3 Dioxin concentrations in Australian air

3.1 Dioxin concentrations - seasonal

Dioxins are predominantly generated as unintended by-products of combustion processes and are usually discharged into the atmosphere. Possible major sources of dioxins in Australia include bushfires and prescribed burning, residential wood combustion and industrial combustion processes, such as sintering. In the recent review of air emissions in Australia (Environment Australia, 2002), combustion sources were hypothesized to contribute up to 95% of the total dioxin emissions, with up to 75% from fossil fuel and biomass combustion. In many Australian cities residential wood combustion is a major source of winter aerosol mass (see for example Gras et al. 1992, Gras, 1996, Gras et al. 2000). In the tropical north of Australia, widespread biomass burning is common throughout the dry season and particularly towards the end of the dry season (around September - October). Sources of dioxin-like PCBs may include combustion of various fuels, including coal and wood, metallurgical and sintering processes, also potentially, storage or disposal of some industrial electrical products. Various processes, including degradation may influence seasonal variation in concentrations, and partitioning between condensed and vapour phases. In order to assess whether these various processes impact on the atmospheric concentrations of dioxins and dioxin-like materials, sampling was conducted at all locations over a full annual cycle.

An overall view of concentrations of dioxins in air can be seen in Figure 3.1, which shows the annual variation in TEQ loadings for the sum of all toxic PCDD/PCDF congeners at all of the sampling locations. In this (and the subsequent) figure, the 12 monthly TEQ values are plotted as a 16-month series to give an expanded view of the annual cycle. For all sites other than Netley, the loadings for September through to December 2002 are plotted again following August 2003, and for Netley, the September to December 2003 data are also plotted before the January 2003 data. It should be noted that concentrations reported use the Australian air quality convention, that concentrations are reported for an air density representing one standard atmosphere and 0 ºC (STP). As a result, ambient concentrations will be slightly lower than those indicated, for example at 20 ºC, they would be 7% lower. Also, all sample concentrations of PCDD/PCDFs and ‘dioxin-like’ PCBs have been corrected for the recovery of ^{13}C surrogate (internal) standards.

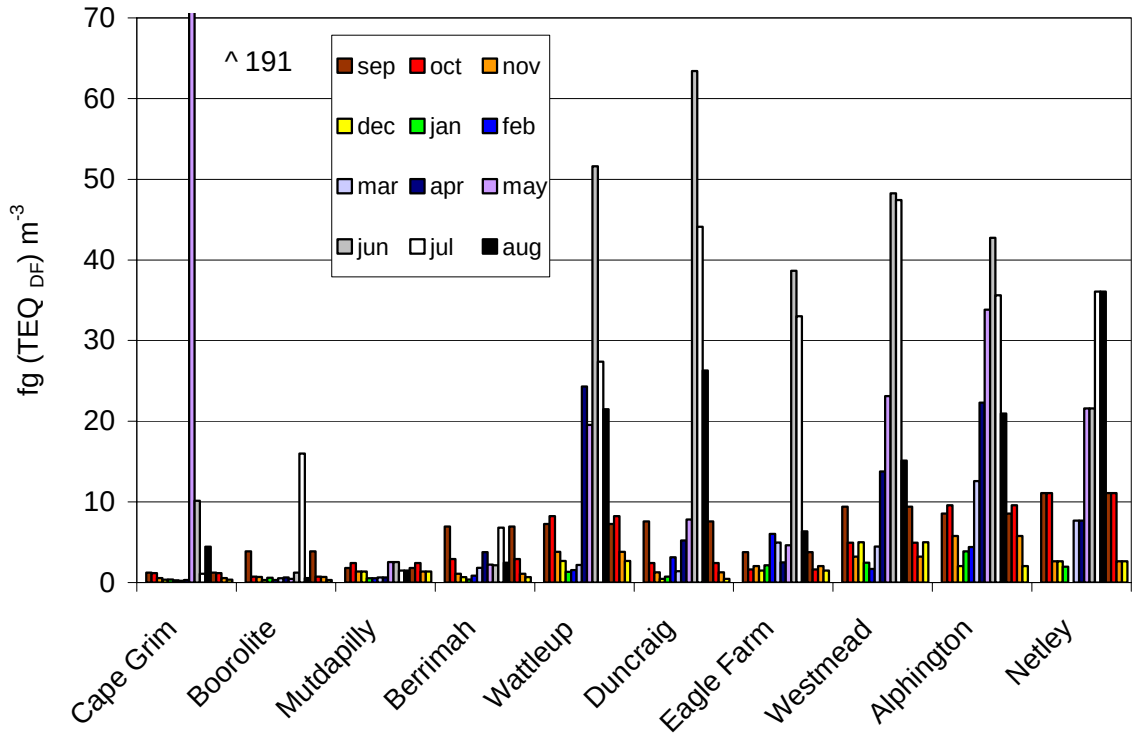

Figure 3.1 Variation in concentrations as TEQDF for Netley.

A summary of ambient concentrations for all locations sampled is also given in Table 3.2, which includes monthly mean, maximum and minimum values. For Table 3.2, concentrations less than LOD are replaced with one half LOD (middle bound). Data for Cape Grim, the background reference site, are shown at the left of Figure 3.1 and these also include the two months with local contamination (May - June). The suspected source for this contamination occurred over the period of 23 May and 10 June, with an electrical burnout of a controller on a nearby sampler that also operated only during clean conditions. Start and end limits for the period of contamination are known from equipment inspections. This controller was located about three metres from the dioxin sampler, down wind during clean on-shore conditions and transport to the dioxin sampling is assumed to be from local eddying. Data from May and June should be excluded from considerations of background levels. The composition of the plastic components that burnt is not known, and some surface finishing material on the instrument housing the controller was also damaged. The congener profile for the period, predominantly hepta and octa dioxin congeners, suggests source material with abundant chlorine. For the unaffected months there is an indication of an annual cycle in PCDD/PCDF TEQ with a winter maximum, although concentrations are near the limit of detection. This seasonal pattern, which is similar to those in the other southern Australian locations, may have resulted from air mass mixing during transitions to clean air (frontal passages). Strong transport of air from Melbourne and the Latrobe Valley typically occurs in the immediate pre-frontal conditions (for example Gras 2001). The overall annual mean TEQ, excluding May and June was 1 fg TEQ m^{-3}, with one-half

LOD for samples with concentrations less than LOD and without blank correction. For the first six months with the medium volume sampler, the mean field blank represents approximately 0.7 fg TEQ m^{-3} and for the second six months with the high volume sampler slightly less than 0.2 fg TEQ m^{-3}, thus, the 1 fg TEQ m^{-3} level can be considered a conservative upper limit.

Neither of the rural locations, Boorolite in north-east. Victoria and Mutdapilly in south-east Queensland, shows winter increases as strong as those seen in the urban locations, although in both cases the winter TEQ levels are higher than those from summer. For Boorolite, the ratio of June to September and November to March TEQ is approximately 11 (5.4 fg TEQ m^{-3} and 0.5 fg TEQ m^{-3}) whereas for Mutdapilly the corresponding ratio is two times (1.8 fg TEQ m^{-3} and 0.9 fg TEQ m^{-3}).

Elevation in PCDD/PCDF TEQ levels during the dry season at Berrimah is also apparent. The main biomass-burning peak usually occurs towards the end of the dry season although very high smoke loadings are sporadic and depend on fire locations. For example, the ratio for the May to October period was approximately four times that for November to March (4 fg TEQ m^{-3} and 1.0 fg TEQ m^{-3}) and the highest monthly TEQ_{DF} were observed in September and July (6.9 fg TEQ m^{-3} and 6.8 fg TEQ m^{-3}).

All of the urban locations, including Eagle Farm in Queensland, show a marked winter enhancement in TEQ_{DF} loadings. The period of enhanced loadings is much shorter in Queensland than further south. For Eagle Farm, the period of enhanced loadings appears effectively limited to June and July whereas for Westmead, Alphington and both Perth locations, enhanced loadings are evident from at least April through September.

Winter/summer ratios are also large, as typified by the ratio of monthly maximum and minimum TEQ_{DF} loadings, as shown in Table 3.1

During the study period bushfire activity was very strong in both southeastern and southwestern Australia, notably over the summer of 2002-2003. Smoke from bushfire burning was reported for example from Wattleup and Duncraig in November - December 2002 and extremely heavy smoke was observed at both Boorolite and Alphington in Victoria in early February 2003. In all of these cases, the presence of smoke is confirmed by marked elevation of non-sea salt potassium (nssK) concentrations. However, PCDD/PCDF concentrations do not show elevations as strong as those observed during winter for comparable elevation of nssK concentrations. The implication is that open burning of biomass either does not produce PCDD/PCDFs with the same efficiency as that in domestic burning or that these materials are rapidly chemically transformed. The former explanation is the more plausible and this hypothesis is being tested through the parallel project examining bushfire dioxin emissions.

Table 3.1 Ratio of monthly maximum and minimum TEQ_{DF} loadings.

	max/min
Wattleup	38
Duncraig	141
Eagle Farm	26
Westmead	29
Alphington	21
Netley	18

PCB concentration as TEQ_P are generally less than TEQ_{DF}, and more or less follow the regional distribution pattern of the TEQ_{DF} being least at Cape Grim, slightly greater at the rural locations and highest in the urban locations. There is no overall pattern of seasonal variation although there is a clear indication of an annual cycle with a summer maximum at several locations, including Alphington, Wattleup and Netley. This form of variation is consistent with seasonal change in volatilisation of existing material and is most obvious for PCB77. Overall concentrations for Eagle Farm, Westmead and Alphington are similar. Interestingly, for the Wattleup site, located at the Kwinana industrial complex south of Perth, TEQ_P concentrations are significantly less than these three large, established, urban areas. Duncraig a northern Perth residential suburb, and Berrimah a largely residential Darwin suburb both have TEQ_P concentrations close to those observed in the rural locations. Typically these TEQ_{PCB} concentrations are less than 1 fg TEQ_P m^{-3} and are comparable with the cleaner rural sites in New Zealand (Buckland et al. 1999). The South Australian light industrial site, Netley, stands out relative to the other major city sites with TEQ_P concentrations more than double those of Eagle Farm, Westmead and Alphington. These concentrations are still relatively low, for example they are about one half those found in Auckland South by Buckland et al. (1999). PCB concentrations at Cape Grim during May and June do not show marked elevation comparable to those observed for PCDD/PCDF, although the highest individual PCB loading for Cape Grim occurred in May for PCB126 at 0.38 fg TEQ_P m^{-3}, also the highest monthly average (see Figure 3.2).

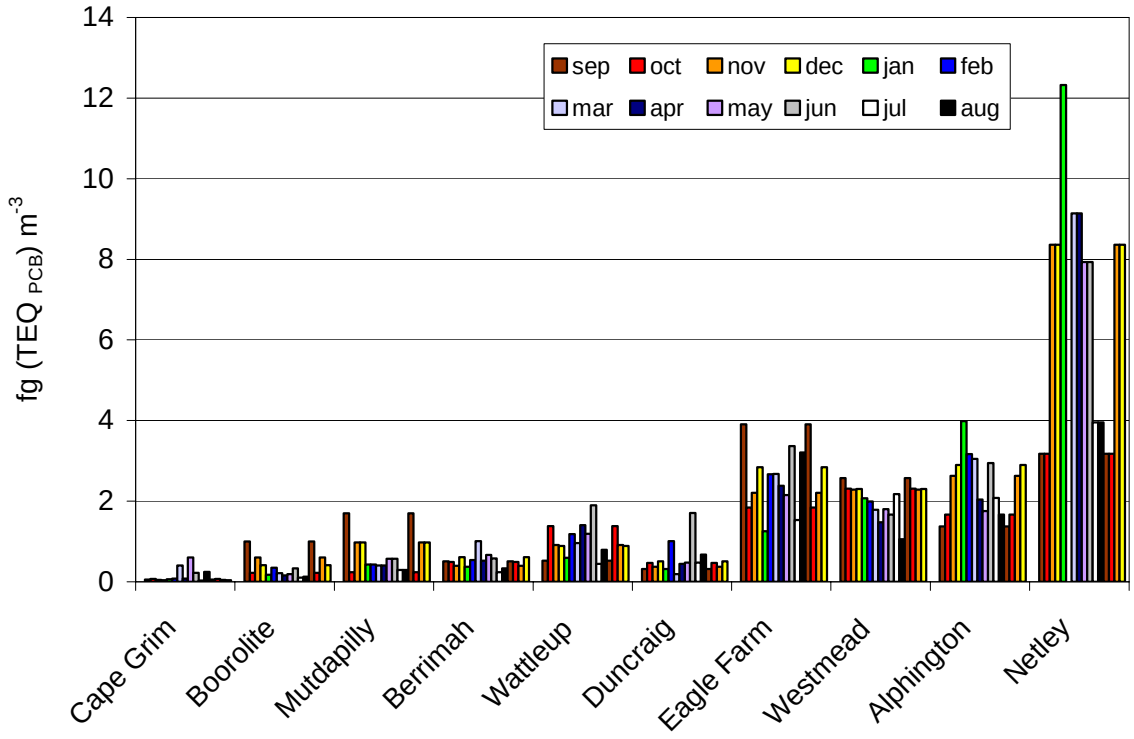

Figure 3.2 Variation in concentrations as TEQPCB for Netley.

