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Undesirable substances in seafood products. Results from the Icelandic marine monitoring activities year 2008

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Ágrip á íslensku:	Árið 2003 hófst, að frumkvæði sjávarútvegsráðuneytisins, vöktun á óæskilegum efnum í sjávarafurðum, bæði afurðum sem ætlaðar eru til manneldis sem og afurðum til lýsis- og mjöliðnaðar. Tilgangurinn með vöktuninni er að meta ástand íslenskra sjávarafurða með tilliti til magns aðskotaefna. Gögnunum sem safnað er í vöktunarverkefninu verða einnig notuð í áhættumati og til að byggja upp gagnagrunn um aðskotaefni í íslensku lífríki. Umfjöllun um aðskotaefni í sjávarafurðum, bæði í almennum fjölmiðlum og í vísindaritum, hefur margoft krafist viðbragða íslenskra stjórnvalda. Nauðsynlegt er að hafa til taks vísindaniðurstöður sem sýna fram á raunverulegt ástand íslenskra sjávarafurða til þess að koma í veg fyrir tjón sem af slíkri umfjöllun getur hlotist. Ennfremur eru mörk aðskotaefna í sífelldri endurskoðun og er mikilvægt fyrir Íslendinga að taka þátt í slíkri endurskoðun og styðja mál sitt með vísindagögnum. Þetta sýnir mikilvægi þess að regluleg vöktun fari fram og að á Íslandi séu stundaðar sjálfstæðar rannsóknir á eins mikilvægum málaflokki og mengun sjávarafurða er. Þessi skýrsla er samantekt niðurstaðna vöktunarinnar árið 2008. Mat á ástandi íslenskra sjávarafurða með tilliti til aðskotaefna er langtímaverkefni og verður einungis framkvæmt með sívirkri vöktun. Á hverju ári er því farið vandlega yfir hvaða gögn vantar og þannig stefnt að því að fylla í eyðurnar. Árið 2008 voru mæld: dioxin, dioxinlík PCB og bendi PCB efni, PBDEs, PAH auk tíu mismunandi tegunda varnarefna, í sjávarafurðum sem ætlaðar eru til manneldis sem og afurðum til lýsis- og mjöliðnaðar. Gert var sérstak átak í mælingum á PBDE og PAH efnum árið 2008 og mældist mjög lítið af þessum efnum í íslenskum sjávarafurðum. Eins og áður mældist almennt lítið magn óæskilegra efna í íslensku sjávarfangi árið 2008. Olía og mjöl gert úr kolmunna á það þó til að vera nálægt eða yfirstíga leyfileg mörk fyrir viss efni.		
Lykilorð á íslensku:	*Sjávarfang, vöktun, Díoxín, díoxínlík PCB, PCB, varnarefni, PBDEs, PAH*		

Summary in English:	This project was started in 2003 at the request of the Icelandic Ministry of Fisheries and Agriculture. Until then, monitoring of undesirable substances in the edible portion of marine catches had been rather limited in Iceland. The purpose of the project is to gather information and evaluate the status of Icelandic seafood products in terms of undesirable substances. The information will also be utilized for a risk assessment and gathering of reference data. This report summarizes the results obtained in 2008 for the monitoring of various undesirable substances in the edible part of marine catches, fish meal and fish oil for feed. The monitoring began in 2003 and has now been carried out for five consecutive years. The evaluation of the status of the Icelandic seafood products in terms of undesirable substances is a long term project which can only be reached through continuous monitoring. For this reason, we carefully select which undesirable substances are measured in the various seafood samples each year with the aim to fill in the gaps in the available data over couple of year time. In 2008, data was collected on dioxins, dioxin-like PCBs, marker PCBs, ten different types of pesticides, PBDEs and PAHs in the edible part of fish, fish liver, fish oil and meal for feed. Samples collected in 2008 contained generally low concentrations of undesirable substances. These results are in agreement with our previous results obtained in monitoring programmes 2003-2007. This year (2008) special emphasis was laid on gathering information on PBDE and PAHs and the results reveal that these compounds are in very low amounts in fish and fish products and most PAHs are actually below detection limits. Blue whiting meal and oil can contain undesirable substances in concentration close to or exceeding the maximum level set by the EU.
English keywords:	*Marine catches, monitoring, dioxin, PCB, pesticides, PBDEs, PAH*

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1 Introduction

The monitoring of various undesirable substances in the edible part of marine catches, as well as in fish meal and fish oil for feed started in 2003 and has thus been carried out for five years. The project is funded by the Ministry of Fisheries and Agriculture in Iceland. The monitoring project is the first comprehensive study on the status of Icelandic seafood products in terms of undesirable substances. The project includes measurements of many marine species from Icelandic fishing grounds that have never been studied before. In addition, information is gathered on numerous substances that have not been previously measured. The substances investigated in this monitoring project are: polyaromatic hydrocarbons (PAHs), polychlorinated dibenzo dioxins and dibenzo furans (commonly called dioxins), dioxin-like polychlorinated biphenyls (PCBs), marker PCBs, polybrominated flame retardants (PBDEs) and 29 pesticides and breakdown products (i.e. HCB, DDTs, HCHs, dieldrin, endrin, chlordanes, toxaphenes and endosulfan substances) and inorganic trace elements e.g. 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) To examine how products measure up against the limits set by EU for dioxins (polychlorinated dibenzodioxins and dibenzofurans) (Regulation (EC) No 1882/2003).
C) To gather information on the concentration of marker PCBs for the purpose of setting limits, but a risk assessment is now in progress in EU regarding this class of substances.
D) To evaluate how products measure up to limits currently in effect for inorganic trace elements, organic contaminants and pesticides in the EU. The information will also be utilized for a risk assessment and the setting of maximum values that are now under consideration within EU (e.g. PAHs, inorganic arsenic and brominated flame retardants).

This report summarizes results from the monitoring programme in 2008. The results obtained in 2003-2007 have already been published and are accessible at the Matis website (Auðunsson, 2004, Ásmundsdóttir et al., 2005, Ásmundsdóttir and Gunnlaugsdóttir, 2006, Ásmundsdóttir et al., 2008, Jörundsdóttir et al., 2009).

2 Summary

This report summarizes the results obtained in 2008 for the monitoring of various undesirable substances in the edible part of marine catches, fish meal and fish oil for feed. This project began in 2003 and has now been carried out for five years.

In the year 2008 emphasis was laid on gathering information on the organic compounds PBDE and PAHs in the edible part of marine catches. Generally the results obtained 2008 are in agreement with our previous results for undesirable substances in the edible part of marine catches, fish meal and fish oil for feed obtained in the monitoring years 2003-2007.

This report shows that the edible part of Icelandic seafood products contain negligible amounts of persistent organic pollutants (POPs) like dioxins, dioxin like PCBs and pesticides. The results for PBDE and PAHs also reveal that these compounds are in very low amounts in fish and fish products, most PAHs are actually below detection limits. The concentration of marker PCBs is also found to be low in the edible part of fish muscle, compared to the maximum limits in the European countries, where such limits exist.

The samples of fish meal and fish oil for feed measured are subjected to different maximum limits by the EU. Two samples of cod liver contained high concentrations of sum of dioxins and DL-PCBs, with one sample exceeding the EU maximum limits.

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), toxafen-substances (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).

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

PAH-substances (17 congeners):
Phenanthrene, Anthracene, Fluoranthene, Pyrene, Benzo(b)naphto(2,1d)thiophene, Benzo(c)phenanthrene, Benzo(a)anthracene, Chrysen/Triphenylen, Benzo(ghi)fluoranthene, Benzo(bjk)fluoranthene, Benzo(e)pyrene, Benzo(a)pyrene, Indeno(1,2,3-cd)pyrene, Benzo(ghi)perylene, Anthanthrene, Dibenzo(a,h)anthracene, Coronene.

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

4.1.1 Seafood

All the analysis was done on the edible parts of the seafood products. The fish was collected from the fishing grounds around Iceland which are divided into five areas, as illustrated on Figure 1. All samples are identified with the location of the fishing area, except when the sample contains individuals from more than one area. Each fish sample consists of at least ten individuals of a specific length distribution.

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, the sampling was distributed over the year.

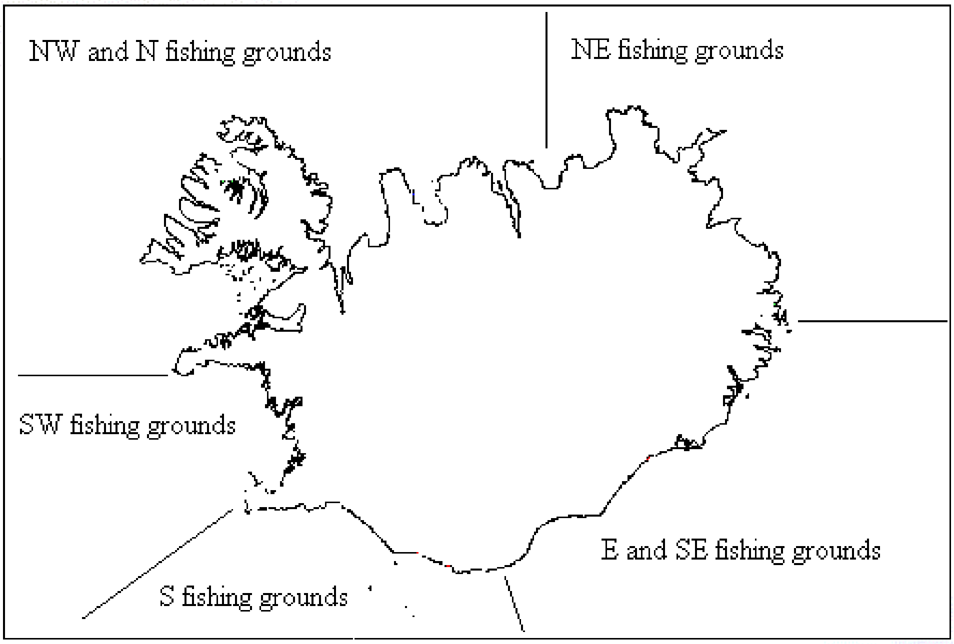

Figure 1: The division of the fishing grounds around Iceland used in this research

4.2 Analysis

The organic contaminants were measured by Eurofins, Hamburg, Germany. Eurofins has taken part in international inter-laboratory quality control study organized by WHO and EU and uses accredited methods for analyzing dioxin, WHO-PCBs, marker-PCBs, pesticides, PBDEs and PAHs.

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). The WHO-TEQ values have been adapted by the World Health Organization (WHO) in 1997 and by EU in its legislations.

