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Joint report with SciCom

Advantages and disadvantages of eating fish and seafood

Part 2: Dioxins and dioxin-like polychlorinated biphenyls

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FOR THE SAFETY OF THE FOOD CHAIN

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Advantages and disadvantages of eating fish and seafood
Part 2: Dioxins and dioxin-like polychlorinated biphenyls

Common advisory report approved by the Scientific Committee established at the FASFC
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The Superior Health Council and the Scientific Committee provide the following common advisory report.

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Keywords and MeSH descriptor terms[1]

MeSH terms*
Diet
Nutrition policy
Risk assessment
Food safety
Dietary exposure
Dioxins
Polychlorinated Biphenyls
Fishes

Keywords	Sleutelwoorden	Mots clés	Schlüsselwörter
Nutrition	Voeding	Nutrition	Ernährung
Recommendations	Aanbevelingen	Recommandations	Empfehlungen
Risk assessment	Risico-evaluatie	Evaluation du risque	Risiko-Bewertung
Food safety	Voedselveiligheid	Sécurité alimentaire	Ernährungssicherheit
Dietary exposure	Voedingsblootstelling	Exposition alimentaire	Ernährungsbedingte Exposition
Dioxins	Dioxines	Dioxines	Dioxine
Polychlorinated Biphenyls	Polychloorbifenylen	Polychlorobiphényles	Polychlorierte Biphenyle
Fish	Vis	Poisson	Fisch

MeSH (Medical Subject Headings) is the NLM (National Library of Medicine) controlled vocabulary thesaurus used for indexing articles for PubMed: https://www.ncbi.nlm.nih.gov/mesh.

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[1] The Council wishes to clarify that the MeSH terms and keywords are used for referencing purposes as well as to provide an easy definition of the scope of the advisory report. For more information, see the section entitled "methodology".

ABBREVIATIONS AND SYMBOLS

#N/A	Not Applicable
ANSES	French Agency for Food, Environmental and Occupational Health & Safety
b.w.	Body Weight
DALYs	Disability-Adjusted Life Years
DGAPF	Directorate-General Animal, Plant, Food of the FPS HFSE
DHA	Docosahexaenoic Acid (omega-3 polyunsaturated fatty acid)
DLCs	Dioxin-Like Compounds
DL-PCBs	Dioxin-Like Polychlorinated Biphenyls
EC	European Commission
EFSA	European Food Safety Authority
EPA	Eicosapentaenoic Acid (omega-3 polyunsaturated fatty acid)
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FASFC	Belgian Federal Agency for the Safety of the Food Chain
FCS	Food Consumption Survey
FF/ff	Fatty Fish
FPS HFSE	Belgian Federal Public Service Health, Food Chain Safety and Environment
Hg	Mercury
LB	Lower Bound
LF/lf	Lean Fish
LOD	Limit Of Detection
LOQ	Limit Of Quantification
MeHg	Methylmercury
MTX	EFSA FoodEx2 Matrix catalogue
NOAEL	No Observed Adverse Effect Level
n.s.	Not Specified
PCBs	Polychlorinated Biphenyls
PCDDs	Polychlorinated Dibenzo-p-Dioxins
PCDFs	Polychlorinated Dibenzofurans
PCP	Pentachlorophenol
Pq	Picogramme
RBA	Risk-Benefit Assessment
REP	Relative Effect Potency
RIVM	*Rijksinstituut voor Volksgezondheid en Milieu* (The Netherlands)
SciCom	Scientific Committee established at the FASFC
SHC	Superior Health Council
SPADE	Statistical Program to Assess Dietary Exposure
TCDD	2,3,7,8 Tetrachlorodibenzo-p-dioxin
TEFs	Toxic Equivalency Factors
TEQs	Toxic Equivalency Quotients
TWI	Tolerable Weekly Intake
UB	Upper Bound
WHO	World Health Organization
ww	Wet Weight

SUMMARY

This opinion evaluates dietary exposure to dioxins and dioxin-like polychlorinated biphenyls (PCDD/Fs and DL-PCBs) associated with fish and seafood consumption in Belgium for children (3 - 9 years), adolescents (10 - 17 years), and adults (18 - 64 years) and considers these exposures within a benefit–risk perspective. The assessment integrates national occurrence data with food consumption information to characterise exposure patterns across population groups, with particular attention to children.

Fish and seafood represent a nutritionally valuable component of the diet, notably as a source of long-chain omega-3 fatty acids (EPA and DHA). At the same time, these food groups contribute to dietary exposure to dioxins and DL-PCBs.

Exposure estimates were derived in accordance with established EFSA risk assessment approaches for the sum of 17 PCDD/F congeners and the sum of 29 PCDD/F and DL-PCB congeners. Calculations were performed using the WHO2005 Toxic Equivalency Factors (TEFs), while a parallel evaluation incorporated the WHO2022 TEFs, which reflect recent scientific advances in the assessment of congener-specific toxic potency. A comparative analysis of both TEF schemes was undertaken to characterise the influence of revised toxicological weighting on TEQ-based exposure metrics and benefit–risk interpretation.

Under the WHO2005 TEF scheme, mean exposure levels ranged from 0.037 to 0.069 pg WHO2005-TEQ/kg body weight per day for the 17 congeners and from 0.107 to 0.198 pg WHO2005-TEQ/kg body weight per day for the 29 congeners. Under this framework, exceedances of the current Tolerable Weekly Intake (TWI) of 2 pg WHO2005-TEQ/kg body weight per week were observed at lower percentiles of the exposure distribution, particularly among children.

Application of the WHO2022 TEF framework yielded lower TEQ estimates. The mean dietary exposure estimates (lower and upper bounds) ranged from 0.022 to 0.046 pg WHO2022-TEQ/kg body weight per day for the 17 congeners and from 0.060 to 0.116 pg WHO2022-TEQ/kg body weight per day for the 29 congeners. Across all evaluated groups, children consistently exhibited the highest exposure levels.

For children, exceedances of the TWI were observed primarily at the upper percentiles of the exposure distribution, particularly under the upper bound conservative assumption in which non-quantified contaminant concentrations were replaced by their Limit Of Quantification. These findings indicate potential concern for high-consumption individuals rather than for the average population.

Across all population groups, diadromous fish species (e.g. salmon) were identified as the primary contributors to fish-related exposure to dioxins and DL-PCBs, followed by processed fish products. Fish constitute the most contaminated food group on a concentration basis, with species selection and portion size acting as key determinants of individual exposure. These findings highlight the importance of balanced and diversified fish consumption patterns in dietary guidance.

The benefit–risk evaluation indicates that balanced consumption patterns combining fatty and lean fish can support adequate EPA and DHA intake while maintaining contaminant exposure below the toxicological reference value (TWI). Intake scenarios associated with favourable benefit–risk profiles corresponded to weekly combinations such as 100 g fatty fish + 100 g lean fish in adults, and in children to balanced patterns such as 70 g fatty fish + 50 g lean fish per

week (with similar favourable profiles also observed for 50 g fatty fish + 50 – 70 g lean fish). In contrast, scenarios with high weekly intake of fatty fish tended to be more toxicologically relevant, whereas scenarios with very low fatty fish intake were more likely to fall short of the EPA+DHA target.

Several data-related limitations were identified, including constraints in the representativeness of occurrence data, restricted species-level detail in consumption records, and classification harmonisation challenges. Addressing these gaps would support improved resolution and robustness of future exposure and benefit–risk assessments.

Overall, this opinion supports the continued inclusion of fish in the diet within the framework of balanced consumption patterns. Particular attention should be given to portion size and fish type in dietary advice for children, recognising their greater sensitivity to contaminant exposure on a body-weight basis.

1. REFERENCE TERMS

1.1. Question

The Directorate-General for Animals, Plants and Food (DGAPF) initiated an advisory request on 15 February 2016 concerning the "Advantages and disadvantages of fish and seafood consumption for the Belgian population, including specific risk groups." The primary objective was to update the Superior Health Council (SHC) 2004 advisory report, "Fish and Health in Adults" (SHC, 2004), by incorporating subsequent scientific advancements.

In December 2022, an initial advisory opinion addressing the presence of mercury (Hg) and methylmercury (MeHg) in fish was published (SHC/SciCom, 2022). In continuation of this work, the SHC decided to broaden the scope of the assessment to include polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/Fs) as well as dioxin-like polychlorinated biphenyls (DL-PCBs) in fish and seafood, and to evaluate the associated health risks for the Belgian population.

1.2. Scientific background and rationale

In its 2004 opinion, SHC (2004) consistently highlighted the nutritional benefits of fish consumption, while emphasising the need for caution due to contamination by environmental pollutants such as dioxins, PCBs, and mercury. That opinion recommended regular monitoring of fish consumption patterns through food consumption surveys and encouraged further research into associations between fish intake and health outcomes, including morbidity and mortality potentially linked to contaminant exposure.

For the adult population, SHC (2004) considered a fish consumption of approximately 20 – 40 g per day, corresponding to one to two fish meals per week, as appropriate, balancing nutritional benefits with contaminant-related risks. The principal health benefit of fish consumption was identified as its contribution to long-chain omega-3 polyunsaturated fatty acids (EPA and DHA), rather than protein intake alone. In this context, replacing meat with fish was viewed as beneficial both through increased omega-3 intake and reduced consumption of saturated fats.

For vulnerable population groups, particularly children, pregnant women, and women of childbearing age, SHC (2004) advised increased caution. It was noted that, in the absence of contamination, fish consumption could theoretically be recommended without restriction at all ages; however, environmental pollution necessitated limitations for individuals in critical developmental stages. Particular attention was drawn to the variability in fat content and omega-3 fatty acids levels across fish species, as well as to the importance of diversifying both species and origin.

In paediatric and maternal contexts, SHC (2004) recognised that fish consumption confers developmental and cardiovascular benefits, while simultaneously posing potential health concerns related to contaminant exposure. As a precautionary measure, diversified fish consumption —typically **two meals per week**, varying species and origin— was advised. Where uncontaminated fish could not be guaranteed, supplementation with purified omega-3 fatty acids was suggested as an alternative, particularly for pregnant women and infants.

With respect to dioxins, SHC (2004) acknowledged associations reported in the literature between dioxin exposure and increased risk of certain cancers. At the same time, studies of populations with high fish consumption, such as Baltic Sea fishermen, suggested a complex health profile combining elevated contaminant body burdens with reduced cardiovascular mortality and lower incidence of some cancers, alongside increased risk for specific outcomes such as multiple myeloma. These findings supported the conclusion that the overall health impact of fish consumption should be evaluated holistically, considering both nutritional benefits and contaminant-related risks.

Recent national evidence further illustrates the complexity of dietary exposure to dioxins and DL-PCBs in Belgium. The TEQFOOD project[2], which assessed total dietary exposure across food groups using Belgian consumption and occurrence data, demonstrated that DL-PCBs contribute to the majority of total TEQ exposure (around 80 %) and that exposure arises from a broad range of food groups, with dairy products —particularly milk and ripened cheese— being major contributors across age groups. These findings underline that dietary exposure to dioxins and DL-PCBs is cumulative and multi-sources in nature.

This national evidence reinforces the need for updated, integrated benefit–risk assessments of fish consumption that account for both its nutritional role and its contribution to background exposure in the context of total diet.

More recently, updated dietary recommendations were issued by the SHC in 2025 (SHC, 2025), informed by new data from the Belgian Food Consumption Survey (FCS 2022 – 2023). These guidelines reaffirm fish as an important component of a healthy diet and provide more explicit quantitative advice, recommending a consumption of fish, molluscs, and crustaceans of at least 200 g per week, including at least one portion of fatty fish (defined as fish containing ≥ 4 % lipids). Fatty fish include anchovy, eel, carp, gilthead seabream, butterfish, swordfish, halibut, gurnard, herring, mackerel, sardine, salmon, bluefin tuna, and trout. This amount was calculated to cover EPA+DHA needs, to have a positive impact on health and reduce the risk of developing a wide range of diseases, while taking into account the aspect of reducing the risk of exposure to the various contaminants. The updated recommendations continue to emphasise variation in species and origin, while recognising the need to balance nutritional benefits—particularly long-chain omega-3 fatty acids—with potential risks related to contaminant exposure, especially for vulnerable population groups.

In its advisory report on vegetarian diets, SHC (2021) also addresses the benefits and risks associated with fish consumption. For pesco-vegetarians, the regular intake of fatty fish such as sardines, mackerel, or salmon and/or fish oil can provide adequate levels of EPA and DHA, which are essential long-chain omega-3 fatty acids. As frequent consumption of the same fish species —especially fatty fish or species higher in the food chain— may increase contaminants exposure if dietary variation is insufficient, SHC emphasizes variation in food sources and fish species as a key risk management measure.

1.3. Legal and regulatory context

The regulation of dioxins and dioxin-like polychlorinated biphenyls (DL-PCBs) in food is grounded in European Union legislation aimed at reducing the exposure for the protection of public health. Commission Regulation (EU) 2023/915[3] establishes maximum levels for various

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[2] See RT 22/06 TEQFOOD project "Occurrence and exposure to dioxins, furans and halogenated biphenyls in foodstuffs": https://www.health.belgium.be/fr/research/occurrence-exposure-dioxins-furans-halogenated-biphenyls-foodstuffs.

[3] Commission Regulation (EU) 2023/915 of 25 April 2023 on maximum levels for certain contaminants in food and repealing Regulation (EC) No 1881/2006. URL: <https://eur-lex.europa.eu/eli/reg/2023/915>.

chemical contaminants in foodstuffs, including dioxins and DL-PCBs. It is prohibited to market food exceeding these maximum levels.

In addition, Directive 2002/32/EC[4] (Annexes I and II), as amended, sets both maximum levels and action thresholds for these substances in animal feed. Commission Recommendation 2013/711/EU[5] on the reduction of the presence of dioxins, furans and PCBs in feed and food, as amended in 2014, is still the reference for action levels for food, to initiate investigations to identify the source of contamination and to take measures to reduce or eliminate the source of contamination.

In November 2018, the European Food Safety Authority (EFSA) CONTAM Panel published a revised opinion on dioxins, a comprehensive group of 29 compounds encompassing 7 polychlorinated dibenzodioxins (PCDDs), 10 polychlorinated dibenzofurans (PCDFs), and 12 DL-PCBs[6]. This revision established a new TWI of 2 pg TEQ/kg body weight/week. This update was predicated on the evaluation of new epidemiological data, rigorously supported by animal studies. The critical endpoint identified for this assessment was reduced sperm concentration, observed following pre- and post-natal exposure. The relevant studies demonstrated a no-observed-adverse-effect level (NOAEL) of 7.0 pg PCDD/F TEQ/g fat (derived from blood samples of 9-year-old boys), which formed the basis for the derivation of the aforementioned TWI (EFSA CONTAM Panel, 2018). As clarified by the EFSA CONTAM Panel, the TWI is derived to prevent women of childbearing age from reaching body burdens that could result in adverse *in utero* or lactational exposure in offspring. Although infants may experience higher exposure per kilogram body weight during breastfeeding, this was explicitly taken into account when deriving the TWI; consequently, the TWI is not applicable to infants, and direct comparison with infant exposure is not considered appropriate.

EFSA's exposure assessments considered both the 17 PCDD/F congeners and the full set of 29 congeners, including DL-PCBs. Analyses demonstrated substantial interspecies variability in contamination levels, with fish and seafood identified as major contributors to total dietary exposure alongside other food groups such as meat and dairy products. Exposure estimates indicated that a significant proportion of the European population exceeds the established TWI, particularly among toddlers and young children, highlighting the relevance of dietary patterns and food source contributions.

These findings prompted EFSA to recommend updated benefit–risk assessments of fish consumption that explicitly account for exposure to PCDD/Fs and DL-PCBs. To support harmonised implementation, EFSA engaged with national authorities to clarify the scientific rationale and methodological approach underlying the assessment.

Following the 2018 EFSA CONTAM Panel opinion, regulatory updates were introduced through Regulation (EU) 2022/2002[7] to strengthen consumer protection, including the extension or lowering of maximum levels for dioxins and DL-PCBs in several food categories, notably milk and dairy products, with particular consideration for vulnerable population groups.

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[4] Directive 2002/32/EC of the European Parliament and of the Council of 7 May 2002 on undesirable substances in animal feed. URL: <http://data.europa.eu/eli/dir/2002/32>.

[5] Commission Recommendation of 3 December 2013 on the reduction of the presence of dioxins, furans and PCBs in feed and food (Text with EEA relevance) (2013/711/EU). URL: <http://data.europa.eu/eli/reco/2013/711>.

[6] On 30 May 2001, the EFSA Scientific Committee for Food (SCF) first adopted an opinion on dioxins and dioxin-like PCBs in food, fixing a TWI of 14 pg TEQs/kg bw for dioxins and dioxin-like PCBs (EFSA SCF, 2001).

[7] Commission Regulation (EU) 2022/2002 of 21 October 2022 amending Regulation (EC) No 1881/2006 as regards maximum levels of dioxins and dioxin-like PCBs in certain foodstuffs (Text with EEA relevance). URL: <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32022R2002&qid=1772790178587>. *Rem.: no longer in force, implicitly repealed by Commission Regulation (EU) 2023/915.*

EFSA is currently addressing question EFSA-Q-2024-00227[8] under mandate M-2024-00042 which aims to integrate 2022 revised World Health Organization (WHO) Toxic Equivalence Factors (TEFs) into the risk assessment of dioxins and DL-PCBs in food. When this opinion is available, a comprehensive review of maximum levels will be started.

