# Niðurstöður sívirkrar vöktunar á óæskilegum efnum í sjávarfangi úr auðlindinni 2023

## Undesirable substances in seafood – results from the Icelandic marine monitoring activities in the year 2023

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| *Ágrip á íslensku:* | Í þessari skýrslu eru teknar saman niðurstöður vöktunar á óæskilegum efnum í ætum hluta sjávarfangs 2023. Vöktunin hófst árið 2003 fyrir tilstuðlan þáverandi Sjávarútvegsráðuneytis, núverandi Matvælaráðuneytið, og sá Matís ohf. um að safna gögnum og útgáfu á skýrslum vegna þessarar kerfisbundnu vöktunar á tímabilinu 2003-2012. Vegna skorts á fjármagni í þetta vöktunarverkefni var gert hlé á þessari mikilvægu gagnasöfnun sem og útgáfu niðurstaðna á tímabilinu 2013-2016. Verkefnið hófst aftur í mars 2017 en vegna fjárskorts nær það nú eingöngu yfir vöktun á óæskilegum efnum í ætum hluta sjávarfangs úr auðlindinni sem ætlað er til manneldis, en ekki fiskimjöl og lýsi fyrir fóður. Af sömu ástæðu eru ekki lengur gerðar efnagreiningar á PAH og PBDE efnum. Árið 2023 voru bætt við mælingar á PFAS efnum.<br><br>Markmiðið með verkefninu er að sýna fram á stöðu íslenskra sjávarafurða m.t.t. öryggi og heilnæmis og hægt að nýta gögnin við gerð áhættumats á matvælum til að tryggja hagsmuni neytenda og lýðheilsu. Verkefnið byggir upp þekkingargrunn um magn óæskilegra efna í efnahagslega mikilvægum tegundum og sjávarafurðum, það er skilgreint sem langtímaverkefni þar sem útvíkkun og endurskoðun er stöðugt nauðsynleg.<br><br>Almennt voru niðurstöðurnar sem fengust 2023 í samræmi við fyrri niðurstöður frá árunum 2003 til 2012 sem og 2017 til 2022. Niðurstöðurnar sýndu að íslenskar sjávarafurðir innihalda óverulegt magn þrávirkra lífrænna efna s.s. díoxín, PCB og varnarefni.<br><br>í þessari skýrslu voru hámarksgildi Evrópusambandsins (ESB) fyrir díoxín, díoxínlík PCB (DL-PCB) og ekki díoxínlík PCB (NDL-PCB) í matvælum samkvæmt reglugerð nr. 2023/915 notuð til að meta hvernig íslenskar sjávarafurðir standast kröfur ESB. Niðurstöður ársins 2023 sýna að öll sýni af sjávarafurðum til manneldis voru undir hámarksgildum ESB fyrir þrávirk lífræn efni og þungmálma. Þá reyndist styrkur svokallaðra ICES6-PCB efna vera lágur í ætum hluta sjávarfangs, miðað við hámarksgildi ESB samkvæmt reglugerð nr. 2023/915. Sömuleiðis sýndu niðurstöðurnar að styrkur þungmálma, t.d. kadmíum (Cd), blý (Pb) og kvikasilfur (Hg) í íslenskum sjávarafurðum var alltaf undir hámarksgildum ESB. Styrkur PFAS var undir hámarksgildi ESB, fyrir öll sýni nema þorskhrogn. | | |
| | *Sjávarfang, vöktun, Díoxín, díoxínlík PCB, PCB, varnarefni, þungmálmar, hámarksgildi, heilnæmi, lýðheilsa* | | |

| | |
|---|---|
| *Summary in English:* | This report summarises the results obtained in 2023 for the screening of various undesirable substances in the edible part of Icelandic marine catches.<br><br>The main aim of this project is to gather data and evaluate the status of Icelandic seafood products in terms of undesirable substances and the data can be utilised to estimate the exposure of consumers to these substances from Icelandic seafood and risks related to public health. The surveillance programme began in 2003 and was carried out for ten consecutive years before it was interrupted in 2013. The project was revived in March 2017 to fill in knowledge gaps regarding the level of undesirable substances in economically important marine catches for Icelandic export. Due to financial limitations the monitoring now only covers screening for undesirable substances in the edible portion of marine catches for human consumption and not feed or feed components. The limited financial resources also required the analysis of PAHs and PBDEs to be excluded from the monitoring, providing somewhat more limited information than before. However, it is considered a long-term project where extension and revision are constantly necessary. In the year 2023, PFAS were added to the monitoring.<br><br>In general, the results obtained in 2023 were in agreement with previous results on undesirable substances in the edible part of marine catches obtained in the monitoring years 2003 to 2012 and 2017 to 2022.<br><br>In this report from the monitoring programme, the maximum levels for dioxins, dioxin-like PCBs and non-dioxin-like PCBs in foodstuffs (Commission Regulation 2023/915) were used to evaluate how Icelandic seafood products measure up to limits currently in effect.<br><br>The results show that in regard to the maximum levels set in the regulation, the edible parts of Icelandic seafood products contain negligible amounts of dioxins, dioxin like and non-dioxin-like PCBs. In fact, all samples of seafood analysed in 2023 were below EC maximum levels.<br><br>Furthermore, the concentration of ICES6-PCBs was found to be low in the edible part of the marine catches, compared to the maximum limits set by the EU (Commission Regulation 2023/915).<br>The results also revealed that the concentrations of heavy metals, e.g., cadmium (Cd), lead (Pb) and mercury (Hg) in the edible part of marine catches were in all samples well below the maximum limits set by the EU. All samples contained PFAS below EU maximum limits, except for cod roe. |
| *English keywords:* | *Marine catches, monitoring, dioxin, PCB, pesticides, heavy metals, maximum limits, human consumption, public health* |

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# 1 Introduction

In 2003, the Icelandic Ministry of Fisheries, now the Ministry of Food, Agriculture and Fisheries, initiated a project aimed at screening for undesirable substances in the edible portion of marine catches from Icelandic waters, as well as in the fish meal and fish oil produced for feed. Matis was assigned the responsibility of carrying out the monitoring programme, which was on-going for ten consecutive years. In the period 2013-2016 this important collection of information and publication of the results was interrupted since Matis did not receive funding to work on this monitoring project. In March 2017 the monitoring programme was revived with funding from the Ministry of Industries and Innovation in Iceland to continue gathering data and evaluate the status of Icelandic seafood products regarding undesirable substances, however, the current funding only covers screening for undesirable substances in the edible portion of marine catches for human consumption and not feed or feed components. The project includes measurements on various undesirable substances in several economically important marine species from Icelandic fishing grounds to gather information and evaluate the status of Icelandic seafood products in terms of undesirable substances. This report summarises results from the screening programme in the year 2023. The substances investigated in this monitoring project are: polychlorinated dibenzo dioxins and dibenzo furans (commonly called dioxins), dioxin-like polychlorinated biphenyls (PCBs), ICES-6 PCBs, perfluoroalkyl substances (PFAS), 30 pesticides and breakdown products (i.e. HCB, DDTs, HCHs, dieldrin, endrin, chlordanes, toxaphenes and endosulfan substances), and inorganic trace elements such as heavy metals.

The purpose of this work is:

1. To gather information and evaluate the status of Icelandic seafood products in terms of undesirable substances.
2. Provide scientific evidence that Icelandic seafood products conform to regulations on seafood safety. That is, to evaluate how products measure up to limits currently in effect for inorganic trace elements, organic contaminants and pesticides in the EU (Commission regulation (EC) No 2023/915).

3. Provide data gathered in this programme for that can be utilised for risk assessment and the setting of maximum values within EU & the European Economic Area (EEA) area, which are constantly being reviewed based on new data.
4. Provide independent scientific data on undesirable substances in Icelandic seafood for food authorities, fisheries authorities, industry, markets and consumers.

In this report the maximum levels for dioxins, dioxin-like PCBs and non-dioxin-like PCBs in foodstuffs are used to evaluate how Icelandic seafood products measure up to European commission (EC) limits currently in effect. The results obtained in the years 2003 to 2012, as well as 2017 to 2022, have already been published and are accessible at the Matis website (http://www.matis.is: Auðunsson, 2004, Ásmundsdóttir et al., 2005, Ásmundsdóttir and Gunnlaugsdóttir, 2006, Ásmundsdóttir et al., 2008, Jörundsdóttir et al., 2009, Jörundsdóttir et al., 2010a, Jörundsdóttir et al., 2010b, Baldursdóttir et al., 2011, Jörundsdóttir et al., 2012, Jensen et al., 2013, Jensen et al., 2018, Jensen et al. 2019, Jensen et al. 2020, Jensen et al. 2021, Jensen et al. 2022, Jensen et al. 2023). The above-mentioned EU regulation have been implemented in the Icelandic legal framework regarding undesirable substances in food (Regulation (EC) No 2023/915), which means that the maximum limits for undesirable substances in Icelandic seafood products are in line with the limits for these products in the EU member states.

## 2 Contaminants measured in the project

The following contaminants were measured in the edible parts of seafood and other seafood products for human consumption:

**Dioxins, PCDD/Fs:** Dioxins (dibenzo-p-dioxins) and dibensofurans (17 congeners according to WHO): 2.3.7.8-Tetra-CDD, 1.2.3.7.8-Penta-CDD, 1.2.3.4.7.8-Hexa-CDD, 1.2.3.6.7.8-Hexa-CDD, 1.2.3.7.8.9-Hexa-CDD, 1.2.3.4.6.7.8-Hepta-CDD, OCDD, 2.3.7.8-Tetra-CDF, 1.2.3.7.8-Penta-CDF, 2.3.4.7.8-Penta-CDF, 1.2.3.4.7.8-Hexa-CDF, 1.2.3.6.7.8-Hexa-CDF, 1.2.3.7.8.9-Hexa-CDF, 2.3.4.6.7.8-Hexa-CDF, 1.2.3.4.6.7.8-Hepta-CDF, 1.2.3.4.7.8.9-Hepta-CDF, OCDF.

