Undesireable substances in seafood – results from the Icelandic marine monitoring activities in the year 2017

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Icelandic Food and Biotech R&D

Report summary

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Titill / Title	Niðurstöður sívirkrar vöktunar á óæskilegum efnum í sjávarfangi úr auðlindinni 2017 **/ Undesirable substances in seafood – results from the Icelandic marine monitoring activities in the year 2017**		
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Ágrip á íslensku:	Í þessari skýrslu eru teknar saman niðurstöður vöktunar á óæskilegum efnum í ætum hluta sjávarfangs 2017. Vöktunin hófst árið 2003 fyrir tilstuðlan þáverandi Sjávarútvegsráðuneytis, núverandi Atvinnuvega- og nýsköpunar-ráðneytisins, og sá Matís ohf. um að safna gögnum og útgáfu á skýrslum vegna þessarar kerfisbundnu vöktunar á tímabilinu 2003-2012. Undanfarin ár hefur skort fjármagn til að halda áfram vinnu við þetta vöktunarverkefni og því 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 voru ekki gerðar efnagreiningar á PAH, PBDE og PFC efnum í þetta sinn. Markmiðið með verkefninu er að sýna fram á stöðu íslenskra sjávarafurða m.t.t. öryggi og heilnæmis og 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 eftirlit og endurskoðun er stöðugt nauðsynlegt. Almennt voru niðurstöðurnar sem fengust 2017 í samræmi við fyrri niðurstöður frá árunum 2003 til 2012. Niðurstöðurnar sýndu að íslenskar sjávarafurðir innihalda óverulegt magn þrávirkra lífrænna efna s.s. díoxín, PCB og varnarefni. Hámarksgildi ESB fyrir díoxín og díoxínlík PCB (DL-PCB) í matvælum og fóðri voru lækkuð 1. janúar 2012 (ESB reglugerð nr. 1259/2011) ásamt því að hámarksgildi voru í fyrsta sinn sett fyrir „ekki díoxínlík“ PCB (NDL-PCB). Nýju hámarksgildin eru notuð í þessari skýrslu til að meta hvernig íslenskar sjávarafurðir standast kröfur ESB. Niðurstöður ársins 2017 sýna að þrátt fyrir breytingu á hámarksgildum fyrir díoxín, DL-PCB og NDL-PCB eru öll sýni af sjávarafurðum til manneldis undir hámarksgildum ESB fyrir þrávirk lífræn efni og þungmálma. Þá reyndist styrkur svokallaðra ICES6-PCB efna vera lágur í ætum hluta fisks, miðað við ný hámarksgildi ESB. Sömuleiðis sýndu niðurstöðurnar að styrkur þungmálma, t.d. kadmíum (Cd), blý (Pb) og kvikasilfur (Hg) í íslenskum sjávarafurðum var alltaf undir hámarksgildum ESB.		
Lykilorð á íslensku:	*Sjávarfang, vöktun, Díoxín, díoxínlík PCB, PCB, varnarefni, þungmálmar, hámarksgildi, heilnæmi, lýðheilsa*		

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Report summary

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Summary in English:	This report summarises the results obtained in 2017 for the screening of various undesirable substances in the edible part of marine catches. The surveillance program began in 2003 and was carried out for ten consecutive years before it was interrupted. The project was revived in March 2017 to fill in gaps of knowledge regarding the level of undesirable substances in economically important marine catches for Icelandic export. Due to financial restrictions the surveillance now only covers screening for undesirable substances in the edible portion of marine catches for human consumption not feed or feed components. The limited financial resources also required that the analysis of PAHs, PBDEs and PFCs were excluded in the surveillance, and therefore this report provides somewhat more limited data than previously. However, it is considered to be a long-term project where extension and revision is constantly necessary. The main aim of this project is to gather data and evaluate the status of Icelandic seafood products in terms of undesirable substances and to utilise the data to estimate the exposure of consumers to these substances from Icelandic seafood and risks related to public health. Generally, the results obtained in 2017 are in agreement with previous results on undesirable substances in the edible part of marine catches obtained in the monitoring years 2003 to 2012. The results show that the edible parts of Icelandic seafood products contain negligible amounts of persistent organic pollutants (POPs) such as; dioxins, dioxin like PCBs and pesticides. As of January 1st 2012 Commission Regulation No 1259/2011, regarding maximum levels for dioxins, dioxin-like PCBs and non-dioxin-like PCBs in foodstuff came into force. This amendment to the existing regulation (No 1881/2006) resulted in changes in maximum levels for dioxins and dioxin-like PCBs for many food products due to changes in toxicological assessment of dioxins. Furthermore, maximum levels for non-dioxin-like PCBs have now been established in foodstuffs. In this report, we use these revised maximum levels for dioxins, dioxin-like PCBs and non-dioxin-like PCBs in foodstuffs to evaluate how Icelandic seafood products measure up to limits currently in effect. The results obtained year 2017 reveal that all samples of seafood for human consumption were below EC maximum levels for POPs and heavy metals. Furthermore, the concentration of ICES6-PCBs was found to be low in the edible part of fish muscle, compared to the maximum limits set by the EU (Commission Regulation 1259/2011). The results showed that the concentrations of heavy metals, e.g. cadmium (Cd), lead (Pb) and mercury (Hg) in Icelandic seafood products was always well below the maximum limits set by EU.
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 Industries and Innovation, initiated a project aimed at screening for undesirable substances in the edible portion of marine catches, as well as in fish meal and fish oil for feed, captured in Icelandic waters. Matís was assigned the responsibility of carrying out the surveillance 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 Matís did not receive funding to work on this monitoring project. However, in March 2017 the surveillance programme was revived with funding from the Ministry of Industries and Innovation in Iceland to gather 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 not feed or feed components. The project includes measurements on various undesirable substances in several economically important marine species from Icelandic fishing grounds in order 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 2017. 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, 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:

A) To gather information and evaluate the status of Icelandic seafood products in terms of undesirable substances.
B) 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 1881/2006 and its amendments).

C) To utilise the data gathered in this programme for a 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.

