Speciation of the UK Polychlorinated Biphenyl emission Inventory

A report produced for Department for Environment, Food and Rural Affairs, the National Assembly for Wales, the Scottish Executive and the Department of the Environment in Northern Ireland.

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Executive Summary

Polychlorinated biphenyls (PCB) have been widely used in a variety of industrial applications since they were first used industrially in the late 1920's. Theoretically 209 different PCB congeners exist, however only about 100 individual congeners are likely to occur in significant quantities in commercial mixtures.

Prior to this report the National Emissions Inventory (NAEI) reported PCB emissions as total PCB, there was no speciation. This study has produced estimated speciation for a large proportion (93%) of the estimated atmospheric emission. Speciated emission profiles have been produced for most of the major PCB emission sources, these include transformers, capacitors, landfills, fragmentisers, electric arc furnaces, industrial combustion, domestic combustion, and some agricultural combustion. These profiles are used in the NAEI to produce an estimate of the speciated emission of PCB congeners.

Introduction

Polychlorinated biphenyls (PCB) have been widely used in a variety of industrial applications since they were first synthesised in the late 1920's. Theoretically 209 different PCB congeners exist, however only about 100 individual congeners are likely to occur in significant quantities in commercial mixtures. In production, the congener composition normally depends on the ratio of biphenyl to chlorine during the formation reaction however the distribution of individual PCBs can be different between production batches. The American multinational, Monsanto was the major manufacturer of PCBs in the UK before their production was discontinued in 1977. Monsanto marketed the PCB mixtures under the trade name of Aroclor followed by a four-digit number of which the last two digits usually described the percentage of the chlorine in the product. For example Aroclor 1256 had a chlorine content of 56% by weight, the mixture contained many congeners in varying concentrations. PCBs were also marketed in the UK under the trade name of Pyrochlors. In Europe commercial PCB mixtures were marketed under various trade names and produced by various manufacturers, some of the trade names used by reported[1] manufacturers are shown in Table 1.

Table 1. Manufacturers and Trade Names for PCB Commercial Mixtures.

Manufacturer	Country	Trade name(s)
Monsanto	UK	Aroclor, Pyroclor
Bayer A. G.	Federal Republic of Germany	Clophen, Elaol
DSW-VEB	German Democratic Republic	Orophene
Caffaro	Italy	Fenoclor, Pyralene
S.A. Cros	Spain	Fenoclor,Pyralene
Prodelec	France	Phenoclor, Pyraléne

PCBs were extensively used in electrical equipment such as capacitors and transformers[1]. Their use in open applications was widely banned in 1972 and they have not been used in the manufacture of new equipment since 1986[2], plant that had been installed prior to 1986 was allowed to continue until the end of its working life. The PCBs currently found in the atmosphere are widely considered to result from the redistribution of PCBs already present in the environment, the release from transformers and capacitors and other PCB wastes at disposal sites and incineration of PCB-containing waste[3].

Due to their extreme persistence, PCBs have been recognised as environmental contaminants since the mid 1960's and are now ubiquitous in the environment[4].

Before this report was produced, the UK National Atmospheric Emissions Inventory (NAEI) reported PCBs as total PCB. However, as individual PCBs have different levels and mechanisms of toxicity, it enhances the value of inventories if individual PCBs are reported. The World Health Organisation (WHO) have produced toxic equivalence factors (TEFs) for PCBs relative to 2,3,7,8 Tetrachlorodibenzo-*p*-dioxin, (2,3,7,8-TCDD). These factors are used to assess the dioxin-like toxicity of individual PCBs. The TEFs proposed in 1997 for PCB species are indicated in the Table 2.

Table 2: World Health Organisation Proposed TEFs for PCB congeners (1997).