Table 3.2 Summary of PCDD/F and PCB concentrations as fg m^{-3} in Australia *

* Values less then the LOD are included as one half LOD

	Wattleup			Duncraig			Berrimah			Eagle Farm			Mutdapilly		
PCDD Congeners	**mean**	**max**	**min**	**mean**	**max**	**min**	**mean**	**max**	**min**	**mean**	**max**	**min**	**mean**	**max**	**min**
2,3,7,8-TCDD	0.9	4.2	0.0	0.8	3.8	0.0	0.2	0.5	0.0	0.3	0.7	0.1	0.2	0.3	0.0
1,2,3,7,8-PeCDD	2.4	10.2	0.1	2.5	11.0	0.1	0.5	2.5	0.1	0.6	1.7	0.1	0.2	0.5	0.1
1,2,3,4,7,8-HxCDD	2.4	9.3	0.1	2.8	11.7	0.1	0.6	3.2	0.0	0.8	3.2	0.1	0.3	0.5	0.1
1,2,3,6,7,8-HxCDD	3.8	14.0	0.5	5.1	23.5	0.2	1.0	4.5	0.1	1.5	5.2	0.3	0.5	1.7	0.1
1,2,3,7,8,9-HxCDD	2.9	11.5	0.1	4.5	20.3	0.1	1.4	10.3	0.1	1.1	4.1	0.3	0.6	2.8	0.1
1,2,3,4,6,7,8-HpCDD	25.9	83.5	4.4	51.0	192.4	0.6	16.0	84.5	3.0	18.4	57.9	6.1	5.1	9.2	2.3
OCDD	80.0	161.9	20.0	139.5	505.4	10.0	216.5	1182	34.1	161.1	266.6	95.0	69.0	150.5	16.6
PCDF Congeners															
2,3,7,8-TCDF	14.7	67.6	1.2	9.6	40.3	0.5	8.4	55.7	0.3	46.9	268.4	0.1	3.8	16.6	0.1
1,2,3,7,8-PeCDF	7.0	23.4	1.1	6.5	31.9	0.2	0.6	1.2	0.2	4.3	28.9	0.1	0.5	0.8	0.1
2,3,4,7,8-PeCDF	10.5	36.7	0.8	10.0	51.0	0.1	0.7	1.4	0.1	3.7	11.6	0.5	0.8	1.2	0.2
1,2,3,4,7,8-HxCDF	9.3	35.1	0.6	8.3	42.5	0.1	0.7	2.5	0.1	2.4	7.8	0.2	0.5	1.0	0.2
1,2,3,6,7,8-HxCDF	7.7	28.4	0.4	6.3	31.9	0.1	0.5	1.3	0.1	1.9	5.8	0.3	0.4	0.8	0.2
2,3,4,6,7,8-HxCDF	7.7	26.7	0.3	6.0	25.5	0.1	0.5	1.7	0.1	1.7	4.9	0.3	0.4	0.6	0.1
1,2,3,7,8,9-HxCDF	0.6	2.3	0.0	0.6	2.8	0.0	0.1	0.1	0.0	0.2	0.8	0.0	0.0	0.1	0.0
1,2,3,4,6,7,8-HpCDF	20.7	63.4	3.0	16.1	74.3	0.5	2.4	7.0	0.3	7.4	16.8	3.3	1.3	1.9	0.4
1,2,3,4,7,8,9-HpCDF	3.3	14.4	0.1	2.9	17.6	0.1	0.3	0.9	0.1	0.8	2.6	0.1	0.2	0.4	0.0
OCDF	10.6	25.0	3.0	9.0	29.7	0.7	1.6	5.5	0.1	6.1	15.8	1.0	1.0	2.1	0.3
PCDD Homologues															
TCDD	36.8	166.8	1.9	17.8	72.2	1.3	9.7	27.9	0.3	13.6	21.9	4.6	8.7	20.7	1.3
PeCDD	36.1	175.3	2.5	27.0	144.4	0.7	7.0	32.2	1.3	4.7	14.2	0.5	3.3	12.1	0.6
HxCDD	62.2	228.7	1.3	62.6	246.3	0.7	19.6	90.0	1.3	23.4	63.7	3.1	8.1	22.1	1.4
HpCDD	53.9	180.3	4.7	96.3	342.0	3.5	39.1	203.2	2.8	37.6	110.0	11.3	11.1	18.2	5.4
PCDF Homologues															
TCDF	189.4	656.1	0.5	167.5	781.4	0.5	74.4	489.7	0.6	191.1	926.4	1.2	27.3	68.1	4.9
PeCDF	108.2	405.7	0.4	96.2	490.5	0.4	7.8	16.7	0.5	35.5	153.4	1.1	8.7	12.5	4.7
HxCDF	72.7	260.4	0.4	61.8	316.4	0.4	5.2	14.5	0.4	17.0	55.0	0.9	2.8	5.7	1.0
HpCDF	35.9	128.5	0.3	30.5	165.6	0.3	3.2	10.6	0.3	11.9	31.8	0.8	2.1	3.1	0.7
Non-Ortho PCBs															
PCB 77	90.3	152.0	27.8	51.2	105.9	20.3	100.5	195.1	41.5	290.8	374.5	170.5	46.7	99.3	18.8
PCB 81	5.8	8.7	2.6	3.3	6.8	1.7	5.3	10.6	2.5	14.2	17.7	9.4	2.3	5.5	0.5
PCB 126	7.6	15.0	3.2	4.2	13.4	0.5	2.9	6.2	1.4	17.1	29.7	6.1	4.2	14.0	0.5
PCB 169	0.6	2.0	0.0	0.4	2.3	0.0	0.2	0.6	0.0	0.4	1.2	0.1	0.1	0.4	0.0
Mono-Ortho PCBs															
PCB 105	523	1094	144	305	760	94	449	748	210	1553	3127	997	542	974	298
PCB 114	31	61	9	20	42	6	31	52	12	101	191	51	30	51	15
PCB 118	1219	2625	328	772	1472	319	1212	2113	426	3729	6398	2031	1145	1739	599
PCB 123	37	75	10	24	48	8	36	60	10	118	258	46	37	71	13
PCB 156	82	262	13	47	144	17	50	94	23	265	620	123	81	152	35
PCB 157	15	57	1	10	34	2	11	23	4	55	122	14	18	30	4
PCB 167	34	126	5	31	140	4	32	88	6	109	438	25	62	348	8
PCB 189	2.5	8.4	0.1	1.8	5.7	0.4	0.4	0.6	0.1	9.5	28.1	1.4	1.5	5.5	0.2
Sum of PCDD/Fs (exc)[1]	678.7	2387	15.0	706.5	3079	14.1	367.8	1652	17.5	478.3	1563	36.2	139.8	240.9	74.5
WHO_{98} TEQ_{DF} (inc)[2]	14.65	55.02	0.98	13.75	64.67	0.27	2.83	12.73	0.29	8.89	40.46	0.73	1.54	4.04	0.27
WHO_{98} TEQ_{PCB} (inc)[2]	1.05	2.26	0.07	0.59	1.82	0.06	0.53	1.18	0.11	2.47	6.35	0.54	0.66	2.39	0.16

1= excluding LOD values

2= including half LOD values

3=contamination events excluded

Table 3.2 continued.

	Westmead			Boorolite			Alphington			Cape Grim[3]			Netley		
PCDD Congeners	**mean**	**max**	**min**	**mean**	**max**	**min**	**mean**	**max**	**min**	**mean**	**max**	**min**	**mean**	**max**	**min**
2,3,7,8-TCDD	0.7	2.8	0.1	0.1	0.4	0.0	0.9	2.7	0.1	0.3	1.4	0.0	1.3	3.2	0.1
1,2,3,7,8-PeCDD	2.6	9.6	0.1	0.3	1.5	0.1	2.7	7.5	0.2	0.3	29.1	0.0	2.9	7.9	0.3
1,2,3,4,7,8-HxCDD	3.0	10.3	0.2	0.2	1.6	0.0	2.8	7.8	0.5	0.2	106.5	0.0	2.7	9.6	0.2
1,2,3,6,7,8-HxCDD	6.7	29.6	0.5	0.3	1.7	0.1	4.6	12.1	0.5	0.5	263.2	0.0	4.5	14.1	0.7
1,2,3,7,8,9-HxCDD	5.5	22.0	0.3	0.3	1.3	0.1	3.8	11.3	0.2	0.5	219.3	0.0	3.5	10.7	0.2
1,2,3,4,6,7,8-HpCDD	61.1	193.3	6.7	3.0	6.2	0.6	39.7	112.9	7.1	3.3	3008	0.3	59.3	186.1	1.3
OCDD	350.2	677.1	112.9	39.9	82.8	4.6	274.8	414.8	152.6	7.5	5263	1.0	220.5	564	1.1
PCDF Congeners															
2,3,7,8-TCDF	15.7	67.9	0.7	13.0	150.3	0.0	22.4	66.0	2.8	0.2	1.5	0.0	19.1	32.9	1.4
1,2,3,7,8-PeCDF	6.7	22.2	1.0	0.4	1.7	0.0	7.8	21.4	0.5	0.2	13.2	0.0	7.8	18.6	0.7
2,3,4,7,8-PeCDF	10.5	37.1	1.2	0.4	1.6	0.0	12.6	33.6	1.6	0.2	37.6	0.0	9.8	23.7	0.9
1,2,3,4,7,8-HxCDF	7.8	27.5	0.4	0.3	2.4	0.0	9.6	27.5	0.5	0.3	103.4	0.0	5.8	19.2	0.9
1,2,3,6,7,8-HxCDF	6.7	21.8	1.0	0.2	1.4	0.0	7.8	21.4	1.0	0.3	103.4	0.0	4.2	10.7	1.0
2,3,4,6,7,8-HxCDF	6.1	19.0	0.3	0.2	1.4	0.0	7.8	21.4	0.8	0.4	200.5	0.0	2.9	7.3	0.4
1,2,3,7,8,9-HxCDF	0.5	2.0	0.0	0.1	0.5	0.0	0.7	1.7	0.0	0.0	17.2	0.0	0.3	0.8	0.1
1,2,3,4,6,7,8-HpCDF	16.9	44.3	5.4	0.7	2.0	0.3	20.0	58.0	3.7	1.3	845.9	0.1	10.8	20.3	1.0
1,2,3,4,7,8,9-HpCDF	2.3	8.0	0.2	0.1	0.6	0.0	2.9	10.2	0.3	0.1	153.5	0.0	1.3	3.0	0.1
OCDF	10.2	25.5	1.4	0.9	3.8	0.0	13.0	27.5	4.4	0.4	689.2	0.1	12.2	22.4	0.3
PCDD Homologues															
TCDD	26.4	71.1	1.6	1.6	5.7	0.5	28.6	76.3	2.3	3.3	21.5	0.1	110.2	161.1	2.2
PeCDD	26.0	103.3	0.8	1.1	3.3	0.3	31.9	112.9	3.1	2.5	285.1	0.2	88.1	124.7	3.0
HxCDD	78.1	296.7	1.0	4.1	15.0	1.0	61.7	164.6	1.5	5.6	2130	0.4	125.3	219.8	1.5
HpCDD	113.8	351.2	3.8	9.1	25.4	1.7	76.6	212.2	5.7	7.6	4699	1.2	233.7	424.1	2.5
PCDF Homologues															
TCDF	241.0	654.6	0.4	21.6	197.8	0.7	266.3	659.3	0.6	11.0	100.8	0.0	607.7	829.0	0.6
PeCDF	97.5	351.8	0.4	2.6	8.9	0.4	132.2	383.0	0.5	3.7	213.0	0.1	205.4	279.5	0.5
HxCDF	60.9	208.9	0.3	1.6	6.0	0.2	77.1	215.2	0.5	2.5	751.9	0.2	80.8	128.5	0.4
HpCDF	29.8	88.0	0.3	1.6	3.4	0.3	33.3	106.8	0.4	1.9	1206	0.2	30.4	48.2	0.4
Non-Ortho PCBs															
PCB 77	251.1	342.0	106.1	47.9	92.1	11.4	362.0	735.1	176.8	13.2	61.7	2.6	668.1	1492	295.6
PCB 81	13.8	18.7	7.2	2.8	6.1	0.7	20.0	36.8	10.7	0.7	3.0	0.1	31.3	70.1	14.1
PCB 126	13.4	17.0	8.1	1.3	5.0	0.2	17.2	27.6	9.6	0.5	3.8	0.1	54.8	95.5	23.8
PCB 169	0.6	1.9	0.1	0.1	1.2	0.0	1.1	4.0	0.2	0.1	7.2	0.0	1.2	2.1	0.3
Mono-Ortho PCBs															
PCB 105	1219	1762	485.9	419.4	1010	128.8	1395	2450	704.3	134.9	388.1	41.5	2894	5371	1354
PCB 114	78.0	118.3	30.7	29.3	59.4	11.6	101.6	183.8	49.3	7.5	22.2	0.8	185.2	328.2	75.6
PCB 118	3150	4339	1202	998.7	2968	321.9	3590	6279	1878	294.5	831.6	97.9	8544	14621	3779
PCB 123	113.2	178.8	38.4	29.5	80.3	8.3	133.4	275.7	58.7	7.5	20.8	1.5	319.8	552.0	118.4
PCB 156	167.7	265.6	84.4	48.1	98.5	12.9	161.9	260.4	86.9	22.4	77.6	3.9	328.8	626.6	191.8
PCB 157	36.7	60.5	11.9	9.1	24.6	2.3	37.0	64.1	6.8	4.5	26.9	0.0	96.4	164.1	51.4
PCB 167	124.6	480.6	5.7	70.9	539.9	4.3	89.6	381.1	16.1	7.4	24.9	1.6	98.4	298.4	56.4
PCB 189	4.3	6.9	1.4	0.9	2.1	0.2	5.2	7.4	1.5	0.5	40.7	0.1	7.8	12.1	5.7
Sum of PCDD/Fs (exc)[1]	1002	2639	12.2	84.2	405.9	15.1	966.5	1755	18.1	41.3	220.6	3.5	1865	2879	17.6
WHO_{98} TEQ_{DF} (inc)[2]	15.05	54.60	1.40	2.17	18.93	0.17	17.17	42.60	1.99	1.05	121.6	0.11	14.56	36.59	1.40
WHO_{98} TEQ_{PCB} (inc)[2]	1.96	4.18	0.40	0.29	1.16	0.08	2.36	4.38	0.38	0.11	0.41	0.02	7.04	12.34	3.10

1= excluding LOD values

2= including half LOD values

3=contamination events excluded

3.2 Dioxin-Furan Toxic Congener and Homologue group profiles

Figures 3.3 to 3.22 show dioxin-furan toxic congener, and homologue group profiles by site, in the order of background reference site, rural-remote and urban-industrial. Only congeners with concentrations values greater than the LOD are plotted.

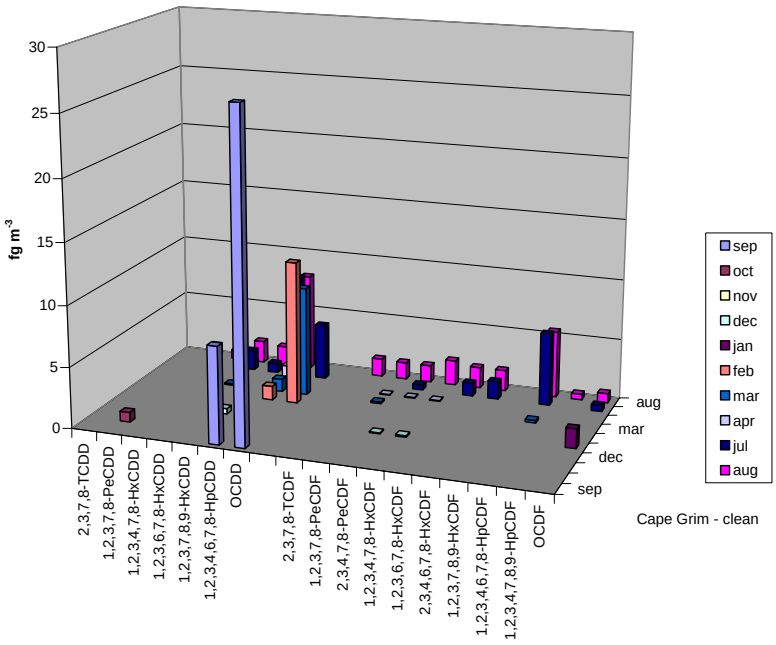

Figure 3.3 Cape Grim toxic congener profile (excludes May and June).

