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Undesirable substances in seafood products – results from the Icelandic marine monitoring activities in the year 2012

Sophie Jensen
Hrönn Ólína Jörundsdóttir
Natasa Desnica
Þuríður Ragnarsdóttir
Helga Gunnlaugsdóttir

Öryggi, umhverfi og erfðir

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Report summary

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Titill / Title	**Undesirable substances in seafood products – results from the Icelandic marine monitoring activities in the year 2012**		
Höfundar / Authors	Sophie Jensen, Hrönn Ólína Jörundsdóttir, Natasa Desnica, Þuríður Ragnarsdóttir, Helga Gunnlaugsdóttir		
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Ágrip á íslensku:	Í þessari skýrslu eru teknar saman niðurstöður vöktunar á óæskilegum efnum í sjávarfangi, fiskimjöli og lýsi fyrir fóður frá árinu 2012. Hámarksgildi ESB fyrir díoxín og díoxínlík PCB (DL-PCB) í matvælum og fóðri voru nýlega lækkuð 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. Vöktunin hófst árið 2003 fyrir tilstuðlan þáverandi Sjávarútvegsráðuneytis, núverandi Atvinnuvega- og nýsköpunar-ráðneytis, og hefur nú verið framkvæmt í tíu ár samfleytt. Verkefnið byggir upp þekkingargrunn um magn óæskilegra efna í efnahagslega mikilvægum tegundum og sjávarafurðum, það er skilgreint sem langtímaverkefni þar sem eftirlit og endurskoðun eru stöðugt nauðsynleg. Árið 2012 var áhersla lögð á að safna saman upplýsingum um lífrænu efnasamböndin PFC og ólífræn snefilefni í ætum hluta sjávarfangs, en einnig í fiskimjöli og lýsi fyrir fóður. Almennt voru niðurstöðurnar sem fengust 2012 í samræmi við fyrri niðurstöður frá árunum 2003 til 2011. Niðurstöðurnar sýndu að íslenskar sjávarafurðir innihalda óverulegt magn þrávirkra lífrænna efna s.s. díoxín, PCB, varnarefni og PBDE. Þetta var annað árið sem PFC eru greind í íslenskum sjávarafurðum og perfluorooctane sulfon amide (PFOSA) var eina PFC efnið sem var yfir greiningarmörkum, önnur PFC efni mældust ekki. Niðurstöðurnar frá árinu 2012 sýndu að þrátt fyrir breytingu á hámarksgildum fyrir díoxín, DL-PCB og NDL-PCB (ESB reglugerð nr. 1259/2011) eru öll sýni af sjávarafurðum til manneldis undir hámarksgildum ESB fyrir þrávirk lífræn efni og þungmálma. Þá reyndist styrkur viðmiðunar-PCB efna (marker PCBs) vera í lágmarki 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. Í mars 2012 tók gildi ESB reglugerð nr 277/2012 þar sem hámarksgildi fyrir díoxín og DL-PCB í fóðri voru lækkuð, en einnig voru sett hámarksgildi fyrir NDL-PCB. Þrátt fyrir þessa breytingu voru öll sýni af fiskimjöli og lýsi fyrir fóður sem voru mæld undir hámarksgildum, fyrir utan eitt kolmunnamjölssýni sem innihélt toxafen yfir hámarksgildum ESB.		
Lykilorð á íslensku:	*Sjávarfang, vöktun, Díoxín, díoxínlík PCB, PCB, varnarefni, PFC, PBDEs, þungmálmar*		

Skýrsluágrip Matís ohf
Icelandic Food and Biotech R&D

Report summary

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Summary in English:	This report summarises the results obtained in 2012 for the screening of various undesirable substances in the edible part of marine catches, fish meal and fish oil for feed. The newly established maximum levels for dioxins, dioxin-like PCB and non dioxin-like PCB in foodstuffs and animal feed are used to evaluate how Icelandic seafood products measure up to EC limits currently in effect. The surveillance program began in 2003 and has now been carried out for ten consecutive years. The project fills in gaps of knowledge regarding the level of undesirable substances in economically important marine catches for Icelandic export. It is considered to be a long-term project where extension and revision are constantly necessary. In the year 2012 emphasis was laid on gathering information on the organic compounds PFCs and inorganic trace elements in the edible part of marine catches as well as in the fish meal and fish oil for feed. Generally, the results obtained in 2012 are in agreement with previous results from the years 2003 to 2011. The results show that the Icelandic seafood products contain negligible amounts of persistent organic pollutants (POPs) such as dioxins, dioxin like PCBs, pesticides and PBDEs. This is the second time PFCs are analysed in Icelandic seafood and fish products and the results show that the main PFC compound, perfluorooctane sulfone amide (PFOSA) was the only congener detected. The results obtained in the year 2012 reveal that despite of the recent change by the EC in maximum levels for dioxins, dioxin-like PCB and non dioxin-like PCB in foodstuffs, all samples of seafood for human consumption were below EC maximum levels for POPs and heavy metals. Furthermore, the concentration of marker 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. In March 2012 Commission Regulation No 277/2012, regarding maximum levels for dioxins and PCB in animal feed came into effect and after the implementation of this regulation maximum levels are now also set for non dioxin-like PCB. Despite of this change all samples of fish meal and fish oil for feed measured were below the EC maximum limits for feed components of marine origin except for one blue whiting meal sample that exceeds the maximum limits for toxaphene.
English keywords:	*Marine catches, monitoring, dioxin, PCB, pesticides, PFC, PBDEs, heavy metals*

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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. Matis was assigned the responsibility of carrying out the surveillance programme, which has now been on-going for ten consecutive years. The goal of the surveillance programme is to gather information and evaluate the status of Icelandic seafood products regarding undesirable substances and is funded by the Ministry of Industries and Innovation in Iceland. The project includes measurements on various undesirable substances in a number of economically important marine species from Icelandic fishing grounds in order to gather information for Icelandic export. This report summarises results from the screening programme in the year 2012 with special emphasis on poly- and perfluorinated compounds (PFC), where limited knowledge is available on levels and distribution of these compounds in the Icelandic marine environment. This is the second time that PFCs are included in the present screening program. The substances investigated in this monitoring project are: poly- and perfluorinated compounds, polychlorinated dibenzo dioxins and dibenzo furans (commonly called dioxins), dioxin-like polychlorinated biphenyls (PCBs), marker PCBs, polybrominated flame retardants (PBDEs), 30 pesticides and breakdown products (i.e. HCB, DDTs, HCHs, dieldrin, endrin, chlordanes, toxaphenes and endosulfan substances), PFCs 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 (Regulation (EC) No 1881/2006, Commission Regulation (EC) No 629/2008, Commission Directive 2002/32/EC, Commission Directive 2003/100/EC and their amendments).
C) To utilise the data gathered in the programme for a risk assessment and the setting of maximum values that are now under consideration within EU e.g. for PAHs, PCBs, inorganic arsenic and brominated flame retardants, etc.
D) Provide independent scientific data on undesirable substances in Icelandic seafood for food authorities, fisheries authorities, industry, markets and consumers.

This report summarises results from the screening programme in the year 2012. In this annual report the newly established maximum levels for dioxins, dioxin-like PCB and non dioxin-like PCB in foodstuffs and animal feed are used to evaluate how Icelandic seafood products measure up to EC limits currently in effect. The results obtained in the years 2003 to 2011 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). The above mentioned EU regulations have now been implemented in the Icelandic legal framework regarding undesirable substances in food and feed (Reglugerð 265/2010).

2 Summary

This report summarises the results obtained in 2012 for the screening of various undesirable substances in the edible part of marine catches, fish meal and fish oil for feed. The surveillance program began in 2003 and has now been carried out for ten consecutive years. The project fills in gaps of knowledge regarding the level of undesirable substances in economically important marine catches for Icelandic export. It is considered to be a long-term project where extension and revision is constantly necessary.

In the year 2012 emphasis was laid on gathering information on the organic compounds PFCs and inorganic trace elements in the edible part of marine catches as well as in the fish meal and fish oil for feed. Generally, the results obtained in 2012 are in agreement with previous results on undesirable substances in the edible part of marine catches, fish meal and fish oil for feed obtained in the monitoring years 2003 to 2011. 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. The results for PBDEs reveal that these compounds are also in very low amounts in fish and fish products. This is the second time PFCs are analysed in Icelandic seafood and fish products and the results show that the main PFC compound, perfluorooctane sulfone amide (PFOSA) was the only congener detected; all other congeners (11 in total) were under limit of detection (LOD). As of January 1st 2012 Commission Regulation No 1259/2011, regarding maximum levels for dioxins, dioxin-like PCB and non dioxin-like PCB 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 PCB for many food products due to changes in toxicological assessment of dioxins. Furthermore, maximum levels for non dioxin-like PCB have now established in foodstuffs for the first time. In this annual report from the surveillance programme we use these newly established maximum levels for dioxins, dioxin-like PCB and non dioxin-like PCB in foodstuffs to evaluate how Icelandic seafood products measure up to limits currently in

effect. The results obtained year 2012 reveal that despite of this change in the maximum levels all samples of seafood for human consumption were below EC maximum levels for POPs and heavy metals. Furthermore, the concentration of marker 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.

The samples of fish meal and fish oil for feed measured are subjected to different maximum limits by the EC. In March 2012 Commission Regulation No 277/2012, regarding maximum levels for dioxins and PCB in animal feed came into effect and after the implementation of this regulation maximum levels are now also set for non dioxin-like PCB. Despite of this change all samples of fish meal and fish oil for feed measured were below the EC maximum limits for feed components of marine origin except for one blue whiting meal sample that exceeds the maximum limits for toxaphene.

3 Contaminants measured in the project

The following contaminants are measured in edible parts of seafood and fish oil for human consumption, as well as in fish meal and fish oils used as feed ingredients:

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).

Marker- PCB (7 congeners):
CB-28, CB-52, CB-101, CB-118, 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).

PBDEs (10 congeners):
BDE-28, BDE-47, BDE-66, BDE-100, BDE-99, BDE-85, BDE-154, BDE-153, BDE-183, BDE-209.

Inorganic trace elements:
Hg (mercury), Cd (cadmium), Pb (lead), total As (organic and inorganic arsenic), chromium (Cr), iron (Fe), copper (Cu), zinc (Zn) and selenium (Se).

PFCs (11 congeners):
Perfluorobutane sulfonat (PFBS), Perfluorodecanoate (PFDA), Perfluorodecane sulfonate (PFDS), Perfluorododecanate (PFDoA), Perfluoroheptanoate (PFHpA), Perfluorohexanoate (PFHxA), Perfluorohexane sulfonate (PFHxS), Perfluorononaoate (PFNA) Perfluoroctanoate (PFOA), Perfluoroctane sulphonamide (PFOSA), Perfluoroctane sulfonate (PFOS).

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 Directive 2001/22/EC, Commission directive 2002/69/EC). Fish samples were collected by the Marine Research Institute (MRI) in Iceland. Fish meal and fish oil were gathered by collaborating partners in the industry.

4.1.1 Seafood

Every analysis was done on the edible parts of the seafood products as well as some fish organs (lumpfish skin and liver). The fish was collected from the fishing grounds of Iceland andthey are divided into five areas, as illustrated in
Figure 1. All samples were identified with the location of the fishing area. Each seafood sample consisted of a pooled sample from the entire edible part (e.g. skinless fish fillet) from at least ten individuals of a specific length distribution. The liver sample consisted of a pooled sample from 10 individuals.

