TEMPORAL TRENDS IN ORGANIC CONTAMINANTS IN SALMONID FEEDS SAMPLED THROUGH THE NORWEGIAN FISH FEED MONITORING PROGRAM

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Introduction

With increasing production of farmed salmonids, especially Atlantic salmon (*Salmo salar*) and Rainbow trout (*Oncorhynchus mykiss*), the amount of produced feed and use of ingredient have been steadily increasing. The amount of fish feed sold in Norway exceeded 900 000 tons in 2005 and with such a volume it is a major flow of organic material with ecological impacts.

Feed for the salmonid aquaculture species is produced by a mixture of commercially available ingredients where the most important is fish meal, as the principal source of protein, and fish oil, as the principal source of lipids. These two major ingredients are complimented and exchanged by a row of other ingredients, both terrestrial based and other marine sources, for both protein and lipids. As carnivorous fish, salmonids can only to a limited extent utilise the cheaper carbohydrates, so the levels of these are low, even though some is used both as a minor energy source and also for it binding capacities.

It has been shown to some extent the fish is what it eats. That implies that the level of both essential nutrients such as iodine[1] and selenium[2] and toxic contaminants such as cadmium[3] and mercury[4] in the farmed fish is partly decided by the feed level. The same has also been suspected[5] and also shown[6,7] to be the case for organic contaminants, especially dioxin.

In order to secure that fish fillet is within safe limits for contaminants, it is therefore essential that the levels of contaminants in complete feeds is properly controlled so that eventual elevated levels of contaminants can be detected and contaminated feeds taken off the market. The primarily responsible for this control is the feed manufacturer, but in addition, also an open control program to study temporal trends and secure public data and data on compliance with feed regulations and flow of contaminants are important.

To this end, a control programme for fish feed was established in Norway since early about 1990 and the data from the programme provides important information about the development of contaminant level in the marine environment in addition to provide data for feed and food security measures.

Materials and methods

Since its starts by the Directorate of Fisheries, the Norwegian Feed Monitoring program has gradually increased both in numbers of sampled fish feed and later also feed ingredients and especially in the numbers of components to be analysed. Today this monitoring programme is one of several programmes under the jurisdiction of the Norwegian Food Safety Authority (NFSA) that is run by the National Institute of Nutrition and Seafood Research.

In the programme samples of complete feed and feed ingredients have been collected by local inspectors from the NFSA after a predefined yearly plan. The last four years, the number of samples taken has varied from 650 to 800. The aim is to do one sampling per 1000 tons complete feedstuff produced. In the planning it is selected how many analyses it is necessary and economically feasible to perform on the both contaminants but also on illegal and legal feed additives to ensure a control of safe feed and fair and honest trade on feeds. The samples are done so that all Norwegian fish feed plants are sampled according to their production volume. The fish feed plants are obliged by law to let the NFSA inspectors do their sampling.

After sampling, samples were shipped to laboratories and normally analysed for *Salmonella* before further handling. At the laboratories samples are divided into 3-4 subsamples where one is kept as back-up sample and the other divided to different analyses.

PCBs, DDT and metabolites, dioxins (dioxins and furans) dioxin-like PCBs and brominated flame retardants has been analysed at our laboratory by accredited analytical methods (Norwegian Accreditation Authority, Lab; Test 050). DDT which includes the o,p and p,p forms of DDT, DDE and DDD, has been analysed since the start in 1996 along with PCB and metals. Dioxins were added to the program in year 2000. The first two year dioxins was included, the five and ten feed samples respectively, were analysed by the Norwegian Air Research Institute. Brominated flame retardants (PBDE) were included in year 2003. A row of other pesticides in addition to DDT have further been added to the programme and data are now available. However, only results for PCBs and dioxins will be discussed here.

The data has been reported to the Norwegian competent Authority which before 2004 was the Directorate of Fisheries and since it has been the Norwegian Food Safety Authority.

Results and Discussion

As there are being done many comparisons between feed complete feedingstuff to different animals it is important to also analyse the major composition of the fish feed. During the surveillance the major constituents have been analysis with emphasis in controlling for compliance with given values. This show that the feed is very much a predator feed, high in lipids and proteins. The lipid content is important to explain level of organic contaminants and as seen from Table 1, the lipid level is high in salmonid feed, with a stable mean value of about 31-32 % during the last 4 years.

Table 1. Content of protein, lipid, water and ash in complete feedstuff for salmonids produced in Norway in the period 2002 to 2005. The number of analyses was about 200 in 2002 but has been reduced to about 50 in the following years.