1.4. Methodology

Following the analysis of the advisory requests submitted to both the SHC and the Scientific Committee (SciCom) established at the Federal Agency for the Safety of the Food Chain (FASFC), it was decided to issue a joint opinion. To this end, an *ad hoc* working group was established, composed of experts with relevant domain-specific expertise.

All members of the working group completed both general and *ad hoc* declarations of interest. These were evaluated by the SHC's Committee on Deontology to assess any potential risks of conflict of interest, in accordance with the Council's ethical guidelines.

This advisory report is based on a review of the scientific literature published in peer-reviewed journals and reports issued by competent national and international authorities. The literature review includes studies and evaluations available up to the time of the working group's deliberations, with particular reference to the 2018 scientific opinion of the EFSA CONTAM Panel on the health risks of dioxins and DL-PCBs in food and feed (EFSA CONTAM Panel, 2018).

Dietary exposure estimates were derived using nationally available data, specifically food consumption data from the Belgian National Food Consumption Survey of 2014, and those reported in the EFSA CONTAM Panel opinion (2018) for contamination data. Although a formal uncertainty analysis of exposure was not performed, uncertainties were considered in the context of risk characterization and the interpretation of results.

The draft conclusions were presented to the working group for discussion, and the draft report was subsequently circulated for internal scientific consultation. The final report was endorsed by the *ad hoc* working group, the standing Working Group on Nutrition, Health and Food Safety (NHFS), the Scientific Committee established at the FASFC, and the Board of the SHC.

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[8] See the "Request for an update of the scientific opinion on the risk for animal and human health related to the presence of dioxins and dioxin-like PCBs in feed and food on the basis of the new 2022 WHO TEF values": https://open.efsa.europa.eu/questions/EFSA-Q-2024-00227.

2. INTRODUCTION

2.1. Introduction and issue

Polychlorinated dibenzo-p-dioxins (PCDDs) and dibenzofurans (PCDFs) are two groups of tricyclic planar compounds that together are often referred to as “dioxins”. Dependent on the number of chlorine atoms and their positions at the rings 75 PCDDs and 135 PCDFs, termed “congeners”, can occur (EFSA CONTAM Panel, 2018). Polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/Fs) have never been intentionally produced on an industrial scale, nor do they have any technological applications. Instead, they are formed unintentionally during various industrial and thermal processes, such as uncontrolled waste incineration (Olie et al., 1977). Additionally, the production of chlorinated chemicals, including herbicides like 2,4,5-trichlorophenoxy acetic acid (a component of “Agent Orange”), polychlorinated biphenyls (PCBs), and chlorophenols, can lead to PCDD/F contamination. Notably, trichlorophenols were the source of TCDD in the Seveso incident, and pentachlorophenol (PCP), widely used for wood preservation and as a fungicide, was linked to incidents such as the contamination of guar gum in 2007 (Wahl et al., 2008). Chlorophenols also caused one of the earliest documented food chain contamination events, when fat scraped from treated cowhides was used in the production of chicken feed (Higginbotham et al., 1968). Another notable case occurred in 2010, when industrial-grade fatty acids containing chlorophenols were used in feed production in Germany (Hoogenboom et al., 2015).

PCDD/Fs are also produced during burning processes, including large-scale waste incineration (e.g., municipal waste incinerators; Liem et al., 1991) and smaller, local activities such as farm waste burning and metal recycling. In the 1980s, emissions from solid waste incinerators were one of the primary sources of PCDD/F pollution in Europe. However, the implementation of stricter regulations and improved incineration techniques has led to a reduction of more than 90 % in these emissions.

Dioxin-like polychlorinated biphenyls (DL-PCBs) are a group of organochlorine compounds that are produced through the chlorination of biphenyl. There are 209 possible congeners, determined by the number and positions of chlorine atoms on the biphenyl two rings. DL-PCBs share structural characteristics and toxicological effects with non- DL-PCBs (NDL-PCBs). DL-PCBs consist of 12 congeners that are non-ortho or mono-ortho chlorine substituted and have at least four chlorine substituents, can easily adopt a coplanar structure and show toxicological properties similar to TCDD. The group of so called “non-dioxin like PCB’s” (NDL-PCBs) is bigger and counts 197 PCB congeners. These are also non- or mono-ortho PCBs that contain less than four chlorines.

DL-PCBs were widely used in various industrial applications as complex mixtures. Although Directive 96/59/EC mandated the disposal and decontamination of PCB-containing equipment by the end of 2010, many diffuse sources, like paints, remain. Currently, approximately 20 % of all produced PCBs have been eliminated.

Both PCDD/Fs and PCBs belong to the initial list of 12 persistent organic pollutants (POPs) regulated under the Stockholm Convention on POPs. The main pathway of human exposure for the majority of the population is food consumption, with the exception of specific cases of accidental or occupational exposure. The compounds' persistent characteristics make them relevant for monitoring in food and risk assessment.

Over the past several decades, strict regulatory controls on major industrial sources, such as waste incineration and chemical manufacturing, coupled with national and international monitoring programs, have led to significant reductions in environmental emissions of PCDDs, PCDFs, and PCBs. These measures, alongside routine screening and quantification of these compounds in animal feed and food products, have contributed to an approximate 90 % reduction in human exposure to dioxins since the 1960s. Consequently, a global decline in the levels of dioxins detected in human plasma and breast milk has been observed over the last few decades.

Despite this substantial progress, several factors continue to influence human exposure and human body burden. For instance, variations in dietary habits —such as high or low consumption of animal products— geographical location (living in an industrialized versus a rural area), and age play significant roles in determining individual exposure levels. Additionally, certain populations with higher consumption of contaminated fish or other food sources may experience elevated exposure.

Although human exposure and body burdens of dioxins and related compounds have declined significantly, there remains a toxicological concern due to the lowering of the TWI. Current exposure levels in certain populations may still exceed safety thresholds established to protect human health, particularly with respect to their long-term effects on vulnerable groups such as infants, pregnant women, and individuals with high dietary intake of contaminated animal products. Continued risk management and risk assessment are therefore essential to continuously ensure that exposure levels continue to decrease and remain as low as achievable, particularly in light of evolving of safety thresholds.

EFSA CONTAM Panel (2018) reported that concentrations of the 17 PCDD/F congeners, as well as the total of 29 PCDD/F and DL-PCB congeners, were highest in fish and fish-derived products, particularly in less commonly consumed items such as fish liver. According to this EFSA opinion, the dietary exposure to PCDD/Fs and DL-PCBs arises predominantly from fish consumption, with significantly lower contributions from other food groups.

The objectives of this advisory report are to update previous fish intake recommendations from the SHC for the Belgian population, as a whole, considering both nutritional benefits and risks linked to dioxins (including PCDD/Fs and DL-PCBs) exposure.

2.2. Study description

For this advisory report, the available food consumption data from the Belgian National Food Consumption Survey (2014) were used. At the time of analysis, individual anonymized food consumption data from the most recent survey cycle (2022 - 2023) were not yet available. The FCS_2014 dataset was therefore analysed to identify and classify reported consumption events related to fish and fish products, enabling the development of representative consumption scenarios.

Occurrence data previously compiled and evaluated at European level and published in the 2018 EFSA CONTAM Panel opinion—was used to characterize contaminant concentrations relevant to fish consumption. Based on these data, dietary exposure to 17 PCDD/F congeners and to the sum of 29 PCDD/F and DL-PCB congeners was estimated for the Belgian population aged 3 to 64 years. Risk characterization was subsequently conducted using the established health-based guidance value (TWI).

Recent scientific advances in toxicological assessment were considered by applying the updated WHO TEF values (WHO2022-TEFs). These values reflect advances in evaluating congener-specific toxic potency. This re-evaluation introduced a more systematic and transparent framework for assigning TEFs, incorporating data weighting by type, quality, and relevance, and applying Bayesian approaches to dose-response modelling. The resulting TEF scheme, referred to as WHO2022-TEF, was published in 2024 (DeVito et al., 2024).

For the present scientific advice, all PCDD/Fs and DL-PCBs concentrations originally expressed in pg WHO2005-TEQ/kg were first converted to absolute concentrations for each congener (pg/kg) and subsequently recalculated using the updated WHO2022-TEF values to obtain revised TEQ estimates.

In addition to the risk assessment, the nutritional relevance (beneficial health effects) of fish consumption was considered. An indicative risk-benefit perspective was applied to integrate both nutritional advantages and toxicological concerns.

Finally, conclusions and recommendations were formulated, taking into account both the potential health considerations and recognised dietary benefits associated with fish consumption.

3. ADVISORY REPORT

3.1. Data sources and methodology

3.1.1. Occurrence of dioxins in fish

3.1.1.1 *Occurrence data definition*

Occurrence data describe the presence and concentration of chemical contaminants in food and other matrices, including food, water, air, or biological samples. Within the context of this advisory opinion, occurrence data specifically refer to measured concentration of dioxins and DL-PCBs in fish and fish products.

The occurrence data used in this assessment were derived from official national and international monitoring and surveillance programmes and are used to evaluate the frequency, distribution, and magnitude of contamination. These data form the basis for calculating mean contaminant concentrations per food group and play a critical role in estimating human exposure to contaminants, informing risk characterization, and supporting the establishment of regulatory limits.

To allow cumulative assessment of dioxins and DL-PCBs, analytical results were expressed as toxic equivalents (TEQs) using TEFs established under the auspices of the WHO. In line with recent scientific developments, the revised WHO2022 TEF scheme was applied as the primary basis for occurrence characterisation, while WHO2005 TEF scheme was retained for comparative analysis.

3.1.1.2 *Origin of the occurrence data*

The occurrence data used in the preparation of this advisory opinion were extracted from the dataset published in Annex B of the 2018 EFSA CONTAM Panel opinion on dioxins and DL-PCBs in food and feed[9] (EFSA CONTAM Panel, 2018), specifically from the table entitled *"Table_2A OCC29 FOOD congspec"*. These data, covering the period from 2010 to December 2016, were submitted to EFSA by 23 European countries, notably by the FASFC for Belgium, and had already undergone cleaning, validation, and harmonisation by EFSA for the purpose of their own assessment. The summary of this data is given in Table 1.

The EFSA validation process included the identification of duplicate entries and verification of critical parameters such as the analytical methods used ("Analytical methods"), the units reported ("Reporting unit"), and the coding of food samples according to the FoodEx2 classification system. Where necessary, EFSA consulted data providers for clarification.

Left-censored data (i.e. results below the Limit Of Detection (LOD) or Limit Of Quantification (LOQ)) were treated using the substitution method, as recommended by WHO/IPCS (2009) and described in EFSA's scientific report on the management of left-censored data in dietary exposure assessment (EFSA, 2010).

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[9] See Annex B "Occurrence data in food and feed submitted to EFSA and dietary exposure assessment for humans": https://efsa.onlinelibrary.wiley.com/action/downloadSupplement?doi=10.2903%2Fj.efsa.2018.5333&file=efs25333-sup-0002-Annex_B.xls

Following this approach, the lower bound (LB) and upper bound (UB) values were calculated for substances expected to be present in food, such as PCDD/Fs and DL-PCBs. For the LB scenario, values below LOD or LOQ were set to zero; for the UB scenario, values below LOD were replaced by the LOD, and values below LOQ were replaced by the reported LOQ.

Table 1. Mean and P95 levels (expressed in pg/g ww) for PCDD/Fs and for the sum of PCDD/Fs and DL-PCBs in fish groups as summarised in Table 17 of EFSA CONTAM Panel opinion (EFSA CONTAM Panel, 2018).

Foodstuff	**Sum of PCDD/Fs (WHO2005-PCDD/F-TEQ) (LB/UB)**			**Sum of PCDD/Fs and DL-PCBs (WHO2005-PCDD/F/DL-PCB-TEQ) (LB/UB)**		
	n	**Mean**	**P95**	**n**	**Mean**	**P95**
Muscle meat of fish and fishery products						
Salmon and trout	907	0.27 / 0.33	1.93 / 1.95	857	0.88 / 0.94	5.82 / 5.82
Herring	401	1.22 / 1.25	3.37 / 3.37	399	2.34 / 2.39	6.36 / 6.36
Mackerel	322	0.37 / 0.43	1.23 / 1.24	317	1.36 / 1.44	4.72 / 4.78
Eels	258	0.97 / 1.00	3.28 / 3.28	258	9.17 / 9.21	32.2 / 32.2
Sprat	91	1.57 / 1.58	2.86 / 2.87	91	3.43 / 3.47	6.39 / 6.40
Sardine / Pilchard	177	0.29 / 0.29	0.89 / 0.89	177	1.65 / 1.66	3.96 / 3.96
Bream	106	0.61 / 0.62	2.41 / 2.41	100	2.92 / 2.94	12.9 / 13.0
Carp	88	0.09 / 0.13	0.16 / 0.19	87	0.32 / 0.42	0.58 / 0.62
Cod and Whiting	384	0.04 / 0.08	0.09 / 0.21	375	0.17 / 0.28	0.48 / 0.88
Halibut	466	0.31 / 0.35	0.92 / 0.94	466	1.12 / 1.16	3.32 / 3.36
Tuna	117	0.01 / 0.04	0.05 / 0.16	101	0.13 / 0.17	0.45 / 0.45
Crab	275	0.62 / 0.63	2.28 / 2.28	274	1.26 / 1.27	4.18 / 4.18
Mussel	325	0.18 / 0.21	0.57 / 0.59	320	0.54 / 0.57	1.68 / 1.68
Oyster	235	0.41 / 0.41	0.93 / 0.93	235	0.89 / 0.89	2.11 / 2.11
Fish meat (unspecified)	589	0.14 / 0.16	0.62 / 0.62	655	0.80 / 0.82	3.19 / 3.19
Fish offal	911	4.33 / 4.89	12.7 / 13.1	911	21.7 / 22.0	60.3 / 60.5

LB: lower bound; UB: upper bound; P95: 95th percentile; DL-PCBs: dioxin-like polychlorinated biphenyls; PCDD/Fs: polychlorinateddibenzo-p-dioxins and dibenzofurans; TEQ: toxic equivalents; ww: wet weight.

3.1.1.3 *Toxicity Equivalency Concept*

To assess the risk associated with dioxins, the TEF approach is used to express the toxicity of individual congeners on a common scale. This approach accounts for the differing toxicological potency of each compound by assigning a specific TEF, derived by comparing its relative effect to that of the reference congener, 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD). The concentration of each congener is multiplied by its corresponding TEF, and the resulting values are summed to yield the total TEQ for a given mixture, such as food, feed, or biological samples (e.g. human milk). This methodology facilitates risk characterization of complex mixtures of dioxin-like compounds and has been widely adopted in regulatory toxicology.

TEF values have been developed under the auspices of the WHO since the mid-1990s. The TEFs currently in use in EU legislation to express maximum levels of PCDD/Fs and DL-PCBs in food and feed are based on the WHO2005 scheme. In 2022, a revised set of TEFs (WHO2022-TEFs) was proposed, based on a substantial body of new data, and published in a dedicated issue of Regulatory Toxicology and Pharmacology (DeVito et al., 2024). This revision incorporated more than 700 additional Relative Effect Potency (REP) datasets not available during the 1998 or 2005 WHO expert consultations (Van den Berg et al., 1998 - 2006; Haws et al., 2006). The expanded dataset enabled a more comprehensive evaluation of REP distributions and improved characterization of uncertainty across congeners. The 2022 WHO-

TEFs for the 29 PCDD/F and DL-PCB congeners discussed in this opinion are listed and compared to the 2005 WHO-TEFs in Table 2.

TCCD is still the reference congener for toxicity with a TEF of 1, while among the six other PCDDs, 4 congeners have a decreased TEF and for 2 of them, the TEF is increased. Among the 10 PCDFs congeners, the TEF is increased for 6 congeners, unchanged for 2 congeners and decreased for 2 congeners. Among the 12 DL-PCBs, the TEF is unchanged for 8 congeners (the mono-ortho DL-PCBs), while the TEF is decreased for 3 non-ortho DL-PCBs (PCB 126 and 169) and inceased for the two other non-ortho DL-PCBs (77 and 81).

Table 2. The 2022 WHO-TEFs for dioxin and dioxin-like compounds and comparison with 2005 WHO-TEFs (DeVito et al., 2024).

Congener	2005 WHO-TEFs	2022 WHO-TEFs
Polychlorinated Dibenzo-p-dioxins and Polychlorinated Dibenzofurans (PCDD / F)		
1,2,3,7,8-PeCDD	**1**	**0.4**
1,2,3,4,7,8-HxCDD	**0.1**	**0.09**
1,2,3,6,7,8-HxCDD	**0.1**	**0.07**
1,2,3,7,8,9-HxCDD	**0.1**	**0.05**
1,2,3,4,6,7,8-HpCDD	**0.01**	**0.05**
OCDD	**0.0003**	**0.001**
TCDF	**0.1**	**0.07**
TCDD	**1**	**1**
1,2,3,7,8-PeCDF	**0.03**	**0.01**
2,3,4,7,8-PeCDF	**0.3**	**0.1**
1,2,3,4,7,8-HxCDF	**0.1**	**0.3**
1,2,3,6,7,8-HxCDF	**0.1**	**0.09**
1,2,3,7,8,9-HxCDF	**0.1**	**0.2**
2,3,4,6,7,8-HxCDF	**0.1**	**0.1**
1,2,3,4,6,7,8-HpCDF	**0.01**	**0.02**
1,2,3,4,7,8,9-HpCDF	**0.01**	**0.1**
OCDF	**0.0003**	**0.002**
Dioxin-like Polychlorinated Biphenyls (DL-PCB)		
PCB77	**0.0001**	**0.0003**
PCB81	**0.0003**	**0.006**
PCB126	**0.1**	**0.05**
PCB169	**0.03**	**0.005**
PCB105	**0.00003**	**0.00003**
PCB114	**0.00003**	**0.00003**
PCB118	**0.00003**	**0.00003**
PCB123	**0.00003**	**0.00003**
PCB156	**0.00003**	**0.00003**
PCB157	**0.00003**	**0.00003**
PCB167	**0.00003**	**0.00003**
PCB189	**0.00003**	**0.00003**

3.1.1.4 *Data analysis and validation*

The European occurrence dataset was assessed for completeness and consistency. Missing values were identified, and the data were linked to consumption data for subsequent exposure assessment. The dataset contained no duplicates and was validated by the expert group for further use.