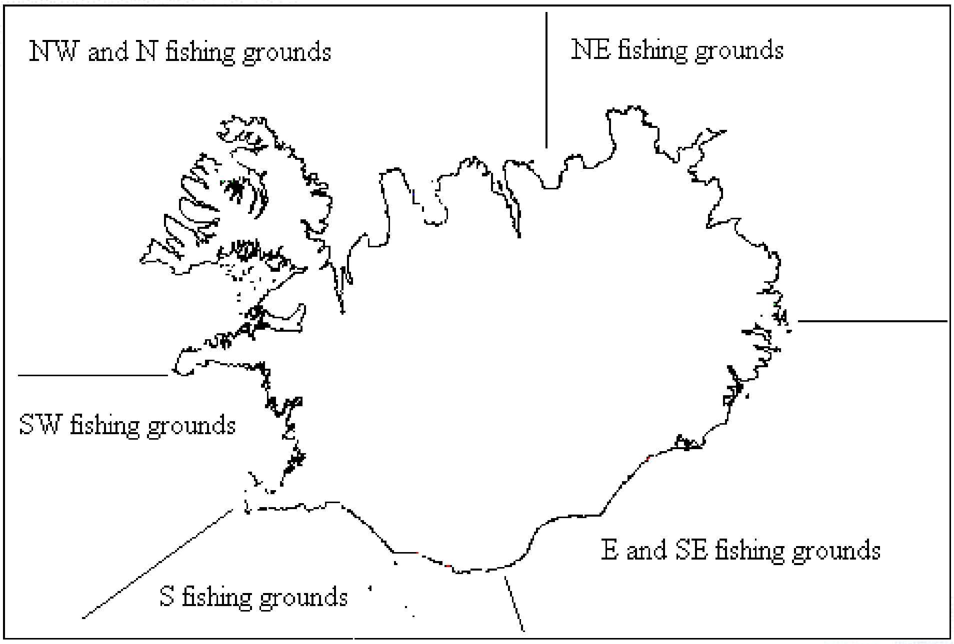

Figure 1: The division of the fishing grounds around Iceland used in this research.

4.1.2 Fish meal and fish oil for feed

The fish meal and fish oil samples were taken at the production sites and, when possible, sampling was distributed over the year. When possible, the fish meal and fish oil samples originated from the same batch.

4.2 Analysis

The 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, marker-PCBs, pesticides and PBDEs.

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 amended in the current EU legislation i.e. Commission Regulation (EU) No 1259/2011 for foodstuffs and Commission Regulation (EU) No 277/2012 for animal feed.

5 Results of monitoring of fish and seafood products in Iceland

All results of the monitoring program in 2012 are listed in Tables 1-12 in the Appendix.

5.1 Dioxins (PCDD/Fs) and dioxin like PCBs

5.1.1 Dioxins and dioxin like PCBs in seafood

All the fish species measured are far below the limits set by EU for the sum of dioxins and dioxin like PCBs (Figure 2 and Table 1 in the Appendix) as well as non-dioxin like PCBs. 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 (sample no. 10), contain more dioxins and dioxin like PCBs than species which accumulate fat in the liver and thus have almost no fat in the muscle. Lumpfish and lumpfish liver also have higher lipid content (17 and 21%, respectively) and have therefore higher levels of dioxins and dioxin-like PCBs. 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 (length) and habitat. Greenland halibut can become quite old, which probably contributes considerably to the high dioxins and dioxin-like PCBs values obtained for this species (Figure 2).

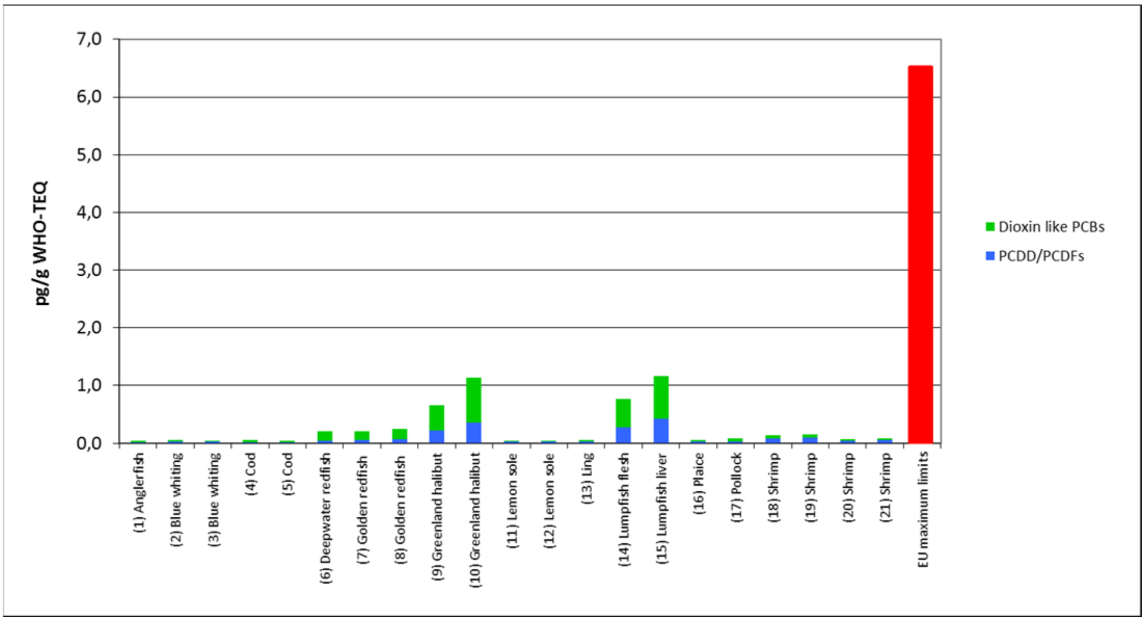

Figure 2: Dioxins and dioxin-like PCBs in the edible part of fish muscle from Icelandic fishing grounds in 2012 in relation to maximum EU limit in WHO-TEQ pg/g wet weight. The number within parenthesis is the sample number indicated in Table 1.

5.1.2 Dioxins and dioxin like PCBs in fish oil for human consumption

There were no samples of fish oil for human consumption analysed or collected from the fish oil industry this year. Earlier results from 2005 and 2006 showed concentrations below the EU maximum limit (Ásmundsdóttir and Gunnlaugsdóttir, 2006, Ásmundsdóttir et al., 2008, Regulation (EC) No 1881/2006).

5.1.3 Dioxins and dioxin like PCBs in fish meal and fish oil for feed

Samples of fish meal and fish oil for feed are taken annually. The samples taken in the year 2012 consisted of capelin and herring meal and corresponding capelin and herring oil, as well as one blue whiting meal sample. Concentrations of dioxins and dioxin like PCBs are shown in Tables 2 and 3 in the Appendix. The EU maximum limits for dioxins and dioxin-like PCBs in fish meal and fish oil for feed are set relatively low in order to prevent the accumulation of these toxic substances in the food chain (Commission Directive 2006/13/EC Commission Regulation No 277/2012). For this reason, results for these products are closer to the maximum limits than in the edible part of the fish muscle discussed in chapter 5.1.1.

The sum of dioxins and dioxin-like PCBs was lower than the EU maximum limit in all fish meals tested (Figure 3). The same was observed for the fish oil (Figure 4).

All fish oil samples measured in this study can be paired with specific fish meal samples, i.e. fish oil and meal samples were obtained from the same original raw material and samples of the oil and meal were taken during production of this raw material. The fish oil samples correspond to the fish meal sample with the same number.

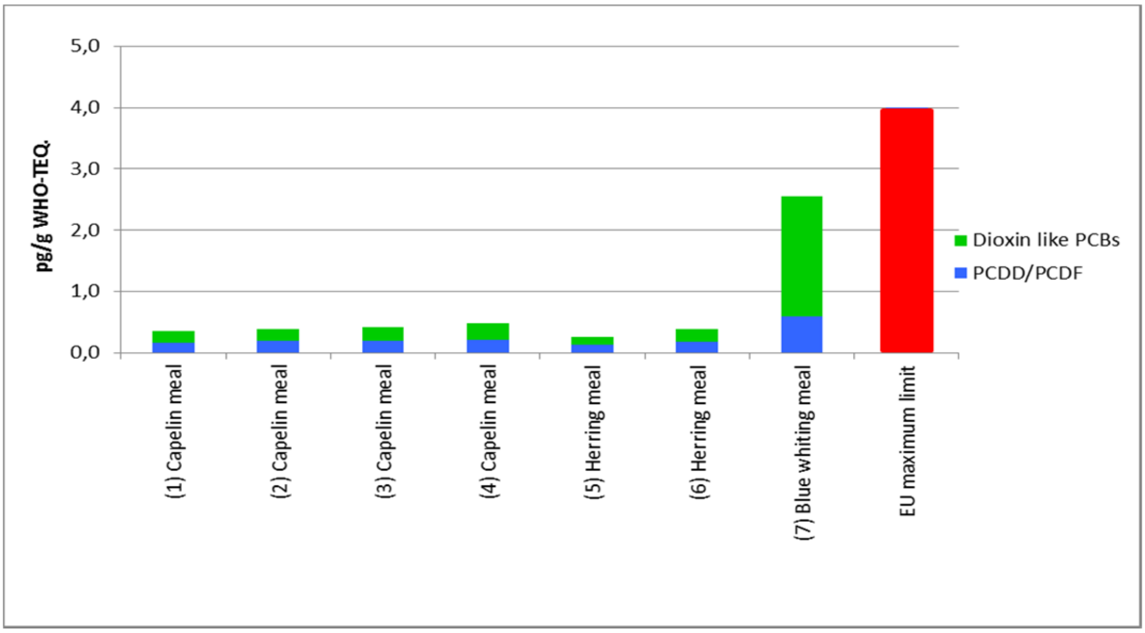

Figure 3: Dioxins and dioxin-like PCBs (in pg/g WHO-TEQ) in samples of fish meal from Iceland 2012 calculated in relation to 12% moisture compared to the EU maximum limit.

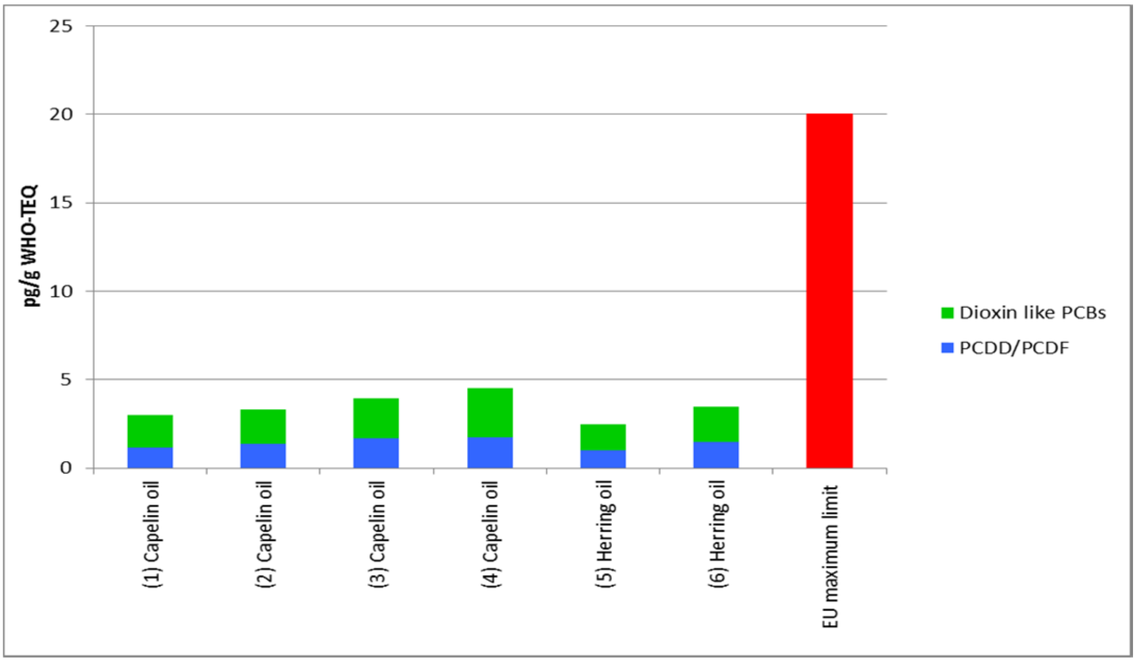

Figure 4: Dioxins and dioxin-like PCBs in samples of fish oil for feed from Iceland in 2012 (in pg/g WHO-TEQ) compared to the EU maximum limit.