**Dioxin like PCB** (12 congeners according to WHO): non-ortho (CB-77, CB-81, CB-126, CB-169) and mono-ortho (CB-105, CB-114, CB-118, CB-123, CB-156, CB-157, CB-167, CB-189).

**ICES-6-PCBs** (6 congeners): CB-28, CB-52, CB-101, CB-138, CB-153, CB-180.

**Pesticides**: DDT-substances (6 congeners: pp-DDT, op-DDT, pp-DDD, op-DDD, pp-DDE and op-DDE), HCH-substances (4 isomers: α-, β-, γ-(Lindane), and δ-hexachlorocyclohexan), HCB, chlordanes (4 congeners and isomers: α- and γ-chlordane, oxychlordane and trans-nonachlor), toxaphenes (3 congeners, P 26, 50 and 62), aldrin, dieldrin, endrin, endosulfan (3 congeners and isomers: α- and β-endosulfan and endosulfansulfat) and heptachlor (3 congeners: heptachlor, cis-hepatchlorepoxid, trans-heptachlorepoxid).

**Inorganic trace elements**: Hg (mercury), Cd (cadmium), Pb (lead), total As (organic and inorganic arsenic), chromium (Cr) and tin (Sn).

**Perfluoroalkyl substances (PFAS):** perfluorooctane sulfonic acid (PFOS), perfluorooctanoic acid (PFOA), perfluorononanoic acid (PFNA), perfluorohexane sulfonic acid (PFHxS).

# 3 Sampling and analysis

## *3.1 Sampling*

The collection of samples and the quality criteria for the analytical methods were in accordance with conditions set out by the EU for the information gathering campaign on dioxins and dioxin-like PCBs as well as for metals (Commission regulation 333/2007/EC, Commission regulation 2017/644/EC, Commission regulation EU 2022/1428). The fish samples were collected by the Marine and Freshwater Research Institute (MRI) in Iceland according to sampling protocols provided by Matis and the samples were kept frozen until preparation for analysis (see section 3.1.1). The cod roe sample was provided by Marz Seafood and shrimp was provided by Iceland Seafood. Blue whitening was provided by BRIM and the capelin and mackerel samples were provided by Síldarvinnslan. Fishing grounds around Iceland are divided into five areas, as illustrated in Figure 1. Samples were identified and labelled with the fishing area where they were caught.

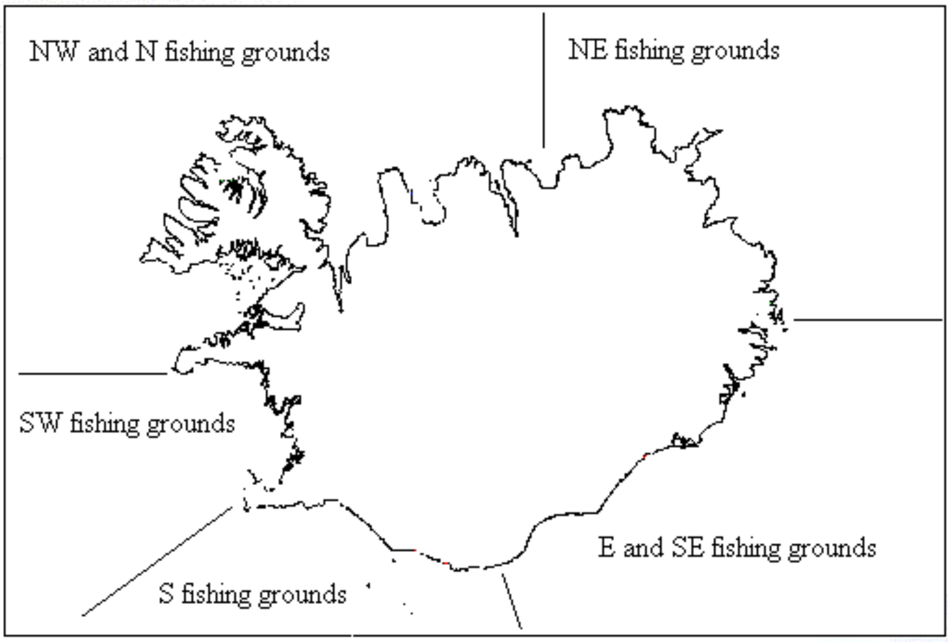


***Figure 1:*** *The division of the fishing grounds around Iceland used in this research.*

### Sample preparation

All analyses were performed on edible parts of the fish samples. Each fish sample consisted of a pool from at least ten individuals of a specific length distribution. For details on length distribution and fishing grounds of the samples see Table 1 and 2 in the Appendix.

Prior to sample preparation each fish was defrosted, after that the total weight and length of each individual fish was recorded as well as gender, gut weight and weight of fillets. The skinless fish fillets from the individuals were then pooled, homogenised and frozen again for analysis of organic contaminants or freeze-dried for heavy metal analysis. The ten cod livers, capelin, shrimp and cod roes were pooled as individual samples, homogenised and freeze-dried before analysis.

### *3.2 Analyses*

The heavy metal analysis of chromium, arsenic, tin, cadmium, mercury and lead was carried out at Matís. Inorganic contaminants in samples were determined by ICP-MS according to an accredited in-house method SV-25-02-SN in Matís Quality manual (modified NMKL 186 (2007) method). Matís is a National Reference Laboratory for heavy metal analysis in food and feed and has been taking part in various international inter-laboratory studies for many years. The lipid content and organic contaminants were measured by Eurofins, Hamburg, Germany. Eurofins has taken part in an international inter-laboratory quality control study organised by WHO and EU and uses accredited methods for analysing lipids, dioxin, WHO-PCBs, ICES-6-PCBs, PFAS and pesticides. All results are expressed as upper bond level, which means that when the concentration of a substance is measured to be below limit of detection (LOD) or limit of quantification (LOQ) of the analytical method, the concentration is set to be equal to the LOD/LOQ. In the case of dioxins and dioxin-like PCBs, the analytical data are converted to pg/g WHO-TEQ where the toxicity of each congener has been calculated using WHO-TEF (Toxic Equivalence Factor) based on the existing knowledge of its toxicity (Van den Berg et al., 1998). WHO-TEQ values have been adapted by the World Health Organization (WHO) in 1997 and by EU in its legislations. In 2005 the WHO-TEF values were re-evaluated based on existing toxicological data (Van den Berg et al., 2005, Haws et al., 2006) and expert judgment. These new TEF values have been established as the WHO-2005-TEQs for human risk assessment of the concerned compounds and have been implemented in the current EU legislation i.e., Commission Regulation (EU) No 2023/915.

# 4 Results from monitoring of fish and fishery products in Iceland

All results for undesirable substances from the monitoring programme in 2023 are listed in Tables 1-4 in the Appendix. The sections below contain an overview of the results obtained in samples of fish taken as part of the monitoring activities 2023.

## *4.1 Dioxins (PCDD/Fs) and dioxin like PCBs*

All the samples analysed contained dioxins (PCDD/PCDFs) below EU maximum limits (Figure 2 and Table 1 in the Appendix).

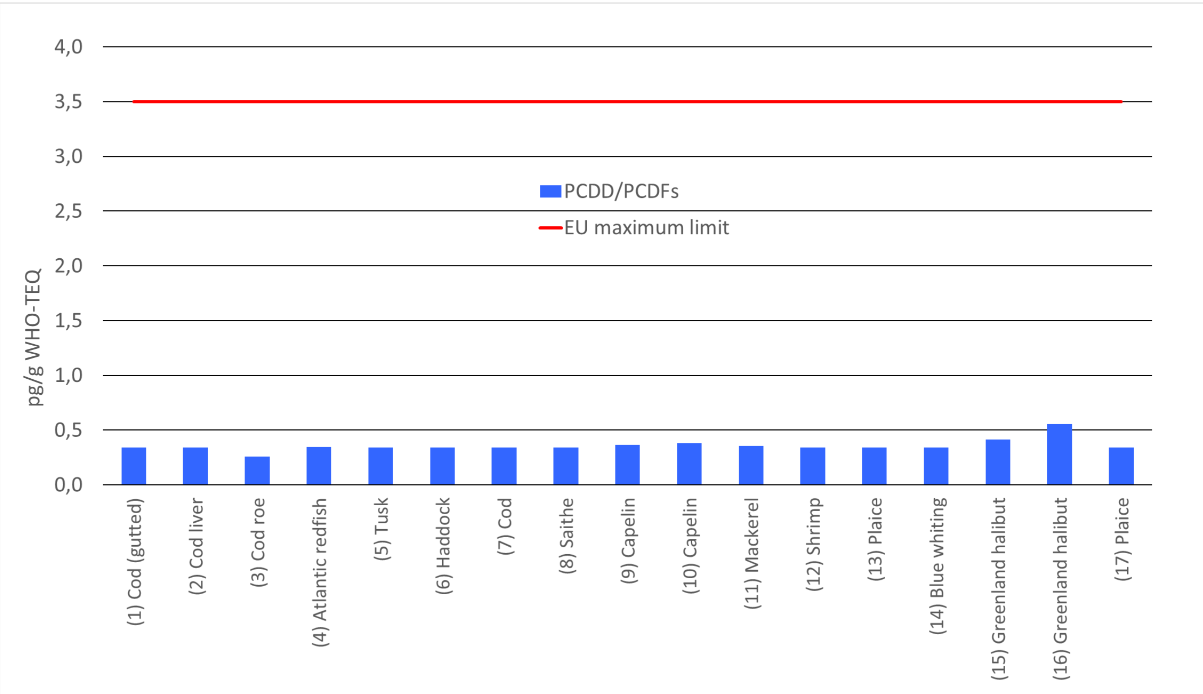


***Figure 2:*** *Dioxins (PCDD/PCDFs) in marine catches from Icelandic fishing grounds in 2023 in relation to maximum EU limit in WHO-TEQ pg/g wet weight. The number within parenthesis is the sample number indicated in Table 1 in the Appendix.*

Almost no difference was observed in the dioxin content for the analysed marine species. The species that accumulate fat in the muscle, like capelin, mackerel and Greenland halibut (samples no. 9, 10, 11, 15 & 16), were the only samples with detectable levels of dioxins. The dioxin content in the cod muscle and liver from the same individuals (samples no. 1 & 2) was 0,34 pg/g WHO-TEQ. This is very different from the results reported by Jensen et al. 2023, where the dioxin content was almost four times lower in the muscle meat than the liver.