The distribution of analytical results across fish species was analysed to determine the number of data points, the species represented, and the average concentrations of the 17 PCDD/F congeners and the full set of 29 PCDD/F and DL-PCB congeners. The sum of congeners per fish species was calculated based on individual concentration values reported for each compound. Annex 1 illustrates the average concentrations of each congener of the full set of 29 PCDD/F and DL-PCB congeners for mussels (*Mytilus edulis*) for the LB scenario under the two WHO TEFs schemes (2005 and 2022).

3.1.2. Fish consumption

As stated in 2.2. Study description, the available national food consumption obtained from the nationally representative Belgian Food Consumption Survey 2014 (FCS_2014) were used. This covered individuals aged 3 to 64 years. The objectives, design, and methodology of the survey have been described in detail elsewhere (Bel et al., 2016).

For adolescents and adults (aged > 10 years), dietary intake was assessed using the 24-hour dietary recall method, conducted on two non-consecutive days with the computerised GloboDiet® software (formerly EPIC-Soft). For children aged 3 to 9 years, two self-administered one-day food diaries were completed on non-consecutive days, followed by a GloboDiet® completion interview with a proxy respondent.

GloboDiet® uses pre-defined, coded lists of foods, recipes, facets, and descriptors. Facets refer to specific attributes of food items, such as cooking method, brand name, or preservation technique. Descriptors are standardised answers linked to each facet—for example, “grilled,” “fried,” or “boiled” under the facet “cooking method” (Crispim et al., 2014).

3.1.3. Data classification

3.1.3.1 *Classification systems*

For this opinion, both consumption and occurrence data were coded using the FoodEx2 classification system developed by EFSA. At the time of analysis, version 14.3 of the FoodEx2 catalogue (MTX) was used. FoodEx2, introduced by EFSA (EFSA, 2011), is a hierarchical system that organizes individual food items into nested food groups through a parent-child structure. It consists of 20 main food groups at the first level, which are subdivided into approximately 140 items at the second level, 1,261 items at the third level, and around 1,800 food names or generic items at the fourth level.

Consumption data originally coded using the GloboDiet® classification system had previously been mapped to FoodEx2 in the context of the SHC Report 9343/SciCom Opinion 17-2022 “Advantages and disadvantages of eating fish and seafood. Part 1: Mercury and methylmercury in fish.” (SHC/SciCom, 2022). Where required, FoodEx2 codes were updated to ensure alignment with the current catalogue version. Annex 2 gives an overview of the matched consumption items through FoodEx2 and GloboDiet® (used in Belgian Food Consumption Survey) classifications.

For the evaluation of the nutritional benefits of fish consumption, nutrient composition data were retrieved from the Belgian NUBEL food composition table[10]. Information on total fat and omega-3 fatty acids was extracted for each fish species.

The complete codification map used for this assessment is provided in SHC Report 9343/SciCom Opinion 17-2022 (SHC/SciCom, 2022).

3.1.3.2 *Matching of analytical results to fish consumption data*

Occurrence data for dioxins and DL-PCBs were reported at the third level of the FoodEx2 hierarchy. Prior to exposure assessment, the identification of the most appropriate FoodEx2

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[10] See the Belgian NUBEL food composition table: https://www.nubel.be/foodtable/?lang=fr.

“termCode” for each food item was required to enable consistent linkage between occurrence and consumption data.

For fish and fish products, species information was used as a key variable to guide the matching process between analytical and corresponding consumption items. This approach ensured alignment across classification systems and supported species-specific exposure estimation where data allowed.

To ensure consistency between consumption and occurrence datasets, aggregation was applied where appropriate. For example:

- Generic fish meat and fish product entries were matched to the consumption category “Fish, not specified (n.s.)”.
- For the purpose of matching, species such as clam (*Mya arenaria*), cockle (*Cardium edule*), queen scallop (*Chlamys opercularis*), water molluscs, and whelk (*Buccinum undatum*, *Fusus antiquus*) were grouped under “Molluscs, not specified (n.s.)”.
- Less commonly consumed species such as cuttlefish (*Sepia officinalis*), octopus (*Octopus vulgaris*) and squid (*Loligo vulgaris*) were aggregated into a shared category.

Facets and descriptors available in FoodEx2 and GloboDiet® were not considered in this matching process in order to ensure a sufficient number of consumption records per fish category.

3.1.4. Exposure assessment

3.1.4.1 *Methodology*

To estimate long-term average intake from short-term consumption data, statistical modelling was required to account for both between-person and within-person variation. The habitual (or usual) intake distributions were estimated using the Statistical Program to Assess Dietary Exposure (SPADE) developed by Dekkers et al. (2014) and implemented via the R-package SPADE.RIVM© (version 4.1)[11].

SPADE models habitual intake as a function of age and accommodates the non-daily (episodic) nature of certain food items. In this analysis, the two-part model was applied, as fish was not consumed daily by all individuals in the survey. To quantify uncertainty around the estimated habitual intake distributions, a bootstrap procedure with 1,000 replicates was used, providing confidence intervals at the desired confidence level. To ensure nationally representative results, weighting factors were applied based on age, sex, province, season, and day of the week (weekday vs. weekend). This ensured that the habitual intake distribution reflected the structure and temporal variability of the Belgian population.

For the exposure modelling, food consumption data were combined with measured concentrations of either 17 or 29 PCDD/F and DL-PCB congeners. Mean concentration values were used in the calculations: Individual intake of each compound was estimated using the following equation:

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[11] See the Statistical Program to Assess habitual Dietary Exposure (SPADE) of RIVM: https://www.rivm.nl/en/spade.

$$Y_i = \sum_{k=1}^{n} \frac{X_{k,i} \times C_k}{bw_i}$$

where: Yi is the daily intake of dioxins of a given individual i (pg WHO2005 (or 2022)-TEQ (kg b.w.)$^{-1}$ day^{-}1.); n is the number of food items containing the dioxins, b.w.$_i$ is the measured body weight of a given individual i (kg); $X_{k,i}$ is the amount of the food k consumed on that day (g day^{-1}); Ck is the dioxins concentration (mean or P95) in the food item k (WHO2005 (or 2022)-TEQ g^{-1}).

3.1.4.2 *Exposure scenario based on different assessment approaches*

Exposure scenarios were developed to characterise dietary exposure to dioxins through fish consumption under different analytical assumptions, while accounting for variability in consumption patterns within the Belgian population. Dietary exposure was modelled using SPADE to capture the distribution of habitual intake, integrating consumption frequency and amounts with concentration data. This represents variability in consumption frequency and consumed amounts.

Concentration inputs were incorporated using mean analytical values rather than full concentration distributions. As a result, variability in exposure estimates primarily reflects differences in consumption behaviour, while concentration-related uncertainty was addressed by applying alternative lower and upper bound assumptions, as defined earlier in this opinion. Mean and higher-end exposure estimates were subsequently derived from the modelled intake distribution using these alternative concentration assumptions (lower and upper bounds), as defined earlier in this report.

Two congener groupings were considered throughout all scenarios:
(i) the 17 PCDD/F congeners, and
(ii) an extended set of 29 congeners, comprising the 17 PCDD/Fs and 12 DL-PCBs.

All congeners were expressed as TEQ using WHO TEFs. The extended congener set provides a more comprehensive representation of long-term dietary exposure by capturing the broader spectrum of dioxin-like compounds typically present in fish.

Scenario 1: LOWER BOUND exposure based on mean concentration levels (17 and 29 congeners)

This scenario estimates mean dietary exposure to dioxins and DL-PCBs under lower-bound concentration assumptions. Exposure was calculated by combining total fish consumption data for Belgian individuals with the corresponding mean concentrations per fish group. This scenario represents a minimally conservative estimate of chronic dietary intake and serves as a baseline for comparison with more conservative exposure assumptions.

Scenario 2: UPPER BOUND exposure based on mean concentration levels (17 and 29 congeners)

This scenario estimates mean dietary exposure using upper bound concentration assumptions and reflects a conservative but plausible long-term exposure situation. As in Scenario 1, exposure was calculated using Belgian fish consumption data and mean concentrations per fish group. This scenario represents a worst case estimate of chronic exposure, assuming that in non-quantified samples, dioxins and DL-PCBs are present at concentrations approaching analytically plausible upper limits.

3.1.4.3 *Fish species contributing to the total PCDD/F/DL-PCBs exposure of the general population*

The contribution of different fish species, grouped according to the FoodEx2 hierarchy, to the total estimated exposure via fish consumption was calculated. These calculations were based on deterministic exposure estimates generated using the ImproRisk model (Kafouris et al., 2024). ImproRisk is an open-access, R-based tool designed to support transparent, standardized, and harmonized dietary exposure assessments across Europe[12].

3.1.5. Risk assessment

The risk assessment was conducted by comparing the estimated dietary exposure to dioxins and DL-PCBs with the TWI established by EFSA. The EFSA CONTAM Panel set a TWI of 2 pg TEQ/kg body weight per week for dioxins and DL-PCBs (EFSA CONTAM Panel, 2018), which is currently the applicable reference value for risk characterisation.

TEFs used to derive TEQ values are established under the auspices of the WHO. The TEF scheme originally adopted in 2005 (Van den Berg et al., 2006) has recently been re-evaluated, with revised TEF values proposed in 2022 and reported by DeVito et al. (2024). This scientific re-evaluation has subsequently been considered by EFSA, and a new EFSA opinion reflecting the updated TEFs is expected in 2026.

To assess the potential impact of these revised TEFs on risk characterisation, dietary exposure estimates were evaluated using both the 2005 WHO TEF scheme and the revised 2022 TEF scheme. This comparison is made within the risk assessment framework, examining how updates in toxicological weighting may influence the interpretation of exposure relative to the established TWI. This comparison is also justified by the fact that current TWI and maximum levels for dioxins and DL-PCBs in foodstuffs set by the EU legislation are based on the 2005 WHO TEF scheme.

The resulting exposure estimates, stratified by population group (children (3 - 9 years), adolescents (10 - 17 years), and adults (18 - 64 years)) and analytical assumptions (lower and upper bounds), are summarised in Figure 1. In total, eight exposure estimates were generated per population group, allowing a structured comparison of risk characterisation outcomes under the two TEF schemes.

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[12] See also: https://www.improrisk.com/.

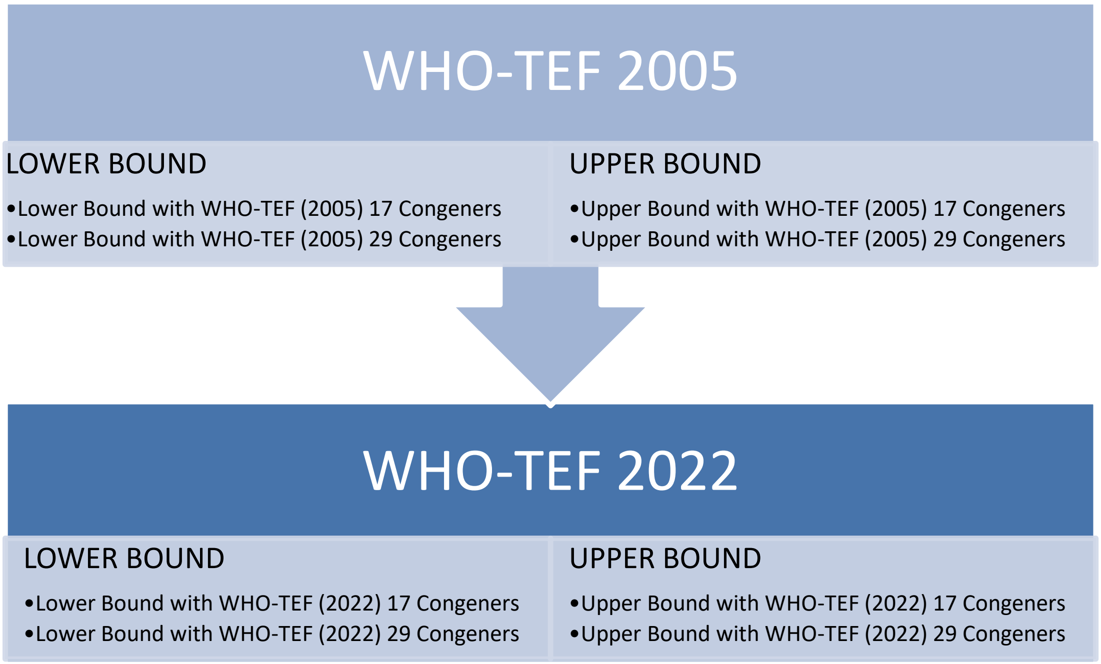

Figure 1. Graphical presentation of the considered exposure scenarios to PCDD/Fs (17 congeners) and PCDD/F/DL-PCBs (29 congeners) using WHO-TEF from 2005 and the current revised WHO-2022 TEF.

3.1.6. Risk - benefit of fish consumption

Fish consumption is widely recognised for its nutritional value, particularly as a source of essential omega-3 polyunsaturated fatty acids, vitamin D, iodine, selenium and high-quality protein—which are associated with nutritional benefits, including support for cardiovascular health, neurodevelopment (for more details, see the SHC report No. 9809/SciCom Opinion xx-2026 “Advantages and disadvantages of eating fish and seafood. Part 3: Nutritional and health aspects, overall analysis and recommendations.”, which will be available soon). Fish also contributes other nutrients such as vitamin D which is relevant for bone strength and muscle function. However, for the purpose of the present assessment, the benefit evaluation was deliberately restricted to omega-3 fatty acids.

This restriction was applied to ensure methodological consistency and interpretability, as a multi-nutrient benefit assessment would require separate or integrated evaluation of different nutritional components (e.g. omega-3 fatty acids and vitamin D), analogous to mixture considerations in contaminant risk assessment. Focusing on omega-3 fatty acids allowed a transparent and quantitative linkage between recommended intake levels and fish consumption within the scope of the present analysis.

3.1.6.1 *Risk-Benefit Assessment (RBA) methodology*

The nutritional benefits of fish consumption must be weighed against potential health risks associated with dietary exposure to persistent organic pollutants, notably dioxins and DL-PCBs, which are known to bioaccumulate in fatty fish.

To quantitatively assess this trade-off between nutritional benefit and toxicological risk, a scenario-based exposure estimation was performed. This estimation relied on recommended intake levels of omega-3 fatty acids for adults and children and assumed that these intakes would be met entirely through fish consumption. A deterministic approach was applied to calculate the corresponding dietary exposure to dioxins under these consumption scenarios.

Because the TWI for dioxins is expressed in picograms of WHO2005-TEQ per kilogram of body weight per week, fish consumption data —typically reported per day— required careful interpretation. A direct multiplication of daily consumption by seven to approximate weekly intake would likely overestimate actual weekly intake due to within-person variability and non-daily consumption patterns. Therefore, rather than converting the TWI to a daily value — the risk-benefit evaluation was conducted directly within a weekly framework, aligned with the structure of the benefit scenario.

Using this risk–benefit approach, the number of weekly fish servings (as combinations of fatty fish, i.e. salmon, and lean fish, i.e. cod) associated with the meeting omega-3 fatty acids (eicosapentaenoic acid (EPA) + docosahexaenoic acid (DHA)) intake recommendations was estimated and compared with the TWI for dioxins and dioxin-like compounds. This enables a more nuanced assessment of whether recommended levels of fish consumption for nutritional benefit may lead to exceedances of toxicological thresholds, particularly in sensitive population groups such as children, pregnant women or high fish consumers.

3.1.6.2 *Nutritional Value Data considered in the Risk-Benefit Assessment*

Nutrient composition, in particular EPA and DHA, data were retrieved primarily from the Belgian Nubel food composition table (Nubel, 2022) and supplemented by data from the NEVO[13] (Netherlands) and Ciqual[14] (France) databases. Recommended nutrient intakes were derived from national (SHC, 2004 – 2016 – 2019 – 2021 - 2025) and European[15] sources.

3.1.7. Uncertainties

The inherent uncertainties in the risk assessment on 29 congeners of PCDD/Fs have been noted and listed. Their evaluation was done according to EFSA guidelines (EFSA, 2007). The uncertainties were evaluated according to their source (the assessment objectives, the exposure scenario(s), the exposure model, the model inputs, and the performance of the assessment) and their type (vague or imprecise description, measurement uncertainty, sampling uncertainty due to limited sample sizes), default value uncertainty, extrapolation uncertainty, uncertainty about model structure, uncertainty about correlations or dependencies between inputs, differences in expert opinion, excluded factors, and ignorance which reflects (the possibility that unknown factors may influence exposure).

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[13] See the NEVO Dutch food composition database of RIVM: https://www.rivm.nl/en/dutch-food-composition-database.

[14] See the Ciqual French food composition table of ANSES: https://ciqual.anses.fr/.

