Annex 2
Contribution of PCBs to Total TEQ Exposure

1. Sources of PCBs and Routes to Exposure

Leaks from capacitors, where PCBs have been used as flame retardents and insulators, have been identified as the most important source of PCBs in the UK. They were estimated to represent 77% of total emissions to air (Dyke 1997). Other sources of PCBs are similar to those of dioxins, because PCBs are also a by-product of combustion, although the relative importance of these sources is different. PCB sources in the UK are listed in Table A2-1.

Table A2-1 Estimated emissions of PCBs to air in the UK

Process	**Release to air** (kg PCB/yr)	**Percent of total**
Leaks from capacitors	4400	77.4
Steel production	459	8.1
Coal combustion	260	4.6
Scrap metal reclamation	240	4.2
Application of sewage sludge to land	99	1.7
Oil combustion	91	1.6
Leaks from transformers	75	1.3
Sinter production	36	0.6
Waste incineration	13.3	0.2
Manufacture of RDF	10	0.2
Combustion of wood	2.15	0.0
Landfill	1.25	0.0
Combustion of tyres	0.085	0.0
Combustion of straw	0.06	0.0
Combustion of RDF	0.02	0.0
TOTAL	5687	100

Routes of exposure to PCBs are the same as those for dioxins, with the foodchain being the most important. This is a result of the similar properties and behaviour of these groups of chemicals, in particular that they are lipophilic and bind tightly to particles, therefore accumulating in fatty tissues, soils and sediments

2. Toxicity of PCBs

PCB molecules consist of two connected benzene rings on which up to 10 hydrogen atoms are substituted by chlorine atoms. Only those PCBs that are similar in structure to dioxins have similar toxicological properties. The toxicity is based on the planar configuration of some PCBs. This structure allows the molecule to bind to the ‘Ah receptor’, thus causing similar toxic effects to dioxins (see Task 8 on Human Toxicology for more details). The properties of individual dioxin-like PCB congeners are reflected in the toxic equivalent values shown in Table A2-2. It can also be seen from Table A2-2 that the PCB congeners are generally less toxic than the PCDD and PCDF congeners. However, levels in the environment are much higher for PCBs than dioxins and, therefore, the overall toxic equivalent exposure is comparable.

The Toxic Equivalency Factor **(**TEF) system allows these compounds to be considered together in exposure calculations and, thus, assessed in relation to the Tolerable Daily Intake, which has recently been revised by WHO to include both dioxins and dioxin-like PCBs. It is, therefore, important to consider the relative exposure of populations to dioxins and PCBs, in order to assess the detailed data provided in Annex 1 in the context of total TEQ exposure.

Table A2-2 Toxic Equivalency Factors used to express toxicity of mixtures of PCDDs, PCDFs and PCBs

PCDDs and PCDFs			**PCBs**			
Structure	I-TEF	WHO-TEF	IUPAC no.	Structure	WHO-TEF (1994)	WHO-TEF (1997)
Dioxins			Non-ortho (planar) PCBs			
2,3,7,8-TCDD	1	1	77	3,4,3’,4’-TCB	0.0005	0.0001
1,2,3,7,8-PeCDD	0.5	1	81	3,4,5,3’-TCB		0.0001
1,2,3,4,7,8-HxCDD	0.1	0.1	126	3,4,5,3’,4’-PeCB	0.1	0.1
1,2,3,6,7,8-HxCDD	0.1	0.1	169	3,4,5,3’,4’,5’-HxCB	0.01	0.01
1,2,3,7,8,9-HxCDD	0.1	0.1				
1,2,3,4,6,7,8-HpCDD	0.01	0.01	Mono-ortho PCBs			
OCDD	0.001	0.0001	105	2,3,4,3’,4’-PeCB	0.0001	0.0001
			114	2,3,4,5,4’-PeCB	0.0005	0.0005
Furans			118	2,4,5,3’,4’-PeCB	0.0001	0.0001
2,3,7,8-TCDF	0.1	0.1	123	2,4,5,2’,4’-PeCB	0.0001	0.0001
1,2,3,7,8-PeCDF	0.05	0.05	156	2,3,4,5,3’,4’-HxCB	0.0005	0.0005
2,3,4,7,8-PeCDF	0.5	0.5	157	2, 3,4,3’,4’,5’-HxCB	0.0005	0.0005
1,2,3,4,7,8-HxCDF	0.1	0.1	167	2,4,5,3’,4’,5’-HxCB	0.00001	0.00001
1,2,3,6,7,8-HxCDF	0.1	0.1	189	2,3,4,5,3’,4’,5’-HpCB	0.0001	0.0001
1,2,3,7,8,9-HxCDF	0.1	0.1				
2,3,4,6,7,8-HxCDF	0.1	0.1	Di-ortho PCBs			
1,2,3,4,6,7,8-HpCDF	0.01	0.01	170	2,3,4,5,2’,3’,4’-HpCB	0.0001	0
1,2,3,4,7,8,9-HpCDF	0.01	0.01	180	2,3,4,5,2’,4’,5’-HpCB	0.00001	0
OCDF	0.001	0.0001				