PCB Congener	IUPAC PCB number	TEF
34,3'4'-tetrachlorobiphenyl	77	0.0001
345,4'-tetrachlorobiphenyl	81	0.0001
345,3'4'-pentachlorobiphenyl	126	0.1
345,3'4'5'-hexachlorobiphenyl	169	0.01
234,3'4'-pentachlorobiphenyl	105	0.0001
2345,4'-pentachlorobiphenyl	114	0.0005
245,3'4'-pentachlorobiphenyl	118	0.0001
345,2'4'-pentachlorobiphenyl	123	0.0001
2345,3'4'-hexachlorobiphenyl	156	0.0005
234,3'4'5'-hexachlorobiphenyl	157	0.0005
245,3'4'5'-hexachlorobiphenyl	167	0.00001
2345,3'4'5'-heptachlorobiphenyl	189	0.0001

The TEFs range over four orders of magnitude and cover just those 12 congeners which exhibit dioxin-like toxicity; the remainder may exhibit different mechanisms of toxicity. The observed difference in the toxicity of congeners means that inventories reporting total PCB could be misleading since the impact of each source could be different from that suggested solely by the total mass of PCB emitted and hence policy actions to abate releases misplaced. A speciated emissions inventory is therefore important.

Methods.

1.1 EMISSION ESTIMATES

There are limited numbers of measurements speciating the atmospheric emissions of PCB. Where measurements have been made they are typically for a restricted range of PCB congeners. There have however been some studies which estimate the releases of PCBs to the UK environment, these have been completed by ETSU[3] and APARG[5]. The ETSU estimates, being more recent, are considered the most accurate to date. The averages of the emission range given in the ETSU report[3] for each source are used in the NAEI, and are also used in this report.

1.2 SPECIATION

Speciation is required both for sources which contain PCBs e.g. capacitors, and also for sources where PCBs are formed *in situ*, such as during combustion.

1.2.1 Sources containing PCBs

Analyses of many commercially produced Aroclors have been reported in literature. The information from Schulz[7] was most extensive but some information from WHO 1993[6] was also used for NAEI purposes. A number of additional assumptions were made in order to develop speciated emissions profiles:

- the only Aroclors used in individual sources were as reported in Environmental Protection Bulletin 004. PCBs: Properties, Health Risks and Legislation[8];
- where a number of Aroclors were used in a source sector the ratio of each Aroclor used in the UK has been assumed to be the same as the US sales ratios found in De Voogt et al[1];
- the PCBs that are released from sources are identical to the congener ratios in the Aroclors which the sources contain;
- there was no selective release of particular PCB congeners from sources and no selective degradation or chemical changes of congeners occurs during the normal usage of Aroclors.

American (USA) figures were used because UK figures were not available and as the major UK manufacturer of Aroclors was Monsanto, a US company, it seemed reasonable that the production of individual Aroclors were in the same ratios in the US and the UK. There is some uncertainty concerning the US sales figures and this leads to uncertainty in the emission profiles. The estimates made by De Voogt et al[1] have been used because a summary of available literature was carried out and estimates given. Without reliable UK sales data estimates it isn't possible to remove uncertainty in this area.

The contribution of a particular congener from a particular Aroclor X to emissions from a source Y is calculated using the equation below:

$$A_y = B\left(\frac{S}{U}\right)R$$

Where: A_y is the Contribution to source Y of congener A from Aroclor X
B is the fraction of congener A in Aroclor X
S is the US sales[*1] of Aroclor X
U is the total US sales[*1] of **all** the Aroclors used in source Y
and R is the Release from the source per year.

[*] sales from 1957-1975

This calculation is completed for all of the Aroclors used in source Y and for all the congeners. The sum of congeners' contributions from each of the Aroclors used in source Y is then calculated.

Capacitors and Transformers releases.

The PCB mixtures used in transformers and capacitors are not the same. The calculation shown above was used to estimate separate species profiles for releases from capacitors and transformers. These two profiles were, in turn, used to derive profiles for other emission sources that emit PCB congeners in the course of disposal of old transformers and capacitors, such as fragmentisers, landfill sites and electric arc furnaces.

Fragmentisers and Landfill releases.

PCB emission profiles for fragmentisers and landfill releases were assumed to be similar to releases from leaking capacitors of the type used in industrial and domestic appliances. Transformers were assumed not be included in the waste materials handled by fragmentiser plants and landfill sites.

Electric Arc Furnaces releases.

Estimates of emissions from electric arc furnaces have been calculated from the proportions of individual PCBs used in transformers and capacitors in the UK.

1.2.2 Processes Producing PCB – Combustion Sources

There is little information regarding speciated emissions of PCB formed during combustion and the Department of the Environment, Transport and the Regions (DETR) commissioned studies to produce improved estimates. The tests determined a number of congeners including the 12 PCBs with WHO toxic equivalent factors.