[15] See the DRV Finder of EFSA for dietary reference values for the EU: https://multimedia.efsa.europa.eu/drvs/index.htm?lang=en.

3.2. Results

3.2.1. Fish consumption

According to FCS_2022 - 2023 (Sciensano, 2025), the mean weekly consumption of fish, molluscs, and crustaceans among Belgian adults was 132 g/week in the 18 – 64 age group and 164 g/week in individuals aged 65 years and older. Consumption patterns further indicated that 23 % of adults consumed more than 200 g per week, while 6.2 % of adults aged 18 – 39 years, 3.5 % of those aged 40 – 64 years, and 3.0 % of those aged 65 years and older reported never consuming fish. Fish represents the second most important source of dietary protein after meat, underscoring its nutritional relevance.

Publicly available summary results from FCS_2022 - 2023 further report a mean consumption of 19 g/day of fish and shellfish in the population aged 3 years and older, comprising approximately 14 g/day of fish, 4 g/day of crustaceans and molluscs, and 1 g/day of fish products. Mean consumption levels were reported to be similar in men and women.

Earlier findings from FCS_2014 had already highlighted fish as nutritionally relevant food group, contributing long-chain omega-3 fatty acids, vitamin D, iodine and high-quality protein. Based on these data, the SHC issues dietary guidelines in 2019 recommending the consumption of fish, seafood, or shellfish once to twice per week, including at least one serving of oily fish, while encouraging variation in species and origin. At that time, the average usual consumption of (preparations with) fish, shellfish, and seafood was 23 g/day, with higher values in older age groups.

When expressed on a daily basis, the mean consumption reported in FCS_2022-2023 (19 g/day) appears lower than the average usual consumption of 23 g/day reported in FCS_2014. However, this observation should be interpreted with caution, as it is based on summary statistics derived from different survey waves, population age ranges, and reporting formats. A direct, harmonised comparison of consumption trends over time would require additional analyses beyond the scope of the present opinion.

These findings reinforce the continuity and strengthening of public health messages between SHC (2019) and SHC (2025), with the aim of increasing fish consumption in Belgium for its nutritional benefits and as an alternative protein source.

The Belgian Food Consumption Survey 2014 (FCS_2014) was used in the preparation of this opinion as the detailed data from the more recent survey (FCS_2022-2023) were not available yet at the time this study was performed. The FCS 2014 provides nationally representative data on individual food intake, including the consumption of fish and seafood, recorded per specific food codes (foodnums). These data served as the basis for estimating intake levels relevant to both nutritional benefits and chemical exposure within the scope of this advisory opinion.

A more detailed evaluation of fish consumption by species and subgroup is presented in SHC Report 9343/SciCom Opinion 17-2022 “Advantages and disadvantages of eating fish and seafood. Part 1: Mercury and methylmercury in fish.” (SHC/SciCom, 2022).

Fish and seafood products included in this assessment were classified using the FoodEx2 system to ensure harmonised linkage between occurrence and consumption data. Occurrence data from the EFSA dataset were originally reported at the third level of the FoodEx2 hierarchy, comprising 59 fish and seafood species or product groups.

Of these 59 reported species or groups, 47 could be used for quantitative analysis. For a subset of species, a direct one-to-one match with consumption data was possible. For others, aggregation of closely related species or product groups was required to ensure compatibility with the structure and detail of the Belgian food consumption data. The remaining reported species could not be reliably linked to consumption data and were therefore not considered further.

Following this matching and aggregation step, 40 analytical fish and seafood consumption groups were defined and evaluated in the exposure and risk–benefit assessment. These groups represent the final level at which both occurrence data (mean concentrations) and consumption data were jointly available and suitable for quantitative analysis.

No further disaggregation by FoodEx2 facets or descriptors was applied. This stepwise approach ensured consistency between occurrence and consumption data while maintaining sufficient data coverage and robustness of the exposure estimates.

3.2.2. Occurrence data

3.2.2.1 *Concentration data (WHO2005-TEQs)*

The total of 7,009 analytical results related to fish and fish products was linked to 59 individual fish species which corresponded to the third level of FoodEx2 classification. Half of all the results were related to fish offal (13.28 %), salmon and trout (12.49 %), fish meat (8.24 %), halibut (6.79 %), herring (5.82 %) and cod and whiting (5.47 %). The number of results for each remaining group represented less than 5 % of total results.

Figure 2 illustrates the mean concentration of the sum of 29 congeners of PCDD/F/DL-PCBs in fish and seafood. The highest mean LB/UB concentrations for the sum of PCDD/F/DL-PCBs was found in the least consumed items like fish offal, in particular tarama (21.7 pg WHO2005-TEQ/g wet weight, LB), lumpfish roe (8.2 pg WHO2005-TEQ/g wet weight) and brill, smelt and fishpate (5 - 6 pg WHO2005-TEQ/g wet weight). The more consumed fish species like tuna, salmon, cod had levels below 1 pg WHO2005-TEQ/g wet weight. See also Annex 3.

In addition, for salmon and trout, EFSA compared concentrations by production type. Higher levels of all congener groups were observed in *wild/gathered/hunted* salmon originating from countries bordering the Baltic Sea. Samples from this region also showed elevated levels of PCDD/Fs and DL-PCBs overall. A similar pattern was found for herring, with higher concentrations reported in samples from the same region.

3.2.2.2 *Concentration data (WHO2022-TEQs)*

For all results, the new 2022 TEFs were applied, leading to a general trend of decreased TEQ concentrations compared to previous assessments. This decrease reflects the adjustments made in the WHO2022-TEF scheme, which takes into account updated data and a more refined approach to evaluating relative potencies. Figure 2 illustrates these differences for all fish samples reported in the EFSA CONTAM Panel 2018 assessment, demonstrating the impact of the updated TEF values on estimated TEQ concentrations. The reduction is particularly evident in certain fish species with historically higher levels of dioxin-like compounds, highlighting the potential for revised regulatory limits and risk assessments based on the new framework.

The application of the updated WHO 2022 TEF scheme resulted in overall lower TEQ concentrations compared with previous assessments based on earlier TEF values, reflecting revised Toxic Equivalency Factors derived from updated toxicological evidence.

Detailed mean concentrations data calculated using both WHO 2005 and 2022 TEF are shown in annex 3.

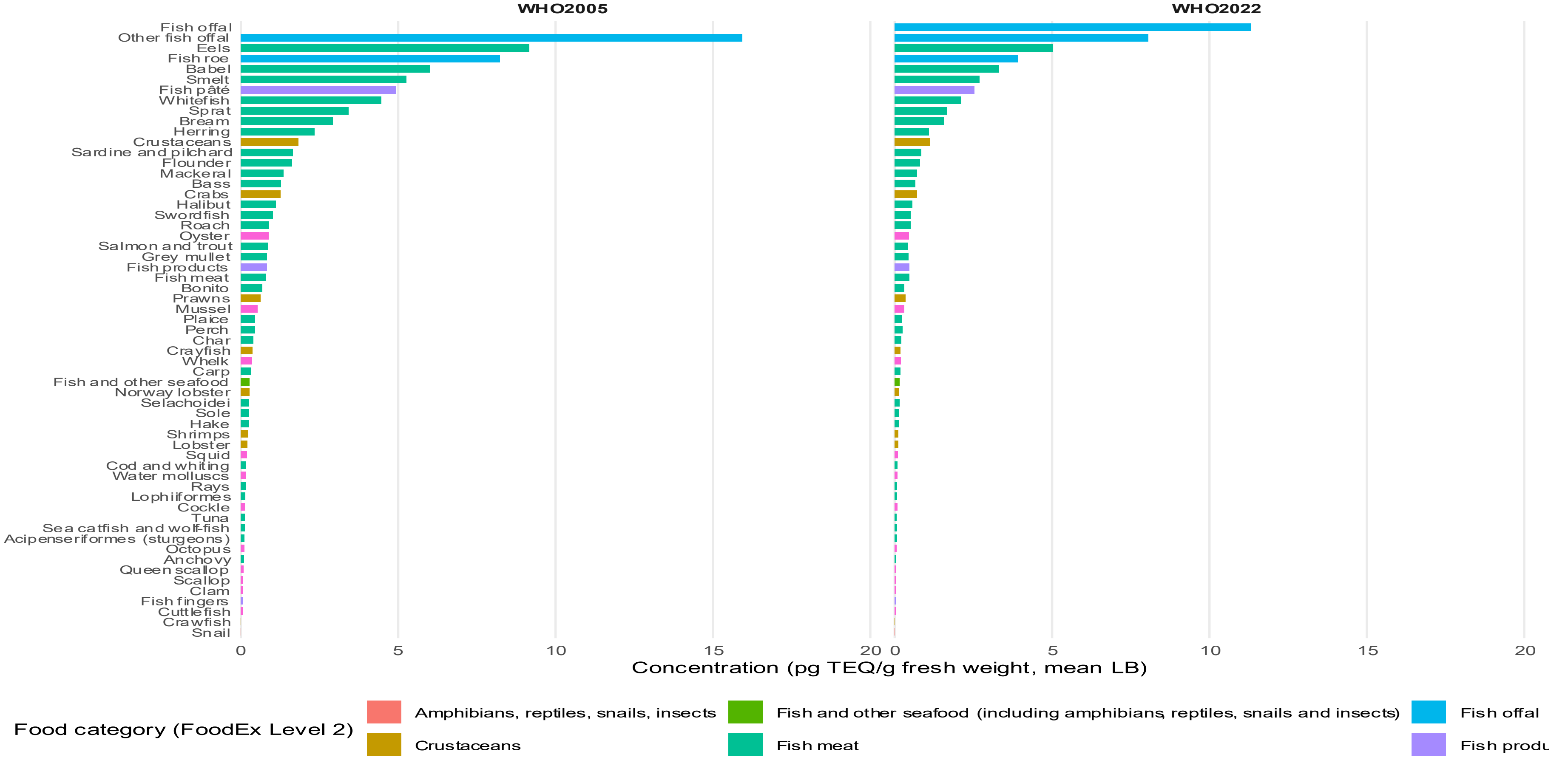

Figure 2. TEQ mean concentrations expressed under the WHO2005 and WHO2022 TEF scheme. Based on the dioxin and dioxin like-PCB concentrations reported by EFSA (EFSA CONTAM Panel, 2018, Annex B).

3.2.3. Exposure assessment (WHO-TEF2005)

The exposure assessment estimated dietary intake of dioxins and DL-PCBs through fish consumption for three population groups (children, adolescents and adults). Exposure was calculated for both the sum of 17 PCDD/F congeners and the sum of 29 PCDD/F and DL-PCB congeners, based on mean analytical concentrations and expressed using the WHO2005 TEFs.

Based on WHO2005-TEF, mean chronic dietary exposure estimates (lower and upper bounds) ranged from 0.037 to 0.069 pg WHO2005-TEQ/kg b.w./day for 17 congeners and from 0.107 to 0.198 pg WHO2005-TEQ/kg b.w./day for 29 congeners (Table 3). Children were the population group with the highest exposure.

Table 3. Mean chronic dietary exposure estimates (LB and UB*) of the Belgian population to 17 PCDD/Fs and 29 PCDD/F/DL-PCBs expressed as pg WHO2005-TEQ (kg b.w.)$^{-1}$ day^{-1} based on mean analytical concentrations in fish.

Population	Mean exposure estimates pg WHO2005-TEQ (kg b.w.)$^{-1}$ day^{-1}	
	Mean (LB, 17 PCDD/Fs)	**Mean (LB, 29 PCDD/F/DL-PCBs)**
Children	0,046	0,178
Adolescents	0,037	0,107
Adults	0,037	0,115
	Mean (UB, 17 PCDD/Fs)	**Mean (UB, 29 PCDD/F/DL-PCBs)**
Children	0,069	0,198
Adolescents	0,040	0,117
Adults	0,042	0,124

*LB/UB approach reflects the censoring of analytical results (see occurrence data), where for the LB scenario, analytical results below LOD or LOQ were set to zero; for the UB scenario, values below LOD were replaced by the LOD, and values below LOQ were replaced by the reported LOQ.

3.2.4. Exposure assessment (WHO-TEF2022)

For comparison, dietary exposure was also calculated using the WHO2022 TEF scheme. These calculations were performed to evaluate the impact of the revised toxicological weighting on exposure estimates and risk interpretation.

Using the revised WHO2022-TEFs, mean chronic dietary exposure estimates (lower and upper bounds) ranged from 0.022 to 0.046 pg WHO2022-TEQ/kg b.w./day for the 17 congeners and from 0.060 to 0.116 pg WHO2022-TEQ/kg b.w./day for the 29 congeners across the three population groups (Table 4). Among the evaluated groups, children consistently exhibited the highest exposure levels.

Table 4. Mean chronic dietary exposure estimates (LB and UB*) of the Belgian population to 17 PCDD/Fs and 29 PCDD/F/DL-PCBs expressed as pg WHO2022-TEQ (kg b.w.)$^{-1}$ day^{-1} based on mean analytical concentrations in fish.

Population group	Mean exposure estimates pg WHO2022-TEQ (kg b.w.)$^{-1}$ day^{-1}	
	Mean (LB, 17 PCDD/Fs)	**Mean (LB, 29 PCDD/F/DL-PCBs)**
Children	0,028	0,098
Adolescents	0,022	0,060
Adults	0,023	0,064
	Mean (UB, 17 PCDD/Fs)	**Mean (UB, 29 PCDD/F/DL-PCBs)**
Children	0,046	0,116
Adolescents	0,027	0,067
Adults	0,028	0,071

*LB/UB approach reflects the censoring of analytical results (see occurrence data), where for the LB scenario, analytical results below LOD or LOQ were set to zero; for the UB scenario, values below LOD were replaced by the LOD, and values below LOQ were replaced by the reported LOQ.

3.2.5. Identification of the main fish species contributors

The percentage of contribution of the different fish categories to the total exposure to 29 PCDD/Fs and DL-PCBs was calculated for each age group, based on the fish categories previously defined for the exposure assessment. The LB mean exposure scenario was used for this calculation. Results are presented in Figure 3.

Across all evaluated age groups, diadromous fish species, which migrate between freshwater and seawater environments represent the dominant contributor to fish-related exposure. This fish group includes salmon, trout, smelts, and similar species, which together can account for approximately one-third of the total exposure.

The next most relevant contributor is processed and preserved fish (17–27%) which comprises dried, smoked, canned, marinated, and salt-preserved fish products. Within this category, fish-based processed items are particularly relevant for children and adolescents, reflecting age-specific consumption patterns. Other contributors include: Fish meat (7–22%), Shrimps and prawns (8–10%), and Mussels (2–6%).

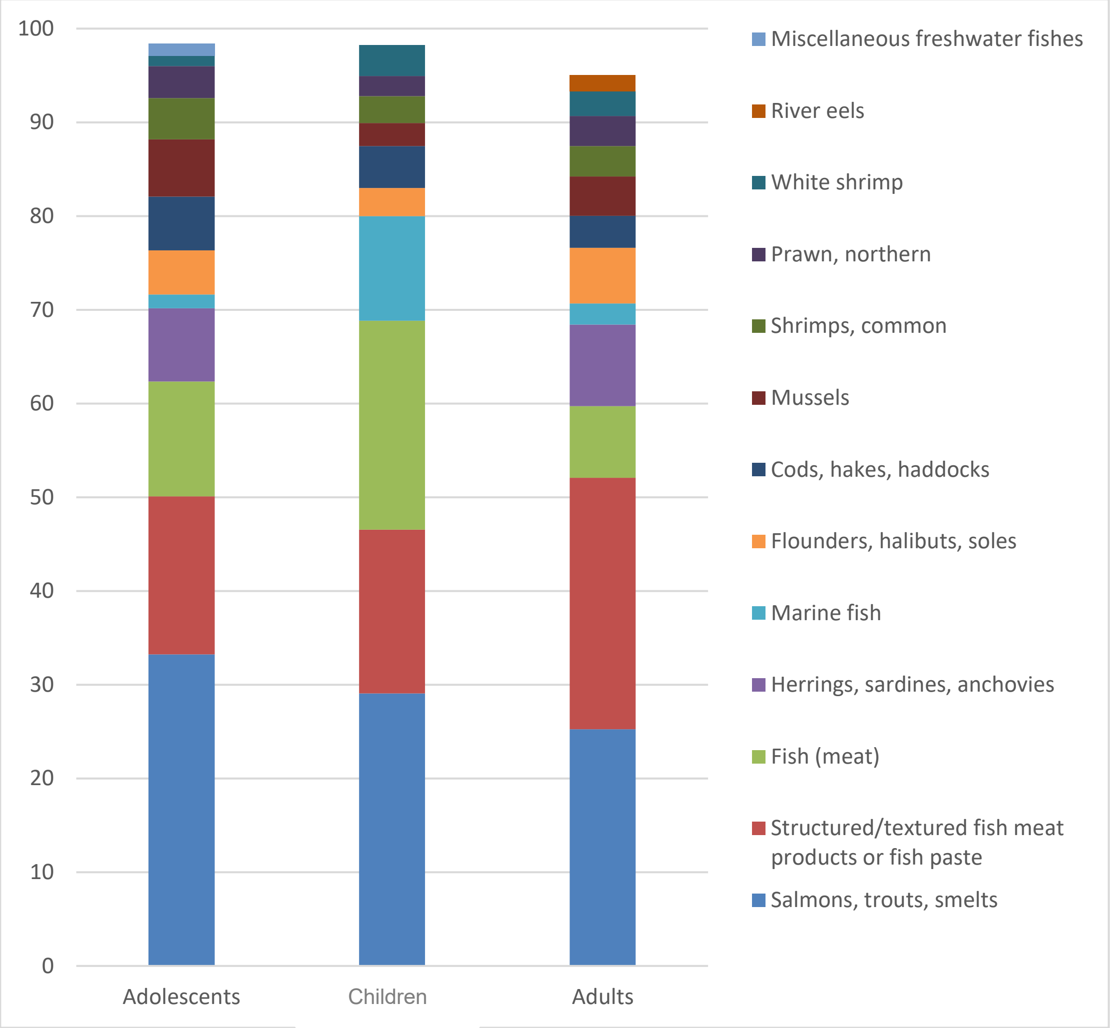

Figure 3. Contribution to the total exposure due to fish products to 29 congeners PCDD/F/DL-PCB (pg WHO2005-TEQ (kg b.w.)$^{-1}$ day^{-1}) from each fish species aggregated to FoodEx2 level4 and expressed for three population groups (children, adolescents and adults).

