DIOXIN-LIKE PCB CONGENERS IN PASTURE GRASS GROWING IN CONTAMINATED FLOODPLAIN SOIL

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Introduction

Depending on farm management practices, dairy cattle may be exposed to soil contaminants by consuming pasture grass or feed products (e.g., corn silage and hay) that grow in contaminated soil and by inadvertently ingesting soil while grazing. This study was conducted to quantify the relationship between dioxin-like polychlorinated biphenyl (PCB) congener concentrations in soil and grass in a large floodplain that has been contaminated with PCBs originating from river sediments. Portions of several dairy operations occur within the floodplain, including cultivation areas for corn- and grass-based feeds and grazing areas for non-lactating dairy animals. Samples were collected adjacent to the river channel to assess possible accumulation of dioxin-like PCB congeners in dairy cattle that graze in the floodplain or consume grass-based feeds grown in the floodplain.

Transfer of PCBs to plants is essentially a surface phenomenon that can occur by the following mechanisms:

- Deposition of particle-phase contaminants on or sorption of vapor-phase contaminants to aboveground vegetation (e.g., leaves and fruits); and
- Partitioning from contaminated soil to belowground vegetation (e.g., roots or tubers).

PCB transfer to plants can be influenced by a number of variables, including chemical and physical properties of congeners (vapor pressure, partition coefficients), environmental conditions (organic carbon content of soil), plant characteristics (growing period, height, surface area-to-volume ratio, lipid content), and crop management (canopy density). The scientific literature includes laboratory and field studies demonstrating soil-to-plant transfer of PCBs under a variety of field and laboratory conditions, but limited congener-specific information is available. Therefore, this site-specific field study was conducted to obtain congener-specific information relevant to growing conditions in the floodplain area under consideration.

Materials and Methods

Sampling

Ten pairs of Reed canary grass (*Phalaris arundinacea*) and co-located soil samples were collected from a former dairy farm in early July 2001 when hay harvesting typically occurs. All sampling locations represented areas of relatively high PCB concentrations to avoid results below detection limits so that plant-to-soil concentration ratios could be calculated. These areas were immediately adjacent to the river channel, typically near exposed, wet sediment. Sampling was not conducted during or immediately following a heavy rain or elevated air temperatures.

Grass samples consisted of 80-100 g of material, excluding dead and decaying material from a previous season. Samples were collected from dense stands of grass that were 4-5 feet (1.2–1.5 m) high in areas where recent inundation with floodwaters was evident. Grass was cut to within about 3 in (8 cm) of the ground surface to simulate grazing patterns. Soil samples were collected from the top 3 inches in the immediate vicinity of the grass sample. Samples were collected using solvent-rinsed equipment, including aluminum foil, scissors and trowels, and were not washed prior to laboratory analysis.

Laboratory Analysis and Results

All samples were analyzed at the Geochemical and Environmental Research Group (GERG) laboratory at Texas A&M University using a method developed in the GERG laboratory[1]. Sample extraction followed USEPA Method 8290, which employs soxhlet extraction. Extracts were cleaned using acid:silica, alumina, and charcoal:silica cleanup steps. Mono-ortho congeners (i.e. IUPAC Numbers 105, 114, 118, 123, 156, 157, 167, 189) and planar congeners (i.e. IUPAC Numbers 77, 81, 126, and 169) were quantified using high resolution GC/ECD and isotopic dilution HRGS/HRMS (GERG SOP 9728). PCB congeners other than planar, mono-ortho, and di-ortho congeners were quantified using GC/ECD (GERG SOP 9810). Total PCB concentrations represent the sum of 125 congener concentrations. There were numerous co-eluting pairs and triplets among the PCB congeners.

Results and Discussion

Summary statistics of soil and grass concentrations for twelve dioxin-like PCB congeners and total PCBs (quantified as the sum of 125 congeners) are presented in Table 1. Soil and plant characteristics that potentially influence PCB transfer from soil to grass are summarized in Table 2. The concentration of PCBs in grass was a relatively small fraction of the concentration in soil. Two congeners (Nos. 81 and 114) were never detected in grass, while other dioxin-like congeners and total PCBs were frequently detected.

Congener patterns in soil and grass were compared by plotting homolog group weight percents for each medium in Figure 1. The patterns were similar, with a slightly more volatile mixture of congeners in grass than in soil. However, the grass congener pattern reflected a mixture of relatively low volatility that was similar to co-located soil samples. This similarity suggests dominance of the local source over ambient background sources.

Soil-to-grass transfer factors for total PCBs and dioxin-like PCB congeners are listed in Table 3. These factors represent the mean “grass-to-soil” concentration ratios (dw/dw) measured in site-specific samples, without plant lipid or soil organic carbon content normalization. These factors were estimated using only results above detection limits.

