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Exposure assessment for the intake of PCDD/Fs and dioxin-like PCBs as well as PFAS through the consumption of different fish species

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Many fish and seafood are rich in vitamins and trace elements. However, they can also contain undesirable substances that might accumulate in the fat. The German Federal Institute for Risk Assessment (BfR) has calculated the amounts of such substances that consumers ingest when eating one to three servings (150 g each) of fish per week. The substances under consideration are divided into two groups:

1. Dioxins (PCDD/Fs) and dioxin-like (dl) PCBs are long-living contaminants that enter the environment through human activities (in the case of dioxins, also through forest fires or volcanic eruptions).

2. Per- and polyfluoroalkyl substances (PFAS) are a group of organic fluorinated compounds that originate from industrial processes and are found, inter alia, in impregnating agents, outdoor clothing, and fire-fighting foams.

The occurrence of these environmental contaminants can vary greatly from region to region. This was taken into account in the calculations. Evaluations were made with regard to mean and high levels for the different fish species. No data were available for seafood.

The highest mean levels of PCDD/F-PCBs are found in eels, sharks/curled strips of smoked dogfish, and bream. The lowest levels are found in codfish and tuna. For PFAS, the highest mean levels were detected in perch-like freshwater fish and eels, and the lowest levels in pollock/Alaskan pollack, tuna, and pangas catfish. The occurrence data used come from various programmes of the official food surveillance authorities. Even though suspect and follow-up samples were excluded, no conclusion about the representativeness of the samples for the entire German market can be made.

The determined intake levels were compared with the respective health-based guidance values of the European Food Safety Authority (EFSA). For both substance groups, the EFSA has derived a *tolerable weekly intake* (TWI) at which no adverse health effects are to be expected. For PCDD/F-PCBs, the TWI is 2 pg per kg body weight (bw) per week. This TWI is already exceeded with the consumption of one portion of fish per week for eels, curled strips of smoked dogfish, bream, trout, herring fish, pike, and other fish with mean levels of dioxins and PCBs. The lowest intakes of PCDD/F-PCBs were found for the consumption of codfish, tuna, and rainbow trout.

For PFAS, the EFSA derived a TWI of 4.4 ng per kg bw per week. For some fish species for which the present hypothetical exposure assessment was conducted, the TWI for the sum of the four PFAS was exceeded already when one fish meal per week is assumed.

PCDD/F-PCBs and PFAS are undesirable in the food chain. In recent decades, legal regulations have considerably reduced the amount of these substances released into the environment by humans. The intake of these via food has thus decreased considerably. Nevertheless, reduction efforts should be continued. For PFAS, a restriction proposal was submitted to the European Chemicals Agency (ECHA) in March 2023. This was prepared with the participation of the BfR.

PCDD/F-PCBs are found mainly in fatty animal food products such as fatty fish. If consumers limit the consumption of such foods, they can reduce the intake of these substances. However, when considering fish consumption, the focus should not be only on the levels of contaminants, but also on the health benefits, which, among other things, result from the supply of vitamins, trace elements, and polyunsaturated fatty acids.

1 Subject of the assessment

The German Federal Institute for Risk Assessment (BfR) has estimated the intake of dioxins and dioxin-like PCBs as well as PFAS (perfluorooctanoic acid (PFOA), perfluorooctanesulfonic acid (PFOS), perfluorononanoic acid (PFNA) and perfluorohexanesulfonic acid (PFHxS)) through the consumption of various fish species based on currently available occurrence data.

2 Result

The BfR carried out exposure assessments on the basis of occurrence data collected by the official food surveillance authorities of the German federal states. The intake of the sum of PCDD/Fs and dioxin-like PCBs as well as the sum of the four PFAS (PFOS, PFOA, PFNA and PFHxS) via the consumption of different fish species by women aged 15–49 years was modelled.

The occurrence data from 2,204 fish samples for PCDD/Fs and dioxin-like PCBs and from 1,504 fish samples for PFAS were taken into account. No data were available for seafood. Evaluations were made with regard to mean and high levels (95th percentile) for the different fish species. The highest mean levels of PCDD/F-PCBs are found in eel, shark/curled strips of smoked dogfish, and bream. The lowest levels are found in codfish and tuna. For PFAS, the highest mean levels were detected in perch-like freshwater fish and eels, and the lowest levels in pollock/Alaskan pollack, tuna, and pangas catfish.

For further evaluation, exposure was also calculated for different consumption scenarios and compared with the respective TWI derived by the EFSA. In some of the fish species for which the present hypothetical exposure was calculated, the TWI for dioxins or the sum of the four PFAS was exceeded with only one portion of fish per week.