5 Results of monitoring of fish and seafood products in Iceland

All results of the monitoring program in 2008 are expressed in details in Tables 1-9 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. This can be seen in Figure 2 and in Table 1 in the Appendix. 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 and redfish (samples no. 5, 7 and 8), contain more dioxins and dioxin like PCBs than species which accumulate fat in the liver and thus have almost no fat in the muscle. Herring has also higher lipid content in the muscle and therefore higher dioxin and dioxin like PCB concentrations. The level of dioxin 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.

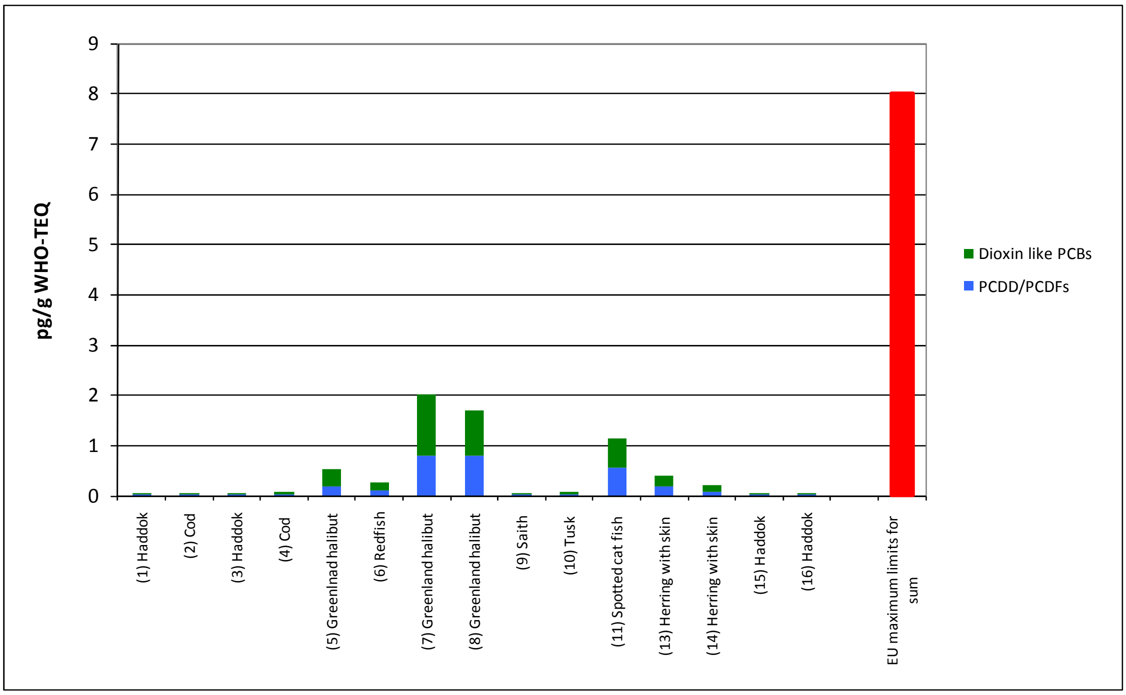

Figure 2: Dioxins and dioxin-like PCBs in the edible part of fish muscle from Icelandic fishing grounds in 2008 in relation to maximum limit in EU in WHO-TEQ pg/g wet weight. The number within parenthesis is the sample number indicated in Table 1.

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

No samples of fish oil for human consumption were analysed or collected from the fish oil industry this year. Earlier results from 2005 and 2006 showed concentrations below the EU maximum limit of 2 pg/g WHO-TEQ for dioxins or the EU maximum limit of 10 pg/g WHO-TEQ for the sum of dioxins and dioxin like PCBs (Ásmundsdóttir and Gunnlaugsdóttir, 2006, Ásmundsdóttir et al., 2008).

5.1.3 Dioxins and dioxin like PCBs in cod liver

Five samples of cod livers were analysed for dioxins and dioxin like PCBs (Table 2). Four of these samples are individual cod samples (i.e. are not combined samples from ten fish). These samples were collected to gather some information regarding the effect of individual variation in the concentration of dioxins and dioxin like PCBs as this information is of importance for the producers of canned cod livers. The concentration of dioxins and dioxin like PCBs in these samples was lower than the EUs maximum with one exception, where the concentration was more than twice the EU maximum level of 25 pg/g WHO-TEQ (Table 2). In addition, one liver contained Dioxins and DL-PCBs in a concentration close to the EU maximum level as shown in Figure 3.

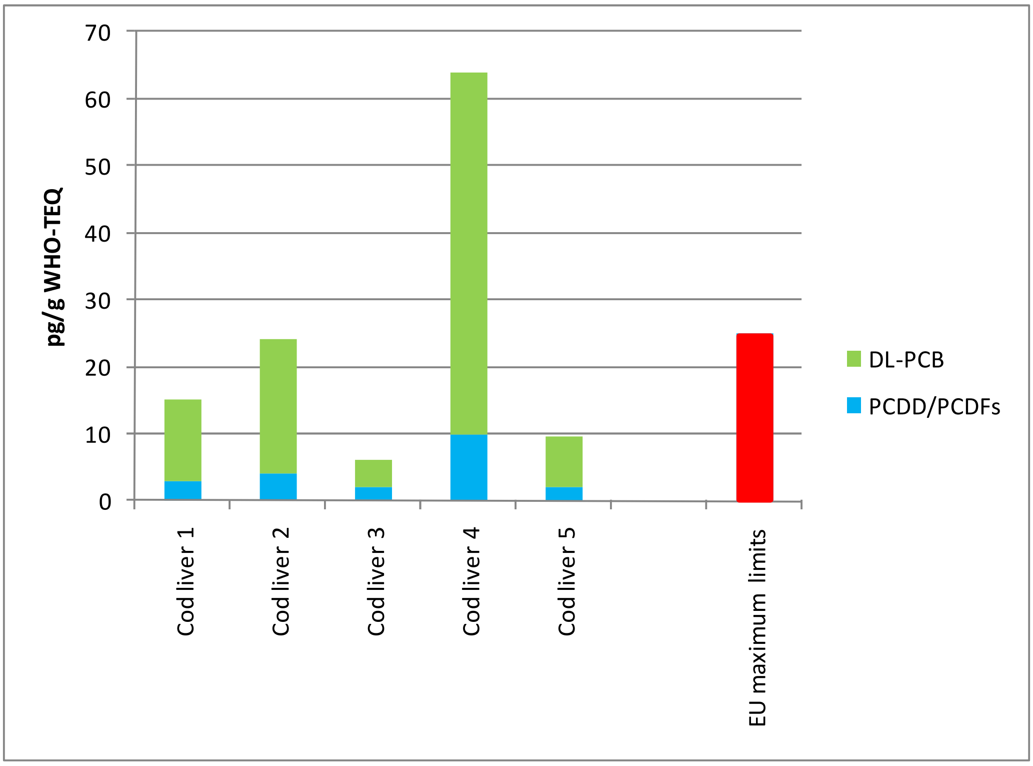

Figure 2: Dioxins and dioxin-like PCBs cod livers from Icelandic fishing grounds in 2008 in relation to maximum limit in EU in WHO-TEQ pg/g wet weight.

Cod liver 1 is a pooled sample from about 10-15 individuals. Livers 2 – 5 are individual livers. For details on the individuals behind these samples, refer to Table 2. The highest value for the sum of dioxins and dioxin-like PCBs was measured in cod liver nr 4, 64 pg WHO-TEQ/g (wet weight). This concentration exceeds the maximum level set by the EU of 25,0 pg WHO-TEQ/g (wet weight), while cod livers 2, 3 and 5 are below this maximum level. Cod liver nr 4 is from a large and old cod which seems to be in a poor nutritional condition as the lipid content of the liver of this cod is low (52,6%). Persistent organic compounds are not excreted when the lipid in the liver of the cod is depleted for energy use, therefore the concentration is higher in this individual. Figure 2 shows that the second highest concentration for the sum of dioxins and dioxin-like PCBs was found in cod liver nr 2. This liver is also from a large and old cod. However, this cod is in fairly good nutritional condition, as the lipid content in the liver is high (93,7%) compared to individual number 5, and the amount of PCBs and dioxins are therefore diluted in larger amount of lipids in the liver.

5.1.4 Dioxins and dioxin-like PCBs in fish meal and fish oil for feed

Samples of fish meal and fish oil are taken annually. This year samples consisted of blue whiting, mackerel, herring and capelin meal and oil. Maximum limits in EU 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. 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 dioxin and dioxin-like PCB is lower than the EU maximum limit in all fish meals tested (Figure 4). The same is observed for the fish oil with the exception of the blue whiting oil sample, which exceeds the limits for the sum of dioxins and DL-PCBs (Figure 5). Further the concentration of marker-PCBs is high in this sample (Figure8).

It has been shown that the level of persistent organic pollutants in fish meal and fish oil for feed is related to the fat content of the fish used as raw material. The fat content of the fish, on the other hand, depends very much on the nutritional condition of the fish and consequently varies through the seasons (Anon., 2003, Ásmundsdóttir et al., 2005). Figures 4 and 5 show the amount of dioxins and dioxin-like PCBs in fish meal and fish oil samples compared to the EU limit. The samples were taken throughout the year 2008 and further details on the results for dioxins and dioxin-like PCBs in these samples can be found in Tables 3 and 4 in the Appendix. Fish meal and fish oil samples nr. 1 contain the highest amounts of dioxin and dioxin-like PCBs compared to fish meal from other species. These samples are from meal of blue whiting caught in April/ May which is the period just after spawning, when the fat content in the fish is low.

