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FISH MEAL AND FISH OIL DIOXIN LEVELS

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SUMMARY

Bearing in mind that several EU governments have been monitoring the dioxin levels in food products including fish over the past 20 years and have found that the levels in the food basket are within acceptable WHO guidelines, it would seem unreasonable to set such tight limits on dioxin levels in animal feedingstuffs that they would be less than those normally reflected in feedstuffs over the past few years.

Except for industrial accidents or criminal acts toxic levels of dioxins have never been found in foods or animal feedingstuffs in the past. Any limits proposed by the EU on animal feedingstuffs will not in future prevent industrial accidents taking place but will provide a framework by which the industry can be routinely monitored to ensure that dioxin levels do not increase unexpectedly in the future.

Fish meals and fish oils have similar levels of dioxin and furans to the wild fish, most of which are also consumed as food. Levels found in a recent survey of meals and oils range from 180 to 46,961 pg/kg fat.

With the introduction of environmental pollution controls it will be possible to decrease some of these levels in the future.

In view of the difficulty of accurately analysing for the trace amounts of dioxins and furans in fish products from environmental origin, it is strongly recommended that at this stage limits should not be introduced for their content in those products used for animal or fish feeding. Competent laboratories should first be identified and data obtained for a wide range of fishery products.

Before the EU member states agree limits on dioxins which could have a detrimental effect on food supplies it is necessary to carefully monitor the situation and to provide appropriate risk assessment in order to define figures which are helpful to the maintenance of food supplies and the continued health of the population.

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1. What is fish meal and oil?

Fish meal and oil are prepared from wild fish taken from the seas and oceans. The majority of these fish species are either used as food for human consumption or processed into fish meal and fish oil (e.g. pilchard, sardine, anchovy, herring). A minority of the fish species are used only for manufacture of fish meal (e.g. sandeel, menhaden). About 10% of the fish material used to manufacture meal and oil is from trimmings from edible fish mainly caught for human food (e.g. cod).

Annually about 30 million tonnes of fish are processed into meal and oil worldwide which is equivalent to about one-third of the world's catch.

In Europe about 5.5 million tonnes of fish or fish trimmings are processed into meal and oil.

2. What are the Main Fish Species Used for Meal and Oil?

Table 1 summarises the species used for the manufacture of fish meal and oil in different countries exporting these products to Europe or produced in Europe itself.

Table 1

Production of Fish Meal and Oil in Europe and Main Exporters to Europe: Main Species		
Country	Species	Available for human food
Peru	Anchovy	Yes
	Sardine	Yes
	Jack mackerel	Yes
	Pacific mackerel	Yes
Chile	Anchovy	Yes
	Sardine	Yes
	Jack mackerel	Yes
Iceland	Herring	Yes
	Capelin	Female
	Trimmings	Yes
	Blue whiting	Yes
Norway	Herring	Yes
	Capelin	Female
	Sandeel	No
	Blue whiting	Yes
	Norwegian pout	No
	Trimmings	Yes

USA	Menhaden Trimmings Pollock	No Yes Yes
Spain	Trimmings Sardine	Yes Yes
Portugal	Trimmings Sardine	Yes Yes
Italy	?	?
Germany	Trimmings	Yes
France	Trimmings	Yes
Belgium	Trimmings	Yes
Denmark	Sandeel Sprat Herring Norway pout	No Yes Yes No
UK	Sandeel Herring Blue whiting Trimmings Mackerel	No Yes Yes Yes Yes
Ireland	Mackerel Herring Trimmings	Yes Yes Yes
Faroe Islands	?	?

3. How much fish meal/oil consumed in Europe

Of the world's consumption of fish meal, nearly 23% (1.56 million tonnes) is consumed in Europe based on average figures for the years 1993-1997 (see Table 2). Average production for the whole of Europe over this period is 1.1 million tonnes (Table 2); thus production is lower than consumption. Bearing in mind that there is some export from European producers outside of Europe there is a requirement for imports in order to meet consumption in excess of 0.5 million tonnes principally supplied by Peru and Chile (See Table 3).