In general, the level of dioxins in the edible part of the fish increases as the fat percentage in the muscle increases, but other important variables are age (size) and habitat. Greenland halibut can become quite old, which can contribute to higher levels of dioxins and dioxin-like PCBs sometimes observed for this species, while capelin, mackerel and herring are high in fat content but do not become very old and therefore accumulate less dioxins over their whole life span (Table 1 in the Appendix). Compared to results for Greenland halibut from Jensen et al. 2023, the fat content, the size of the fish and the dioxin levels of the samples were similar.

Figure 3 shows the sum of dioxins and dioxin-like PCBs in all samples analysed.

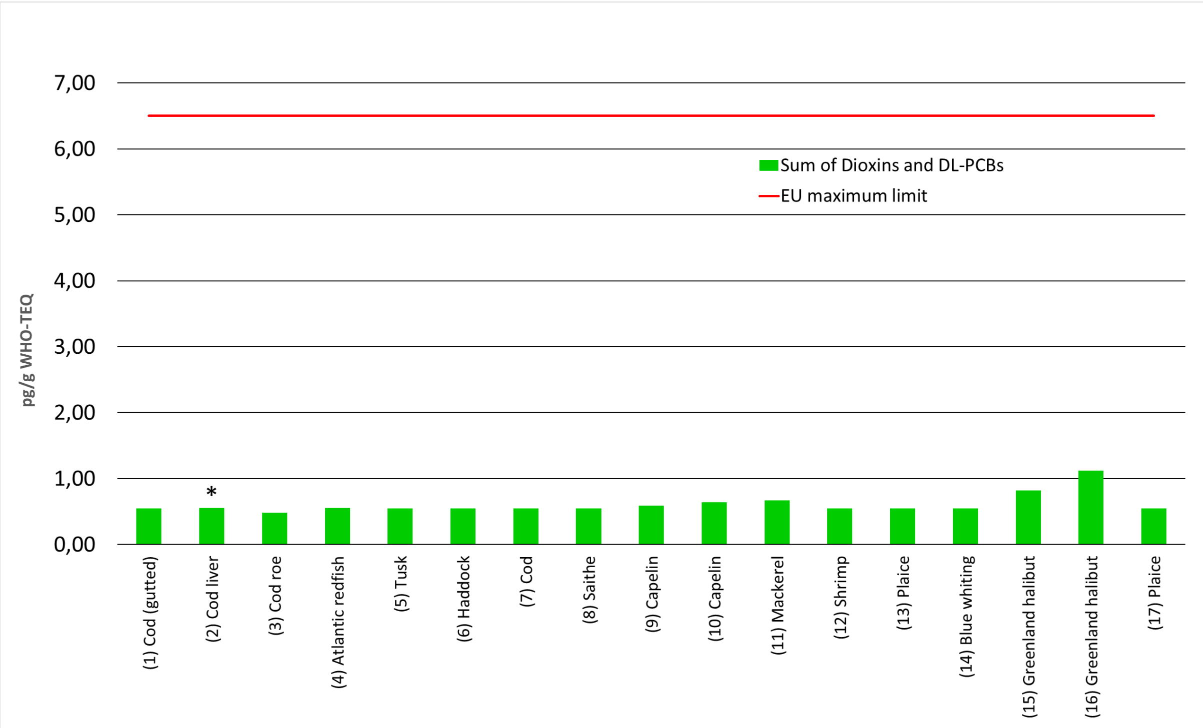


***Figure 3:*** *Sum of dioxins and dioxin-like PCBs in marine catches from Icelandic fishing grounds in 2023 in relation to maximum EU limit in WHO-TEQ pg/g wet weight. The number within parenthesis is the sample number indicated in Table 1 in the Appendix.*
**EU maximum limit for fish liver is 20 WHO-TEQ pg/g wet weight.*

The results show that the sum of dioxins and dioxin-like PCBs in all the samples analysed contained total dioxins and dioxin-like PCBs below EU maximum limits (Figure 3 and Table 1 in the Appendix).

## 4.2 *Marker PCBs*

Marker PCBs have been used as indicators of the total PCB content or body burden of environmental biota, food and human tissue. The most frequent approach is to use either the total level of six or seven of the most commonly occurring PCBs. Nevertheless, the EU maximum limits are set for the sum concentration of ICES-6, i.e., CB-28, -52, -101, -138, -153 and -180 (Commission Regulation (EU) No 2023/915). To enable comparison to earlier results, the sum of seven marker PCBs is presented in Table 1 in the Appendix, while the ICES-6 maximum limits are presented in Figure 4 to evaluate how Icelandic seafood products measure up to EU maximum limits.

### 4.2.1 ICES-6 PCBs in fish and fishery products from Icelandic waters

The results obtained for all the samples analysed in 2023 were well below the maximum limit set for non-dioxin-like PCBs i.e., the so-called ICES-6 (Figure 4).

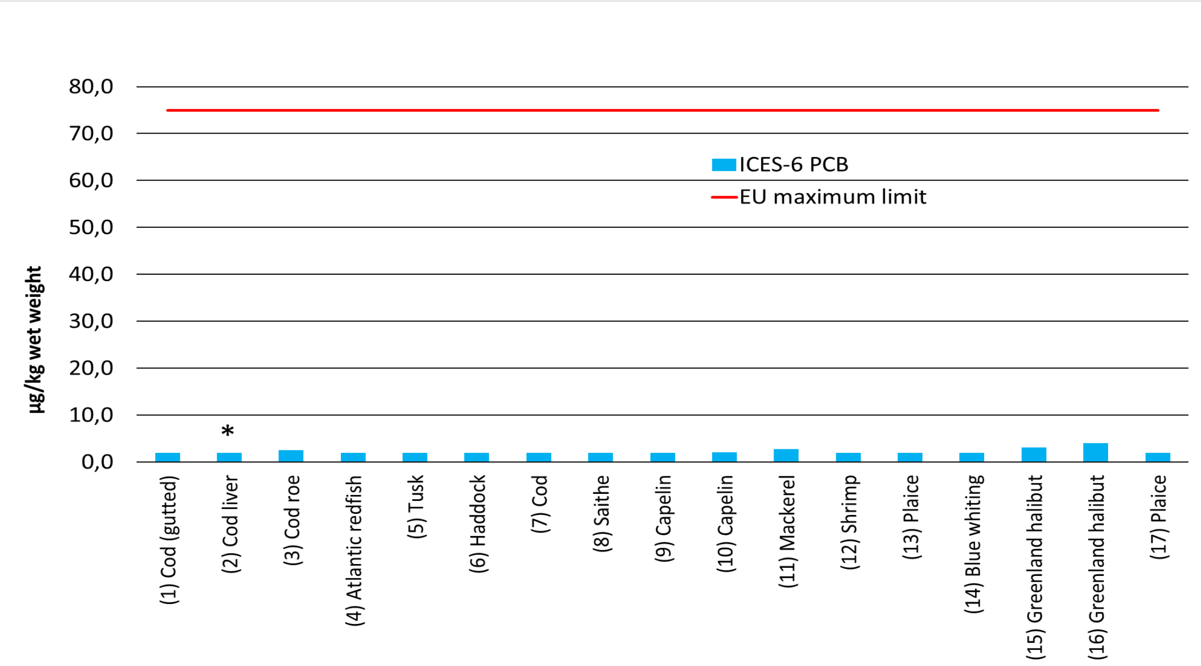


***Figure 4:*** *ICES-6 PCBs in marine catches from Icelandic fishing grounds in 2023 in relation to maximum EU limit in µg/kg wet weight. Number in parenthesis is the sample number designated to each sample, see Table 1 in Appendix.*
**EU maximum limit for fish liver is 200 µg/kg wet weight.*

In this study, the highest total concentration for the sum of all six marker PCBs in the muscle samples was measured in mackerel and Greenland halibut (samples no. 11, 15 and 16, Figure

4). A total of 2,7, 3,1 and 4,0 µg/kg wet weight, respectively. The highest individual PCB congener measured in both species was PCB-153 with 0,76, 0,87 and 1,32 µg/kg wet weight, respectively, or around one third of the total. As for the dioxins and dioxin-like PCBs (section 4.1.), the highest concentrations of the ICES-6 PCBs were found in species with higher lipid content in the muscle. For details, see Table 1 in the Appendix.

## *4.3 Polycyclic aromatic hydrocarbons (PAHs)*

PAHs are not included in the regulation for fresh fish. PAHs were not analysed in the samples this year. Results on PAHs in Icelandic seafood have been published in previous reports (Jörundsdóttir et al., 2010, Jensen et al., 2013).