Domestic combustion.
Emission were quantified from a combustion unit burning seasoned hardwood and house coal in two separate tests. The 12 'WHO' PCB congeners plus an additional 38 congeners were analysed. It has been assumed, where the analysis indicated that there was co-elution of congeners, that the amount of each PCB co-eluting was equal. PCB emission profiles with all

of the PCBs analysed were constructed for each of the two fuels, domestic coal and domestic wood.

Industrial Combustion.

Tests were carried out at two locations within the UK:

- An industrial furniture manufacturing operation that burns the waste wood that is not used in the manufacturing process[9].
- A school in Yorkshire with a coal fired boiler providing heating and hot water to the school[10].

The 12 'WHO' PCB congeners plus an additional 12 PCB congeners were analysed and profiles constructed for the two fuels: industrial coal and industrial wood.

The concentrations of the individual PCB found in the flue gas were made into fractions of the overall PCB emissions measured to producing emission profiles for the two appliances. As with the domestic combustion sources, the only PCBs reported in the NAEI were those analysed. A full analysis of all of the 209 PCBs would be required to produce a full speciation.

The individual profiles produced are given in Appendix 1, the profiles used for each source are shown in table 3.

Table 3. Summary of profile used for emission sources.

Source	Profile Used
Agricultural Coal Combustion	Industrial Coal
Agricultural Straw Combustion	Unspeciated
Application of Sewage Sludge to Land	Unspeciated
Basic Oxygen Furnaces	Unspeciated
Capacitor leakage	Capacitors/Fragmentisers/landfill
Coal Combustion for Autogenerators	Industrial Coal
Coke Production	Industrial Coal
Combustion of RDF	Unspeciated
Combustion of Scrap Tyres	Unspeciated
Combustion of Waste Oils	Unspeciated
Domestic Coal Combustion	Domestic Coal
Domestic Wood Combustion	Domestic Wood
Electric Arc Furnaces	Electric Arc
Fragmentisers	Capacitors/Fragmentisers/Landfill
Incineration - Chemical Waste	Unspeciated
Incineration - Clinical Waste	Unspeciated
Incineration - Sewage Sludge	Unspeciated
Industrial Coal Combustion	Industrial Coal
Industrial Wood Combustion	Industrial Wood
Landfill	Capacitors/Fragmentisers/Landfill
Power Stations - Coal	Unspeciated
Power Stations - Municipal Waste	Unspeciated
Power Stations - Oil	Unspeciated
RDF Manufacture	Unspeciated
Sinter Plant	Unspeciated
Smokeless Solid Fuel Production	Industrial Coal
Transformers	Transformer

Results

The speciation profiles derived by this work and used in the NAEI are shown in Appendix 1. The speciation of >90% of the known PCB emission sources is shown in Table 4 together with an indication of the toxic equivalence values

Table 4. Summary of PCB emission estimates in 1999.

Source	kg Total PCB	%	kg PCB Total TEF	% (Total PCBTEF)
Agricultural Coal Combustion	<0.01	<0.01%	3.35E-06	0.01%
Agricultural Straw Combustion	0.1	<0.01%	Unspeciated	Unspeciated
Application of Sewage Sludge to Land	25.5	1.23%	Unspeciated	Unspeciated
Basic Oxygen Furnaces	22.7	1.10%	Unspeciated	Unspeciated
Capacitor leakage	1571.4	75.89%	3.52E-02	69.60%
Coal Combustion for Autogenerators	0.7	0.03%	7.12E-04	1.41%
Coke Production	4.0	0.19%	Unspeciated	Unspeciated
Combustion of RDF	0.01	0.00%	Unspeciated	Unspeciated
Combustion of Scrap Tyres	0.2	0.01%	Unspeciated	Unspeciated
Combustion of Waste Oils	1.3	0.06%	Unspeciated	Unspeciated
Domestic Coal Combustion	14.9	0.72%	5.23E-04	1.03%
Domestic Wood Combustion	1.8	0.09%	1.82E-03	3.61%
Electric Arc Furnaces	219.9	10.62%	3.76E-03	7.44%
Fragmentisers	85.7	4.14%	1.92E-03	3.80%
Incineration - Chemical Waste	0.7	0.03%	Unspeciated	Unspeciated
Incineration - Clinical Waste	0.4	0.02%	Unspeciated	Unspeciated
Incineration - Sewage Sludge	0.2	0.01%	Unspeciated	Unspeciated
Industrial Coal Combustion	1.8	0.08%	5.91E-03	11.69%
Industrial Wood Combustion	0.1	0.01%	7.74E-05	0.15%
Landfill	1.1	0.05%	2.44E-05	0.05%
Power Stations - Coal	35.0	1.69%	Unspeciated	Unspeciated
Power Stations - Municipal Waste	5.3	0.25%	Unspeciated	Unspeciated
Power Stations - Oil	3.0	0.14%	Unspeciated	Unspeciated
RDF Manufacture	3.6	0.17%	Unspeciated	Unspeciated
Sinter Plant	39.9	1.92%	Unspeciated	Unspeciated
Smokeless Solid Fuel Production	0.3	0.01%	3.08E-04	0.61%
Transformers	31.30	1.51%	3.05E-04	0.60%
Total	2070.6		5.05E-02	