5.2 Marker PCBs

Marker PCBs, sometimes called “Dutch seven” or ICES7, are seven PCBs that have been measured for many years as an indication of the total PCB contamination. Nevertheless, the EU maximum limits are set for the sum concentration of ICES6, i.e. only 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 Tables 1-3 in the Appendix and all Figures related to marker PCBs, while the ICES6 maximum limits are presented to evaluate how seafood products measure up to limits.

5.2.1 Marker PCBs in seafood

The results obtained for the majority of the Icelandic fish species are well below the recently established maximum limits set for non dioxin-like PCBs ICES 6 mentioned above. In this study, the highest total concentration for the sum of all seven marker PCBs was measured in Greenland halibut (sample no. 10, Figure 5), a total of 6.7 µg/kg wet weight, the highest individual PCB congener measured in the halibut was PCB-153 with 1.9 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 fillet. Apart from the edible part of the fish, lumpfish liver contained high concentration of marker PCBs, or 6.8 µg/kg wet weight and the reason is most likely due to the high lipid content of the liver. For details, see Table 1 in the Appendix.

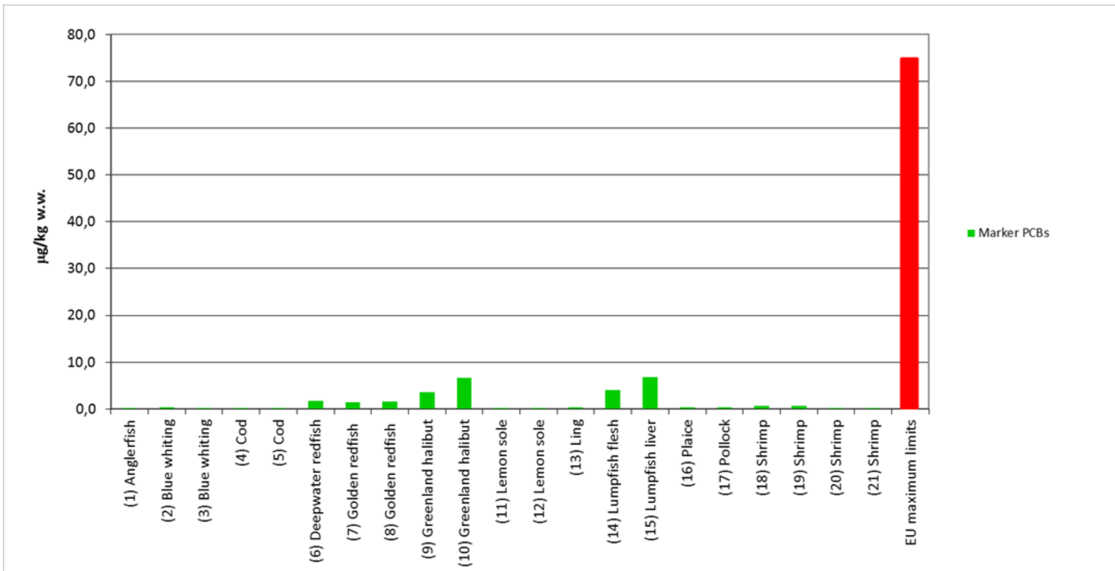

Figure 5: Marker PCBs in the edible part of fish muscle from Iceland in 2012 (in µg/kg wet weight). Number in parenthesis is the sample number designated to each sample, see Table 1 in Appendix.

5.2.2 Marker PCBs in fish oil for human consumption

There were no samples of fish oil for human consumption analysed this year. Earlier results from 2005 and 2006 were reported in previous reports from the Icelandic surveillance program (Ásmundsdóttir and Gunnlaugsdóttir, 2006, Ásmundsdóttir et al., 2008).

5.2.3 Marker PCBs in fish meal and fish oil for feed

The results for the marker PCBs in fish meal and fish oil samples measured in this study are shown in Tables 2 and 3 in the Appendix and in Figure 6 and Figure 7 below. After the implementation of Commission Regulation No 277/2012 maximum levels for non dioxin-like PCBs i.e. ICES6 in animal feed were enforced and our results show that all meal and fish oil samples measured this year are below these limits. The same patterns that are seen in different capelin meal samples are observed in the corresponding capelin oil.

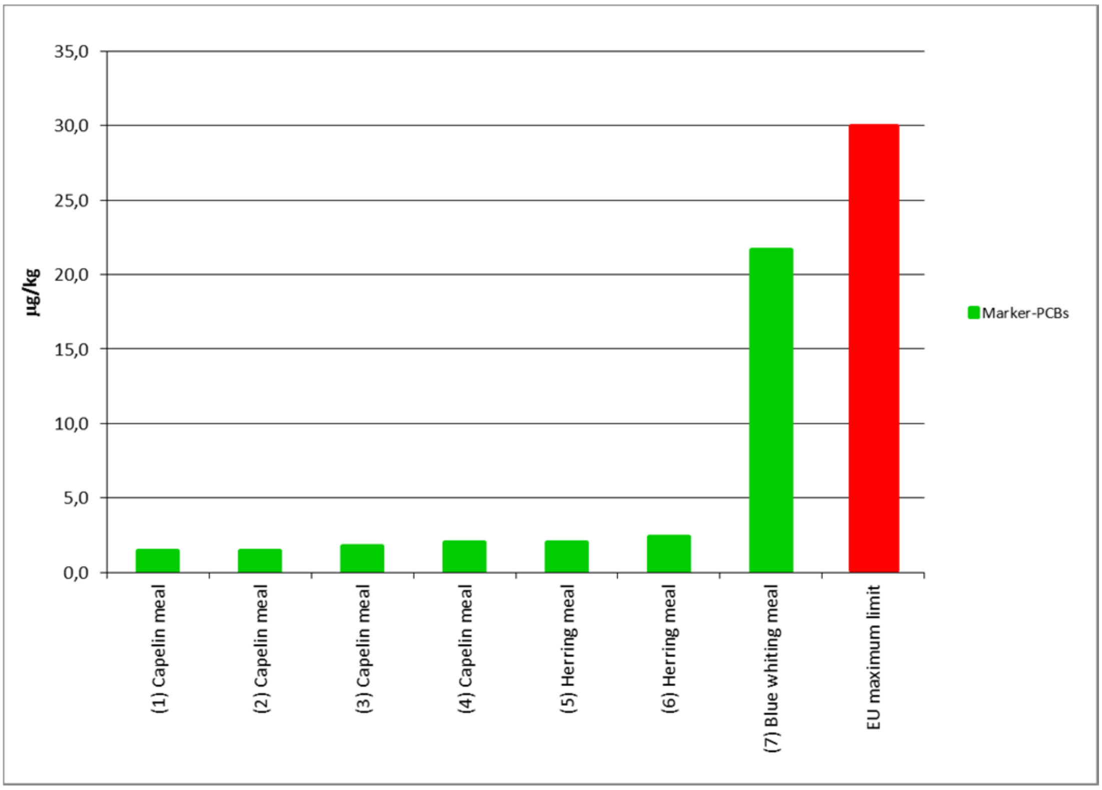

Figure 6: Marker PCBs in fish meal from Iceland in 2012 calculated in relation to 12% moisture compared to the EU maximum limit for ICES6

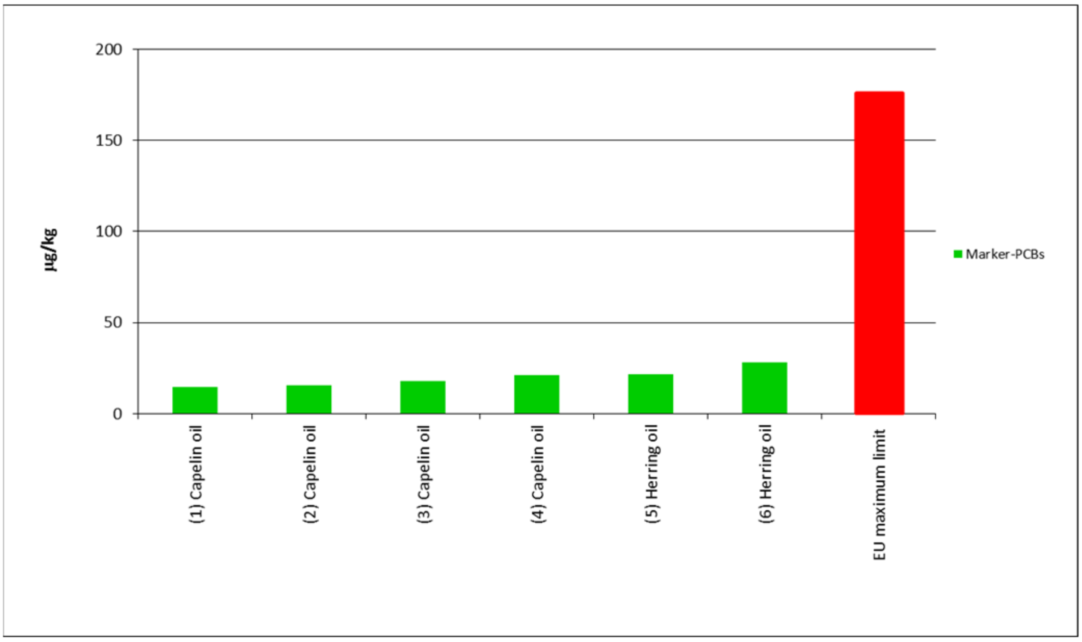

Figure 7: Marker PCBs in fish oils from Iceland in 2012 compared to the EU maximum limit for ICES6.

5.3 Brominated flame retardants (BFRs)

Brominated flame retardants (BFRs) have been accumulating in the environment over the last decade as their use in industry has increased. One group of BFRs is Polybrominated dipheynyl ethers (PBDEs). No maximum limits have yet been set in the EU, but they have been estimated to be ten times less toxic than the pesticide DDT (Scientific Advisory Committee on Nutrition (SACN, 2005). There were three major PBDE products (PentaBDE, OctaBDE and DecaBDE) available on the global market and two of them, PentaBDE and OctaBDE, have been banned in the EU and all use of PBDEs has been restricted by the RoHS directive (Restriction of the use of certain Hazardous substances in electrical and electronic equipment).

5.3.1 PBDE in seafood

There is still limited data available on PBDEs in seafood from Iceland (Ásmundsdóttir et al., 2008; Rabieh et al., 2008, Jörundsdóttir et al., 2010 a, Jörundsdóttir *et al.*, 2010b). Therefore a special emphasis was laid on gathering information on PBDE in 2009, 2010 and again in 2011. In 2012 PBDEs were measured in 9 samples of fish muscle. The PBDEs are reported here as the upper bound sum of BDE-28, BDE-47, BDE-66, BDE-100, BDE-99, BDE-85, BDE-154, BDE-153 and BDE-183. BDE-209 is not included in the sum as it was not detected in any sample. No maximum limits have been set for PBDEs in seafood.

The results in Figure 8 show generally very low levels of PBDEs in fish muscle from Icelandic fishing grounds except for the species that accumulate fat in the muscle, like the Greenland halibut. The results are reported in detail in Table 1 in the Appendix.