With regard to fish oil, average level over the past five years of consumption in Europe is 686 TT greater than 50% of total world consumption. The principle consuming countries as shown in Table 2 are Norway, UK, Netherlands, Spain and Germany. In Norway and UK the main driving force of consumption in recent years has been the salmon industry requiring high levels of fish oil in the diet. Germany and Netherlands have mainly used fish oil after refining and hydrogenation as an edible food.

Table 2

CONSUMPTION AND PRODUCTION OF FISH MEAL AND FISH OIL.

	FISH MEAL		**FISH OIL**	
	CONSUMPTION	PRODUCTION	CONSUMPTION	PRODUCTION
	Avg. 93-97	Avg. 93-97	Avg. 93-97	Avg. 93-97
UK	286	52	111	11
Norway	243	230	188	90
Spain	121	69	77	11
Netherlands	114	0	116	0
Denmark	113	340	34	115
France	101	22	13	4
Germany	63	22	75	8
E.Europe	133	49	16	0
Rest of Europe	385	319	56	146
TOTAL EUROPE	1,559	1103	686	385
TOTAL WORLD	6,818	6,755	1,338	1,281

Table 3

Average Fish Meal and Fish Oil Imports into Europe (1993-1997)					
	Chile	Peru	USA	Japan	Panama
Fish Meal*	218	458			
Fish Oil**	53	73	60	1	4

*1994-1997 figures used
**Import data only available for UK, Germany and Netherlands

Production of fish oil in Europe at about 385 TT is well below the consumption figure necessitating significant imports from USA, Peru and Chile (see Table 3 for the average imports from these countries over the period 1993-1997 into Europe).

4. Fish Meal Consumption in the European Community

In the last five years for which information is available (1993-1997), the average consumption of fish meal in the European Community by farm animals including farmed fish was 1.032 million tonnes (see Table 4). Consumption by poultry and pigs was similar, 31% and 32% respectively; aquaculture consumed 25%. The remainder (12%) went into petfood and feed for dairy cows, beef cattle and sheep.

Within the European Community the countries with the biggest consumption of fish meal are the UK, Spain, Netherlands, Denmark and

France. Consumption by species within each country tends to reflect the animal and fish production within that country. For example, in the UK, Spain, France and Belgium poultry account for the largest share of the fish meal consumption; in the Netherlands, Denmark and Germany pigs represent the largest consumers. In the UK, Denmark, Spain, France and Italy the highly developed aquaculture industry is a significant fish meal consumer.

Table 4

FISH MEAL CONSUMPTION IN EUROPEAN UNION (1993-1997)
Thousand Tonnes (TT)

	UK	Spain	N'lands	Denmark	France	Italy	Germany	Belgium	Ireland	Others	EU Total
Total	286	121	114	113	101	89	63	49	30	66	1032
Poultry	103	45	29	15	37	27	5	30	7	25	323
Pigs	52	25	75	50	15	20	35	16	10	30	328
Aqua[1]	77	35	0	40	35	35	20	0	10	7	259
Other	54	16	10	8	14	7	3	3	3	4	122

5. Fish Oil Consumption in the European Community

In the last five years for which data is available the average consumption of fish oil in the European Community was 412 thousand tonnes per annum (Table 5). Most of this (74%) was used in food production. Use in producing fish feeds for aquaculture was the next largest outlet (17%). This use in aquaculture is growing rapidly whereas the use in food production is tending to decline reflecting the reduction in hardening of both fish and vegetable oils for the food industry. Other uses include incorporation in petfood diets and a small amount which is used for industrial purposes such as the manufacture of leather, paint production and non toxic biodegradable lubricating oils, etc.