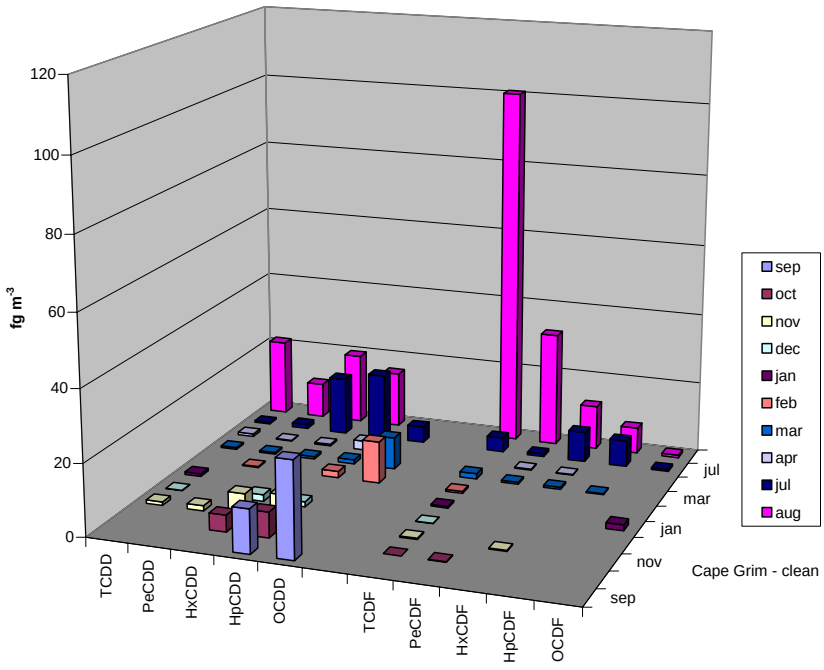

Figure 3.4 Cape Grim homologue group profile.

Remote/rural sites

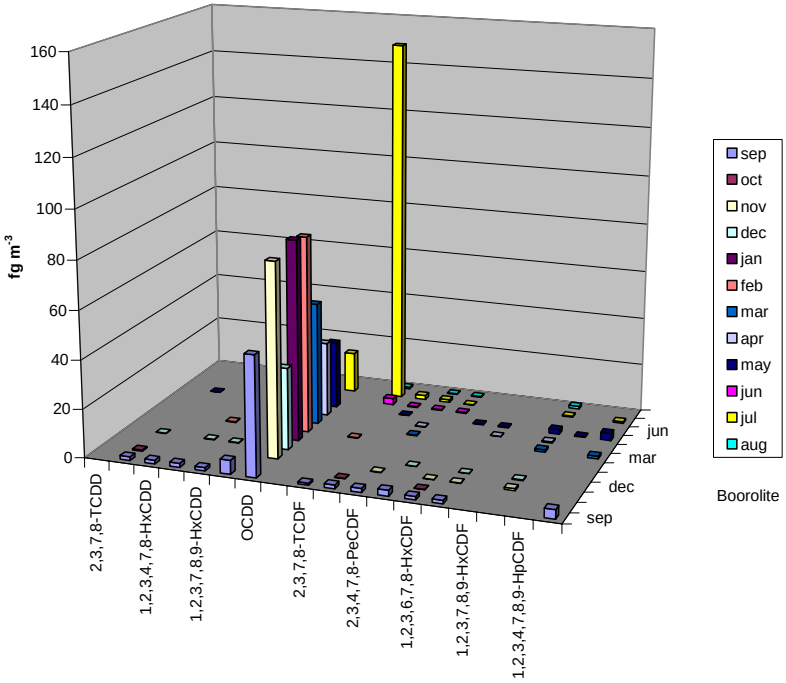

Figure 3.5 Boorolite, north-east Vic (rural) toxic congener profile.

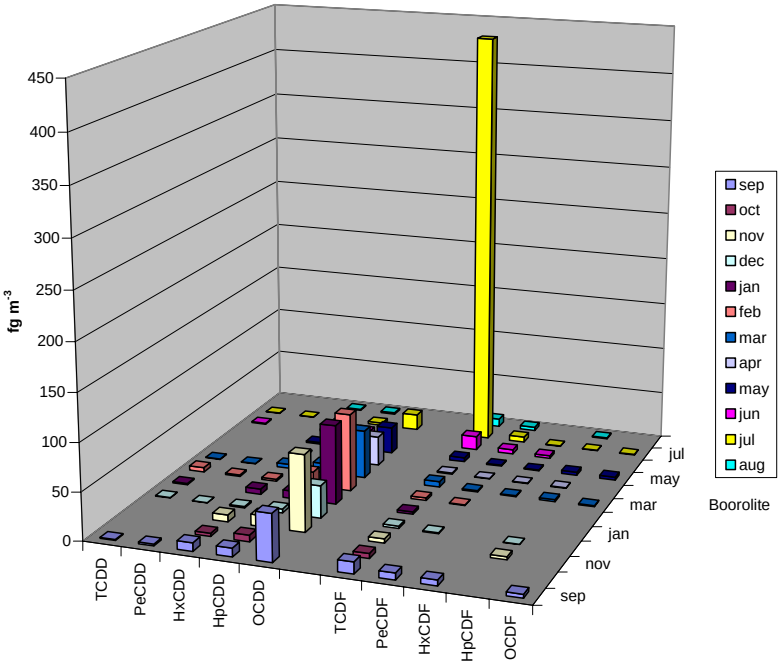

Figure 3.6 Boorolite, north-east Vic (rural) homologue group profile.

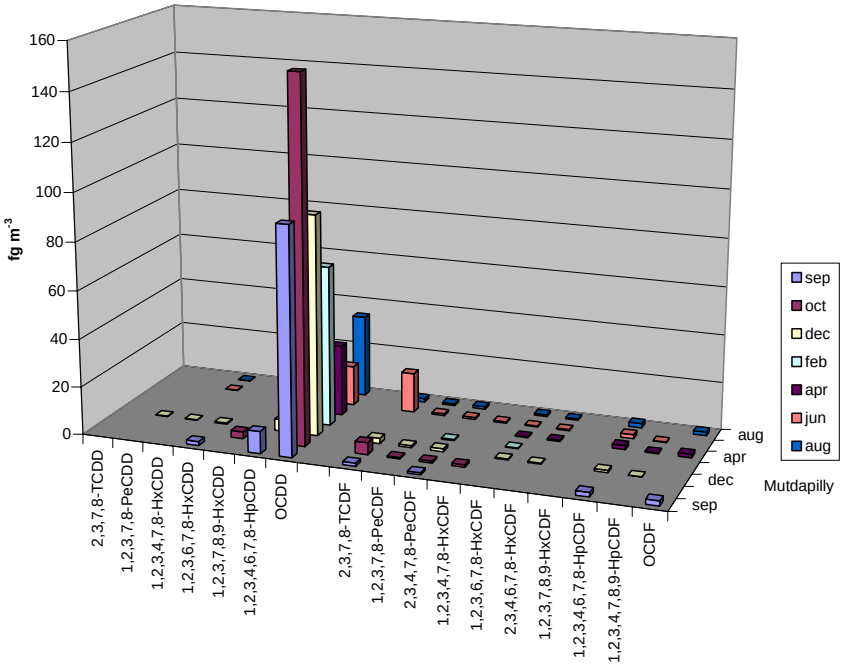

Figure 3.7 Mutdapilly, south-east Qld (rural) toxic congener profile.

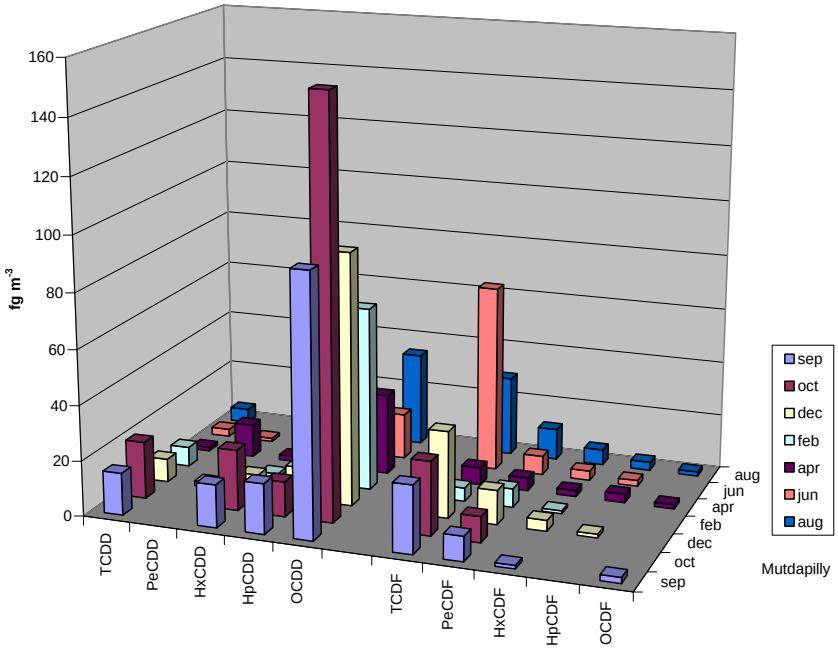

Figure 3.8 Mutdapilly, south-east Qld (rural) homologue group profile.

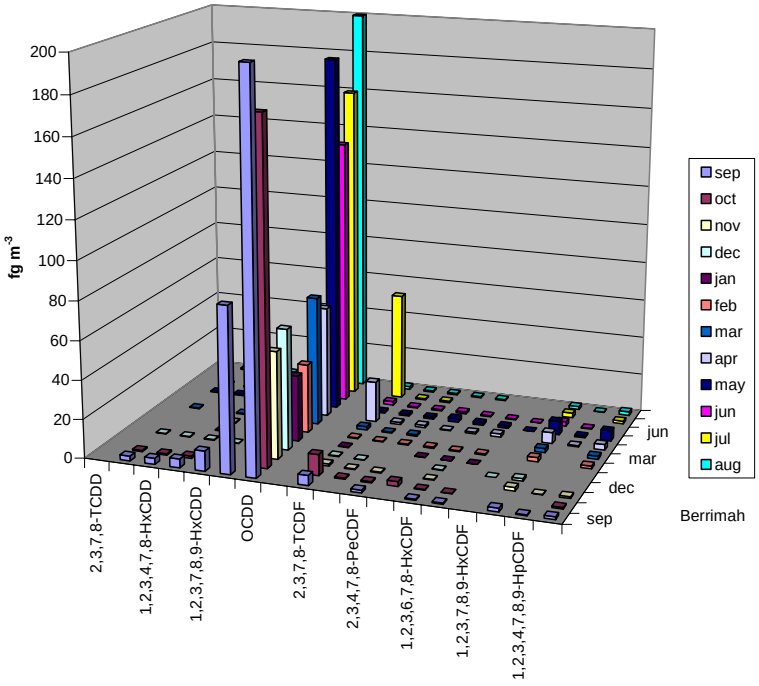

Figure 3.9 Berrimah, NT (remote - residential) toxic congener profile.

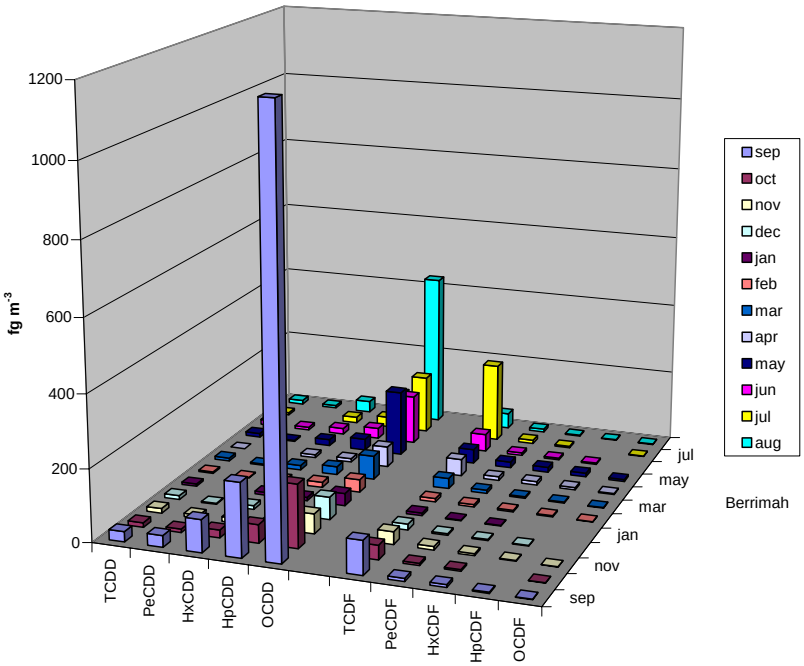

Figure 3.10 Berrimah, NT (remote - residential) homologue group profile.

Urban and industrial sites

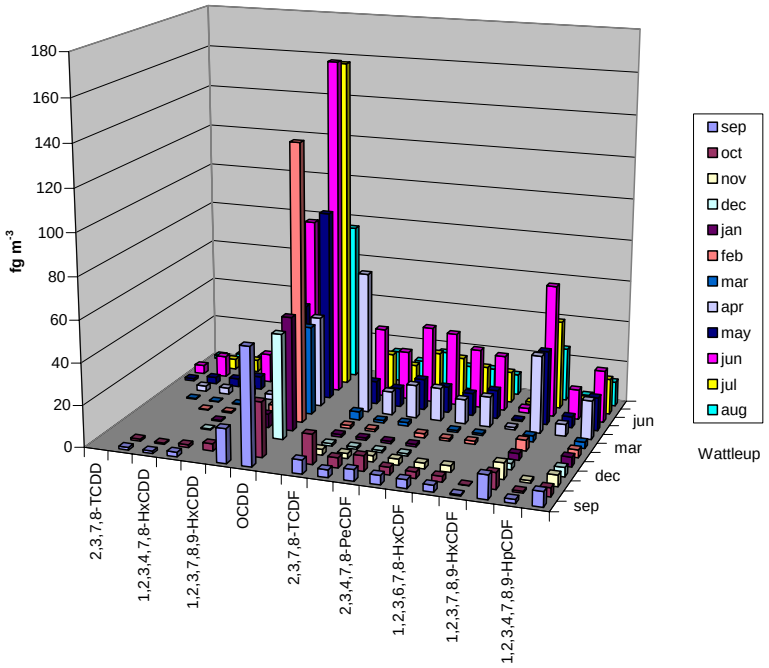

Figure 3.11 Wattleup, WA (Kwinana industrial region) toxic congener profile.

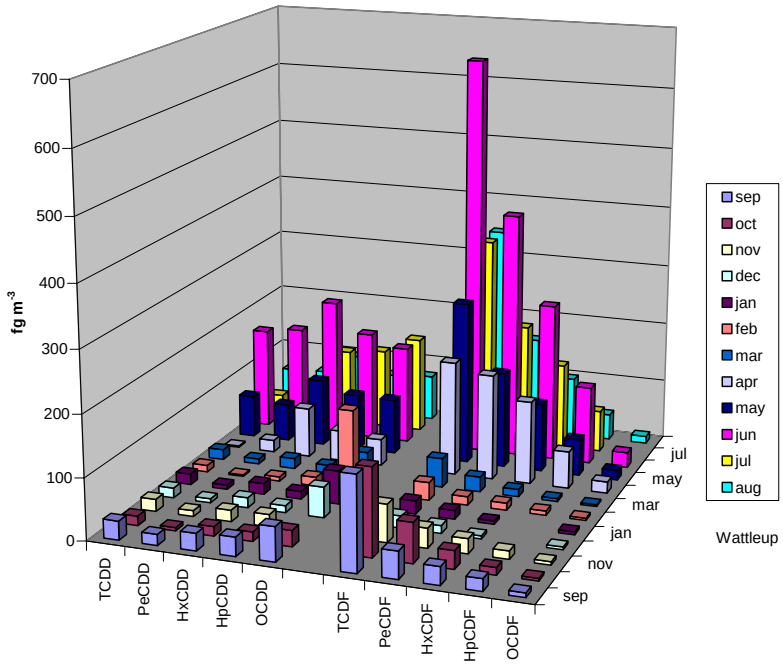

Figure 3.12 Wattleup, WA (Kwinana industrial region) homologue group profile.