## *4.4 Brominated flame retardants (BFRs)*

BFRs are not included in the regulation for fresh fish. BFRs have been accumulating in the environment over the last decade as their use in industry has increased. BFRs were not analysed in the samples this year. Results on BFRs in Icelandic seafood have been published in a previous report (Jensen et al., 2013).

## *4.5 Pesticides*

In total 12 different pesticides or groups of pesticides were measured in the monitoring programme. In this section, the results for these different classes of pesticides are discussed. Results are shown in Table 2 in the Appendix.

**DDT** (dichloro diphenyl trichloroethan) is probably the best-known insecticide. The technical product DDT is fundamentally composed of p,p'-DDT (80%) (Buser, 1995). DDT breaks down in nature, mostly to DDE but also to DDD. The concentration of DDT presented in this report is the sum of p,p'-DDT, o,p´-DDT, p,p'-DDE, o,p´-DDE, p,p´-DDD and o,p´-DDD.

**HCH** (hexachlorocyclohexane) is an insecticide which has been used since 1949. It is still produced and used in numerous countries, although it has been banned in many countries since the 1970s. Technical-grade HCH is a mixture of mainly four isomers: $\alpha$-, $\beta$-, $\gamma$-(Lindane), and $\delta$-HCH. Of these, only Lindane is an active substance comprising approximately 15% of the total mixture, while $\alpha$-HCH is 60-70% of the mixture. The Food and Agriculture Organization of the UN (FAO) has prohibited the use of the HCH mixture since in the 1980s, after that it was only allowed to use 99% pure Lindane. In this report the concentration of $\alpha$-, $\beta$-, $\gamma$-(Lindane), and $\delta$-HCH in the samples are reported.

**HCB** (hexachlorobenzene) is a fungicide, but it has also been used for industrial purpose and was e.g., produced in Germany until 1993. Today, HCB is mainly a by-product in different industrial processes such as production of pesticides but also from waste incineration and energy production from fossil fuels.

**Chlordanes** is a group of compounds and isomers where $\alpha$- and $\gamma$-chlordane, oxychlordane and *trans*-nonachlor are the most common, but over 140 different chlordanes were produced from 1946 until 1988 when the production was banned. Chlordanes have been widely used all over the world as insecticides. In this report the concentration of chlordanes is reported as the sum of $\alpha$-chlordane, $\gamma$-chlordane and oxychlordane. *Trans*-nonachlor is reported separately.

The **Toxaphenes** measured in the samples are the so-called parlar 26, 50 and 62. Toxaphene was used as an insecticide after the use of DDT was discontinued. Toxaphenes use was widespread, and the toxaphene congeners are numerous. Several hundred have been analysed but they are thought to be tens of thousands. The substances measured, i.e., the parlar 26, 50 and 62, are the most common toxaphenes (about 25% of the total amount in nature) and these are used as indicators of toxaphene pollution. In this report the concentration of toxaphenes is reported as the sum of toxaphene 26, 50 and 62.

**Aldrin and Dieldrin** are widely used insecticides, but in plants and animals aldrin is transformed to dieldrin. Hence, the concentration of aldrin was below LOD in all the samples measured, while dieldrin was in some samples above LOD. The results are presented as the sum of these two.

Two **Endosulfans** were measured, $\alpha$- and $\beta$-endosulfan, as well as endosulfansulfat which is the breakdown product of endosulfan. Endosulfans are not as persistent as the other insecticides measured in this project. In this report the concentration of endosulfans is reported as the sum of $\alpha$-endusulfan, $\beta$-endusulfan and endosulfansulfat. Other pesticides measured were **Endrin**, the sum of **Heptachlores** (cis-heptachlorepoxide, trans-heptachlorepoxide and heptachlor), **Pentachlorobenzene**, **Mirex** and **Octachlorostyrene**.

### 4.5.1 Pesticides in fish and fishery products from Icelandic waters

The results show that most of the pesticides measured in edible parts of marine catches from Icelandic waters were below the limit of quantification (see Table 2 in the Appendix). However, as mentioned before the results presented as sums are expressed as upper bond and are therefore likely to be an overestimation. HCB was detected in 8 out of 17 samples analysed and *trans*-Nonachlor was detected in 10 samples. γ- and δ-HCHs were always below LOQ, whilst β-HCH was detected in cod liver and α-HCH was detected in cod liver and Greenland halibut. Figure 5 shows the level of total DDT in the different marine catches analysed, while Figure 6 shows the level of HCB in the same samples.

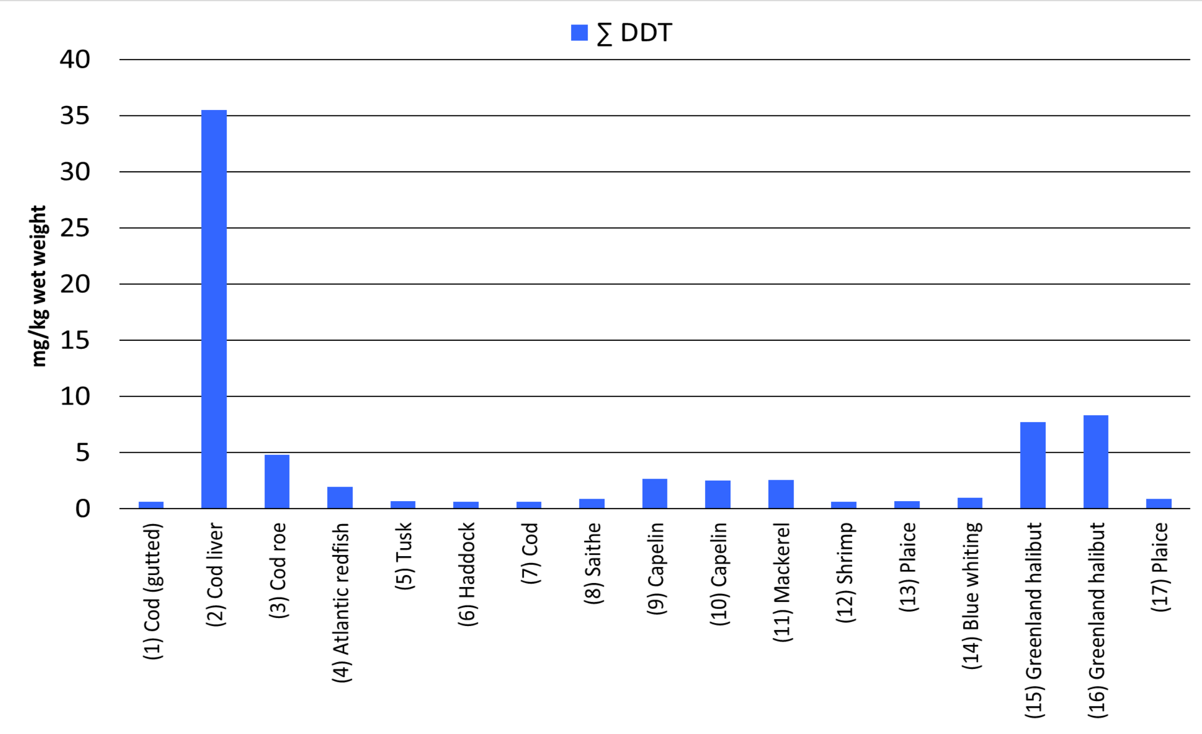


***Figure 5:*** *∑DDT in marine catches from Icelandic fishing grounds in 2023 in µg/kg wet weight.*

No limits have yet been set for pesticides in seafood, but to enable comparison with earlier measurements presented in previous reports from this project (Jensen, et al. 2013, Jensen, et al. 2018, Jensen, et al. 2019, Jensen, et al. 2020, Jensen, et al. 2021, Jensen, et al. 2022, Jensen, et al. 2023), the results of ∑DDT and HCB are presented from the monitoring in 2023. In general, the concentration of pesticides is higher in Icelandic fish and fishery products with a higher lipid content (Table 2 in Appendix).