Although fish remains the principal dietary contributor to PCDD/Fs and DL-PCBs intake, it is not the only source. Other food groups —particularly meat, dairy products, and eggs— also significantly contribute to cumulative exposure. Therefore, a comprehensive risk assessment must consider the total dietary burden from all sources to accurately characterize potential health risks.

In 2024, the scientific project TEQFOOD[2] evaluated the presence of various dioxins and dioxin like compounds. TEQFOOD reported a mean lower bound dietary exposure to the sum of 29 PCDD/Fs and DL-PCBs of 1.8 pg WHO2005-TEQ/kg b.w./week for adults, 2.6 pg WHO2005-TEQ/kg b.w./week for adolescents and 4.6 pg WHO2005-TEQ/kg b.w./week for children. High-percentile (P95) exposures were approximately 70 – 80 % higher than mean values, indicating substantial inter-individual variability.

When applying the revised WHO2022 TEFs, mean exposure estimates were reduced by approximately 25 – 29 %; however, the total dietary exposure range still encompassed the WHO2005-based TWI of 2 pg TEQ/kg b.w./week, particularly for children and adolescents.

Results from the TEQFOOD project further clarify the role of fish and fishery products in the overall dietary exposure to dioxins and DL-PCBs and in addition to brominated dioxins and furans (PBDD/Fs) and other halogenated compounds (PBDD/Fs, but also PXDD/Fs and PXBs) in Belgium. Although fish and seafood contribute a relatively modest proportion of total TEQ intake at population level, they represent the most contaminated food group on a concentration basis. In particular, DL-PCBs—especially PCB126—dominate TEQ levels in fish, with herring, sardine, mackerel, and molluscs identified as the most contaminated composite samples, while raw fish fillets generally show lower contamination levels.

These findings indicate that fish consumption acts as a high-impact exposure pathway: while its contribution to total dietary exposure is limited by lower consumption volumes compared with dairy or meat, species selection and portion size can substantially influence individual exposure. This reinforces the relevance of species-specific and scenario-based risk–benefit assessments for fish consumption.

3.2.6. Risk assessment

3.2.6.1 *Risk assessment reported by EFSA*

The EFSA CONTAM Panel established a TWI of 2 pg WHO2005-TEQ/kg body weight per week in 2018 (EFSA CONTAM Panel, 2018).

In its 2018 assessment, based on occurrence and consumption data from multiple European countries, the EFSA CONTAM Panel estimated the mean dietary intake of total TEQ across all food categories to range from approximately 0.30 to 1.50 pg TEQ/kg b.w. per day (corresponding to 2.1 – 10.5 pg TEQ/kg b.w. per week) for adolescents, adults, the elderly, and the very elderly. At the high end of exposure (P95), corresponding intake estimates ranged from approximately 0.76 to 4.34 pg TEQ/kg b.w. per day (corresponding to 5.3 – 30.4 pg TEQ/kg b.w. per week), indicating substantial exceedance of the TWI. Within these overall exposure estimates, the contribution of fish and seafood products to total TEQ intake ranged from 30 % to 50 %, depending on population subgroup and consumption patterns.

Following the revision of TEFs in 2022, EFSA was mandated to update those aspects of the risk assessment potentially affected by the revised TEF values.

3.2.6.2 *Risk assessment performed for Belgian population*

For this opinion, risk characterisation for Belgian population was performed by comparing estimated dietary exposure to dioxins and DL-PCBs with the TWI of 2 pg TEQ/kg b.w./week established by the EFSA CONTAM Panel (EFSA CONTAM Panel, 2018).

Figure 4 and Figure 5 illustrate the distribution of dietary exposure to dioxins and DL-PCBs through fish consumption in Belgium, expressed using both the WHO2005 and WHO2022 TEFs, and evaluated in relation to the health-based guidance value (TWI/7).

When exposure estimates are interpreted under the WHO2005 TEF scheme in relation to the TWI of 2 pg WHO2005-TEQ/kg b.w. per week (i.e. 0.29 pg/kg b.w. per day), exceedances occur at relatively low percentiles of the exposure distribution. Figure 4 shows the distribution of these estimates and indicates indeed that the TWI divided by seven is exceeded for children at the 80th percentile (LB) and 75th percentile (UB). This pattern is most evident in children and, to a lesser extent, adolescents, and are more pronounced when considering the 29-congener assessment. Within this framework, the TWI is exceeded across a substantial part of the upper exposure distribution, indicating a more widespread potential concern associated with fish consumption.

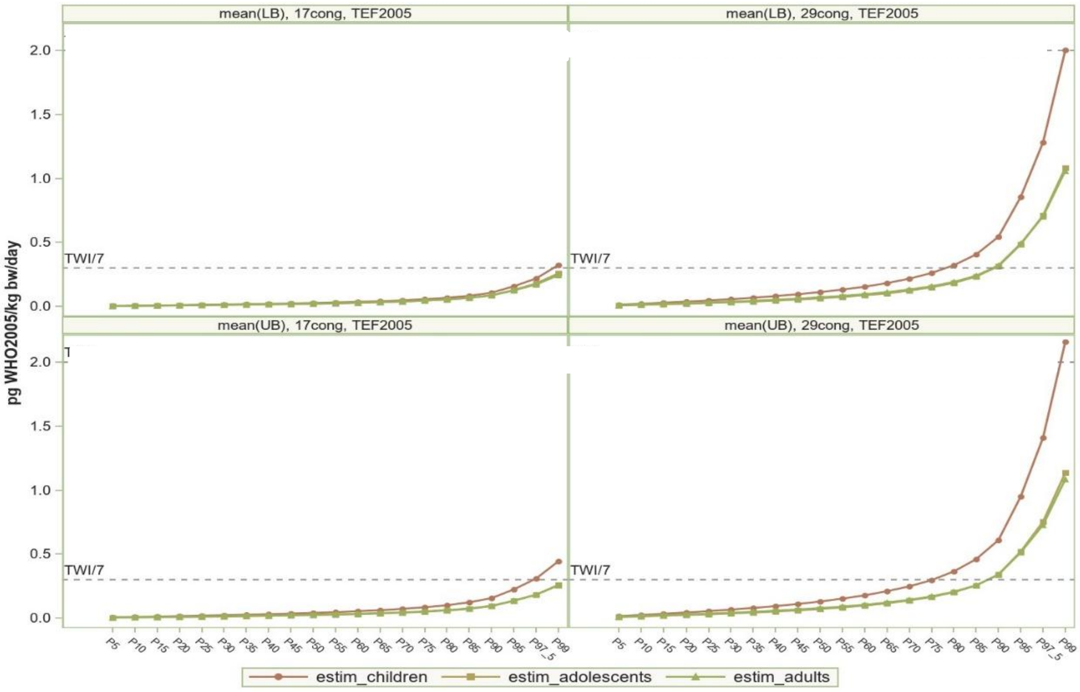

Figure 4. Distribution of exposure estimates to 17 PCDD/Fs and 29 PCDD/F/DL-PCBs through fish consumption for children, adolescents and adults expressed as pg WHO2005-TEQ (kg b.w.)$^{-1}$ day^{-1} for LB and UB approaches based on mean analytical concentrations in fish (TWI/7 corresponds to 0.29 pg TEQ (kg b.w.)$^{-1}$ day^{-1}).

Application of the revised WHO2022 TEFs modifies this interpretation. The updated toxicological weighting yields in lower estimated TEQ intakes compared with calculations based on earlier TEFs. Figure 5 presents the distribution of exposure estimates and shows indeed that, when expressed on a daily basis, exceedance of the TWI divided by seven occurs for children above the 90th percentile under the lower bound scenario. Under this approach, the TWI of 2 pg TEQ/kg body weight per week continues to provide an adequate margin of protection for the majority of the population, with estimated exposures for adolescents and adults remaining below TWI/7 across nearly the entire distribution.

Under the WHO2022 framework, exceedances are largely confined to the upper percentiles of exposure and remain most prominent in children, particularly when applying the 29-congener assessment. This shift does not indicate a change in exposure drivers but reflects the influence of revised toxicological weighting on TEQ calculations, resulting in a more concentrated identification of higher-exposure subgroups.

Annex 4 facilitates comparison of consumer exposure between the two WHO TEFs schemes (2005 and 2022).

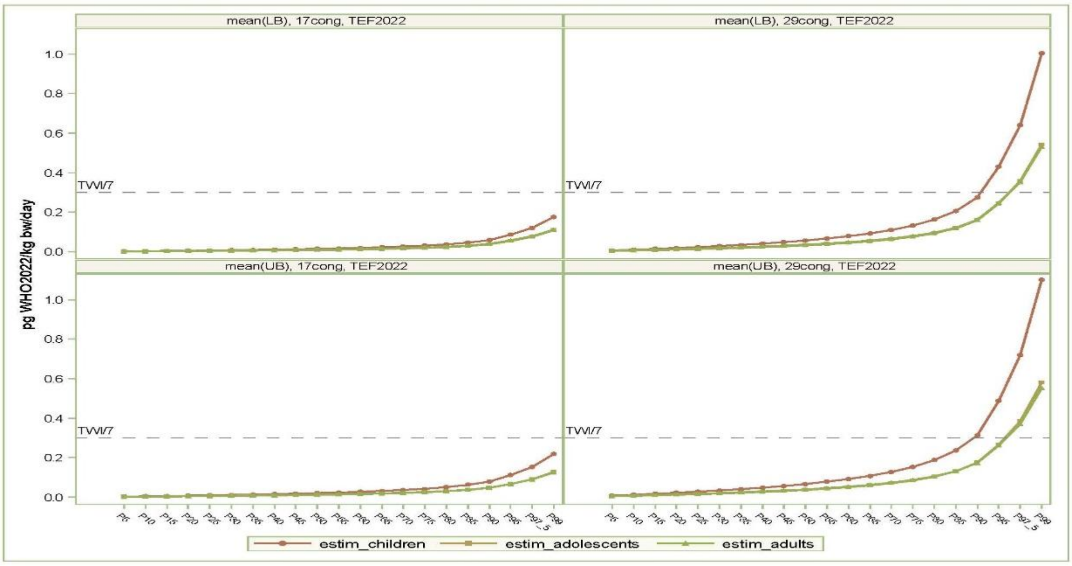

Figure 5. Distribution of exposure estimates to 17 PCDD/Fs and 29 PCDD/F/DL-PCBs through fish consumption for children, adolescents and adults expressed as pg WHO2022-TEQ (kg b.w.)$^{-1}$ day^{-1} for LB and UB approaches based on mean analytical concentrations in fish (TWI/7 corresponds to 0.29 pg TEQ (kg b.w.)$^{-1}$ day^{-1}).

These observations show that the current TWI of 2 pg TEQ/kg body weight per week offers relative protection. Even at significantly lower hypothetical guidance levels, the concern pattern is mainly influenced by high-exposure individuals, not a general population shift.

The Belgian results are consistent with EFSA's risk characterisation, which identify children as the most sensitive population group and emphasise the importance of interpreting dietary exposure in light of evolving toxicological reference frameworks.

3.2.7. Risk-Benefit Assessment

3.2.7.1 *Benefit exposure scenario's*

An integrated evaluation of fish consumption scenarios was conducted to examine the balance between nutritional benefits and potential toxicological concerns. The analysis considered the contribution of long-chain omega-3 fatty acids (EPA and DHA) alongside exposure to dioxins and DL-PCBs (PCDD/Fs and DL-PCBs). A range of realistic weekly consumption patterns involving fatty fish (FF) (i.e. salmon) and lean fish (LF) (i.e. cod) was assessed to reflect dietary behaviours relevant to both adults and children.

The assessment was developed in the context of public health guidance issued by SHC (2025), which recommends regular fish consumption with at least 200 g of fish per week, including at least one portion of fatty fish. For children, a minimum intake of 100 mg EPA+DHA/day was used as the nutritional reference value, consistent with SHC guidance (SHC, 2016). This intake corresponds approximately to 70 g of fatty fish per week, depending on species and fat content. For adolescents and adults, a minimum intake of 250 mg EPA+DHA/day was used as the nutritional reference value, consistent with SHC guidance (SHC, 2016). This intake corresponds approximately to 200 g of fatty fish per week, depending on species and fat content.

3.2.7.2 *Risk benefit estimates*

From a public health perspective, this analysis identifies a range of fish consumption scenarios that balance nutritional benefit with toxicological considerations. The evaluated scenarios which are illustrated in Figure 6 and Figure 7 are defined by fixed combinations of fatty fish and lean fish, allowing direct comparison of their respective contributions to beneficial nutrient intake and contaminant exposure. Both exposure and intake estimates are presented within the same graphical framework to support integrated assessment of predefined consumption scenarios.

Colours are used solely to differentiate the two assessment components. Green bars represent total EPA+DHA intake, whereas red bars indicate weekly exposure to dioxins. The divergent graphical format enables simultaneous presentation of nutritional intake and contaminant exposure across predefined consumption scenarios.

The decision to display both dimensions within a single figure was made to facilitate integrated interpretation of benefit and risk for identical dietary scenarios. Although the metrics are expressed in different units and are not directly comparable in magnitude, they are presented in their original measurement scales to preserve transparency and avoid artificial normalisation. Each consumption scenario has to be interpretated relative to the current TWI of 2 pg TEQ/kg b.w./week in terms of risk (left-hand side of Figures 6 and 7) and to the dietary recommendation of minimum 1.75 g EPA+DHA/person/week for adults (= 7*250mg/person/day) or 0.7 g EPA+DHA/person/week for children (= 7*100mg/person/day) in terms of benefit (right-hand side of Figures 6 and 7).

The quantitative estimates associated with these scenarios depend on the TEF scheme applied. Differences observed between calculations based on the WHO2005 and WHO2022 TEFs reflect revisions in toxicological weighting rather than changes in consumption patterns or exposure conditions. The application of updated TEFs, therefore, influences the magnitude of TEQ estimates without altering the underlying dietary scenarios.

Consumption patterns falling below the EPA+DHA intake threshold are considered insufficient to ensure optimal cardiovascular and developmental benefits. Conversely, scenarios exceeding the current TWI indicate increased toxicological relevance, even when nutritional targets are achieved. This relationship highlights the need to consider both benefit and risk dimensions when formulating dietary guidance.

Higher fish consumption generally improves EPA+DHA intake but is also associated with increased exposure to dioxins and DL-PCBs. As a result, nutritional benefit and toxicological burden do not increase proportionally. An intermediate range of intake scenarios can be identified in which nutritional objectives are achieved without a corresponding increase in toxicological concern.

Under the WHO2005 TEF scheme, moderate consumption scenarios yield TEQ estimates that are comparatively higher, resulting in a greater proportion of intake combinations approaching or exceeding the current TWI. Application of the WHO2022 TEFs leads to lower TEQ estimates for identical dietary scenarios, thereby reducing the frequency of TWI exceedances. These differences arise from updated toxicological weighting and do not indicate changes in dietary exposure patterns.

Child-specific scenarios demonstrate greater sensitivity to variation in intake combinations when body weight is normalised. Consequently, shifts along the risk dimension are more pronounced in children than in other population groups, underscoring the importance of age-specific considerations in benefit–risk evaluation.

Overall, this analysis confirms that fish represents an important source of nutritionally relevant omega-3 fatty acids. However, the results also indicate that not all intake scenarios are equally favourable from a combined benefit–risk perspective, reinforcing the relevance of balanced consumption patterns.