D) 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 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). The above mentioned EU regulations have now been implemented (Reglugerð 265/2010) in the Icelandic legal framework regarding undesirable substances in food (Regulation (EC) No 1881/2006), 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 Summary

This report summarises the results obtained in 2017 for the screening of various undesirable substances in the edible part of marine catches. The surveillance program began in 2003 and was carried out for ten consecutive years before it was interrupted. The project was revived in March 2017 to fill in gaps of knowledge regarding the level of undesirable substances in economically important marine catches for Icelandic export. Due to financial limitations the surveillance now only covers screening for undesirable substances in the edible portion of marine catches for human consumption not feed or

feed components. The limited financial resources also required the analysis of PAHs, PBDEs and PFCs to be excluded in the surveillance, and therefore this report provides somewhat more limited information than in 2013. However, it is considered to be a long-term project where extension and revision is constantly necessary. Generally, the results obtained in 2017 are in agreement with previous results on undesirable substances in the edible part of marine catches obtained in the monitoring years 2003 to 2012. The results show that the edible parts of Icelandic seafood products contain negligible amounts of persistent organic pollutants (POPs) such as; dioxins, dioxin like PCBs and pesticides. As of January 1st 2012 Commission Regulation No 1259/2011, regarding maximum levels for dioxins, dioxin-like PCBs and non-dioxin-like PCBs in foodstuff came into force. This amendment to the existing regulation (No 1881/2006) resulted in changes in maximum levels for dioxins and dioxin-like PCBs for many food products due to changes in toxicological assessment of dioxins. Furthermore, maximum levels for non-dioxin-like PCBs have now been established in foodstuffs. In this report from the surveillance programme we use these maximum levels for dioxins, dioxin-like PCBs and non-dioxin-like PCBs in foodstuffs to evaluate how Icelandic seafood products measure up to limits currently in effect. The results obtained year 2017 reveal that all samples of seafood for human consumption were below EC maximum levels for POPs and heavy metals. Furthermore, the concentration of ICES6-PCBs was found to be low in the edible part of fish muscle, compared to the maximum limits set by the EU (Commission Regulation 1259/2011). The results showed that the concentrations of heavy metals, e.g. cadmium (Cd), lead (Pb) and mercury (Hg) in Icelandic seafood products was always well below the maximum limits set by EU.

3 Contaminants measured in the project

The following contaminants were measured in edible parts of seafood 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).

4 Sampling and analysis

4.1 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). The fish samples were collected by the Marine and Freshwater Research Institute (MRI) in Iceland and the Icelandic Food and Veterinary Authority (MAST) according to sampling protocols provided by Matís and the samples were kept frozen until preparation for analysis (see section 4.1.1). Fishing grounds around Iceland are divided into five areas, as illustrated in Figure 1. All the fish samples were identified and labelled with the fishing area where they were caught. The fish roe sample was taken at the production site and represents commercial fish roe production from one batch, the producer also provided information regarding the fishing area for this batch.

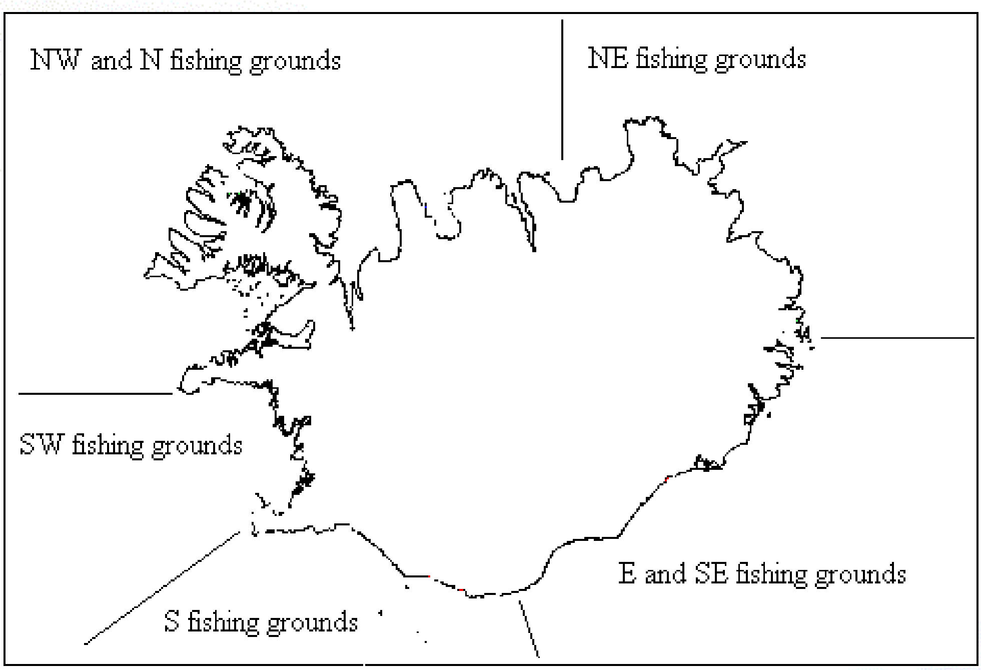

Figure 1: The division of the fishing grounds around Iceland used in this research.

4.1.1 Sample preparation

All analyses were performed on the edible parts of the fish and the roe sample. 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 10 individuals were then pooled, homogenised and frozen again for analysis of organic contaminants or freeze-dried for heavy metal analysis.

4.2 Analyses

The heavy metal analysis of chrome, 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 dioxin, WHO-PCBs, ICES-6-PCBs, 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 1259/2011 for foodstuffs.

5 Results of monitoring of fish and seafood products in Iceland

All results for undesirable substances from the surveillance program in 2017 are listed in Tables 1-3 in the Appendix. The sections below contain an overview of the results obtained in samples of fish and seafood products taken as part of the monitoring activities 2017.

5.1 Dioxins (PCDD/Fs) and dioxin like PCBs

5.1.1 Dioxins and dioxin like PCBs in seafood

All the fish species analysed contained total levels of dioxins and dioxin like PCBs (Figure 2 and Table 1 in the Appendix) as well as non-dioxin like PCBs far below the limits set by EU. As in previous years, a considerable difference was observed in the dioxin content between different fish species. The species that accumulate fat in the muscle, like for example Greenland halibut (samples no. 3 and 4), contain more dioxins and dioxin like PCBs than species which accumulate fat in the liver and thus have almost no fat in the muscle. The highest lipid content was seen in the mackerel samples (29, 23 and 25%, respectively). This was however not reflected in higher levels of dioxins and dioxin-like PCBs compared to fish with lower lipid content such as Greenland halibut (11% fat). Generally, 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 probably contributes considerably to the higher dioxins and dioxin-like PCBs values observed for this species (Figure 2 and 3).

