dietary exposure to mercury, although smaller amounts of inorganic mercury are present in other food sources. All forms of mercury entering the aquatic environment, as a result of man's activities or

from geological sources, are converted into methylmercury by microorganisms and subsequently concentrated in fish and other aquatic species. Fish may concentrate the methylmercury either directly from the water or through consuming other components of the food chain. Methylmercury has a half-life of approximately 2 years in fish thus large older fish, particularly predatory species, will have accumulated considerably more mercury than small younger fish.

Previous COT evaluation

6. COT previously considered the results of a survey of metals and other elements in marine fish and shellfish [4] published by the Ministry of Agriculture, Fisheries and Food (MAFF) in 1998. The survey examined a number of fish and shellfish species landed in the UK or imported from overseas ports including cod, haddock, herring, mackerel, lobster, mussels, crab and shrimps and samples of cod fish fingers. The survey also produced estimates of the mean and 97.5th percentile dietary intakes of the elements surveyed.

7. The 1998 survey demonstrated that the levels of mercury in the fish and shellfish tested were low and that average and high level fish and shellfish consumers in the UK would not exceed the provisional tolerable weekly intake (PTWI) for mercury or methylmercury. The estimated mercury intake for the highest level consumer was 1.1 μg/kg bw/week including mercury intake from the rest of the diet. The main conclusion drawn from the survey was that "dietary intakes of the elements surveyed were below safe limits, where defined, and did not represent any known health risk even to consumers who eat large amounts of marine fish or shellfish".

International Safety Guidelines

Joint FAO/WHO Expert Committee on Food Additives (JECFA)

8. In 1972, JECFA established a PTWI of 5 μg/kg bw/week for total mercury, of which no more than two thirds (3.3 μg/kg bw/week) should be from methylmercury [5]. The PTWI of 3.3 μg/kg bw/week for methylmercury was subsequently confirmed in 1989 and 2000 [6,7]. The PTWI was derived from toxicity data resulting from poisoning incidents at Minamata and Niigata in Japan. In these incidents the lowest mercury levels associated with the onset of clinical disease in adults were reported to be 50 μg/g in hair and 200 μg/L in whole blood. Individuals displaying clinical effects, such as peripheral neuropathy, at these mercury levels were considered to be more sensitive than the general population, because there were a number of persons in Japan and other countries with higher mercury levels in hair or blood who did not experience such effects. However the methods employed in determining the intake associated with toxicity, and the subsequent establishment of the PTWI are unclear.

9. In 1989, JECFA had noted that pregnant women and nursing mothers may be at greater risk than the general population to adverse effects from methylmercury. Therefore it subsequently paid particular attention to possible effects of prenatal and postnatal exposure. Large long-term prospective epidemiological studies have been conducted in the Seychelles Islands and the Faroe Islands which attempted to identify the lowest dietary mercury exposure associated with subtle effects on the developing nervous system [8,9,10,11]. The studies have followed the neurological development of the children by testing their learning and spatial abilities at a number of time-points during their childhood. A number of smaller studies were also available.

10. Comparing the two main studies, the Faroe Islands cohort was tested up to the age of 7 years, whereas the Seychelles cohort has so far been tested up to the age of 5.5 years. Exposure in the Seychelles is through consumption of a range of fish species mostly with mercury concentrations between 0.05 and 0.25 mg/kg. In the Faroe Islands, most of the population consume fish at least three times a week and there is also occasional (approximately once per month) consumption of pilot whale which contains up to 3 mg/kg mercury. Pilot whale also contains high concentrations of polychlorinated biphenyls (PCBs), but a recent reanalysis of the data indicate that the effects seen could not be attributed to confounding by the PCBs [12]. There are also differences in the methods used to assess exposure. The Seychelles study used maternal hair samples (approx. 9cm long), one taken shortly after birth to estimate methylmercury exposure during pregnancy and one taken 6 months later. The Faroe Islands study used cord blood and maternal hair (various lengths) taken at birth. The studies used different batches of tests to assess the effects of methylmercury on neurological development. The tests used in the Faroe Islands study each examined specific domains in the brain (visual, auditory, etc.) however the Seychelles study used tests of a more global nature, with each test examining a number of domains.