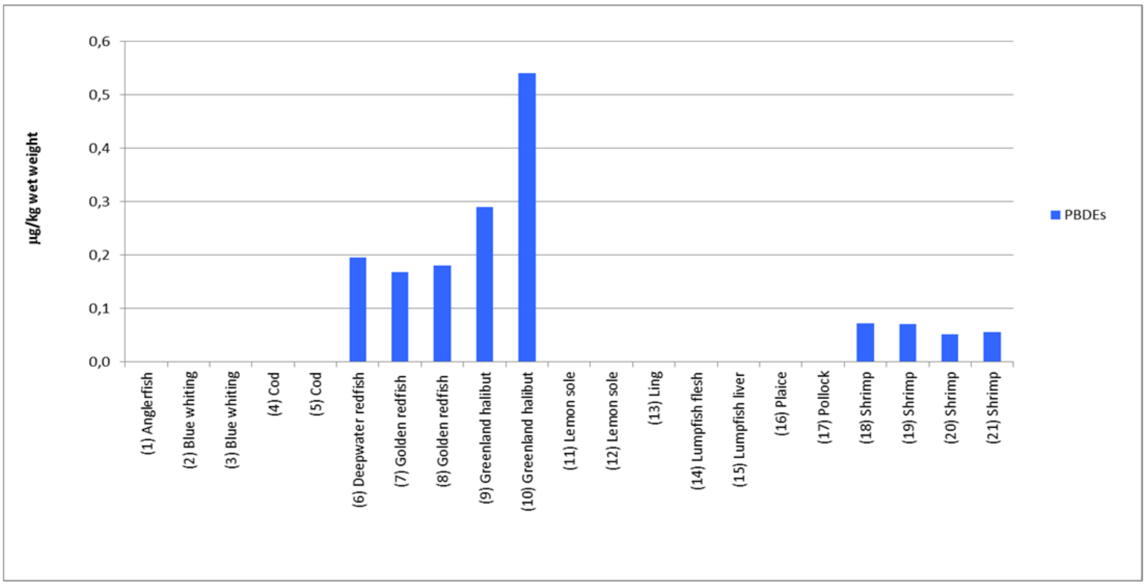

Figure 8: PBDE in fish muscle from Icelandic fishing ground in 2012 in µg/kg wet weight sum of: BDE-28, BDE-47, BDE-66, BDE-100, BDE-99, BDE-85, BDE-154, BDE-153 and BDE-183. PBDEs were not analysed in samples 1-5 and 11-17.

5.3.2 PBDEs in fish oil and fish meal for feed

PBDEs were only analysed in the herring meal and oil where the sum concentration is 0.39 and 0.58 µg/kg calculated for 12% moisture in the meal samples and 3.1 and 3.5 µg/kg in the oil samples, see further Table 2 and 3 in the Appendix. PBDE presented is the upper bound sum of BDE-28, BDE-47, BDE-66, BDE-100, BDE-99, BDE-85, BDE-154, BDE-153 and BDE-183. BDE-209 is not included in the sum as it was not detected in any sample.

5.4 PAH

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).

5.5 Pesticides

In this chapter, the results for 12 different classes of pesticides are discussed. Results are shown in Tables 4 to 6 in the Appendix. Without exception, the fish muscle samples contained negligible amount of pesticides (Regulation (EC) No 396/2005). All samples of seafood contained pesticides below the EU maximum limits (Commission Directive 2002/32/EC, Commission Directive 2003/100/EC).

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 α-chlordane, γ-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 α-endusulfan, β-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 show very low concentrations of all pesticide groups measured in fish muscle from Icelandic waters (see Table 4 in the Appendix). As mentioned before, the results are expressed as upper bond, but most of the pesticides were below the limit of detection and therefore the results presented are likely to be an overestimation. Negligible amounts of ΣDDT, Pentachlorobenzene, HCB, Heptachlores, Aldrin/Dieldrin, Toxaphene, Chlordane and *trans*-Nonachlore were measured in almost all fish species and δ-HCH was always below LOQ. Figure 9 shows the level of total DDT in fish muscle. All fish samples have ΣDDT concentration lower than the EU maximum limit of 500 µg/kg w.w. Of the fish species analysed, Greenland halibut and lumpfish have the highest concentrations of all the pesticides investigated.

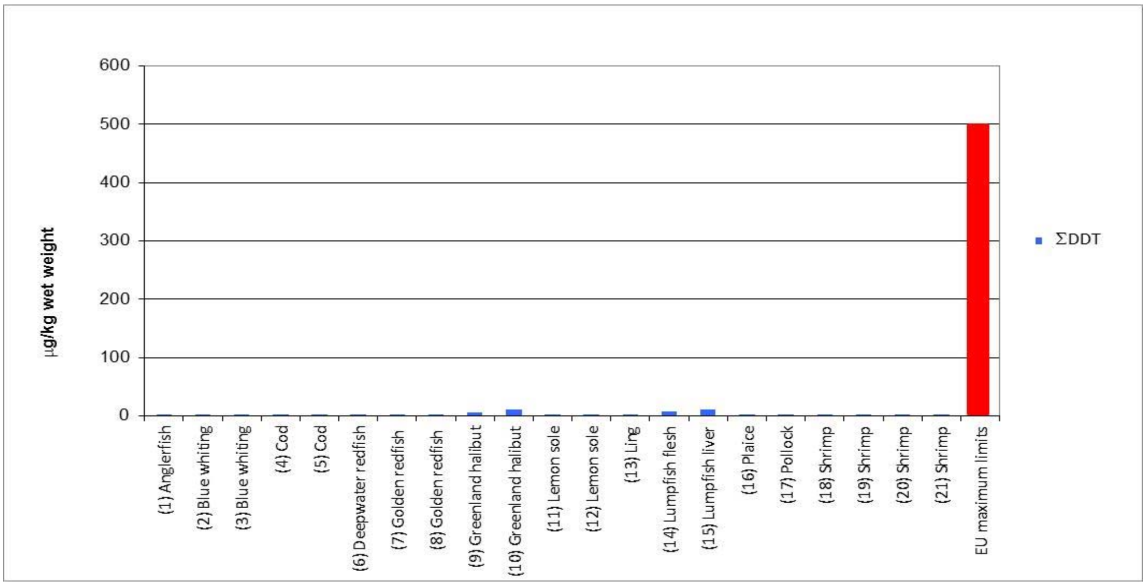

Figure 9: ΣDDT in fish muscle and one liver from Icelandic fishing grounds in 2012 in µg/kg wet weight.

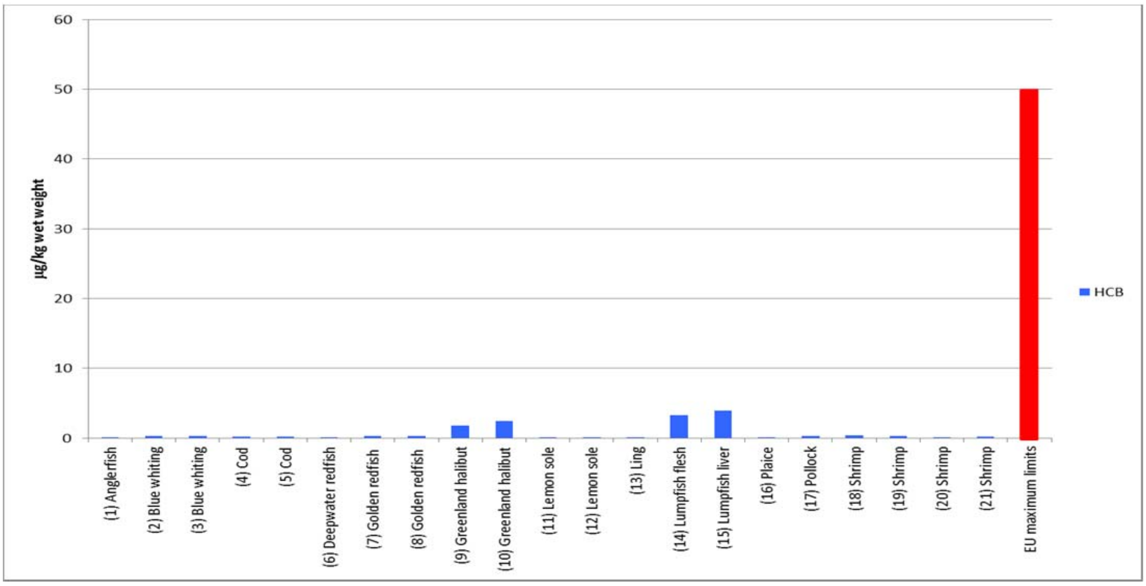

Figure 10: HCB in fish muscle and one liver from Icelandic fishing grounds in 2011 in µg/kg wet weight.

5.5.2 Pesticides in fish oil for human consumption

There were no samples of fish oil for human consumption analysed in the monitoring program in the year 2012.

5.5.3 Pesticides in fish meal and fish oil for feed

Several pesticides were measured in fish meal and fish oil for feed (see Tables 5 and Table 6 in the Appendix). There is some variation in the pesticide concentration in different capelin meal and herring meal samples and the pesticide concentration is generally lower than in the blue whiting meal sample. No blue whiting oil sample was analysed, but similar variation is seen in the pesticide concentration in different capelin oil and herring oil samples. No meal or oil samples exceed the maximum allowed pesticide level according to EU regulations except for toxaphene in blue whiting meal as seen in Figure 13.

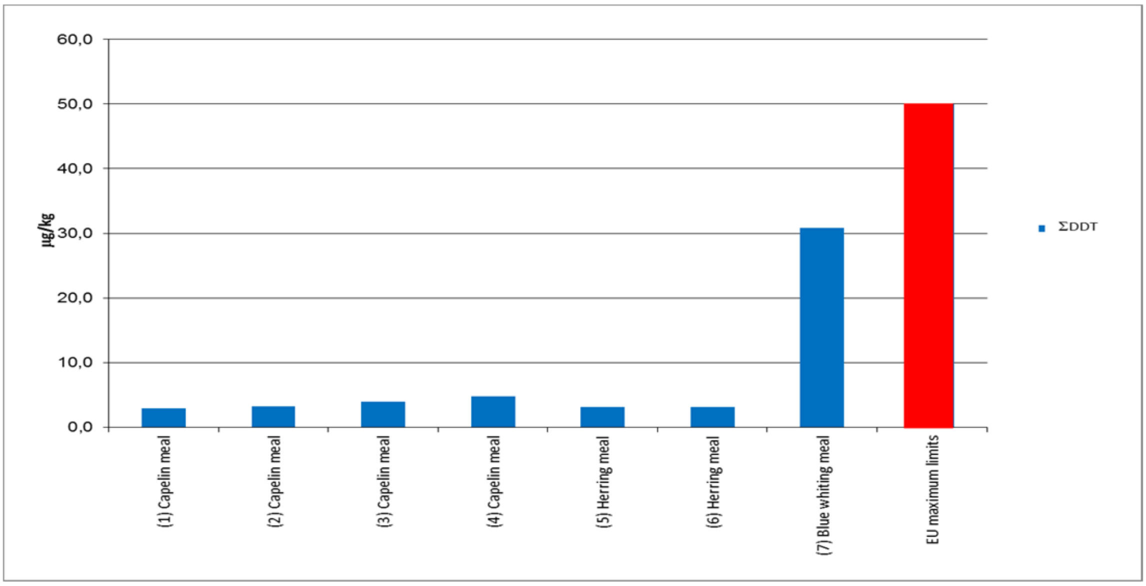

Figure 11: ΣDDT in samples of fish meal from Iceland 2012 calculated in relation to 12% moisture compared to the EU maximum limit.