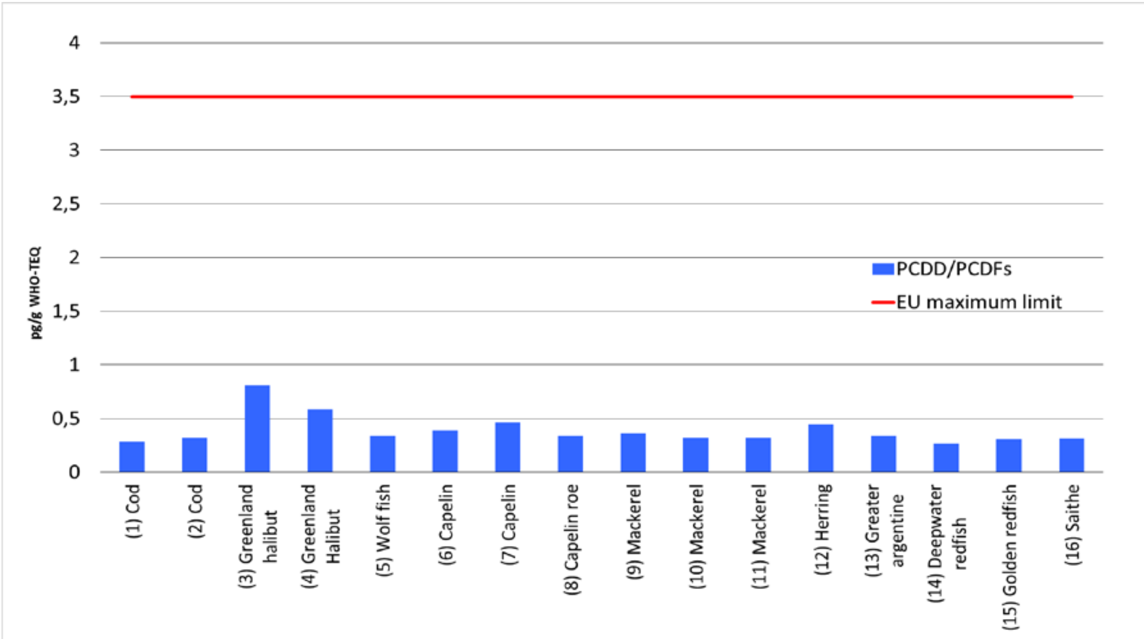

Figure 2: Dioxins and dioxin-like PCBs in the edible part of fish muscle from Icelandic fishing grounds in 2017 in relation to maximum EU limit in WHO-TEQ pg/g wet weight. The number within parenthesis is the sample number indicated in Table 1.

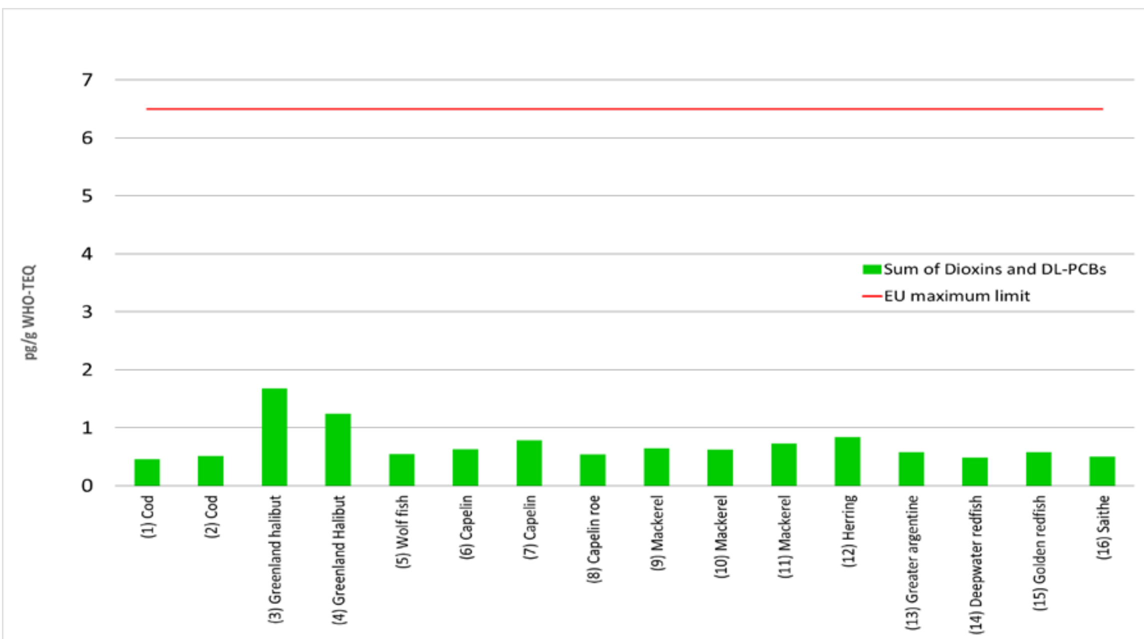

Figure 3: Sum of dioxins and dioxin-like PCBs in the edible part of fish muscle from Icelandic fishing grounds in 2017 in relation to maximum EU limit in WHO-TEQ pg/g wet weight. The number within parenthesis is the sample number indicated in Table 1.

5.2 *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 1259/2011). To enable comparison to earlier results, the sum of seven marker PCBs are presented in Table 1 in the Appendix, while the ICES-6 maximum limits are presented in Figure 4 to evaluate how seafood products measure up to EU maximum limits.

5.2.1 ICES-6 PCBs in seafood

The results obtained for all of the Icelandic fish species were well below the recently established maximum limits set for non-dioxin-like PCBs i.e. the so-called ICES-6. In this study, the highest total concentration for the sum of all six marker PCBs was measured in Greenland halibut (sample no. 3, Figure 4), a total of 9.4 µg/kg wet weight, the highest individual PCB congener measured in the halibut was PCB-153 with 3.5 µg/kg wet weight, or approximately one third of the total. As for the dioxins and dioxin-like PCBs, the highest concentrations of PCBs are found in fish with high lipid content in the muscle. For details, see Table 1 in the Appendix.

