AGENCE FRANÇAISE
DE SÉCURITÉ SANITAIRE
DES ALIMENTS

Maisons-Alfort, 14 June 2010

THE DIRECTOR GENERAL

OPINION

of the French Food Safety Agency regarding the benefits/risks of fish consumption

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1. Context of the request

On 21 April 2008, the French Food Safety Agency (AFSSA) received a request from the Directorate General for Health for an Opinion regarding the benefits/risks of fish consumption.

2. Background

The French National Nutrition and Health Programme (PNNS) recommends consuming fish at least twice a week. In 2006, the CALIPSO study (AFSSA 2006a) assessed intakes of n-3 long-chain polyunsaturated fatty acids (LC-PUFAs) and exposure to physico-chemical contaminants in subjects who consumed large amounts of seafood products and confirmed these recommendations.

However, specific recommendations concerning the consumption of wild predatory fish likely to contain non-negligible amounts of methylmercury (MeHg) were also proposed by AFSSA for pregnant and breastfeeding women and for children under the age of 30 months because of the central nervous system's particular sensitivity to the toxic action of MeHg in the development period (AFSSA 2002, AFSSA 2006b, AFSSA 2009a). Moreover, with respect to polychlorinated biphenyl (PCB) contamination in fish, AFSSA recommended that women of childbearing age and children under the age of 3 years eat a variety of fish, avoiding, as a precautionary measure, the exclusive consumption of fatty fish from PCB-contaminated fishing zones (AFSSA 2007).

A working group on 'Dietary intakes related to the consumption of fish, molluscs and shellfish; human health risks' produced a report (under finalisation) that also contains new data likely to contribute to the debate on the analysis of benefits and risks related to seafood consumption.

In light of all of this work, AFSSA has been requested to assess the benefit/risk ratio of fish consumption and to make, if necessary, new consumption recommendations for the most sensitive population groups and possibly for the general population.

3. Expert assessment method

The expert assessment was conducted on the basis of:
- an analysis by the 'Physico-Chemical Risk Assessment', 'Nutrition and Nutritional Risk Assessment' and 'Quantitative Physico-Chemical Risk Assessment' units of information available on:

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i) the chemical risks and nutritional benefits of fish consumption, and
ii) dietary exposure data specific to the French population,

- then a collective expert assessment undertaken by the Scientific Panel on 'Human nutrition' which met on 29 January 2010 and the Scientific Panel on 'Physical and chemical contaminants and residues' which met on 26 October 2009 and 13 January 2010.

4. FISH CONSUMPTION LEVELS IN FRANCE

According to the data from the INCA2 study (AFSSA 2009b),

- More women consume fish than men (82% vs. 77%). Mean consumption levels (± standard deviation) are 26.6±27.8 g/day for men and 26.5±22.4 g/day for women, or slightly less than 2 servings per week[1]. Fish are more frequently consumed by elderly subjects, more specifically as part of their midday meal. People consume fish preferentially at home (73.8±1.1% vs. 26.2±1.1% away from home). The mean consumption level increases with the consumer's education level (primary school 21.4±1.7 g/day; middle school 23.7±0.9 g/day; high school 30.9±1.3 g/day; higher education 29.5±1.0 g/day).
- In children, mean consumption levels are 19.3±19.0 g/day for boys and 17.2±16.2 g/day for girls, or slightly less than 2 servings per week**Erreur ! Signet non défini.**. Like adults, children consume fish preferentially at home (64.6±1.4% vs. 35.4±1.4% away from home).
- Overall, fish consumption has stagnated since 1998 (Volatier 1999, AFSSA 2009b).

The data from the ENNS 2006 study show that around 30% of adults and children consume fishery products at least twice a week, and this is comparable for both genders (InVS 2007).

5. BENEFIT-RISK ASSESSMENT METHODOLOGIES

Foods are vectors of essential nutrients for our metabolism but can also be vectors of chemical contaminants. To protect consumer health, a balance must therefore be maintained between the benefits and risks of consuming some food groups. To do so, it is necessary first to prevent the onset of nutritional imbalances and second to limit exposure to some chemical contaminants in populations, particularly during the critical period of gestation.

Most of the time, the following are assessed separately:

1. the nutritional benefit which is defined as an increase in the amplitude of a positive effect on human health and/or a decrease in a harmful effect on human health,
2. the toxicological risk which is defined as the likelihood that a harmful effect on human health will occur.

This separation is related to approach and analysis methodologies that are specific to the two disciplines of nutrition and toxicology, and to the difficulty in obtaining valid scientific data concerning benefits, risks and exposure levels for foods and contaminants.

Several approaches for simultaneously assessing the risks and benefits of exposure to one or more factors (environmental, dietary, etc.) have nevertheless been developed in populations (DALY and QALY[2]). These analyses use models that require knowledge of both:

[1] According to the INCA2 data, an average serving is around 100 g for adults and around 75 g for children.
[2] DALY (*Disability-Adjusted Life Year*): Approach based on the development of an indicator combining mortality and morbidity in populations, expressed in disability-adjusted life years. QALY (*Quality-Adjusted Life Year*): approach based on the development of an indicator combining years lived in perfect health with years lived in a given health state (trade-off between quantity and quality of life).

- levels of beneficial and harmful components
- effect indicators (mortality, disease).

These approaches are particularly complex to apply to the analysis of dietary factors, because of:

- uncertainty surrounding the relationships that exist between dietary intakes, dietary exposure and health effects,
- the coexistence of several protective nutrients and the high variability of levels of physico-chemical contaminants potentially found in foods,
- insufficient knowledge of the way in which these compounds interact,
- scientific and social difficulties expressing observed effects in terms of extra life-years or life-years lost.

The simplest and most commonly used approaches to assess benefits/risks in human nutrition rely on the use of the following reference values:

- Dietary Reference Intakes (DRIs), for benefits related to nutrients (see Section 6.2.2 below),
- Human Toxicity Values (HTVs), for risks related to hazards (Annex 1).

Two types of stepwise approach are implemented that assess risks then benefits or benefits then risks.
The first consists in: i) estimating, in light of food contamination data, the 'no-risk' consumption level for the various population groups[3] and ii) comparing dietary intake of the nutrient(s) in question with the DRI.
The second consists in: i) estimating, in light of food composition data, the consumption level which meets the DRIs and ii) comparing dietary exposure with the HTV(s) for the hazard(s) in question.

Risk-benefit analyses can be undertaken using several statistical approaches, some of which take into account the variability of consumption and contamination data. Risk is then expressed as the likelihood of exceeding the HTV by consuming foods that meet the DRIs.
This type of approach was used by Sioen *et al.* to assess the respective benefits/risks of intakes of n-3 LC-PUFAs and of dioxins and Dioxin-Like (DL) PCBs from fish (Sioen *et al.* 2007; Sioen *et al.* 2008a; Sioen *et al.* 2008b).

However, these approaches remain theoretical and when an HTV is exceeded, it does not systematically correspond to the onset of harmful effects in humans namely because of safety factors that are applied on the basis of observations made from animal models.
Available human data should therefore be given priority when they exist, particularly when determining a critical contamination threshold (i.e. the level of bodily contamination below which no harmful effects are observed in humans).

6. THE BENEFITS OF FISH CONSUMPTION

This section summarises the data that are currently available on the beneficial effects that fish consumption has on human health. Further information can be found in summaries of the literature that have been compiled in the framework of other general studies by AFSSA (AFSSA 2010a, AFSSA 2010b, AFSSA 2010c).