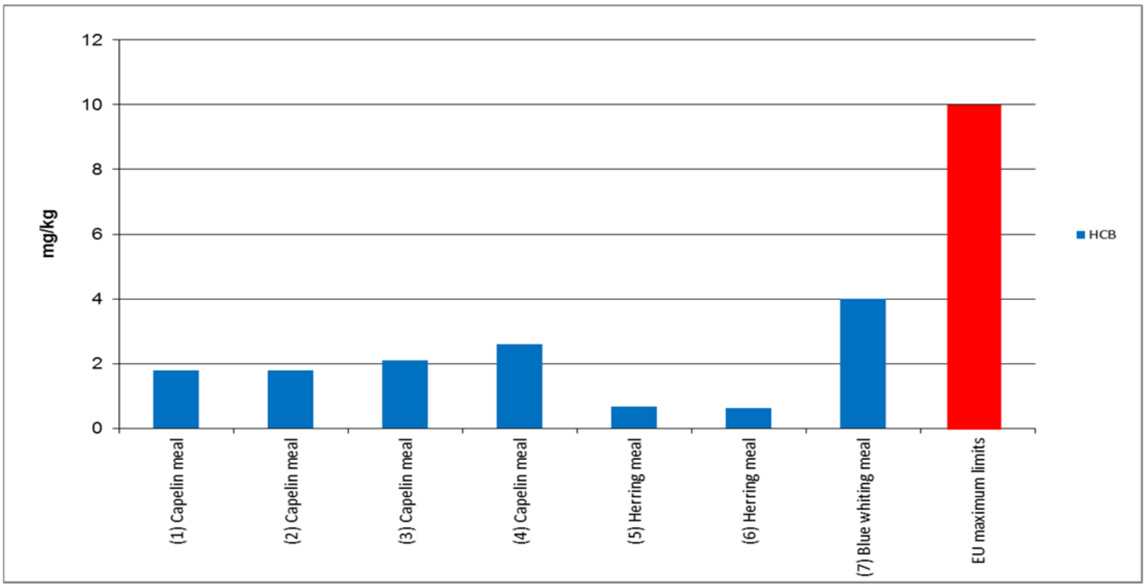

Figure 12: HCB in samples of fish meal from Iceland 2012 calculated in relation to 12% moisture compared to the EU maximum limit.

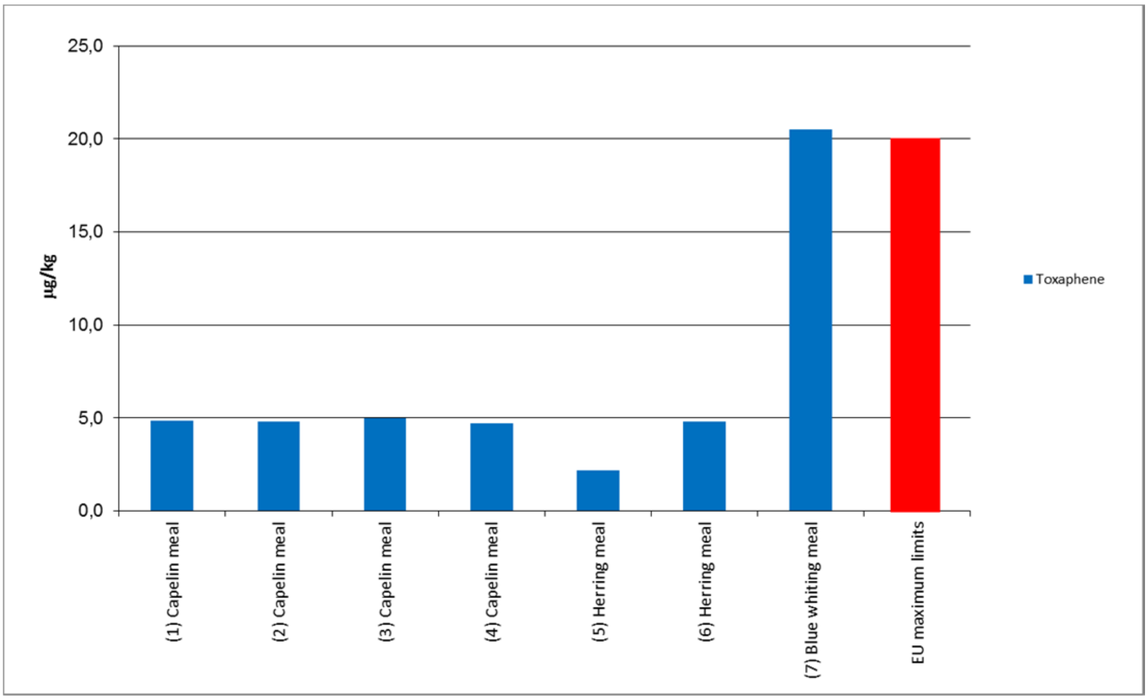

Figure 13: Toxaphene in samples of fish meal from Iceland 2012 calculated in relation to 12% moisture compared to the EU maximum limit.

Concentrations of pesticides in fish oil were below EU maximum limits in all cases (Commission Directive 2006/77/EC, Table 8 in Appendix).

5.6 *Inorganic trace elements*

Inorganic trace elements were analysed in all (except the lumpfish samples and one capelin oil sample) samples from the year 2012. The following inorganic trace elements were analysed: Hg (mercury), Cd (cadmium), Pb (lead), As (arsenic), Se (selenium), Zn (zinc), Cu (copper) and Fe (iron). Some of the elements like Se, Zn, Cu and Fe are essential minerals and thus do not fall into the category undesirable substances, however, the ICP-MS technology used to measure the trace elements enables us to measure these elements as well for relatively little extra cost. Therefore, all the previously mentioned trace elements are reported in Table 7-9 in the Appendix.

5.6.1 Inorganic trace elements in seafood

In short, the concentration of heavy metals like 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 1881/2006, Commission Regulation (EC) No 629/2008). The concentration of mercury (Hg) in the fish samples is shown in Figure 14.

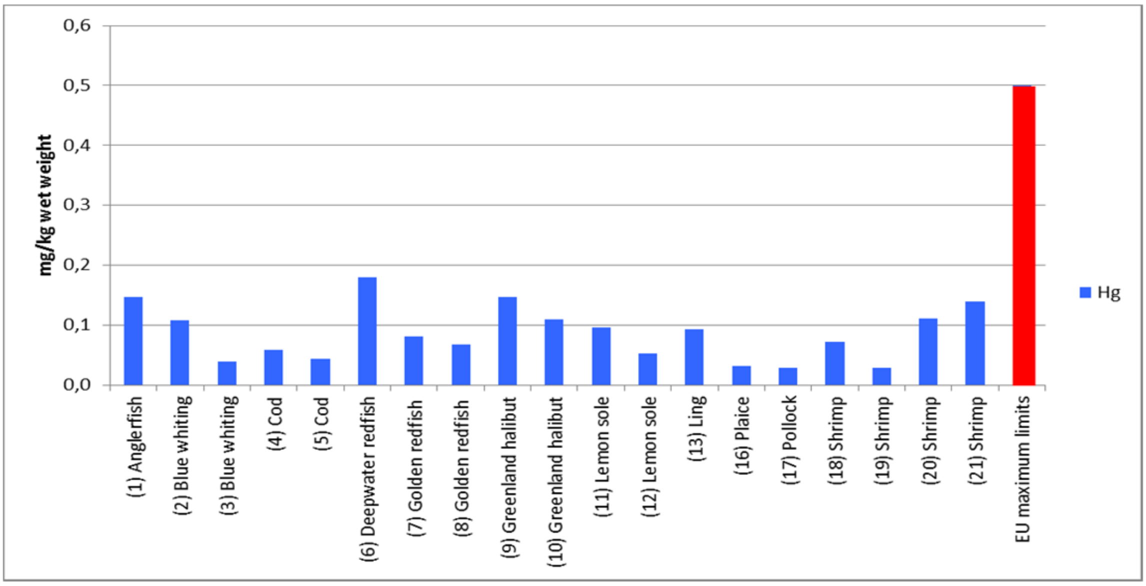

Figure 14: Hg in fish muscle from Icelandic fishing grounds in 2012 in mg/kg wet weight.

The concentration of lead (Pb) in fish muscle was very low as can be seen in Table 7 in the Appendix; in fact no sample contained lead in concentrations above limits of detection. No limits have yet been set for arsenic, but results from the monitoring in 2012, which are shown in Figure 15 were in agreement with earlier measurements (Auðunsson, 2004, Ásmundsdóttir et al. 2005, Ásmundsdóttir and Gunnlaugsdóttir, 2006, Jörundsdóttir et al., 2009, Baldursdóttir, 2011). High levels of As was found in lemon sole (sample 11 and 12) as seen in Figure 15. This is in accordance with results from 2007 (Jörundsdóttir et al. 2009). Arsenic in shrimps ranged between 12 and 29 mg/kg w.w. Other fish species contained of arsenic well below 25 mg/kg. The total arsenic concentration was measured in the samples, but not the concentration of the toxic form i.e. inorganic arsenic.

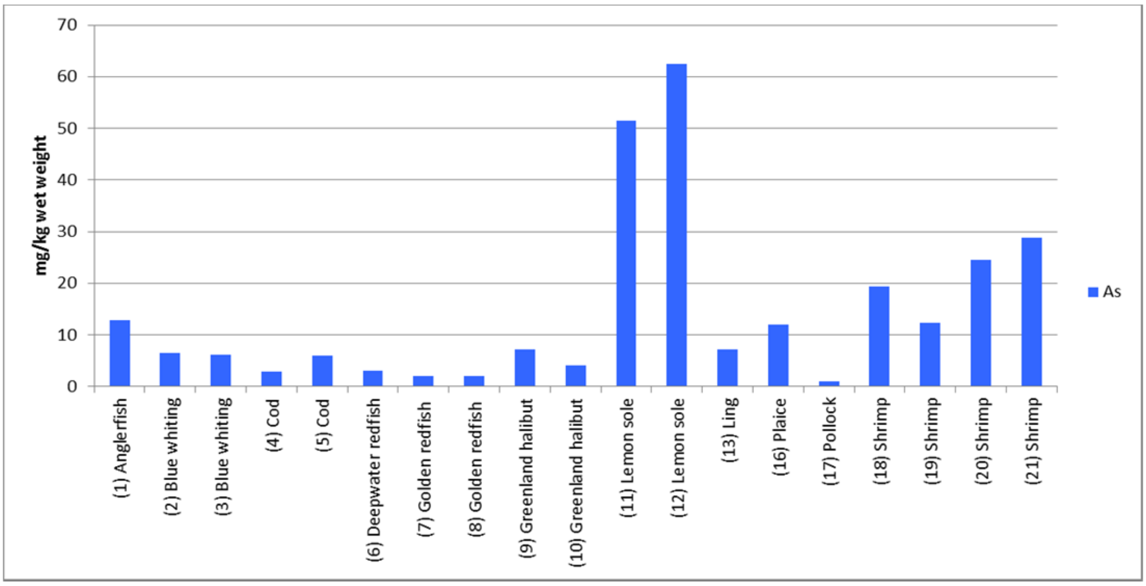

Figure 15: As in fish muscle from Icelandic fishing grounds in 2012 in mg/kg wet weight.

5.6.2 Inorganic trace elements in fish oil and fish meal

Inorganic trace elements were analysed in fish oil and fish meal for feed as shown in Table 8 and 9 in the Appendix. Both undesirable and essential metals as well as metalloids were analysed. Maximum limits exist for arsenic, cadmium, mercury and lead in fish meal and oil for feed (Directive 2002/32/EC, Commission Directive 2003/100/EC, Commission Directive 2005/87/EC, Commission Directive 2009/141/EC). Levels of these metals were lower than the maximum limit in all cases both in meal and oil samples (Figure 16 and Figure 17).