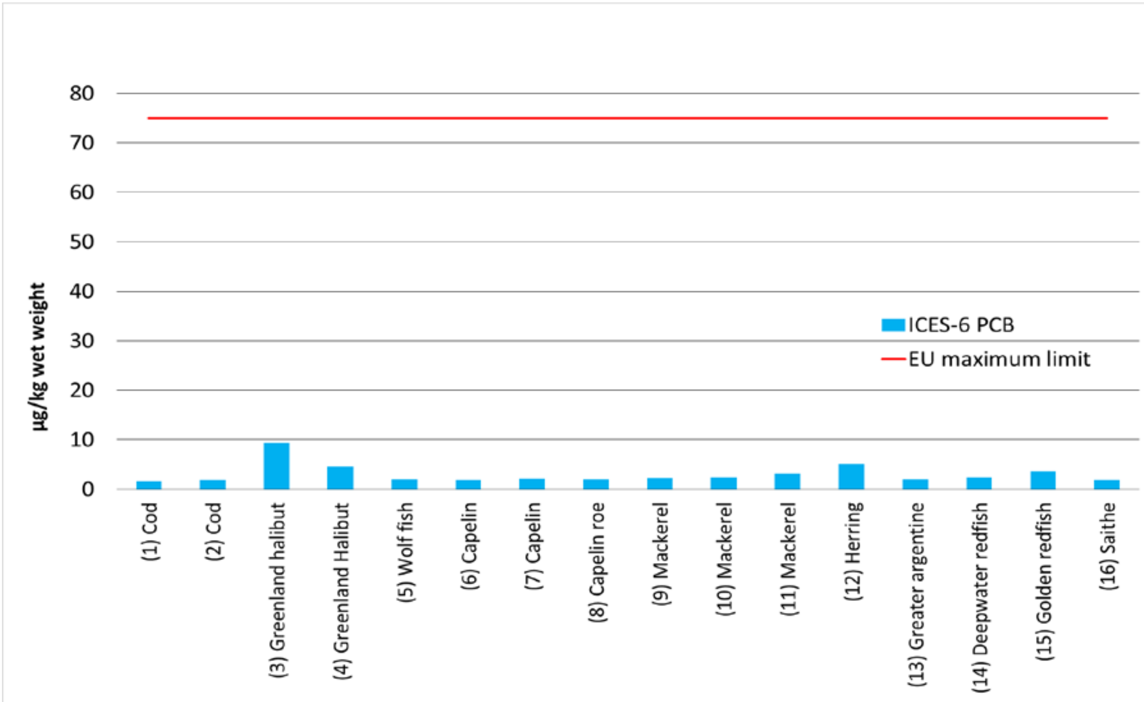

Figure 4: ICES-6 PCBs in the edible part of fish muscle from Iceland in 2017 (in µg/kg wet weight). Number in parenthesis is the sample number designated to each sample, see Table 1 in Appendix.

5.3 Polycyclic aromatic hydrocarbons (PAHs)

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).

5.4 Brominated flame retardants (BFRs)

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 previous reports (Jensen et al., 2013).

5.5 Pesticides

In this section, the results for 12 different classes of pesticides are discussed. Results are shown in Table 2 in the Appendix.

12 different pesticides or groups of pesticides were measured in the monitoring program.

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 (hexachlorocyclohexan) 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: α-, β-, γ-(Lindane), and δ-HCH. Of these, only Lindane is an active substance comprising of approximately 15% of the total mixture, while α-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 α-, β-, γ-(Lindane), and δ-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 fuel.

Chlordanes is a group of compounds and isomers where α- and γ-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 ⍰-chlordane, ⍰-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 always above LOD. The maximum value in the EU is set for the sum of aldrin and dieldrin and the results are therefore presented as the sum of these two.

Two **Endosulfans** were measured, α- and β-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 ?-endusulfan, ?-endusulfan and endosulfansulfat.

Other pesticides measured were **Endrin**, the sum of **Heptachlores** (cis-heptachlorepoxide, trans-heptachlorepoxide and heptachlor), **Pentachlorobenzene**, **Mirex** and **Octachlorostyrene**.

5.5.1 Pesticides in seafood

The results showed that most of the pesticides measured in fish muscle and capelin roe from Icelandic waters were below the limit of detection (see Table 2 in the Appendix). However, as mentioned before the results are expressed as upper bond, and therefore the results presented are likely to be an overestimation. HCB and *trans*-Nonachlore were measured in almost all fish species, whilst β-, γ- and δ-HCHs were always below LOQ. Figure 5 shows the level of total DDT in fish muscle and capelin roe, while Figure 6 shows the level of HCB in the same samples. No limits have yet been set for pesticides in seafood, but to enable comparison with earlier measurements (Jensen, et al. 2013), results of ∑DDT and HCB are presented from the monitoring in 2017. Of the fish species analysed, herring and Greenland halibut had the highest concentrations of all the pesticides investigated.

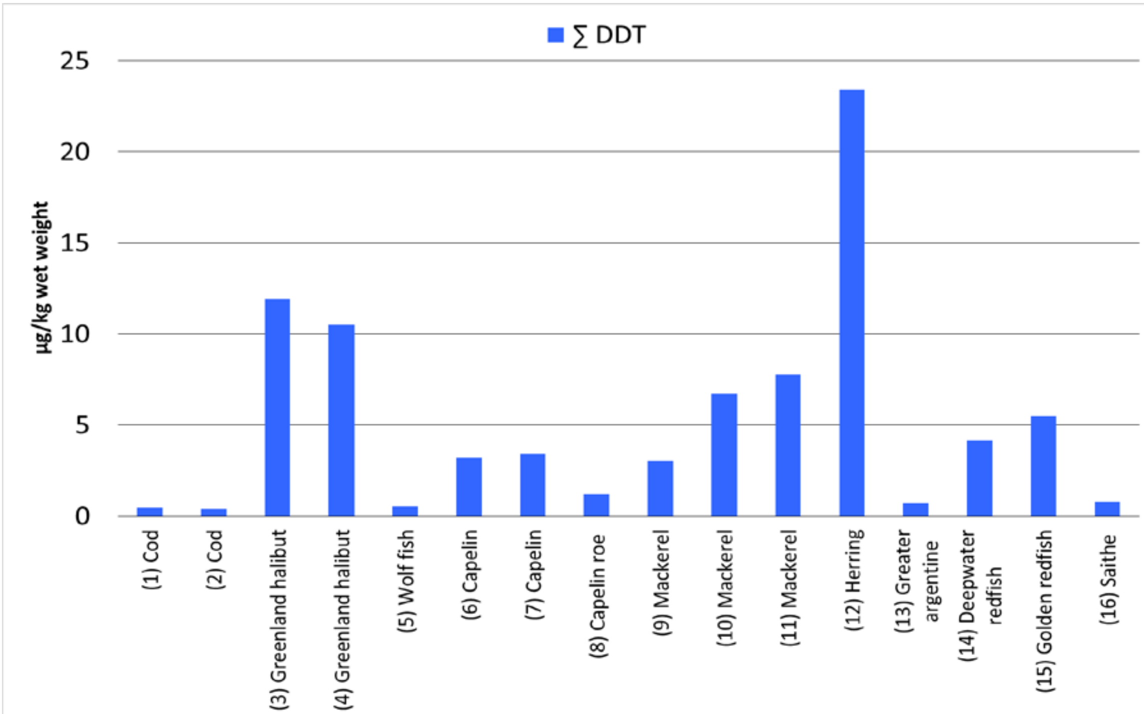

Figure 5: ΣDDT in fish muscle and one roe sample from Icelandic fishing grounds in 2017 in µg/kg wet weight.