The countries in the European Community that are the largest users of fish oil are the Netherlands, UK and Germany. This reflects the large hardening industry in those countries. Use in aquaculture feeds is greatest in the UK reflecting the fact that the UK is a major producer of salmon and trout; in Denmark and Italy where aquaculture also accounts for a significant use of fish oil, both countries have significant trout production and, in addition, Italy has developing production of seabass and seabream.

Table 5

FISH OIL CONSUMPTION IN EUROPEAN UNION (1993-1997)
Thousand Tonnes (TT)

	N'lands	UK	Germany	Denmark	Italy	Belgium	Spain	France	Others	EU Total
Total	116	111	75	34	22	18	16	13	7	412
Food[2]	106	76	67	16	4	16	11	2	5	303
Aqua[1]	0	25	0	15	15	0	2	10	1	68
Indust[3]	10	10	8	3	3	2	3	1	1	41

[1]Aqua=Aquaculture [2]Food=Food Production [3]Indust=Industrial

The use of fish oil in fish feeds in Europe in the past few years has risen partly due to the increase in fish farming and partly due to higher levels of incorporation in the diets. This year for example salmon production is expected to exceed 500 thousand tonnes (TT) including Norway with EC countries; trout production will reach 320 TT and Mediterranean sea bass and sea bream 80 TT. To produce 1 kg of fish requires 1.4 kg feed for salmon, 1.2 kg feed for trout and 1.6 kg feed for sea bass and bream. This feed contains typically 30% to 35% fat for salmon and trout, and 20% for bass and bream. The use of fish oil is typically 25% in feeds for salmon and trout and 15% in feeds for bass and bream. Feeds required and the fish oil use are estimated to be as follows:

	Feed (TT)	Fish oil use (TT)
Salmon	700	175
Trout	350	88
Sea bass and bream	120	18
TOTAL		281

It is estimated that this year fish oil use in aquaculture feeds in the EU and Norway will be 281 TT of which around 130 TT will be used by Norway; that is, 151 TT use of fish oil for aquaculture in the EU.

6. Dioxin values in fish meal and fish oil

Table 6 shows the results (expressed as I-TEQs PCDD and PCDF) of an international collaborative work of recent analyses (all during 1999) of dioxins and furans in fish meals and fish oils taken from important international sources. Where possible the species of the fish have been identified.

The results show a wide spread of levels of dioxins and furans reflecting anticipated pollution levels within these geographical areas. In general levels in the S.E. Pacific are lower than those found in European waters and N.W. Atlantic.

The levels of these contaminants found in fish meals and fish oils reflect those levels found in the wild fish. Processing of the caught fish into meal and oil neither adds or takes away the dioxin levels (see Section 7).