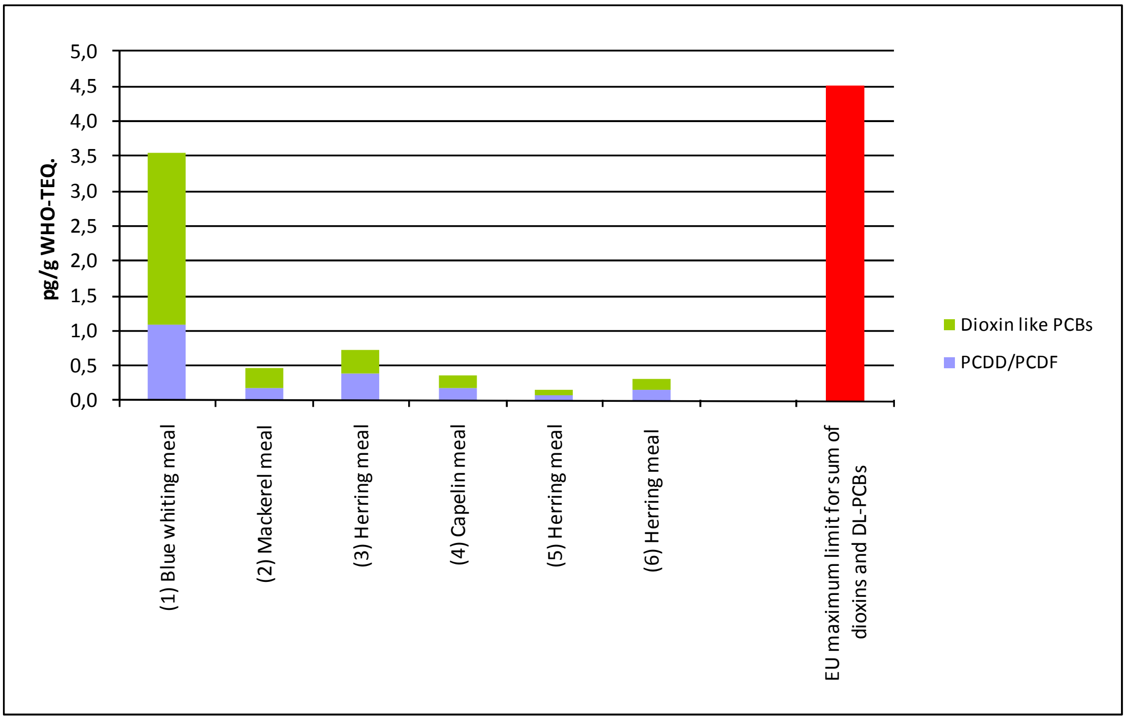

Figure 4: Dioxins and dioxin-like PCBs in samples of fish meal from Iceland in 2008 (in pg/g WHO-TEQ) in relation to maximum limit in EU).

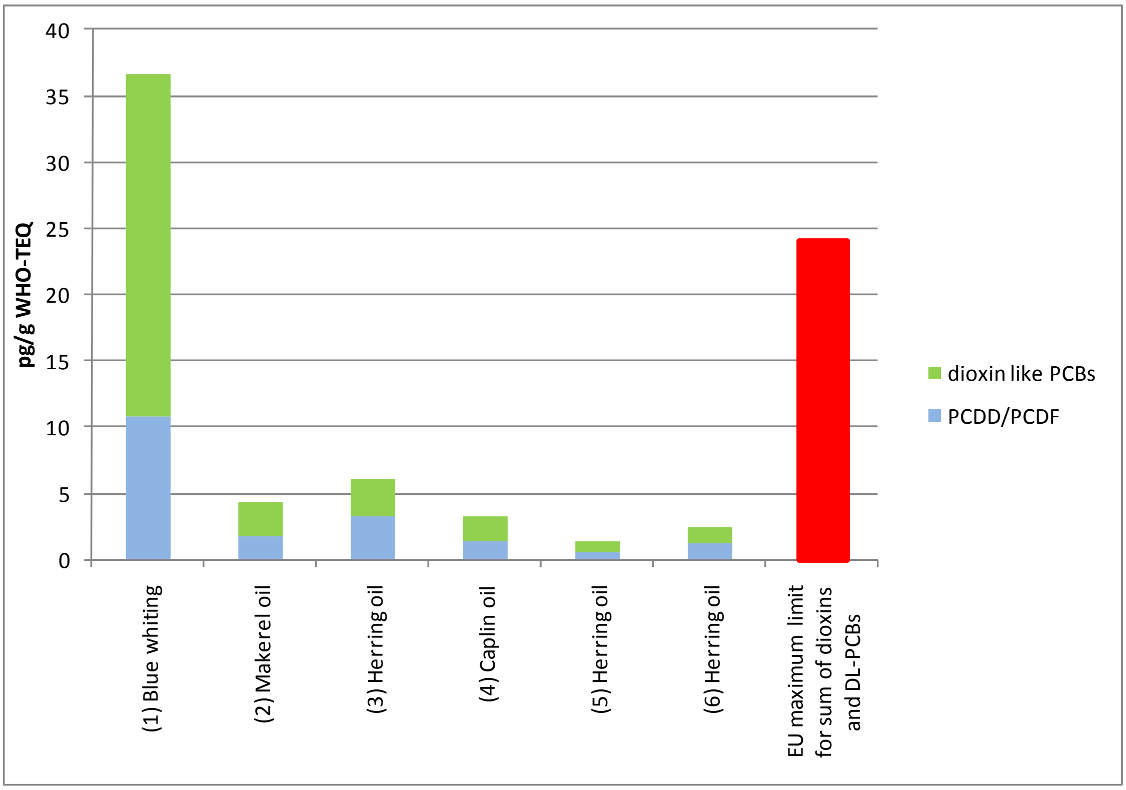

Figure 5: Dioxins and dioxin-like PCBs in samples of fish oil for feed from Iceland in 2008 (in WHO-TEQ) in relation to maximum limit in EU.

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. One of these seven, PCB-118, is classified as a dioxin-like PCB, but the toxicity factor of the other six has not yet been estimated. The EU is working on a risk assessment for marker PCBs in order to establish a maximum level in the nearest future. Maximum levels of marker PCBs exist for some or all of the seven marker PCBs in Germany, Holland, Sweden, USA and Iceland for instance.

5.2.1 Marker PCBs in seafood

The results obtained for the Icelandic fish species are far below the limits for marker PCBs in the countries mentioned above. The maximum level of each of the individual PCB congeners range from 40 µg/Kg to 120 µg/Kg in Germany, Holland and Sweden. In Iceland the limits are much lower. The maximum limit in Iceland for the sum of all seven marker PCBs is 200 µg/Kg wet weight and the maximum limit for the individual congeners range from 10 µg/Kg to 60 µg/Kg. In this research, the highest total concentration for the sum of all seven marker PCBs was measured in Greenland halibut (sample nr. 7), a total of 14 µg/Kg wet weight. That level is less than one tenth of the maximum limits in Iceland. As for the dioxins and dioxin-like PCBs, the highest concentrations of PCBs are found in fish with high lipid content in the filet. For details see Table 1 in the Appendix.

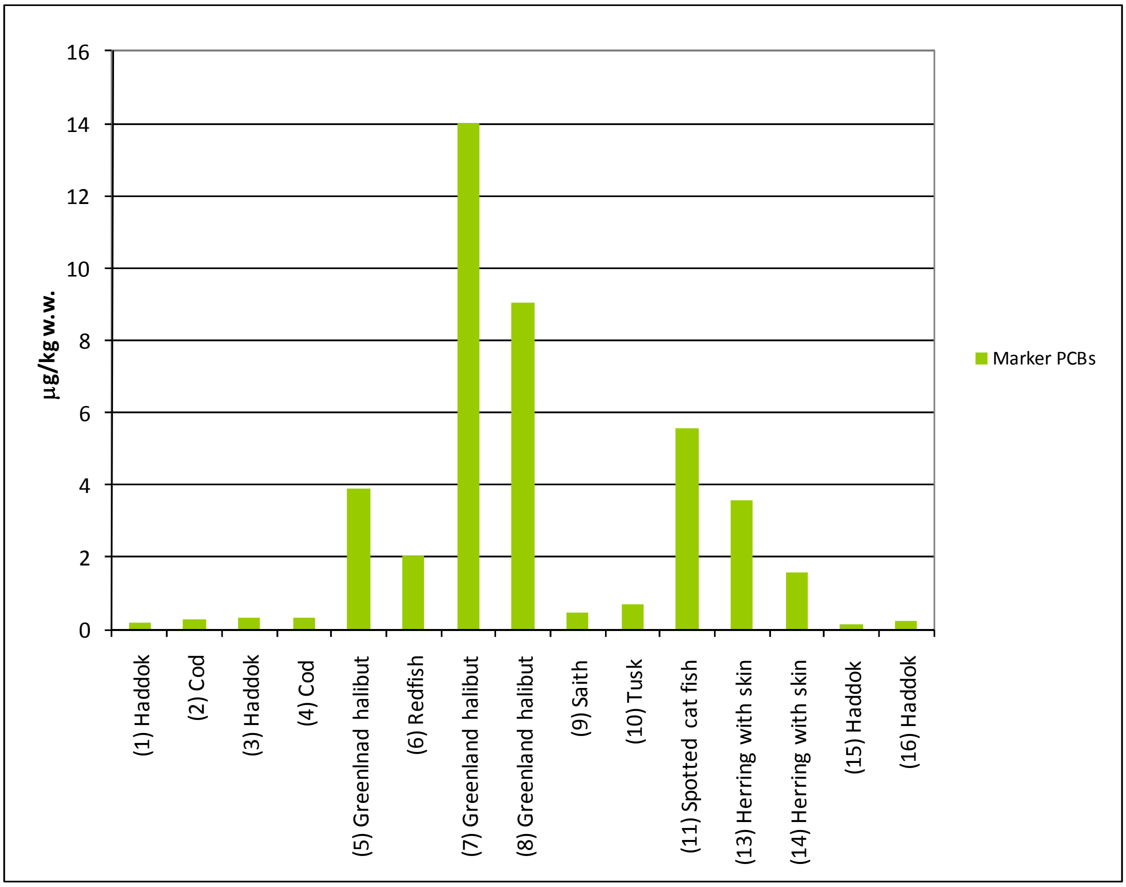

Figure 6: Marker PCBs in the edible part of fish muscle from Iceland in 2008 (in µg/kg wet weight). Number in parenthesis is the sample number designated to each sample, see in Table 1 in Appendix.

5.2.2 Marker PCBs in fish oil for human consumption

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

5.2.3 Marker PCBs in cod liver

The concentration of marker PCBs in the cod livers are reported in Table 2. The concentrations are ranging from 61 to 377 µg/kg. Highest concentration was measured in cod liver nr 5, which also contained the highest value for dioxins and dioxin-like PCBs and the second highest value was measured in cod liver nr 2 as was the case for dioxins and dioxin-like PCBs (se discussion in section 5.1.3). No maximum limits have been set for marker PCBs in fish liver or products derived from fish liver by the EU.

5.2.4 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 3 and 4 in the appendix and in Figures 7 and 8 below. No limits have yet been set for these substances in the EU. The concentration of marker PCBs is more than five times higher in the blue whiting oil and meal samples compared to the other fish oil samples.