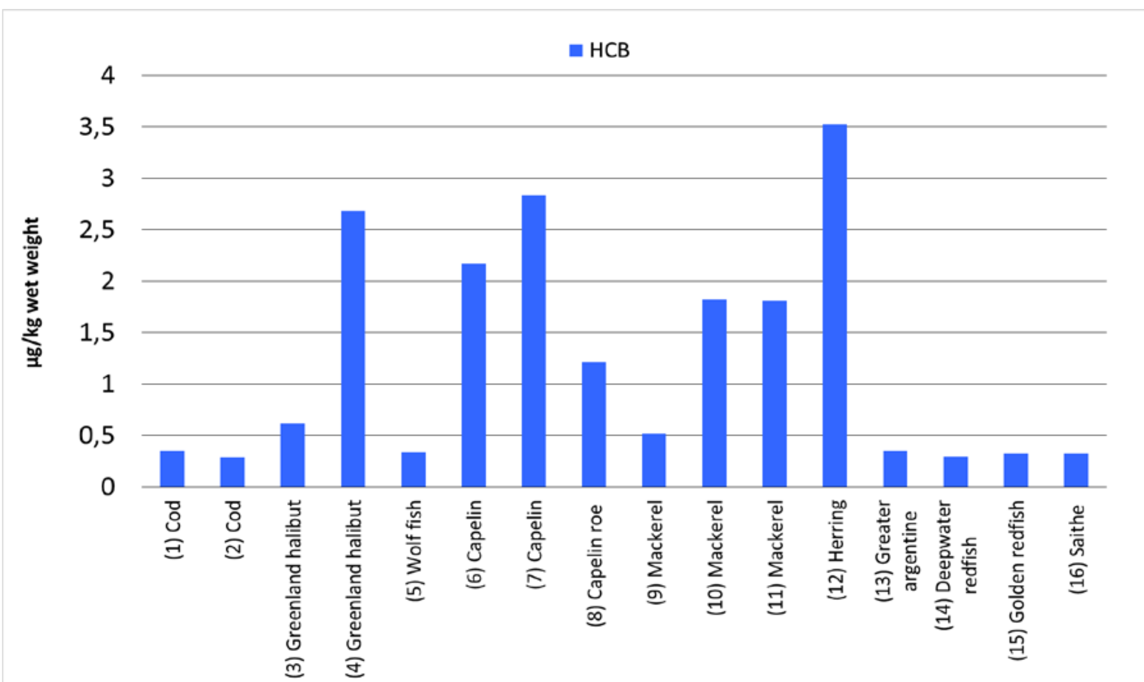

Figure 6: HCB in fish muscle and one roe sample from Icelandic fishing grounds in 2017 in µg/kg wet weight.

5.6 *Inorganic trace elements*

Inorganic trace elements were analysed in all samples from the year 2017. 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.

5.6.1 Inorganic trace elements in seafood

In short, the concentration of the heavy metals Hg, Pb and Cd in all the samples of the edible part of fish muscle was well below the maximum limits set by EU (Commission regulation (EC) No 1881/2006 and its amendments). Maximum limits set by EU (Commission regulation 1881/2006) 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 capelin roe and fish muscle 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 fish samples is shown in Figure 7.

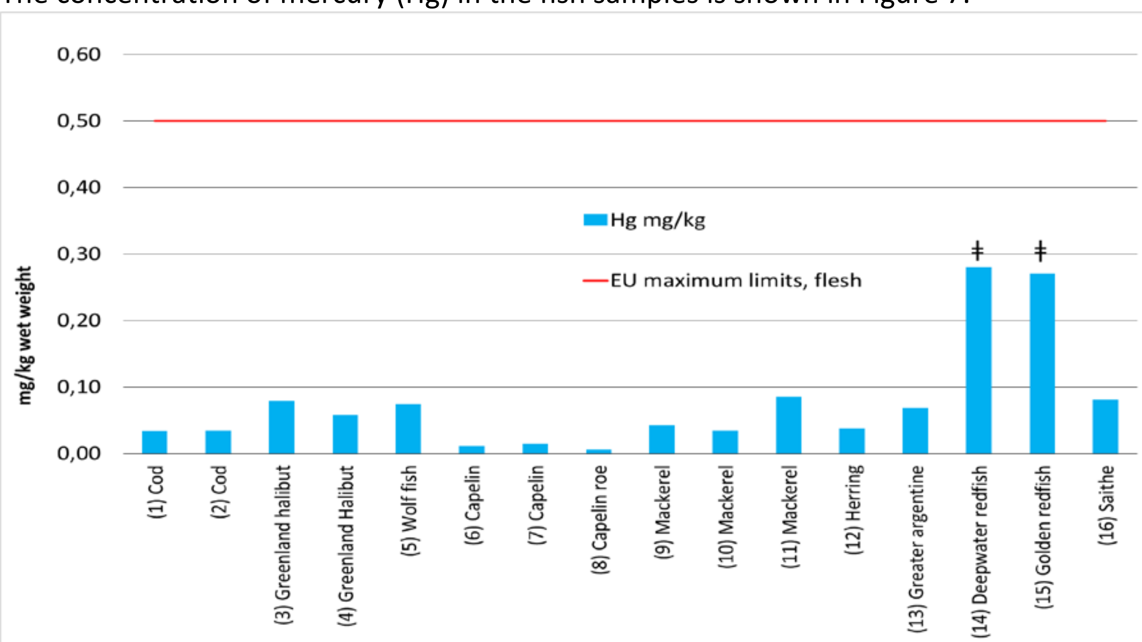

Figure 7: Hg in fish muscle and capelin roe from Icelandic fishing grounds in 2017 in mg/kg wet weight.
ǂEU maximum limit for mercury in deepwater redfish and golden redfish is 1.0 mg/kg wet weight.

The concentration of lead (Pb) in fish muscle and capelin roe was very low as can be seen in Figure 8 and Table 3 in the Appendix; in fact no sample contained lead in concentrations above limits of detection.