6.1. Nutritional composition of fish

[3] This refers to the consumption level that does not exceed the HTV, which is usually determined on the basis of animal testing data.

Apart from their high protein content, fish are preferred sources of omega-3 long-chain polyunsaturated fatty acids (n-3 LC-PUFAs) and valuable sources of fat-soluble (A, D, E) and water-soluble (B_6, B_{12}) vitamins, minerals and trace elements.

In a given species, the amount of protein in fish flesh does not vary much, since this flesh does not undergo modifications related to the animal's age or diet or the catch season.

Fats and fatty acids are the nutrients whose levels vary the most between fish species, according to the season, the reproduction cycle and the animal's diet: for example, for sardines, the muscle's fat content varies from 1.2 to 18.4 g per 100 g over the course of the year (Bandarra *et al.* 1997). The most frequently consumed fish species in France are: 'yellowfin' tuna, Alaska pollock, pollock, hake, cod and tilapia for so-called lean species (the flesh's fat content is less than 2 g/100g); and salmon, herring and sardines for so-called fatty species. Albacore tuna, bluefin tuna and trout each have intermediate fat content (Sainclivier 1983).
Fish are preferred sources of n-3 LC-PUFAs, particularly eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA).
In general, the fattier the fish's flesh, the more EPA and DHA it contains. The respective proportion of these two fatty acids varies according to species, but levels of DHA are generally higher than those of EPA. The n-3 or n-6 PUFA content of fish flesh almost exclusively depends on the animal's diet, i.e. the aquatic food chain (algae, phytoplankton and zooplankton) for wild fish, and feed constituents (mainly oils) for farmed fish (Corraze and Kaushik 1999).

Vitamin A, D and E levels are proportional to the flesh's fat content. For example, tuna, whose red muscle is particularly developed, and herring, whose flesh is fatty, contain significant amounts of vitamins A and D. In farmed fish, the muscle's vitamin E content increases with the feed's vitamin E content (added for its antioxidant properties, particularly against LC-PUFAs) and the level of malondialdehydes (products of lipid peroxidation) is inversely proportional to the flesh's vitamin E content (Frigg *et al.* 1990).

Fish flesh is rich in vitamin B_{12}. Fish contains more vitamin B_6 than any other food of animal origin. It also contains other group B vitamins, but in lesser quantities.

The main minerals and trace elements found in fish are potassium, phosphorus, selenium, iodine, iron and zinc. The levels of these various elements vary according to the composition of the fish's diet.

6.2. Fish consumption and nutritional benefits

6.2.1 Fish consumption and human health

Most of the studies that have analysed the impact that fish consumption has on human health have essentially examined n-3 LC-PUFAs (EPA and DHA), which are considered to be the main compounds of interest in fish flesh.
A summary of these studies is given in Annex 2. It shows the importance of the n-3 LC-PUFAs EPA and DHA, and of fish consumption more generally, in terms of human health. These beneficial effects are related both to brain development and function and to the reduction of disease risk. While some of these beneficial effects (cardiovascular) have been clearly proven, others are underpinned by several epidemiological arguments based on observations or animal studies (neurodegenerative diseases, cancers, age-related macular degeneration (AMD)) and need to be confirmed by prospective studies or human interventions.

6.2.2. Dietary reference intakes of n-3 long-chain polyunsaturated fatty acids

On the basis of the data in the literature related to dietary requirements and to the consequences of an imbalanced intake of these fatty acids in terms of pathological mechanisms, AFSSA is proposing the following dietary reference intakes for the various age groups (AFSSA 2010a).

Table 1: Dietary reference intakes of DHA and EPA for the French population

Age group	DHA (mg)	EPA+DHA (mg)
Young children aged 1-3 years	70	-[a]
Children 3-9 years	125	250
Adolescents 10-18 years	250	500
Adults, including elderly subjects	250	500
Pregnant women	250	500
Breastfeeding women	250	500

[a] *There are no scientific data that can be used to define this age group's EPA requirements.*

Dietary reference intakes (DRIs) are average reference values established by nutrient and population group in order to meet average dietary requirements.
For essential and 'conditionally essential'[4] fatty acids (FAs) like DHA, physiological requirements correspond to the intake needed:

- to avoid any dietary deficiency of these FAs and ensure the proper functioning of the entire body, and especially brain development and function; this refers to *minimum physiological requirements*;
- and for physio-pathological prevention: metabolic syndrome, diabetes, obesity, cardiovascular diseases, cancers (namely breast and colon) and other diseases such as AMD; this refers to *optimal physiological requirements* (primary prevention) (AFSSA 2010a).

Several approaches are used to establish physiological requirements: cellular and animal models, human physiological approaches, food studies, clinical and epidemiological approaches. The relative weight of each of these approaches varies from one nutrient to another and according to the scientific and nutritional context (Martin et al. 2001).

7. THE CHEMICAL RISKS OF FISH CONSUMPTION

For many years, fish have been considered to be potential vectors of toxic substances (AFSSA 2006a, AFSSA 2010c).

In light of:

- the dietary habits of the population in mainland France;
- data on seafood contamination that are available in France and Europe;
- and available toxicological data;

it appears that fish are non-negligible vectors of arsenic (As), methylmercury (MeHg), PCB, dioxin/furan (PCDD/F) and polybrominated diphenyl ether (PBDE) intake (Annex 3).

7.1 Arsenic and polybrominated diphenyl ethers

According to the available toxicological data and contamination data related to fish that are caught and consumed in France and Europe (AFSSA 2006a, AFSSA 2009c, EFSA 2009), the health impact of arsenic contamination is not currently considered to be of concern because fish

[4] Some PUFAs are so-called 'essential' precursors (linoleic acid, C18: 2 n-6 and alpha-linoleic acid, C18:3 n-3) because they are essential for growth and physiological functions and cannot be synthesised by humans. The derivatives of these essential precursors are said to be 'conditionally essential' since humans and animals can synthesise them (as long as they have the essential precursor FAs). The other FAs (other polyunsaturated, monounsaturated and saturated FAs) are nutrients that can be synthesised *de novo* by the human body.

are minor sources of exposure to inorganic arsenic (iAs), which has been proven to be the most toxic.

With respect to PBDEs, fish and seafood products have been identified as the main vectors of dietary intake (30 to 60% of total exposure). However, because there are insufficient data on contamination in other dietary vectors that could also contribute to dietary exposure (meat, poultry, milk, etc.) and since there is no human toxicity value, it is not currently possible to undertake a precise risk assessment (AFSSA 2006c). The contribution of fish and seafood products to total exposure in France is however of the same order of magnitude as reported in other European countries and falls below the intake levels that are considered to be no-effect on the basis of available toxicity data in animals, which have been weighted out of precaution by a protection factor of 100 (AFSSA 2010c).

7.2 Methylmercury

On the other hand, fish appear to be the leading vectors of exposure to methylmercury (MeHg).

Because the central nervous system is highly vulnerable to the toxic action of MeHg during foetal development, and since the HTV (Provisional Tolerable Weekly Intake) of 3.3 µg of MeHg/kg b.w./week proposed by the Joint FAO/WHO Expert Committee on Food Additives (JECFA) was lowered to 1.6 µg/kg b.w/week in 2003, AFSSA proposed specific food consumption recommendations in its Opinion of 16 March 2004 for young children and for pregnant and breastfeeding women (AFSSA 2004). These recommendations promoted the consumption of a variety of fish species, and as a precautionary measure advised against the exclusive consumption of wild predatory fish[5], which have higher levels of MeHg. They especially recommended, respectively for children aged 0-30 months and for pregnant and breastfeeding women, not consuming more than 60 g or 150 g of wild predatory fish per week and avoiding, as a precautionary measure, the consumption of swordfish, marlin and siki (AFSSA 2006b).