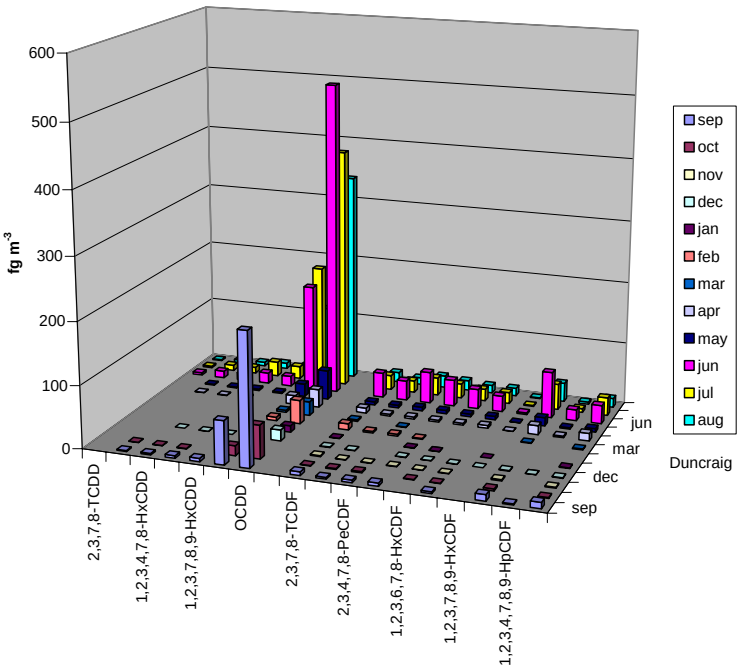

Figure 3.13 Duncraig, WA (residential area) toxic congener profile.

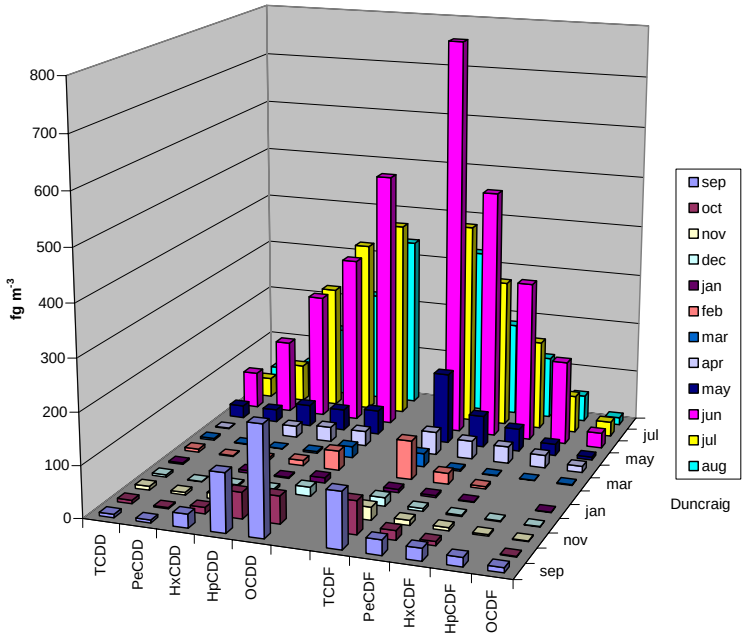

Figure 3.14 Duncraig, WA (residential area) homologue group profile.

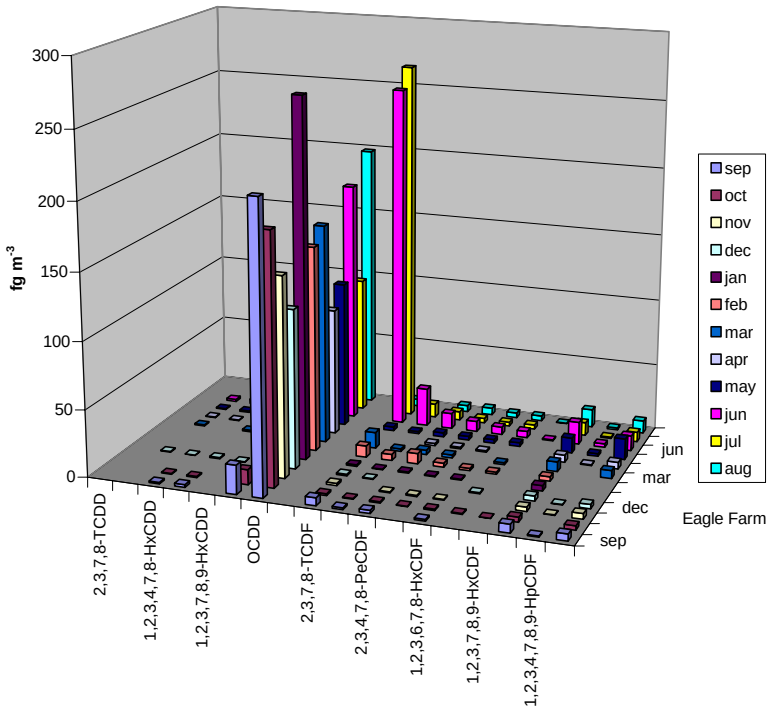

Figure 3.15 Eagle Farm, Qld (light-industrial area) toxic congener profile.

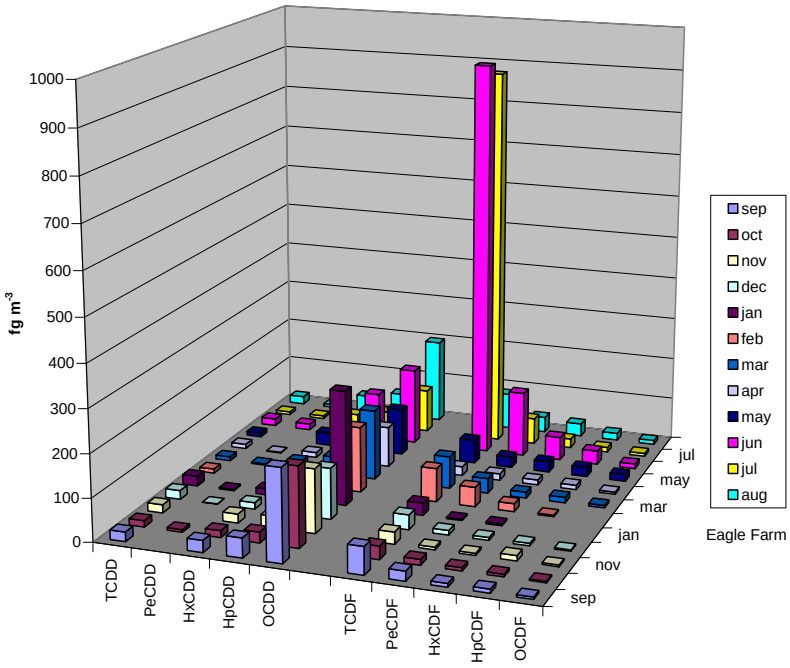

Figure 3.16 Eagle Farm, Qld (light-industrial area) homologue group profile.

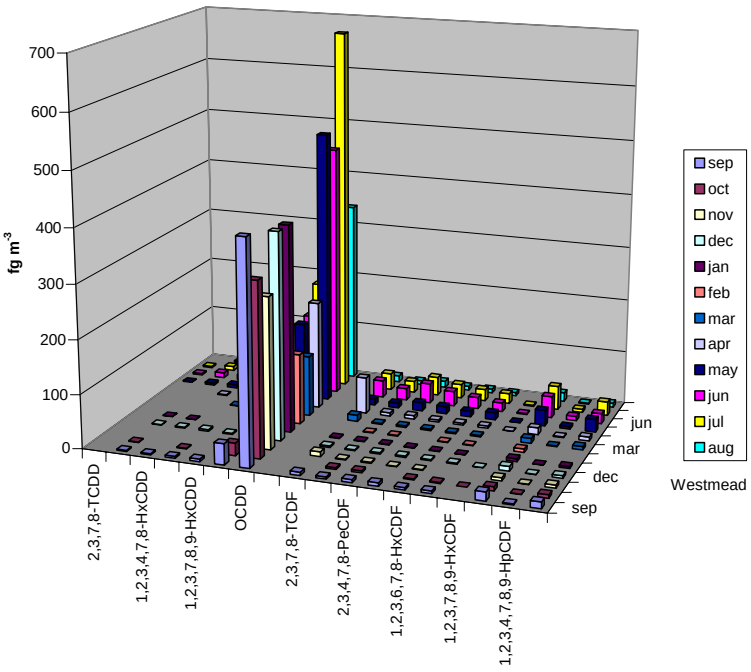

Figure 3.17 Westmead, NSW (residential area) toxic congener profile.

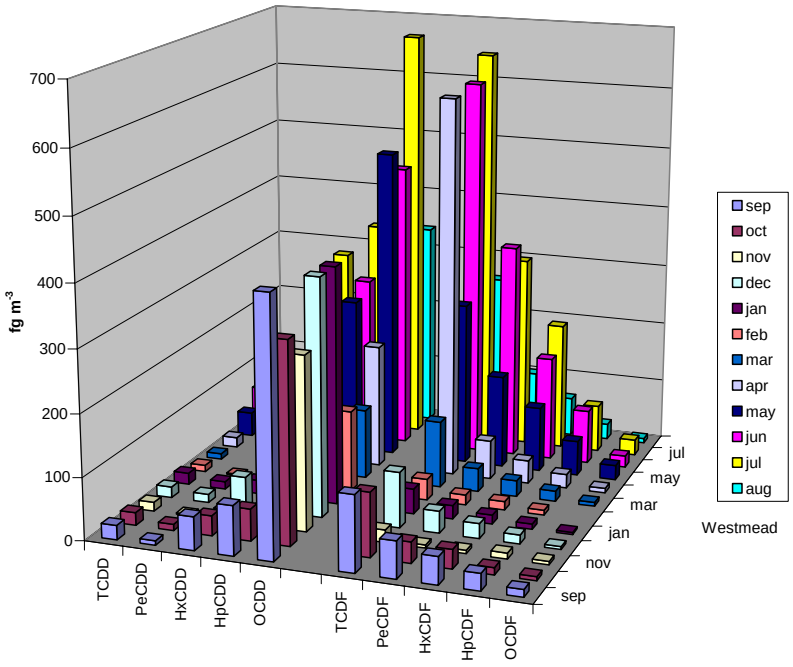

Figure 3.18 Westmead, NSW (residential area) homologue group profile.

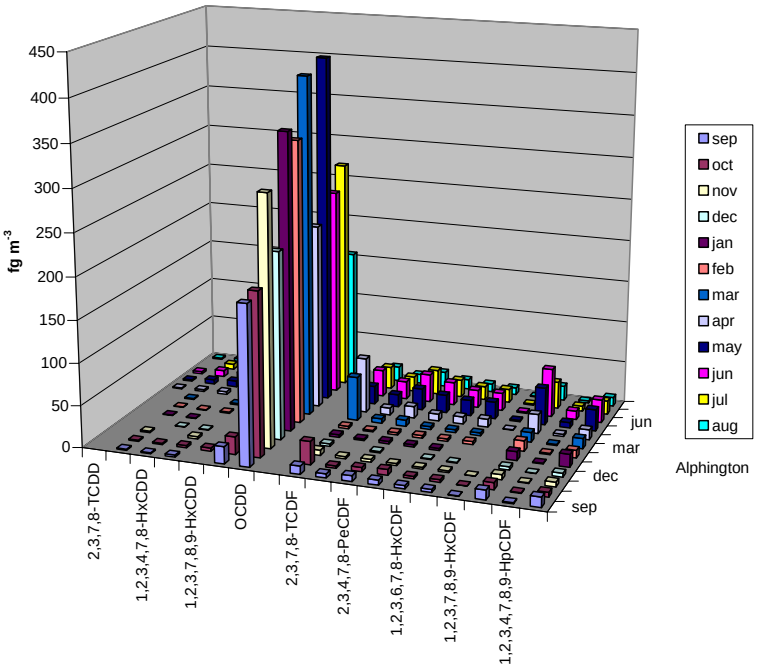

Figure 3.19 Alphington, Vic (residential area) toxic congener profile.

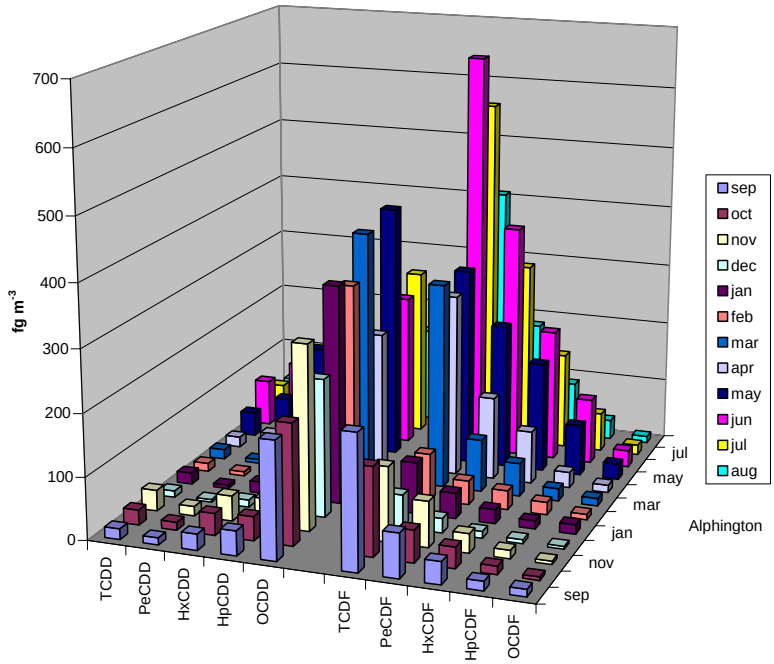

Figure 3.20 Alphington, Vic (residential area) homologue group profile.

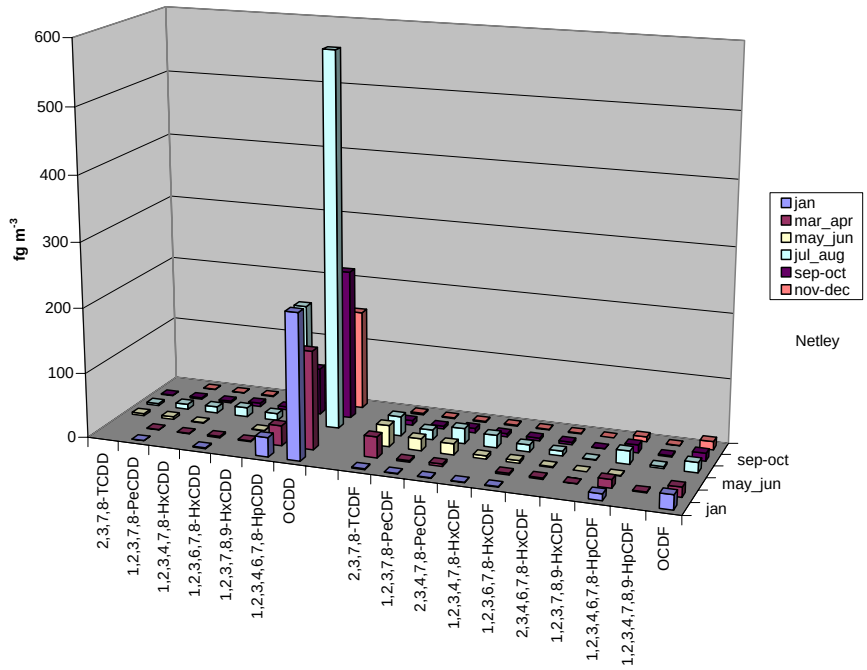

Figure 3.21 Netley, SA (residential-light industrial) toxic congener profile.