11. These studies are continuing, but the results at present are conflicting. The mean mercury exposures (assessed by maternal hair mercury) during pregnancy were similar (Seychelles: arithmetic mean 6.8 μg/g, range 0.5-26.7 μg/g; Faroes: geometric mean, 4.27 μg/g, the upper mercury level in maternal hair is not clear from the reported data but may be as high as 70 μg/g). In the Faroes study, regression analysis showed an association between methylmercury exposure and impaired performance in neuropsychological tests, an association that remained even after excluding the results of children with exposures associated with greater than 10 μg/g maternal hair mercury. However in the Seychelles study regression analysis has identified no adverse trends, but a small statistically significant increase in test scores on several of the developmental outcomes. The investigators noted that this was probably due to beneficial nutritional effects of fish. A secondary analysis was performed where the results were split into sub-groups based on the maternal hair mercury level. Test scores in children with the highest mercury exposures (12 - 27 μg/g maternal hair) were not significantly different from the test scores in children with lowest exposure (< 3μg/g maternal hair).

12. A smaller study carried out in New Zealand on 6 year-old children [13] used a similar batch of tests to the Seychelles study and had similar exposure to methylmercury, yet found methylmercury related effects on behavioural test scores. However there were possible confounding factors that may have influenced the results of the New Zealand study, such as the ethnic group and social class of the children studied.

13. Having considered all of the epidemiological evidence, JECFA concluded that the Faroe Islands and Seychelles Islands studies did not provide consistent evidence of neurodevelopmental effects in children whose mothers had hair mercury levels of 20 μg/g or less. Because there was no clear indication of a consistent risk in these epidemiological studies, JECFA did not revise the PTWI, but recommended that methylmercury should be re-evaluated when the 96-month evaluation of the Seychelles study and other relevant data become available [7].

Environmental Protection Agency (EPA)

14. In 1997 the US EPA established a reference dose of 0.1 μg/kg bw/day for methylmercury [14]. This was based on a peak maternal hair mercury level during pregnancy of 11 μg/g, which was associated with developmental effects (e.g. late walking, late talking, mental symptoms, seizures) in children exposed *in utero* during a poisoning incident in Iraq in 1971.

15. In 2000, the US National Research Council (NRC) published a review of this EPA reference dose [15]. Following analysis of the data resulting from the available epidemiological studies, the NRC identified a benchmark dose of 58 μg/L in cord blood (corresponding to 12 μg/g in maternal hair). This was the lowest dose considered to produce a sufficiently reliable neurological endpoint (a 5% increase in abnormal scores on the Boston Naming Test[§]) in the Faroe Islands study. The NRC made a number of assumptions in deriving an estimate of methylmercury intake and included a composite uncertainty factor of 10, resulting in the same reference dose of 0.1 μg/kg bw/day, as had previously been used by the EPA. This reference dose is approximately one fifth of the current JECFA PTWI of 3.3 μg/kg of body weight/week.

Survey of the mercury levels in fish

16. The new FSA survey complements the previous MAFF survey since it has examined a wider range of fish, including imported exotic species of fish that have become more widely available on the UK market. These included shark, swordfish, marlin, orange roughy, red snapper and monkfish, as well as UK farmed fish such as salmon and trout [1].

[§] The Boston Naming Test is a neuropsychological test that assesses an individual's ability to retrieve a word that appropriately expresses a particular concern, for example naming an object portrayed by a simple line drawing.

17. Of the fish species covered by the survey, all but 3 species had mean mercury levels falling within the range 0.008 – 0.88 mg/kg of fish. This range is in line with the levels defined by European Community Regulation 466/2001 as amended by European Community Regulation 221/2002 (0.5 mg of mercury/kg for fish in general and 1.0 mg mercury/kg for certain larger predatory species of fish including shark, swordfish, marlin, tuna and orange roughy).

18. The 3 species with the highest mercury content were shark, swordfish and marlin. These fish had mean mercury levels of 1.52, 1.36, and 1.09 mg/kg respectively and were therefore above the levels defined in European Community Regulation 221/2002. Fresh tuna contained mercury levels ranging from 0.141 to 1.50 mg/kg with a mean of 0.40 mg/kg (only one sample out of 20 exceeded 1 mg/kg, the maximum mercury concentration in the other 19 samples was 0.62 mg/kg), whereas canned tuna had a lower mean mercury level of 0.19 mg/kg. It is assumed that canned tuna have lower mercury levels than fresh tuna, because the fish used in the production of canned tuna are smaller and younger and subsequently have accumulated less methylmercury.