In light of MeHg contamination data from 91 analyses that were undertaken in lampreys and selachians in 2007, AFSSA extended the list of fish species to be avoided for these population groups to sharks and lampreys (AFSSA 2009a).

Furthermore, it was indicated that some specific groups in the French population, namely the American Indian population of French Guiana, may be exposed to much higher levels of MeHg than the mainland population primarily because of significant pollution of human origin (gold washing, for example) and a diet that essentially consists of fish.

7.3 Dioxins and PCBs

With respect to dioxins (PCDD/F) and PCBs (DL-PCBs and NDL-PCBs), in France and in other European countries, dietary exposure levels are likely, independently of fish consumption, to exceed the HTVs that were set respectively at 70 pg TEQ_{WHO}/kg b.w./month[6] for dioxins and DL-PCBs by JECFA in 2001 and at 20 ng/kg b.w./day for all PCB congeners by WHO in 2003.

Although fish are not the dominant dietary vectors of exposure to dioxins, they significantly contribute to dietary exposure to PCBs (38% of total exposure), particularly in children[7] (AFSSA 2005, Annex 4).

[5] Predatory fish (Regulation EC no. 1881/2006): Anglerfish (*Lophius species*), Atlantic catfish (*Anarhichas lupus*), bonito (*Sarda sarda*), eel (*Anguilla species*), emperor, orange roughy, rosy soldierfish (*Hoplostethus species*), grenadier (*Coryphaenoides rupestris*), halibut (Hip*poglossus hippoglossus*), marlin (*Makaira species*), megrim (*Lepidorhombus species*), mullet (*Mullus species),* pike (*Esox lucius*), plain bonito (*Orcynopsis unicolor*), poor cod (*Tricopterus minutus)*, Portuguese dogfish (*Centroscymne coelolepis*), rays (*Raja species*), redfish (*Sebastes marinus*, *S. mentella*, *S. viviparus*), sail fish (*Istiophorus platypterus*), scabbard fish (*Lepidopus caudatus*, *Aphanopus carbo)*, seabream, pandora (*Pagellus species*), shark (all species), snake mackerel or butterfish (*Lepidocybium flavobrunneum*, *Ruvettus pretiosus, Gempylus serpens)*, sturgeon (*Acipenser species*), swordfish (*Xiphias gladius*), tuna (*Thunnus species*, *Euthynnus species*, *Katsuwonus pelamis*)

[6] TEQ: Toxic EQuivalent. The toxic equivalents of all the mixture's constituents are added together to give the overall TEQ.

[7] When HTVs (expressed by kg of body weight) are exceeded in young children, the latter's low body weights and dietary consumption should be taken into consideration.

Because of the various toxic effects of PCBs (DL-PCBs and NDL-PCBs) that have been reported both in animals and in humans, and especially because of their known effects on the cerebral and motor development of children exposed *in utero*, special attention should be paid to PCB contamination levels in fish and especially in fish originating in current or former industrial zones[8].

At the present time, the regulatory limits that have been established in Europe for marketed fish species (Regulation (EC) no. 1881/2006) concern only DL-PCBs+PCDD/F (total TEQ) and their main objective is to remove the most contaminated fish from the market. Discussions are however underway, in Europe, to propose regulatory limits of NDL-PCBs in foods.
Since 2006, several fishing restrictions and recommendations to not consume the fish species with the highest PCB levels (eel, fatty fish, high bioaccumulating species) have been introduced, on the basis of the current regulations, particularly in the Rhône, Somme, Seine and Garonne sectors.
A national inventory of at-risk sites (PCB measurements in sediments and fish) was also undertaken in early 2008 in the framework of the national PCB action plan.

8. Benefits/risks of fish consumption

Fish consumption recommendations should take into account the need to meet beneficial nutrient requirements while laying down food safety conditions for consumers. Only chemical risks likely to induce long-term health effects (and not microbiological or accidental risks) have been considered in this Opinion.

Furthermore, the benefit/risk assessment was undertaken on the basis of available data at the time of publication for nutrients and contaminants whose exposure levels are mainly related to fish consumption, i.e.: i) EPA and DHA for nutritional benefits and ii) methylmercury, dioxins and PCBs for physico-chemical risks.

8.1 Estimate of n-3 long-chain polyunsaturated fatty acid intakes and exposure to methylmercury, dioxins and PCBs in the French population according to the number of fish consumed.

- ***Methodology***

Average EPA and DHA intakes, and exposure to methylmercury, dioxins and PCBs, were estimated for the general population (Annex 5) on the basis of French consumption data from the INCA2 study (2005-2007). This study, which was representative of the French population, recorded the food consumption of 4,079 individuals (2,624 adults aged 18 to 79 years, and 1,455 children aged 3 to 17 years).
The levels presented here correspond to intake and exposure levels related to the consumption of all fish and aquatic products, including when used as ingredients. Other foods were not used to calculate EPA and DHA intakes or methylmercury exposure, since they are insignificant vectors. However, for exposure to dioxins and PCBs, the calculation took into account the consumption of meat, eggs and dairy products, which are other non-negligible intake sources.

For the calculation of EPA and DHA intakes, consumption data were cross-referenced with composition data from the CIQUAL food composition table (AFSSA 2008). Processed fish-based products (fish mousses and terrines, taramasalata, etc.) were not taken into account in this assessment, since the compositions of the fish mixtures used vary considerably.
For the calculation of exposure to contaminants, consumption data were cross-referenced i) for seafood products, with contamination data from the CALIPSO study (AFSSA 2006a) and ii) for other animal products, with data from DGAI surveillance plans (2004-2006).

[8] For more information, refer to previous AFSSA Opinions on PCBs, which are available on the following website: www.afssa.fr

Several weekly fish consumption frequencies (servings of fish consumed), as observed in the INCA2 study, were examined[9]:

- 1 fish
- 2 fish including 1 fatty fish
- 2 fatty fish
- 3 fish including 1 fatty fish
- 3 fish including 2 fatty fish

The serving used for the calculations corresponded to the average serving consumed by the French population in the INCA2 study, i.e. 100 g for adults and children over the age of 10 years and 75 g for children aged 3 to 10 years.

The fat content used to distinguish between ‘fatty’ and ‘non-fatty’ (so-called 'lean') fish was set at 2%.

- ***Estimate of exposure to Dioxins, PCBs and Methylmercury***

The estimation of exposure and intake for MeHg, dioxins and PCBs (Annex 5) shows that:

- exposure to MeHg in the population of mainland France (children and adults) is lower than the HTV, with the exception of some categories of children who consume large amounts of fish (95th percentile) (AFSSA 2004);
- average exposure to dioxins and PCBs in children aged 3 to 10 years is higher than the HTV, independently of fish consumption;
- consumption of 3 servings of fish per week leads to exposure levels that are higher than the HTVs set for dioxins and PCBs in almost all of the population’s age groups;
- exposure to PCBs increases with the number of fish consumed and *a fortiori* with the number of fatty species consumed, which is mainly due to the large contamination differences that can be observed between fatty fish and lean fish.

- ***Estimate of intakes of n-3 long-chain polyunsaturated fatty acids***

As expected, EPA and DHA intakes increase essentially with fish consumption frequency and *a fortiori* with fatty fish consumption frequency.
Average EPA+DHA requirements (250 mg/day for children aged 3-9 years and 500 mg/day for children aged 10 years and older and adults) are met at a rate of 48 to 68% and 61 to 98% for a weekly fish consumption frequency of 2 and 3 servings respectively.