3. Data available on PCBs

The analysis undertaken in this project did not include collection of detailed data on PCBs in foods and total diet. However, data on concentrations of PCBs in foodstuffs measured in the UK, the Netherlands and Sweden are presented here.

Different PCB congeners were analysed in these countries. In the UK 54 PCB congeners were quantified; in Sweden 5 co-planar PCBs (77, 126, 169, 105 and 118) were quantified; and in the Netherlands only the non-ortho PCBs (77, 126 and 169) were quantified. These differences mean that the results are not directly comparable, but all analysis included the two most toxic congeners (126 and 169) and, therefore, the large proportion of the TEQ contribution.

Table A2-3 shows concentrations in foodstuffs for the UK and
Table A2-4 shows the total dietary intakes based on these for various hypothetical consumers in different age groups (MAFF 1997a). The ranges of daily intake represent upper and lower

bound estimates, based on the varying assumptions made about TEQ concentrations where some congeners were not detected in foods.

Table A2-3 UK: Dioxins and PCBs in foods (1992)

Food Group	**Concentration** (ng TEQ/kg fat basis)	
	Dioxins	**PCBs**
Carcass meat	0.94	0.87
Offals	9.7	2.9
Meat products	0.4	0.35
Poultry	1.7	0.93
Fish	2.7	5.3
Oils and fats	0.26	0.35
Milk	2	1.3
Dairy products	0.75	0.56
Eggs	1.8	0.97
Misc. cereals	2.4	0.36
Bread	1.4	0.67

Table A2-4 UK: Daily dietary intakes of dioxins and PCBs by age (pg TEQ/kg bw) (1992)

	Dioxin	PCBs	Total
Toddlers (1.5-2.5 yrs)			
Average consumer	2.4-3.7	1.8-2.4	4.2-6.0
High level consumer	3.7-5.8	2.8-3.7	6.5-9.5
Toddlers (2.5-3.5 yrs)			
Average consumer	2.2-3.4	1.6-2.2	3.9-5.6
High level consumer	3.3-5.0	2.4-3.2	5.7-8.3
Toddlers (3.5-4.5 yrs)			
Average consumer	2.0-3.3	1.5-2.1	3.5-5.5
High level consumer	3.1-4.7	2.3-3.0	5.3-7.7
School children (10-15 yrs)			
Average consumer	1.1-1.8	0.8-1.0	1.9-2.8
High level consumer	2.0-2.9	1.3-1.7	3.2-4.5
Adults			
Average consumer	1.0-1.5	0.7-0.9	1.7-2.4
High level consumer	1.7-2.6	1.3-1.7	3.0-4.2

Table A2-5 shows concentrations in foodstuffs in the Netherlands and Table A2-6 shows total dietary intakes of dioxins and PCBs, both based on the thesis of Liem and Theelen (1997).

Table A2-5 The Netherlands: Concentrations of dioxins and PCBs (1991)

Food type	Dioxins (pg I-TEQ /g fat)	PCBs (pg WHO-TEQ /g fat)
Refined fish oils	0.99	1.3
Consumer milk	1.5	1.3
Butter	1.8	2.1
Cheese	1.4	1.6
Animal fat	0.43-14	0.16-25
Animal liver	3.3-61	2.1-28
Meat products	0.68	0.48
Nuts	0.26	0.06
Egg	2	1.8
Cereals	0.74-0.85	0.19-1.2
Lean Sea Fish	49	103
Freshwater Fish	2.4	4.5
Fatty Sea Fish	6.8	11
Game	17	17

Table A2-6 The Netherlands: Daily intake of dioxins and PCBs (1991)

	Daily intake (pg/day)		By body weight (pg/kg bw/day)*	
	median	95 percentile	median	95 percentile
PCDD/Fs (I-TEQ)	65	159	1.1	3.1
PCBs (WHO-TEQ)	70	183	1.2	3.6
Total	135	342	2.3	6.7

* Body weight data was collected during the survey and therefore these figures are based on the actual body weights in these population groups

Table A2-7 and Table A2-8 shows food concentration data for Sweden. The data on dioxins is given as Nordic TEQ. Table A2-9 shows total dietary intakes of dioxins and PCBs in Sweden. The Swedish data have been extracted from De Wit and Strandell (draft).