Discussion.

Speciation has been completed for a large percentage (>90%) of the total estimated atmospheric emission; sources include transformers, capacitors, landfills, fragmentisers, electric arc furnaces, industrial combustion, domestic combustion, and some agricultural combustion. In the case of industrial and domestic combustion, the speciation only covers a limited set of the more toxic PCBs.

At first glance, the high level of speciation of the PCB inventory (93% of PCB emissions by mass), would appear to ensure reasonably robust estimates of the total emissions expressed as TEQ. However, many of the data used to create the base inventory are estimates or assumptions, only a small number of congeners have TEFs and these congeners are present at very low concentrations in the commercial mixtures. As a result, care should be exercised when using the figures produced.

At present the major source in terms both of total PCB and toxic equivalence (TEQ) is the leakage of material from capacitors and transformers. The source that presently appears to be second in terms of TEQ is industrial coal combustion; this appears to emit 11.7 % of the toxic equivalent but only 1.8 % of the total PCB. In contrast domestic coal combustion is estimated to emit 14.9 % of the total PCB but only 1.0 % of the TEQ. Given the similarity of the processes this suggests that measurement uncertainty is significant especially where only one set of tests is used to determine the PCB profile.

US information have been used to create the PCB speciated profiles for capacitor and transformer releases by assuming that the fraction of the different commercial grades sold in the UK is the same as that in the US. It was also assumed that the composition of the grades was the same in the two countries. These assumptions have not been validated and investigation into recreating the historical situation while important to reduce uncertainty may no longer be possible.

Other information needed to further improve the speciated emissions from the evaporative sources (such as landfills and sewage sludge to land.etc.) include:

- the age profile of disposed white goods and electrical items to enable an assessment of the PCB mixtures present,
- congener specific evaporation rates and chemical reactivity and degradation information to convert the release of PCBs into emission.

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Appendices

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Appendix 1
Speciation Profiles.

The species profiles used in the NAEI are shown in the Tables below. Where no number is given, no analysis was carried out and no data are available.

IUPAC PCB	Emission Profile			
	Transformer	Capacitor, Fragmentisers, Landfill	Electric Arc	Domestic Coal
1	0.003884059	0.034370855	0.021647897	
2	0.000210699	0.003068348	0.001875774	
3	0.000998861	0.01668636	0.010139546	
4	0.024765643	0.020927662	0.022529355	
5	0.000983264	0.001282728	0.001157754	
6	0.008411278	0.00799876	0.008170915	
7	0.001583065	0.0021451	0.001910548	
8	0.043187963	0.03754428	0.039899541	
9	0.002831665	0.003095741	0.002985535	
10	0.000772565	0.000934818	0.000867105	
11	7.02331E-05	0.000166179	0.000126138	
12	0.000351166	0.000675053	0.000539886	
13	0.001394705	0.001906566	0.001692952	
14	0	2.07667E-05	1.21002E-05	
15	0.012274101	0.011785502	0.011989407	
16	0.021917278	0.014312791	0.017486347	
17	0.022728881	0.015112761	0.018291172	1.39389E-05
18	0.065205657	0.046138522	0.05409575	1.39389E-05
19	0.005656588	0.003771788	0.004558366	
20	0.00358189	0.002561054	0.002987077	
21	0	0	0	
22	0.017493692	0.012587788	0.014635153	0.026799932
23	7.02331E-05	3.63643E-05	5.04987E-05	
24	0.000772565	0.000529867	0.000631151	
25	0.00379259	0.002592204	0.003093158	
26	0.008255214	0.005912068	0.006889926	
27	0.003230725	0.002088318	0.002565075	
28	0.042913772	0.030454226	0.035653929	0.037333122
29	0.000561865	0.000348046	0.000437278	