19. Dietary exposure to mercury has been estimated for those fish species for which reliable consumption data are available [16, 17, 18, 19] (salmon, prawns and canned tuna) together with exposure from the rest of the diet (Table 1). Of these fish, canned tuna provided the largest contribution to dietary mercury exposure for high level consumers. Total fish consumption by the high level consumer was equivalent to approximately five portions per week (688g).

20. Estimates were also made of the methylmercury intake resulting from consumption of one portion of shark, marlin, swordfish or fresh tuna, for which consumption data are not available (Table 2), using portion sizes as recorded in the NDNS for fish consumption [17, 18, 19]. For comparative purposes similar estimates were made for canned tuna. For children up to the age of 14 and adult consumers, the mercury intake resulting from one portion of shark, marlin or swordfish per week would be close to or above the PTWI for methylmercury.

Blood mercury levels in British adults

21. We also considered a report produced by the Medical Research Council Human Nutrition Research in March 2002 detailing the provisional blood total mercury data obtained from 1320 adults (aged 19-64 years) participating in the National Diet and Nutritional Survey (NDNS) [2].

22. The mean and 97.5th percentile blood mercury levels in the survey were 1.6 and 5.88 μg mercury/L respectively. The highest blood mercury level found in the study was approximately 26 μg/L in an individual with a high fish intake. If the blood mercury level was at steady state, and assuming a body

weight of 70 kg, then this would correspond to a mercury intake of approximately 2.6 μg/kg bw/week, which is within the JECFA PTWI.

23. Of the population covered by the survey, 97.5% had blood mercury levels indicating that their mercury intakes were below the EPA reference dose.

COT evaluation

24. The Committee discussed the possible risks associated with dietary exposure to methylmercury, in the light of the new information on intakes from fish and on blood mercury levels in the UK population.

Toxicokinetic considerations

25. Following ingestion, approximately 95% of methylmercury is absorbed through the gastrointestinal tract, and is subsequently distributed to all tissues in about 30 hours with approximately 5% found in blood and 10% in the brain. The methylmercury concentration in red blood cells is approximately 20 times higher than that in the plasma. Methylmercury readily crosses the placental barrier. Fetal brain mercury levels are approximately 5-7 times higher than in maternal blood. Methylmercury readily accumulates in hair and the ratio of hair mercury level (μg/g) to blood mercury level (μg/L) is approximately 1:4. Based on comparisons to hair concentrations, cord blood concentrations are reported to be 25% higher than the concentrations in maternal blood.[8] Table 3 shows the blood and hair mercury concentrations associated with exposures resulting in adverse effects and with the JECFA PTWI and EPA reference dose.

26. The excretion process for methylmercury involves transfer of the glutathione-mercury complex into the bile, demethylation by gut microflora to the inorganic form, then elimination from the body in the faeces. The half-life of mercury in the body is approximately 70 days in adults, with steady state being reached in about one year. Significant amounts of methylmercury also pass into the breast milk of lactating women, resulting in a decreased mercury half-life of approximately 45 days [20].

27. Doherty and Gates (1973) [21] reported that the excretion rate of mercury in the suckling rodent is less than 1% of the adult excretion rate. Sundberg *et al.* (1998) [22] reported a low elimination of mercury in suckling mice until lactational day 17. This is probably because biliary secretion and demethylation by microflora (which lead to faecal excretion) do not occur in suckling animals. The role of these processes in suckling human infants is unknown [3].

28. The concentration of mercury in breast-milk is approximately 5% of the blood mercury concentration of the mother [20]. Amin-Zaki *et al.* [23] reported that in women exposed to high levels of methylmercury during the Iraqi poisoning

incident, 60% of the mercury in breast-milk was in the form of methylmercury. Therefore it may be estimated that the concentration of methylmercury in the breast-milk is approximately 3% of the total mercury concentration in the blood. If a breastfeeding mother was exposed to methylmercury at the JECFA PTWI then the suckling infant would be exposed to the following approximate amount of methylmercury:

Blood mercury level	= 33 μg/L
Amount of methylmercury in milk	= 0.99 μg/L
Assuming a daily milk intake of 150 mL/kg bw	
Methylmercury intake	= 0.15 μg/kg bw/day

29. Therefore the infant is exposed to methylmercury at a level substantially below the JECFA PTWI but 50% above the EPA reference dose.