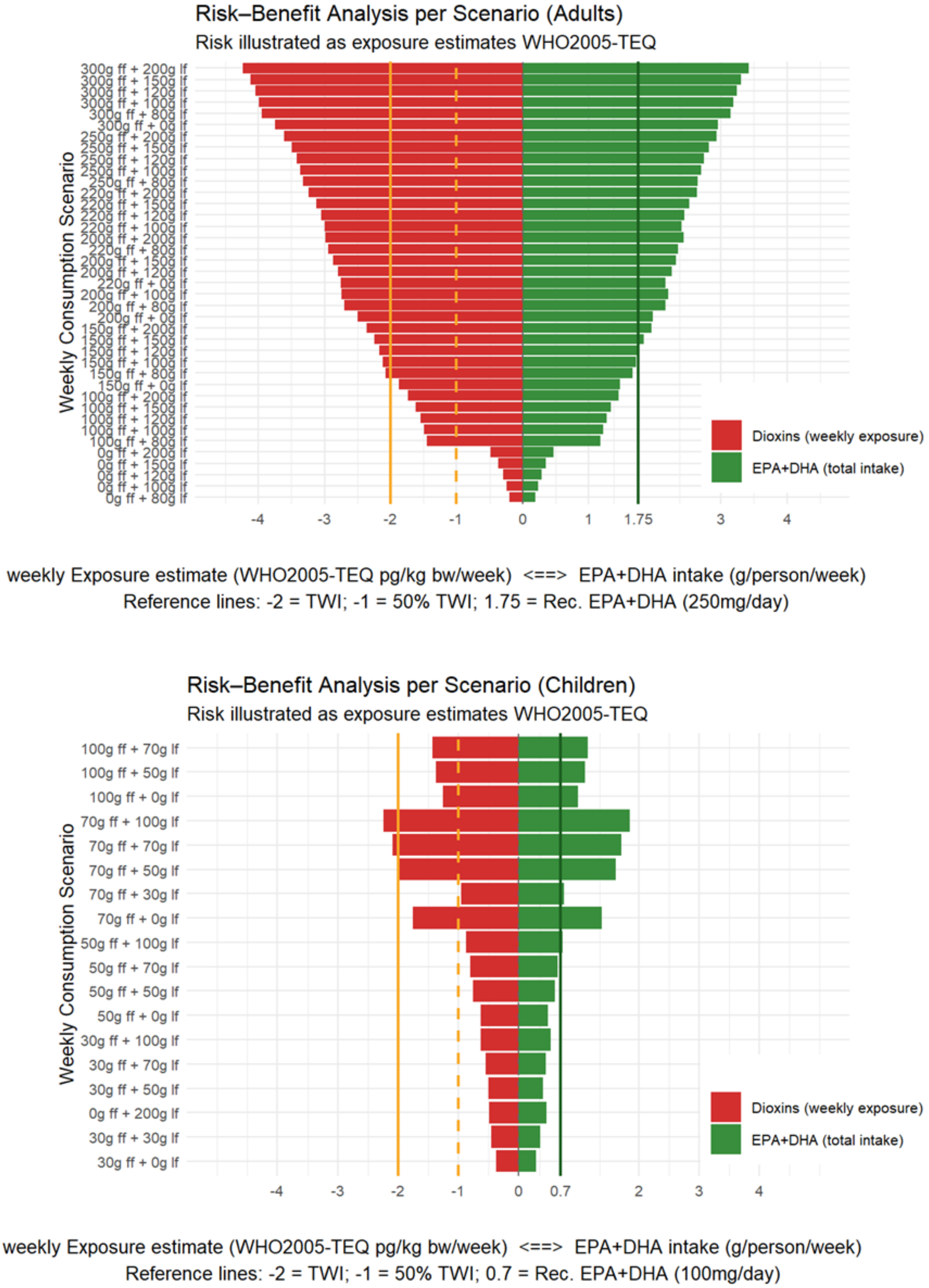

Figure 6. Risk-benefit analysis for adults and children based on EPA and DHA and exposure estimates expressed in WHO2005-TEFs based on mean analytical concentrations in fish (*ff, fatty fish; lf, lean fish).

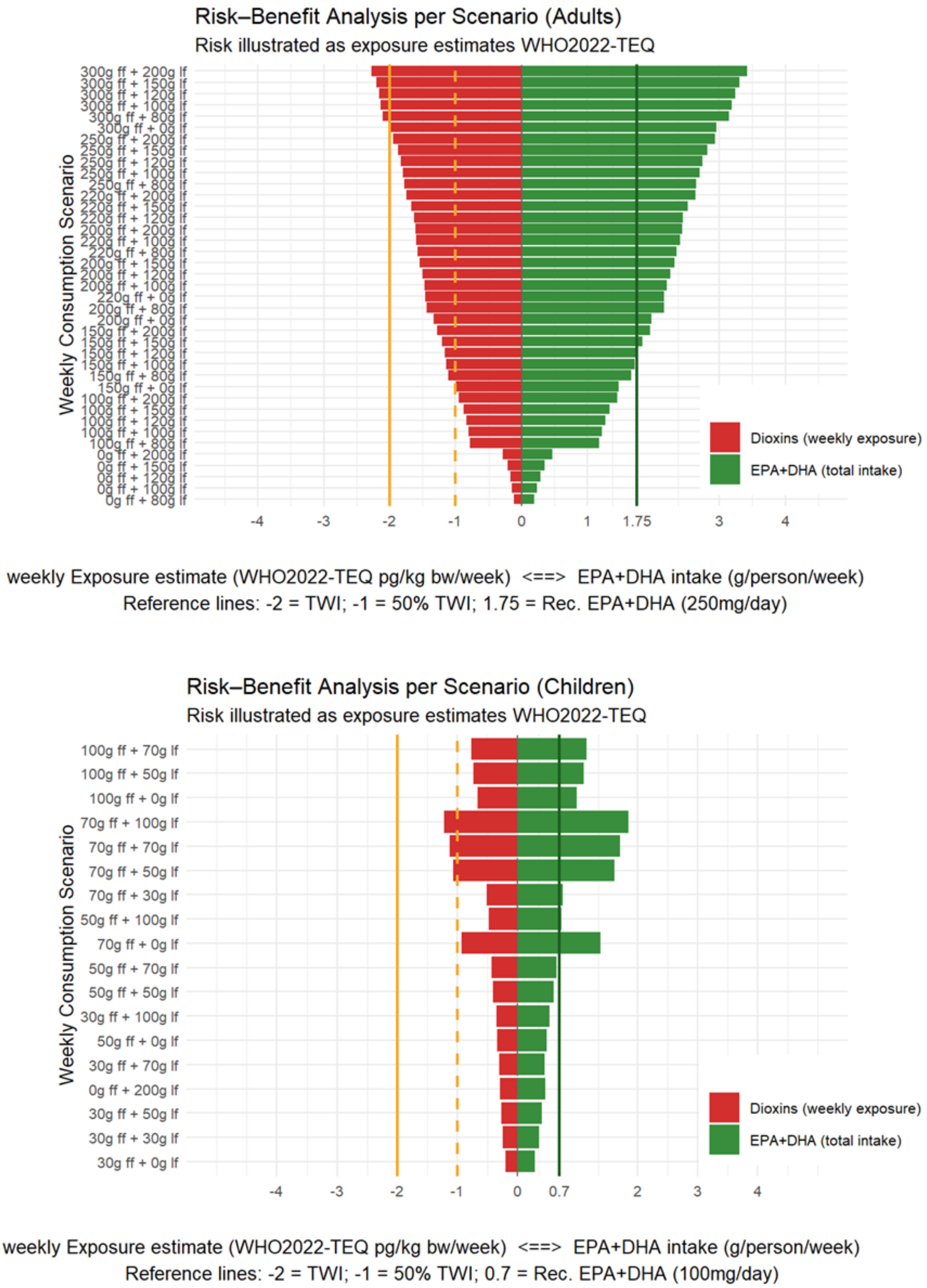

Figure 7. Risk-benefit analysis for adults and children based on EPA and DHA and exposure estimates expressed in WHO2022-TEFs based on mean analytical concentrations in fish (*ff, fatty fish; lf, lean fish).

3.2.8. Uncertainty analysis

A qualitative evaluation of key uncertainties affecting the dietary exposure and risk assessment of PCDD/Fs and DL-PCBs is summarized in Table 5, including an indication of the likely direction of their influence — either toward overestimation (+) or underestimation (–).

Table 5. Summary of qualitative evaluation of the impact of uncertainties on the exposure and risk assessment of the dietary exposure to PCDD/F/DL-PCBs.

Sources of uncertainty	Direction[a]
ANALYTICAL RESULTS	
Measurement uncertainty of analytical results The analytical results were collected over the period of years, in which the analytical method could have been modified leading to various measurement uncertainties.	-/+
Use of analytical data from targeted sampling Analytical results were obtained from food control programmes at European level (not specifically Belgium) which is a risk-based system to monitor contaminants in food available on the market or to be placed on the market.	++
Mean concentration values were used for the assessments Worst case scenario of people consuming highly contaminated fish were not included.	-
Use of the substitution method for non-detects Lower and upper bounds approach were applied. Percentage of censored data was not reported.	+
Occurrence data derived from before 2018 The underlying datasets were previously evaluated at European level and therefore reflect contamination patterns representative of the corresponding assessment period. As a result, potential temporal changes in contaminant levels arising from subsequent risk-management or mitigation measures are not explicitly captured. Consequently, reductions in contamination that may have occurred following the original data collection would not be reflected in the present exposure estimates. Updated analytical initiatives, such as the TEQFOOD project, provide complementary evidence suggesting that temporal variations in TEQ levels may occur when more recent occurrence data are considered.	+
EXPOSURE MODELLING	
Matching the analytical results to the best possible consumption data There were 3 matched groups. Several concentration data were aggregated. The analytical results were matched using FoodEx2 classification which increased the reliability. On the other side, matching to the consumption data was difficult for some fish species which were vaguely defined in FCS_2014.	--/++

To match consumption of fatty fish, marine fish and whitefish aggregated groups were made. For fatty fish, fat percentage > 5 % as registered in NUBEL was taken into account, namely these were: halibut, eel, tuna, salmon, see catfish. Marine fish was selected according to the indication on the concentration data (anchovis, teleosts, shak, halibot, cod, merlin, eel, pangasius, rye, plaice, sole, sea bass, marine catfish, sea devil, swordfish, whiting). As white fish following fish species for which the analytical results were available, were considered: cod, pangasius, pike, plaice, tilapia, tong, nile perch and whiting. Occurrence data reported for "fish meat" and "fish products" were matched to consumption of "Fish n.s.". Occurrence data for clam (*Mya arenaria*), cockle (*Cardium edule*), queen scallop (*Chlamys opercularis*) and water molluscs were matched to the consumption of "Molluscs n.s." and occurrence data for cuttlefish (*Sepia officinalis*), octopus (*Octopus vulgaris*) and squid (*Loligo vulgaris*) were matched to the consumption of "Cuttlefish/squid".	
Consumption of fish preparation ("fish dish") Several fish species are used for the preparation of fish-based salads, the sauce-based food preparation where in most of the cases canned fish would be used (e.g. tuna salad). General recipes are used for conversions of the concentrations in this kind of food (Bel et al., 2016). However, it is challenging to find the real fish source in these foods which might underestimate the real concentration of either measured contaminants.	-
Exposure estimation from rarely consumed fish and/or in high consumers Fish offal was one of the highly contaminated fish related products, but it is less consumed by children.	-/+
Different time frame between concentration data and consumption data Concentration data from EFSA database were used for the assessment reported in EFSA CONTAM Panel opinion (2018). They were collected in the period from 2010 onwards to the end of December 2016. On the other, consumption data used in this assessment were collected in 2014. Therefore, the time frame is different but may be considered applicable.	+/-
Long-term (chronic) exposure assessed from few days of consumption FCS_2014 is a cross-sectional study for which information on food intake was collected in adults with two non-consecutive 24-h dietary recalls. The long-term exposure is evaluated on a weekly level. Although data collection was divided equally over the four seasons and days of the week in order to incorporate seasonal effects and day-to-day variation in food intake it is limited in representing the whole week consumption.	+

RISK ASSESSMENT	
Expression of TWI based on the daily intake To perform the risk characterization, the TWI values was divided by seven to match daily intakes (results from 2X24H consumption recalls). This may overestimate the intake for many consumers.	+
[a]+ = uncertainty with potential to cause over-estimation of exposure; - = uncertainty with potential to cause under-estimation of exposure	
	-/+

Given the range of data sources, assumptions, and aggregation steps involved in the exposure estimation process, the cumulative uncertainty may be significant. While the applied methodology aligns with established EFSA and SHC practices, a more refined uncertainty analysis —ideally integrating probabilistic or distribution-based exposure modelling— could further enhance the robustness and interpretability of the results.

4. CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

4.1.1. General conclusions

Based on the results of the present assessment, children constitute the population group with the highest dietary exposure to dioxins and DL-PCBs from fish and seafood consumption. This pattern primarily reflects their lower body weight combined with consumption levels that are comparable, in relative terms, to those observed in other age groups. Exposure estimates for adolescents and adults were consistently lower.

Mean dietary exposure estimates (WHO2005 TEQ and WHO2022 TEQ) for the sum of PCDD/Fs and DL-PCBs derived from fish and seafood alone, remained mostly below the TWI established by the EFSA CONTAM Panel (2018) for the Belgian population in all exposure scenarios. In children, however, exceedances of the TWI were observed at higher percentiles of the exposure distribution, particularly under upper bound assumption. This finding indicates potential concern for high consumers within this age group rather than for the population average.

Application of the updated TEF scheme yielded comparable distributional patterns. Although TEQ magnitudes differed due to revised toxicological weighting, the relative identification of children as the most exposed population subgroup remained unchanged. The same holds considering other TWI values than that established by the EFSA CONTAM Panel in 2018.

It is important to note that the exposure estimates presented in this opinion are limited to fish and seafood consumption and therefore reflect only a portion of total dietary exposure to PCDD/Fs and DL-PCBs. Evidence from the European dietary exposure assessment (EFSA CONTAM Panel, 2018) indicates that, although fish and seafood represent a significant contributor to overall TEQ intakes (approximately 30 – 50 %), cumulative exposure also arises from other food groups, notably meat, dairy products, and eggs. Accordingly, exposure levels derived from fish consumption should be interpreted within the context of total dietary intake. Scenarios approaching the TWI based on fish consumption alone may yield a smaller difference from the toxicological reference value when background exposure from the remainder of the diet is considered. This consideration supports a cautious interpretation of high-exposure scenarios and underscores the relevance of balanced dietary patterns.

In parallel, the nutritional benefits associated with fish consumption —based on the intake of long-chain omega-3 fatty acids— were evaluated using a scenario-based risk–benefit approach. This evaluation illustrates that balanced combinations of fatty and lean fish, when consumed in nutritionally relevant quantities, can provide adequate levels of EPA and DHA while maintaining exposures to dioxins and DL-PCBs below the toxicological reference value (TWI). While this scenario-based analysis represents a simplified and defined intake combinations, it does not capture the full extent of variation in concentration, inter-individual variability or long-term dietary patterns. Further refinement using population-based modelling approaches would therefore support a more comprehensive characterisation of the benefit–risk balance and may assist in informing future dietary recommendations.

For children, the balance between nutritional benefit and toxicological safety is inherently more constrained. Both scenario-based and modelled estimates indicate that moderate consumption levels may already approach the health-based guidance value (TWI). This observation underscores the importance of portion size, fish category, and species diversity when formulating dietary advice for younger age groups.

The present assessment includes deterministic intake scenarios (defined scenarios) based on available consumption and occurrence data. Nevertheless, certain dimensions of dietary exposure remain only partially characterized, including inter-individual variability, long-term dietary habits, and combined exposure from multiple food sources. Further refinement through fully probabilistic, distribution-based benefit–risk modelling would support more robust population-level guidance and may be recommended for future assessments.

4.1.2. Data gaps

Several data limitations were identified during the preparation of this opinion, that are relevant for interpretation of the exposure and risk assessment results. Where necessary, specific assumptions were applied, as described in the uncertainty analysis. Due to their importance for future assessments, the principal gaps are summarised below.

- **Representativeness and coverage of analytical data:**

The available occurrence data were derived primarily from European food control programmes, which applies targeted sampling strategies based on prior risk analysis. While suitable for regulatory monitoring, such data are not designed to represent average contamination levels in fish products consumed by the general population. For example, certain species or in some parts, such as fish offal, were highly represented in the analytical dataset despite minimal reported consumption. This imbalance may influence risk characterisation. Broader integration of occurrence data from research, surveillance, and complementary monitoring initiatives would support improved representativeness.

- **Limited detail in food consumption data:**

A substantial proportion of fish consumption entries in the Belgian food consumption database (FCS_2014) lacked species-level detail (e.g. coded as "Fish n.s."). This limited granularity constrained the development of species-specific exposure scenarios and required aggregating different species into broader food groups. While aggregation enabled alignment with analytical data and classification systems, it introduced uncertainty in the estimates. Future dietary surveys would benefit from increased specificity of food coding and improved characterisation of fish consumption patterns. Enhanced identification of fish species at the reporting stage (by survey respondents) would further support exposure assessment accuracy and may assist in informing consumer-oriented educational initiatives.

- **Classification and harmonisation constraints:**

The EFSA occurrence data and national food consumption data are based on different classification systems, requiring additional mapping and harmonization. Although the data were aligned using the FoodEx2 classification system, future data collection efforts should ensure greater consistency in food description and categorisation across datasets. This would improve the reliability and efficiency of future risk assessments.

- **Processed and composite fish products:**

Processed products such as mixed fish dishes, spreads, and sauces (e.g. tuna salad) introduce additional uncertainty due to variable or undefined fish content or source. Exposure reconstruction relied on generic recipes, which may not reflect real-world variation. Improved labelling practices and better access to compositional data would enhance the accuracy of such estimates. This objective is consistent with the initiatives such as ScanFoodLabel[16], which aims to facilitate structured ingredient identification, classification, and extraction from food labels.

- **Integration of health outcome data for risk-benefit analysis:**

While nutrient exposure and contaminant exposure were estimated, integration into a quantitative population-level risk-benefit framework remains limited by the availability of national health outcome data. Current national burden of disease estimates in Belgium do not yet fully cover dietary risk factors such as specific nutrient intakes or chemical exposures. Future efforts should aim to incorporate such parameters into burden of disease analyses to support quantitative risk-benefit assessments in a more holistic and policy-relevant manner.

- **Sustainability considerations:**

This assessment did not integrate environmental sustainability dimensions, such as the ecological impact of fish consumption patterns or the origin of fish species. For a comprehensive risk-benefit evaluation, future work may benefit from inclusion of sustainability indicators (e.g. biodiversity impact, carbon footprint, fishing practices) to support balanced dietary recommendations that are both health-promoting and environmentally responsible.