PCDD/F, dl-PCBs, and PFAS are essentially undesirable substances in the food chain. Efforts to reduce the levels in food should therefore be continued. However, it is difficult to influence their occurrence in the individual foodstuffs. In particular, the occurrence of PFAS in foodstuffs can be reduced by sealing the sources responsible for their release into the environment.

The BfR points out that when it comes to fish consumption, not only the level of contaminants, but also the health benefits should be taken into account. These health benefits result, among other things, from the supply of vitamins, trace elements, and polyunsaturated fatty acids.

3 Rationale

3.1 Risk assessment

3.1.1 Hazard identification and hazard characterisation

The term dioxins refers to two classes of polychlorinated substances derived from dibenzo-p-dioxin (PCDD) and dibenzofuran (PCDF). They are formed as impurities in combustion processes and industrial processes. The term dioxin-like (dl) PCBs covers 12 polychlorinated substances that are derived from biphenyl and have effects similar to that of dioxins.

They are widely distributed in the environment and accumulate in fatty tissue. In 2018, EFSA derived a *tolerable weekly intake* (TWI) for dioxins and dl-PCBs of 2 pg per kg body weight (bw) per week; this can be used for risk characterisation.

Per- and polyfluoroalkyl substances (PFAS) are a group of organic fluorinated compounds that originate exclusively from industrial processes. They are, for example, a component of impregnating agents, outdoor clothing, and fire-fighting foams. In the context of official food monitoring, the four substances PFOA, PFOS, PFNA, and PFHxS are in the focus.

In 2020, the EFSA derived a TWI for the sum of the four PFAS (PFOS, PFOA, PFNA, PFHxS) of 4.4 ng per kg bw per week. This can be used for risk characterisation.

With the exception of farmed fish, fish live freely in the water. Depending on their species, origin, or age, they can therefore also absorb and contain hazardous substances from the environment via their respective food chains. These include PCDD/Fs, PFAS, and methylmercury. The consumption of fish is nevertheless recommended because it is associated with certain health benefits (DGE, 2016).

3.1.2 Exposure assessment

<u>Occurrence data</u>

As part of the project “Risk Assessment Strategies for Contaminants in Seafood” (RASCS), BfR requested via the Federal Office of Consumer Protection and Food Safety (BVL) occurrence data for various substances in fish and seafood from the official food surveillance authorities of the German federal states. These data include levels of PCDD/Fs and dl-PCBs as well as PFAS in fish.

For the evaluation, the suspect and follow-up samples were excluded. The modified *lower bound* approach (mLB) and the *upper bound* approach (UB) were used to account for non-quantifiable and non-detectable levels. For the mLB, the values below the limit of detection (LOD) are set to 0 and those below the limit of quantification (LOQ) to the limit of detection. For the UB, all values below the LOD/LOQ are set to the respective LOD/LOQ.

If at least 20 results were available for a fish species, it was evaluated as a separate group. In the case of a lower number of results, the species was assigned to the corresponding main group.

Dioxins and dl-PCBs

For the evaluation of PCDD/Fs and dl-PCBs, after exclusion of suspect and follow-up samples, occurrence data are available for 2,204 samples of various fish species from the years 2017–2020; which belong to 18 food groups. The data set also includes the samples collected within the framework of the National Monitoring (n = 461). Data on seafood were not available. For the following evaluations, the results with reference to fresh weight were used. If the data were transmitted with reference to “fat”, a conversion to the reference to fresh weight was carried out using the transmitted fat content for that sample.

In Table 1, the results are summarised as the mean and 95th percentile of the sum values of WHO-PCDD/F-PCBs using the *lower* and *upper bound* approach reported by the federal states. The federal states have already applied the *lower* and *upper bound* approach for the individual congeners to calculate the total. For the present evaluation, these were each evaluated again according to the mLB and UB approach in order to take into account that the sum value may also be non-detectable or non-quantifiable. However, only in one sample of all values transmitted, the total value was marked as non-quantifiable. Consequently, there are no differences in the mLB and UB; this is why only the lower bound (LB) and the upper bound (UB) are shown in Table 1 . For some samples, only values for the sum of PCDD/F-PCBs-WHO_{2005}-TEQ (*upper bound*) were available. The higher levels in fish for the sum of PCDD/F-PCBs-WHO_{2005}-TEQ (*lower bound*) are therefore due to the different number of samples. Because of the high levels and the fact, that sharks are explicitly mentioned in the consumer tip of the Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection, they are presented separately here despite a sample number of less than 20. Therefore, the 95th percentile of the levels for this food group also represent the maximum levels.

The highest mean levels of PCDD/F-PCBs-WHO_{2005}-TEQ are reported for eel, shark/curled strips of smoked dogfish, and bream. The lowest levels are found in codfish and tuna (Table 1).