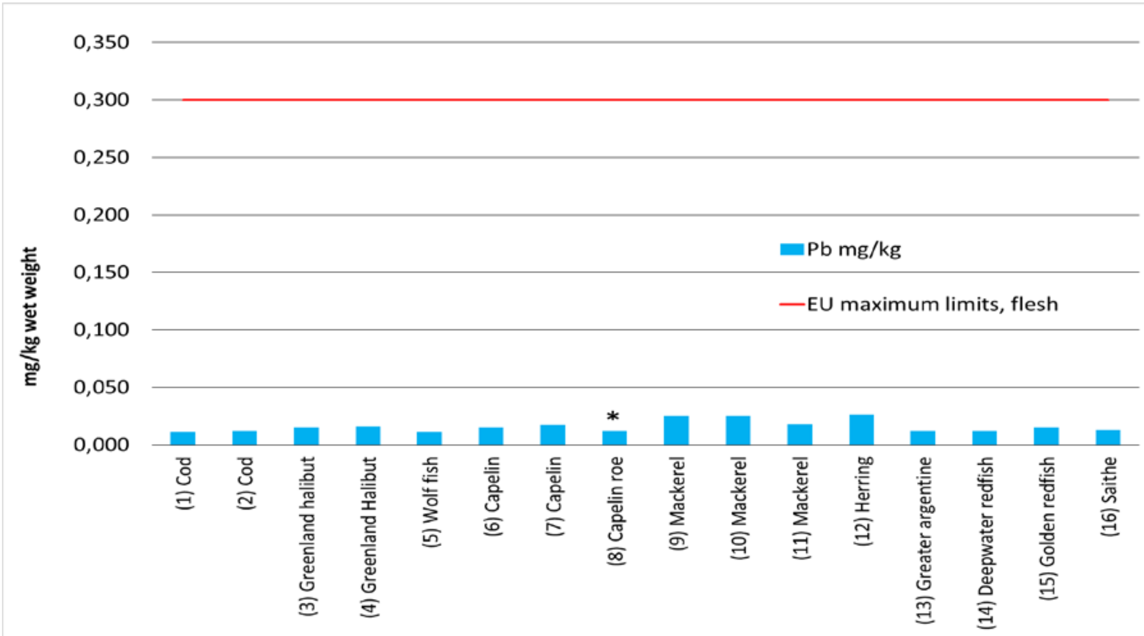

*Figure 8: Pb in fish muscle and capelin roe from Icelandic fishing grounds in 2017 in mg/kg wet weight. *EU maximum limit for Pb does not apply to capelin roe since it is set for muscle meat of fish.*

The concentration of cadmium (Cd) in fish muscle and capelin roe was very low as can be seen in Figure 9 and Table 3 in the Appendix; in fact no sample contained cadmium in concentrations above limits of detection.

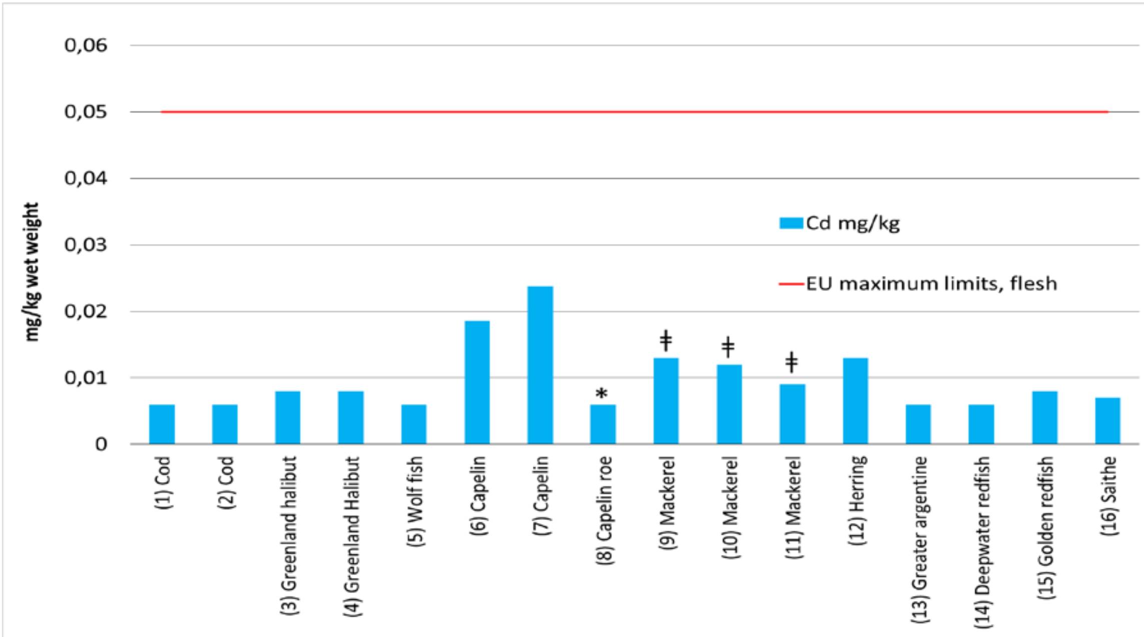

Figure 9: Cd in fish muscle and capelin roe from Icelandic fishing grounds in 2017 in mg/kg wet weight.
**EU maximum limit for Cd does not apply to capelin roe since it is set for muscle meat of fish.*
ǂEU maximum limit for cadmium in mackerel is set to 0.1 mg/kg wet weight.

No limits have yet been set for arsenic in foodstuffs, but results from the monitoring in 2017, which are shown in Figure 10 were in agreement with earlier measurements (Auðunsson, 2004, Ásmundsdóttir et al. 2005, Ásmundsdóttir and Gunnlaugsdóttir, 2006, Jörundsdóttir et al., 2009, Baldursdóttir, 2011). The highest level of As was found in wolf fish (sample 5) as seen in Figure 10. Although wolf fish was not analysed in 2012, results for other species are in accordance with results from 2012 (Jensen, et al. 2013) and contained arsenic below 10 mg/kg. The total arsenic concentration was measured in the samples, but not the concentration of the toxic form i.e. inorganic arsenic.