Susceptible populations

30. The Committee noted that the JECFA PTWI may not be sufficiently protective for high-risk groups and therefore gave particular consideration to determining which groups are at higher risk.

31. The critical effect of methylmercury is on the developing central nervous system and therefore pregnant women are considered to be the most susceptible population because of the risk to the fetus. There have been no studies of the effects of exposure prior to becoming pregnant. However, because the half-life of methylmercury in the human body is approximately 70 days, steady state concentration is attained in approximately one year and a woman's blood mercury level at the time of becoming pregnant is dependent on the exposure to methylmercury during the preceding year. The Committee therefore agreed that women who may become pregnant within the next year should also be considered as a susceptible population.

32. The evidence regarding consideration of other susceptible populations is not conclusive. Animal experiments indicate that exposure via breast-milk has less serious consequences to the central nervous system than prenatal exposure. Spyker and Spyker [24] reported that the effects of prenatal exposure to methylmercury dicyandiamide on the survival and weight gain of the offspring were more severe than those seen with postnatal exposure, and were greatest when the methylmercury was administered late in the period of organogenesis. However, these results are not necessarily relevant to the health effects of concern in human exposure.

33. Data from a 5-year longitudinal study following the Iraq poisoning incident have suggested that some children exposed to methylmercury via breast-milk demonstrated delayed motor development [23]. The maternal blood mercury levels immediately following the incident were estimated by extrapolation to be in the range of approximately 100μg/L to 5000 μg/L. Mothers who showed signs and symptoms of poisoning (ataxia, dysarthria,

visual disturbance etc.) had the higher blood levels (3000 to 5000 μg/L) although some women with levels in this range were asymptomatic.

34. The affected infants all had blood mercury levels above those associated with the JECFA PTWI, and most of them had blood mercury levels higher than the minimum toxic level of 200 μg/L, defined by JECFA. There was no paralysis, ataxia, blindness or apparent sensory change and there were no cases of the severe mental destruction and cerebral palsy that were seen in the prenatally exposed infants of Minamata. However, language and motor development of the children were delayed. The authors of the study concluded that breast-fed infants are not as much at risk as the fetus, since most of the brain development has already occurred and the effects seen in the breast-feeding infant are different from those seen in infants exposed prenatally and not as severe.

35. There is no evidence that chronic exposure to methylmercury via the breast milk at levels below those observed in the Iraqi incident has any adverse effect on the neurophysiological/psychological development of the child. Data from the Faroe Islands study suggests that the beneficial effects of nursing on early motor development are sufficient to compensate for any adverse impact that prenatal exposure to low concentrations of methylmercury might have on these endpoints [25, 26]. Grandjean *et al* [25] looked at the relationship between seafood consumption and concentrations of contaminants in breast-milk in the Faroes Island population. Of 88 samples of breast-milk, three had a mercury level that would cause the infant to exceed the PTWI for mercury.

36. There have been few studies of the effects of methylmercury on young children. Most information has come from the poisoning incidents in Minamata, Niigata and Iraq. In all of these cases the exposures were very high, and in Iraq, the exposure was acute. Methylmercury is excreted by children as efficiently as by adults [2]. In the incidents where children were exposed directly to methylmercury and not prenatally, the damage seen in the brain was similar to that seen in adults: focal lesions of necrosis. The damage seen when the fetus is exposed is much more widespread [3].

37. The longitudinal study in the Seychelles has attempted to examine the effects of postnatal exposure to methylmercury [10]. This is complicated by the facts that in the Seychelles, the children exposed to methylmercury postnatally are also exposed prenatally, and the study has been unable to demonstrate any mercury-related deficits in the neurological development of children. However higher postnatal methylmercury exposure had a positive association with test scores. It was suggested that this may be because a higher mercury level indicates a high fish intake and therefore a diet rich in n-3-polyunsaturated fatty acids and vitamin E, which have beneficial effects and may mask any subtle neurological deficits due to chronic low level exposure to methylmercury. Fish consumed in the Seychelles Islands contain similar concentrations of methylmercury to fish commonly consumed in the UK[10], but methylmercury intakes appear to be higher in the Seychelles than in the UK.