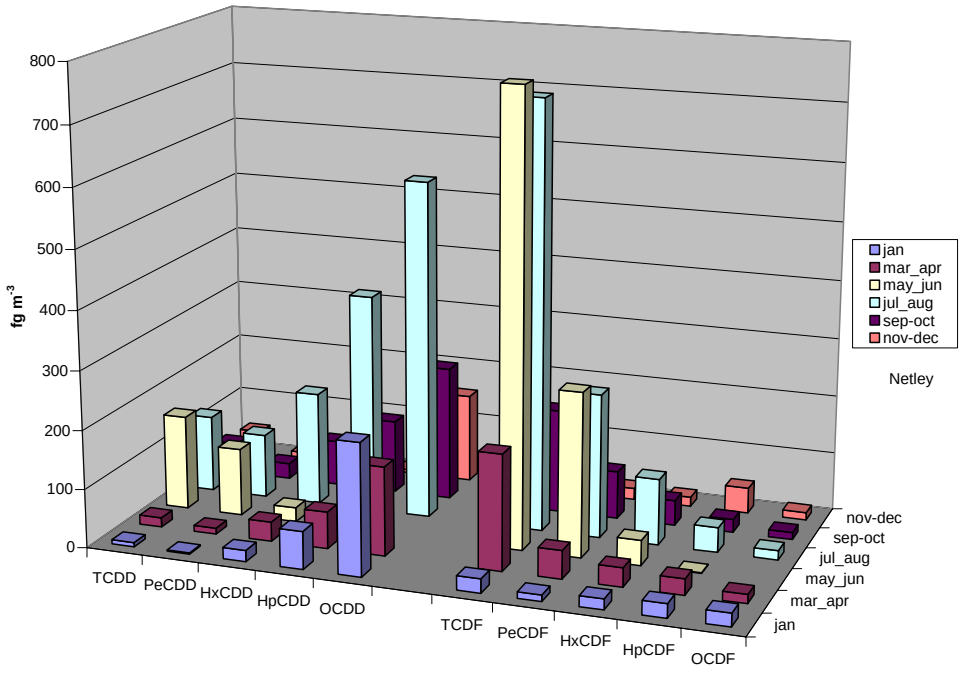

Figure 3.22 Netley, SA (residential-light industrial) homologue group profile.

Whilst it is generally difficult to directly relate source and ambient PCDD/PCDF congener profiles, the winter patterns (both the toxic congener and homologue group) in the present study show a very consistent pattern for Duncraig, Wattleup, Westmead, Alphington and to some extent Eagle Farm. The homologue group profile, for example at Duncraig, is essentially identical to winter homologue group profiles at Masterton and Christchurch, NZ, both of which have been attributed to wood combustion for domestic heating (Buckland et al. 1999). Figure 3.23 gives the toxic congener profile for wood smoke determined recently by Gras et al. (2002) and this pattern of elevated furans, particularly the decrease with increasing chlorination and the small peak around 1,2,3,4,6,7-HpCDF, is substantially preserved in the ambient urban profiles. OCDD is notably more prevalent in most of the ambient samples than the near-source wood-smoke profiles and also correlates less strongly than the other congeners typical of wood-smoke.

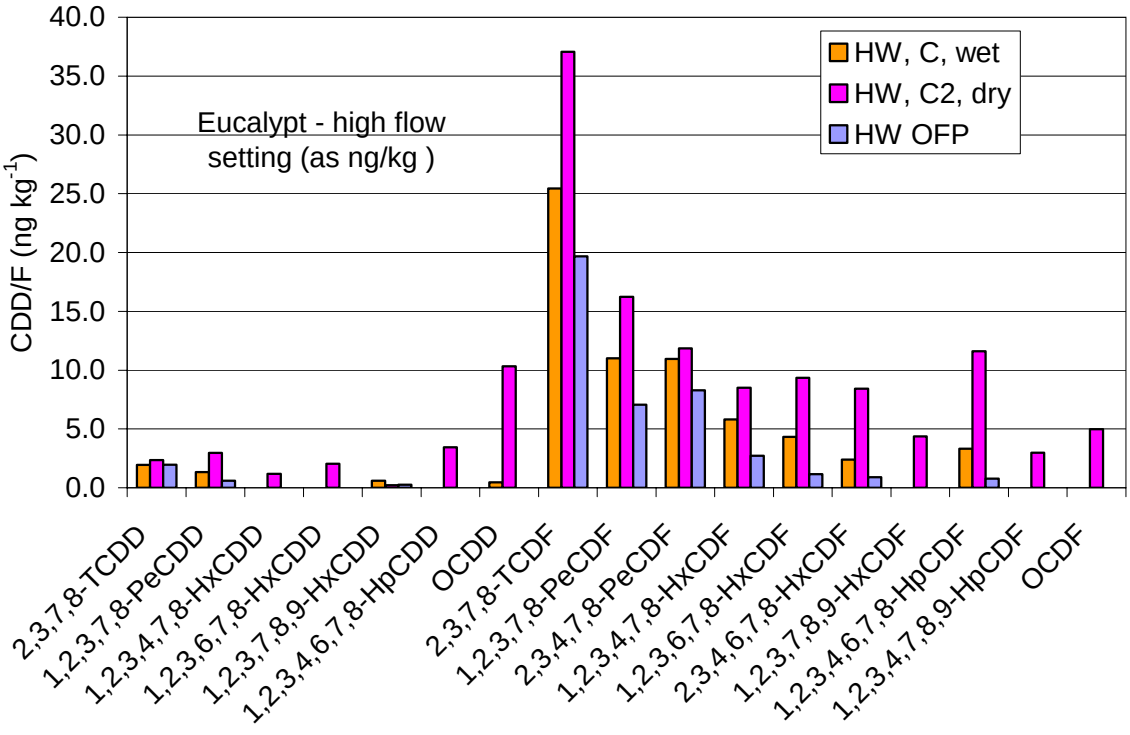

Figure 3.23 Congener profile for eucalypt wood smoke from domestic heating.

3.3 PCB profiles

PCB profiles as shown in Figure 3.24 to 3.33 are plotted with two separate groups of PCB congeners, non-ortho congeners (also co-planar) on the left and mono-ortho species (those with only one chlorine in the ortho position) on the right. These profiles are presented in the order of background reference site, rural, remote, urban-industrial. Only congeners with concentrations values greater than the LOD are plotted.

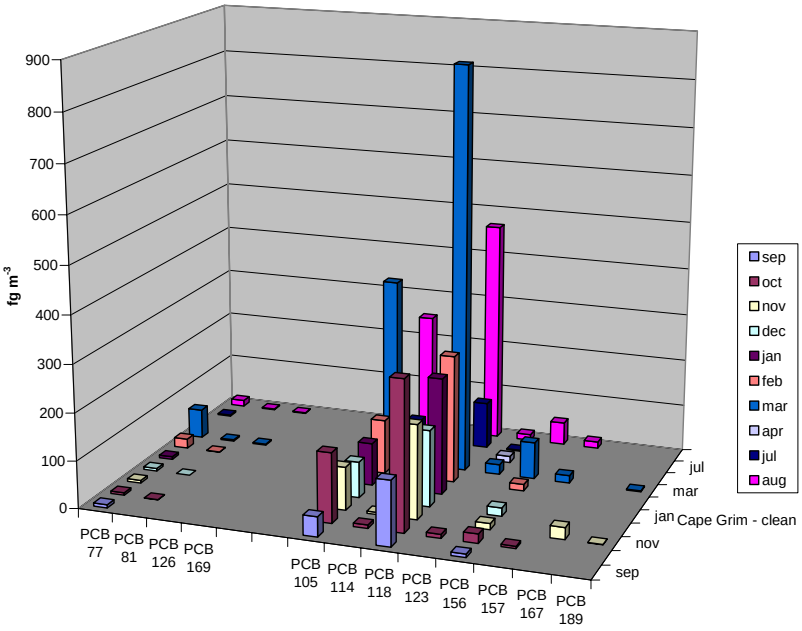

Figure 3.24 Cape Grim dioxin-like PCB congener profile.

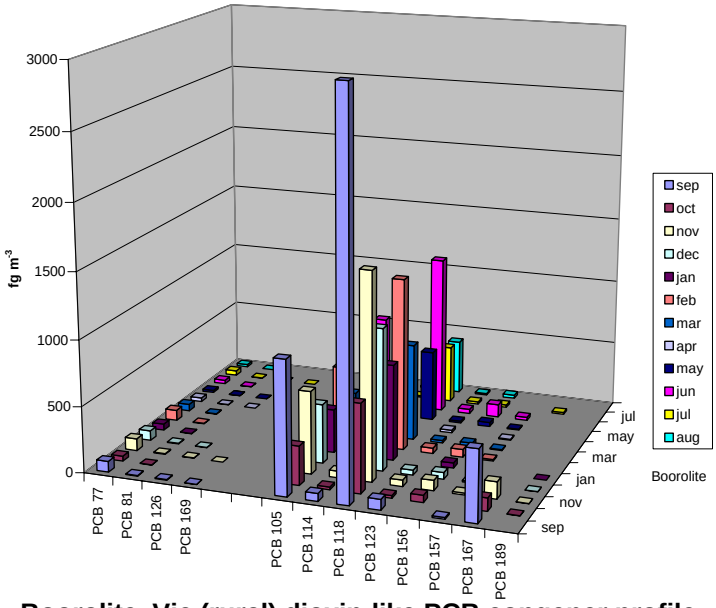

Figure 3.25 Boorolite, Vic (rural) dioxin-like PCB congener profile.

Remote/rural sites - PCB profiles

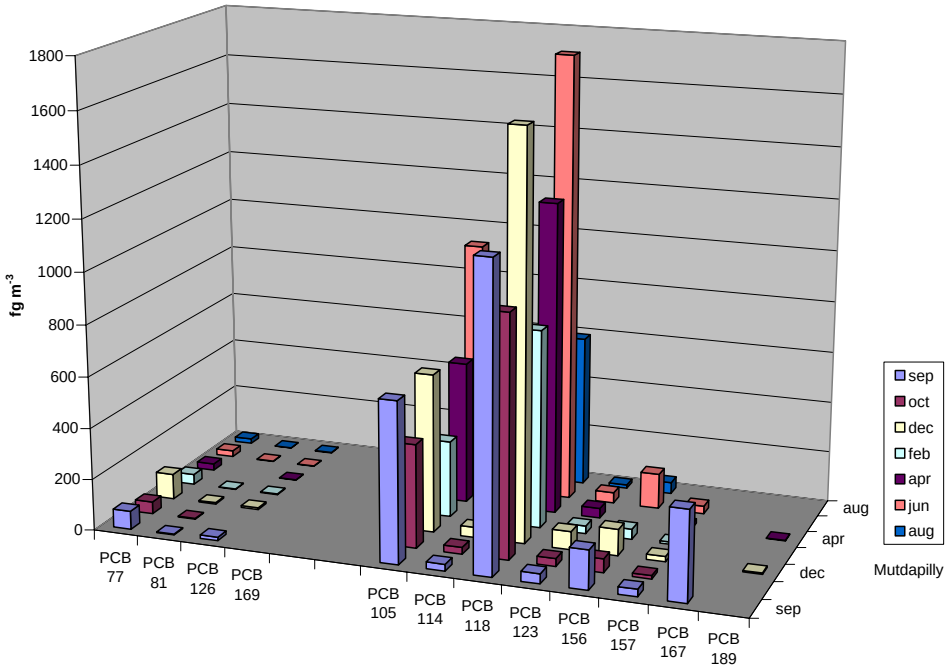

Figure 3.26 Mutdapilly, Qld (rural) dioxin-like PCB congener profile.

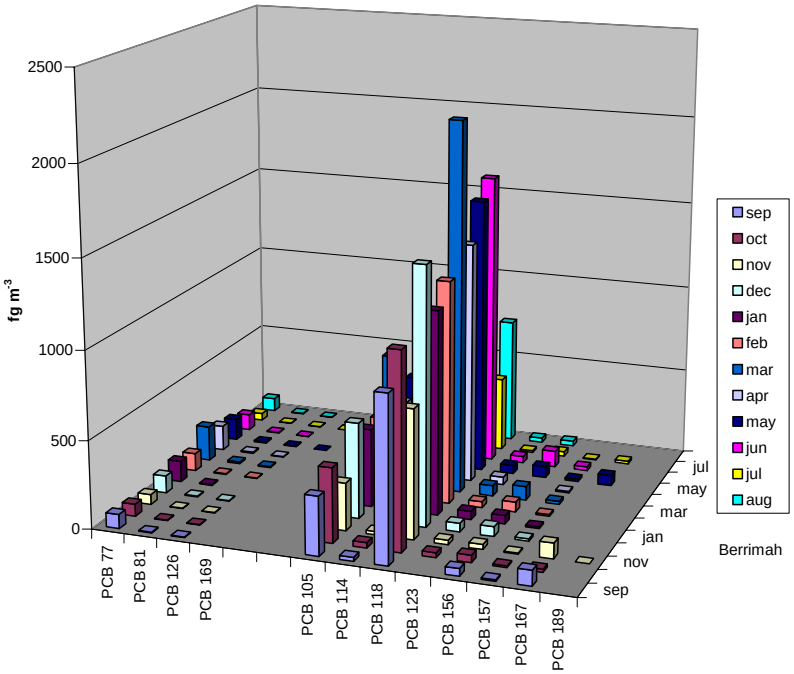

Figure 3.27 Berrimah, NT (remote-residential) dioxin-like PCB congener profile.

Urban and industrial sites - PCB profiles

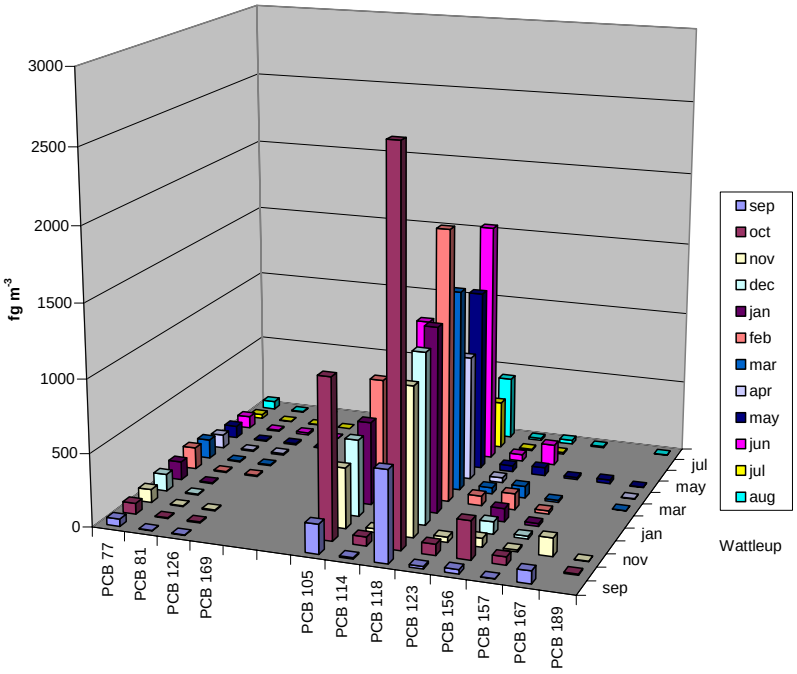

Figure 3.28 Wattleup, WA (industrial) dioxin-like PCB congener profile.