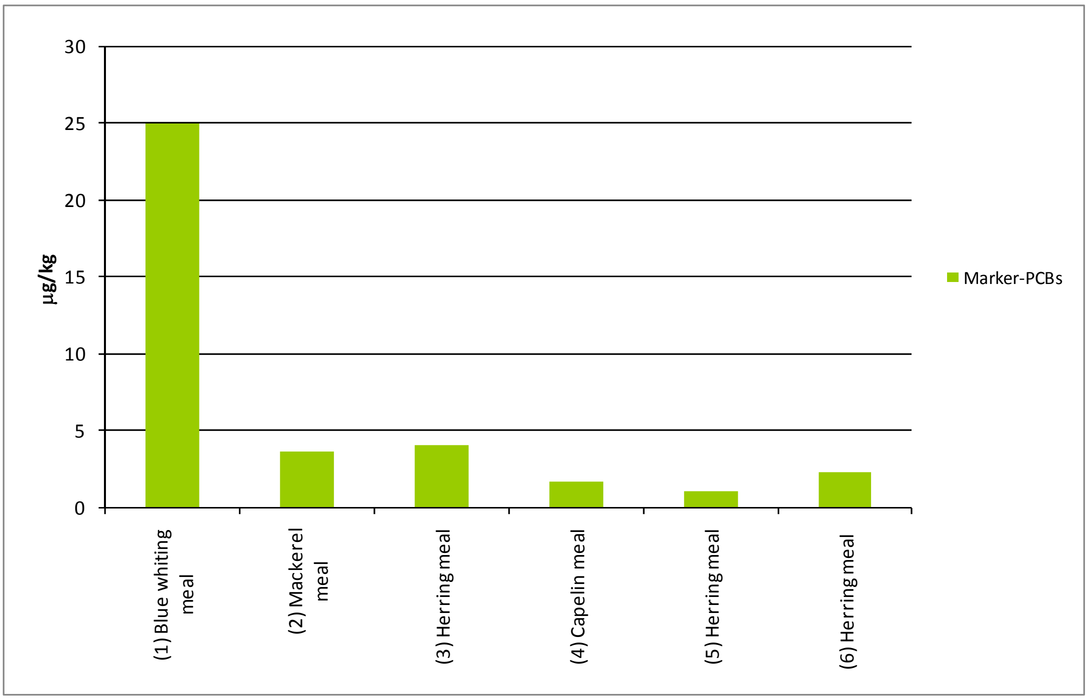

Figure 7: Marker PCBs in fish meal from Iceland in2008.

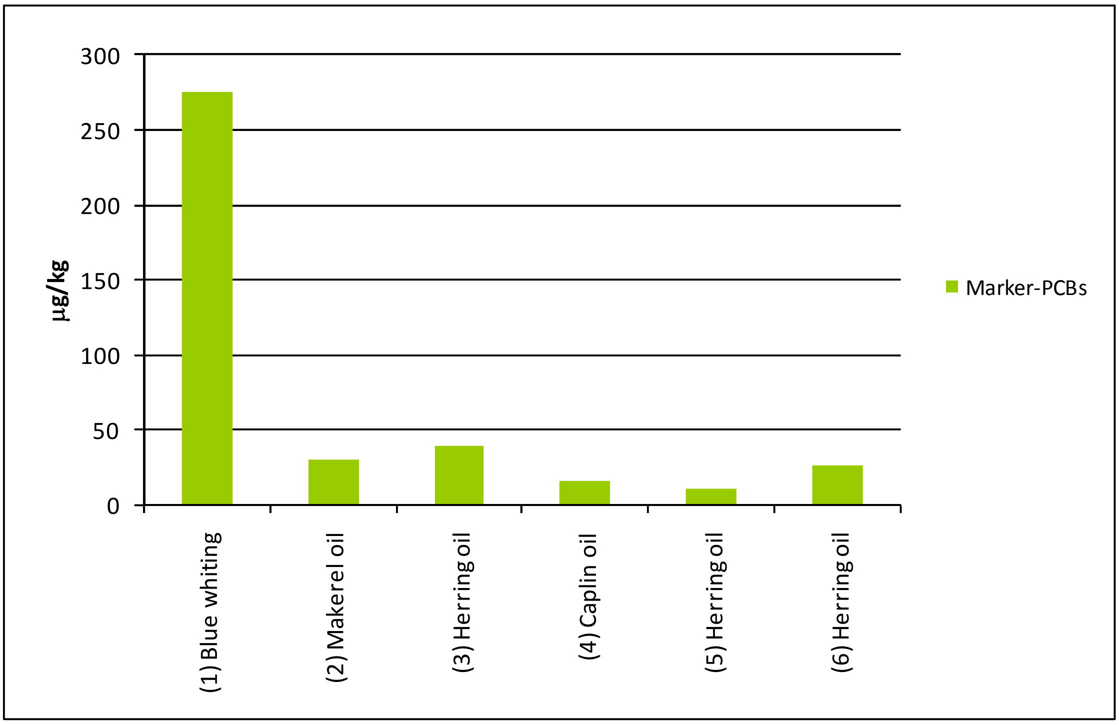

Figure 8: Marker PCBs in fish oils from Iceland in 2008.

5.3 Brominated flame retardants (PBDE)

Brominated diphenyl ethers or PBDE have been accumulating in the environment over the last decade as their use in industry has increased. 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 are 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). Therefore a special emphasis was laid on gathering information on PBDE this year and PBDEs were measured in 15 samples of fish muscle. The PBDE are here reported 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 of the samples tested. No maximum limits have been set for PBDE in seafood

The results in Figure 9 show in general very low level of PBDEs in fish muscle from Icelandic fishing grounds, with halibut as an exception. The results are reported in detail in Table 1 in the appendix.

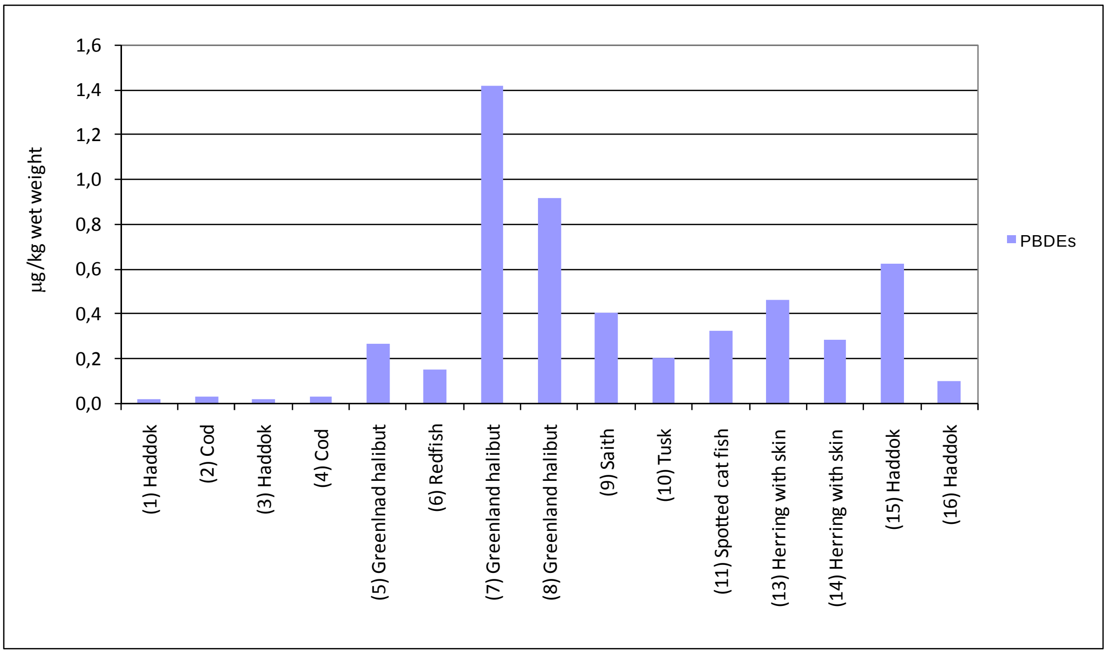

Figure 9: PBDE in fish muscle from Icelandic fishing ground in 2008 in µg/kg wet weight sum of: BDE-28, BDE-47, BDE-66, BDE-100, BDE-99, BDE-85, BDE-154, BDE-153 and BDE-183.

5.3.2 PBDEs in cod liver

PBDEs were not analysed in the cod liver samples.

5.3.3 PBDEs in fish oil and fish meal for feed

This year (2008) a special emphasis was also laid on gathering information on PBDEs in fish meal and fish oil. The results are shown in Table 3 and 4. PBDE in the table 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. As for the marker PCBs, the concentration of PBDEs are higher in the blue whiting meal and oil samples compared to the other meal and oil samples.

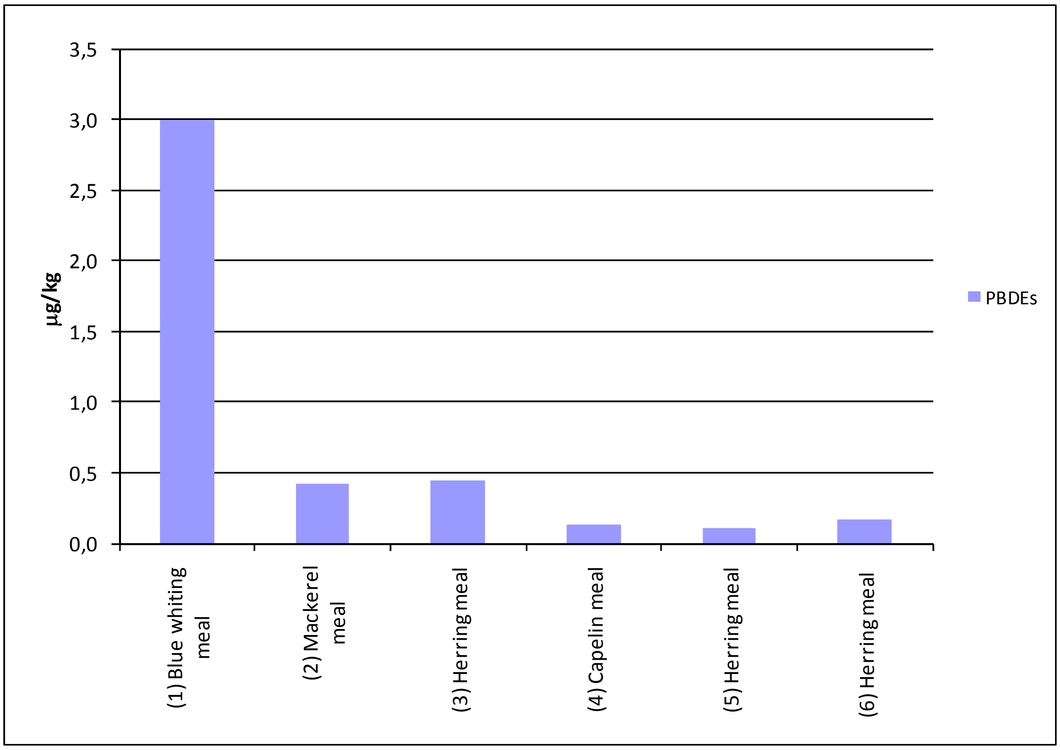

Figure 10: PBDE in fish meal from feed from Icelandic fishing ground in 2008 in µg/kg wet weight sum of: BDE-28, BDE-47, BDE-66, BDE-100, BDE-99, BDE-85, BDE-154, BDE-153 and BDE-183.