A review of the BVL monitoring reports of recent years showed comparable mean levels for plaice (2019, n = 58) of 0.29 pg WHO_{2005}-TEQ/g vs. 0.32 pg WHO_{2005}-TEQ/g in the present assessment. The results for tuna were 0.08 pg WHO_{2005}-TEQ/g (n = 71, mean, UB) and thus identical to the values presented here (2018 monitoring report). For herring, a mean level of 1.77 pg WHO_{2005}-TEQ/g (n = 47) was documented in the 2016 monitoring report; this is slightly higher than the value of 1.35 pg WHO_{2005}-TEQ/g found in the current evaluation for herring fish.

The BfR had already carried out initial evaluations of occurrence data for dioxins and ndl-PCBs in river fish in 2021 on the basis of available data from the BVL and the results of the Lower Saxony River Fish Monitoring. Here, BVL data from 2000–2018 also showed high levels for PCDD/F-PCBs-WHO_{2005}-TEQ for eel (10.9 pg WHO_{2005}-TEQ/ g (mean) and 35.1 pg WHO_{2005}-TEQ/g (P95)). The values for bream were comparable with the current evaluations (3.8 pg WHO_{2005}-TEQ/g (mean) and 17.0 pg WHO_{2005}-TEQ/g (P95)).

Table 1: WHO-PCDD/F-PCBs levels in fish (lower bound and upper bound). Order in decreasing order of mean levels in the *upper bound* (BVL, 2017–2020)

Food group	PCDD/F-PCBs levels in pg WHO_{2005}-TEQ/g (fresh weight)					
	lower bound (LB)			upper bound (UB)		
	N (100% quantifiable)	Mean	P95	N (100% quantifiable)	Mean	P95
Eel	41	6.18	15.70	99	6.98	15.76
Sharks/curled strips of smoked dogfish	18	3.01	5.58*	19	2.87	5.63*
Bream[1]	31	3.44	16.92	42	2.84	10.81
Other fish	34	1.68	8.9	42	2.52	17.5
Trout	25	1.75	7.65	27	1.64	7.65
Herring fish	62	1.27	2.90	110	1.35	2.90
Pike	23	1.12	2.85	29	1.11	4.10
Perch-like freshwater fish	26	0.67	2.55	30	0.67	2.55
Chub	24	0.65	2.12	24	0.65	2.12
Whitefish (family Coregonidae)	103	0.54	1.14	104	0.57	1.24
Perciformes (marine fish)	27	0.45	0.74	28	0.47	0.75
Cyprinids	63	0.41	0.79	73	0.43	0.97
Salmon-like freshwater fish	89	0.35	0.90	91	0.36	0.90
Plaice	77	0.31	1.10	80	0.32	1.02
Redfish (*Sebastes marinus*)	31	0.28	0.75	31	0.28	0.75
Rainbow trout	65	0.17	0.54	72	0.18	0.56
Tuna	82	0.06	0.16	84**	0.08	0.17
Codfish	18	0.03	0.20*	25	0.06	0.20

[1]Deviations in the levels may result from the different numbers of samples (N) in the lower and upper bound.
* Value corresponds to the maximum because N < 20
** contains a value that cannot be quantified

Also, the BfR MEAL study examined fish for PCDD/Fs and dl-PCBs levels (Stadion et al., 2022). The mean levels (fresh weight) in eel (0.5–1.6 pg WHO_{2005}-TEQ/g) were considerably lower than the 6.2 pg WHO_{2005}-TEQ/g described above. However, the results for shark/curled strips of smoked dogfish shown in Table 1 are within the same range as the value for spiny dogfish (*Squalus acanthias*) of 3.6 pg WHO_{2005}-TEQ/g measured in the BfR-MEAL study. For all other fish species, the mean levels in the BfR-MEAL study were usually lower than the data from food monitoring programmes. This may be due to differences in study design (including consideration of preparation, composition/representativeness of the respective sample, and LOD and LOQ).

For the exposure assessment, the *upper bound* levels (mean and 95th percentile) of the BVL data from 2017–2020 are used.

PFAS

For the consideration of the sum of the four PFAS in fish, occurrence data from 2017–2020 were used for PFOA, PFNA, PFHxS, and PFOS. Only samples for which measurements of all four PFAS were available were included in the evaluation. After exclusion of the suspect and follow-up samples[1], 1,504 samples were available, which belong to 18 food groups. Of these, 533 samples came from monitoring programmes, including project monitoring programmes. Measurements for PFAS were available only for fish but not for seafood.

Table 2 shows the results for the individual fish species or fish groups in descending order with regard to the mean levels of the sum of the four PFAS. The highest levels were reported for perch-like freshwater fish followed by eels and perch. The lowest levels of PFAS are found in pangas catfish, tuna, and pollack. Sometimes considerable differences between the values in the mLB and UB (e.g. for rainbow trout, plaice and salmon-like freshwater fish) occur. This indicate that the LOQ or LOD were, for some samples higher than the levels determined in other samples.