Nevertheless, the available data show that foods other than fish, especially eggs and animal products, also contribute to around 15-20% of total EPA and DHA intake because of their high level of consumption in Western countries (Astorg *et al.* 2004; Howe *et al.* 2006; Sioen *et al.* 2006).

- ***Conclusions***

These exposure data show that if two or more fish are consumed per week, including one or two fatty fish, for some population groups, the HTVs for PCBs and dioxins may be exceeded.
The number of fish consumed and the fat content of fish (‘fatty’ vs. ‘lean’ fish) are therefore not sufficient indicators to establish fish consumption recommendations to meet EPA and DHA requirements while limiting exposure to contaminants.

8.2 Consideration of the nature of fatty acids in fish species for the benefit/risk assessment.

Given the nutritional benefits of fish, it was necessary to consider, in addition to fat content, the nature of the fatty acids contained in fish. In fact, for the same fat content, fish can have very

[9] Salmon consumed as an ingredient in a tart is not counted as a fish serving.

different EPA and DHA levels. For example, with an equivalent total fat content of around 4 g/100 g, dogfish and mackerel have EPA and DHA content of 0.1-0.2 mg/100 g and 2-4.5 g/100g respectively.

Table 2 below classifies fish according to their EPA and DHA content.

Table 2: Classification of various fish species according to their EPA and DHA content

Total fat content	Omega-3 EPA and DHA*** content	Fish species
Fatty fish (>2%)	High (3 g/100g)	Salmon*, Sardines*, Mackerel*, Herring*, Smoked trout**
	Medium (1.4 g/100g)	Goatfish, Anchovies, Pilchard Sea Bass, Trout, Sea Bream, Turbot, Smelt, Pike, Halibut,
Lean fish (<2%)	Low (0.3 g/100g)	Tuna (canned), Pollock, Cod, Whiting, Sole, Ling, Ray, Hake, Monkfish, Plaice, Dab

** any preserving method (fresh, deep-frozen, smoked, canned, etc.)*
*** smoked trout is not the same species as 'traditional' river trout*
**** The contents given are estimates established on the basis of data collected by CIQUAL, including data from the CALIPSO study and the NUTRAQUA project as well as data from the international literature. Natural variability is expected around these estimates. In fact, the size of fish, the reproduction cycle period, the sample location, the fillet sample area (ventral or dorsal, anterior or posterior) and farming conditions for aquaculture products can influence the nutritional composition of aquatic products to varying degrees.*

On the basis of data related to:

- EPA and DHA levels in the CIQUAL food composition table,
- the contamination results reported in the CALIPSO study and surveillance plans;
- the average fish serving sizes reported in the INCA2 study;
- levels that exceed the HTVs set for dioxins and PCBs in almost all population groups, for fish consumption greater than or equal to two servings per week including one or two fatty fish;
- and considering that 15-20% of dietary intake of EPA and DHA come from foods other than fish, and especially from terrestrial animal products;

a 'no-risk' consumption approach was implemented. Further to this analysis, a list of fish species whose consumption meets EPA and DHA requirements while limiting the risk of exceeding the HTVs set for dioxins and PCBs and for MeHg was defined (Table 3).

In light of this analysis, it appears that (Tables 2 and 3):

- fish rich in n-3 LC-PUFAs (medium and high EPA and DHA content) belong to the so-called fatty fish category;
- consumption of 1 or 2 servings/week of some of these species meets EPA and DHA requirements while limiting the risk of exceeding the HTVs;
- consumption of more than two fish rich in n-3 LC-PUFAs (medium and high EPA and DHA content) per week exceeds the HTVs set for dioxins and PCBs in almost all age groups in the population;
- consuming only lean fish species (low EPA and DHA content) does not meet n-3 LC-PUFA requirements, irrespective of the population group (Annex 5).

Table 3: Fish consumption scenarios that meet nutritional EPA and DHA requirements, while limiting exposure to dioxins and PCBs

Fish consumption scenario		Population groups	
		Adults and children over the age of 10 years, women of childbearing age, pregnant women, breastfeeding women	**Children aged 3 to 10 years**
Option 1	1 serving/week	Salmon*, Sardines*, Mackerel*, Herring*, Smoked trout**	Salmon*, Sardines*, Mackerel*, Herring*, Smoked trout**, Goatfish, Anchovies, Pilchard
Option 2	2 servings/week	Goatfish, Anchovies, Pilchard	Sea Bass, Trout, Sea Bream, Turbot, Smelt, Pike, Halibut
Option 3	1 serving/week	Salmon*, Sardines*, Mackerel*, Herring*, Smoked trout**	Salmon*, Sardines*, Mackerel*, Herring*, Smoked trout**, Goatfish, Anchovies, Pilchard
	And 1 serving/week	Sea Bass, Trout, Sea Bream, Turbot, Smelt, Pike, Halibut, Goatfish, Anchovies, Pilchard, Tuna (canned), Pollock, Cod, Whiting, Sole, Ling, Ray, Hake, Monkfish, Plaice, Dab	Sea Bass, Trout, Sea Bream, Turbot, Smelt, Pike, Halibut, Tuna (canned), Pollock, Cod, Whiting, Sole, Ling, Ray, Hake, Monkfish, Plaice, Dab

** any preserving method (fresh, deep-frozen, smoked, canned, etc.)*
*** smoked trout is not the same species as 'traditional' river trout*

Moreover, the analysis of the various fish consumption scenarios shows that options 1 and 2 (Table 3), while they sufficiently meet nutritional EPA and DHA requirements, are difficult to reconcile with a sufficiently diverse diet and individual preferences (some species such as anchovies, goatfish and pilchard are not heavily consumed by the French population).

However, option 3: i) meets EPA+DHA requirements, ii) limits the risk of over-exposure to contaminants and iii) ensures the sufficiently diverse consumption of various fish species. It therefore appears to be the most relevant option on which to base fish consumption recommendations for the French population.

Furthermore, adherence to these fish consumption recommendations would improve average dietary intakes of vitamin D (i.e. vitamin D status) since it would ensure an average intake of around 2.3 µg/day for children and 3.3 µg/day for adults, or a 36 and 27% increase respectively in the dietary intakes currently estimated for these two categories of the French population.
For information, around 2/3 of vitamin D intake comes from cutaneous sun exposure, and fatty fish are the main dietary source (30% of dietary intake with a vitamin D content that is around 10 times higher than other foods, including foods that are enriched for public health purposes).

8.3 Results of the various approaches to assessing the benefits and risks of fish consumption

Whether they come from theoretical exposure calculations or epidemiological data, the results reported in the international literature are consistent with the results given in this Opinion and identify MeHg, dioxins and PCBs as the most critical food contaminants in relation to fish consumption.

As for MeHg, with the exception of pregnant women and young children, who are advised not to consume certain predatory fish species, the benefits of fish consumption appear to outweigh the risks (Ginsberg and Toal 2008; Hibbeln *et al.* 2007; Oken *et al.* 2008; Verger *et al.* 2008, FAO/WHO 2010).
However, the risk of over-exposure of the population to PCBs from fish consumption has been proven due to the high contamination levels in some 'bioaccumulating' species and the non-negligible contribution of other dietary vectors (meat and dairy products) (Sioen *et al.* 2008a; Verger *et al.* 2008).
In light of the nutritional and especially cardiovascular benefits of fish consumption, several specific consumption recommendations have therefore been issued on the international level.
These recommendations generally aim to limit weekly fish consumption to 2 servings per week and to promote the consumption of certain species rich in n-3 LC-PUFAs (Issfal 2007) while limiting the consumption of fish species from areas with the highest PCB contamination levels or that may have high levels of MeHg (Domingo *et al.* 2007, FAO/WHO 2010).