30	0	3.63643E-05	2.11885E-05	
31	0.044851528	0.033349459	0.038149581	0.037333122
32	0.012015507	0.008405937	0.009912307	
33	0.030444569	0.022355084	0.025731043	
34	0.000210699	0.000145457	0.000172685	
35	0.000421399	0.000238953	0.000315092	
36	0.000343321	0	0.000143277	
37	0.012577372	0.003953893	0.007552702	
38	0	0	0	
39	0	0	0	
40	0.005828865	0.003345314	0.004381767	
41	0.005874815	0.007131232	0.006606896	0.176708564
42	0.008175331	0.005691711	0.006728192	
43	0.001264197	0.000981836	0.001099673	
44	0.024742462	0.019189491	0.021506895	0.019774707
45	0.006544063	0.004712747	0.005477005	
46	0.002917495	0.002083477	0.002431535	
47	0.006914351	0.005036169	0.005819985	
48	0.008296675	0.006048828	0.006986915	
49	0.021154802	0.01534529	0.017769755	0.38464035
50	0.000140466	0.000166224	0.000155475	
51	0.001193963	0.000846763	0.000991659	
52	0.024731835	0.020130247	0.022050613	0.013181589
53	0.004762679	0.003518595	0.004037785	
54	7.02331E-05	8.3112E-05	7.77373E-05	3.63342E-05
55	0.000584204	0.000244405	0.000386212	
56	0.011694955	0.007785407	0.009416966	0.005505881
57	0.000210699	3.63643E-05	0.000109119	
58	7.02331E-05	0	2.93102E-05	
59	0.001918634	0.001283462	0.001548536	
60	0.007910257	0.004417538	0.005875143	0.005505881
61	0	0	0	0.003775129
62	0	0	0	
63	0.001347119	0.000855303	0.001060551	
64	0.012522867	0.008826067	0.010368841	0.176708564
65	0	0	0	
66	0.029331346	0.022121089	0.025130123	
67	0.000865137	0.000291243	0.000530744	
68	0	0	0	
69	7.02331E-05	3.63643E-05	5.04987E-05	
70	0.034475224	0.037562371	0.036274022	0.013846012
71	0.006202061	0.004642032	0.005293074	
72	0.000140466	3.63643E-05	7.98089E-05	
73	0	3.63643E-05	2.11885E-05	
74	0.017562147	0.015170591	0.016168652	0.003775129
75	0.006367775	0	0.002657443	
76	0.000443738	6.26733E-05	0.000221702	
77	0.001861089	0.000710174	0.001190482	0.002376124

78	0	0	0	
79	0	0	0	
80	0	0	0	
81	0.00331258	0.008899615	0.006567995	
82	0.002339855	0.001462254	0.0018285	
83	0.000507229	0	0.00021168	
84	0.005499366	0.00855891	0.00728208	
85	0.007090975	0.014357037	0.011324715	
86	0.000367071	0.000438713	0.000408815	
87	0.010870416	0.020133369	0.01626769	0.002566623
88	9.2572E-05	6.26733E-05	7.51508E-05	
89	0.000485199	0.00037604	0.000421595	
90	0.002124316	0.00075208	0.001324751	0.005766074
91	0.002607435	0.003362237	0.003047237	
92	0.002443252	0.003216779	0.002893966	
93	0.000162805	6.26733E-05	0.000104461	
94	9.2572E-05	9.90377E-05	9.63394E-05	
95	0.012366305	0.012440302	0.012409421	0.008135694
96	0.000233038	0.000171766	0.000197337	
97	0.008521233	0.016049218	0.012907587	
98	0	0	0	
99	0.010716168	0.022316552	0.017475401	0.003726343
100	0	0	0	
101	0.020351031	0.03105897	0.026590259	0.005766074
102	0.000670343	0.000646844	0.000656651	
103	9.2572E-05	9.90377E-05	9.63394E-05	
104	0	0	0	1.39389E-05
105	0.01646368	0.038031965	0.029030941	0.004432582
106	0	3.63643E-05	2.11885E-05	
107	0	0	0	
108	0	0	0	
109	0.001866681	0.004011094	0.003116173	
110	0.02394861	0.046602288	0.0371483	0.009766549
111	0	0	0	
112	9.2572E-05	6.26733E-05	7.51508E-05	
113	0.000982908	0.002757627	0.002016989	
114	0.000925542	0.002005547	0.001554832	0.000255547
115	0.000351166	0	0.000146551	0.002566623
116	0.000268066	0.00075208	0.000550088	
117	0.027620441	0.076900196	0.056334432	
118	0.005907496	0.000965708	0.003028049	0.01067258
119	0.000140466	0	5.86204E-05	
120	0	0	0	
121	0	0	0	
122	0.000587243	0.001253467	0.000975434	
123	0.000791509	0.001629507	0.001279788	0.000734117
124	0.001161002	0.002381587	0.001872204	
125	8.93553E-05	0.000250693	0.000183363	