Table 6

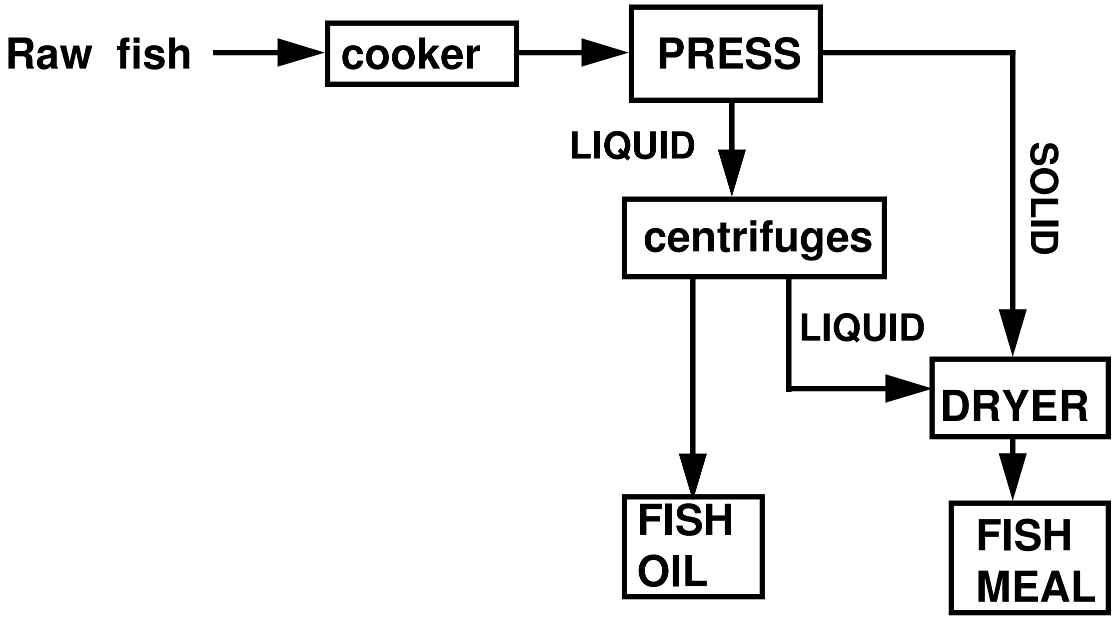
Dioxins and Furans in fish meals and fish oils expressed as I-TEQs← pg/kg fat				
Area	Species (if known)	Meal↑ or Oil	I-TEQs (pg/kg fat)	Ref
Asia	Tuna	O	890	10
	Unknown	M	1280	10
S.E. Pacific	Anchovy	M	180	1
	Anchovy	O	270	1
	Anchovy	O (sr→)	230	1
	Anchovy	O (sr)	260	1
	Jack mackerel	M	410	1
	Jack mackerel	O	170	1
	Unknown	M	1600	2
	Unknown	M	1622 (e)	4
	Unknown	M	2104 (e)	4
	Unknown	O	1000	2
	Unknown	O	2600	6
	Unknown	O	2200	8
Europe	Blue whiting	O	7004	5
	Blue whiting	M	20304	5
	Blue whiting	M	7323	5
	Blue whiting	M	20804	5
	Capelin	M	1260	3
	Capelin	M	1070	3
	Capelin	M	1020	3
	Capelin	O	5610	3
	Capelin	O	1500	3
	Capelin	O	2400	6
	Capelin	O	1560	6
	Capelin	O	2100	6
	Capelin	O	2310	6
	Capelin	O	2510	9
	Herring	M	8530	3
	Herring	M	3200	3
	Herring	M	16280	6
	Herring	M	17920	6
	Herring	O	6810	3
	Herring	O	5294	5
	Herring	O	6138	5
	Herring	O	8500	6
	Herring	O	4500	6
	Herring	O	4060	6
	Herring	O	2320	6
	Herring	O	5950	6
	Herring	O	5290	6
	Herring	O	2980	6

	Herring	O	2920	6
	Herring	O	5780	7
	Herring	O	5230	7
	Mixed species	O	12377	5
	Norway pout	M	8820	6
	Norway pout	M	9230	6
	Norway pout/blue whiting	O	11281	5
	Sandeel	M	13278	5
	Sandeel	M	12605	5
	Sandeel	M	5537	5
	Sandeel	M	10909	5
	Sandeel	M	6200	5
	Sandeel	M	10546	5
	Sandeel	M	7176	5
	Sandeel	M	6838	5
	Sandeel	O	9955	5
	Sandeel	O	6605	5
	Sandeel	O	6607	5
	Sandeel	O	6289	5
	Sandeel	O	6115	5
	Sandeel	O	5066	5
	Sandeel	O	7400	5
	Sandeel	O	8810	5
	Sandeel	O	9280	9
	Sprat	M	23669	5
	Sprat	M	18239	5
	Sprat	M	37090	5
	Sprat	M	20804	5
	Sprat	M	13843	5
	Sprat	M	38794	5
	Sprat	M	46961	5
	Sprat	O	17275	5
	Sprat	O	20107	5
	Trimmings	M	7140	7
	Trimmings	M	6520	7
	Trimmings	M	6200	7
	Unknown	M	5500	2
	Unknown	M	6500	2
	Unknown	O	1000	2
	Unknown	O	5520	6
	Unknown	O	12600	6
	Unknown	O	5080	6
	Unknown	O	5520	9
	Unknown	O	12600	9
	Unknown	O	5080	9
Gulf & N.W. Atlantic	Menhaden	O	11500	6
	Unknown	O	11500	8