[1] Suspect and follow-up samples are samples that are not taken representatively but rather in a risk-oriented manner. For its evaluations, the BfR usually takes into account the samples that give the most representative picture of the market situation.

Table 2: PFAS levels in fish (BVL, 2017–2020) as modified lower bound and upper bound and in each case the mean and 95th percentile are shown. Decreasing order by mean levels using the modified lower bound

Food groups	Total PFAS (PFOA, PFNA, PFHxS, PFOS) in µg/kg				
	Number (quantifiable)	mod. lower bound		upper bound	
		Mean	P95	Mean	P95
Perch-like freshwater fish	26 (100%)	55.8	244.0	57.7	247.0
Eel	45 (93%)	30.8	122.4	32.1	122.4
Perch	46 (98%)	11.1	24.1	11.6	24.1
Whitefish (family Coregonidae)	99 (98%)	10.9	17.3	11.6	17.4
Cyprinids	126 (75%)	10.8	76.3	12.2	76.7
Other fish	104 (47%)	9.77	20.0	10.8	23.0
Trout	54 (37%)	6.87	30.3	8.47	30.8
Bream	39 (82%)	6.21	54.9	7.40	54.9
Chub	28 (75%)	3.21	7.00	5.75	10.0
Herring fish	185 (47%)	1.15	6.67	1.36	6.67
Rainbow trout	98 (27%)	0.46	2.00	2.58	6.50
Plaice	63 (43%)	0.23	0.87	2.13	6.50
Mackerel	22 (73%)	0.22	0.40	0.23	0.40
Salmon-like freshwater fish	197 (11%)	0.20	0.14	2.60	8.00
Codfish	45 (67%)	0.19	0.48	0.32	0.55
Alaskan pollock/pollack	87 (59%)	0.12	0.31	0.18	0.35
Tuna	148 (19%)	0.11	0.50	2.17	4.00
Pangas catfish	92 (17%)	0.06	0.50	2.12	4.00

The amount of quantifiable values results from the samples in which at least one of the four PFAS compounds was quantifiable. Overall, PFOA and PFHxS in particular were often non-detectable, which is why Table 3 shows the number of samples with quantifiable, non-quantifiable, and non-detectable levels separately for each PFAS for the different fish species.

Table 3: Number of quantifiable, non-quantifiable, and non-detectable levels for PFOA, PFHxS, PFOS, and PFNA in fish (BVL, 2017–2020)

	PFOA			PFHxS			PFOS			PFNA		
	q.	n. q.	n. d.	q.	n. q.	n. d.	q.	n. q.	n. d.	q.	n. q.	n. d.
Perch-like freshwater fish	4	1	21	5	0	21	26	0	0	12	3	11
Eel	23	0	22	23	1	21	42	0	3	25	1	19
Perch	1	40	5	6	35	5	45	0	1	41	0	5
Whitefish (family Coregonidae)	0	80	19	40	40	19	97	0	2	80	0	19
Cyprinids	14	21	91	26	4	96	94	9	23	37	7	82
Other fish	29	11	64	17	1	86	48	23	33	49	4	51
Trout	4	13	37	5	11	38	20	10	24	9	9	36
Bream	14	0	25	8	1	30	32	0	7	25	2	12
Chub	0	1	27	0	0	28	21	4	3	2	2	24
Herring fish	58	6	121	63	2	120	87	35	63	81	14	90
Rainbow trout	10	21	67	13	11	74	26	18	54	6	12	80
Plaice	15	5	43	10	1	52	27	5	31	23	1	39
Mackerel	7	1	14	12	1	9	16	4	2	11	0	11
Salmon-like freshwater fish	14	3	180	18	2	177	8	14	175	21	0	176
Codfish	22	4	19	13	0	32	27	11	7	30	6	9
Alaskan pollock/pollack	45	10	32	28	0	59	30	32	25	51	4	32
Tuna	13	6	129	12	0	136	28	5	115	18	1	129
Pangas catfish	9	1	82	3	0	89	3	7	82	16	3	73