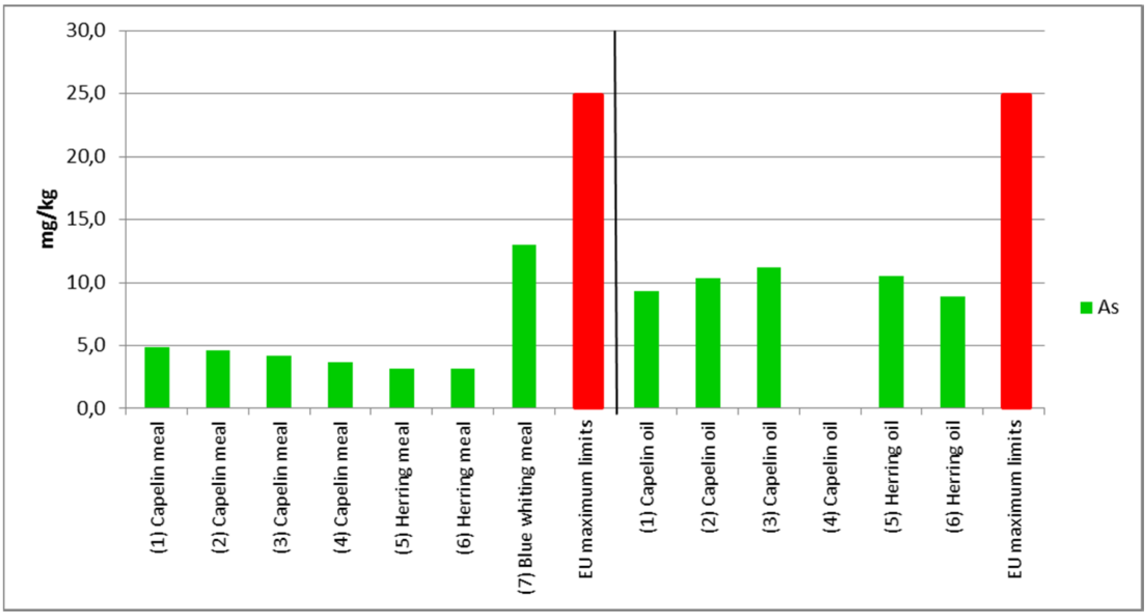

Figure 16: As in fish meal and oil from Icelandic fishing grounds in 2012 in mg/kg wet weight (i.e. meal measured as received from industrial partner).

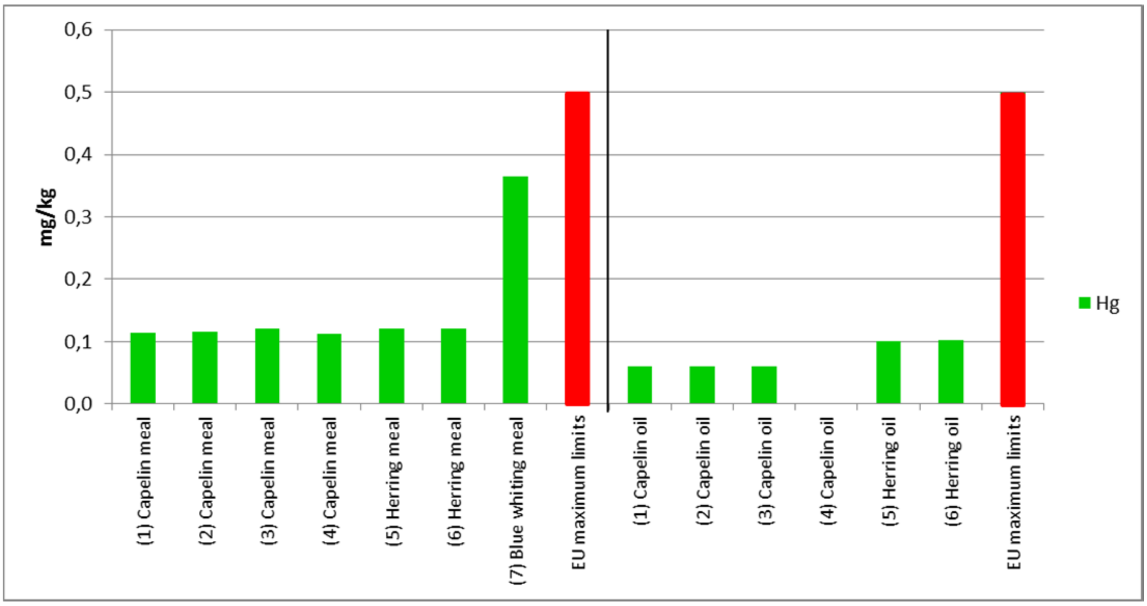

Figure 17: Hg in fish meal and oil from Icelandic fishing grounds in 2012 in mg/kg wet weight (i.e. meal measured as received from industrial partner).

5.7 Poly- and perfluorinated compounds

Poly- and perfluorinated compounds (PFC) are receiving more and more attention since they were first analysed in environmental samples (Giesy and Kannan, 2001; Hansen *et al.*, 2001). The group consists of long chain alkane compounds where most or all chain hydrogens have been exchanged for fluorine. One of the major compounds, perfluorooctane sulfonate (PFOS) has been included into the Stockholm Convention on persistent organic pollutants. Very limited information is available on PFCs in Icelandic environment and this is the second year that these compounds are analysed in Icelandic fish and seafood products. For this reason emphasis was laid on gathering information about PFCs in the edible part of marine catches as well as in the fish meal and fish oil for feed in the year 2012. No maximum levels have yet been issued for PFCs by the EU in food or feed products.

5.7.1 PFCs in seafood

PFCs were not detected in the muscle tissue of any of the fish species origination from Icelandic waters and investigated in 2012 as shown in Table 10 in the Appendix.

5.7.2 PFC in fish meal and oil for feed

Table 11 and 12 in the Appendix show PFC concentrations in fish meal and oil for the year 2012 calculated in relation to 12% moisture. PFOSA was detected in one of the fish oil for feed samples and in one of the fish meal samples analysed in this study. PFCs are not lipophilic and bind to proteins (Jones *et al*., 2003) and the fish oil contains virtually no proteins.

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Commission Regulation (EU) No 277/2012 of 28th March 2012

Directive 2002/32/EC of the European Parliament and of the Council of 7 May 2002

Regulation (EC) No 396/2005 of the European Parliament and of the Council of 23 of February 2005

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

7 Appendix

Table 1: Dioxins PCBs and PBDE 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 %	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	PBDEs µg/kg
R12-834-8	1	Anglerfish	*Lophius piscatorius*	*NW*	41-89	1,2	0,022	0,024	0,046	0,24	n.a.
R12-834-9	2	Blue whiting	*Micromesistius poutassou*	*NW*	30-40	0,64	0,026	0,030	0,056	0,31	n.a.
R12-834-10	3	Blue whiting	*Micromesistius poutassou*	*NW*	<30	0,84	0,027	0,022	0,049	0,25	n.a.
R12-834-6	4	Cod	*Gadus morhua*	*NW*	40-50	0,70	0,022	0,031	0,053	0,22	n.a.
R12-834-7	5	Cod	*Gadus morhua*	*NW*	60-70	0,89	0,022	0,022	0,044	0,19	n.a.
R12-2742-5	6	Deepwater redfish	*Sebastes mentella*	*NW*	38-46	0,80	0,048	0,16	0,21	1,7	0,20
R12-2742-1	7	Golden redfish	*Sebastes marinus*	*NW*	33-38	1,9	0,059	0,15	0,21	1,5	0,17
R12-2742-2	8	Golden redfish	*Sebastes marinus*	*NW*	38-44	1,9	0,069	0,18	0,25	1,6	0,18
R12-2742-3	9	Greenland halibut	*Reinhardtius hippoglossoides*	*NW*	48-57	8,7	0,22	0,44	0,66	3,6	0,29
R12-2742-4	10	Greenland halibut	*Reinhardtius hippoglossoides*	*NW*	60-76	9,2	0,35	0,78	1,1	6,7	0,54
R12-834-3	11	Lemon sole	*Pseudopleuronectes americanus*	*NW*	30-35	0,32	0,023	0,019	0,042	0,20	n.a.
R12-834-4	12	Lemon sole	*Pseudopleuronectes americanus*	*NW*	35-40	0,53	0,024	0,021	0,045	0,27	n.a.
R12-834-1	13	Ling	*Molva molva*	*NW*	55-81	0,38	0,024	0,027	0,051	0,38	n.a.
R11-1835-1	14	Lumpfish	*Cyclopterus lumpus*	*NW*	35-43	17	0,28	0,50	0,77	4,1	n.a.
R11-1835-2	15	Lumpfish liver	*Cyclopterus lumpus*	*NW*	35-43	21	0,43	0,73	1,2	6,8	n.a.
R12-834-2	16	Plaice	*Pleuronectes platessa*	*NW*	30-41	0,54	0,027	0,031	0,058	0,30	n.a.
R12-834-5	17	Pollock	*Pollachius virens*	*NW*	61-69	1,1	0,029	0,049	0,078	0,42	n.a.
R12-2098-1	18	Shrimp	*Pandalus borealis*	*NW*		0,80	0,089	0,055	0,14	0,64	0,072
R12-2098-2	19	Shrimp	*Pandalus borealis*	*NW*		0,80	0,094	0,064	0,16	0,66	0,071
R12-2098-3	20	Shrimp	*Pandalus borealis*	*NW*		1,0	0,036	0,036	0,072	0,21	0,052
R12-2098-4	21	Shrimp	*Pandalus borealis*	*NW*		0,80	0,051	0,031	0,082	0,28	0,056
		EU action level								*	*
		EU maximum limits‡					3,50	3,00	6,50	75	*

*No maxinmum limits exist in the EU for the substances

n.a. Not analysed

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

PBDEs are BDE-170, -28, -47, -49, -66, -71, -85, --99, -100, -119, -126, -138, -153, -154, -183, -184, -196, -197, -206 and -207. BDE-209 was not detected in any sample.

‡ Maximum level for non dioxin like PCBs, i.e. Marker PCBs excluding CB-118

Table 2: Dioxins and PCBs in fish meal for feed calculated in relation to 12% moisture

Sample code	**Meal sample no.**	**Sample name**	**Latin name**	**PCDD/PCDF** 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	**PBDEs** µg/kg
R12-834-11	1	Capelin meal	*Mallotus villosus*	0,17	0,19	0,36	1,4	n.a.
R12-834-13	2	Capelin meal	*Mallotus villosus*	0,20	0,19	0,39	1,5	n.a.
R12-834-15	3	Capelin meal	*Mallotus villosus*	0,20	0,21	0,41	1,8	n.a.
R12-834-17	4	Capelin meal	*Mallotus villosus*	0,22	0,26	0,48	2,0	n.a.
R12-2922-1	5	Herring meal	*Clupea harengus*	0,13	0,13	0,26	2,0	0,39
R12-2922-3	6	Herring meal	*Clupea harengus*	0,18	0,20	0,38	2,4	0,58
R12-834-19	7	Blue whiting meal	*Micromesistius poutassou*	0,60	2,0	2,5	22	n.a.
		EU action level		1,00	2,50	3,50	*	*
		EU maximum limits‡		1,25		4,00	30	*

* No maximum limits exist in the EU for substances

n.a. Not analysed

PCDD/PCDFs are 2,3,7,8-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.

PBDEs are BDE -170, -28, -47, -49, -66, -71, -77, -85, -99, -100, -119, -126, -138, -153, -154, -183, -184, -196, -197, -206, and -207.

BDE-209 was not detected in any sample.