9. Conclusions

Considering on the one hand:

- that fish are a preferred source of n-3 long-chain fatty acids (n-3 LC-PUFAs), fat-soluble (A, D, E) and water-soluble vitamins (B_6, B_{12}), minerals and trace elements (potassium, phosphorus, selenium, iodine, iron and zinc);
- that the effect of n-3 LC-PUFAs, particularly of EPA and DHA, and more generally of fish consumption, on human health is currently proven in terms of the reduction of cardiovascular risk, development of the brain and brain function;
- that fat and n-3 LC-PUFA content varies significantly between fish species and according to the season, the reproduction period and the fish’s diet.

Considering on the other hand:

- that fish are considered to be major contributors to dietary exposure to dioxins, PCBs and MeHg;
- that high PCB contamination levels have been observed in some so-called bioaccumulating fish species;
- that the central nervous system is particularly vulnerable to the toxic action of chemical contaminants and especially of MeHg and PCBs during the perinatal period;
- that there is a high risk of over-exposure to dioxins, PCBs and MeHg in children;
- that contamination levels vary significantly between the various fish species and according to their origin;

AFSSA therefore recommends, for the entire population and as part of a balanced diet, consuming 2 servings of fish per week, including one with high EPA and DHA levels, and varying the species and source (wild, farmed, fishing location, etc.). This consumption optimally meets nutritional requirements while limiting the risk of over-exposure to chemical contaminants.

As for women of childbearing age, pregnant women and breastfeeding women, and for children under the age of 3 years, young girls and teenage girls, AFSSA recommends avoiding, as a precautionary measure, the consumption of so-called PCB bioaccumulating fish, and particularly eel, barbel, bream, carp and catfish.

Pregnant women, breastfeeding women and children under the age of 3 years are advised to limit their consumption of wild predatory fish and to avoid, as a precautionary measure, the consumption of swordfish, marlin, siki, shark and lamprey because of the risk related to MeHg.

To help consumers make choices, AFSSA will publish on its website the list of fish and their characteristics, as well as consumption options, so as to bring these recommendations into line with each consumer's dietary habits and preferences.

The Director General

Marc MORTUREUX

ANNEX 1

Human Toxicity Values

Human Toxicity Values (HTVs) are values used to establish a relationship between exposure to a chemical substance and a human health effect. They are specific to a substance, an exposure time (acute, subchronic or chronic), an exposure route (inhalation, oral, skin contact) and a population group. Moreover, their establishment differs according to the hypothesis or data related to the substance's mechanisms of toxic action.
For example, in most cases, when a substance is known to have a direct impact on human genetic material (DNA), it is considered that the adverse effects that may be caused by exposure to this substance can occur even at the smallest dose received, and that the likelihood that this effect will occur increases with the dose. This is referred to as the 'non-threshold dose HTV' or 'non-toxic threshold dose HTV'.
If a substance has no direct impact on human genetic material, it is considered that the adverse effect occurs above a certain dose and it is the severity of the effect that increases with the dose rather than the likelihood it will occur. This is referred to as the 'threshold dose HTV' or 'toxic threshold dose HTV'.

'Threshold dose HTVs' are generally expressed as acceptable or tolerable daily intakes or concentrations (ADI, TDI, CAA, FCR), or reference doses or concentrations (RfD or RfC).
'Non-threshold dose HTVs' are generally expressed as unit risk values (DWUR, IUR, SF, CR, etc.).

The establishment of these HTVs follows a highly structured and demanding approach that involves collective assessments by expert groups. In practice, the definition of an HTV includes the following four stages:

- choice of the critical effect;
- choice of a high-quality scientific study to establish a dose-response (or dose-effect) relationship;
- choice or establishment of a critical dose on the basis of experimental doses and/or epidemiological data;
- application of safety factors to the critical dose to take into account variability and uncertainties.

ANNEX 2

Fish consumption and nutritional benefits

This summary was written on the basis of the AFSSA report on the update of French population reference intakes for fatty acids (AFSSA Opinion of 1 March 2010).

Fish consumption and cerebral and visual development

Studies specifically investigate the effects of the LC-PUFAs EPA and DHA on nervous system development in foetuses (mother's diet during pregnancy) and in young children (breastfeeding).
The incorporation of n-3 LC-PUFAs, and specifically DHA, in the cerebral membranes (brain, retina) is essential to the anatomo-functional development of the central nervous systems of foetuses and newborns. In fact, DHA is involved in multiple cell functions in which lipid mediators such as docosanoids play a role. This PUFA is incorporated massively into the brain between the 3rd trimester of pregnancy and the first 2 years of life and is linked to neural development (Cetin and Koletzko 2008; Clandinin *et al.* 1980a; b; Koletzko *et al.* 2008; Martinez and Mougan 1998).

The clinical studies that have been undertaken in pregnant women clearly demonstrate that DHA supplementation in pregnancy increases relative plasma concentrations in mothers and in newborns (Al *et al.* 2000; Connor *et al.* 1996; Dunstan *et al.* 2004; Innis and Friesen 2008; Krauss-Etschmann *et al.* 2007). Data taken from correlation studies consistently indicate a direct relationship between the DHA blood levels of the mother or infant at birth and the child's visual (electroretinogram, visual acuity) and cognitive (habituation) development during the first 2 years (Colombo *et al.* 2004). However, while it has been demonstrated that supplementation is justified in the event of a deficiency, these studies do not indicate the longer-term neurofunctional benefits of systematic LC-PUFA supplementation for foetuses and newborns.
Dietary DHA intake in pregnancy also 1) increases the mother's reserves, which are necessary to transfer this FA to the breast milk (Dunstan *et al.* 2007) and to the foetus in the event of a subsequent pregnancy (Al *et al.* 2000) and 2) increases the newborn's bodily reserves, which partially meet its requirements in the first few months of life.
Therefore, DHA intake via the mother's diet during pregnancy and breastfeeding, and in the first few years of life, is a key parameter for cerebral development and maturation in newborns and young children.

Fish consumption and cardiovascular diseases

Available data come from epidemiological observation studies and clinical trials with supplements (generally fish oil) aiming to assess the effects that n-3 LC-PUFA, EPA and DHA consumption has on cardiovascular risk factors or the occurrence of cardiovascular events.

Several meta-analyses from epidemiological observation studies highlight inverse associations between fish consumption or tissue content of n-3 LC-PUFAs and the occurrence of cardiovascular events (cerebrovascular accidents, ischemic heart disease, sudden death) (He *et al.* 2004a; He *et al.* 2004b; Wang *et al.* 2006). These associations appear to be more pronounced for fatal coronary events.