4.2 Recommendations

Based on the estimated dietary exposure to dioxins and DL-PCBs through fish consumption, as well as the demonstrated nutritional benefits of fish and seafood, SHC/SciCom issues the following high-level recommendations:

1. **Encourage balanced and varied fish consumption.**

For the general adult population, a minimum consumption of 200 g per week of fish, molluscs, and crustaceans, including at least one portion of fatty fish, is recommended in line with the updated dietary guidelines of SHC (2025). This level of intake supports the adequate provision of essential nutrients such as EPA, DHA, iodine, selenium, and vitamin D, while maintaining a balanced approach to managing exposure to persistent contaminants such as dioxins and dioxins like PCBs.

2. **Favour diversity in species and origin.**

To support a balanced benefit–risk profile, consumption of a variety of fish species and sources is advisable. Diversification reduces the likelihood of sustained exposure to contaminants associated with specific species while preserving the recognized nutritional benefits of fish intake. In this context, disproportionately large portions of species known to exhibit higher contamination levels should be avoided.

Such an approach helps limit cumulative dietary exposure to dioxins and DL-PCBs, which may vary substantially across species, trophic levels, and environmental conditions. While fish commonly consumed within typical dietary patterns generally display comparatively lower mean concentrations, less frequently consumed species and fish offal may contain elevated levels.

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[16] See the 2024/DGAPF/CC/ScanFoodLabel project “The development of a database of information on the labelling and packaging of food products on the Belgian market”: https://www.sciensano.be/en/projects/development-a-database-information-labelling-and-packaging-food-products-belgian-market.

Based on the occurrence data evaluated in this assessment and the scenario-based benefit–risk analysis, fish species associated with comparatively lower mean levels of dioxins and DL-PCBs, while contributing meaningfully to EPA and DHA intake, include salmon, trout, cod, pollock, haddock, tuna, herring, and sardine.

3. Maintain protective guidance for vulnerable groups.

For children, pregnant women, and women of childbearing age, fish consumption, including fatty fish, remains recommended. Specific dietary patterns such as pesco-vegetarian diets were not separately assessed in this opinion, but the findings remain relevant given the potentially higher relative contribution of fish to total dietary exposure in such groups.

This consumption may contribute essential nutrients, particularly long chain omega-3-fatty acids (EPA and DHA) and also iodine, selenium and vitamin D which are essential for neurodevelopment and maternal health. However, clearer consumer guidance is needed to avoid high-risk species, notably fish offal (including roe-based products such as tarama or lumpfish roe), and babel, smel and fish *pâté* that have shown higher mean concentrations in monitoring data.

4. Advanced risk-benefit integration and health impact quantification.

This opinion demonstrates the feasibility of structured risk-benefit assessment for fish consumption. However, future assessments would benefit from full quantitative integration of nutritional benefits and toxicological risks health impact metrics such as disability-adjusted life years (DALYs)[17]. Building such a framework —leveraging national initiatives, like the Belgian Burden of Disease Study— could enable harmonized comparison across nutrients, contaminants and food groups, thereby enhancing prioritization and supporting more coherent and actionable dietary guidance.

5. Improved compositional data and product transparency are needed.

Processed products such as mixed fish dishes, salads, or sauces often lack clear information on fish species, origin, or proportion. This limits the reliability of exposure assessments. In this analysis, generic recipes had to be used, which may not accurately reflect real-world variation. Better data on product composition and labelling —supported by structured ingredient databases and new technologies— would allow for more precise evaluations and should be actively pursued.

6. Improved data harmonization and future fitness.

Despite progress in food classification systems such as FoodEx2, inconsistencies between chemical occurrence data and food consumption data persist, particularly in the level of detail and coding for fish species and derived products. These discrepancies limit the accuracy of integrated assessments. It is therefore necessary to harmonize data collection protocols and coding practices across monitoring and consumption surveys, improve interoperability through shared classification and metadata standards, and ensure transparent, standardized data

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[17] See the “Global Health Estimates: Life expectancy and leading causes of death and disability” in the Global Health Observatory of WHO: https://www.who.int/data/gho/data/themes/mortality-and-global-health-estimates/global-health-estimates-leading-causes-of-dalys.

submission procedures. These efforts are essential to support more robust and future-ready dietary exposure and benefit-risk analyses in the Belgian context and beyond.

7. Improved contamination mitigation.

The present assessment indicates that despite the well-established nutritional benefits of fish consumption, particularly as a source of long chain omega-3 fatty acids, there remain structural challenges to achieving an optimal benefit-risk balance under current contamination levels.

The maximum levels set in the regulation have been amended to improve consumer and human health protection. The TEF values have also been updated based on the new data with a view to updating the health-based guidance value, namely the TWI, and the exposure assessment.

In this context, the TWI was revised to lower values and taking into account that fish and fishery products may contribute to 30 – 50 % to the burden of PCDD/Fs + PCBs coming from diet, it is necessary to further monitor the levels and where necessary, apply additional mitigation measures in food and feed, and related to the environmental sources.

This includes sustained monitoring of contaminant levels in fish and fishery products, targeted mitigation measures in primary production and feed, and actions addressing relevant environmental sources of contamination. Such upstream interventions remain essential to preserve the nutritional role of fish in the diet while ensuring compliance with increasingly protective health-based guidance values.

4.3 Recommendations for research

Several knowledge gaps identified during the preparation of this opinion warrant further investigation to strengthen future exposure and benefit–risk assessments.

First, limitations in food consumption data remain an important source of uncertainty. Reported consumption events frequently lack species-level specificity, constraining the development of species-resolved exposure estimates. In addition, consumers may have limited awareness of fish species characteristics, production systems, and product origin, particularly for processed products where species identification is not evident (e.g. breaded or composite fish products). Dedicated research aimed at evaluating consumer awareness, understanding, and interpretation of fish species and origin would therefore support both survey design and risk communication strategies.

Similarly, enhancing labelling practices —particularly for species identification and origin details of processed fish products— would improve the clarity of consumption data and aid in more accurate exposure reconstruction. Future dietary surveys could benefit from more detailed food coding, ideally supported by digital or automated data collection tools currently being developed in Belgium. These improvements may be especially useful for less commonly consumed species, which tend to have higher variability and greater uncertainty in exposure assessments.

From an occurrence-data perspective, risk assessment could be refined through expanded and more representative monitoring of dioxins and dioxin-like compounds, including novel forms like brominated and halogenated in fish and fishery products, with emphasis on species and products most relevant to Belgian consumption patterns. Enhanced alignment between occurrence datasets and consumption classifications would further improve the robustness of exposure modelling.

Further research should also prioritise methodological developments enabling more integrated use of consumption and concentration data, thereby improving the characterisation of population-level exposure distributions. Within this context, application of benefit–risk modelling frameworks tailored to Belgian dietary patterns would support evaluation of potential mitigation or risk-management scenarios. In addition, development of improved analytical and decision-support tools for structured benefit–risk evaluation is warranted. Such tools should facilitate transparent integration of nutritional and toxicological evidence, explicit handling of uncertainty, and consistent comparison of alternative dietary scenarios

An additional area requiring further investigation concerns the behaviour and fate of dioxins and dioxin-like compounds during food processing and preparation. Industrial processing steps (e.g. trimming, smoking, canning, breading) as well as domestic preparation methods (e.g. cooking, frying, grilling) may influence contaminant concentrations through mechanisms such as fat loss, moisture changes, or redistribution within the food matrix. Improved empirical data describing these processes would support more realistic exposure estimation and reduce uncertainty associated with concentration assumptions applied in dietary assessments.

In addition, future assessments should extend beyond dioxins and DL-PCBs to encompass a broader spectrum of relevant contaminants. Persistent organic pollutants, including brominated compounds, per- and polyfluoroalkyl substances (PFAS), and metals (next to mercury also other metals), represent relevant co-exposure drivers. Addressing these aspects requires not only expanded analytical datasets but also continued advancement of toxicological knowledge concerning combined and cumulative effects associated with dietary exposure to multiple contaminants.

Final, comprehensive benefit–risk evaluations should also consider the complex interactions between nutritional constituents and contaminants. Nutrients may interact with one another, and certain components may influence toxicokinetic or toxicodynamic processes associated with chemical exposures. Consequently, assessment frameworks should progressively move towards more integrative approaches that account for both combined contaminant effects and potential nutrient–nutrient and nutrient–contaminant interactions.

For the Scientific Committee,
The President,
Dr. Lieve Herman,

(signed)

Brussels, 05/06/2026

For the Superior Health Council,
The President,
Prof. Yves Van Laethem

(signed)

Brussels, 03/06/2026

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6. COMPOSITION OF THE WORKING GROUP

The following experts have cooperated in drawing up the advice in the framework of a common working group SciCom - SHC:

Andjelkovic M. (SHC)	Chemical residues and contaminants	Sciensano
De Meulenaer B. (SciCom, SHC)	Food chemistry, more specifically chemical quality and food safety	UGent
Eppe G. (SHC)	Inorganic analytical chemistry	ULiège
Maindiaux V. (SHC)	Dietetics, nutrition	HE Vinci
Pussemier L. (SHC)	Residues and contaminants, chemical risks, quality, hygiene	CODA-CERVA
Robbens J. (SciCom)	Aquatic environment and quality	ILVO
Schoeters G. (SHC)	Biomonitoring	UAntwerpen
Scippo M.-L. (SciCom, SHC)	Residues and contaminants, food analysis	ULiège
Van Loco J. (SHC)	Chemistry, contaminants	Sciensano

The administration was represented by:

Carletta A.	FPS HFSE
Vinkx C.	FPS HFSE
Vromman V.	FASFC

The presidency of the working group was assumed by Luc Pussemier and Marie-Louise Scippo and the scientific administration by Florence Bernardy (for SHC), Michèle Ulens (for SHC), Gaëlle Vandermeulen (for SHC) and Olivier Wilmart (for SciCom).

7. APPROVAL AND VALIDATION

The advice was approved by the Scientific Committee established at the FASFC during the plenary session of 27 March 2026 and by the permanent working group "Food and Health, including Food Safety" of the SHC during the session of 20 May 2026. It was validated by the Board of the SHC during the session of 3 June 2026.

The names of the experts of the SHC appointed by Royal Decree as well as the members of the Board and Committee are available on the website of the SHC (link: composition and operation).

The Scientific Committee is composed of the following members (https://favv-afsca.be/nl/wetenschappelijk-comite/leden).

8. CONFLICT OF INTEREST

The experts of the working group have completed a general and an *ad hoc* declaration of interests. The potential risk of a conflict of interest was evaluated by the SHC's Deontological Committee and the Bureau of the Scientific Committee. No conflict of interest was established for the experts of the working group.

9. ACKNOWLEDGEMENTS

The Scientific Committee established at the FASFC and the Board of the SHC acknowledge N. Gillard (SciCom) and H. Nauwynck (SciCom) for their deep-reading of this opinion.

10. LEGAL FRAMEWORK OF THE ADVISORY REPORT

For the Scientific Committee:

Law of 4 February 2000, on the creation of the Federal Agency for the Safety of the Food Chain, in particular article 8;

The Royal Decree of 19 May 2000, on the composition and operating procedures of the Scientific Committee, as established at the Federal Agency for the Safety of the Food Chain;

The Internal Rules as mentioned in Article 3 of the Royal Decree of 19 May 2000, on the composition and operating procedures of the Scientific Committee, as established at the Federal Agency for the Safety of the Food Chain, approved by the Minister on 24 September 2020.

For the Superior Health Council (SHC):

The Superior Health Council is a federal service that is a part of the FPS Health, Food Chain Safety and Environment. The Council was established in 1849 and provides scientific advice on public health to the ministers of public health and environment, to their administrations and to some of their agencies. It provides this advice on demand or on its own initiative. The SHC does not take policy decisions, nor does it execute these decisions, but based on the most recent scientific knowledge it tries to provide a guideline for the policy on public health.

In addition to an internal secretariat of about 25 collaborators, the Council has an extensive network of more than 500 experts (university professors, collaborators of scientific institutions) at its disposal of which 300 have been appointed as Council Experts; the experts convene in multidisciplinary working groups to draw up advices.

As an official organ, the Superior Health Council believes it is essential to guarantee the neutrality and impartiality of the scientific advices it provides. To this end, it has worked out a structure, rules and procedures that allow to efficiently meet these needs at every step of the creation of the advices. Key moments in doing this are the preliminary analysis of the demand, the assignment of experts for the working groups, the putting into place of a system for managing possible conflicts of interest (based on the declaration of interest, investigations of possible conflicts of interest and a Deontological Commission and the eventual validation of the advices by the Committee (the final decision-making body). This coherent whole should allow for the delivery of advices that are based on the highest possible scientific expertise available within the highest degree of impartiality.

The advices of the working groups are submitted to the Committee. After being validated, they are sent to the applicant and to the minister of public health and the public advices are published on the website (https://www.hgr-css.be/). In addition, a number of the advices are communicated to the press and to target groups among health care practitioners.

The SHC is also an active partner in the EuSANH network (*European Science Advisory Network for Health*) that is currently under construction and which is intended to elaborate advices on the European level.

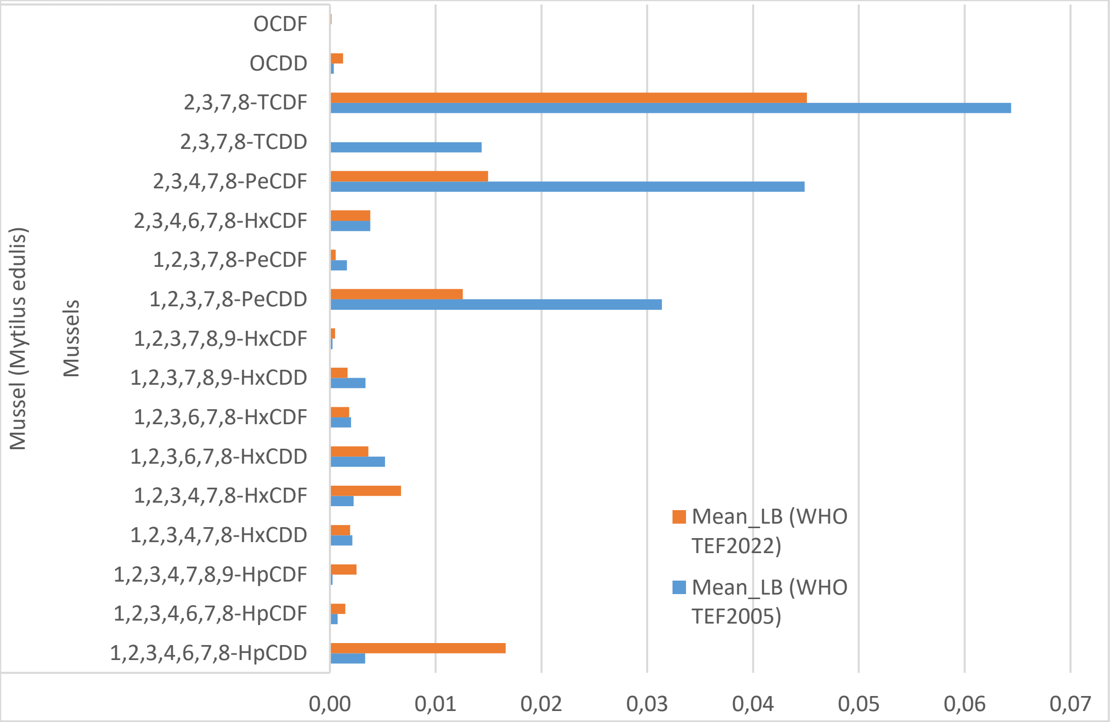
If you wish to stay informed on the activities and publications of the SHC, you can send an e-mail to info.hgr-css@health.belgium.be.

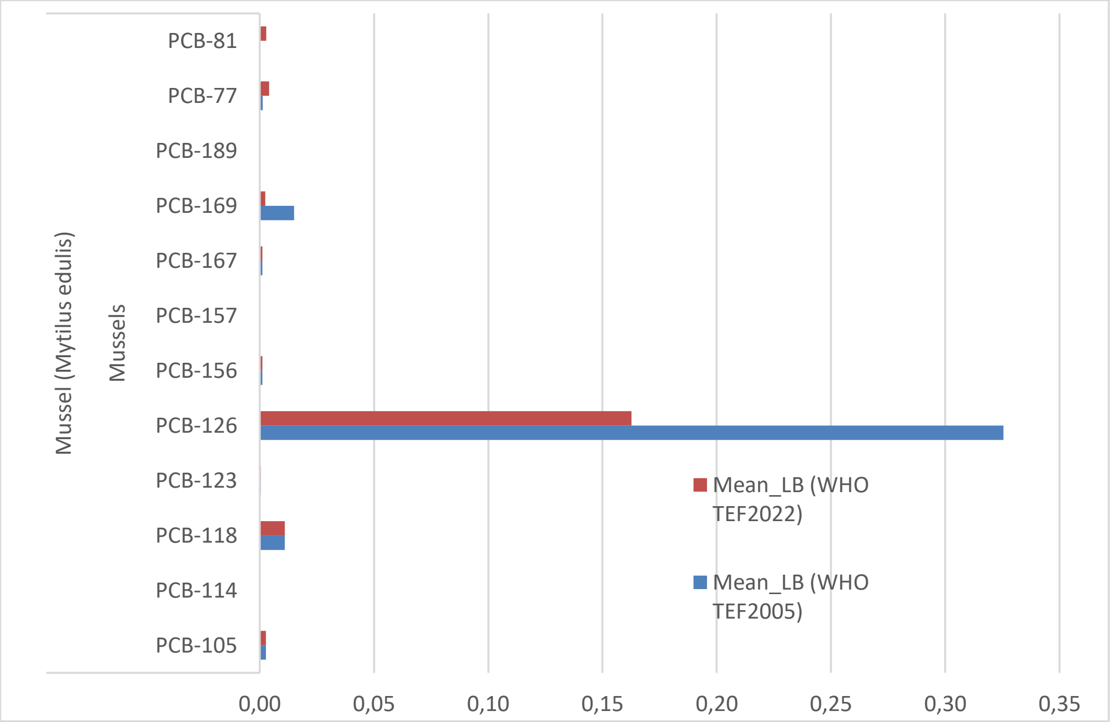
11. DISCLAIMER

The Scientific Committee established at the FASFC and the Board of the Superior Health Council (SHC) at all times reserve the right to modify the advice by mutual consent, should new information and data become available after the publication of this version.