‡ Maximum level for non dioxin like PCBs, i.e. Marker PCBs excluding CB-118

Table 3: Dioxin, PCB and PBDE in fish oil for feed

Sample code	Fish oil sample no.	Sample name	Latin name	PCDD/PCDF 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	PBDEs µg/kg
R12-834-12	1	Capelin oil	*Mallotus villosus*	1,2	1,8	3,0	14	n.a.
R12-834-14	2	Capelin oil	*Mallotus villosus*	1,4	1,9	3,3	15	n.a.
R12-834-16	3	Capelin oil	*Mallotus villosus*	1,7	2,2	3,9	18	n.a.
R12-834-18	4	Capelin oil	*Mallotus villosus*	1,7	2,8	4,5	21	n.a.
R12-2922-2	5	Herring oil	*Clupea harengus*	1,0	1,5	2,5	22	3,1
R12-2922-4	6	Herring oil	*Clupea harengus*	1,5	2,0	3,5	28	3,5
		EU maximum limits‡		5,0		20	175	*
		EU action level		5,0	15			*

* No maxinum limits exist in the EU for the substances.

n.a. Not analysed

PCDD/PCDFs are 2,3,7,8-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.

PBDEs are BDE -170, -28, -47, -49, -66, -71, -77, -85, -99, -100, -119, -126, -138, -153, -154, -183, -184, -196, -197, -206, and -207.

BDE-209 was not detected in any sample.

‡ Maximum level for non dioxin like PCBs, i.e. Marker PCBs excluding CB-118

Table 4: Pesticides in fish mucle and one liver 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	Σ DDT µg/kg	Pentachlor benzene µg/kg	HCB µg/kg	Σ Heptachlores µg/kg
R12-834-8	1	Anglerfish	*Lophius piscatorius*	*NW*	41-89	1,2	< 0,0044	0,0080	< 0,0090	< 0,0044	0,23	0,0098	0,085	0,051
R12-834-9	2	Blue whiting	*Micromesistius poutassou*	*NW*	30-40	0,64	0,0053	0,0077	< 0,0094	< 0,0044	0,25	0,019	0,26	0,052
R12-834-10	3	Blue whiting	*Micromesistius poutassou*	*NW*	<30	0,84	< 0,0044	0,011	< 0,0093	< 0,0044	0,31	0,027	0,27	0,054
R12-834-6	4	Cod	*Gadus morhua*	*NW*	40-50	0,70	< 0,0040	0,0056	< 0,0065	< 0,0040	0,16	0,013	0,23	0,048
R12-834-7	5	Cod	*Gadus morhua*	*NW*	60-70	0,89	< 0,0040	< 0,0040	< 0,0084	< 0,0040	0,13	0,012	0,21	0,053
R12-2742-5	6	Deepwater redfish	*Sebastes mentella*	*NW*	38-46	0,80	0,013	< 0,010	< 0,024	< 0,010	2,5	< 0,010	0,16	0,12
R12-2742-1	7	Golden redfish	*Sebastes marinus*	*NW*	33-38	1,9	0,018	0,016	< 0,035	< 0,010	2,3	0,018	0,27	0,16
R12-2742-2	8	Golden redfish	*Sebastes marinus*	*NW*	38-44	1,9	0,014	0,018	< 0,033	< 0,010	2,3	0,015	0,27	0,15
R12-2742-3	9	Greenland halibut	*Reinhardtius hippoglossoides*	*NW*	48-57	8,7	0,11	0,18	0,052	< 0,010	6,6	0,033	1,8	0,52
R12-2742-4	10	Greenland halibut	*Reinhardtius hippoglossoides*	*NW*	60-76	9,2	0,11	0,099	0,083	< 0,010	11	0,063	2,4	0,53
R12-834-3	11	Lemon sole	*Pseudopleuronectes americanus*	*NW*	30-35	0,32	< 0,0040	< 0,0040	< 0,0083	< 0,0040	0,11	0,0061	0,047	0,046
R12-834-4	12	Lemon sole	*Pseudopleuronectes americanus*	*NW*	35-40	0,53	0,0051	0,0048	< 0,0088	< 0,0044	0,13	0,0071	0,065	0,052
R12-834-1	13	Ling	*Molva molva*	*NW*	55-81	0,38	0,005	< 0,0084	0,015	< 0,012	0,19	0,0082	0,087	0,051
R11-1835-1	14	Lumpfish	*Cyclopterus lumpus*	*NW*	35-43	17	0,19	0,59	0,15	< 0,020	7,8	0,43	3,3	1,2
R11-1835-2	15	Lumpfish liver	*Cyclopterus lumpus*	*NW*	35-43	21	0,23	0,59	0,22	< 0,020	11	0,42	3,9	1,1
R12-834-2	16	Plaice	*Pleuronectes platessa*	*NW*	30-41	0,54	0,0041	0,0075	< 0,0080	< 0,0040	0,17	0,0071	0,080	0,049
R12-834-5	17	Pollock	*Pollachius virens*	*NW*	61-69	1,1	0,0059	0,017	< 0,0094	< 0,0044	0,54	0,021	0,33	0,071
R12-2098-1	18	Shrimp	*Pandalus borealis*	*NW*		0,80	< 0,010	0,011	< 0,031	< 0,010	0,11	0,035	0,39	0,14
R12-2098-2	19	Shrimp	*Pandalus borealis*	*NW*		0,80	< 0,010	< 0,010	< 0,032	< 0,010	0,11	0,037	0,30	0,13
R12-2098-3	20	Shrimp	*Pandalus borealis*	*NW*		1,0	< 0,010	0,011	< 0,037	< 0,010	0,084	0,017	0,15	0,12
R12-2098-4	21	Shrimp	*Pandalus borealis*	*NW*		0,80	< 0,010	0,016	< 0,035	< 0,010	0,092	0,031	0,23	0,10
		EU maximum limits					50	50	50		500		50	50

Table 4 (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
R12-834-8	1	Anglerfish	*Lophius piscatorius*	*NW*	41-89	1,2	0,061	0,18	< 0,0044	< 0,0048	0,22	0,051	0,054	0,0050
R12-834-9	2	Blue whiting	*Micromesistius poutassou*	*NW*	30-40	0,64	0,052	0,16	0,0055	< 0,0044	0,22	0,045	0,039	0,0073
R12-834-10	3	Blue whiting	*Micromesistius poutassou*	*NW*	<30	0,84	0,12	0,27	0,0058	0,019	0,22	0,076	0,062	0,0060
R12-834-6	4	Cod	*Gadus morhua*	*NW*	40-50	0,70	0,096	0,13	0,0046	< 0,0042	0,22	0,045	0,042	0,0054
R12-834-7	5	Cod	*Gadus morhua*	*NW*	60-70	0,89	0,085	0,12	0,0061	< 0,0040	0,22	0,050	0,045	< 0,0040
R12-2742-5	6	Deepwater redfish	*Sebastes mentella*	*NW*	38-46	0,80	0,15	2,1	0,019	< 0,014	0,20	0,27	0,42	0,034
R12-2742-1	7	Golden redfish	*Sebastes marinus*	*NW*	33-38	1,9	0,31	3,7	0,041	0,031	0,25	0,53	0,60	0,025
R12-2742-2	8	Golden redfish	*Sebastes marinus*	*NW*	38-44	1,9	0,46	3,7	0,026	0,028	0,24	0,63	0,71	0,020
R12-2742-3	9	Greenland halibut	*Reinhardtius hippoglossoides*	*NW*	48-57	8,7	2,6	12	0,052	0,46	0,23	3,1	3,4	0,062
R12-2742-4	10	Greenland halibut	*Reinhardtius hippoglossoides*	*NW*	60-76	9,2	3,5	18	0,11	0,55	0,25	5,1	4,7	0,13
R12-834-3	11	Lemon sole	*Pseudopleuronectes americanus*	*NW*	30-35	0,32	0,053	0,075	< 0,0040	< 0,0040	0,22	0,021	0,022	< 0,0040
R12-834-4	12	Lemon sole	*Pseudopleuronectes americanus*	*NW*	35-40	0,53	0,058	0,13	< 0,0044	< 0,0047	0,22	0,027	0,027	< 0,0044
R12-834-1	13	Ling	*Molva molva*	*NW*	55-81	0,38	0,051	0,12	< 0,0044	< 0,0044	0,22	0,043	0,057	< 0,0044
R11-1835-1	14	Lumpfish	*Cyclopterus lumpus*	*NW*	35-43	17	4,2	8,0	0,058	1,0	0,30	3,7	2,1	0,040
R11-1835-2	15	Lumpfish liver	*Cyclopterus lumpus*	*NW*	35-43	21	6,5	9,3	0,084	1,0	0,30	3,6	1,8	0,075
R12-834-2	16	Plaice	*Pleuronectes platessa*	*NW*	30-41	0,54	0,041	0,18	< 0,0040	< 0,021	0,22	0,014	0,034	0,0055
R12-834-5	17	Pollock	*Pollachius virens*	*NW*	61-69	1,1	0,24	0,63	0,013	0,041	0,22	0,23	0,17	0,0082
R12-2098-1	18	Shrimp	*Pandalus borealis*	*NW*		0,80	0,16	0,52	< 0,010	0,024	0,23	0,081	0,13	0,026
R12-2098-2	19	Shrimp	*Pandalus borealis*	*NW*		0,80	0,17	0,47	< 0,010	< 0,014	0,24	0,082	0,14	0,014
R12-2098-3	20	Shrimp	*Pandalus borealis*	*NW*		1,0	0,11	0,18	< 0,010	< 0,020	0,24	0,035	0,025	< 0,010
R12-2098-4	21	Shrimp	*Pandalus borealis*	*NW*		0,80	0,16	0,21	< 0,010	< 0,016	0,25	0,034	0,056	0,011
		EU maximum limits					50			50		100		

Table 5: Pesticides in fish meal for feed on wet weight

Sample code	Meal sample no.	Sample name	β-HCH µg/kg	α-HCH µg/kg	γ-HCH µg/kg	δ-HCH µg/kg	Σ DDT µg/kg	Pentachlor benzene µg/kg	HCB µg/kg	Σ Heptachlores µg/kg
R12-834-11	1	Capelin meal	0,13	0,053	0,080	< 0,020	2,9	0,21	1,8	0,63
R12-834-13	2	Capelin meal	0,12	0,068	0,084	< 0,020	3,2	0,20	1,8	0,51
R12-834-15	3	Capelin meal	0,12	0,11	0,15	< 0,020	4,0	0,23	2,1	0,57
R12-834-17	4	Capelin meal	0,097	0,10	0,11	< 0,020	4,8	0,26	2,6	0,57
R12-2922-1	5	Herring meal	< 0,027	0,051	< 0,087	< 0,027	3,1	0,094	0,68	0,54
R1202922-3	6	Herring meal	< 0,16	< 0,29	0,21	< 0,44	3,2	< 0,25	0,63	0,52
R12-834-19	7	Blue whiting meal	0,034	0,049	0,027	< 0,020	31	0,096	4,0	0,69
		EU maximum limits	10	20	200		50		10	

Table 5 (cont.): Pesticides in fish meal for feed on wet weight.