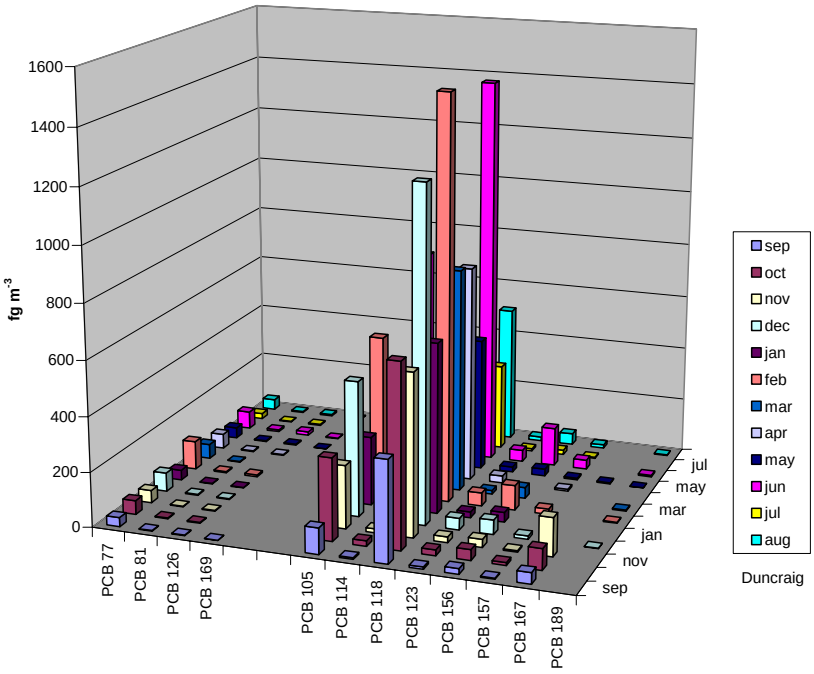

Figure 3.29 Duncraig, WA (residential) dioxin-like PCB congener profile.

Urban and industrial sites – PCB profiles

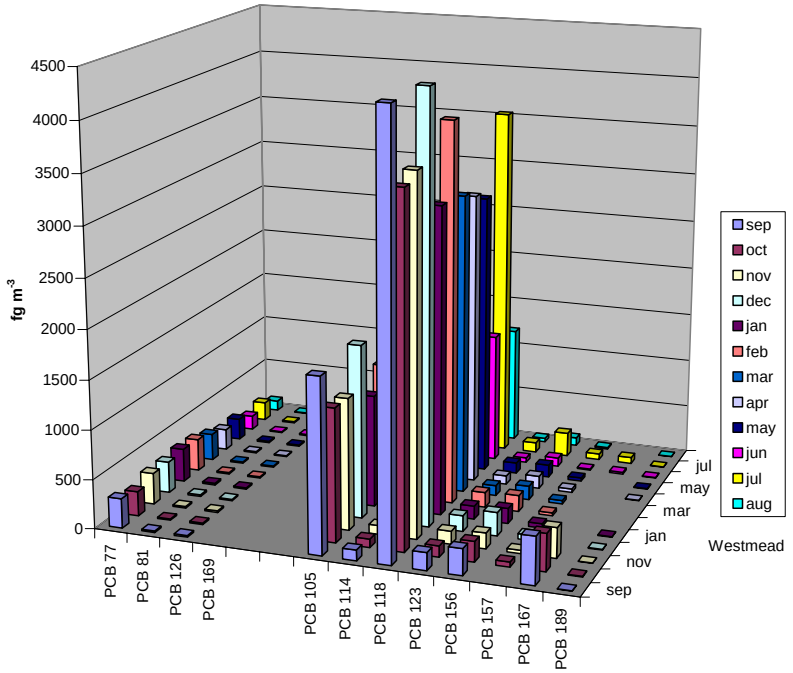

Figure 3.30 Eagle Farm, Qld (light-industrial) dioxin-like PCB congener profile.

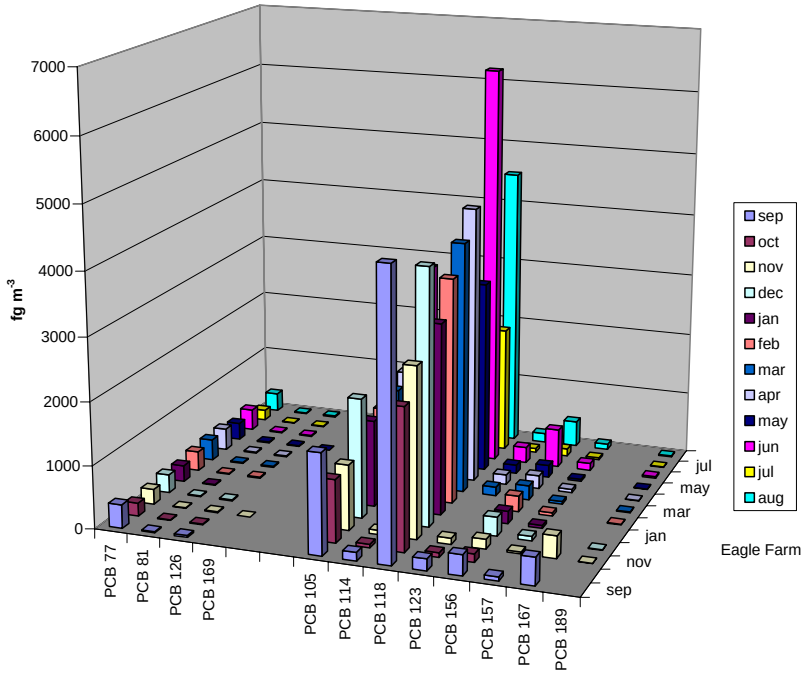

Figure 3.31 Westmead, NSW (residential) dioxin-like PCB congener profile.

Urban and industrial sites - PCB profiles

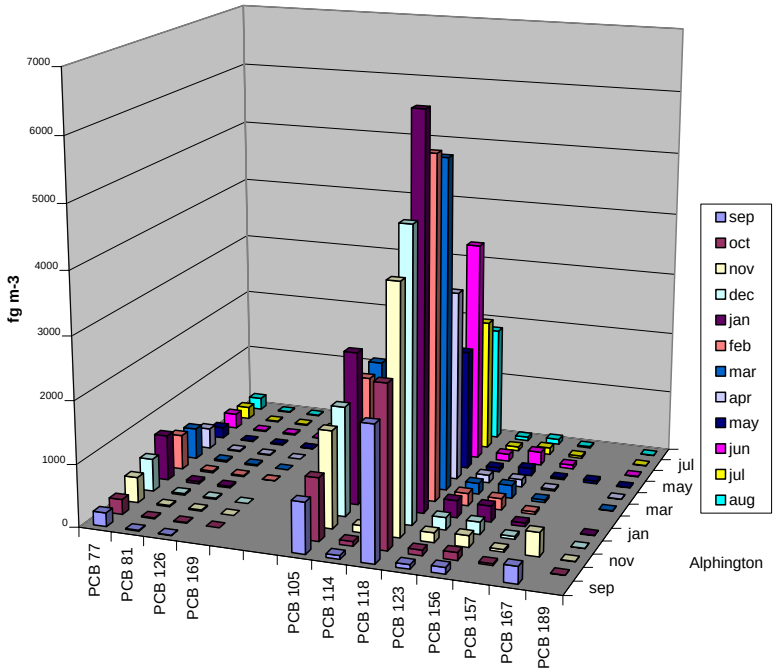

Figure 3.32 Alphington, Vic (residential) dioxin-like PCB congener profile.

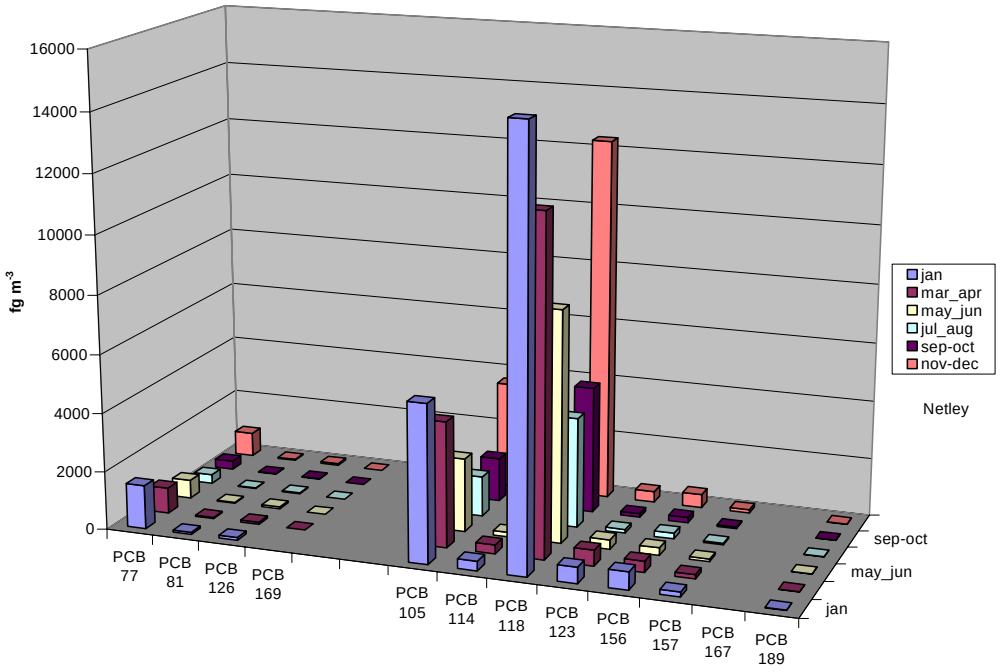

Figure 3.33 Netley, SA (residential-light industrial) dioxin-like PCB congener profile.

In terms of atmospheric mass loading, the typical order of abundance of the PCB congeners is PCB118, PCB105 and PCB77 whereas in terms of TEQ the abundance is typically PCB126, PCB118, PCB105, PCB156 (in order of TEQ loading); typically, PCB126 dominates the PCB TEQ. These abundance patterns are remarkably consistent across the observing locations.

3.4 Factors contributing to concentration differences around Australia.

Many factors may influence the distribution of toxic dioxins and dioxin-like species in Australian cities and rural areas. The exceptionally low dioxin concentrations observed in clean on-shore air at Cape Grim throughout the year, and the very low concentrations observed in summer in the large urban locations are clear indicators that the majority of these species are relatively locally generated. As a group, all of the observed species can be considered semi-volatile with the degree of partitioning largely controlled by the vapour pressure of the individual congener. Lower chlorinated congeners tend to be present predominantly in the vapour phase and the higher chlorinated congeners in the particulate or condensed phase (see for example, Harrad 1998). This may influence both the transport and removal processes, which in general will differ for gaseous and particle-bound species. Re-entrainment of soil for example will primarily affect particle bound species as will condensation and precipitation scavenging; lighter species will be more likely to volatalise and be present in gaseous form at higher temperatures.

In general, separate analyses of the gas and particle phase were not conducted for this study. However, an indication of the vapour/particle partitioning for Westmead, can be determined from analyses for the months of June and July 2003.

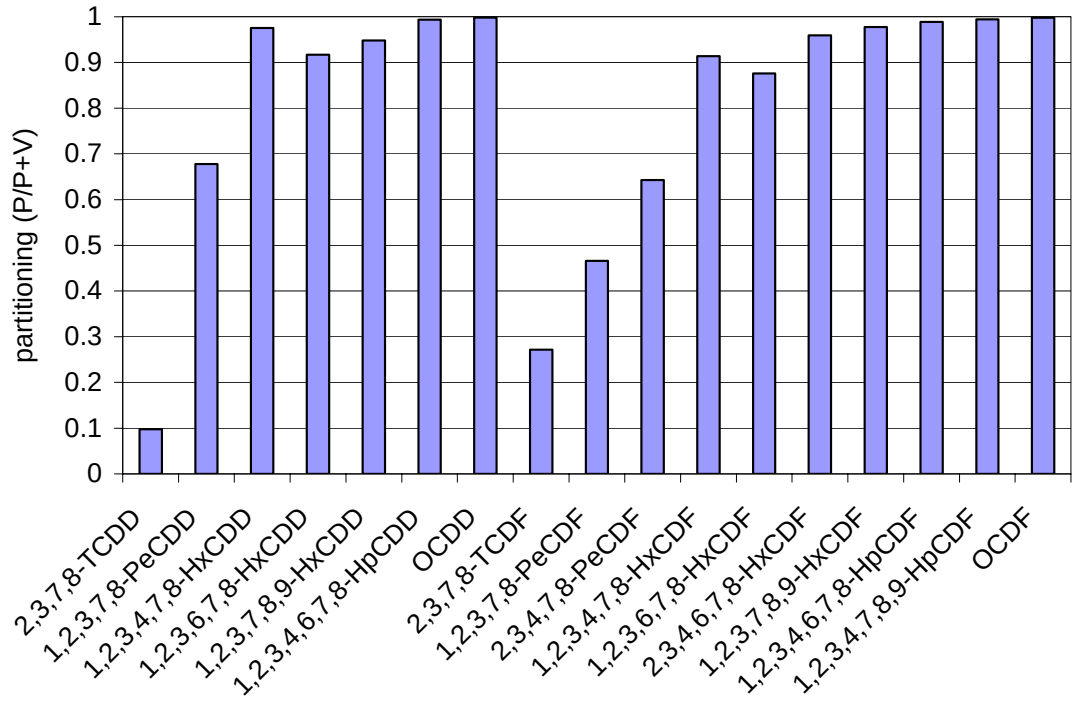

Figure 3.34 Indicative partitioning of PCDD/F congeners at Westmead.

For these samples, the July gas trap was inadvertently analysed together with the June filters and to facilitate some recovery of the individual monthly data the June gas trap and July filters were analysed separately. Overall concentrations were similar for these two months (less than 10% difference) and an overall ratio of the collected species concentrations was estimated from the particle bound species where the derived particle phase comprised greater than 0.99. This concentration ratio was used to recalculate the separate June and July gas and particle phase contributions. The resulting mean value of partitioning is shown for the PCDD/PCDF toxic congeners in Figure 3.34.

The general form of the partitioning is consistent with that shown by Harrad (1998) from consideration of the vapour pressure and shows a strong tendency for most of the PCDD/PCDF material to be present in a particle-bound form. Corresponding partitioning for the dioxin-like PCB congeners is shown on Figure 3.35. In this case, most congeners tend to be present predominantly in the gas phase. Derivation of gas-particle partitioning in this manner from filter/trap sampling is known to have limitations and should be considered indicative rather than quantitative for all species.