126	4.46777E-05	0.000125347	9.16813E-05	0.000202161
127	0	0	0	
128	0.004300322	0.009536732	0.007351438	
129	0.001097419	0.002444261	0.001882188	
130	0.001000923	0.00169218	0.0014037	
131	0.000279035	0.00056406	0.000445112	
132	0.007073802	0.008784652	0.008070668	0.006202827
133	0.000258811	0.00037604	0.000327117	
134	0.000863273	0.001065447	0.000981074	
135	0.00249614	0.001817527	0.00210073	
136	0.002743181	0.00150416	0.002021237	
137	0.001106675	0.002820301	0.002105159	
138	0.019653525	0.032360214	0.027057371	
139	0.000134033	0.00037604	0.000275044	
140	6.70165E-05	0.00018802	0.000137522	
141	0.005317707	0.003760401	0.004410306	0.002002561
142	0	0	0	
143	4.46777E-05	0.000125347	9.16813E-05	
144	0.001003248	0.000626733	0.000783863	
145	0	0	0	
146	0.002637314	0.002694954	0.002670899	
147	0.000187566	0.000438713	0.000333903	
148	0	0	0	
149	0.016523076	0.010790199	0.013182682	0.005738196
150	0	0	0	
151	0.005369853	0.00112812	0.002898309	0.001816708
152	0	0	0	
153	0.021114226	0.019251101	0.020028633	0.006202827
154	6.70165E-05	0.00018802	0.000137522	
155	0	0	0	5.57558E-05
156	0.003069481	0.006204661	0.004896267	0.001421772
157	0.00082684	0.001378814	0.00114846	0.000274132
158	0.002785019	0.004575154	0.003828083	0.001352077
159	0	0	0	
160	0	0	0	
161	0	0	0	
162	0.000153858	0.000125347	0.000137245	
163	0.005791359	0.005264561	0.005484408	
164	0.000635137	0.001201177	0.000964953	
165	0	0	0	
166	0.000111694	0.000313367	0.000229203	
167	0.000952017	0.001817527	0.001456327	0.000580789
168	3.7936E-05	6.26733E-05	5.23498E-05	
169	0	0	0	0.001230808
170	0.006339793	0.0018802	0.003741308	0.000954817
171	0.001840961	0.000532209	0.001078386	
172	0.000924862	0.00018802	0.000495524	
173	9.35832E-05	0	3.90548E-05	