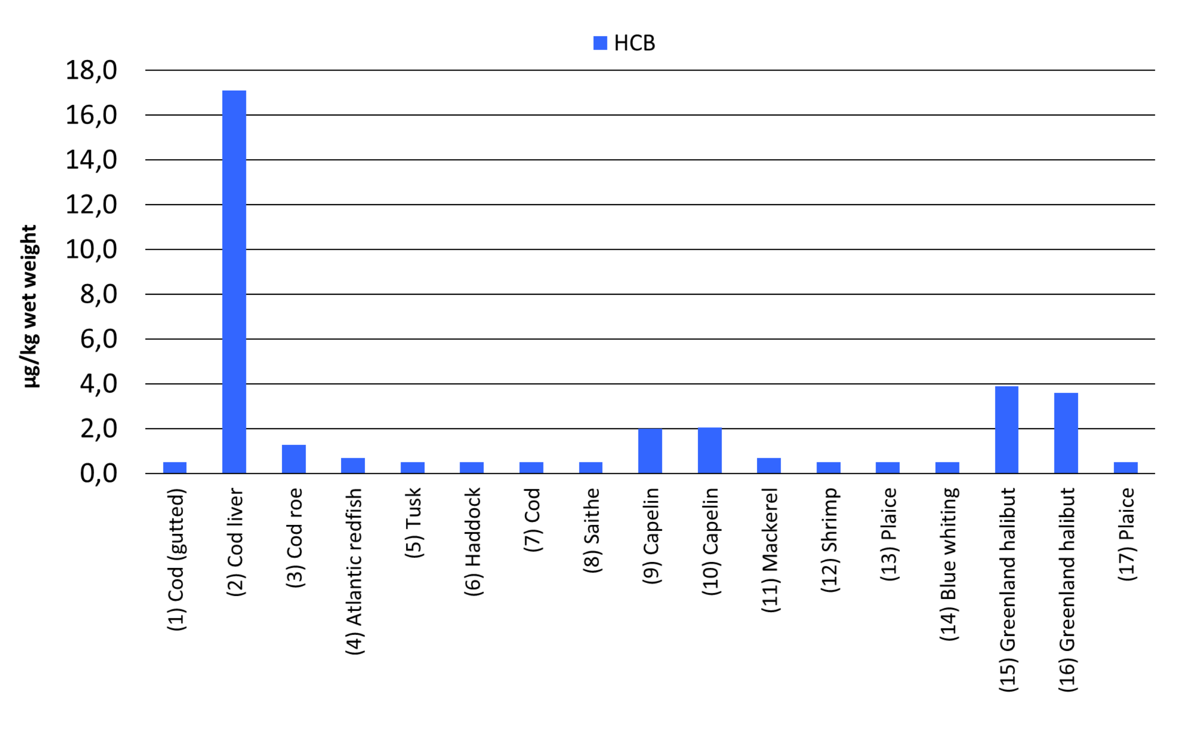


***Figure 6:*** *HCB in marine catches from Icelandic fishing grounds in 2023 in µg/kg wet weight.*

## 4.6 Inorganic trace elements

Inorganic trace elements were analysed in all samples from the year 2023. The following inorganic trace elements were analysed: Hg (mercury), Cd (cadmium), Pb (lead), As (arsenic), Sn (tin) and Cr (chromium). As mentioned before, the results are expressed as upper bond and therefore the results presented are likely to be an overestimation. All results for the analysed trace elements are reported in Table 3 in the Appendix.

### 4.6.1 Inorganic trace elements in fish and fishery products from Icelandic waters

In short, the concentration of the heavy metals Hg, Pb and Cd in all samples consisting of the edible part of fish were well below the maximum limits set by EU (Commission regulation (EC) No 2023/915). Maximum limits set by the EU (Commission regulation 2023/915) for tin (Sn) only apply to canned food products and no maximum limits exist in the EU for tin (Sn) in fish or fishery products. The concentration of tin (Sn) in all the samples analysed was very low as can be seen in Table 3 in the Appendix; in fact, no sample contained tin in concentrations above limits of detection.

The concentration of mercury (Hg) in the samples is shown in Figure 7.

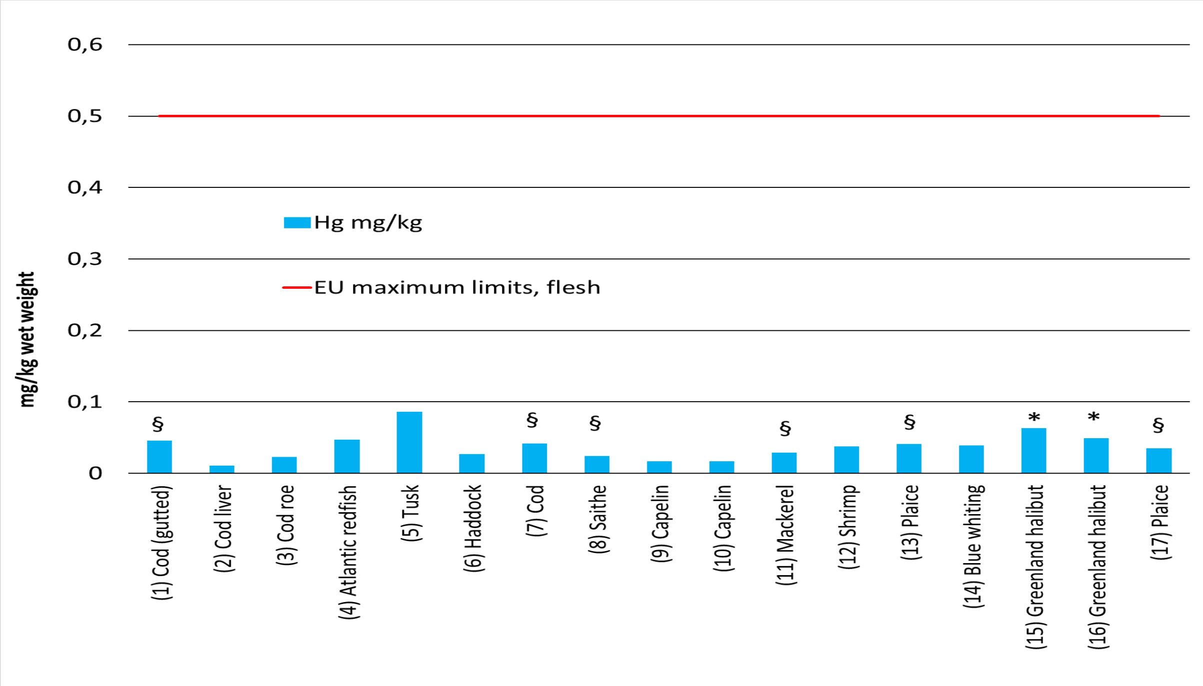


***Figure 7:*** *Mercury (Hg) in marine catches from Icelandic fishing grounds in 2023 in mg/kg wet weight. *EU maximum limit for Hg in Greenland halibut is set to 1 mg/kg wet weight.*
*§EU maximum limit for Hg in cod, saithe, mackerel and plaice is set to 0,3 mg/kg wet weight.*

The concentration of lead (Pb) was below the limit of detection for all samples as can be seen in Figure 8 and Table 3 in the Appendix.

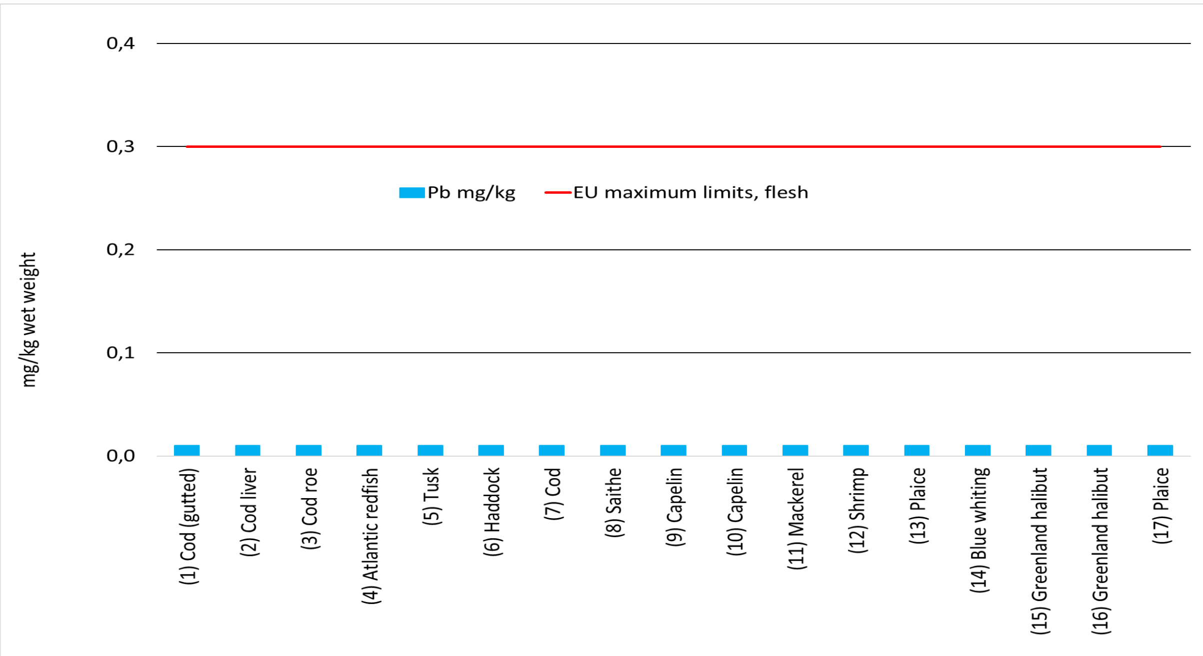


***Figure 8:*** *Lead (Pb) in marine catches from Icelandic fishing grounds in 2023 in mg/kg wet weight. Maximum EU limit only applies to muscle meat of fish.*

The concentration of cadmium (Cd) was below the EU maximum limit in all fish species analysed as can be seen in Figure 9 and Table 3 in the Appendix. The cod liver contained 0,145 mg/kg of cadmium. However, EU maximum limits applies only to muscle meat of fish.