q: quantifiable, n. q.: non-quantifiable, n. d.: non-detectable

With regard to the monitoring reports from 2016–2020, considerably lower values for herring were shown in 2020 for the sum of the four PFAS with 0.14 µg/kg (n = 44, mean, *lower bound*) when compared with the level for herring fish determined in this report with 1.15 µg/kg (n = 185, mean, mLB). However, because the number of samples differs by more than a factor of four and for the mLB many non-detectable values have been included in the present data set with the LOD instead of the value 0, the data can only be compared to a limited extent. In the *upper bound*, the difference is somewhat smaller with 0.94 µg/kg (mean) in the 2020 monitoring report compared with 1.36 µg/kg (mean) in Table 2. Furthermore, in the 2019 monitoring report, results for the individual PFAS are listed for shark catfish (n = 39 and 40) with one less sample measured for PFHxA than for the others. If the mean levels of the individual PFAS are nevertheless summed, the values in the *upper bound* are comparable with the evaluations in Table 2. For plaice, the estimated sum from the results of the 2019 monitoring report is only slightly lower in the *lower bound* than in the mLB determined here; in the *upper bound*, it is higher with around 4 µg/kg (n = 60). In the monitoring report of 2018, there are also results on mussels (n = 45), which were not included in this data set. Here, the sum of the PFAS based on the published values for the individual PFAS shows levels of 0.04 µg/kg in the *lower bound*. Also, in 2018 and in 2017, tuna was analysed for individual PFAS, each with different sample numbers. These cannot be compared with the present results because based on the published monitoring data the four PFAS cannot be summed up. The same applies to the data on trout and salmon from the 2017 monitoring year.

In 2021, BVL data on PFAS from the years 2007–2020 (July) were evaluated and used in the BfR Opinion No. 20/2021. Comparable levels *(lower bound*) for the sum of PFAS were found for plaice with 0.25 µg/kg (mean) and 0.87 µg/kg (P95), for tuna with 0.09 µg/kg (mean) and 0.40 µg/kg (P95) and for cod with 0.15 µg/kg (mean) and 0.31 µg/kg (P95). For pangas catfish, the evaluations at that time showed higher levels *(lower bound)* of 0.70 µg/kg (mean) and 3.28 µg/kg (P95). The same can be observed in pollack with a considerable higher level (mean, *lower bound)* of 1.23 µg/kg compared with the present value in the mLB (0.12 µg/kg) in Table 2. However, the high level (P95, *lower bound*) for pollack from the 2021 opinion is consistent with the current level of 0.31 µg/kg (P95, mLB). Carp stood out in the 2021 evaluations because of higher PFAS levels *(lower bound)* of 18.93 µg/kg (mean) and 47.78 µg/kg (P95). In the present assessment, the measured levels for cyprinids are somewhat lower in the mean value (mLB; 10.8 µg/kg) and somewhat higher in the 95th percentile (76.3 µg/kg). In the current evaluation, higher PFAS levels are also shown in herring fish compared with herring (2021; 0.38 µg/kg (mean) and 3.57 µg/kg (P95)). The same applies to trout with comparably lower levels *(lower bound*) with 1.21 µg/kg (mean) and 4.98 µg/kg (P95) and to eel with 6.34 µg/kg (mean) and 28.41 µg/kg (P95). In Opinion No. 20/2021 it was discussed that the regional origin of the fish can have a considerable influence on the levels of PFAS and that the corresponding data reflect a large variability in the case of inhomogeneous sampling. For this reason, the deviations from the current evaluation seem plausible.

<u>Exposure scenarios</u>

In the following, the hypothetical intake amounts are calculated for the sum of PCDD/Fs and dl-PCBs as well as for the sum of PFAS in different scenarios for the consumption of one to three portions of fish per week using an assumed portion size of 150 g. This portion size has already been used and described in previous opinions of the BfR on mercury as well as on PCDD/Fs (e. g. No. 041/2006, No. 005/2010). According to the German Nutrient Database (BLS, Version 3.02), a mean portion corresponds to 150 g of fish; this is also used by the German Nutrition Society (DGE) for their consumption recommendation of one to two portions of fish per week (DGE, 2016). A consumption frequency of three times per week can thus be considered as a scenario for frequent consumers and results in higher intakes.

Because the TWI was derived with a special focus on women of child-bearing age, the hypothetical intakes are related to the mean body weight of 65 kg for women aged 15–49 years, which was collected as part of the National Nutrition Survey II (MRI, 2008), to allow a comparison with the health-based guidance values.

Dioxins and dl-PCBs

In Table 4, the hypothetical intake amounts for the sum of PCDD/F-PCBs-WHO_{2005}-TEQ are shown for different frequencies of consumption of 150 g portions of fish related to the body weight of women aged 15–49 years. For further assessment, the exhaustions of the EFSA-derived TWI of 2 pg WHO_{2005}-TEQ per kg bw per week (EFSA, 2018) were also calculated for the different scenarios.