←Calculated using international toxic equivalent factors; WHO-TEQs in Appendix Table 1 (excluding PCBs) are similar
↑Meal generally contains 7-12% fat; figures expressed on fat basis not product basis
→Semi-refined

7. Processing of fish meal and fish oil to reduce dioxin levels

A simplified form of the process of manufacture of fish meal and oil is as follows:



Research conducted by IFOMA has shown that the type of dryer in the fish meal operation has no effect on the dioxin levels in the finished fish meal.

Similar fish raw material was processed in one of three types of dryer commonly used by the industry, namely a direct fired dryer (highest temperature), a steam dryer (lower temperatures) or an indirect hot air dryer which can be used for production of low temperature fish meal. The results showed the same levels of dioxins in all three types of meals produced through different dryers.

As dioxins are localised in the fat component, reducing the fat level in fish meal will reduce the dioxin level, provided the results are expressed on a product weight basis rather than fat basis.

As can be seen from the above diagram the purpose of the fish meal process is to separate the protein and oil fractions as best as possible, as well as removing water. However a typical process does not totally remove fat from the fish meal leaving residual fat levels of 7-12%.

Fat levels can be reduced to lower levels by the use of solvent extraction as an additional processing step. However this process is expensive and has not found favour in the fish meal industry.

The oil separated during processing carries most of the dioxin with it. Typically 1,000 kg of fish containing 50 kg of oil (5%), would have 37 kg of the oil separated from the protein (meal) and stored as a separate product.

Traditionally this oil has been used to manufacture margarines and cooking fats. In order to prepare the fish oil in a suitable format for such usage it is neutralised, bleached, hydrogenated and part-refined. This additional process results in a considerable decrease in dioxins and PCBs.

Taking the additional process step by step the levels of organochlorine contaminants in fish oil were found to be almost constant during the first and second steps namely neutralisation and bleaching.

The deodorisation step (third step) reduced the amount of contaminants with PCB levels going to about half the concentration of the crude fish oil.

The fourth phase consisting of hydrogenation and further deodorisation would reduce levels further (Ref: G Hilbert et al, Chemosphere, Volume 37 Number 7 pages 1241-1252 1998).

Deodorisation implies a steam distillation at high temperature and vacuum. During degassing under vacuum, the oil is heated to 180ºC and kept there for two hours. Water vapour (7% based on oil mass) is finely distributed in the oil during the process, stripping off volatiles at a surface pressure of around 5mbar.

Refining and hydrogenation is an expensive process costing about US$220 per tonne. Furthermore the process results in the elimination of the valuable omega-3 polyunsaturated fatty acids from the fish oil product.

Thus this process would not be suitable for animal feed because it would remove the components which the nutritionists wish to include in the feed namely omega-3 polyunsaturated fatty acids and would add considerable costs to the production of farmed fish in particular.

There may be other processes available which would reduce the dioxin levels in fish oil, but these have not been researched or elaborated into commercial possibilities.

9. Analysis and control of dioxins in feed ingredients

It should be borne in mind that dioxin analysis is variable with coefficients of variation of about 70% or more, time consuming (4 weeks) and expensive (US$1,500 per sample). See Appendix 1 for more details.

Results from tests of dioxins in fish meal and oil from five laboratories would appear to bear out the variability found in the above ring test as the figures below show:

DIOXIN ANALYSIS - VARIATION BETWEEN LABORATORIES pg/kg fat (I-TEQ)						
Species	Meal or Oil	Hamburg Lab 1	Kriel Lab 2	Canada Lab 3	Poland Lab 4	Denmark Lab 5
Sprat	O	17,275				30,000
Sandeel	O	6,289	8,300	14,200		
Sandeel	M	12,605			1,450[1]	
Sprat	M	13,843	15,700	6,300		
Sandeel	M	6,200	4,700	2,500		
Sandeel	M	10,546	10,300	4,200		
Sandeel	M	7,176	5,900	2,600		

[1]Outlier?