Table A2-7 Sweden: Concentrations of dioxins and PCBs in foodstuffs (1990)

Food Type	Dioxins (pg N-TEQ/g fat)		PCBs (pg WHO-TEQ/g fat)	
	Lower bound	Upper bound	Lower bound	Upper bound
Butter	0.35	0.5	0.85	1.2
Chicken eggs	0.89	1.3	9	2
Chicken fat	0.42	1.1	1.3	1.6
Pork fat	0.06	1.2	0.84	1.2
Mutton	0.55	1.3	0.86	1.2
Moose kidney	2	3.9	4.7	4.8
Reindeer kidney North Sweden	0	1.1	1.7	
Reindeer kidney Southern Sweden	3	3.3	12.1	

Table A2-8 Sweden: Concentrations of dioxins and PCBs in fish (1990)

Fish Type	State / Region	**Dioxins** (pg N-TEQ/g fresh weight) Mean concentration	**PCBs** (pg WHO-TEQ/g fresh weight) Mean concentration
Burbot liver	Baltic Sea	80	16
Burbot muscle	Baltic Sea	1.3	0.4
Cod	Baltic Sea	0.36	1.2
Herring	Baltic Sea near the coast	10.4	10.8
Mackerel	Swedish West Coast	2.8	8.1
Plaice	Swedish West Coast	0.35	0.39
Herring	Swedish West Coast	2	2.8
Sea trout	Baltic Sea	8.8	25
Whitefish	Baltic Sea	7.3	4.7

Table A2-9 Sweden: Daily intake of dioxins and PCBs (1990)

Food category	**Intake of Dioxins** (pg N-TEQ / day)	**Intake of PCB-TEQ** (pg/day)
Dairy products	17 - 53 a	39
Meat and meat products	13.1	18.9-19.1
Fats oils and dressings	14.3 b	
Fish and fish products (including shellfish)	50-55	76
Eggs	2.8	5.6
Vegetables	5 b	
Fruits	3.6 b	
Drinking water	0.004	
Total intake	106 - 147	139.5-139.7
Intake per kg bodyweight (bw of 60 kg assumed)	1.8 - 2.5	2.3

4. Discussion

A comparison of the concentrations of dioxins and PCBs in foodstuffs in the tables above shows that there is not a clear difference in TEQ concentration between the two types of contaminant, except for in Sweden where the majority of foods had higher PCB concentrations than dioxins, expressed as TEQ.

The total TEQ exposure data for the UK and the Netherlands give some indication of the variation in exposure within the populations of these countries. For the Netherlands, the exposure of a 'high level consumer' (95 percentile) is 6.7 pg TEQ/kg bw/day and therefore above the WHO TDI of 1-4 pg TEQ/kg bw/day. For the UK, the data in Table A2-4 show that only the average consumers in the school children and adults age groups have exposures within the WHO TDI range using the upper bound estimates. Average upper bound exposures of toddlers range from 3.5-6.0 pg TEQ/kg bw/day, and for high level consuming toddlers the range is 5.3-9.5 pg TEQ/kg bw/day, i.e. all above the TDI. Furthermore, a large proportion of the population will have exposures above the averages given in this tables and therefore it is of some concern that many people, especially children, are exposure to levels of TEQ above that recommended by WHO.

Table A2-10 shows a comparison of the relative contributions of dioxins and PCBs to overall exposure to TEQ in the three countries. It can be seen that in the UK dioxins are more important than PCBs, even though there was a larger number of PCBs included in the UK analysis. In the Netherlands and Sweden the two sources contribute a roughly equal portion of the total exposure.

Table A2-10 Contributions of dioxins and PCBs to total dietary exposure to TEQ

	Contribution of dioxins to total TEQ intake (%)	**Contribution of PCBs to total TEQ intake (%)**
UK		
Mean total dietary exposure	63	37
High level consumer exposure	60	40
Netherlands		
Median total dietary exposure	48	52
95 percentile total dietary exposure	46	54
Sweden		
Mean total dietary exposure	43-51	49-57

A more detailed analysis of the contribution of dioxin-like PCBs to total TEQ exposure has been undertaken (Alcock 1998). This study also found that the PCBs represent a significant source of TEQ, especially in fish (up to 90% of total TEQ in some cases). Furthermore, analysis of two separate cows' milk surveys in the UK showed that, although total TEQ concentrations are declining, the proportion of TEQ from PCBs is increasing, from 38% in 1982 to 64% in 1995 (MAFF 1997a; MAFF 1997b).

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