Table 4: Hypothetical intake of PCDD/F-PCBs-WHO_{2005}-TEQ and exhaustion of the TWI (2 pg/kg bw per week) via fish consumption for women (15–49 years) assuming a portion size of 150 g and a consumption frequency of one to three times per week at mean and high levels *(upper bound*). Grey markings: Exhaustion of the TWI > 100%

	Mean level						P95 level					
Food group	**PCDD/F-PCBs-WHO_{2005}-TEQ intake in pg/kg bw per week (150 g portion, 65 kg bw)**			**TWI exhaustion (2 pg WHO_{2005}-TEQ /kg bw) in %**			**PCDD/F-PCBs-WHO_{2005}-TEQ intake in µg/kg bw per week (150 g portion, 65 kg bw)**			**TWI exhaustion (2 pg WHO_{2005}-TEQ /kg bw) in %**		
	1x	**2x**	**3x**	**1x**	**2x**	**3x**	**1x**	**2x**	**3x**	**1x**	**2x**	**3x**
Eel	16.11	32.22	48.33	805	1,611	2,416	36.37	72.74	109.1	1,818	3,637	5,455
Curled strips of smoked dogfish	6.62	13.25	19.87	331	662	994	12.99	25.98	38.98	650	1,299	1,949
Bream	6.55	13.11	19.66	328	655	983	24.95	49.89	74.84	1,247	2,495	3,742
Other fish	5.82	11.65	17.47	291	582	874	40.38	80.77	121.2	2,019	4,038	6,058
Trout	3.77	7.55	11.32	189	377	566	17.65	35.31	52.96	883	1,765	2,648
Herring fish	3.11	6.22	9.33	156	311	467	6.69	13.38	20.08	335	669	1,004
Pike	2.57	5.14	7.71	129	257	386	9.46	18.92	28.38	473	946	1,419
Perch-like freshwater fish	1.54	3.07	4.61	77	154	231	5.88	11.76	17.65	294	588	882
Chub	1.51	3.01	4.52	75	151	226	4.89	9.78	14.68	245	489	734
Whitefish (family Coregonidae)	1.32	2.64	3.97	66	132	198	2.86	5.72	8.59	143	286	429
Perciformes (marine fish)	1.09	2.18	3.26	54	109	163	1.73	3.46	5.19	87	173	260
Cyprinids	0.99	1.99	2.98	50	99	149	2.24	4.48	6.72	112	224	336
Salmon-like freshwater fish	0.82	1.65	2.47	41	82	124	2.08	4.15	6.23	104	208	312
Plaice	0.75	1.50	2.24	37	75	112	2.34	4.68	7.03	117	234	351
Redfish (*Sebastes marinus*)	0.66	1.31	1.97	33	66	98	1.73	3.46	5.19	87	173	260
Rainbow trout	0.41	0.81	1.22	20	41	61	1.30	2.60	3.90	65	130	195
Tuna	0.18	0.35	0.53	9	18	26	0.39	0.78	1.18	20	39	59
Codfish	0.14	0.29	0.43	7	14	22	0.46	0.92	1.38	23	46	69

The values highlighted in grey are fish species for which consumption in the corresponding scenarios results in an exhaustion of the TWI of more than 100%. It can thus be seen that the consumption of only one portion of fish per week results in an exceedance of the TWI for both mean and high levels in the case of eel, shark/curled strips of smoked dogfish, bream, trout, herring fish, pike, and other fish. Only in the case of tuna and codfish the consumption of up to three portions per week would lead to an intake of PCDD/Fs and dl-PCBs below the TWI – even at high levels.

In its latest opinion (2018), the EFSA calculated a mean intake for adults of 0.76 pg WHO_{2005}-TEQ per kg bw per day. This corresponds to a weekly intake of 5.32 pg WHO_{2005}-TEQ per kg bw, a level that already clearly exceeds the TWI of 2 pg WHO_{2005}-TEQ per kg bw per week. The food group “fatty fish” contributed approx. 56% to the total exposure of PCDD/Fs and dl-PCBs.

PFAS

In contrast to the intake estimates for dioxins and dl-PCBs, the results from the calculation of the *modified lower bound* are used for the estimation of PFAS intake instead of the *upper bound* levels because of the high LOD and LOQ in certain cases. In Table 5, the hypothetical intake for the sum of the four PFAS (PFOA, PFNA, PFHxS, and PFOS) are shown for the scenarios for women of child-bearing age. For further evaluation, the exhaustions of the TWI of 4.4 ng per kg bw per week derived by EFSA 2020 are additionally shown. In case the consumption in the corresponding scenario exceeds the TWI, the figures are high-lighted in grey.