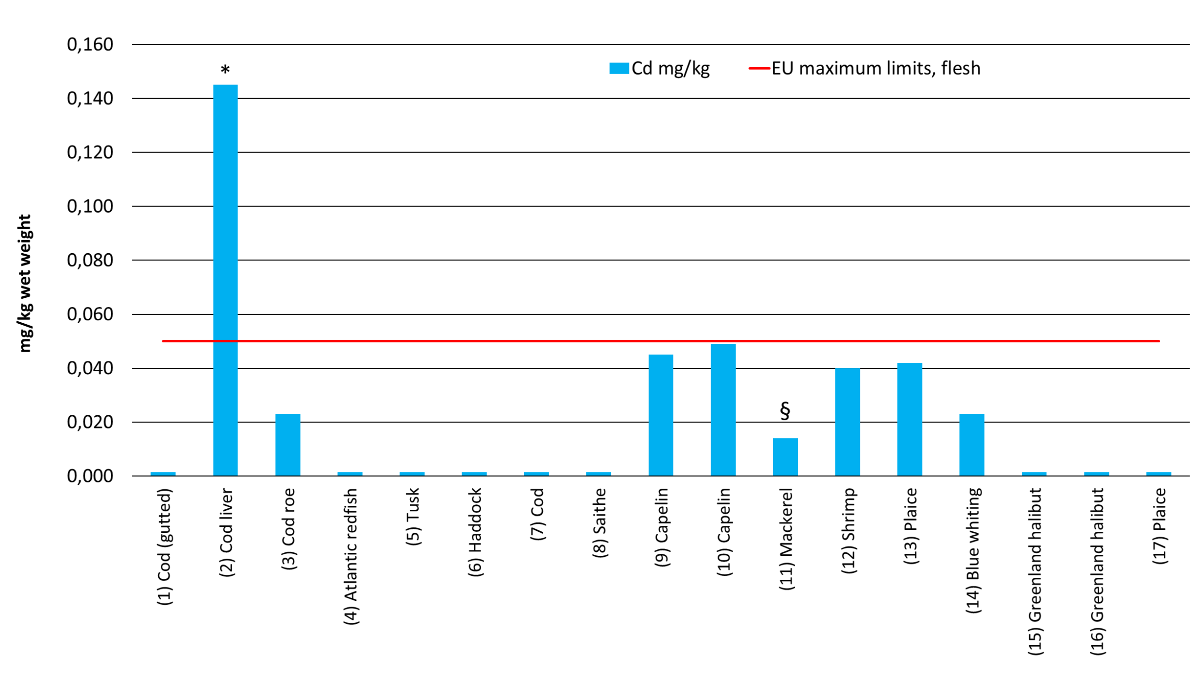


***Figure 9:*** *Cadmium (Cd) in marine catches from Icelandic fishing grounds in 2023 in mg/kg wet weight. EU maximum limit for Cd in mackerel is set to 0,1 mg/kg wet weight.*
**Maximum EU limit only applies to muscle meat of fish.*

No limits have yet been set for arsenic in seafood, but results from the monitoring in 2023, which are shown in Figure 10 were mostly in agreement with measurements from previous years (Auðunsson, 2004, Ásmundsdóttir et al. 2005, Ásmundsdóttir and Gunnlaugsdóttir, 2006, Jörundsdóttir et al., 2009, Baldursdóttir et al, 2011, Jörundsdóttir et al., 2012, Jensen et al., 2013, Jensen et al., 2018, Jensen et al., 2019, Jensen, et al. 2020, Jensen, et al. 2021 & Jensen, et al. 2022, Jensen, et al. 2023). The highest levels of As (7,53, 8,55 and 7,48 mg/kg) were found in the haddock, shrimp and plaice samples (sample no. 6, 12, 13 and 17) as seen in Figure 10. This is similar to the results from 2022 (Jensen, et al. 2023) where haddock and plaice samples also contained the highest levels of arsenic. Haddock and plaice are demersal species, but shrimp also has its habitat in proximity to the sediment where arsenic may settle. The total arsenic concentration was measured in the samples, but not the concentration of the toxic form i.e., inorganic arsenic.

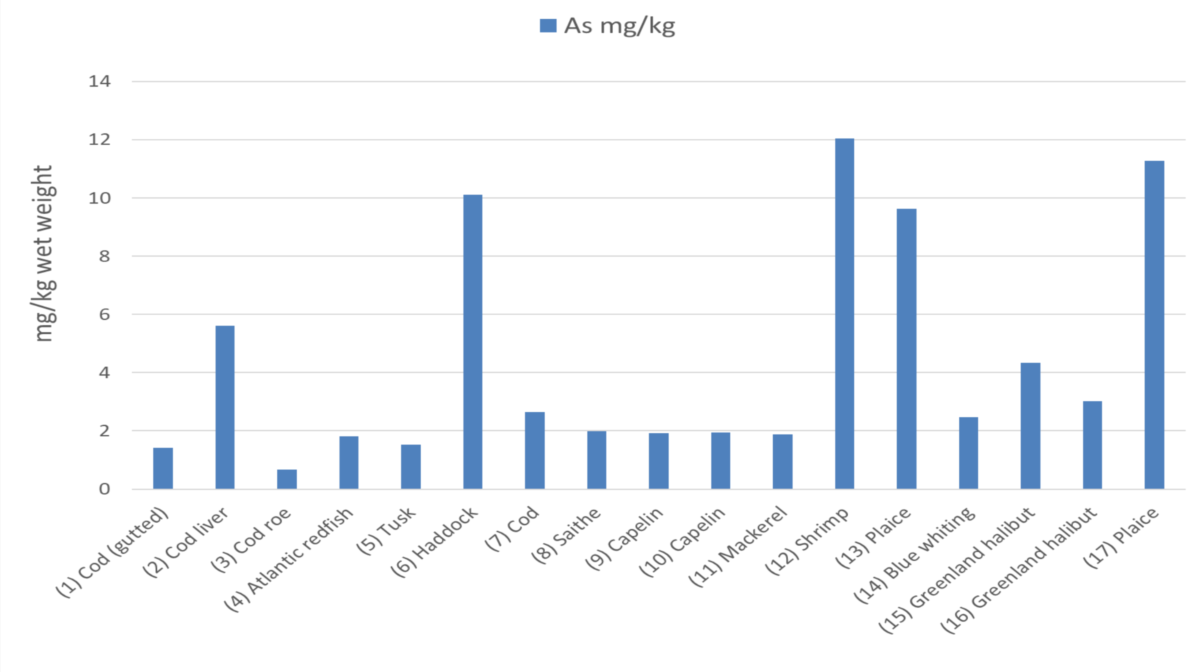


***Figure 10:*** *Arsenic (As) in marine catches from Icelandic fishing grounds in 2023 in mg/kg wet weight.*

## *4.7 Perfluoroalkyl substances (PFAS)*

A total of four PFAS were measured in the marine catches of the 2023 monitoring. The results are presented in Figure 11 as the sum of PFOS, PFOA, PFNA and PFHxS. All samples were below the EU maximum limit, except for the cod roe, with a level of 2,63 µg/kg. All results for the analysed PFAS are reported in Table 4 in the Appendix.

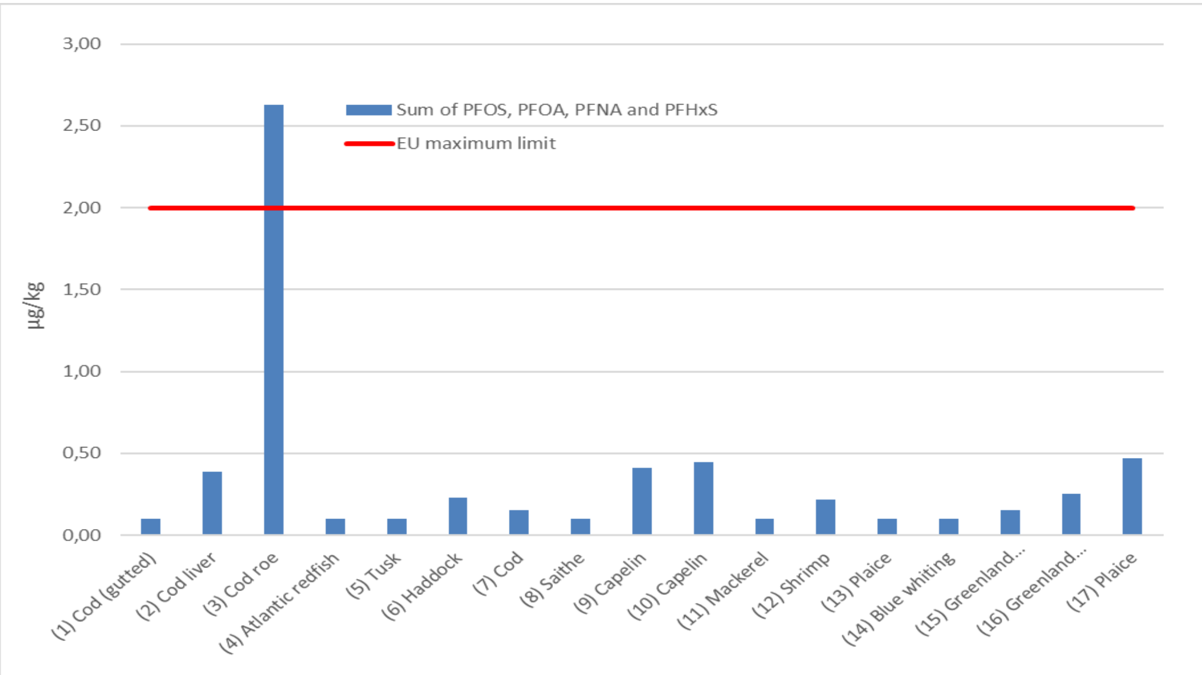


***Figure 11:*** *Sum of PFOS, PFOA, PFNA and PFHxS in marine catches from Icelandic fishing grounds in 2023 in µg/kg.*

# 5 Acknowledgements

Special thanks to the Icelandic marine and freshwater research institute (MFRI) for the sampling of fish samples. Thanks to Síldarvinnslan hf for providing the capelin and mackerel samples and thanks to BRIM for providing the blue whitening. Marz Seafood and Iceland Seafood are acknowledged for providing the cod roe and shrimp, respectively.

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Commission Regulation (EC) No 2017/644 laying down methods of sampling and analysis for the control of levels of dioxins, dioxin-like PCBs and non-dioxin-like PCBs in certain foodstuffs.

Commission Regulation (EC) No 2022/1428 laying down methods of sampling and analysis for the control of perfluoroalkyl substances in certain foodstuffs.

Commission Regulation (EC) No 2023/915 on maximum levels for certain contaminants in food and repealing Regulation (EC) No 1881/2006.

