AIR-TO-GRASS TRANSFER OF PCBs

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Introduction. The air-to-plant-to-ruminant food chain provides an appreciable fraction of human exposure to PCBs in Western industrialised societies, with the most effective bioconcentration occurring during the transfer from air-to-plant (1). These factors - together with evidence that plant uptake represents an important atmospheric removal mechanism for SOCs like PAH (2) - has generated a need to enhance understanding of the air-to-plant transfer process. Recent work (3,4) has identified the following key points: (i) that it is an equilibrium process, with the log of the plant air partition coefficient (K_{PA}) – also referred to as the scavenging coefficient, and defined as the ratio of contaminant concentration in the plant (C_P) to that in the air (C_A) in which it is immersed - being positively linearly related to log K_{OA}; (ii) that at temperatures between 5 and 35 C, air-plant equilibrium is reached in under 2 weeks; (iii) that octanol is not an ideal model for the partitioning properties of common European pasture grass and herb species; and (iv) that the extent to which octanol fails to acts as an ideal model, is subject to considerable interspecies differences.

This paper reports on 2 experiments studying aspects of the transfer of PCBs between air and grass. Experiment 1 aimed to provide confirmation of the existence of the air/plant equilibrium for a mixed sward under the full range of climatic conditions annually experienced in southern England. Verifying the existence of plant-air equilibrium year-round is important for two principal reasons: (a) it has been suggested that above a certain value of log K_{OA}, kinetic limitations imposed by the air-side resistance will result in a failure to reach equilibrium. By studying air-to-grass transfer year-round, we were able to check for the existence of equilibrium at the potentially higher K_{OA} values experienced outside – as opposed to during - the growing season; and (b) although transfer outside the growing season is of limited relevance with respect to food chain transfer, knowledge of whether such transfer outside this period is an equilibrium process, is necessary to fully evaluate the significance of vegetative uptake as an atmospheric removal mechanism. Experiment 2 studied the behaviour of 5 individual pasture species with the aims of: (1) extending the range of species studied; and (2) verifying the existence of interspecies differences.

Sampling and Analysis.

Experiment 1 A $1m^2$ plot of pasture grass was "fenced-off" at the same background urban site as that where air monitoring was conducted (5). The plot was cut back on 8 July 1997 and sampled approximately every four weeks until 27 July 1998, giving a total of 13 samples. The species composition of the mixed sward was typical of U.K. pasture grassland, consisting of predominantly Perennial ryegrass (*Lolium perenne*), Yorkshire Fog (*Holcus lanatus*), Creeping soft-grass (*Holcus mollis*) and one member of the bent family (*Agrostis capillaris*) as well as three non-grass herbs (*Cerastium fontanum*, *Stellaria graminea* and *Plantago lanceolata*).

Experiment 2 Five individual plant species were grown in approximately 0.5 m^2 growing trays at the same site as experiment 1. These were: Perennial ryegrass (*Lolium perenne*; var. Gilford), Italian ryegrass (*Lolium Multiflorum*; var. Abercomo), Creeping fescue (*Festuca rubra*; var. Boreal), Meadow fescue (*Festuca pratensis*; var. Senu Raj) and Timothy (*Phleum nodosum*; var. Erect2). Seeds were planted on 7 April 1998, cut back on 3 June and samples collected on 18 June, 29 June and 27 July 1998. Unfortunately, the Creeping and Meadow fescue sample mass was sufficient for analysis only on 18 June.

In both experiments, PCB concentrations in air (5) were assumed to be the arithmetic mean of those daily samples (3-5 air samples per grass sample for experiment 1, 1-2 for experiment 2 due to the shorter grass sampling periods) falling within the grass sampling period. Automatic monitoring of air temperature was conducted during all sampling events. PCB concentrations in both air (C_A) and grass samples (C_G) were determined using well-validated containment-enrichment, GC/MS procedures reported elsewhere (6,7). To avoid contamination, grass samples were freeze-dried, rather than air-dried prior to extraction. The moisture content of each grass sample was determined by drying a representative subsample to constant weight; whilst lipid content was determined gravimetrically following solvent removal from an accurately known portion of the crude soxhlet extract prepared for PCB determination.

Results and Discussion

Experiment 1

For each grass sampling event, log C_G/C_A (calculated on a grass lipid weight basis) was plotted against log K_{OA} (corrected for the mean air temperature over each sampling period). In all cases, a highly significant (>99.9%) linear correlation was observed. Figure 1 plots mean log C_G/C_A values versus log K_{OA} (corrected for the mean air temperature over the whole of experiment 1 = 14 C). Even for the December, January, and February samples, when the lower temperatures (mean monthly average for these months was 5 to 8 C) would have maximised K_{OA}, there was no evidence of plant-air equilibrium not being attained. Clearly, our data suggests that air-to-grass transfer of PCBs reaches equilibrium within 4 weeks all year round, *for this sward, at this site.*