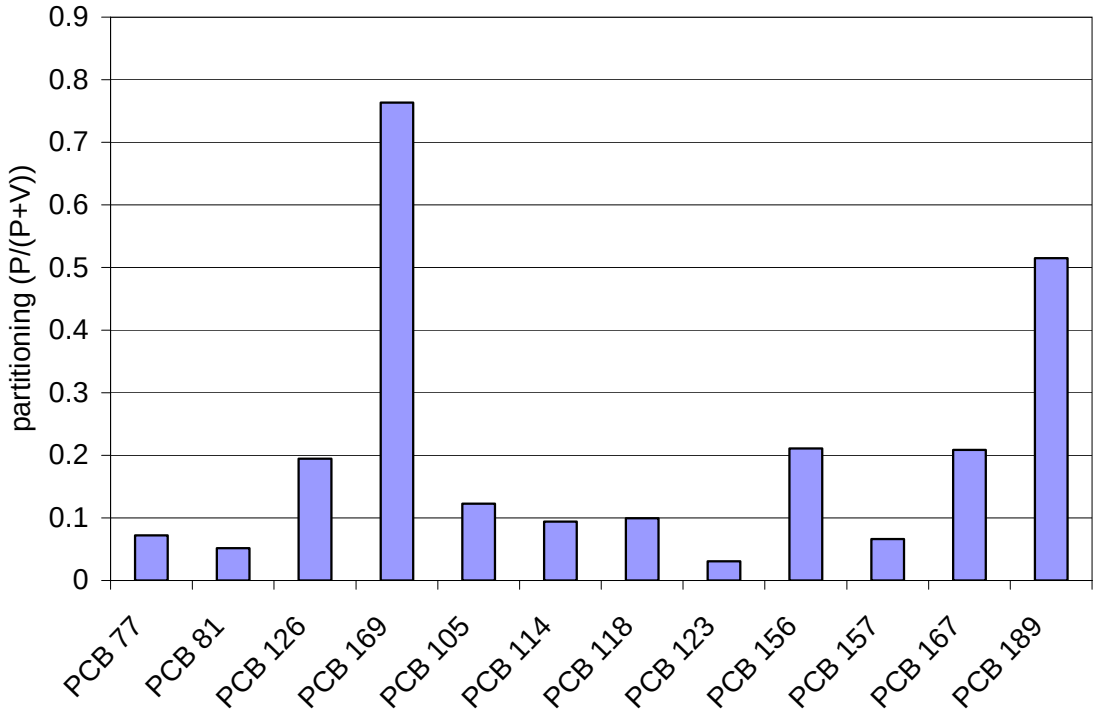

Figure 3.35 Indicative partitioning for dioxin-like PCB congeners derived at Westmead.

3.4.1 Common factors - correlation matrices

A number of methods are available to examine common factors amongst the toxic congener concentrations and other variables such as tracer compounds. Probably the simplest of these, is a complete or partial correlation table. Table 3.3 is a correlation matrix for the six urban sites, (Wattleup, Duncraig, Eagle Farm, Westmead, Alphington and Netley) which utilises only concentrations with a value above the LOD.

Table 3.3 Correlation matrix for urban sites

	2,3,7,8-TCDD	1,2,3,7,8-PeCDD	1,2,3,4,7,8-HxCDD	1,2,3,6,7,8-HxCDD	1,2,3,7,8,9-HxCDD	1,2,3,4,6,7,8-HpCDD	OCDD	2,3,7,8-TCDF	1,2,3,7,8-PeCDF	2,3,4,7,8-PeCDF	1,2,3,4,7,8-HxCDF	1,2,3,6,7,8-HxCDF	2,3,4,6,7,8-HxCDF	1,2,3,7,8,9-HxCDF	1,2,3,4,6,7,8-HpCDF	1,2,3,4,7,8,9-HpCDF	OCDF
2,3,7,8-TCDD	1.00	**0.84**	0.59	0.60	0.44	0.34	0.35	0.33	**0.88**	**0.77**	**0.67**	0.61	0.40	0.58	0.42	**0.76**	0.58
1,2,3,7,8-PeCDD	**0.84**	1.00	**0.96**	**0.89**	**0.85**	**0.83**	**0.52**	0.11	**0.86**	**0.97**	**0.96**	**0.94**	**0.88**	**0.89**	**0.87**	**0.87**	**0.76**
1,2,3,4,7,8-HxCDD	0.59	**0.96**	1.00	**0.94**	**0.93**	**0.93**	**0.65**	0.19	**0.84**	**0.94**	**0.95**	**0.94**	**0.90**	**0.90**	**0.89**	**0.83**	**0.86**
1,2,3,6,7,8-HxCDD	0.60	**0.89**	**0.94**	1.00	**0.98**	**0.94**	**0.70**	0.17	**0.80**	**0.87**	**0.85**	**0.85**	**0.81**	**0.81**	**0.79**	**0.68**	**0.79**
1,2,3,7,8,9-HxCDD	0.44	**0.85**	**0.93**	**0.98**	1.00	**0.94**	**0.73**	0.02	**0.70**	**0.81**	**0.83**	**0.83**	**0.79**	**0.81**	**0.76**	**0.67**	**0.80**
1,2,3,4,6,7,8-HpCDD	0.34	**0.83**	**0.93**	**0.94**	**0.94**	1.00	**0.77**	0.09	**0.72**	**0.81**	**0.81**	**0.79**	**0.74**	**0.73**	**0.75**	**0.63**	**0.76**
OCDD	0.35	**0.52**	**0.65**	**0.70**	**0.73**	**0.77**	1.00	0.01	**0.43**	**0.50**	**0.49**	**0.45**	**0.42**	**0.53**	**0.43**	0.29	**0.55**
2,3,7,8-TCDF	0.33	0.11	0.19	0.17	0.02	0.09	0.01	1.00	**0.45**	0.16	0.12	0.11	0.08	0.13	0.15	0.06	0.14
1,2,3,7,8-PeCDF	**0.88**	**0.86**	**0.84**	**0.80**	**0.70**	**0.72**	**0.43**	**0.45**	1.00	**0.92**	**0.87**	**0.87**	**0.81**	**0.83**	**0.82**	**0.83**	**0.75**
2,3,4,7,8-PeCDF	**0.77**	**0.97**	**0.94**	**0.87**	**0.81**	**0.81**	**0.50**	0.16	**0.92**	1.00	**0.98**	**0.98**	**0.93**	**0.95**	**0.92**	**0.92**	**0.82**
1,2,3,4,7,8-HxCDF	**0.67**	**0.96**	**0.95**	**0.85**	**0.83**	**0.81**	**0.49**	0.12	**0.87**	**0.98**	1.00	**0.99**	**0.96**	**0.98**	**0.96**	**0.95**	**0.84**
1,2,3,6,7,8-HxCDF	0.61	**0.94**	**0.94**	**0.85**	**0.83**	**0.79**	**0.45**	0.11	**0.87**	**0.98**	**0.99**	1.00	**0.98**	**0.98**	**0.97**	**0.95**	**0.84**
2,3,4,6,7,8-HxCDF	0.40	**0.88**	**0.90**	**0.81**	**0.79**	**0.74**	**0.42**	0.08	**0.81**	**0.93**	**0.96**	**0.98**	1.00	**0.96**	**0.98**	**0.93**	**0.91**
1,2,3,7,8,9-HxCDF	0.58	**0.89**	**0.90**	**0.81**	**0.81**	**0.73**	**0.53**	0.13	**0.83**	**0.95**	**0.98**	**0.98**	**0.96**	1.00	**0.96**	**0.93**	**0.89**
1,2,3,4,6,7,8-HpCDF	0.42	**0.87**	**0.89**	**0.79**	**0.76**	**0.75**	**0.43**	0.15	**0.82**	**0.92**	**0.96**	**0.97**	**0.98**	**0.96**	1.00	**0.96**	**0.88**
1,2,3,4,7,8,9-HpCDF	**0.76**	**0.87**	**0.83**	**0.68**	**0.67**	**0.63**	0.29	0.06	**0.83**	**0.92**	**0.95**	**0.95**	**0.93**	**0.93**	**0.96**	1.00	**0.83**
OCDF	0.58	**0.76**	**0.86**	**0.79**	**0.80**	**0.76**	**0.55**	0.14	**0.75**	**0.82**	**0.84**	**0.84**	**0.91**	**0.89**	**0.88**	**0.83**	1.00
PCB_77	0.13	-0.33	-0.32	-0.23	-0.33	-0.20	0.20	0.01	-0.18	-0.25	-0.26	-0.30	-0.34	-0.31	-0.24	-0.37	0.12
PCB_81	0.19	-0.26	-0.22	-0.15	-0.25	-0.13	0.28	0.03	-0.09	-0.16	-0.17	-0.21	-0.22	-0.19	-0.15	-0.27	0.20
PCB_126	0.41	-0.11	-0.08	-0.10	-0.18	-0.08	0.17	0.02	0.01	-0.07	-0.07	-0.11	-0.10	-0.12	-0.11	-0.09	0.25
PCB_169	0.58	**0.71**	**0.61**	**0.59**	0.45	0.40	0.33	0.47	**0.79**	**0.77**	**0.69**	**0.69**	**0.65**	0.56	**0.67**	**0.73**	**0.76**
PCB_105	0.39	-0.29	-0.23	-0.16	-0.24	-0.13	0.20	0.18	-0.04	-0.17	-0.18	-0.23	-0.24	-0.21	-0.16	-0.24	0.17
PCB_114	0.28	-0.31	-0.25	-0.18	-0.26	-0.16	0.22	0.14	-0.07	-0.20	-0.21	-0.26	-0.25	-0.22	-0.18	-0.27	0.13
PCB_118	0.28	-0.30	-0.26	-0.18	-0.29	-0.15	0.21	0.11	-0.08	-0.20	-0.22	-0.27	-0.28	-0.26	-0.20	-0.30	0.14
PCB_123	0.21	-0.32	-0.28	-0.23	-0.30	-0.19	0.16	0.09	-0.12	-0.24	-0.27	-0.29	-0.28	-0.28	-0.23	-0.30	0.12
PCB_156	0.51	-0.26	-0.17	-0.13	-0.20	-0.09	0.17	0.29	0.08	-0.12	-0.12	-0.18	-0.17	-0.12	-0.12	-0.17	0.15
PCB_157	0.48	-0.19	-0.12	-0.08	-0.21	-0.08	0.14	0.23	0.11	-0.07	-0.07	-0.14	-0.11	-0.16	-0.07	-0.12	0.20
PCB_167	0.23	-0.37	-0.40	-0.41	-0.21	-0.40	0.08	-0.37	-0.46	-0.49	-0.51	-0.55	-0.44	-0.60	-0.50	**-0.65**	-0.37
PCB_189	0.42	-0.17	-0.04	-0.11	-0.09	-0.05	-0.03	**0.51**	0.29	-0.07	-0.11	-0.09	-0.14	-0.06	-0.08	-0.03	0.07
TEMPS	-0.24	**-0.67**	**-0.67**	**-0.64**	**-0.60**	**-0.63**	**-0.43**	-0.24	**-0.68**	**-0.70**	**-0.67**	**-0.67**	**-0.63**	**-0.60**	**-0.63**	**-0.52**	**-0.60**
NSSK	0.32	**0.53**	**0.51**	**0.55**	0.43	**0.48**	**0.63**	0.03	**0.45**	**0.54**	**0.53**	**0.52**	**0.49**	**0.48**	**0.48**	**0.41**	**0.50**

Table 3.3 continued.

	PCB_77	PCB_81	PCB_126	PCB_169	PCB_105	PCB_114	PCB_118	PCB_123	PCB_156	PCB_157	PCB_167	PCB_189	TEMPS	NSSK
2,3,7,8-TCDD	0.13	0.19	0.41	0.58	0.39	0.28	0.28	0.21	0.51	0.48	0.23	0.42	-0.24	0.32
1,2,3,7,8-PeCDD	-0.33	-0.26	-0.11	**0.71**	-0.29	-0.31	-0.30	-0.32	-0.26	-0.19	-0.37	-0.17	**-0.67**	**0.53**
1,2,3,4,7,8-HxCDD	-0.32	-0.22	-0.08	**0.61**	-0.23	-0.25	-0.26	-0.28	-0.17	-0.12	-0.40	-0.04	**-0.67**	**0.51**
1,2,3,6,7,8-HxCDD	-0.23	-0.15	-0.10	**0.59**	-0.16	-0.18	-0.18	-0.23	-0.13	-0.08	-0.41	-0.11	**-0.64**	**0.55**
1,2,3,7,8,9-HxCDD	-0.33	-0.25	-0.18	0.45	-0.24	-0.26	-0.29	-0.30	-0.20	-0.21	-0.21	-0.09	**-0.60**	0.43
1,2,3,4,6,7,8-HpCDD	-0.20	-0.13	-0.08	0.40	-0.13	-0.16	-0.15	-0.19	-0.09	-0.08	-0.40	-0.05	**-0.63**	**0.48**
OCDD	0.20	0.28	0.17	0.33	0.20	0.22	0.21	0.16	0.17	0.14	0.08	-0.03	**-0.43**	**0.63**
2,3,7,8-TCDF	0.01	0.03	0.02	0.47	0.18	0.14	0.11	0.09	0.29	0.23	-0.37	**0.51**	-0.24	0.03
1,2,3,7,8-PeCDF	-0.18	-0.09	0.01	**0.79**	-0.04	-0.07	-0.08	-0.12	0.08	0.11	-0.46	0.29	**-0.68**	**0.45**
2,3,4,7,8-PeCDF	-0.25	-0.16	-0.07	**0.77**	-0.17	-0.20	-0.20	-0.24	-0.12	-0.07	-0.49	-0.07	**-0.70**	**0.54**
1,2,3,4,7,8-HxCDF	-0.26	-0.17	-0.07	**0.69**	-0.18	-0.21	-0.22	-0.27	-0.12	-0.07	-0.51	-0.11	**-0.67**	**0.53**
1,2,3,6,7,8-HxCDF	-0.30	-0.21	-0.11	**0.69**	-0.23	-0.26	-0.27	-0.29	-0.18	-0.14	-0.55	-0.09	**-0.67**	**0.52**
2,3,4,6,7,8-HxCDF	-0.34	-0.22	-0.10	**0.65**	-0.24	-0.25	-0.28	-0.28	-0.17	-0.11	-0.44	-0.14	**-0.63**	**0.49**
1,2,3,7,8,9-HxCDF	-0.31	-0.19	-0.12	0.56	-0.21	-0.22	-0.26	-0.28	-0.12	-0.16	-0.60	-0.06	**-0.60**	**0.48**
1,2,3,4,6,7,8-HpCDF	-0.24	-0.15	-0.11	**0.67**	-0.16	-0.18	-0.20	-0.23	-0.12	-0.07	-0.50	-0.08	**-0.63**	**0.48**
1,2,3,4,7,8,9-HpCDF	-0.37	-0.27	-0.09	**0.73**	-0.24	-0.27	-0.30	-0.30	-0.17	-0.12	**-0.65**	-0.03	**-0.52**	**0.41**
OCDF	0.12	0.20	0.25	**0.76**	0.17	0.13	0.14	0.12	0.15	0.20	-0.37	0.07	**-0.60**	**0.50**
PCB_77	1.00	**0.99**	**0.91**	-0.09	**0.93**	0.30	**0.95**	0.21	**0.75**	**0.61**	**0.74**	0.03	0.20	0.16
PCB_81	**0.99**	1.00	**0.90**	0.02	**0.92**	0.29	**0.93**	0.20	**0.74**	**0.61**	**0.65**	0.03	0.10	0.23
PCB_126	**0.91**	**0.90**	1.00	0.22	**0.89**	0.25	**0.91**	0.19	**0.72**	**0.62**	**0.65**	0.01	0.08	0.26
PCB_169	-0.09	0.02	0.22	1.00	0.13	-0.24	0.10	-0.25	0.17	-0.08	-0.29	-0.27	**-0.65**	**0.69**
PCB_105	**0.93**	**0.92**	**0.89**	0.13	1.00	**0.99**	**0.99**	**0.97**	**0.91**	**0.96**	**0.78**	**0.56**	0.16	0.2
PCB_114	0.30	0.29	0.25	-0.24	**0.99**	1.00	0.15	**1.00**	0.26	**0.84**	-0.15	**0.97**	0.18	0.2
PCB_118	**0.95**	**0.93**	**0.91**	0.10	**0.99**	0.15	1.00	0.05	**0.85**	**0.57**	**0.83**	-0.15	0.17	0.2
PCB_123	0.21	0.20	0.19	-0.25	**0.97**	**1.00**	0.05	1.00	0.18	**0.80**	-0.18	**0.99**	0.21	0.19
PCB_156	**0.75**	**0.74**	**0.72**	0.17	**0.91**	0.26	**0.85**	0.18	1.00	**0.70**	**0.69**	0.04	0.15	0.13
PCB_157	**0.61**	**0.61**	**0.62**	-0.08	**0.96**	**0.84**	**0.57**	**0.80**	**0.70**	1.00	0.00	**0.74**	0.13	0.21
PCB_167	**0.74**	**0.65**	**0.65**	-0.29	**0.78**	-0.15	**0.83**	-0.18	**0.69**	0.00	1.00	-0.27	0.43	-0.14
PCB_189	0.03	0.03	0.01	-0.27	**0.56**	**0.97**	-0.15	**0.99**	0.04	**0.74**	-0.27	1.00	0.09	-0.11
TEMPS	0.20	0.10	0.08	**-0.65**	0.16	0.18	0.17	0.21	0.15	0.13	0.43	0.09	1.00	**-0.46**
NSSK	0.16	0.23	0.26	**0.69**	0.2	0.2	0.2	0.19	0.13	0.21	-0.14	-0.11	**-0.46**	1.00