# 7 Appendix

**Table 1:** Dioxins and PCBs in fish and fishery product samples on wet weight

| Sample code | Fish sample no. | Sample name | Latin name | Fishing ground | Size [cm] | Lipid content % | PCDD/PCDFs pg/g WHO-TEQ | Dioxin like PCBs pg/g WHO-TEQ | Sum of Dioxins and DL-PCBs pg/g WHO-TEQ | Marker PCBs µg/kg | ICES-6 PCBs µg/kg |
|---|---|---|---|---|---|---|---|---|---|---|---|
| R23-739-1 | 1 | Cod (gutted) | *Gadus morhua* | *NW* | 60-70 | 0,5 | 0,34 | 0,206 | 0,55 | 2,05 | 2,0 |
| R23-739-2 | 2 | Cod liver | *Gadus morhua* | *NW* | | 69,9 | 0,34 | 0,209 | 0,55 | 2,11 | 2,0 |
| R23-739-3 | 3 | Cod roe | *Gadus morhua* | *SW* | | 2,9 | 0,26 | 0,227 | 0,49 | 2,78 | 2,5 |
| R23-739-4 | 4 | Atlantic Redfish | *Sebastes mentella* | *N* | 30-40 | 4,1 | 0,34 | 0,208 | 0,55 | 2,08 | 2,0 |
| R23-739-5 | 5 | Tusk | *Brosme brosme* | *NW* | 40-50 | 0,6 | 0,34 | 0,206 | 0,55 | 2,05 | 2,0 |
| R23-739-6 | 6 | Haddock | *Melanogrammus aeglefinus* | *N* | 50-60 | 0,8 | 0,34 | 0,206 | 0,55 | 2,05 | 2,0 |
| R23-739-7 | 7 | Cod | *Gadus morhua* | *NE* | 50-60 | 0,8 | 0,34 | 0,206 | 0,55 | 2,05 | 2,0 |
| R23-739-8 | 8 | Saithe | *Pollachius virens* | *NE* | 60-70 | 1,3 | 0,34 | 0,206 | 0,55 | 2,05 | 2,0 |
| R22-2523-1 | 9 | Capelin | *Mallotus villosus* | *S* | | 9,1 | 0,37 | 0,226 | 0,59 | 2,19 | 2,0 |
| R22-2523-2 | 10 | Capelin | *Mallotus villosus* | *S* | | 10,0 | 0,38 | 0,259 | 0,64 | 2,30 | 2,1 |
| R22-2523-3 | 11 | Mackerel | *Scomber scombrus* | *W* | 30-40 | 24,6 | 0,36 | 0,314 | 0,67 | 2,99 | 2,7 |
| R22-2523-4 | 12 | Shrimp | *Pandalus borealis* | *N* | | 1,0 | 0,34 | 0,207 | 0,55 | 2,06 | 2,0 |
| R22-2523-5 | 13 | Plaice | *Pleuronectes platessa* | *NW* | 40-50 | 1,9 | 0,34 | 0,206 | 0,55 | 2,05 | 2,0 |
| R22-2523-6 | 14 | Blue whiting | *Micromesistius poutassou* | *SE* | 20-30 | 2,4 | 0,34 | 0,206 | 0,55 | 2,05 | 2,0 |
| R22-2523-7 | 15 | Greenland halibut | *Reinhardtius hippoglossoides* | *W* | 50-60 | 12,2 | 0,41 | 0,411 | 0,82 | 3,58 | 3,1 |
| R22-2523-8 | 16 | Greenland halibut | *Reinhardtius hippoglossoides* | *N* | 50-60 | 13,4 | 0,56 | 0,567 | 1,12 | 4,66 | 4,0 |
| R22-2523-9 | 17 | Plaice | *Pleuronectes platessa* | *NW* | 40-50 | 1,5 | 0,34 | 0,208 | 0,55 | 2,09 | 2,0 |
| | | EU maximum limits‡ | | | | | 3,5 | * | 6,5 | * | 75 |

*No maximum limits exist in the EU for the substances
PCDD/PCDFs are 2,3,7,5,8-PCDDs and PCDFs.
DL-PCBs are CB-77, -81, -126, -169, -105, -114, -118, -123, -156, -157, -167 and -189
Marker PCBs are CB-28, -52, -101, -118, -138, -153 and -180
ICES-6 PCBs are marker PCBs excluding CB-118

**Table 2:** Pesticides in fish and fishery product samples on wet weight

| Sample code | Fish sample no. | Sample name | Latin name | Fishing ground | Size [cm] | Lipid content % | a-HCH µg/kg | b-HCH µg/kg | d-HCH µg/kg | g-HCH µg/kg | ∑ DDT µg/kg | Pentachlor benzene µg/kg | HCB µg/kg | ∑ Heptachlores µg/kg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| R23-739-1 | 1 | Cod (gutted) | *Gadus morhua* | *NW* | 60-70 | 0,5 | <0,250 | <0,250 | <0,250 | <0,250 | 0,6 | <0,500 | <0,500 | 0,55 |
| R23-739-2 | 2 | Cod liver | *Gadus morhua* | *NW* | | 69,9 | 0,86 | 0,818 | <0,581 | <0,581 | 35,5 | 2,08 | 17,1 | 2,78 |
| R23-739-3 | 3 | Cod roe | *Gadus morhua* | *SW* | | 2,9 | <0,250 | <0,250 | <0,250 | <0,250 | 4,8 | <0,500 | 1,3 | 0,55 |
| R23-739-4 | 4 | Atlantic Redfish | *Sebastes mentella* | *N* | 30-40 | 4,1 | <0,250 | <0,250 | <0,250 | <0,250 | 2,0 | <0,500 | 0,7 | 0,55 |
| R23-739-5 | 5 | Tusk | *Brosme brosme* | *NW* | 40-50 | 0,6 | <0,250 | <0,250 | <0,250 | <0,250 | 0,7 | <0,500 | <0,500 | 0,55 |
| R23-739-6 | 6 | Haddock | *Melanogrammus aeglefinus* | *N* | 50-60 | 0,8 | <0,250 | <0,250 | <0,250 | <0,250 | 0,6 | <0,500 | <0,500 | 0,55 |
| R23-739-7 | 7 | Cod | *Gadus morhua* | *NE* | 50-60 | 0,8 | <0,250 | <0,250 | <0,250 | <0,250 | 0,6 | <0,500 | <0,500 | 0,55 |
| R23-739-8 | 8 | Saithe | *Pollachius virens* | *NE* | 60-70 | 1,3 | <0,250 | <0,250 | <0,250 | <0,250 | 0,9 | <0,500 | <0,500 | 0,55 |
| R22-2523-1 | 9 | Capelin | *Mallotus villosus* | *S* | | 9,1 | <0,250 | <0,250 | <0,250 | <0,250 | 2,6 | <0,500 | 2,0 | 0,68 |
| R22-2523-2 | 10 | Capelin | *Mallotus villosus* | *S* | | 10,0 | <0,250 | <0,250 | <0,250 | <0,250 | 2,5 | <0,500 | 2,1 | 0,74 |
| R22-2523-3 | 11 | Mackerel | *Scomber scombrus* | *W* | 30-40 | 24,6 | <0,250 | <0,250 | <0,250 | <0,250 | 2,6 | <0,500 | 0,7 | 0,55 |
| R22-2523-4 | 12 | Shrimp | *Pandalus borealis* | *N* | | 1,0 | <0,250 | <0,250 | <0,250 | <0,250 | 0,6 | <0,500 | <0,500 | 0,55 |
| R22-2523-5 | 13 | Plaice | *Pleuronectes platessa* | *NW* | 40-50 | 1,9 | <0,250 | <0,250 | <0,250 | <0,250 | 0,7 | <0,500 | <0,500 | 0,55 |
| R22-2523-6 | 14 | Blue whiting | *Micromesistius poutassou* | *SE* | 20-30 | 2,4 | <0,250 | <0,250 | <0,250 | <0,250 | 1,0 | <0,500 | <0,500 | 0,55 |
| R22-2523-7 | 15 | Greenland halibut | *Reinhardtius hippoglossoides* | *W* | 50-60 | 12,2 | <0,250 | <0,250 | <0,250 | <0,250 | 7,7 | <0,500 | 3,9 | 0,74 |
| R22-2523-8 | 16 | Greenland halibut | *Reinhardtius hippoglossoides* | *N* | 50-60 | 13,4 | 0,26 | <0,250 | <0,250 | <0,250 | 8,3 | <0,500 | 3,6 | 0,71 |
| R22-2523-9 | 17 | Plaice | *Pleuronectes platessa* | *NW* | 40-50 | 1,5 | <0,250 | <0,250 | <0,250 | <0,250 | 0,9 | <0,500 | <0,500 | 0,55 |