12. ANNEXES

Annex 1. Analytical results per congener for mussels.





Annex 2. Overview of the matched consumption items through FoodEx2 and GloboDiet® (used in Belgian Food Consumption Survey) classifications.

termCode	FOODNUM	match_to_FCS	Name_ENG	Name_NED	Name_FR	termExtendedName	FDX_L2	FDX_L3
A026V	01080	Fish (meat)	Fish n.s.	Vis n.s.	Poisson n.s.	Fish (meat)	Fish meat	Fish meat
A026V	01080	Fish (meat)	Fish n.s.	Vis n.s.	Poisson n.s.	Fish (meat)	Fish products	Fish products
A027D	01120	Carp	Carp	Karper	Carpe	Carp, common	Fish meat	Carp (Cyprinus)
A028G	01115	#N/A	Eel river-	Paling rivier-	Anguille de rivière	River eels	Fish meat	Eels (Apodes)
A028N	01116	Nile perch	Nile perch	Victoriabaars	Perche du Nil	Nile perch	Fish meat	Perch (Perca)
A028P	01130	Salmons	Salmon	Zalm	Saumon	Atlantic salmon	Fish meat	Salmon and trout (Salmo spp.)
A029B	01121	Smelt	Smelt	Spiering	Eperlan	Smelt	Fish meat	Smelt (Osmerus)
A029Q	01081	Fish white, n.s	Fish white n.s.	Vis wit n.s.	Poisson, blanc n.s.	Whitefishes or coregonus	Fish meat	Whitefish (Coregonus)
A02AY	01105	Halibut	Halibut	Heilbot	Flétan	Halibut	Fish meat	Halibut (Hippoglossus spp.)
A02BC	01098	Plaice	Plaice	Pladijs	Plie	Plaice	Fish meat	Plaice (Pleuronectes)
A02BF	01099	Sole	Common sole, Dover sole	Tong zee-	Sole	Sole	Fish meat	Sole (Limanda; Solea)
A02BH	01103	Brill	Brill	Griet	Barbue	Brill	Fish meat	Babel (Barbus)
A02BV	01092	COD	Cod	Kabeljauw	Cabillaud	Cod	Fish meat	Cod and whiting (Gadus spp.)
A02CB	01111	HAKE	#N/A	#N/A	#N/A	Hakes	Fish meat	Hake (Merluccius)
A02CT	01090	Mackerel	Mackerel	Makreel	Maquereau	Mackerel	Fish meat	Mackeral (Scomber)
A02DB	01088	European sardine	Sardine	Sardien	Sardine	European sardine	Fish meat	Sardine and pilchard (Sardina)
A02DD	02275	Anchovies	Anchovy	Ansjovis	Anchois	Anchovies	Fish meat	Anchovy (Engraulis)
A02DE	01087	Herrings	Herring	Haring	Hareng	Herrings	Fish meat	Herring (Clupea)
A02DH	01089	Sprat	Sprat	Sprot	Esprot	Sprat	Fish meat	Sprat (Sprattus sprattus)

termCode	FOODNUM	match_to_FCS	Name_ENG	Name_NED	Name_FR	termExtendedName	FDX_L2	FDX_L3
A02DQ	01129	ray	Ray	Rog	Raie	Rays	Fish meat	Rays (Hypotremata)
A02DX	01091	Tuna	Tuna	Tonijn	Thon	Tuna	Fish meat	Tuna (Thunnus)
A02EH	01160	Tarama	Tarama	Tarama	Tarama	Fish offal	Fish offal	Fish offal
A02FD	01135	Crustaceans	Crustaceans n.s.	Schaaldieren n.s.	Crustacés n.s.	Crustaceans	Crustaceans	Crustaceans
A02FG	01141	Crayfish	Crayfish	Rivierkreeft	Ecrevisse de rivière	Freshwater crayfishes	Crustaceans	Crayfish (Astacus spp.)
A02FL	01136	Crabs, sea-spiders	Crab	Krab	Crabe	Crabs, sea-spiders	Crustaceans	Crabs (Cancer spp.)
A02FP	01137	Lobsters	Lobster	Kreeft zee-	Homard	Lobsters	Crustaceans	Lobster (Homarus vulgaris)
A02FS	02272	Lobster, norway	Norway lobster (Nephrops norvegicus)	Langoestine (met scharen, kleiner dan kreeft)	Langoustine (avec pince, plus petit que	Lobster, norway	Crustaceans	Norway lobster (Nephrophs norvegicus)
A02FZ	01139	Prawn, northern	Shrimp brown	Garnalen, grijze	Crevette, grise	Prawn, northern	Crustaceans	Prawns (Palaemon serratus)
A02GB	01133	Shrimps, common	Gamba (giant shrimp; deep sea)	Gamba	Gambas	Shrimps, common	Crustaceans	Shrimps (Crangon crangon)
A02GM	01143	Mollucs, ns	Molluscs n.s.	Weekdieren n.s.	Mollusque n.s.	Molluscs	Water molluscs	Queen scallop (Chlamys opercularis)
A02GM	01143	Mollucs, ns	Molluscs n.s.	Weekdieren n.s.	Mollusque n.s.	Molluscs	Water molluscs	Water molluscs
A02GM	01143	Mollucs, ns	Molluscs n.s.	Weekdieren n.s.	Mollusque n.s.	Molluscs	Water molluscs	Whelk (Buccinum undatum, Fusus antiquus)
A02GM	01143	Molluscs, ns	Molluscs n.s.	Weekdieren n.s.	Mollusque n.s.	Molluscs	Water molluscs	Clam (Mya arenaria)
A02GM	01143	Molluscs, ns	Molluscs n.s.	Weekdieren n.s.	Mollusque n.s.	Molluscs	Water molluscs	Cockle (Cardium edule)
A02HF	01145	Mussels	Mussels	Mosselen	Moule	Mussels	Water molluscs	Mussel (Mytilus edulis)

termCode	FOODNUM	match_to_FCS	Name_ENG	Name_NED	Name_FR	termExtendedName	FDX_L2	FDX_L3
A02HG	01146	Oysters	Oysters	Oesters	Huitre	Oysters	Water molluscs	Oyster (Ostrea edulis)
A02HN	01147	Scallops, pectens	Scallop	Sint-Jacobsschelpen	Coquille St. Jacques	Scallops, pectens	Water molluscs	Scallop (Pecten spp.)
A02HZ	01144	Squids, cuttlefishes, octopuses	Cuttlefish/squid	Inktvis	Calamar	Squids, cuttlefishes, octopuses	Water molluscs	Cuttlefish (Sepia officinalis)
A02HZ	01144	Squids, cuttlefishes, octopuses	Cuttlefish/squid	Inktvis	Calamar	Squids, cuttlefishes, octopuses	Water molluscs	Octopus (Octopus vulgaris)
A02HZ	01144	Squids, cuttlefishes, octopuses	Cuttlefish/squid	Inktvis	Calamar	Squids, cuttlefishes, octopuses	Water molluscs	Squid (Loligo vulgaris)
A02KC	01157	Fish fingers, breaded	Fish finger/steaks	Vissticks/-steaks	Fish stick/steack poisson pané	Fish fingers, breaded	Fish products	Fish fingers
A02KR	01079	Frogs (legs)	Frog's legs	Kikkerbillen	Cuisses de grenouilles	Frogs meat	Fish and other seafood (including amphibians, reptiles, snails and insects)	Fish and other seafood (including amphibians, reptiles, snails and insects)
A02LK	01151	Snails	Snail	Wijngaardslakken	Escargots de Bourgogne	Snails	Amphibians, reptiles, snails, insects	Snail (Helix sp.)
A07Y0	01132	Swordfish	#N/A	#N/A	#N/A	Swordfish	Fish meat	Swordfish (Xiphidae spp.)
A0EYV	01155	Fish pate	Fish pate	Vispate	Pate du poison	Structured/textured fish meat products or fish paste	Fish products	Fish pâté
A0F7F	01161	Lumpfish	Lumpfish	Viseieren/kuit	Oeufs, poisson	Lumpfish roe	Fish offal	Fish roe
A0FBD	01113	Sea catfishes	Catfish	Zeewolf	Loup de mer	Sea catfishes	Fish meat	Sea catfish and wolf-fish (Anarhichas)

FDX_L2 - FoodEx2 level 2 name; FX_L3- FoodEx2 level3 name, termExtendedName – name of a food item in FoodEx2

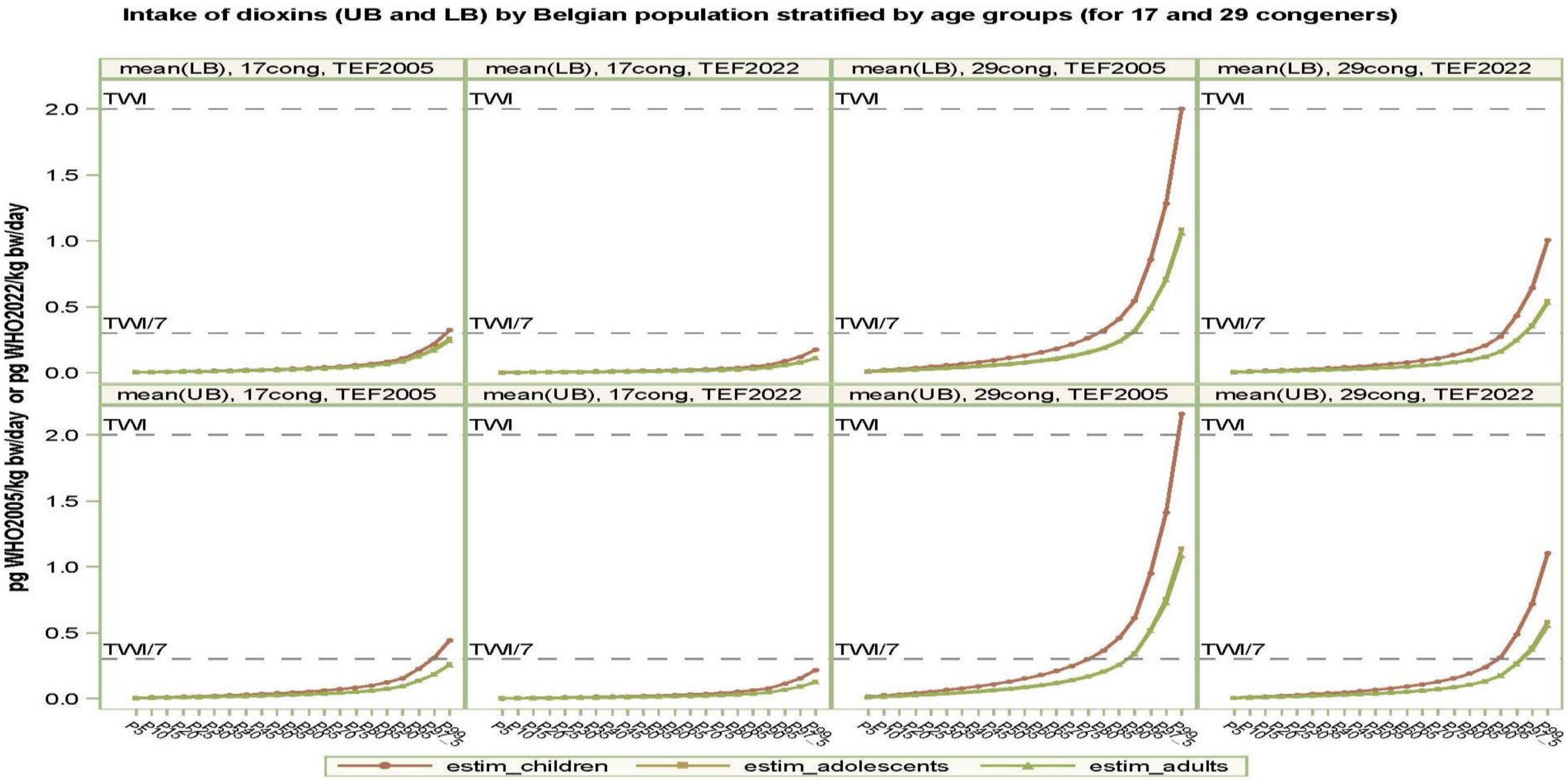
Annex 3. Overview of the mean TEQ concentrations (pg WHO2005-TEQ/kg and pg WHO2022 TEQ/kg) of the 29 PCDD/F/DL-PCBs congeners.

Nam (FoodEx2 – level 3)	Mean pg WHO2005-TEQ/kg		Mean pg WHO2022-TEQ/kg	
	LB	UB	LB	UB
Fish offal	21,68	22,25	12,44	12,95
Eels (Apodes)	9,17	9,21	5,16	5,21
Fish roe	8,24	8,24	4,34	4,35
Babel (Barbus)	6,01	6,02	3,43	3,43
Smelt (Osmerus)	5,26	5,27	2,93	2,95
Fish pâté	**4,94**	4,94	2,68	2,68
Whitefish (Coregonus)	4,46	4,46	2,31	2,31
Sprat (Sprattus sprattus)	3,43	3,47	1,82	1,89
Herring (Clupea)	**2,34**	2,39	1,19	1,24
Crustaceans	1,84	1,84	1,20	1,20
Sardine and pilchard (Sardina)	1,65	1,66	0,86	0,87
Mackeral (Scomber)	1,36	1,44	0,76	0,82
Crabs (Cancer spp.)	1,26	1,27	0,75	0,76
Halibut (Hippoglossus spp.)	1,12	1,16	0,60	0,64
Swordfish (Xiphidae spp.)	1,03	1,03	0,52	0,52
Oyster (Ostrea edulis)	0,89	0,89	0,48	0,49
Salmon and trout (Salmo spp.)	0,87	0,94	0,46	0,52
Fish meat	0,81	0,91	0,48	0,55
Fish products	0,81	0,91	0,48	0,55
Prawns (Palaemon serratus)	0,62	0,63	0,35	0,35
Mussel (Mytilus edulis)	**0,54**	0,57	0,32	0,34

Nam (FoodEx2 – level 3)	Mean pg WHO2005-TEQ/kg		Mean pg WHO2022-TEQ/kg	
	LB	UB	LB	UB
Plaice (Pleuronectes)	0,46	0,51	0,25	0,29
Perch (Perca)	0,46	0,46	0,26	0,26
Crayfish (Astacus spp.)	0,46	0,43	0,21	0,27
Carp (Cyprinus)	0,32	0,41	0,19	0,26
Fish and other seafood (including amphibians, reptiles, snails and insects)	0,27	0,37	0,16	0,24
Norway lobster (Nephrophs norvegicus)	0,27	0,27	0,15	0,16
Sole (Limanda; Solea)	0,25	0,26	0,14	0,15
Hake (Merluccius)	0,25	0,27	0,14	0,15
Shrimps (Crangon crangon)	0,24	0,25	0,15	0,16
Lobster (Homarus vulgaris)	0,21	0,21	0,12	0,12
Cod and whiting (Gadus spp.)	0,17	0,28	0,10	0,18
Queen scallop (Chlamys opercularis)	0,16	0,16	0,10	0,10
Water molluscs	0,16	0,16	0,10	0,10
Whelk (Buccinum undatum, Fusus antiquus)	0,16	0,16	0,10	0,10
Clam (Mya arenaria)	0,16	0,16	0,10	0,10
Cockle (Cardium edule)	0,16	0,16	0,10	0,10
Rays (Hypotremata)	0,15	0,15	0,08	0,09
Tuna (Thunnus)	0,13	0,17	0,07	0,10
Sea catfish and wolf-fish (Anarhichas)	0,13	0,16	0,08	0,10
Cuttlefish (Sepia officinalis)	0,12	0,12	0,07	0,07

Nam (FoodEx2 – level 3)	Mean pg WHO2005-TEQ/kg		Mean pg WHO2022-TEQ/kg	
	LB	UB	LB	UB
Octopus (Octopus vulgaris)	0,12	0,12	0,07	0,07
Squid (Loligo vulgaris)	0,12	0,12	0,07	0,07
Anchovy (Engraulis)	0,10	0,10	0,06	0,06
Scallop (Pecten spp.)	0,07	0,09	0,05	0,06
Fish fingers	0,06	0,10	0,03	0,06
Snail (Helix sp.)	0,00	0,01	0,01	0,01

Annex 4. Overview of the mean exposure estimation for lower and upper bounds approaches based on WHO2005-TEF and WHO-2022 TEF for both 17 PCDD/Fs and 29 PCDD/F/DL-PCBs congeners.



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