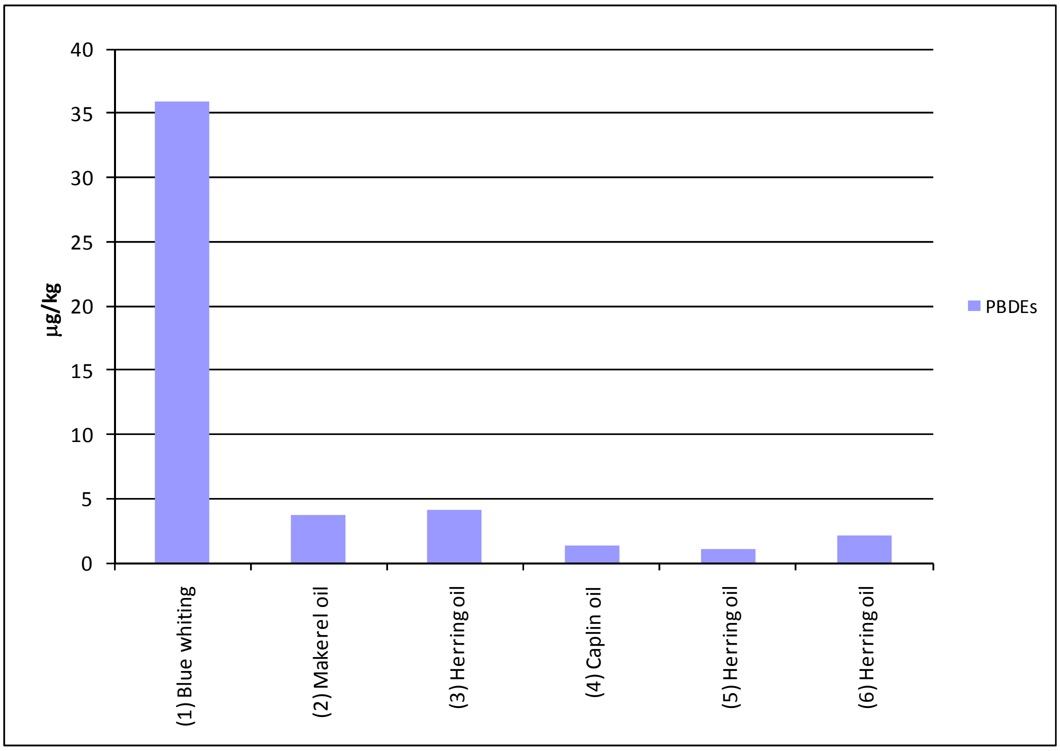

Figure 11: PBDE in fish oil from Icelandic fishing ground in 2008 in µg/kg wet weight sum of: BDE-28, BDE-47, BDE-66, BDE-100, BDE-99, BDE-85, BDE-154, BDE-153 and BDE-183.

5.4 PAH

In the year 2008 emphasis was laid on gathering information on Polyaromatic hydrocarbons (PAH) in edible part of the fish, fish oil and fish meal samples from Iceland. PAHs were not detected in any fish sample, except chrysene/triphenylene was detected and quantified in Greenland halibut sample nr 8 in the concentration of 0,12 µg/kg wet weight. The results from the meal and oil are shown in Tables 8 and 9. The European Union has agreed up on maximum limits for PAH in food (EU regulation No. 208/2005 amending EU regulation No. 466/2001). The new regulation defines maximum limits for benzo(a)pyrene of 2 µg/kg in fish oils for human consumption, the fish oil measured in this program is feed grade, but the results obtained are still well below these limits (Tables 8 and 9). The importance of low levels in feed ingredients should not be underestimated, considering the fact that these compounds are able to bioaccumulate and biomagnificate up the food chain.

5.5 Pesticides

In this chapter, the results for ten different classes of pesticides are discussed. Results are shown in Tables 5 to 7 in the appendix. Without exception, the fish samples contain negligible amount of pesticides. The fish meal and fish oil samples contain more pesticides compared to the edible part of the fish muscle. Blue whiting oil contained higher concentrations of some pesticides compared to fish oil from other species except for HCHs, where capelin oil contained the highest amount. For the meal samples, the blue whiting meal contained the highest concentrations of pesticides in most cases, up to 10 times higher concentration compared to fish meal from other species. All samples contained pesticides below the maximum limits set by EU except for the capelin fish oil which contained higher levels of toxaphene and chlordane than allowed by the EU.

Ten different groups of pesticides are 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 many countries, although it has been banned in many other 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.

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, 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.

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 analyzed 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.

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.

Two E**ndosulfans** are 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.

Other pesticides measured are **Endrin, Heptachlores and Octachlorostyrene**

5.5.1 Pesticides in seafood

The results show very low concentration of all pesticide groups measured in fish from Icelandic waters (for details see Table 5 in the Appendix). As mentioned before, the results are expressed as upper bond, but most of the pesticides are below the limit of detection and therefore the results presented are likely to be an overestimation. Only negligible amounts of ΣDDT, HCB, Chlordane and dieldrin were measured in almost all fish species, δ-HCH was always below LOQ except for a single Greenland halibut sample with concentrations just above LOQ. Figure 12 shows the level of 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 had the highest concentrations of all pesticides.

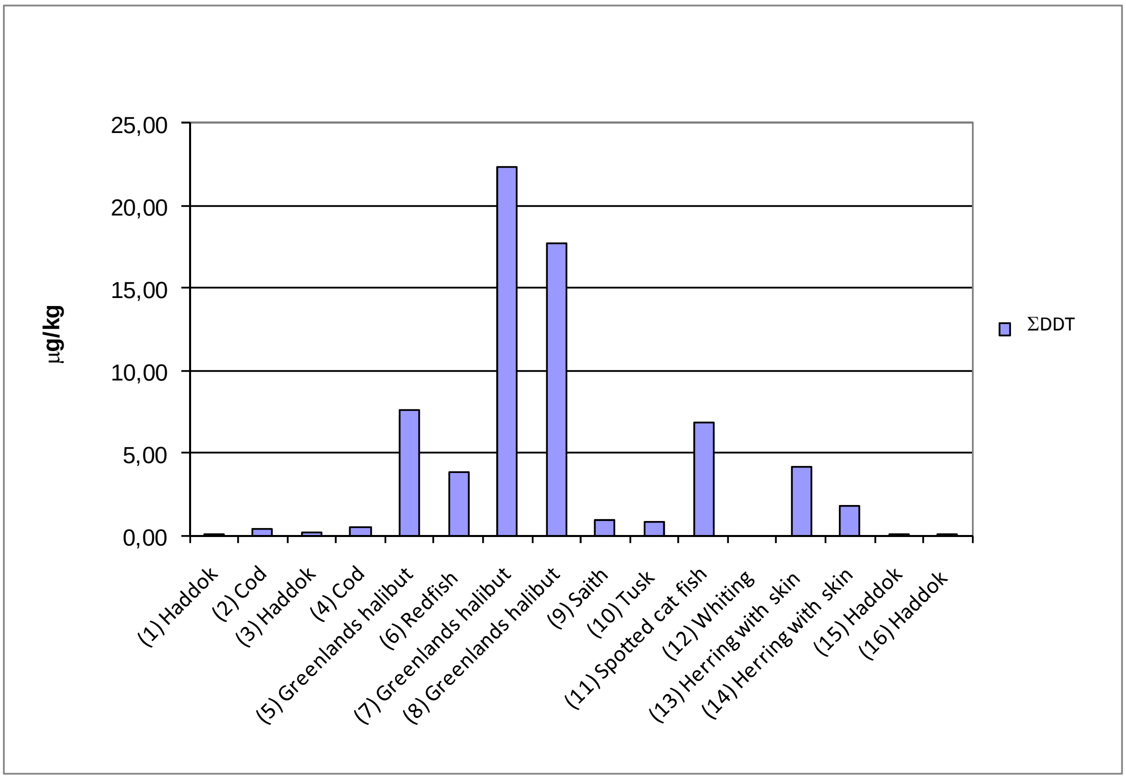

Figure 12: ΣDDT in fish muscle from Icelandic fishing grounds in 2008 in µg/kg wet weight

5.5.2 Pesticides in fish oil for human consumption

No samples of fish oil for human consumption were analysed in the monitoring program this year.

5.5.3 Pesticides in fish meal and fish oil for feed

Several pesticides were measured in fish oil and fish meal for feed (see Table 6 in the Appendix). The concentration of pesticides is highest in the blue whiting meal with the concentrations of ΣDDT, HCB and toxaphene an order of magnitude higher compared to the other meal samples, but under the maximum limits set by the EU.

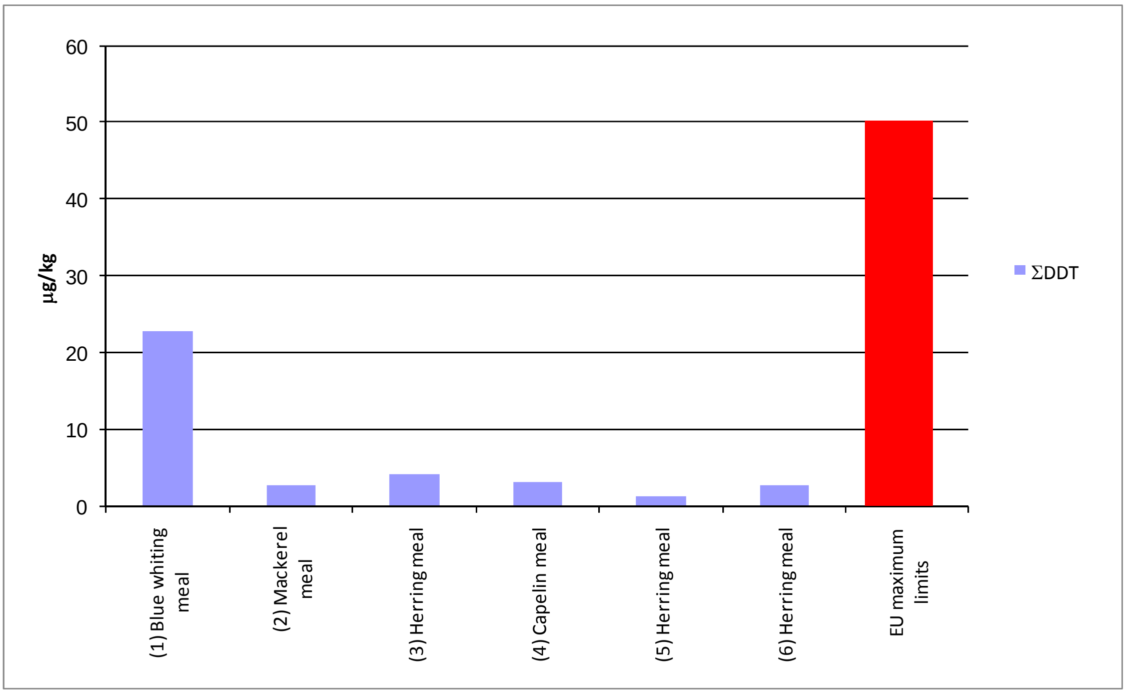

Figure 13: ΣDDT in fish meal from Icelandic fishing grounds in 2008 in µg/kg wet weight