Table 5: Hypothetical intake of PFAS as sum of PFOA, PFNA, PFHxS, and PFOS and exhaustion of the TWI (4.4 ng/kg bw and week) via fish consumption for women (15–49 years) assuming a portion size of 150 g and a consumption frequency of 1–3 times per week at mean and high levels *(modified lower bound)*. Grey markings: Exhaustion of the TWI > 100%

	Mean level						**P95 level**					
Food group	**PFAS intake in ng/kg bw per week (150 g portion, 65 kg bw)**			**TWI exhaustion (4.4 ng/kg bw) in %**			**PFAS intake in ng/kg bw per week (150 g portion, 65 kg bw)**			**TWI exhaustion (4.4 ng/kg bw) in %**		
	1x	**2x**	**3x**	**1x**	**2x**	**3x**	**1x**	**2x**	**3x**	**1x**	**2x**	**3x**
Perch-like fresh-water fish	128.7	257.4	386.1	2,925	5,849	8,774	563.1	1,126.2	1,689.2	12,797	25,594	38,392
Eel	71.0	141.9	212.9	1,613	3,226	4,838	282.4	564.7	847.0	6,417	12,834	19,251
Perch	25.6	51.2	76.9	582	1,164	1,747	55.6	111.2	166.7	1,263	2,526	3,789
Whitefish (family Coregonidae)	25.2	50.3	75.5	572	1,143	1,715	40.0	80.0	119.9	909	1,817	2,726
Cyprinids	24.9	49.7	74.6	565	1,130	1,695	176.1	352.2	528.2	4,002	8,003	12,005
Other fish	22.6	45.1	67.7	513	1,025	1,538	46.2	92.3	138.5	1,049	2,098	3,147
Trout	15.8	31.7	47.5	360	720	1,080	69.9	139.9	209.8	1,589	3,178	4,767
Bream	14.3	28.6	43.0	325	651	976	126.7	253.5	380.2	2,880	5,761	8,641
Chub	7.42	14.8	22.3	169	337	506	16.2	32.3	48.5	367	734	1,101
Herring fish	2.64	5.29	7.93	60	120	180	15.4	30.8	46.2	350	700	1,050
Rainbow trout	1.06	2.13	3.19	24	48	72	4.62	9.23	13.9	105	210	315
Plaice	0.54	1.08	1.62	12	25	37	2.01	4.03	6.04	46	92	137
Mackerel	0.51	1.01	1.52	11	23	34	0.92	1.84	2.76	21	42	63
Salmon-like freshwater fish	0.46	0.92	1.38	10	21	31	0.31	0.62	0.93	7	14	21
Codfish	0.43	0.87	1.30	10	20	30	1.10	2.19	3.29	25	50	75
Alaskan pol-lack/pollack	0.28	0.57	0.85	6	13	19	0.72	1.44	2.16	16	33	49
Tuna	0.24	0.48	0.73	6	11	17	1.15	2.31	3.46	26	52	79
Pangas catfish	0.13	0.26	0.39	3	6	9	1.15	2.31	3.46	26	52	79

For many of the fish species studied, the TWI is exceeded in the hypothetical scenarios considered. For example, for perch-like freshwater fish, eels, perch, whitefish, cyprinids, trout, bream and chub, one portion at both mean and high levels is already enough to considerably exceed the TWI. In the case of herring fish, the intake is below the TWI only when consuming one portion per week with mean PFAS levels. Fish for which the consumption result in an exposure below the TWI in all hypothetical scenarios include pangas catfish, tuna, Alaskan pollock/pollack, cod, salmon-like freshwater fish, and mackerel.

3.1.3 Discussion

The occurrence data from 2,204 fish samples for PCDD/Fs and dl-PCBs and from 1,504 fish samples for PFAS were considered. No data were available for seafood.

When comparing the levels of the substances under consideration PCDD/F, dl-PCBs, and PFAS, in particular the consumption of sharks and eels can result in high intake levels. However, only one sample of shark was analysed for PFAS; this was assigned to the group of other fish, and the value was in the range of the fish with lower concentrations. Tuna is one of the fish which leads to lower intake of PCDD/Fs and PFAS. Pangas catfish showed low levels of PFAS and consequently low hypothetical intakes. For PCDD/F, results from the BfR-MEAL study on concentrations in pangas catfish of 0.015 pg WHO_{2005}-TEQ/kg are available, with which comparatively low intake levels are calculated.

In the present exposure assessment, numerous assumptions were made, which may lead to an under- or overestimation of the actual intake. Thus, the scenarios assume that only one species of fish (with mean or high levels) is consumed at a time. In reality, consumers eat different species, for which the levels vary. In addition, foods other than fish may contribute to exposure to PCDD/F, dl-PCBs, and PFAS. The scenarios with higher levels are only relevant to the long-term exposure assessment considered here, if there is an increased probability of individual consumers consuming fish with high levels over a longer period of time. This could be the case if only regionally caught fish with higher levels are consumed.