Clearly if there is to be legislative controls on dioxin levels in feed ingredients then the commercial realities have to be considered taking into account the feasibility and costs of taking samples for analysis prior to execution of trade contracts and deliveries.

In an extremely competitive agricultural environment where purchasers are obtaining supplies on a hand to mouth basis it is essential to ensure that controls are in place which do not impede normal trade flows of animal feed ingredients which have been used over many years with the satisfaction of all parties.

Dioxins should be added to lists of undesirable substances and products in animal feedingstuffs and monitored in the same way as arsenic and mercury without requiring laboratory certificates as part of every day trade but placing the responsibility of ensuring that deliveries of raw materials are within normal and acceptable limits with the producer having responsibility to ensure that in house screening is in place by taking random samples in order to ensure that they conform with the requirements of the EU.

10. Conclusion

Bearing in mind that several EU governments have been monitoring the dioxin levels in food products including fish over the past 20 years and have found that the levels in the food basket are within acceptable WHO guidelines, it would seem unreasonable to set such tight limits on dioxin levels in animal feedingstuffs that they would be less than those normally reflected in feedstuffs over the past few years.

Except for industrial accidents or criminal acts toxic levels of dioxins have never been found in foods or animal feedingstuffs in the past. Any limits proposed by the EU on animal feedingstuffs will not in future prevent industrial accidents taking place but will provide a framework by which the industry can be routinely monitored to ensure that dioxin levels do not increase unexpectedly in the future.

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With the introduction of environmental pollution controls it will be possible to decrease some of these levels in the future.

In view of the difficulty of accurately analysing for the trace amounts of dioxins and furans in fish products from environmental origin, it is strongly recommended that at this stage limits should not be introduced for their content in those products used for animal or fish feeding. Competent laboratories should first be identified and data obtained for a wide range of fishery products.

Before the EU member states agree limits on dioxins which could have a detrimental effect on food supplies it is necessary to carefully monitor the situation and to provide appropriate risk assessment in order to define figures which are helpful to the maintenance of food supplies and the continued health of the population.

APPENDIX 1

The Content of Dioxins, Furans and PCBs in Fish Meal and Fish Oil - Their Measurement and Reliability of the Methods

Analysis of Fish Meal and Fish Oil for Dioxins, Furans and PCBs

Polychlorinated hydrocarbons are generally analysed using a mass spectrometer. Following ionisation, the charged particle passes through a magnetic field where it is deflected; the angle of deflection reflects the size (mass) of this particle. The atomic mass identifies the PCH. Before the material can be subjected to the mass spectrometer it must first be concentrated and run alongside standard samples of the compounds to be analysed in order to determine their content.

More details of a procedure for the analysis of dioxins, furans and PCBs used by the UK Ministry of Agriculture, Central Science Laboratory in York are given in the Appendix. This laboratory has taken part in a number of ring tests to establish the accuracy of the methods they have used (see Analysis - Accuracy of Results).

Analysis - Requirements Laboratory should Meet

It is recommended that if a laboratory is to produce reliable figures for the content of dioxins, furans and PCBs in a raw material which are being picked up from the environment and, therefore, will be present at extremely low levels (usually expressed in millions of a part per million - pg/g of fat) the following requirements must be met:-

1. All 17 congeners of the dioxins and furans shown in the table below should be measured with the possible exception of OCDD and OCDF which has a much lower TEF value. Of the PCBs the congeners PCB 126 and PCB 169 non-*ortho* forms should be included, if they are to be used to arrive at tolerable daily intakes (TDI) provided by WHO.
2. The laboratory should have taken part in a ring test and/or be able to provide data for analysis of a reference sample such as that supplied by the French Reference Bureau.
3. The method used should routinely incorporate at least 13 and preferably 15 standards for the dioxin and furan congeners, and standards for at least the non-*ortho* PCBs 126 and 169, if these are being determined.
4. The solvents required to remove the fat from the materials should be high grade to ensure freedom from PCHs.