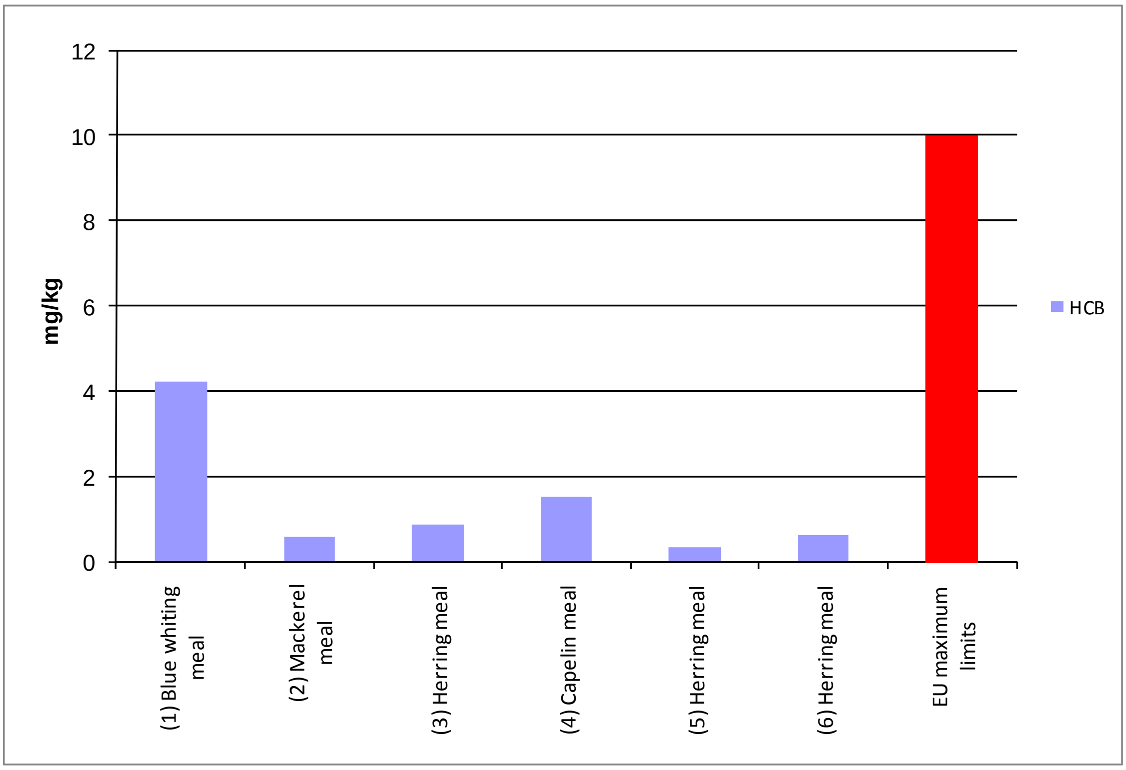

Figure 14: HCB in fish meal from Icelandic fishing grounds in 2008 in µg/kg wet weight

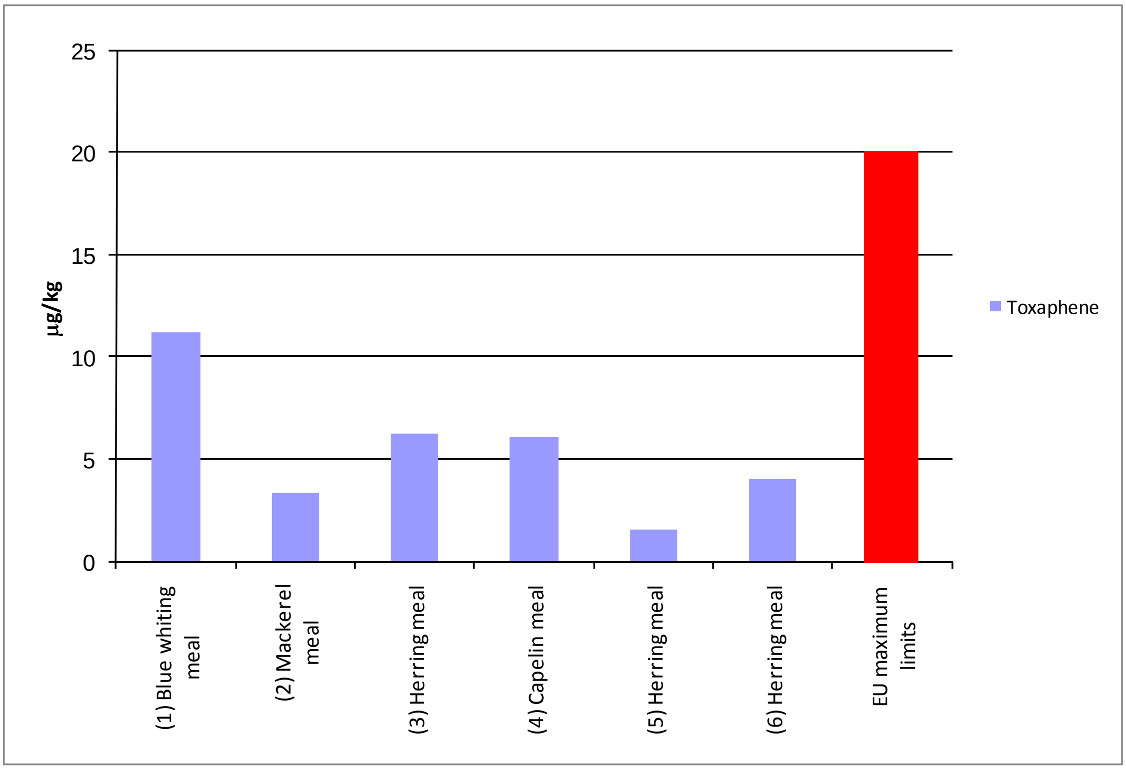

Figure 15: Toxaphene in fish meal from Icelandic fishing grounds in 2008 in µg/kg wet weight

Concentration of pesticides in fish oil is below EU maximum limits in most cases. The exception is the concentration of toxaphene and chlordane in the blue whiting oil that exceeds the EU maximum limits as illustrated in Figure 16 and 17.

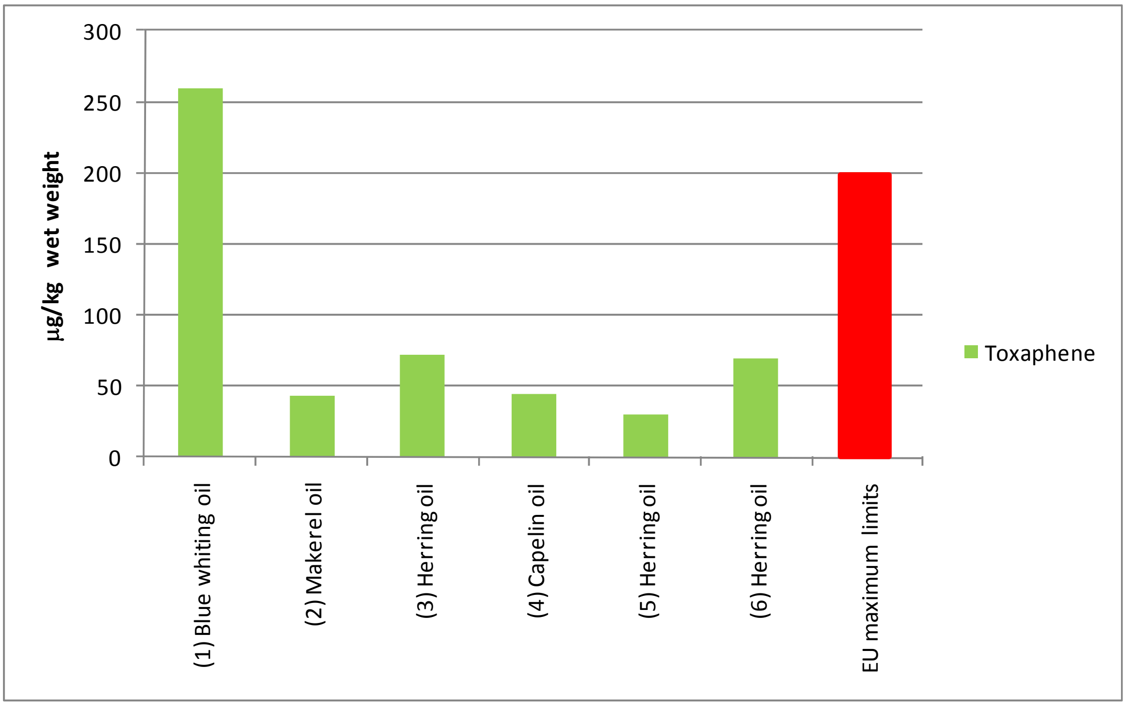

Figure 16: Toxaphene in fish oil from Icelandic fishing grounds in 2008 in µg/kg wet weight.

