Air-milk transfer of PCBs

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Introduction

Grazing animals are a major link in the supply of PCBs to humans from the terrestrial environment, and they receive PCBs primarily through ingestion of grass, silage and concentrate feed (1). PCBs and similar compounds reach grass and other vegetation principally via atmospheric deposition (2), therefore the pathway air-vegetation-grazing animals-meat/dairy products results in human exposure to PCBs and a range of other persistent organic pollutants (POPs). As a consequence it might be expected that air-human foodstuff transfer factors could be derived to describe this pathway directly.

The aim of this study was to derive and test air-milk transfer factors ($TF_{A:M}$) for PCBs under UK husbandry practices using air-grass transfer (scavenging coefficients, $TF_{A:F}$) and feed-milk transfer (BCF, $TF_{F:M}$) measurements detailed elsewhere (3,4).

Derivation of air-milk transfer factors

Air-milk transfer factors were derived by combining BCFs (or $TF_{F:M}$) and air-grass scavenging coefficients (or $TF_{A:F}$) from previous studies conducted at Lancaster (3,4), as shown in Table 1. These are congener-specific and are a function of air-grass partitioning (controlled by K_{OA} (3)), absorption efficiency (controlled by K_{OW}, (4)) and metabolism within the cow (controlled by substitution pattern (4)). It can be seen from Table 1 that PCB-170 is transferred most efficiently from air to milk, with 1 g of milk fat containing the equivalent amount of this congener as 650 m^3 of air.

Variability in $TF_{A:M}$ values for a given congener can be due to a host of factors, but the most important is likely to be the composition of the cows' diet, particularly concentrate feeds. Other factors leading to variability in air-grass scavenging coefficients and feed-cow transfer factors are combined to give the overall standard deviation for $TF_{A:M}$ values shown in Table 1 (around 50 % for the persistent congeners) which excludes the role of 'contaminated' feed supplements.

Table 1 - Derivation of air-milk transfer factors for some non-persistent and persistent PCB congeners.

PCB	BCF* (g DW g^{-1} fat)	Air-Grass Scavenging Coefficient (m^3 air g^{-1} DW)	Air-Milk Transfer Factor ($TF_{A:M}$) (m^3 g^{-1} fat)	Estimated RSD on $TF_{A:M}$† (%)
28	0.5	6.4	3.2	120
66	2.6	11	29	49
118	16	25	400	46
138	12	33	380	53
153	13	21	260	46
170	10	63	650	56
180	11	51	540	39
183	10	41	430	65

* Averaged for five cows throughout a four month period of lactation

† Calculated from the standard deviations of BCFs and Scavenging Coefficients

Experimental

North-west England farm surveys. Eleven farms in a mixture of rural and semi-rural areas in the north-west of England were selected, shown in Figure 1. Samples of silage and milk were taken in May 1996 and samples of silage, milk and supplementary feeds were taken in February 1997. Milk samples (1 L) were taken directly from the farms' bulk tanks. Farmers were issued with a questionnaire on husbandry practices, herd composition and milk yields. In 1996 one farm was unavailable for sampling, and in 1997 one farmer refused to give samples of feed. On both sampling occasions cattle at all of the farms were being kept indoors, under winter husbandry conditions.

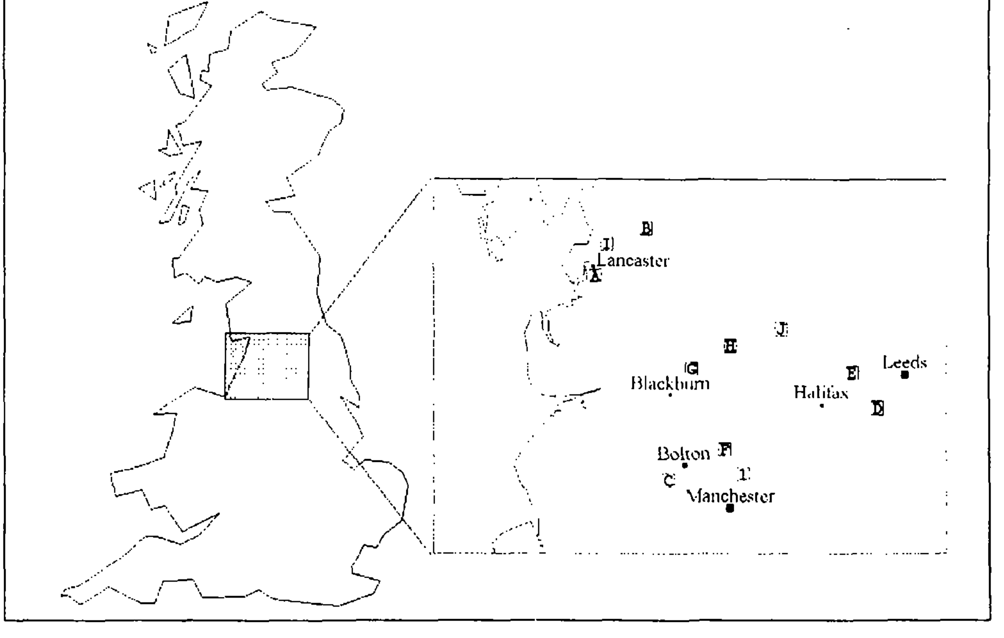
Long-term monitoring of one farm. Throughout the growing season (approximately April-October) of 1996 milk samples were taken every two weeks from the bulk tank of a farm adjacent to the field site concurrently used for air and grass measurements (3). Grass samples were taken from the pasture to which the study cattle were exposed on one occasion to ensure it's comparability with grass samples taken at the adjacent field site.