The FSA survey indicates that in the UK high level dietary exposure to methylmercury from commonly consumed fish ranges from about 0.8 μg/kg bw/week for adults to 2 μg/kg bw/week for toddlers. Based on the correlations in Table 3, it can be estimated that the most exposed individuals in the Seychelles studies had intakes in the region of 4.8-10.8 μg/kg bw/week.

38. The risk is greater for women who are pregnant or likely to become pregnant within the following year because of the effects of methylmercury on the developing central nervous system of the fetus. There is uncertainty with respect to whether infants and young children are at greater risk of methylmercury toxicity whilst the central nervous system is still developing. The limited data available indicate that this is not the case for children but the possibility of increased sensitivity of infants cannot be discounted.

39. The EPA reference dose is derived from data on neurobehavioural development in the Faroe Islands and the Iraqi incident. The population studied in the Seychelles Islands had similar maternal hair mercury concentrations to those in the Faroes and Iraq (Table 3). So far the Seychelles study has been unable to demonstrate any subtle neurobehavioural effects associated with *in utero* exposure, although effects may become apparent when the Seychelles cohort of children is subjected to comparable tests to those used on the Faroe Island children at age 7. Thus there are currently inconsistencies in the evidence of whether adverse effects are expected to arise from maternal exposures resulting in hair mercury concentrations in the region of 10-20 μg/g (corresponding to exposure of 4 - 8 μg/kg bw/week). However in view of the Faroe and Iraqi data, we consider it appropriate to refer to the EPA reference dose (which is equivalent to 0.7 μg/kg bw/week) in assessing the methylmercury intakes of pregnant women, women who may become pregnant within the next year, and breast-feeding mothers. The intakes for other subgroups should be compared with the JECFA PTWI of 3.3 μg/kg bw/week.

Assessment of dietary exposure estimates

40. The estimates of average and high level total dietary exposure to mercury, including from fish for which consumption data are available, are within the JECFA PTWI for methylmercury for all age groups.

41. The estimated high level intake by adult women exceeds the EPA reference dose by 10%. Total dietary exposure to mercury includes inorganic mercury, which is less toxic than methylmercury, and therefore comparison with the reference dose for methylmercury represents an overestimation of the risk. It is therefore unlikely that this small exceedance of the reference dose could result in adverse effects on the developing nervous system of the fetus or of the breast-fed infant.

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42. Because of their nutritional requirements, dietary mercury exposure is comparatively higher in children than in adults. However, taking into account the evidence for the beneficial effects of fish consumption, we consider that

there is an adequate margin of safety between the estimated total dietary exposure for average and high level child consumers and methylmercury exposures that could result in neurotoxicity.

43. For adults, consumption of one portion of shark, swordfish or marlin per week could result in a mercury intake close to the PTWI for methylmercury, before considering intake from the rest of the diet. To exceed the PTWI would require consumption of four portions of fresh tuna, or 8 portions of canned tuna per week by an adult. Children under the age of 14 consuming one portion of shark, swordfish or marlin per week, when considered with the rest of the diet, would exceed the PTWI. To exceed the PTWI would require consumption of about 3 portions per week of fresh tuna, or 6 portions of canned tuna.

44. Consumption of one portion of shark, swordfish or marlin by pregnant or breastfeeding women together with the rest of the diet would exceed the EPA reference dose for methylmercury by about 4-fold. One portion of fresh tuna or 2 portions of canned tuna would slightly exceed (about 10%) the EPA reference dose, which is not expected to result in adverse effects.

Conclusions

45. We *consider* that the JECFA PTWI of 3.3 μg/kg bw/week is sufficiently protective for the general population. We *recognise* that the PTWI may not be sufficiently protective for women who are pregnant, or who may become pregnant within the following year, or for breast-feeding mothers. This is due to the potential risk to the developing fetus or neonate. We therefore consider that the EPA reference dose of 0.1 μg/kg bw/day (0.7 μg/kg bw/week) is more appropriate for these groups.

46. We *consider* the NDNS data are reassuring with respect to average and high level consumption of fish. The adults surveyed had blood mercury levels that indicate that the JECFA PTWI for methylmercury was not being exceeded.