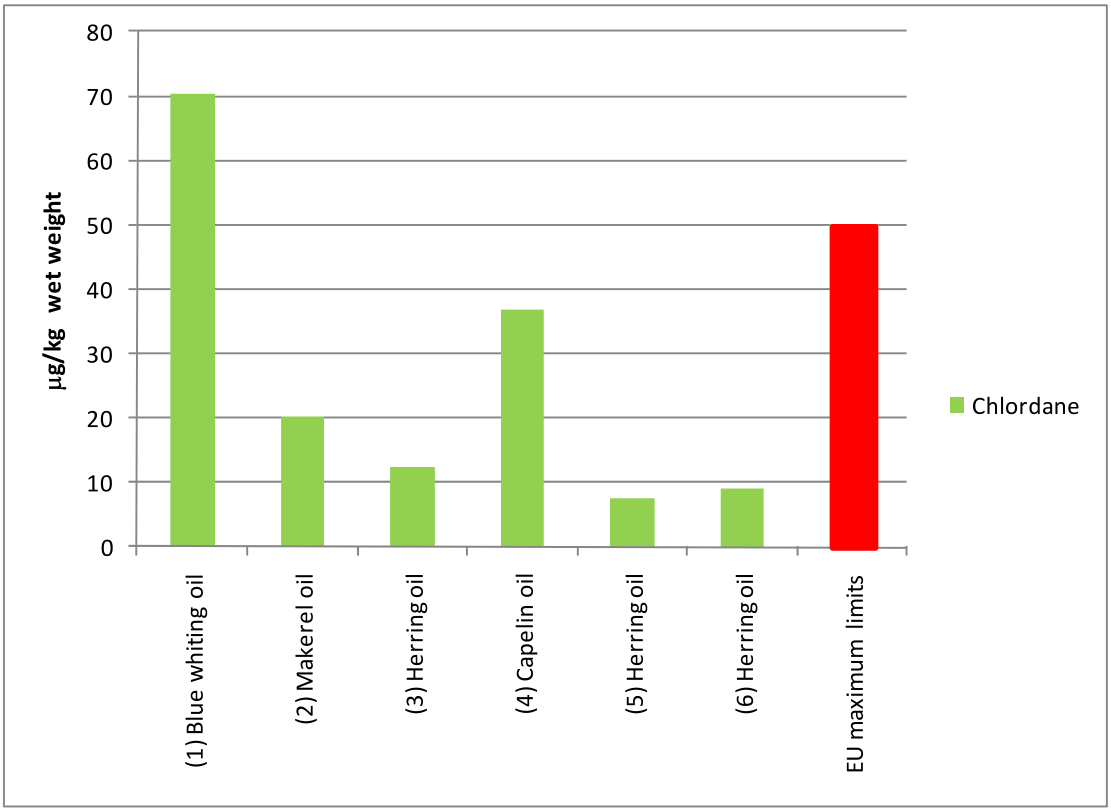

Figure 17: Chlordane in fish oill from Icelandic fishing grounds in 2008 in µg/kg wet weight.

5.6 Inorganic trace elements

No inorganic trace elements were analysed in samples from 2008.

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7 Appendix

7.1 Table 1: Dioxin, PCBs and PBDEs in fish muscle

7.2 Table 2: Dioxin, PCBs and PBDEs in cod liver

7.3 Table 3: Dioxin, PCBs and PBDEs in fish meal for feed

7.4 Table 4: Dioxin, PCBs and PBDEs in fish oil for feed

7.5 Table 5: Pesticides in fish muscle

7.6 Table 6: Pesticides in fish meal for feed

7.7 Table 7: Pesticides in fish oil for feed

7.8 Table 9: PAH in fish oil for feed

7.9 Table 10: PAH in fish meal for feed

Table 1: Dioxins PCBs and PBDE in fish muscle 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
M-2008-2173	1	Haddok	*Melanogrammus aeglefinus*	*NW and N*	*33-39*	0,4	0,015	0,021	0,036	0,18	0,020
M-2008-2174	2	Cod	*Gadus morhua*	*NW and N*	*49-59*	0,6	0,017	0,037	0,054	0,30	0,031
M-2008-2198	3	Haddok	*Melanogrammus aeglefinus*	*NW and N*	*50-57*	0,4	0,018	0,031	0,050	0,31	0,018
M-2008-2197	4	Cod	*Gadus morhua*	*NW and N*	*71-80*	0,60	0,027	0,043	0,070	0,32	0,030
M-2008-2239	5	Greenland halibut	*Reinhardtus hippoglossoides*	*NW and N*		10,10	0,20	0,34	0,54	3,9	0,27
M-2008-2286	6	Redfish	*Sebastes marinus*	*NW and N*	*31-35*	2,70	0,099	0,17	0,27	2,1	0,15
M-2008-4237	7	Greenland halibut	*Reinhardtus hippoglossoides*	*IE, E and SI*	*70-76*		0,80	1,20	2,0	14	1,4
M-2008-4238	8	Greenland halibut	*Reinhardtus hippoglossoides*	*NE*	*51-56*		0,79	0,92	1,7	9,0	0,92
M-2008-4239	9	Saith	*Pollachius virens*	*S,E and SE*	*70-77*		0,033	0,029	0,062	0,49	0,40
M-2008-4240	10	Tusk	*Brosme brosme*	*S*	*36-57*		0,019	0,049	0,068	0,69	0,20
M-2008-4332	11	Spotted cat fish	*Anarhichas minor*	*NW and N*			0,55	0,59	1,1	5,6	0,33
M-2008-4331	13	Herring with skin	*Clupea harengus*	*SW*	*29-35*		0,19	0,21	0,39	3,6	0,46
M-2008-4356	14	Herring with skin	*Clupea harengus*	*SW*	*20-28*		0,091	0,12	0,21	1,6	0,29
M-2008-4357	15	Haddok	*Melanogrammus aeglefinus*	*NE*			0,028	0,017	0,045	0,14	0,62
M-2008-4358	16	Haddok	*Melanogrammus aeglefinus*	*NE*			0,027	0,027	0,054	0,25	0,10
		EU action level					3,00	3,00	*	*	*
		EU maximum limits					4,00	*	8,00	*	*

*No maxinmum 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

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.

Table 2: Dioxins, PCBs and PBDE in cod liver on wet weight

Sample code	Cod liver no.	Cod size [cm]	Estimated age [years]	Liver size [kg]	Lipid content %	PCDD/PCDFs pg/g WHO-TEQ	DL-PCBs pg/g WHO-TEQ	Sum of Dioxins and DL-PCBs pg/g WHO-TEQ	Marker PCBs µg/kg	PBDEs ng/kg
M-2008-3317	1				79,8	3,0	12,0	15	120	na
M-2008-1563	2	92	na	0,298	93,7	4,1	20	24	206	na
M-2008-1586	3	64	6	0,15	77,2	1,9	4,2	6,1	61	na
M-2008-2503	4	86	7	0,132	52,6	9,8	54	64	377	na
M-2008-2509	5	65	6	0,075	57,9	2,0	7,5	9,5	76	na
	EU action level									
	EU maximum limits							25		

* No maximum limits exist in the EU for the substance

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.

Table 3: Dioxins, PCBs and PBDEs in fish meal for feed on wet weight.

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
M-2008-2860	1	Blue whiting meal	*Micromesistius poutassou*	1,1	2,5	3,6	25	3,0
M-2008-2862	2	Mackerel	*Scomber scombrus*	0,17	0,30	0,47	3,6	0,42
M-2008-2864	3	Herring	*Clupea harengus*	0,39	0,34	0,73	4,0	0,44
M-2008-1921	4	Capelin	*Mallotus villosus*	0,19	0,16	0,35	1,6	0,13
M-2008-4451	5	Herring	*Clupea harengus*	0,082	0,08	0,16	1,0	0,11
M-2007-3552	6	Herring	*Clupea harengus*	0,15	0,15	0,31	2,3	0,17
		EU action level		1,00	2,50	3,50	*	
		EU maximum limits		1,25		4,50	*	

* No maximum limits exist in the EU for substances

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

Table 4: Dioxin PCB and PBDE in fish oil for feed on wet weight

Sample code	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
M-2008-2861	1	Blue whiting oil	*Micromesistius poutassou*	11	26	37	276	36
M-2008-2863	2	Makerel	*Scomber scombrus*	1,8	2,5	4,4	31	3,7
M-2008-2865	3	Herring	*Clupea harengus*	3,2	3	6,1	39	4,2
M-2008-1920	4	Capelin	*Mallotus villosus*	1,4	2	3,3	16	1,3
M-2008-4452	5	Herring	*Clupea harengus*	0,6	1	1,4	11	1,1
M-2007-3553	6	Herring	*Clupea harengus*	1,22	1,2	2,4	26	2,1
		EU action level		5,0	14			
		EU maximum limits		6,0		24	*	

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

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

Table 5: Pesticides in fish mucle 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	HCB µg/kg	Σ Heptachlores µg/kg
M-2008-2173	1	Haddok	*Melanogrammus aeglefinus*	*NW and N*	*30-39*	0,40	<0,01	0,04	0,026	<0,01	0,14	0,4	0,13
M-2008-2174	2	Cod	*Gadus morhua*	*NW and N*	*45-59*	0,60	<0,01	0,037	<0,01	<0,01	0,39	0,39	0,12
M-2008-2198	3	Haddok	*Melanogrammus aeglefinus*	*NW and N*	*50-59*	0,40	<0,02	0,034	<0,01	<0,01	0,19	0,36	0,13
M-2008-2197	4	Cod	*Gadus morhua*	*NW and N*	*75-89*	0,60	<0,01	0,036	0,012	<0,01	0,47	0,45	0,12
M-2008-2239	5	Greenlands halibut	*Reinhardtus hippoglossoides*	*NW and N*	*50-59*	10,10	0,21	0,77	0,2	0,019	7,6	3,9	0,76
M-2008-2286	6	Redfish	*Sebastes marinus*	*NW and N*	*30-35*	2,70	0,040	0,14	0,029	<0,01	3,9	0,75	0,28
M-2008-4237	7	Greenlands halibut	*Reinhardtus hippoglossoides*	*NE,E and SE*	*70-79*		0,12	0,60	0,14	<0,03	22	4,2	0,75
M-2008-4238	8	Greenlands halibut	*Reinhardtus hippoglossoides*	*NE*	*50-59*		0,11	0,61	0,16	<0,01	18	4,3	0,68
M-2008-4239	9	Saith	*Pollachius virens*	*S,E and SE*	*70-80*		0,0060	0,028	0,008	<0,001	0,95	0,21	0,03
M-2008-4240	10	Tusk	*Brosme brosme*	*S*	*40-60*		0,002	0,0077	0,0019	<0,001	0,86	0,089	0,023
M-2008-4332	11	Spotted cat fish	*Anarhichas minor*	*NW and N*	*30-90*		0,030	0,11	0,03	<0,005	6,9	1,5	0,46
M-2008-4331	13	Herring with skin	*Clupea harengus*	*SW*	*30-39*		0,072	0,27	0,050	<0,03	4,1	0,73	0,51
M-2008-4356	14	Herring with skin	*Clupea harengus*	*SW*	*20-29*		0,10	0,39	0,11	<0,03	1,8	0,58	0,51
M-2008-4357	15	Haddok	*Melanogrammus aeglefinus*	*NE*	*50-59*		0,0037	0,027	0,007	<0,001	0,13	0,4	0,014
M-2008-4358	16	Haddok	*Melanogrammus aeglefinus*	*NE*	*30-39*		0,0037	0,023	0,0061	<0,0009	0,12	0,29	0,013
		EU maximum limits					50	50	50		500	50	50