Year	Protein (g/kg)	Lipids (g/kg)	Ash (g/kg)	Water (g/kg)
2002	406	321	64	54
2003	407	320	66	56
2004	403	313	72	61
2005	410	312	77	61

With the high content of lipids it is clear the salmonid feed is in risk of obtaining organic contaminants. The PCBs has been known to be one of the most stable of the organic contaminants with a high use over many years in many products up to 1980 when it was banned for use in new products in Norway. However, the products where PCB was used is still not out of circulation further sources, both point sources and diffuse sources to the marine environment adding to burden in the marine environment, also in Norway. Figure 1 shows that the concentration of PCB as PCB7 has only had a minor change form the first measurement in this programme in 1996 until the last measurement series in 2005.

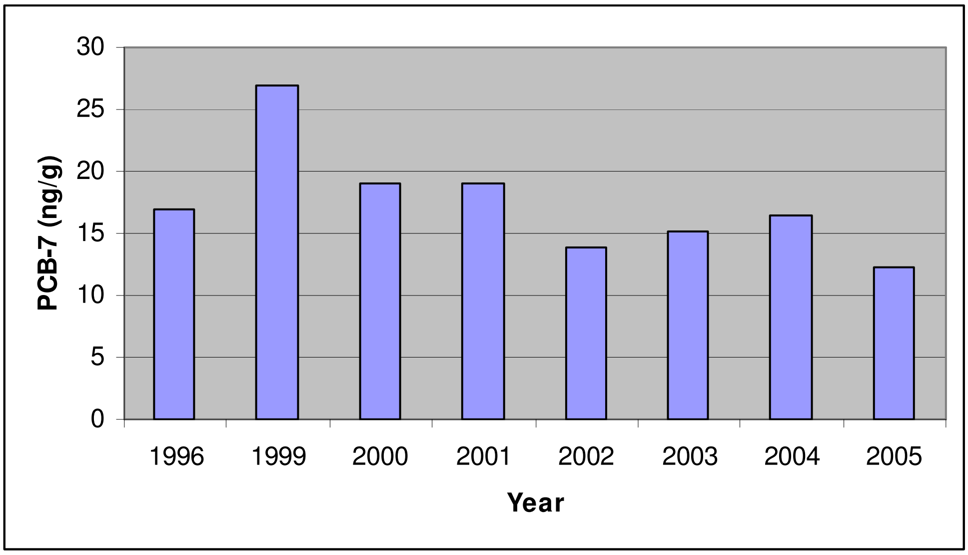

Figure 1. Mean values of PCBs (ng/g feed) in Norwegian fish feed during the control period of 10 years. The number analysed feed/year has varied from only 10 in 2002 to 46 in 2005.

Figure 1 shows the development of PCB_7 concentration in salmonid feed over a period of 10 years. There is a slow trend of declining values in the Norwegian fish feed. The first measurements showed a mean value of 17 µg/kg PCB, while it was 13 µg/kg in 2005. In fact one could expect more variance in these values as less contaminated oil from South America has been introduced.

Also vegetable oil has to some extent been a replacement for fish oil. The PCB level in vegetable oil is in the area of 10% of what is found in fish oil. Interestingly, PCB in vegetable oil has further quite a different congener composition with the dioxin like PCB-118 as the dominating congener. As sees in Figure 2, however, there is nearly at complete overlap of PCB congeners form fish oil and fish feed from both 2002 and 2005. The pattern from vegetable oil is also shown, as well as the PCB-pattern found in a recently investigated release of PCB in a Norwegian fjord[8] with PCB from paint as the source.