In general, the occurrence data used come from various official food surveillance authorities. Even though suspect and follow-up samples were excluded, a conclusion about the representativeness of the samples for the German market cannot be made. Similarly, the analytical limits for some fish species have a considerable influence on the *upper bound* levels.

Finally, a standard portion size of 150 g of fish was assumed. Assumptions were also made about the frequency of consumption. This allowed the consideration of the levels for PCDD/F, dl-PCBs, and PFAS in different groups of fish. Nevertheless, the actual consumption of the individual fish species may deviate from the assumptions made here and may thus be associated with an under- or overestimation of intake. In addition, a standard body weight of 65 kg was used for the assessment. In the case of lower body weights, the intake would increase accordingly; in the case of higher body weights, the exposure would be lower if all other assumptions remained unchanged.

3.2 Risk management options, recommendations of measures

The occurrence data from the various monitoring programmes and official food control indicate that high levels of PFAS, PCDD/F, and dl-PCBs may be present in various fish species and in fish from various regions. Temporal and, if necessary, regional trends should continue to be monitored and analysed. The different levels in certain fish species should be taken into account.

Because the total exposure to PCDD/F, dl-PCBs, and PFAS is currently relatively high, foods or food groups other than fish that contribute to the high exposures should continue to be considered in the monitoring programmes.

The BfR recommends that risk management authorities examine whether existing consumption recommendations for fish are still suitable and appropriate.

In the European context, it should be examined whether existing maximum levels for contaminants need to be adjusted or maximum levels should be set for additional food groups.

3.3 Other aspects

In general, PCDD/F, dl-PCBs, and PFAS are undesirable substances in the food chain. Efforts to reduce the levels in foodstuffs should be continued. However, it is difficult to influence their occurrence in the individual foodstuffs. In particular, the occurrence of PFAS in foodstuffs can be reduced by sealing the sources for their release into the environment.

Among other things, because of the relatively high PCDD/Fs and dl-PCBs levels in wild fish, the federal states have developed consumption recommendations. For example, the Ministry of the Environment, Agriculture, Food, Viticulture and Forestry of Rhineland-Palatinate recommends that no yellow and silver eels, white fish (over 40 cm), and catfish from the Rhine, Moselle, Saar and Sauer should be eaten. A maximum of two portions of white fish from the Ahr, Nahe, and Lahn should be consumed monthly (Rheinland-Pfalz, 2012). The Lower Saxony Ministry for Food, Agriculture and Consumer Protection recommends fishers to refrain from regular consumption of fish from rivers in Lower Saxony (Niedersachsen, 2020). Recommendations have also been published by individual federal states such as Lower Saxony and North Rhine-Westphalia to avoid the consumption of fish with regionally high levels of PFAS (Lower Saxony 2019, 2020; North Rhine-Westphalia 2020).

The BfR points out that when it comes to fish consumption, one should consider not only the levels of contaminants in isolation but also the health benefits that result, among other things, from the supply of vitamins, trace elements, and polyunsaturated fatty acids.

Further information on dioxins, dl-PBC, and PFAS on the BfR website:

Communication No. 002/2023 (13 January 2023): Per- and polyfluoroalkyl substances (PFAS): Proposal on restriction submitted to the European Chemicals Agency under the REACH Regulation

https://www.bfr.bund.de/cm/349/per-and-polyfluoroalkyl-substances-pfass-proposal-for-restriction-under-the-reach-regulation-submitted-to-the-european-chemicals-agency.pdf

BfR Opinion No. 020/2021 (28 June 2021):
PFAS in food: the BfR confirms critical exposure to industrial chemicals

https://www.bfr.bund.de/cm/349/pfas-in-food-bfr-confirms-critical-exposure-to-industrial-chemicals.pdf

BfR Opinion No. 028/2020 (6 July 2020):
The consumption of sheep or beef liver can contribute significantly to the total intake of per- and polyfluoroalkyl substances (PFAS)

https://www.bfr.bund.de/cm/349/the-consumption-of-sheep-or-beef-liver-can-contribute-considerably-to-the-total-intake-of-per-and-polyfluoroalkyl-substances-pfas.pdf

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Niedersachsen (2020): Aktualisierung der Verzehrempfehlung für Fische. Niedersächsisches Ministerium für Ernährung, Landwirtschaft und Verbraucherschutz. https://www.ml.niedersachsen.de/startseite/aktuelles/pressemitteilungen/aktualisierung-der-verzehrempfehlung-fur-fische-187563.html

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The German Federal Institute for Risk Assessment (BfR) is a scientifically independent institution within the portfolio of the German Federal Ministry of Food and Agriculture (BMEL). The BfR advises the Federal Government and the German federal states (“Laender”) on questions of food, chemicals, and product safety. The BfR conducts independent research on topics that are closely linked to its assessment tasks.

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