**Table 2 (cont):** Pesticides in fish and fishery product samples on wet weight

| Sample code | Fish sample no. | Sample name | Latin name | Fishing ground | Size [cm] | Lipid content % | Aldrin/ dieldrin µg/kg | Toxaphene µg/kg | Octachloro styrene µg/kg | Endrin µg/kg | Endo-sulfane µg/kg | Chlordane µg/kg | *trans*-Nonachlor µg/kg | Mirex µg/kg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| R23-739-1 | 1 | Cod (gutted) | *Gadus morhua* | *NW* | 60-70 | 0,5 | 0,3 | 2,0 | <0,100 | <0,300 | 1,3 | 0,7 | <0,100 | <0,100 |
| R23-739-2 | 2 | Cod liver | *Gadus morhua* | *NW* | | 69,9 | 15,5 | 6,3 | 0,33 | 2,3 | 3,02 | 17,1 | 9,0 | <0,233 |
| R23-739-3 | 3 | Cod roe | *Gadus morhua* | *SW* | | 2,9 | 3,1 | 2,9 | <0,100 | 0,586 | 1,3 | 2,7 | 1,5 | <0,100 |
| R23-739-4 | 4 | Atlantic Redfish | *Sebastes mentella* | *N* | 30-40 | 4,1 | 0,7 | 2,5 | <0,100 | <0,300 | 1,3 | 0,9 | 0,35 | <0,100 |
| R23-739-5 | 5 | Tusk | *Brosme brosme* | *NW* | 40-50 | 0,6 | 0,3 | 2,0 | <0,100 | <0,300 | 1,3 | 0,7 | <0,100 | <0,100 |
| R23-739-6 | 6 | Haddock | *Melanogrammus aeglefinus* | *N* | 50-60 | 0,8 | 0,3 | 2,0 | <0,100 | <0,300 | 1,3 | 0,7 | <0,100 | <0,100 |
| R23-739-7 | 7 | Cod | *Gadus morhua* | *NE* | 50-60 | 0,8 | 0,3 | 2,0 | <0,100 | <0,300 | 1,3 | 0,7 | <0,100 | <0,100 |
| R23-739-8 | 8 | Saithe | *Pollachius virens* | *NE* | 60-70 | 1,3 | 0,5 | 2,0 | <0,100 | <0,300 | 1,3 | 0,8 | 0,16 | <0,100 |
| R22-2523-1 | 9 | Capelin | *Mallotus villosus* | *S* | | 9,1 | 2,4 | 3,9 | <0,100 | 0,41 | 1,3 | 1,8 | 0,90 | <0,100 |
| R22-2523-2 | 10 | Capelin | *Mallotus villosus* | *S* | | 10,0 | 2,5 | 3,6 | <0,100 | 0,34 | 1,3 | 1,4 | 0,81 | <0,100 |
| R22-2523-3 | 11 | Mackerel | *Scomber scombrus* | *W* | 30-40 | 24,6 | 1,3 | 3,7 | <0,100 | <0,300 | 1,3 | 0,9 | 0,42 | <0,100 |
| R22-2523-4 | 12 | Shrimp | *Pandalus borealis* | *N* | | 1,0 | 0,3 | 2,0 | <0,100 | <0,300 | 1,3 | 0,7 | <0,100 | <0,100 |
| R22-2523-5 | 13 | Plaice | *Pleuronectes platessa* | *NW* | 40-50 | 1,9 | 0,3 | 2,0 | <0,100 | <0,300 | 1,3 | 0,7 | <0,100 | <0,100 |
| R22-2523-6 | 14 | Blue whiting | *Micromesistius poutassou* | *SE* | 20-30 | 2,4 | 0,3 | 2,3 | <0,100 | <0,300 | 1,3 | 0,7 | <0,100 | <0,100 |
| R22-2523-7 | 15 | Greenland halibut | *Reinhardtius hippoglossoides* | *W* | 50-60 | 12,2 | 3,4 | 8,1 | <0,100 | 0,63 | 1,3 | 3,2 | 2,7 | 0,11 |
| R22-2523-8 | 16 | Greenland halibut | *Reinhardtius hippoglossoides* | *N* | 50-60 | 13,4 | 3,2 | 9,9 | <0,100 | 0,64 | 1,3 | 2,8 | 2,3 | 0,13 |
| R22-2523-9 | 17 | Plaice | *Pleuronectes platessa* | *NW* | 40-50 | 1,5 | 0,3 | 2,0 | <0,100 | <0,300 | 1,3 | 0,7 | 0,169 | <0,100 |

**Table 3:** Trace elements in fish and fishery product samples in mg/kg wet weight

| Sample code | Fish sample no. | Sample name | Latin name | Cr | As | Cd | Sn | Hg | Pb |
|---|---|---|---|---|---|---|---|---|---|
| | | | | mg/kg | mg/kg | mg/kg | mg/kg | mg/kg | mg/kg |
| R23-739-1 | 1 | Cod (gutted) | *Gadus morhua* | <0,01 | 1,42 | <0,0015 | <0,01 | 0,046 | <0,01 |
| R23-739-2 | 2 | Cod liver | *Gadus morhua* | <0,01 | 5,60 | 0,145 | <0,01 | 0,011 | <0,01 |
| R23-739-3 | 3 | Cod roe | *Gadus morhua* | <0,01 | 0,66 | 0,023 | <0,01 | 0,023 | <0,01 |
| R23-739-4 | 4 | Atlantic Redfish | *Sebastes mentella* | <0,01 | 1,81 | <0,0015 | <0,01 | 0,047 | <0,01 |
| R23-739-5 | 5 | Tusk | *Brosme brosme* | <0,01 | 1,52 | <0,0015 | <0,01 | 0,086 | <0,01 |
| R23-739-6 | 6 | Haddock | *Melanogrammus aeglefinus* | <0,01 | 10,1 | <0,0015 | <0,01 | 0,027 | <0,01 |
| R23-739-7 | 7 | Cod | *Gadus morhua* | <0,01 | 2,64 | <0,0015 | <0,01 | 0,042 | <0,01 |
| R23-739-8 | 8 | Saithe | *Pollachius virens* | <0,01 | 1,98 | <0,0015 | <0,01 | 0,024 | <0,01 |
| R22-2523-1 | 9 | Capelin | *Mallotus villosus* | <0,01 | 1,93 | 0,045 | <0,01 | 0,017 | <0,01 |
| R22-2523-2 | 10 | Capelin | *Mallotus villosus* | <0,01 | 1,95 | 0,049 | <0,01 | 0,017 | <0,01 |
| R22-2523-3 | 11 | Mackerel | *Scomber scombrus* | <0,01 | 1,87 | 0,014 | <0,01 | 0,029 | <0,01 |
| R22-2523-4 | 12 | Shrimp | *Pandalus borealis* | <0,01 | 12,0 | 0,04 | <0,01 | 0,038 | <0,01 |
| R22-2523-5 | 13 | Plaice | *Pleuronectes platessa* | <0,01 | 9,63 | 0,042 | <0,01 | 0,041 | <0,01 |
| R22-2523-6 | 14 | Blue whiting | *Micromesistius poutassou* | <0,01 | 2,46 | 0,023 | <0,01 | 0,039 | <0,01 |
| R22-2523-7 | 15 | Greenland halibut | *Reinhardtius hippoglossoides* | <0,01 | 4,34 | <0,0015 | <0,01 | 0,06 | <0,01 |
| R22-2523-8 | 16 | Greenland halibut | *Reinhardtius hippoglossoides* | <0,01 | 3,01 | <0,0015 | <0,01 | 0,049 | <0,01 |
| R22-2523-9 | 17 | Plaice | *Pleuronectes platessa* | <0,01 | 11,3 | <0,0015 | <0,01 | 0,04 | <0,01 |

**Table 4:** Perfluoroalkyl substances in fish and fishery product samples in µg/kg.

| Sample code | Fish sample no. | Sample name | Latin name | PFOS µg/kg | PFOA µg/kg | PFNA µg/kg | PFHxS µg/kg | Sum of PFOS, PFOA, PFNA and PFHxS µg/kg |
|---|---|---|---|---|---|---|---|---|
| R23-739-1 | 1 | Cod (gutted) | *Gadus morhua* | 0.100 | <0.100 | <0.100 | <0.100 | 0,10 |
| R23-739-2 | 2 | Cod liver | *Gadus morhua* | 0.387 | <0.100 | <0.100 | <0.100 | 0,39 |
| R23-739-3 | 3 | Cod roe | *Gadus morhua* | 2.34 | <0.100 | 0.293 | <0.100 | 2,63 |
| R23-739-4 | 4 | Atlantic Redfish | *Sebastes mentella* | <0.100 | <0.100 | <0.100 | <0.100 | 0,10 |
| R23-739-5 | 5 | Tusk | *Brosme brosme* | <0.100 | <0.100 | <0.100 | <0.100 | 0,10 |
| R23-739-6 | 6 | Haddock | *Melanogrammus aeglefinus* | 0.112 | <0.100 | 0.117 | <0.100 | 0,23 |
| R23-739-7 | 7 | Cod | *Gadus morhua* | 0.150 | <0.100 | <0.100 | <0.100 | 0,15 |
| R23-739-8 | 8 | Saithe | *Pollachius virens* | <0.100 | <0.100 | <0.100 | <0.100 | 0,10 |
| R22-2523-1 | 9 | Capelin | *Mallotus villosus* | 0.273 | <0.100 | 0.138 | <0.100 | 0,41 |
| R22-2523-2 | 10 | Capelin | *Mallotus villosus* | 0.294 | <0.100 | 0.151 | <0.100 | 0,45 |
| R22-2523-3 | 11 | Mackrel | *Scomber scombrus* | <0.100 | <0.100 | <0.100 | <0.100 | 0,10 |
| R22-2523-4 | 12 | Shrimp | *Pandalus borealis* | 0.216 | <0.100 | <0.100 | <0.100 | 0,22 |
| R22-2523-5 | 13 | Plaice | *Pleuronectes platessa* | <0.100 | <0.100 | <0.100 | <0.100 | 0,10 |
| R22-2523-6 | 14 | Blue whiting | *Micromesistius poutassou* | <0.100 | <0.100 | <0.100 | <0.100 | 0,10 |
| R22-2523-7 | 15 | Greenland halibut | *Reinhardtius hippoglossoides* | 0.152 | <0.100 | <0.100 | <0.100 | 0,15 |
| R22-2523-8 | 16 | Greenland halibut | *Reinhardtius hippoglossoides* | 0.250 | <0.100 | <0.100 | <0.100 | 0,25 |
| R22-2523-9 | 17 | Plaice | *Pleuronectes platessa* | 0.268 | <0.100 | 0.199 | <0.100 | 0,47 |
| | | EU maximum limits‡ | | 2,00 | 0,20 | 0,50 | 0,2 | 2,0 |