Analysis - Accuracy of Results

Several ring tests have been performed to assess the accuracy of the analysis for dioxins and furans in a number of human foodstuffs. The World Health Organisation organised a ring test to study the dioxins and furans in human milk and blood[1]. The laboratories were free to choose their own analytical methods. Laboratories generally used similar but not always identical methods. Some of the samples used were spiked with the compounds being detected; other samples contained only the compounds coming from the environment. The concentration of the dioxins (PCDD) and the furans (PCDF) analysed, on a volume basis, ranged from 0.02 to 18 parts per trillion in milk and from 0.01 to 10 parts per trillion in blood serum. This range of values is probably wider than that found in fish, when expressed on a fat basis. Nevertheless it is believed that this range is sufficiently close to that found in fish products for the accuracies reported to be applied to fish products.

All the laboratories participating were experienced in the analysis and regarded as "WHO qualified laboratories". Even so, accuracy was not high; the mean co-efficient of variation for the data from 11 of the 16 laboratories was in the range 20% to 30%; data from 4 laboratories had a mean co-efficient of variation in the range of 60% to 70%. In other words, a confident laboratory working well could only expect to get to within ±25% of the actual value, with 95% probability; other laboratories could have a variability of ±65% assuming they were no worse than some of the 'WHO qualified' laboratories. However, as many laboratories doing this type of analytical work may not be able to afford the necessary standards required to identify all the required congeners satisfactorily, errors in results from other laboratories that have not taken part in ring tests may be even higher.

So far there does not appear to have been a published ring test involving the non ortho PCBs - that is, the PCBs known to be highest in dioxin like toxicity. These compounds are known to be difficult to identify with the risk that some of the none toxic PCBs may be mistakenly identified as the more toxic congeners, PCB126 and PCB169.

[1] WHO Int. Intercalibration study on Dioxins and Furans in Human Milk and Blood 1992 Anal. Chem. 64 No. 24 pp. 3109-3117

Appendix Table 1. WHO TEF's for human risk assessment based on the conclusions of meeting in Stockholm, Sweden, 15-18 June 1997

Congener	TEF value	Congener	TEF value
Dibenzo-p-dioxins		Non-ortho PCB's	
2,3,7,8-TCDD	1	PCB 77	0.0001
1,2,3,7,8-PnCDD	1	PCB 81	0.0001
1,2,3,4,7,8-HxCDD	0.1	PCB 126	0.1
1,2,3,6,7,8-HxCDD	0.1	PCB 169	0.01
1,2,3,7,8,9-HxCDD	0.1		
1,2,3,4,6,7,8-HpCDD	0.01	Mono-ortho PCB's	
OCDD	0.0001	PCB 105	0.0001
		PCB 114	0.0005
Dibenzofurans		PCB 118	0.0001
2,3,7,8-TCDF	0.1	PCB 123	0.0001
1,2,3,7,8-PnCDF	0.05	PCB 156	0.0005
2,3,4,7,8-PnCDF	0.5	PCB 157	0.0005
1,2,3,4,7,8-HxCDF	0.1	PCB 167	0.00001
1,2,3,6,7,8-HxCDF	0.1	PCB 189	0.0001
1,2,3,7,8,9-HxCDF	0.1		
2,3,4,6,7,8-HxCDF	0.1		
1,2,3,4,6,7,8-HpCDF	0.01		
1,2,3,4,7,8,9-HpCDF	0.01		
OCDF	0.0001		

Toxic Equivalency Factors (TEF's) for PCB's, PCDD's, PCDF's for humans and wildlife. Environmental Health Perspective, 106 (12), 775-792, (1998)

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