47. We *note* that estimates of average and high level dietary mercury exposure, resulting from fish for which consumption data are available, are within the JECFA PTWI for methylmercury for all age groups. Adult women who are high level consumers of these commonly eaten fish may marginally exceed the EPA reference dose. However we *consider* that this dietary exposure is not likely to be associated with adverse effects to the developing fetus.

48. We *note* that consuming one weekly portion of either shark, swordfish or marlin would result in a dietary exposure close to, or exceeding, the PTWI and therefore exceeding the EPA reference dose for methylmercury in all age groups. We *consider* that this consumption would not be expected to result in adverse effects in the general adult population, but could be harmful to the

fetus and to the breast-fed infant. The exceedance of the PTWI is relatively greater for children under 14 years, because their food intake is greater, on a bodyweight basis, than that of adults. However, taking into account the evidence for the beneficial effects of eating fish, consumption of one portion per week of these fish is not expected to result in adverse health effects.

49. We *note* that the mercury content of tuna is lower than that of shark, swordfish or marlin, but higher than that of other commonly consumed fish. We *consider* that consumption of one portion of fresh tuna, or two portions of canned tuna, per week, by pregnant or breast-feeding women is not expected to result in adverse effects on the developing fetus or infant.

50. We *recommend* that further research is required to provide evidence on potential inter-individual differences in the toxicity of methylmercury, including susceptibility of children at different ages particularly infancy, and of factors that may influence its toxicity.

51. We *recommend* that these conclusions should be reviewed following the JECFA evaluation of methylmercury in 2003.

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Table 1: Estimated mean and high level dietary intakes of mercury from salmon, prawns, canned tuna and the whole diet.

Consumer group	Mercury Intake - µg/kg bw/week [1]							
	Salmon [2]		Prawns [2]		Canned Tuna [2]		Whole Diet [3, 4]	
	Mean	97.5%	Mean	97.5%	Mean	97.5%	Mean	97.5%
Infants	0.01	0.01	0.00	0.00	0.04	0.13	0.06	0.14
Toddlers	0.18	0.53	0.13	0.45	0.81	2.45	0.84	2.03
Young People aged 4 – 6	0.18	0.39	0.09	0.34	0.53	1.61	0.77	1.82
Young People aged 7 – 10	0.11	0.36	0.06	0.15	0.39	1.26	0.62	1.40
Young People aged 11 – 14	0.09	0.23	0.04	0.13	0.32	0.98	0.43	1.19
Young People aged 15 – 18	0.08	0.15	0.04	0.11	0.27	0.68	0.36	0.84
Adults	0.06	0.24	0.04	0.14	0.25	0.62	0.35	0.84
Adults – Women only	0.06	0.18	0.04	0.12	0.27	0.62	0.34	0.77

1. Consumption data for salmon, prawns and tuna are taken from the following sources:
   - Dietary and Nutritional Surveys of British Adults. [19]
   - Food and Nutrient Intakes of British Infants Aged 6-12 Months [16]
   - National Diet and Nutrition Surveys Children Aged 1.5 – 4.5 years.[18]
   - National Diet and Nutrition Survey: young people aged 4-18 years. Volume 1 report of the diet and nutrition survey.[17]
2. Mercury intake from eating the named fish only, for the mean and 97.5th percentile consumers.
3. Mercury intake from consumption of fresh salmon, prawns, canned tuna and the rest of the normal UK diet (based on the 1997 Total Diet Study) for consumers of fish [27]. The total mercury intakes do not equal the sum of the mercury intakes from the named fish because the populations of consumers differ (for example not all fish consumers eat prawns).
4. The measurement of mercury does not distinguish between inorganic and organic mercury. Therefore although methylmercury is the major contributor to mercury intake from fish, the estimate of intake from the whole diet also includes inorganic mercury.

Table 2: Mercury intake from one portion of shark, swordfish, marlin, fresh tuna or canned tuna.