174	0.006749759	0.000689407	0.003218555	0.001491466
175	0.000265152	0	0.000110655	0.003475442
176	0.00073981	6.26733E-05	0.000345261	0.000943201
177	0.003534222	0.00037604	0.001694034	0.001904988
178	0.001183273	0.000125347	0.000566848	2.78779E-05
179	0.002805382	0.000125347	0.001243797	7.4341E-05
180	0.014428397	0.00225624	0.007336008	0.003475442
181	0	0	0	
182	0	0	0	
183	0.003610094	0.000501387	0.001798734	0.000943201
184	0	0	0	
185	0.000771004	6.26733E-05	0.000358279	
186	0	0	0	
187	0.007331083	0.000438713	0.003315084	0.001904988
188	0	0	0	2.78779E-05
189	0.000178311	6.26733E-05	0.000110932	7.4341E-05
190	0.001196756	0.000250693	0.000645511	0.000954817
191	0.000233958	0	9.76369E-05	
192	0	0	0	
193	0.000608291	0	0.000253856	
194	0.002549085	6.26733E-05	0.00110032	0.000436753
195	0.001200984	0	0.000501203	
196	0.001232179	0	0.000514221	
197	9.35832E-05	0	3.90548E-05	
198	9.35832E-05	0	3.90548E-05	
199	0.002751849	6.26733E-05	0.001184938	0.000120804
200	0.000343138	0	0.000143201	
201	0.000327541	0	0.000136692	
202	0.000421124	0	0.000175747	
203	0.00151967	6.26733E-05	0.000670717	0.000803812
204	0	0	0	
205	0.000124778	0	5.2073E-05	
206	0.001196939	0.00030261	0.000675838	
207	4.67916E-05	0	1.95274E-05	
208	0.000419102	0.000182478	0.000281227	
209	0	0	0	

IUPAC PCB	Emission Profile		
	Domestic Wood	Industrial Wood	Industrial Coal
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17	0.005361266		
18	0.005361266	0.108013481	0.081251685
19			
20			
21			
22	0.013403165		
23			
24			
25			
26			
27			
28	0.049990183	0.225969693	0.082559724
29			
30			
31	0.049990183	0.22488101	0.104781044
32			
33			
34			
35			
36			
37			
38			
39			
40			
41	0.085653469		
42			
43			

44	0.008476596		
45			
46			
47		0.067467276	0.045676347
48			
49	0.279945025	0.071915063	0.038008561
50			
51		0.016323832	0.012804809
52	0.030139009	0.105803471	0.092582128
53			
54	5.43372E-05		
55			
56	0.027096128		
57			
58			
59			
60	0.027096128		
61	0.027114241		
62			
63			
64	0.085653469		
65			
66			
67			
68			
69			
70	0.066001532		
71			
72			
73			
74	0.027114241		
75			
76			
77	0.004538964	0.021066285	0.015487225
78			
79			
80			
81			
82			
83			
84			
85			
86			
87	0.006118364		
88			
89			
90	0.011990399		
91			

92			
93			
94			
95	0.025755812		
96			
97			
98			
99	0.011700601	0.008169708	0.01653564
100			
101	0.011990399	0.035616861	0.142767639
102			
103			
104	2.71686E-05		
105	0.008911294	0.009047676	0.00344706
106			
107			
108			
109			
110	0.019555218		
111			
112			
113			
114	0.000470922	0.003331442	0.00344706
115	0.006118364		
116			
117			
118	0.01420011	0.014187937	0.028868498
119			
120			
121			
122			
123	0.002028587	0.003331442	0.005335713
124			
125			
126	0.010121925	0.006190209	0.009490631
127			
128			
129			
130			
131			
132	0.014616695		
133			
134			
135			
136			
137			
138		0.019520925	0.108062509
139			

140			
141	0.000724495		
142			
143			
144			
145			
146			
147			
148			
149	0.01503328		
150			
151	0.000217349		
152			
153	0.014616695	0.026899216	0.164261757
154			
155	0.000217349		
156	0.00152144	0.004904681	0.006752203
157	0.000398472	0.003508506	0.005335713
158	0.007679651		
159			
160			
161			
162			
163			
164			
165			
166			
167	0.000652046	0.003862633	0.005836182
168			
169	6.59291E-05	0.003331442	0.007394201
170	0.001032406		
171			
172			
173			
174	0.004600546		
175	0.000217349		
176	0.002680633		
177	0.006049537		
178	0.000217349		
179	0.000108674		
180	0.000217349	0.013325769	0.015866611
181			
182			
183	0.002680633		
184			
185			
186			
187	0.006049537		

188	0.000217349		
189	0.000108674	0.003331442	0.00344706
190	0.001032406		
191			
192			
193			
194	0.002101037		
195			
196			
197			
198			
199	0.000652046		
200			
201			
202			
203	0.003586252		
204			
205			
206			
207			
208			
209			

Appendix 2
NAEI output of estimated speciated emissions.

The following table gives emissions in kgrammes of each congener included in the species profiles for each source that can be speciated.