Intervention trials using supplements confirm the results of observation studies, showing a decrease in fatal coronary events in coronary patients who consume fish or take EPA and DHA supplements.
The consumption of fish oil or EPA and DHA supplements has overall positive or neutral effects on major cardiovascular risk factors (decrease in plasma triglycerides, increase in HDL-cholesterol, stability of total cholesterol, decrease in systolic and diastolic blood pressure) (Balk *et al.* 2006; Dickinson *et al.* 2006; Geleijnse *et al.* 2002). Observed effects depend on the amount of fatty acids ingested.
A secondary prevention trial in patients having suffered a heart attack showed a decrease in fatal cardiovascular events in subjects who received nutritional advice to increase their fish consumption to twice a week compared to the control group (Burr *et al.* 1989).
Secondary prevention trials and trials undertaken in subjects with high cardiovascular risk (hypercholesterolaemic) with n-3 LC-PUFA supplements (GISSI, DART II, JELIS studies) have

shown a decrease mainly in fatal coronary events, in patients with and without histories of myocardial infarctions (Burr *et al.* 2003; Marchioli 1999; Marchioli *et al.* 2002; Yokoyama and Origasa 2003; Yokoyama *et al.* 2007). These results are fairly consistent, suggesting that EPA and DHA reduce the fatal complications of myocardial infarctions (Mozaffarian and Rimm 2006).
Studies have shown that fish oil and the n-3 LC-PUFAs EPA and DHA have a proven impact on heart rate, a risk factor for sudden death (Mozaffarian *et al.* 2005). However, patients with histories of ventricular dysrhythmia, especially with non-ischemic heart disease, do not appear to benefit from treatment with these fatty acids to prevent relapses (Brouwer *et al.* 2006; Geelen *et al.* 2005; Geelen *et al.* 2004; Jenkins *et al.* 2008; Raitt *et al.* 2005).
N-3 LC-PUFAs do not help prevent heart failure relapse (Tavazzi *et al.* 2008).

On the basis of these data, Mozaffarian and Rimm proposed a model of the relationship between the consumption of fish and/or EPA-DHA and cardiovascular benefits (Mozaffarian and Rimm 2006), with the latter depending on assessed parameters (decrease in sudden deaths, decrease in cardiovascular mortality, triglyceride lowering).
In the end, a daily intake of 500 mg of EPA and DHA (or 0.2-0.225% of adult total energy intake) seems justified for the general population for the purposes of cardiovascular prevention.

All of these conclusions were made in the framework of studies among adult subjects. Despite the fact that there are currently no specific data from similar intervention trials or prospective follow-up studies in children, it is reasonable to think that the consumption of the n-3 LC-PUFAs DHA and EPA (and therefore fish) during childhood and adolescence is likely to have the same beneficial cardiovascular effects as those expected during adulthood. This hypothesis is backed by the fact that atherosclerosis lesions can appear during childhood and adolescence (Berenson *et al.* 1998; McGill *et al.* 2000) and that their progression and severity are linked not only to the existence of cardiovascular risk factors but also to their persistence over time (McGill *et al.* 2000; Stary 2000).
Moreover, data have shown a decrease in cardiovascular risk in children from at-risk families who receive n-3 LC-PUFA, EPA and DHA supplementation (Engler *et al.* 2004).

Fish consumption and development of other diseases: cancers, metabolic diseases, age-related neurodegenerative disorders

- ***Cancers***

Prostate cancer
The conclusion in the AFSSA report on relationships between fatty acids and cancers (AFSSA 2003) indicated that: "the consumption of fish or of n-3 long-chain PUFAs (EPA, DHA) is not related, in the majority of studies, to the risk of prostate cancer, although some studies suggest a protective effect". Recent studies (Chavarro *et al.* 2007; Hedelin *et al.* 2007) have been fairly heterogeneous, yet more studies currently show risk reduction than in 2003, which reinforces the suggestion of a probable positive effect of fish consumption in prostate cancers.

Colorectal cancer
In the AFSSA report (2003), tables of epidemiological data showed risk reduction in around half of studies that examined the relationship between fish consumption and colorectal cancers, while the others showed no effect; two Chinese studies showed increased risk. Several recent studies based on a food questionnaire and a meta-analysis of fish consumption suggest the possibility that fish and n-3 LC-PUFAs may have a protective effect against the onset of colorectal cancer (Geelen *et al.* 2007; Kimura *et al.* 2007; Norat *et al.* 2005; Theodoratou *et al.* 2007). These results will need to be confirmed by other studies, and especially prospective studies.

Breast cancer
In the AFSSA 2003 report, it was not possible to issue an opinion on the level of proof linking fish consumption to breast cancer, despite a considerable number of studies (17 control cases and 4 cohorts). In fact, only 1/3 of them showed reduced risk.
Since that report, three studies examining the relationship between fish consumption and breast cancer have been published (Engeset *et al.* 2006; Hirose *et al.* 2003; Stripp *et al.* 2003). The Japanese study (Hirose *et al.* 2003) alone showed reduced risk for heavy fish consumption. Therefore, these new studies do not contain additional information that could lead to a clear conclusion.

Other cancers
With respect to female cancers other than breast cancer, a study with 709 cases and 2,888 controls investigated the relationship between fish, mollusc and shellfish consumption and endometrial cancer (Terry *et al.* 2002). This study distinguished between the consumption of fatty fish and the consumption of other fish. Only the former were associated with risk reduction, for consumption of two servings per week, compared with one serving every five weeks (0.2 weekly servings).
Two recent Japanese studies examined the relationship between fish consumption and lung cancer (Takezaki *et al.* 2001a; Takezaki *et al.* 2001b; Takezaki *et al.* 2003). Both studies show risk reduction related to the increased consumption of fish or seafood, but not with dried or salted fish.
Other studies point more specifically to the consumption of pickled fish: consumption of fermented fish sauce once a week significantly increases the risk of oesophageal carcinoma (squamous cells) (Li and Yu 2003). Increased risk related to the consumption of salted fish can be found in cases of nasopharyngeal carcinomas in China (Zou *et al.* 2000). Contamination may be responsible, inducing the presence of nitrosamines, as has been demonstrated for other similarly processed products (Poirier *et al.* 1987).

Therefore, the majority of recent epidemiological studies suggest a probable reduction in colorectal and prostate cancer risk related to fish consumption. For breast cancer, the results are contradictory and for other cancers, they are insufficient. The observation of risk reduction is backed by a hypothesis about the mechanism of action, which has been experimentally demonstrated in animal models and which puts forward the apoptotic effect of n-3 LC-PUFAs, meaning that they inhibit proliferation. However, there remains a possible factor of confusion, according to which fish consumption does not have a specific effect but indicates a generally favourable nutritional profile.

- ***Metabolic diseases***

Several studies have assessed the effects that fish or n-3 LC-PUFA consumption has on cardiovascular risk factors in diabetic subjects with results similar to those in non-diabetic subjects (Friedberg *et al.* 1998; Hartweg *et al.* 2007a; Hartweg *et al.* 2007b; Montori *et al.* 2000). It appears that n-3 LC-PUFAs do not affect the glycaemic control of these patients as it was suggested in the past.

While there are no double-blind clinical trials for metabolic syndrome prevention with n-3 LC-PUFAs, their positive effects on cardiovascular risk factors, and especially triglyceride levels and blood pressure (Benito *et al.* 2006), suggest that patients' clinical characteristics will improve. Other preliminary studies have shown that n-3 LC-PUFA consumption improves the fatty liver disease that accompanies metabolic syndrome (Capanni *et al.* 2006) (Zivkovic *et al.* 2007).

- ***Neurodegenerative diseases and mental health***

Studies on the relationships between n-3 LC-PUFAs and brain physiology have investigated firstly the role of these FAs in brain function and secondly their involvement in disorders and diseases of the central nervous system (neurodegenerative diseases such as Alzheimer's, psychiatric diseases such as schizophrenia, depression, autism, attention disorders in children).