Missing data are excluded pair-wise, and values shown are the Pearson correlation coefficient. Values shown with light shading are significant at the 0.05 level (2-tailed) and those bold and dark shaded are significant at the 0.01 level (2-tailed). To simplify the table, only a limited set of variables are included. In particular, this set includes the TCDD/TCDF and PCB congeners, nssK as biomass burning tracer (Andreae, 1983) and monthly mean temperature (climatological). The strongest correlations are within the PCCD/PCDF and PCB congener sets with only a weak correlation between a few specific congeners across these two sets. In these data, only one of the PCBs, PCB 169 correlates strongly with the PCDD/PCDFs. The PCDD/PCDFs in general, have a highly significant negative correlation with temperature and positive correlation with nssK (but not 2,3,7,8, TCDD nor 2,3,7,8 TCDF). None of the PCB congeners, apart from PCB169, correlate significantly with monthly temperature and nssK.

Factor analysis allows a relatively straightforward method for simplifying the multiple correlations between a large number of individual variables, identifying those that correlate and allowing construction of a number of new variables (or factors) from those that correlate closely. For the analyses shown here orthogonal (Varimax) rotation has been applied to maximize the separation of the factors.

Table 3.4 presents the (rotated) output factor matrix for principal component analysis with Varimax rotation for dioxin, furan and PCB congeners, the homologue groups and a suite of inorganic and light organic aerosol species. All data used are averages over a dioxin-sampling period (predominantly one month). Missing values are treated as the variable's mean and only the first five factors are retained; these account for 73% of the variance. For this analysis, non-detects need to be treated as missing values to avoid spurious correlation brought about by use of a LOD-based value. The analysis is based on a suite of 64 determinations. For this form of analysis, the values returned in the factor are correlations between the individual species and the identified factor. These are termed loadings and in general a loading of 0.4 or greater is considered significant and 0.6 or greater highly significant. Factors can sometimes be identified with specific sources as in Table 3.4 component (or factor) four which represents the sea-salt component in the aerosol. Component one includes most of the dioxin and furan congeners and the homologue groups, PCB169, also the major loading of nssK an indicator that this factor is most probably biomass combustion related. Neither 2,3,7,8, TCDD nor 2,3,7,8 TCDF associate strongly with this factor suggesting largely independent sources for these lightest congeners, or some environmental process that resulted in independent control of the concentrations of these congeners. 2,3,7,8, TCDD also frequently has the lowest concentration and was most likely to be less than the LOD. None of the dioxin, furan, nor PCB congeners associate strongly with aerosol mass (TSP), urban photochemical aerosol components such as non-sea-salt sulfate and nitrate, nor a range of light organics including the oxalate, acetic and formic ions, methyl sulfonate nor with non-sea-salt calcium which could potentially act as a mineral aerosol tracer. This suggests substantial independence from urban non-combustion aerosol sources normally associated with aerosol mass. Soil is not excluded totally as a source of vapour-phase material, however, since vapour-phase partitioning can occur in the absence of re-entrainment of aerosol-bound soil material.

In this analysis there is some splitting of the PCB congeners into two components or factors (components three and five), additional to PCB169, raising the possibility of source differences for these congener groups.

Table 3.4 Rotated factor matrix - for urban sites.

Rotated Component Matrix

	Component				
	1	2	3	4	5
2,3,7,8-TCDD	0.440	0.029	0.186	0.235	0.004
1,2,3,7,8-PeCDD	**0.897**	-0.045	-0.173	-0.005	-0.011
1,2,3,4,7,8-HxCDD	**0.911**	-0.133	-0.085	-0.006	0.009
1,2,3,7,8,9-HxCDD	**0.774**	-0.122	-0.072	0.143	-0.003
1,2,3,4,6,7,8-HpCDD	**0.834**	-0.212	-0.039	-0.004	0.005
OCDD	**0.607**	0.085	0.323	-0.087	-0.040
1,2,3,6,7,8-HxCDD	**0.869**	-0.152	-0.054	-0.022	0.001
2,3,7,8-TCDF	0.054	-0.250	0.099	-0.455	0.049
1,2,3,7,8-PeCDF	**0.811**	-0.288	0.002	-0.269	0.032
2,3,4,7,8-PeCDF	**0.924**	-0.152	-0.108	-0.186	0.009
1,2,3,4,7,8-HxCDF	**0.916**	-0.157	-0.105	-0.155	0.016
1,2,3,6,7,8-HxCDF	**0.922**	-0.127	-0.178	-0.155	0.020
2,3,4,6,7,8-HxCDF	**0.885**	-0.086	-0.132	-0.123	0.023
1,2,3,7,8,9-HxCDF	**0.820**	0.007	-0.101	-0.068	0.024
1,2,3,4,6,7,8-HpCDF	**0.891**	-0.138	-0.129	-0.169	0.027
1,2,3,4,7,8,9-HpCDF	**0.860**	-0.054	-0.150	0.011	0.037
OCDF	**0.812**	-0.177	0.198	-0.203	0.050
TCDD	**0.709**	-0.078	0.114	-0.043	-0.110
PECDD	**0.897**	-0.142	-0.016	-0.072	-0.003
HXCDD	**0.929**	-0.160	-0.082	-0.144	0.013
HPCDD	**0.851**	-0.216	0.001	-0.102	0.010
TCDF	**0.651**	-0.304	0.089	-0.401	0.018
PECDF	**0.924**	-0.187	-0.025	-0.216	0.008
HXCDF	**0.934**	-0.146	-0.103	-0.194	0.015
HPCDF	**0.905**	-0.110	-0.133	-0.080	0.036
PCB_77	-0.138	0.107	**0.939**	-0.006	0.095
PCB_81	-0.050	0.097	**0.940**	-0.048	0.089
PCB_126	0.036	0.052	**0.890**	-0.014	0.089
PCB_169	**0.604**	0.084	0.110	-0.115	-0.263
PCB_105	-0.090	0.048	**0.954**	-0.120	0.085
PCB_114	-0.044	0.036	0.220	-0.035	**0.960**
PCB_118	-0.108	0.056	**0.965**	-0.082	-0.057
PCB_123	-0.042	0.042	0.124	-0.012	**0.977**
PCB_156	-0.087	-0.018	**0.838**	-0.198	0.104
PCB_157	-0.016	-0.005	0.598	-0.069	**0.747**
PCB_167	-0.211	0.067	0.295	0.000	-0.308
PCB_189	-0.023	0.001	-0.050	0.020	**0.981**
MASS	-0.209	**0.639**	0.225	0.215	0.019
Na+	-0.288	0.243	-0.105	**0.899**	-0.006
NH4+	0.335	0.251	0.229	-0.417	-0.014
K+	0.228	**0.603**	0.104	0.586	-0.030
Mg2+	-0.267	0.303	-0.096	**0.885**	-0.009
Ca2+	-0.078	**0.648**	-0.187	0.202	0.060
Cl-	-0.130	0.099	-0.175	**0.913**	0.013
NO3-	-0.292	**0.710**	0.078	0.043	-0.044
SO42-	-0.444	**0.646**	0.065	0.454	-0.015
C2O42-	-0.383	**0.609**	0.108	0.374	-0.040
PO43-	-0.210	**0.639**	-0.241	-0.159	0.035
F-	-0.212	**0.742**	0.021	0.063	-0.018
ACETIC	0.015	**0.780**	0.301	0.248	-0.013
FORMIC	-0.061	0.523	0.266	0.089	-0.027
MSA-	-0.281	**0.651**	0.093	0.461	0.011
NSSSO4	-0.394	**0.704**	0.165	-0.031	-0.015
NSSK	**0.612**	0.409	0.248	-0.398	-0.027
NSSCA	-0.045	**0.646**	-0.182	0.097	0.064
NSSMG	0.294	0.559	0.119	-0.345	-0.024
TEMPS	-0.571	0.378	0.096	0.388	0.032

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
Rotation converged in 6 iterations.

None of the inorganic or organic aerosol tracers associate with either PCB components making source identification difficult. This remains an area for further investigation.

3.5 Comparison of Australian dioxin concentrations with other countries

Summaries of observed toxic dioxin and furan concentrations previously reported in Australia and overseas, are given as Appendix F. Ambient air concentrations from the present study, as summarised in Table 3.2 (in Section 3.1) are low by international standards. This finding, however, is consistent with previous Australian determinations, including some preliminary studies for the present project by Müller et al. (2003) and the recent NSW EPA study (EPA 2002) as well as findings from New Zealand, by Buckland et al. (1999).

The mean concentration of PCDD/PCDF, as TEQ_{DF}, in clean Southern Ocean air sampled at Cape Grim, for September 2002 to August 2003 (excluding May and June 2003) was less than 1.0 fg TEQ_{DF} m^{-3}. This is given as an upper limit and includes three times sample blank noise for any congener's limit of detection, with half LOD for congeners less than the LOD. The data are not additionally blank-corrected for field blank concentrations. The mean field blank level was typically 0.7 fg TEQ_{DF} m^{-3} for the first six months samples and for the second six months 0.2 fg TEQ_{DF} m^{-3}. The corresponding three times the field blank standard deviation was 1.2 fg TEQ_{DF} m^{-3} for the first six months and for the second period around 0.3 fg TEQ_{DF} m^{-3}. The concentration for Cape Grim is slightly less than, but still consistent with, concentrations observed at the New Zealand reference site (Buckland et al. 1999) and also the Siding Spring site in the NSW EPA study (EPA 2002). It is similar to other remote southern hemisphere sites such as Bird Island and Halley Bay (Lohman et al. 2000). This suggests that concentrations of PCDD/PCDF at less pristine Australian sites, certainly across southern Australia, can be attributed, essentially in total, to Australian sources.

Mean loadings of PCDD/PCDF at the rural/remote sites, Boorolite in north-east Victoria, Mutdapilly in south-east Qld and Berrimah in the NT for September 2002 to August 2003, fall in the range of 1.5 to 2.8 fg TEQ_{DF} m^{-3}. These values, which are also not blank corrected (typical field blank level 0.6 fg TEQ_{DF} m^{-3}), are comparable with the cleanest New Zealand rural locations (Buckland et al. 1999) and the Falkland Islands (Lohman 2000). They are also much lower than the mean of 11-15 fg I-TE m^{-3} reported for rural locations in the USA, and using comparable treatment of samples less than the LOD (Cleverly et al. 2000).

Mean PCDD/F loadings, as TEQ_{DF}, for urban/industrial locations in Australia, range from 9 fg TEQ_{DF} m^{-3} at Eagle Farm to 17.2 fg TEQ_{DF} m^{-3} at Alphington (not field blank corrected). Wattleup, in the Kwinana industrial area south of Perth, shows a mean loading of 14.7 TEQ_{DF} m^{-3}, which is comparable to the value of 13.8 TEQ_{DF} m^{-3} in Duncraig, a Perth residential suburb, also to loadings in Alphington and Westmead, (Melbourne and Sydney residential suburbs). These TEQ_{DF} levels are comparable with New Zealand rural locations (typically 4-16 fg I-TE m^{-3}). As shown, for example in Appendix F1 and Table 5 in Appendix F2, the Australian urban PCDD/PCDF loadings from the present study, are generally comparable with cleaner locations in Europe and significantly less than in urban/industrial regions of central Europe.

PCB levels at rural/remote sites Boorolite in north-east Victoria, Mutdapilly in south-east Queensland and Berrimah in the NT for September 2002 to August 2003, fall in the range of 0.1 to 1.7 fg TEQ_P m^{-3}, with only four values (13% of observations) greater than 1 fg TEQ_P m^{-3}. Few studies have specifically reported the dioxin-like PCBs for remote sites. The NZ study used the old I-TE values for PCBs and reported mean values for reference (remote) and rural sites ranging from 0.64-1.87 fg I-TE_P m^{-3} (Buckland et al. 1999). Hence, the Australian data are similar to the NZ data. From the US, Cleverly et al. (2001, 2002) reported mean values for dioxin-like PCBs of 0.2 and 0.3 fg TEQ_P m^{-3} in samples collected in six National Parks and 0.6 and 1.1 TEQ_P m^{-3} in samples collected in rural areas; these results are similar to the mean values observed at the remote and rural sites in Australia.

Mean concentrations for dioxin-like PCBs at urban/industrial locations in Australia, for September 2002 to August 2003, range from 0.2-12.3 fg TEQ_P m^{-3} although values greater than 4 fg TEQ_P m^{-3} were only observed at the SA site (Netley). For Netley, the average was 7 fg TEQ_P m^{-3}. For the other urban sites the average level was 1.5 fg TEQ_P m^{-3}. For NZ urban sites (not including Auckland), Buckland et al. found mean annual PCB loadings ranging from 2.6-5.1 fg I-TE_P m^{-3} and a mean annual concentration at the industrial site in Auckland of 15.5 fg I-TE_P m^{-3}. Mean PCB levels in the (sub)urban US of 2 and 3 fg TEQ_P m^{-3} were found by Cleverly et al. (2001, 2002) which are very similar to those observed in the urban areas in Australia.