Age group (years)	Body Weight (kg)	Av. Portion Size [a] (g)	Weekly methylmercury intake assuming one portion of fish per week [b] (μg/kg bw/week)				
			Shark	Swordfish	Marlin	Fresh Tuna	Canned Tuna
1.5 – 4.5	14.5	50	5.24	4.62	3.79	1.38	0.66
4 – 6	20.5	60	4.44	3.90	3.22	1.17	0.56
7 –10	30.9	85	4.17	3.69	3.04	1.10	0.52
11 – 14	48.0	140	4.44	3.92	3.21	1.17	0.55
15 – 18	63.8	105	2.51	2.21	1.82	0.66	0.31
Adults	70.1	140	3.04	2.68	2.20	0.80	0.38

a. The average portion size that each age group of the population would consume at a single meal event for fish consumption, as recorded in the following National Diet and Nutrition Surveys (NDNS):

- 1995 National Diet and Nutrition Survey: Children aged one-and-a-half to four-and-a-half years [18].
- 2000 National Diet and Nutrition Survey: young people aged 4 to 18 years [17].
- 1990 The Dietary and Nutritional Survey of British Adults [19].

b. This intake estimate does not include the intake from the rest of the diet, which is estimated to be 0.052 μg/kg bw/day for a 60kg average consumer (0.36 μg/kg bw/week) [27].

Table 3: Summaries of biomarkers and methylmercury intakes

(a) Epidemiological studies

Population studied	Biomarker		NOAEL or LOAEL	Associated weekly dietary intake of methylmercury
	Mercury in Blood	Mercury in Hair		
Adults in Minamata/Niigata	200 μg/L	50 μg/g	LOAEL	*[20 mg/kg bw/week]*[1]
Children in Iraq[3]	*[40 – 80 mg/L in maternal blood]*[1]	10 – 20 μg/g in maternal hair	LOAEL	*[4 – 8 mg/kg bw/week]*
7-year-old children in Faroes Islands[2 3]	58 μg/L (cord blood) *[~48 mg/L in maternal blood]*	12 μg/g in maternal hair	LOAEL	*[4.8 mg/kg bw/week]*
5.5 year-old children in Seychelles[3]	*[48 – 108 mg/L in maternal blood]*	12 – 27 μg/g in maternal hair	NOAEL	*[4.8 – 10.8 mg/kg bw/week]*

1. Values in square brackets [ ] and *Italics* have been calculated using the following assumptions:
   i. The hair mercury level (μg/g) to blood mercury level (μg/L) ratio is 1:4.
   ii. Daily intake at steady state (μg/day) for a 70 kg person equals the blood mercury level (μg/L), i.e. a blood level of 33 μg/L corresponds to an intake of 33 μg/**day** and therefore 3.3 μg/kg bw/**week** for a 70 kg person.
2. Levels in cord blood and maternal hair are associated with a 5% increase in abnormal scores in the Boston Naming Test. These levels were used in the calculation of the EPA Reference Dose.
3. Children exposed prenatally, biomarkers are therefore maternal or in the case of the Faroe Islands, fetal (cord blood).

(b) Safety guidelines

Safety Guideline	Mercury in blood	Mercury in hair	Associated weekly dietary intake of methylmercury
JECFA PTWI[1]	33 μg/L	8.25 μg/g	3.3 μg/kg bw/week
EPA RfD[2]	4.75 μg/L	1.2 μg/g	0.7 μg/kg bw/week

1. The blood and hair levels associated with the JECFA PTWI have been calculated using the following assumptions:
   i. The hair mercury level (μg/g) to blood mercury level (μg/L) ratio is 1:4.
   ii. Daily intake at steady state (μg/day) for a 70 kg person equals the blood mercury level (μg/L). A blood level of 33 μg/L corresponds to an intake of 33 μg/day and therefore 3.3 μg/kg bw/week for a 70 kg person.
2. The EPA reference dose calculates the intake using the following equation (NRC 2000):

$$\text{Daily intake (mg/kg bw/day)} = \frac{\text{concentration in blood} \times \text{elimination constant} \times \text{blood volume}}{\text{absorption factor} \times \text{fraction of daily intake taken up by blood} \times \text{body weight}}$$

The following values were used in calculating the blood mercury level associated with the reference dose in this table:

Daily intake	0.1 μg/kg bw/day
elimination constant	0.014 $days^{-1}$
blood volume	5 L
absorption factor	0.95
fraction of daily intake taken up by blood	0.05
body weight	70 kg

The body weight used by the EPA in calculating the reference dose is **60 kg**. However in order to make the values more comparable to the JECFA PTWI, the blood level associated with the reference dose in this table has been calculated using a bodyweight of **70 kg**.

The hair mercury level was calculated using the ratio of blood to hair mercury employed by JECFA