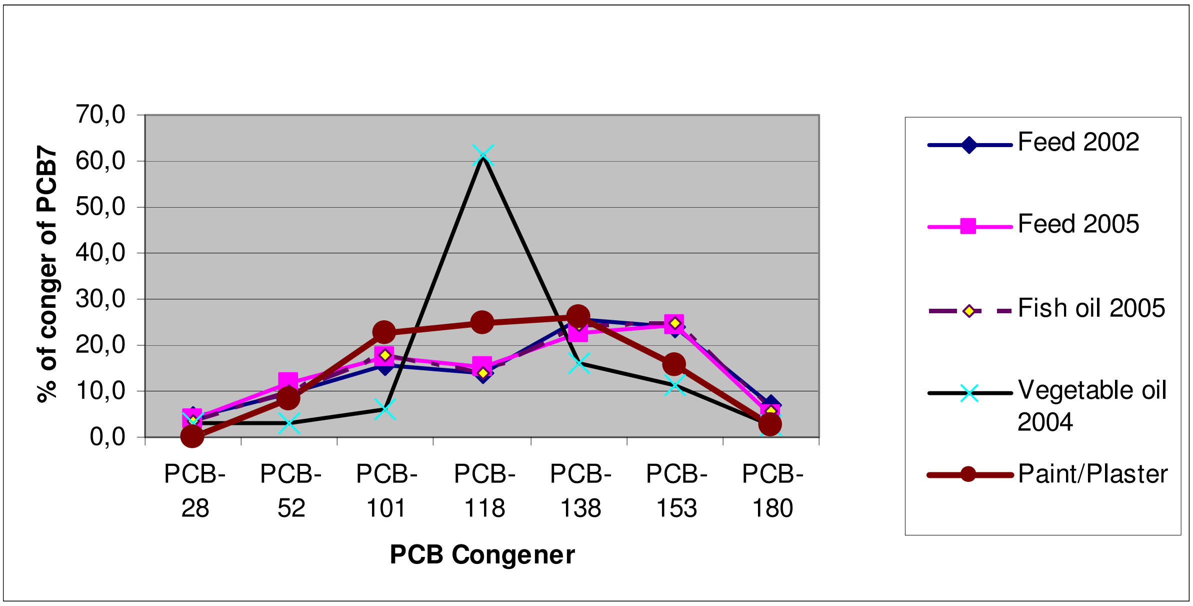

Figure 2. PCB congener pattern in fish feed (2002 and 2005) together with PCB patter in fish oil, vegetable oil and in paint remnants forum in the marine environment.

The first analysis of dioxin in this programme was initially done with 5 feed samples in 2000 and 10 in 2001 but as the method came in house in 2002, the number of samples analysed has increased considerably. The first analyses (Table 2) showed that the mean level was quite close to the limit introduced two years later. However for sum PCDDs+PCDFs, the level has since the showed a decreasing trend and the mean value of dioxins in 2005 was about 1/3 of the level found in 2000. The dioxin like PCBs was analysed for the first time in 2001 and during the 4 years of sampling this has not shown any clear trend.

Table 2. Concentration (mean and range) of dioxins (PCDDs+PCDFs) and dioxin like PCBs (non-orto + mono+orto PCBs) in samples of complete feedingstuff for salmonids sampled in Norway in the period 2000 to 2005.

Year	**Dioxins (PCDD+PCDF) ng WHO TEQ/kg Mean and range**	**EU-limit From 2002 (88 % DM)**	**Dioxin like PCBs ng WHO TEQ/kg Mean and range**	**TOTAL-TEQ ng WHO TEQ/kg**	**EU-limit From 2006 ng WHO TEQ/kg**
2000	**1,50 (0,50-3,50)**				
2001	**1,26 (0,56-2,23)**		**2,31 (0,99-4,25)**	**3,57**	
2002	**1,19 (0,28-2,59)**	**2,25**	**1,23 (0,78-3,55)**	**2,42**	
2003	**1,02 (0,26-2,45)**	**2,25**	**1,78 (0,62-3,81)**	**2,80**	

2004	**0,74 (0,14-2,14)**	**2,25**	**1,88 (0,32-5,06)**	**2,63**	
2005	**0,54 (0,08-1,42)**	**2,25**	**1,53 (0,49-3,61)**	**2,07**	**7,00**

As it is also shown that DL PCB is more likely to be accumulated than dioxins[7], this partitioning does not favour a very large decrease in farmed fish fillets during the period.

By use of these data and assuming that the organic contaminants are evenly distributed throughout the fish, it is also possible to perform a coarse quantification of the flow of the contaminants based on different years where the fish data are based on NIFES searchable database for contaminants in fish (www.nifes.no/seafood data).

Most governments in Europe and also in Norway have put in large resources to reduce the cycle of PCBs since it was forbidden in new use in 1980. These measures has included defining PCB containing materials as toxic waste and make it obligatory to deliver such material for further handling. The rather slow response in the environment for the measures could question their efficiency.

For the aquaculture industry, however, there are other strategies to reduce the concentrations of these substances in complete feedstuff and thereby further reducing the levels in fish fillets. These include more traditional measures such as choosing fish oils low in contaminants, exchanging fish oils with plant oil and also cleaning and refining techniques to reduce the content of contaminants in oils used for feed manufacturing.

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