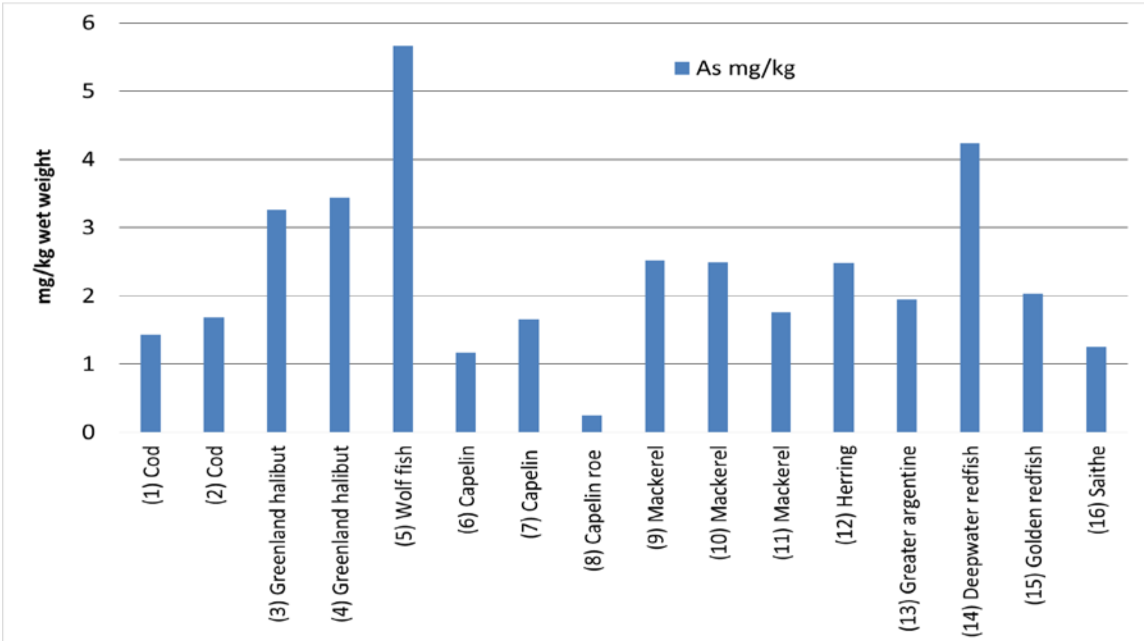

Figure 10: As in fish muscle and capelin roe from Icelandic fishing grounds in 2017 in mg/kg wet weight.

6 Acknowledgements

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Commission Regulation (EC) No 1881/2006 um hámarksgildi fyrir tiltekin aðskotaefni í matvælum, 19th of December 2006

Reglugerð Nr 265/2010 um gildistöku reglugerðar framkvæmdastjórnarinnar (EB) nr. 1881/2006 um hámarksgildi fyrir tiltekin aðskotaefni í matvælum.

8 Appendix

Table 1: Dioxins PCBs and PBDE in fish muscle and one roe sample 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
R17-1318-1	1	Cod	*Gadus morhua*	*N*	50-58	0,7	0,285	0,173	0,458	1,7	1,7
R17-1318-2	2	Cod	*Gadus morhua*	*N*	56-65	0,7	0,318	0,194	0,512	1,9	1,9
R17-1434-1	3	Greenland halibut	*Reinhardtius hippoglossoides*	*SA*	50-56	11	0,808	0,873	1,68	11	9,4
R17-1434-2	4	Greenland halibut	*Reinhardtius hippoglossoides*	*N*	42-68	11	0,587	0,654	1,24	5,4	4,7
R17-1450-1	5	Wolf fish	*Anarhichas lupus*	*S*	40-47	0,5	0,339	0,206	0,546	2,0	2,0
R17-1157-1	6	Capelin	*Mallotus villosus*	*SE*		8,5	0,388	0,243	0,631	2,0	1,8
R17-1157-2	7	Capelin	*Mallotus villosus*	*SE*		11	0,463	0,323	0,786	2,4	2,1
R17-1157-3	8	Capelin roe	*Mallotus villosus*	*NW*		5,2	0,336	0,204	0,540	2,0	2,0
R17-2146-1	9	Mackerel	*Scomber scombrus*	*SW*	33-41	29	0,361	0,288	0,648	2,6	2,3
R17-2303-1	10	Mackerel	*Scomber scombrus*	*SA*	35-47	23	0,318	0,301	0,619	2,7	2,5
R17-2303-3	11	Mackerel	*Scomber scombrus*	*S*	33-40	25	0,320	0,414	0,733	3,7	3,3
R17-2303-2	12	Herring	*Clupea harengus*	*SA*	32-38	10	0,443	0,398	0,841	5,8	5,0
R17-3141-1	13	Greater argentine	*Argentina silus*	*SW*	33-45	0,9	0,337	0,244	0,581	2,0	2,0
R17-3141-2	14	Deepwater redfish	*Sebastes mentella*	*NW*	43-48	1,5	0,269	0,213	0,483	2,7	2,4
R17-3141-3	15	Golden redfish	*Sebastes marinus*	*SW*	36-40	2,5	0,309	0,270	0,579	4,1	3,6
R17-3141-4	16	Saithe	*Pollachius virens*	*NW*	60-69	1,3	0,316	0,191	0,508	1,9	1,8
		EU maximum limits‡					3,50	*	6,50	*	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 mucle and one roe sample on wet weight

Sample code	Fish sample no.	Sample name	Latin name	Fishing ground	Size [cm]	Lipid content %	β-HCH µg/kg	α-HCH µg/kg	γ-HCH µg/kg	δ-HCH µg/kg	∑ DDT µg/kg	Pentachlor benzene µg/kg	HCB µg/kg	Σ Heptachlores µg/kg
R17-1318-1	1	Cod	*Gadus morhua*	*N*	50-58	0,7	<0,164	<0,164	<0,164	<0,164	0,47	<0,329	<0,349	0,361
R17-1318-2	2	Cod	*Gadus morhua*	*N*	56-65	0,7	<0,141	<0,141	<0,141	<0,141	0,40	<0,283	<0,283	0,311
R17-1434-1	3	Greenland halibut	*Reinhardtius hippoglossoides*	*SA*	50-56	11	<0,171	<0,171	<0,171	<0,171	12	<0,341	0,617	0,560
R17-1434-2	4	Greenland halibut	*Reinhardtius hippoglossoides*	*N*	42-68	11	<0,158	0,236	<0,158	<0,158	11	<0,316	2,68	0,750
R17-1450-1	5	Wolf fish	*Anarhichas lupus*	*S*	40-47	0,5	<0,167	<0,167	<0,167	<0,167	0,52	<0,335	<0,335	0,368
R17-1157-1	6	Capelin	*Mallotus villosus*	*SE*		8,5	<0,163	<0,163	<0,163	<0,163	3,2	<0,325	2,17	0,696
R17-1157-2	7	Capelin	*Mallotus villosus*	*SE*		11	<0,197	<0,197	<0,197	<0,197	3,4	<0,394	2,83	0,780
R17-1157-3	8	Capelin roe	*Mallotus villosus*	*NW*		5,2	<0,145	<0,145	<0,145	<0,145	1,2	<0,29	1,21	0,420
R17-2146-1	9	Mackerel	*Scomber scombrus*	*SA*	33-41	29	<0,154	0,201	<0,154	<0,154	3,0	<0,308	0,515	0,516
R17-2303-1	10	Mackerel	*Scomber scombrus*	*SA*	35-47	23	<0,431	0,479	<0,431	<0,431	6,7	<0,862	1,82	1,34
R17-2303-3	11	Mackerel	*Scomber scombrus*	*S*	33-40	25	<0,379	0,728	<0,379	<0,379	7,8	<0,758	1,81	1,38
R17-2303-2	12	Herring	*Clupea harengus*	*SA*	32-38	9,7	<0,532	<0,532	<0,532	<0,532	23	<1,06	3,52	1,63
R17-3141-1	13	Greater argentine	*Argentina silus*	*SW*	33-45	0,9	<0,174	<0,174	<0,174	<0,174	0,72	<0,348	<0,348	0,383
R17-3141-2	14	Deepwater redfish	*Sebastes mentella*	*NW*	43-48	1,5	<0,145	<0,145	<0,145	<0,145	4,2	<0,29	<0,290	0,319
R17-3141-3	15	Golden redfish	*Sebastes marinus*	*SW*	36-40	2,5	<0,163	<0,163	<0,163	<0,163	5,5	<0,325	<0,325	0,358
R17-3141-4	16	Saithe	*Pollachius virens*	*NW*	60-69	1,3	<0,162	<0,162	<0,162	<0,162	0,80	<0,324	<0,324	0,356