In animals, severe dietary deficiencies of n-3 PUFAs generate behavioural problems (altered adaptation and learning capacities, increased anxiety and sensitivity to stress, decreased laterality in behavioural tests) (Bourre *et al.* 1989; Fedorova and Salem 2006; Frances *et al.* 1995; Jensen *et al.* 1996; Takeuchi *et al.* 2003; Vancassel *et al.* 2005; Yamamoto *et al.* 1991) linked to an alteration of some dopaminergic and serotonergic neurotransmitters (Chalon 2006; Chalon *et al.* 1998). Moreover, the results of reversibility and supplementation studies confirm the essential role that these fatty acids play in brain function (Bourre *et al.* 1990; Moriguchi *et al.* 2001; Moriguchi and Salem 2003). The hypothesis that n-3 LC-PUFA deficiencies in humans can be a factor of vulnerability to neurological and psychiatric diseases is therefore raised.
In humans, low serum levels of DHA and high levels of n-6 PUFAs in elderly subjects appear to be associated with the risk of cognitive impairment, suggesting that low dietary intakes of DHA have a harmful effect on cognitive functions (Conquer *et al.* 2000; Dullemeijer *et al.* 2007).

Furthermore, various studies suggest a possible association between high dietary intakes of n-3 LC-PUFAs and a reduced risk of cognitive decline (Barberger-Gateau *et al.* 2002; Kalmijn 2004; van Gelder *et al.* 2007). However, there is currently a lack of data from human supplementation studies with which to confirm the preventive effect of n-3 LC-PUFAs in cognitive disorders (Barberger-Gateau *et al.* 2005; Barberger-Gateau *et al.* 2007; Freund-Levi *et al.* 2008).

The available data give multiple arguments in favour of the role that n-3 LC-PUFAs play in the aetiology of mental disorders, and of the importance of sufficient intake for their prevention and for mental health, but other studies need to be undertaken to confirm and specify their beneficial, and possibly preventive, effects.
For example, several epidemiological observation studies suggest that fish consumption (around twice a week) and n-3 LC-PUFA intakes ≥ 0.1% of energy intakes are associated with a lower prevalence of depression in the population (Appleton *et al.* 2007; Silvers and Scott 2002; Tanskanen *et al.* 2001).

- ***Age-related macular degeneration***

Ecological studies in countries where fish consumption is high provide data related to the role of n-3 LC-PUFAs in age-related macular degeneration (AMD): 1) in Japan, there was a lower prevalence of AMD until recently; 2) in Iceland, exudative forms with drusen (fatty deposits on the inside of the Bruch's membrane adjacent to the pigment epithelium) are rare and atrophic forms are frequent (Jonasson *et al.* 2005; Jonasson *et al.* 2003; Jonasson *et al.* 1987). According to physiopathology data, drusen are the result of the first stages of the disease, in which fats are involved.
A meta-analysis of 9 epidemiological studies shows that a high intake of n-3 LC-PUFAs is associated with a 30% decrease in the risk of late AMD and that fish consumption at least twice a week is associated with a decrease in the risk of early and late AMD (Chong *et al.* 2006).
Overall, epidemiological data (cross-sectional, control case, prospective) suggest that a high n-3 LC-PUFA and fish intake has a positive effect, which could disappear when linoleic acid intake is high. The results of these studies are corroborated by mechanistic data. However, intervention studies need to be undertaken to draw a conclusion as to the existence of a cause-and-effect relationship and therefore the protective role of n-3 LC-PUFAs.

ANNEX 3

Fish consumption and health risks

Methylmercury (MeHg)

Mercury (Hg) is an element found naturally in the soil and rocks, and in lakes, rivers and oceans. The Earth's crust, which releases around 2,700 to 6,000 tonnes of mercury into the atmosphere per year, is the main source of this metal in the environment. In addition to these natural sources, mercury is also released into the environment by human activities, including the paper and pulp industry, mining and the combustion of waste and fossil fuels.

Methylmercury (MeHg) is the most toxic physico-chemical form of mercury. Living organisms easily absorb it but cannot easily excrete it. Biomethylation of inorganic mercury into MeHg is observed in sediments and in marine organisms (fish, shellfish, etc.). Mercury methylation can occur in the marine compartment, and more particularly in anaerobic sediments. The resulting MeHg is then concentrated by phytoplankton and zooplankton and bioaccumulated in aquatic organisms, and more particularly in carnivorous fish.

The main source of exposure to MeHg in humans is the consumption of fish in which mercury mainly exists as MeHg. MeHg levels in fish flesh vary according to the species, age and size of the fish, from 0.001 to 3.7 mg/kg of fresh weight in mainland France.

PBDEs (PolyBrominated Diphenyl Ethers)

PBDEs belong to the family of brominated flame retardants (BFRs), which are chemical products added to the plastic parts of electronic devices (computers, televisions) and electronic circuits to give them fire-retardant properties. They are also found in foams and padding materials (domestic and industrial), car and aircraft interiors and some textiles. Available toxicological studies have not yet established a reference experimental toxicological intake that could be used to define a HTV.

Dioxins and PCBs (PolyChlorinated Biphenyls)

The term 'dioxins' is a generic name that refers to two main categories of compounds, polychlorinated dibenzodioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs). Dioxins are comprised of 75 different compounds (congeners). Dioxins are not produced intentionally but are emitted during thermal processes, whether accidental (fires) or not (incineration of industrial or household waste, wood or fossil fuels), during chemical processes (treatment of paper pulp of plant origin, impurities in the herbicide 2,4,5-T), by motorised transport, and by the ineffectively controlled combustion of coal, fuel oil, wood, etc.

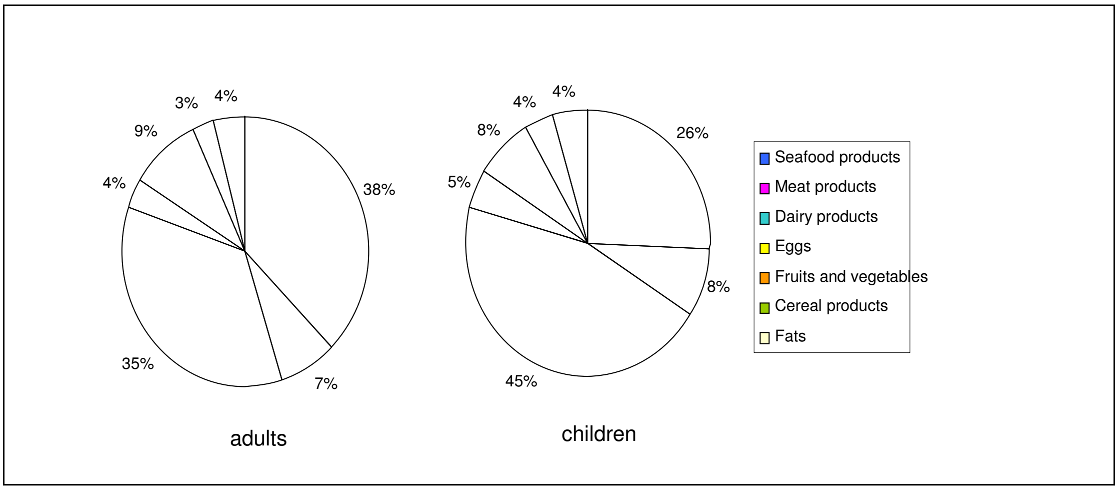
'PCBs' (polychlorinated biphenyls) are chlorinated aromatic compounds that group together 209 theoretically possible compounds or congeners. They are of man-made origin only and the first technical mixtures were synthesised and marketed for the first time in 1929 by the company MONSANTO. Until their marketing was prohibited in 1987, PCBs were commonly used because of their thermal, electric insulation and low-flammability properties (heat transfer fluid, electric insulation and cooling of electrical transformers and capacitors) and as stabilising or fire-resistant additives in ink, paint and plastic materials.