Table 1. Grass and Soil Summary Statistics

PCB	Grass Concentration (ng/g dw) Detection Frequency	Mean (Standard Deviation) [a]	Mean (Standard Deviation) [b]	Soil Concentration (ng/g dw) Detection Frequency	Mean (Standard Deviation) [a]	Mean (Standard Deviation) [b]
77	10/10	0.12 (0.06)	0.12 (0.06)	10/10	0.83 (0.41)	0.83 (0.41)
81	0/10	ND	ND	10/10	0.21 (0.12)	0.21 (0.12)
105	10/10	1.7 (0.37)	1.7 (0.37)	10/10	52 (26)	52 (26)
114	0/10	ND	ND	0/10	ND	ND
118	9/10	4.6 (1.9)	4.7 (1.6)	10/10	110 (52)	110 (52)
123[c]	10/10	21 (6.2)	21 (6.2)	10/10	870 (400)	870 (400)
126	6/10	0.054 (0.055)	0.058 (0.050)	9/10	0.36 (0.33)	0.37 (0.33)
156	10/10	1.4 (0.5)	1.4 (0.5)	10/10	53 (23)	53 (23)
157[d]	10/10	1.1 (0.21)	1.1 (0.21)	10/10	50 (23)	50 (23)
167	10/10	1.1 (0.40)	1.1 (0.40)	10/10	32 (14)	32 (14)
169	9/10	0.14 (0.11)	0.14 (0.11)	10/10	0.15 (0.063)	0.15 (0.063)
189	10/10	0.5 (0.085)	0.5 (0.085)	10/10	14 (4.9)	14 (4.9)
Total PCBs	10/10	331 (92)	331 (92)	10/10	12,000 (5,300)	12,000 (5,300)

ND = Not detected in any sample; [a] Mean calculated using zero for results below detection limits; [b] Mean calculated using one-half the detection limit for results below detection limits; [c] Congener 123 co-eluted with congener 149; [d] Congener 157 co-eluted with congeners 201 and 173

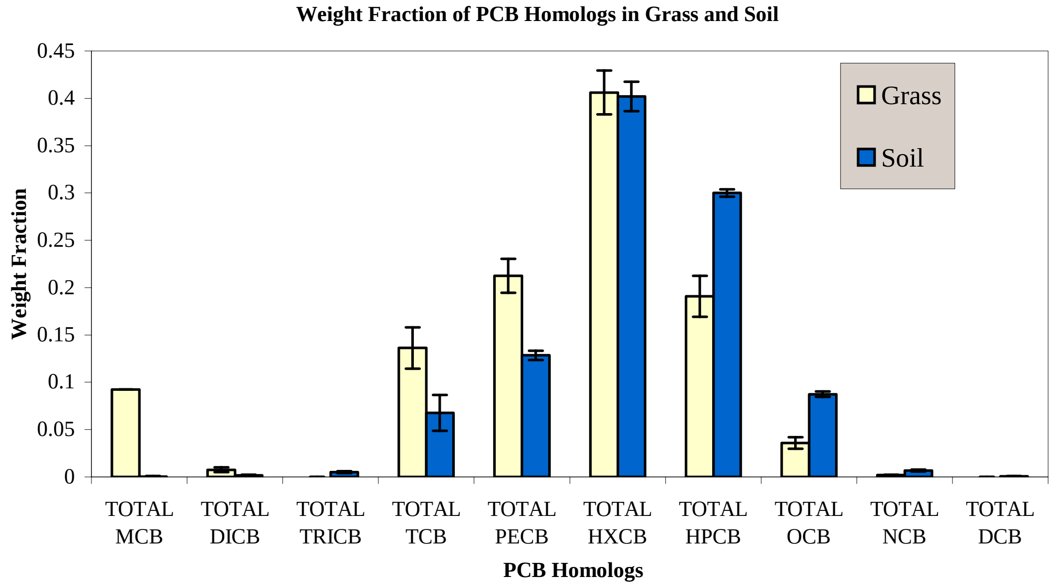
Table 2. Percent Solids, Lipid and Organic Carbon Content of Grass and Soil Samples

	Grass samples Mean (Range)	Soil Samples Mean (Range)
% solids	31 (26 – 33)	51 (30 – 74)
% lipid	0.96 (0.6 – 1.5)	not measured
Total organic carbon (mg/kg)	not measured	53,135 (26,500 – 99,650)

Table 3. Soil-to-Grass Transfer Factors (ng/g dw grass) / (ng/g dw soil)

PCB	Minimum	Mean (Standard Deviation)	Maximum
77	0.02	0.19 (0.14)	0.19
105	0.0097	0.047 (0.043)	0.16
118	0.032	0.058 (0.034)	0.14
123	0.0074	0.031 (0.021)	0.083
126	0.14	0.25 (0.14)	0.43
156	0.006	0.033 (0.024)	0.097
157	0.0086	0.028 (0.016)	0.064
167	0.0066	0.041 (0.026)	0.1
169	0.52	1.3 (0.92)	3.0
189	0.024	0.039 (0.019)	0.089
Total PCBs	0.0097	0.036 (0.023)	0.094

Figure 1



Note: Weight fractions of PCB homologs were calculated by dividing the concentration of each detected PCB homolog by the sum of the detected homolog concentrations. Trichlorinated and decachlorinated biphenyls were not detected in any grass sample; therefore, no weight percent was calculated.

These factors may be more applicable to an exposure scenario involving grazing near a river than consumption of grass-based feed because cultivation areas are unlikely to be adjacent to a river channel. Also, PCBs could be lost during processing of grass-based feeds.

The soil-to-grass transfer factors are subject to numerous uncertainties given the limited data set and the challenge of relating soil concentrations directly to plant concentrations. Despite the fact that shallow soil samples were collected from the immediate area where grass was growing, strong correlations between plant and soil concentrations were not observed for all congeners. It is possible that grass could be affected by soil and sediment concentrations over a wider area, particularly given the proximity to wet, exposed sediment. Also, grass and soil concentrations might reflect varying amounts of regional background PCB concentrations. However, as noted earlier, a comparison of homolog patterns in soil and grass suggests dominance of the local source. Despite these uncertainties, this study illustrates the potential importance of grass-based exposure pathways for cattle, particularly for grazing areas in floodplains of contaminated water bodies.

References

[1] Gardinali P.R., Wade T.L., Chambers L., Brooks J.M. (1996) Chemosphere, 32, 1, 1-11.