Source	PCB Congener						
	28	52	77	105	114	118	123
Coal combustion by agricultural sector	0.000267	0.000299	5.01E-05	1.11E-05	1.11E-05	9.34E-05	1.73E-05
Coal-fired autogeneration plant	0.0567	0.0636	0.0106	0.00237	0.00237	0.0198	0.00366
Leakage from capacitors	47.9	31.6	1.12	59.8	3.15	1.52	2.56
Coal combustion at cement plant	0.0369	0.0413	0.00691	0.00154	0.00154	0.0129	0.00238
Coke ovens	0.326	0.366	0.0612	0.0136	0.0136	0.114	0.0211
Coal combustion at collieries	0.000381	0.000428	7.16E-05	1.59E-05	1.59E-05	0.000133	2.47E-05
Domestic coal combustion	0.552	0.195	0.0352	0.0656	0.00378	0.158	0.0109
Domestic wood combustion	0.0895	0.0540	0.00813	0.0160	0.000843	0.0254	0.00363
Fragmentisers	2.61	1.73	0.0609	3.26	0.172	0.0828	0.140
Coal combustion by the iron and steel sector	0.000381	0.000428	7.16E-05	1.59E-05	1.59E-05	0.000133	2.47E-05
Electric arc furnaces	7.84	4.85	0.262	6.38	0.342	0.666	0.281
Landfill sites	0.0333	0.0220	0.000776	0.0415	0.00219	0.00106	0.00178
Miscellaneous coal combustion	0.000687	0.00077	0.000129	2.87E-05	2.87E-05	0.00024	4.44E-05
Industrial coal combustion	0.0709	0.0795	0.0133	0.00296	0.00296	0.0248	0.00458
Industrial wood combustion	0.0264	0.0123	0.00246	0.00106	0.000389	0.00166	0.000389
Public services' coal combustion	0.0349	0.0392	0.00655	0.00146	0.00146	0.0122	0.00226
Coal combustion by SSF manufacturers	0.0245	0.0275	0.00460	0.00102	0.00102	0.00858	0.00159
Transformers	1.34	0.774	0.0583	0.516	0.0290	0.185	0.0248
Total	**60.90**	**39.9**	**1.65**	**70.1**	**3.72**	**2.83**	**3.06**

Source	PCB Congener						
	138	156	157	167	170	180	189
Coal combustion by agricultural sector	0.000349	2.18E-05	1.73E-05	1.89E-05		5.13E-05	1.11E-05
Coal-fired autogeneration plant	0.0742	0.00464	0.00366	0.00401		0.0109	0.00237
Leakage from capacitors	50.9	9.75	2.17	2.86	2.95	3.55	0.0985
Coal combustion at cement plant	0.0482	0.00301	0.00238	0.00261		0.00708	0.00154
Coke ovens	0.427	0.0267	0.0211	0.0231		0.0627	0.0136
Coal combustion at collieries	0.000499	3.12E-05	2.47E-05	2.70E-05		7.33E-05	1.59E-05
Domestic coal combustion		0.0210	0.00406	0.00859	0.0141	0.0514	0.0011
Domestic wood combustion		0.00273	0.000714	0.00117	0.00185	0.000389	0.000195
Fragmentisers	2.77	0.532	0.118	0.156	0.161	0.193	0.00537
Coal combustion by the iron and steel sector	0.000499	3.12E-05	2.47E-05	2.7E-05		7.33E-05	1.59E-05
Electric arc furnaces	5.95	1.08	0.253	0.320	0.823	1.61	0.0244
Landfill sites	0.0353	0.00678	0.00151	0.00199	0.00205	0.00246	6.84E-05
Miscellaneous coal combustion	0.000899	5.62E-05	4.44E-05	4.85E-05		0.000132	2.87E-05
Industrial coal combustion	0.0928	0.00580	0.00458	0.00501		0.0136	0.00296
Industrial wood combustion	0.00228	0.000572	0.000409	0.00045		0.00155	0.000389
Public services' coal combustion	0.0457	0.00286	0.00226	0.00247		0.00671	0.00146
Coal combustion by SSF manufacturers	0.0321	0.00201	0.00159	0.00173		0.00471	0.00102
Transformers	0.615	0.0961	0.0259	0.0298	0.198	0.452	0.00558
Total	**611.0**	**11.5**	**2.61**	**3.41**	**4.15**	**5.97**	**0.160**