Table 2 (cont): Pesticides in fish muscle and one liver sample 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
R17-1318-1	1	Cod	*Gadus morhua*	*N*	50-58	0,7	0,184	1,3	<0,0329	<0,197	0,94	0,46	<0,0961	<0,0657
R17-1318-2	2	Cod	*Gadus morhua*	*N*	56-65	0,7	0,141	1,1	<0,0283	<0,174	0,74	0,40	0,0560	<0,0565
R17-1434-1	3	Greenland halibut	*Reinhardtius hippoglossoides*	*SA*	50-56	11	2,09	11	0,0962	0,482	0,89	2,3	2,55	0,123
R17-1434-2	4	Greenland halibut	*Reinhardtius hippoglossoides*	*N*	42-68	11	3,09	11	0,138	0,567	0,84	2,4	3,23	0,150
R17-1450-1	5	Wolf fish	*Anarhichas lupus*	*S*	40-47	0,5	0,167	1,3	<0,0335	<0,201	0,87	0,47	<0,109	<0,0669
R17-1157-1	6	Capelin	*Mallotus villosus*	*SE*		8,5	2,21	5,0	0,0527	<0,195	0,85	1,6	0,918	<0,0657
R17-1157-2	7	Capelin	*Mallotus villosus*	*SE*		11	2,76	5,5	0,0428	0,282	1,0	1,8	1,10	<0,0789
R17-1157-3	8	Capelin roe	*Mallotus villosus*	*NW*		5,2	0,984	1,9	<0,0290	<0,174	0,75	0,80	0,356	<0,0579
R17-2146-1	9	Mackerel	*Scomber scombrus*	*SW*	33-41	29	1,41	5,0	0,0332	0,285	0,80	0,97	0,697	<0,0616
R17-2303-1	10	Mackerel	*Scomber scombrus*	*SA*	35-47	23	3,14	9,3	<0,0862	<0,517	2,2	2,2	1,63	<0,172
R17-2303-3	11	Mackerel	*Scomber scombrus*	*S*	33-40	25	4,07	11	0,0894	0,617	2,0	2,4	1,74	<0,152
R17-2303-2	12	Herring	*Clupea harengus*	*SA*	32-38	10	4,54	31	0,493	<0,638	2,8	3,5	5,21	<0,270
R17-3141-1	13	Greater argentine	*Argentina silus*	*SW*	33-45	0,9	0,174	1,4	<0,0348	<0,209	0,90	0,49	0,0842	<0,0696
R17-3141-2	14	Deepwater redfish	*Sebastes mentella*	*NW*	43-48	1,5	0,266	2,4	<0,0290	<0,174	0,75	0,54	0,473	<0,0579
R17-3141-3	15	Golden redfish	*Sebastes marinus*	*SW*	36-40	2,5	0,341	3,2	<0,0325	<0,195	0,85	0,80	0,895	<0,0657
R17-3141-4	16	Saithe	*Pollachius virens*	*NW*	60-69	1,3	0,162	1,3	<0,0324	<0,194	0,84	1,0	0,108	<0,0648

Table 3: Trace elements in fish muscle and one roe sample in mg/kg wet weight

Sample code	Fish sample no.	Sample name	Latin name	Cr mg/kg	As mg/kg	Sn mg/kg	Cd mg/kg	Hg mg/kg	Pb mg/kg
R17-1318-1	1	Cod	*Gadus morhua*	0,03	1,4	<0,006	<0,006	0,03	<0,011
R17-1318-2	2	Cod	*Gadus morhua*	0,03	1,7	<0,006	<0,006	0,03	<0,012
R17-1434-1	3	Greenland halibut	*Reinhardtius hippoglossoides*	<0,04	3,3	<0,008	<0,008	0,08	<0,015
R17-1434-2	4	Greenland halibut	*Reinhardtius hippoglossoides*	<0,04	3,4	<0,008	<0,008	0,06	<0,016
R17-1450-1	5	Wolf fish	*Anarhichas lupus*	<0,03	5,7	<0,006	<0,006	0,07	<0,011
R17-1157-1	6	Capelin	*Mallotus villosus*	0,05	1,2	0,02	<0,007	0,01	<0,015
R17-1157-2	7	Capelin	*Mallotus villosus*	0,07	1,7	0,02	<0,008	0,01	<0,017
R17-1157-3	8	Capelin roe	*Mallotus villosus*	0,05	0,25	<0,006	<0,006	<0,006	<0,012
R17-2146-1	9	Mackerel	*Scomber scombrus*	<0,06	2,5	<0,01	<0,01	0,04	<0,025
R17-2303-1	10	Mackerel	*Scomber scombrus*	<0,06	2,5	<0,01	<0,01	0,03	<0,025
R17-2303-3	11	Mackerel	*Scomber scombrus*	0,05	1,8	<0,009	<0,009	0,09	<0,018
R17-2303-2	12	Herring	*Clupea harengus*	<0,06	2,5	<0,01	<0,01	0,04	<0,026
R17-3141-1	13	Greater argentine	*Argentina silus*	<0,05	1,9	<0,006	<0,006	0,07	<0,012
R17-3141-2	14	Deepwater redfish	*Sebastes mentella*	<0,03	4,2	<0,006	<0,006	0,3	<0,012
R17-3141-3	15	Golden redfish	*Sebastes marinus*	<0,03	2,0	<0,008	<0,008	0,3	<0,015
R17-3141-4	16	Saithe	*Pollachius virens*	<0,03	1,3	<0,006	<0,007	0,08	<0,013