Table 5 (cont): Pesticides in fish muscle on wet weight

Sample code	Fish sample no.	Sample name	Date of catch	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
M-2008-2173	1	Haddok	*Melanogrammus aeglefinus*	*NW and N*	*30-39*	0,40	0,16	0,23	0,01	0,05	0,62	0,078	0,03
M-2008-2174	2	Cod	*Gadus morhua*	*NW and N*	*45-59*	0,60	0,23	0,39	0,01	0,01	0,61	0,14	0,13
M-2008-2198	3	Haddok	*Melanogrammus aeglefinus*	*NW and N*	*50-59*	0,40	0,13	0,19	0,01	0,03	0,64	0,053	0,023
M-2008-2197	4	Cod	*Gadus morhua*	*NW and N*	*75-89*	0,60	0,19	0,44	0,014	0,027	0,62	0,13	0,13
M-2008-2239	5	Greenlands halibut	*Reinhardtus hippoglossoides*	*NW and N*	*50-59*	10,10	4,5	13	0,071	0,77	0,9	4,0	2,8
M-2008-2286	6	Redfish	*Sebastes marinus*	*NW and N*	*30-35*	2,70	1,1	4,2	0,026	0,13	0,87	1,0	0,88
M-2008-4237	7	Greenlands halibut	*Reinhardtus hippoglossoides*	*NE,E and SE*	*70-79*		4,0	32	0,23	0,89	1,6	13	16
M-2008-4238	8	Greenlands halibut	*Reinhardtus hippoglossoides*	*NE*	*50-59*		4,5	22	0,12	0,73	4,6	19	20
M-2008-4239	9	Saith	*Pollachius virens*	*S,E and SE*	*70-80*		0,16	0,82	0,021	0,023	0,094	0,19	0,22
M-2008-4240	10	Tusk	*Brosme brosme*	*S*	*40-60*		0,075	0,52	0,063	0,004	0,083	0,23	0,36
M-2008-4332	11	Spotted cat fish	*Anarhichas minor*	*NW and N*	*30-90*		2,8	10	0,063	0,27	0,58	1,7	2,5
M-2008-4331	13	Herring with skin	*Clupea harengus*	*SW*	*30-39*		2,0	9,1	0,02	0,098	3,1	2,9	3,2
M-2008-4356	14	Herring with skin	*Clupea harengus*	*SW*	*20-29*		1,5	3,8	0,02	0,19	2,3	0,59	0,46
M-2008-4357	15	Haddok	*Melanogrammus aeglefinus*	*NE*	*50-59*		0,057	0,083	0,11	0,039	0,11	0,024	0,022
M-2008-4358	16	Haddok	*Melanogrammus aeglefinus*	*NE*	*30-39*		0,055	0,17	0,013	0,0032	0,095	0,034	0,026
		EU maximum limits					50			50		100	

Table 6: Pesticides in fish meal for feed on wet weight

Sample code	Meal sample no.	Sample name	β-HCH mg/kg	α-HCH mg/kg	γ-HCH mg/kg	δ-HCH mg/kg	Σ DDT mg/kg	HCB mg/kg	Σ Heptachlores mg/kg
M-2008-2860	1	Blue whiting meal	0,042	0,057	0,020	<0,007	23	4,2	1,1
M-2008-2862	2	Mackerel meal	0,039	0,077	0,038	<0,008	2,7	0,57	0,27
M-2008-2864	3	Herring meal	0,058	0,095	0,056	<0,009	4,1	0,85	0,39
M-2008-1921	4	Capelin meal	0,12	0,093	0,10	<0,007	3,0	1,5	0,32
M-2008-4451	5	Herring meal	0,052	0,11	0,033	<0,01	1,2	0,34	0,27
M-2007-3552	6	Herring meal	0,049	0,10	0,035	<0,007	2,7	0,62	0,29
		EU maximum limits	10	20	200		50	10	

Table 6 (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
M-2008-2860	1	Blue whiting meal	3,6	11	0,38	0,49	n.d.	10,5	8,5
M-2008-2862	2	Mackerel meal	0,89	3,3	0,023	0,12	n.d.	2,2	1,3
M-2008-2864	3	Herring meal	1,7	6,2	0,031	0,23	n.d.	2,3	1,7
M-2008-1921	4	Capelin meal	2,4	6,1	0,017	0,46	n.d.	5,0	3,7
M-2008-4451	5	Herring meal	0,93	1,6	0,006	0,074	n.d.	1,2	1,1
M-2007-3552	6	Herring meal	1,1	4,0	0,027	0,069	n.d.	2,1	2,4
		EU maximum limits	10	20		10	100	20	

LOQ for Endosulfan sulfate= 0,1 µg/kg. α-endosulfane= 0,04 µg/kg, β-endosulfane0 0,7 µg/kg

Table 7: Pesticides in fish oil for feed on wet weight

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	HCB µg/kg	Σ Heptachlores µg/kg
M-2008-2861	1	Blue whiting oil	1,2	0,24	0,24	<0,1	366	52	8,7
M-2008-2863	2	Makerel oil	1,6	0,48	0,48	<0,1	30	5,5	2,8
M-2008-2865	3	Herring oil	2,2	0,71	0,71	<0,1	50	9,3	3,6
M-2008-1920	4	Capelin oil	4,1	1,5	1,5	0,11	34	16	4,0
M-2008-4452	5	Herring oil	0,97	0,36	0,36	<0,1	15	4,0	3,4
M-2007-3553	6	Herring oil	1,7	0,43	0,43	<0,1	42	7,9	3,8
		EU maximum limits	100	200	2000		500	200	

Table 7 (cont): Pesticides in fish oil for feed on wet weight

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
M-2008-2861	1	Blue whiting oil	51	260	4,6	8,6	n.d.	70,2	64
M-2008-2863	2	Makerel oil	12	43	0,20	1,4	n.d.	20,1	12
M-2008-2865	3	Herring oil	18	72	0,34	2,5	n.d.	12,5	12
M-2008-1920	4	Capelin oil	26	44	<0,1	4,3	n.d.	37	25
M-2008-4452	5	Herring oil	10	30	<0,1	0,71	n.d.	7,6	4,8
M-2007-3553	6	Herring oil	16	70	0,28	1,2	n.d.	9,1	10,0
		EU maximum limits	100	200		50	100	50	

LOQ for Endosulfane sulfate=1 µg/kg, α-endosulfane=0,5µg/kg, β-endosulfane= 6µg/kg

Table 8 : PAH in fish oil wet weight

Sample code	Oil sample no.	Sample name	Phenanthrene µg/kg	Anthracene µg/kg	Fluoranthene µg/kg	Pyrene µg/kg	Benzo[b]naphtho [2,1-d] thiophene µg/kg	Benzo[c] phenanthrene µg/kg	Benzo[a] anthracene µg/kg	Chrysene - Triphenylene µg/kg	Benzo[b+j+k] fluoranthene µg/kg
M-2008-2861	1	Blue whiging oil	4,2	0,56	1,3	<3	0,12	<0,1	<0,1	0,58	<0,1
M-2008-2863	2	Makerel oil	<2	<0,1	<1	<0,7	<0,1	<0,1	<0,1	0,63	<0,1
M-2008-2865	3	Herring oil	4,8	0,18	<1	<1	0,13	<0,1	<0,1	0,81	<0,1
M-2008-1920	4	Capelin oil	<2	0,20	<1	<1	<0,1	<0,1	<0,1	0,80	<0,1
M-2008-4452	5	Herring oil	5,6	0,17	<1	<2	<0,1	<0,1	<0,1	0,34	<0,1
M-2007-3553	6	Herring oil	<2	<0,1	<1	<0,9	<0,1	<0,1	<0,1	0,27	<0,1
		EU maximum limits									

Table 8 (cont): PAH in fish oil on wet weight

Sample code	Oil sample no.	Sample name	Benzo[ghi] fluoranthene µg/kg	Benzo[e] pyrene µg/kg	Benzo[a] pyrene µg/kg	Indeno[1,2,3-cd] pyrene µg/kg	Benzo[ghi] perylene µg/kg	Anthanthrene µg/kg	Dibenz[ah] anthracene µg/kg	Coronene µg/kg
M-2008-2861	1	Blue whiging oil	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,5
M-2008-2863	2	Makerel oil	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,5
M-2008-2865	3	Herring oil	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,5
M-2008-1920	4	Capelin oil	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,5
M-2008-4452	5	Herring oil	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,5
M-2008-3553	6	Herring oil	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,5
		EU maximum limits								

Table 9: PAH in fish meal on wet weight

Sample code	Meal sample no.	Sample name	Phenanthrene µg/kg	Anthracene µg/kg	Fluoranthene µg/kg	Pyrene µg/kg	Benzo[b]naphtho [2,1-d] thiophene µg/kg	Benzo[c] phenanthrene µg/kg	Benzo[a] anthracene µg/kg	Chrysene - Triphenylene µg/kg	Benzo[b+j+k] fluoranthene µg/kg
M-2008-2860	1	Blue whiting meal	3,7	0,16	1,9	<0,7	<0,1	<0,1	<0,1	0,29	0,27
M-2008-2862	2	Mackerel meal	<2	<0,2	<0,7	<0,6	<0,1	<0,1	<0,1	0,25	<0,1
M-2008-2864	3	Herring meal	<2	<0,1	<0,7	<0,5	<0,1	<0,1	<0,1	<0,1	<0,1
M-2008-1921	4	Capelin meal	7,7	0,23	<0,7	<0,9	<0,1	<0,1	<0,1	0,18	<0,1
M-2008-4451	5	Herring meal	2,7	<0,2	<0,7	<0,9	<0,1	<0,1	<0,1	0,13	<0,1
M-2008-3552	6	Herring meal	<2	<0,1	<0,7	<0,7	<0,1	<0,1	<0,1	<0,1	<0,1
		EU maximum limits									

Table 9 (cont): PAH in fish meal on wet wight

Sample code	Meal sample no.	Sample name	Benzo[ghi] fluoranthene µg/kg	Benzo[e] pyrene µg/kg	Benzo[a] pyrene µg/kg	Indeno[1,2,3-cd] pyrene µg/kg	Benzo[ghi] perylene µg/kg	Anthanthrene µg/kg	Dibenz[ah] anthracene µg/kg	Coronene µg/kg
M-2008-2860	1	Blue whiting meal	0,72	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,5
M-2008-2862	2	Mackerel meal	0,13	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,5
M-2008-2864	3	Herring meal	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,5
M-2008-1921	4	Capelin meal	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,5
M-2008-4451	5	Herring meal	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,5
M-2008-3552	6	Herring meal	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,5
		EU maximum limits								