Large quantities of PCB were therefore released into the environment in the past and considerable amounts can still be found in the soil and in land and marine sediments due to their high persistence.

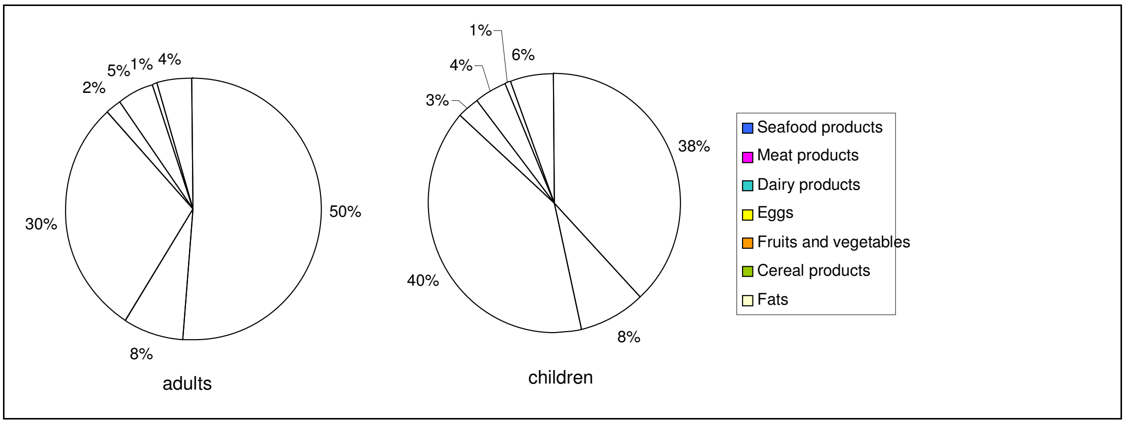
ANNEX 4

Relative contribution of various food groups to total exposure to PCDD/Fs, DL-PCBs and NDL-PCBs (AFSSA Opinion and Report, 2005, 2007)

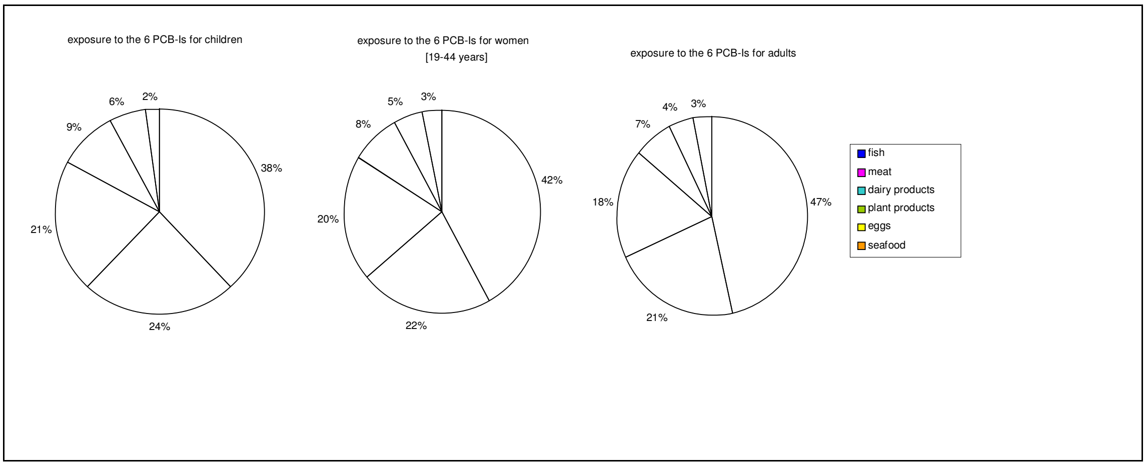
Relative contribution of various food groups to total exposure to PCDD/Fs for adults and children



Relative contribution of various food groups to total exposure to DL-PCBs for adults and children



Relative contribution of various food groups to total exposure to the six NDL-PCBs (PCBs 28, 52, 101, 131, 153 and 180) for children, women of childbearing age (19-44 years) and adults



ANNEX 5

Average exposure to dioxins, PCBs and methylmercury (MeHg) in the French population, and average EPA+DHA intakes, according to age group and the number of fish consumed

Population group	Scenario	n	Total Dioxins+DL-PCBs pg TEQ/kg b.w./day	NDL-PCBs ng/kg b.w./day	MeHg µg/kg b.w./day	EPA+DHA mg/day
[3-10 years]	0 fish	89	2.68	10.86	0.014	21.8
[3-10 years]	1 fish	184	3.32	14.54	0.083	91.6
[3-10 years]	2 fish 1 fatty	39	3.99	18.09	0.154	134.6
[3-10 years]	2 fish 2 fatty	91	4.11	19.12	0.103	189.0
[3-10 years]	3 fish 1 fatty	14	3.11	14.85	0.192	155.9
[3-10 years]	3 fish 2 fatty	19	4.11	18.86	0.148	207.0
[11-14 years]	0 fish	107	1.44	6.40	0.005	20.7
[11-14 years]	1 fish	127	1.95	9.56	0.040	125.5
[11-14 years]	2 fish 1 fatty	33	2.11	10.78	0.079	176.8
[11-14 years]	2 fish 2 fatty	63	2.28	11.56	0.051	297.3
[11-14 years]	3 fish 1 fatty	12	2.26	9.82	0.117	162.9
[11-14 years]	3 fish 2 fatty	13	2.51	13.09	0.093	335.6
[15-17 years]	0 fish	127	1.32	5.70	0.005	15.3
[15-17 years]	1 fish	135	1.52	7.34	0.033	129.5
[15-17 years]	2 fish 1 fatty	16	1.63	7.85	0.068	245.0
[15-17 years]	2 fish 2 fatty	48	1.49	7.86	0.046	252.7
[15-17 years]	3 fish 1 fatty	4	1.74	9.79	0.115	125.0
[15-17 years]	3 fish 2 fatty	9	2.30	12.86	0.076	470.9
[18-64 years]	0 fish	337	1.32	5.77	0.008	38.5
[18-64 years]	1 fish	444	1.58	7.44	0.034	168.1
[18-64 years]	2 fish 1 fatty	126	1.71	8.57	0.066	259.5
[18-64 years]	2 fish 2 fatty	171	1.86	9.57	0.049	352.6
[18-64 years]	3 fish 1 fatty	34	1.74	8.03	0.088	346.4
[18-64 years]	3 fish 2 fatty	72	2.01	10.40	0.087	495.7
[65 years and over]	0 fish	38	1.17	4.74	0.003	31.3
[65 years and over]	1 fish	70	1.44	6.62	0.027	184.2
[65 years and over]	2 fish 1 fatty	29	1.83	8.36	0.070	235.3
[65 years and over]	2 fish 2 fatty	27	2.11	10.68	0.066	479.2
[65 years and over]	3 fish 1 fatty	13	1.59	7.70	0.079	245.7
[65 years and over]	3 fish 2 fatty	16	2.17	11.15	0.067	532.1

These exposure levels should be compared with the HTVs that have been set respectively for methylmercury (1.6 µg/kg b.w./week), total Dioxins+DL-PCBs (2.3 pg TEQ_{WHO}/kg b.w./day) and NDL-PCBs (10 ng/kg b.w./day) and with the DRIs defined for the fatty acids EPA+DHA.

KEYWORDS

BENEFITS, RISKS, FISH, EPA, DHA, VITAMIN D, PCBS, DIOXINS, MERCURY, RECOMMENDATIONS

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