Chemical analysis. The analysis methods for PCBs in the matrices sampled in this study have been presented elsewhere (3,5).

Testing $TF_{A:M}$

The $TF_{A:M}$ values derived in Table 1 were used to predict milk concentrations for the 1996 and 1997 data-sets from air concentrations measured at the semi-rural/urban Lancaster site in 1996/7 and tested against the data obtained from the two farm surveys and the long-term monitoring study at the local farm. The results of this comparison are shown in Table 2; the predicted range is the predicted mean ± the estimated standard deviation of $TF_{A:M}$ (see earlier explanation). It can be seen that there is very good agreement between predicted and measured data for the 1997 survey and especially for the long-term monitoring study (probably illustrating the benefit of using PCB data from air samples taken during the correct growing season). The 1996 survey data for the persistent congeners 138, 153 and 180 were predicted less well, at approximately half of the measured values found in the 1996 survey. However, PCB levels in air from 1996 rather than the 1995 growing season (when the silage fed to the cows would have been exposed) were used for the prediction. The 1996 survey was also undertaken at a time when most farms are ready to turn cows outside for the summer grazing - meaning that very little silage would have been left in the clamps of any of the farms, and some farms may have bought in extra silage from other sources to fill shortfalls in their own supply; this could have caused the silage samples taken to be unrepresentative of the cows' normal diet. PCB concentrations in milk-fat from two UK milk surveys found in the literature (6,7) are underpredicted by up to 50 %, comparable to the 1996 survey, but obviously the temporal and spatial resolution in air data was necessarily compromised by the need to use air concentrations from the Lancaster site.

Figure 1 - Map showing the locations of selected farms for the north-west England surveys



Summary

In summary, TF_{AM} values have been derived and shown to be an effective tool to predict milk concentrations from average air concentrations at the regional scale, to well within an order of magnitude. If air data are available more locally, TF_{AM} can be used to predict the milk concentrations of persistent congeners to within a factor of ~2-3. The main requirements for this approach to monitoring and predicting PCB levels in milk-fat are that: i) pasture is the dominant

feed; ii) silage fed in winter is grown locally to the site of interest; and iii) there is no local intermittent source of PCBs (*i.e.* seasonally steady state conditions of air-pasture transfer apply).

Table 2 - Predicted concentrations of persistent PCBs in milk compared to UK field data.

	Predicted (range)	Measured Survey Averages[a]		Long-term[b]	1990 UK	1993 NW
		1996	1997	Average	Retail Milk[c]	England[d]
PCB	pg g^{-1} fat	pg g^{-1} fat	pg g^{-1} fat	pg g^{-1} fat	pg g^{-1} fat	pg g^{-1} fat
118	770 (410-1120)	1220	966	870	1540 ±180	1240 ±400
138	820 (380-1250)	1798	954	830	1640 ±250	1430 ±410
153	870 (470-1280)	1910	1070	780	1970 ±290	1670 ±430
170	210 (90-330)	289	213	150	na	320 ±140
180	450 (280-630)	688	450	290	850 ±180	720 ±320
183	90 (30-150)	141	119	74	na	220 ±79

na not available

[a] from the north-west England surveys

[b] from the local farm monitoring programme

[c] from ref 6, assumes 3.9 % average milk-fat content of whole milk

[d] from ref 7

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