Slopes of log C_G/C_A versus log K_{OA} plots for individual grass sampling events ranged from 0.18 and 0.45 (*c.f.* those of 0.32 to 0.47 reported for a similar mixed sward in North West England between April and October 1996 (3)). The fact that slopes are less than 1, is consistent with the idea that octanol is not an ideal surrogate for plant lipid (3,4). Table 1 shows mean values of C_G/C_A obtained (i) from the entire duration of experiment 1, and (ii) for the months of April through October only; and compares these with values obtained by Thomas *et al* (3). In both cases, mean C_G/C_A scavenging coefficients for our site are – for most congeners - higher than those reported by Thomas *et al*, suggesting more efficient uptake of PCBs by our sward. However, there is much better agreement between C_G/C_A values obtained for the warmer April-October period, in which temperatures correlated more closely (7 – 17 C for our study *c.f.* 5 – 15 C in reference 3). Overall, given the differences in location – and thus meteorology - and sward composition, the agreement between the two studies is encouraging.

Experiment 2

For each plant species, log C_G/C_A (calculated on a grass lipid weight basis) was plotted against log K_{OA} (corrected for the mean air temperature over each sampling period). In all cases, a highly significant (>99.9%) linear correlation was observed. Table 2 gives the slopes and intercepts for each species. The range of slopes (0.24-0.41, mean = 0.35) is consistent with those observed for our mixed sward in experiment 1. These data support the idea that the ability of octanol to mimic plant uptake of PCBs is dependent on the plant species (4). An interesting observation is that for Italian rye grass, our field-based study yielded an appreciably different slope (0.32) to the value of 1.15 obtained from the lab-based experiments of Kömp and McLachlan (4). As this was the only plant species common to both studies, it is impossible to evaluate whether this a systematic difference, that might be repeated if experiment 2 had included other species studied by Kömp and McLachlan.

References

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Figure 1: Log (C_G/C_A) (Mean Values for Experiment 1) versus log K_{OA}

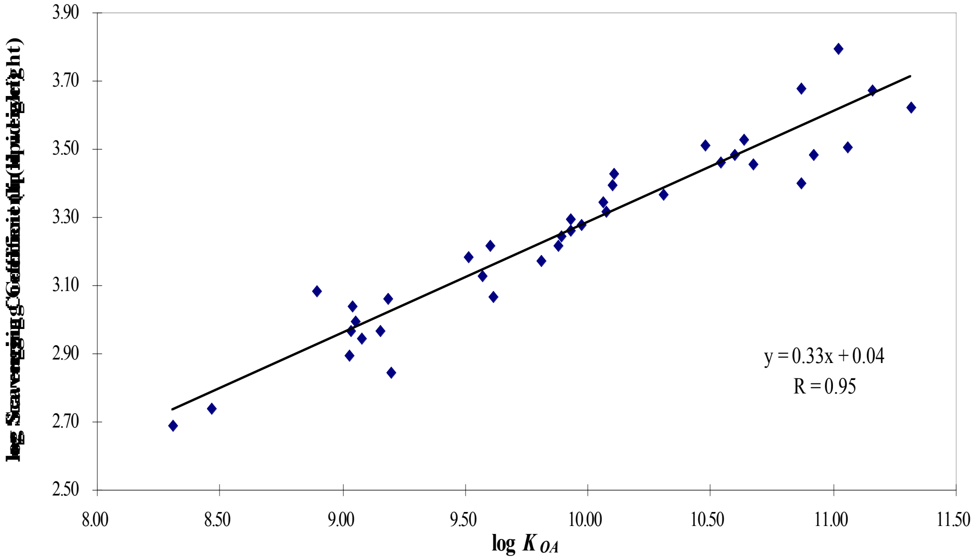

Table 1: A Comparison of C_G/C_A Values (lipid weight basis)

Congener	C_G/C_A (m^3 g^{-1}) – Experiment 1 – All Samples	C_G/C_A (m^3 g^{-1}) – Experiment 1 – April through October Samples Only	C_G/C_A (m^3 g^{-1}) – Values for North West England - Thomas *et al.* (3)
18	490	230	340
31/28	1200	560	320
52	990	510	350
49	920	560	270
44	920	510	330
74	1500	880	470
66	1800	1300	600
90/101	2000	1300	730
87	1900	1300	720
110	2200	1300	690
118	2500	1900	1400
105	3200	2400	1800
151	2700	1300	650
149	2300	1400	810
153	2900	1800	1100
141	3100	1900	840
138/164	2900	2400	1800
187/182	3000	1600	1800
183	4800	1600	2200
180	4200	3000	2700

Table 2: Linear Regression Parameters for plots of log (C_G/C_A) = *m* log K_{OA} for individual plant species

Grass Species	*m* (± error)	*b* (± error)	r	n
Italian ryegrass	0.32 (0.02)	-0.08 (0.21)	0.81	119
Perennial ryegrass	0.41 (0.03)	-1.05 (0.31)	0.79	114
Creeping fescue	0.39 (0.03)	-0.67 (0.32)	0.90	40
Meadow fescue	0.24 (0.05)	0.72 (0.43)	0.70	35
Timothy	0.40 (0.02)	-0.62 (0.22)	0.84	118