Sample code	Meal sample no.	Sample name	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
R12-834-11	1	Capelin meal	2,4	4,9	0,031	0,49	0,50	1,7	0,93	0,022
R12-834-13	2	Capelin meal	2,3	4,8	0,031	0,47	0,50	1,8	0,95	0,032
R12-834-15	3	Capelin meal	2,5	5,0	0,040	0,46	0,50	2,2	1,1	0,031
R12-834-17	4	Capelin meal	2,9	4,7	0,040	0,47	0,50	2,6	1,5	0,045
R12-2922-1	5	Herring meal	1,1	2,2	0,031	0,044	0,65	0,64	0,60	0,027
R1202922-3	6	Herring meal	1,6	4,8	< 0,027	0,15	0,62	0,69	0,89	0,042
R12-834-19	7	Blue whiting meal	2,7	21	0,49	0,26	0,50	6,6	7,6	0,71
		EU maximum limits	10	20		10	100	20		

Table 6: Pesticides in fish oil for feed

Sample code	Fish oil no.	Sample name	β-HCH µg/kg	α-HCH µg/kg	γ-HCH µg/kg	δ-HCH µg/kg	Σ DDT µg/kg	Pentachlor benzene µg/kg	HCB µg/kg	Σ Heptachlores µg/kg
R12-834-12	1	Capelin oil	1,4	3,9	1,3	< 0,10	28	2,8	19	4,7
R12-834-14	2	Capelin oil	1,4	3,9	1,2	< 0,10	36	3,0	22	7,5
R12-834-16	3	Capelin oil	1,2	3,0	0,91	< 0,10	36	3,1	22	4,3
R12-834-18	4	Capelin oil	1,2	2,5	0,60	< 0,10	39	3,1	27	4,3
R12-2922-2	5	Herring oil	0,51	1,7	0,41	< 0,10	36	1,4	9,0	5,7
R12-2922-4	6	Herring oil	< 0,42	0,73	< 0,64	< 0,58	33	2,4	11	3,6
		EU maximum limits	100	200	2000		500		200	

Table 6 (cont): Pesticides in fish oil for feed

Sample code	Fish oil no.	Sample name	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
R12-834-12	1	Capelin oil	21	34	0,27	5,3	4,0	19	10	0,28
R12-834-14	2	Capelin oil	28	57	0,29	5,0	6,1	15	10	0,41
R12-834-16	3	Capelin oil	27	43	0,39	8,1	4,0	21	11	0,22
R12-834-18	4	Capelin oil	31	54	0,43	8,7	4,1	25	14	< 0,10
R12-2922-2	5	Herring oil	15	37	0,36	1,3	2,4	8,9	8,6	0,16
R12-2922-4	6	Herring oil	14	56	0,48	1,7	2,4	7,2	9,3	0,40
		EU maximum limits	100	200		50	100	50		

Table 7: Trace elements in fish muscle on wet weight

Sample code	Fish sample no.	Sample name	Latin name	Cr mg/kg	Fe mg/kg	Cu mg/kg	Zn mg/kg	As mg/kg	Se mg/kg	Cd mg/kg	Hg mg/kg	Pb mg/kg
R12-834-8	1	Anglerfish	*Lophius piscatorius*	0,056	0,83	0,091	3,9	13	0,47	<0,007	0,15	<0,008
R12-834-9	2	Blue whiting	*Micromesistius poutassou*	0,061	1,8	0,25	3,9	6,5	0,73	<0,006	0,11	<0,008
R12-834-10	3	Blue whiting	*Micromesistius poutassou*	0,068	6,3	0,39	5,0	6,2	0,59	0,04	0,038	<0,008
R12-834-7	4	Cod	*Gadus morhua*	0,060	0,92	0,17	3,9	2,9	0,25	<0,006	0,059	<0,008
R12-834-6	5	Cod	*Gadus morhua*	0,061	0,92	0,17	3,6	6,0	0,28	<0,006	0,043	<0,008
R12-2742-5	6	Deepwater redfish	*Sebastes mentella*	0,057	1,0	0,10	2,1	3,0	0,49	<0,006	0,18	<0,008
R12-2742-2	7	Golden redfish	*Sebastes marinus*	0,075	1,8	0,13	2,7	2,0	0,48	<0,007	0,081	<0,009
R12-2742-1	8	Golden redfish	*Sebastes marinus*	0,068	2,5	0,21	2,7	2,0	0,66	<0,007	0,067	<0,009
R12-2742-4	9	Greenland halibut	*Reinhardtius hippoglossoides*	0,11	1,2	0,089	2,6	7,1	0,66	<0,03	0,15	<0,04
R12-2742-3	10	Greenland halibut	*Reinhardtius hippoglossoides*	0,13	1,3	0,11	2,7	4,0	0,45	<0,03	0,11	<0,04
R12-834-4	11	Lemon sole	*Pseudopleuronectes americanus*	0,062	0,75	0,11	3,2	52	0,50	<0,006	0,10	<0,008
R12-834-3	12	Lemon sole	*Pseudopleuronectes americanus*	0,051	0,85	0,088	2,9	63	0,65	<0,006	0,053	<0,008
R12-834-1	13	Ling	*Molva molva*	0,058	0,73	0,14	3,5	7,1	0,42	<0,006	0,092	<0,008
R12-834-2	16	Plaice	*Pleuronectes platessa*	0,051	0,80	0,12	3,5	12	0,62	<0,006	0,032	<0,008
R12-834-5	17	Pollock	*Pollachius virens*	0,066	3,1	0,51	5,1	1,0	0,28	<0,006	0,029	<0,008
R12-2098-4	18	Shrimp	*Pandalus borealis*	0,024	2,8	2,6	10	19	0,39	0,024	0,072	<0,009
R12-2098-3	19	Shrimp	*Pandalus borealis*	0,022	3,7	2,4	10	12	0,41	0,028	0,029	<0,009
R12-2098-2	20	Shrimp	*Pandalus borealis*	0,027	1,9	2,7	9,1	24	0,36	0,043	0,11	<0,009
R12-2098-1	21	Shrimp	*Pandalus borealis*	0,025	2,5	2,8	10	29	0,35	0,048	0,14	<0,009
		EU maximum limits, flesh								0,05	0,5	0,3

Table 8: Trace elements in fish meal for feed on wet weight.

Sample code	**Meal sample no.**	**Sample name**	**Cr** mg/kg	**Fe** mg/kg	**Cu** mg/kg	**Zn** mg/kg	**As** mg/kg	**Se** mg/kg	**Cd** mg/kg	**Hg** mg/kg	**Pb** mg/kg
R12-834-11	1	Capelin meal	0,36	208	2,4	64	4,9	1,6	0,24	0,11	<0,04
R12-834-13	2	Capelin meal	0,15	111	2,1	61	4,7	1,5	0,19	0,12	<0,04
R12-834-15	3	Capelin meal	0,37	93	2,2	70	4,2	1,5	0,18	0,12	<0,04
R12-834-17	4	Capelin meal	0,15	75	1,8	76	3,7	1,5	0,16	0,11	<0,04
R12-2922-1	5	Herring meal	0,38	147	2,1	69	3,2	1,8	0,22	0,12	<0,04
R12-2922-3	6	Herring meal	0,55	197	2,1	60	3,2	2,2	0,23	0,12	<0,04
R12-834-19	7	Blue whiting meal	0,15	115	2,3	48	13	2,3	0,15	0,37	<0,04
		EU maximum limits					25		2	0,5	10

Table 9: Trace elements in fish oil for feed

Sample code	**Fish oil sample no.**	**Sample name**	**Cr** mg/kg	**Fe** mg/kg	**Cu** mg/kg	**Zn** mg/kg	**As** mg/kg	**Se** mg/kg	**Cd** mg/kg	**Hg** mg/kg	**Pb** mg/kg
R12-834-12	1	Capelin oil	0,0029	2,4	0,11	2,8	9,3	0,094	<0,03	0,060	0,043
R12-834-14	2	Capelin oil	0,0026	1,1	0,081	1,6	10	0,10	<0,03	0,060	<0,04
R12-834-16	3	Capelin oil	0,0029	0,52	0,10	2,7	11	0,10	<0,03	0,060	0,095
R12-834-18	4	Capelin oil									
R12-2922-2	5	Herring oil	1,0	5,8	0,080	4,3	11	0,20	<0,03	0,10	<0,04
R12-2922-4	6	Herring oil	0,93	6,2	0,080	1,8	8,9	0,13	<0,03	0,10	<0,04
		EU maximum limits					25		2	0,5	10

Table 10: Perfluorninated compounds in fish muscle on wet weight

Sample code	Fish sample no.	Sample name	PFBS ng/kg	PFDA ng/kg	PFDS ng/kg	PFDoA ng/kg	PFHpA ng/kg	PFHxA ng/kg	PFHxS ng/kg	PFNA ng/kg	PFOA ng/kg	PFOSA ng/kg	PFOS ng/kg
R12-834-8	1	Anglerfish	< 73,7	< 49,1	< 73,7	< 49,1	< 49,1	< 49,1	< 73,7	< 49,1	< 49,1	< 49,1	< 49,1
R12-834-9	2	Blue whiting	< 83,7	< 55,8	< 83,7	< 55,8	< 55,8	< 55,8	< 83,7	< 55,8	< 55,8	< 55,8	< 55,8
R12-834-10	3	Blue whiting	< 70,6	< 47,0	< 70,6	< 47,0	< 47,0	< 47,0	< 70,6	< 47,0	< 47,0	< 47,0	< 47,0
R12-834-6	4	Cod	< 68,4	< 45,6	< 68,4	< 45,6	< 45,6	< 45,6	< 68,4	< 45,6	< 45,6	< 45,6	< 45,6
R12-834-7	5	Cod	< 75,5	< 50,3	< 75,5	< 50,3	< 50,3	< 50,3	< 75,5	< 50,3	< 50,3	< 50,3	< 50,3
R12-834-3	11	Lemon sole	< 63,8	< 42,5	< 63,8	< 42,5	< 42,5	< 42,5	< 63,8	< 42,5	< 42,5	< 42,5	< 42,5
R12-834-4	12	Lemon sole	< 74,2	< 49,5	< 74,2	< 49,5	< 49,5	< 49,5	< 74,2	< 49,5	< 49,5	< 49,5	< 49,5
R12-834-1	13	Ling	< 73,0	< 48,7	< 73,0	< 48,7	< 48,7	< 48,7	< 73,0	< 48,7	< 48,7	< 48,7	< 48,7
R11-1835-1	14	Lumpfish	< 206	< 137	< 206	< 137	< 137	< 137	< 206	< 137	< 137	< 137	< 137
R11-1835-2	15	Lumpfish liver	< 271	< 181	< 271	< 181	< 181	< 181	< 271	< 181	< 181	< 181	< 181
R11-1276-3		Lumpfish skin	< 188	< 125	< 188	< 125	< 125	< 125	< 188	< 125	< 125	< 125	< 125
R11-1835-3		Lumpfish skin	< 225	< 150	< 225	< 150	< 150	< 150	< 225	< 150	< 150	< 150	< 150
R12-834-2	16	Plaice	< 69,5	< 46,4	< 69,5	< 46,4	< 46,4	< 46,4	< 69,5	< 46,4	< 46,4	< 46,4	< 46,4
R12-834-5	17	Pollock	< 73,5	< 49,0	< 73,5	< 49,0	< 49,0	< 49,0	< 73,5	< 49,0	< 49,0	< 49,0	< 49,0

Table 11: Perfluorinated compounds in fish meal for feed

Sample code	Meal sample no.	Sample name	PFBS ng/kg	PFDA ng/kg	PFDS ng/kg	PFDoA ng/kg	PFHpA ng/kg	PFHxA ng/kg	PFHxS ng/kg	PFNA ng/kg	PFOA ng/kg	PFOSA ng/kg	PFOS ng/kg
R12-2922-1	5	Herring meal	< 963	< 642	< 963	< 642	< 642	< 642	< 963	< 642	< 642	< 642	< 642
R12-2922-3	6	Herring meal	< 1000	< 700	< 1000	< 700	< 700	< 700	< 1000	< 700	< 700	< 700	< 700
R12-834-19	7	Blue whiting meal	< 362	< 242	< 362	< 242	< 242	< 242	< 362	< 242	< 242	454	< 242

Table 12: Perfluorinated compounds in fish oil for feed

Sample code	Fish oil no.	Sample name	PFBS ng/kg	PFDA ng/kg	PFDS ng/kg	PFDoA ng/kg	PFHpA ng/kg	PFHxA ng/kg	PFHxS ng/kg	PFNA ng/kg	PFOA ng/kg	PFOSA ng/kg	PFOS ng/kg
R12-2922-2	5	Herring oil	< 300	< 200	< 300	< 200	< 200	< 200	< 300	< 200	< 200	< 200	< 200
R12-2922-4	6	Herring oil	< 300	< 200	< 300	< 200	< 200	< 200	< 300	< 200	< 200	300	< 200