BIOTRANSFER AND BIOACCUMULATION OF DIOXINS AND DIBENZOFURANS FROM SOIL

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INTRODUCTION: A number of recent studies have indicated that food represents the major vector of human exposure to PCDD/Fs[1]. However, significant and fundamental questions remain as to sources and pathways to the human food supply. We recently studied chickens as a model for free range grazing animals that consume significant amounts of soil as they feed[2,3]. These studies indicated that PCDD/Fs are readily absorbed from soils consumed by chickens and that they bioaccumulate in tissues and are expressed in their eggs. The data suggested that bioavailability is highest for the lower chlorinated congeners and that it did not appear to be a function of aging of the soil, which indicates that binding to soil matrices may not be significant. Further studies have attempted to gain an increased understanding of the relationship between low levels of PCDD/F soil concentration and the levels found in grazing animals exposed to these soils.

Through the analysis of soil, feed, tissue, egg and feces samples the objectives were to determine the congener-specific bioavailability from soil, the congener-specific time trends in tissues and eggs over the study period, and the congener-specific bioconcentration in tissues and eggs. In addition, a mass balance of PCDD/F intake, tissue accumulation, and excretion would be determined. This information is used to explore, from a public health perspective, the issue of maximum allowable PCDD/F concentrations in soils used by grazing animals.

STUDY DESIGN: White Leghorn chickens, 20 wk old, were randomly assigned to 3 groups: *CONTROL EXPOSURE GROUP*: 22 chickens were fed a formulated diet containing 10% uncontaminated soil. *LOW EXPOSURE GROUP*: 22 chickens were fed the same formulated diet containing 10% soil found contaminated at the levels shown in Table 1. This soil came from a backyard near a pentachlorophenol plant. *HIGH EXPOSURE GROUP*: 22 chickens were fed the same formulated diet containing 10% of the same soil used in the low exposure group, with certain congeners fortified through spiking (Table 1). The exposure lasted for 178 days followed by a 100 day depuration period. Eggs were collected every 5 days during the first month and every 10 days thereafter, with increased frequency during the first month of the depuration. Liver, adipose, thigh and feces samples were collected on days 0, 10, 20, 40, 80, 164, 188, 208

and 278.

RESULTS and DISCUSSION: Bioavailability was calculated from the difference between the soil and feces concentration for each congener. Assuming that OCDD and OCDF are not absorbed, OCDD becomes a tracer for the soil concentration in the feces. After normalizing for OCDD, soil and feces levels can be directly compared, as shown in Fig. 1. (High Exposure) In the Figures, an asterisk (*) marks the fortified congeners in the High Group. The concentration of each 2,3,7,8-substituted PCDD/F (on a fat weight basis) was tracked over time in all the matrices analyzed. As an example of these time trends, Figure 2 shows the PeCDD concentration in the High Exposure group. Note that the depuration phase started on Day 178.

Table 2 shows the congener-specific bioconcentration factors (BCFs) after 80 days of exposure. The BCFs based on International Toxic Equivalents (I-TEs) reflect the total bioconcentration applicable to the particular PCDD/F profile in the soil that was used in this study. At Day 80 a congener-specific mass balance was calculated for the High Exposure group using data (all measurements on whole wt) on cumulative intake, liver compartment (total ng) = liver size * liver conc of Day 80 birds, adipose compartment (total ng) = adipose size * conc of Day 80 birds, egg compartment (total ng) = (number of eggs)*(sum of size-weighted egg concentrations over the 80 day period). Figure 3 shows the fractions measured in the egg, liver and adipose compartments as a percentage of the cumulative intake over the 80 days. Non-absorbed, metabolized and eliminated PCDD/Fs contribute to the unaccounted fraction.

Using the BCFs presented in Table 2, the relationship between soil concentration of PCDD/Fs and their levels in the edible portions of chickens and eggs can be established. Assuming an allowable daily intake (ADI) of 1 pg/kg/day I-TEs for a 70 kg adult and an average daily portion of 50 g per egg, or 100 g of thigh meat, the maximum allowable concentrations would be: egg = (1 pg/kg-day)*(70kg)*(1 day/egg)*(egg/50g) = 1.4 pg/g I-TEs, thigh = (1pg/kg-day)*(70kg)*(1 day/thigh)*(thigh/100g) = 0.7 pg/g I-TEs . These calculations suggest that maximum soil concentrations of PCDD/Fs in areas used for grazing animals for human food should be in the range of 5-10 pg I-TE/g soil. The apparent ready bioavailability of PCDD/Fs in soil also suggests a possible pathway into the trophic food web.

CONCLUSIONS: In both exposure groups, between 20-50% of the 2,3,7,8-substituted Tetra- through Hexa- and 50-90% of the Hepta- 2,3,7,8-PCDD/Fs present in the feed were eliminated in the feces. No differences in bioavailability were observed between the spiked and unspiked congeners. A mass balance after 80 days in the High Exposure group, showed that between 5 and 30% of any congener ingested over that period was excreted in the eggs, 7-54% was deposited in the adipose tissue, with less than 0.5% measured in the liver. Within each tissue type, the fraction unaccounted for (not absorbed, excreted in the feces, metabolized, or stored in some other tissue) increased with the degree of chlorination.

Bioaccumulation was congener dependent, with the lower chlorinated compounds showing the highest degree of bioaccumulation. Bioaccumulation was also tissue dependent. On a fat weight basis, the liver showed the highest affinity for all congeners, particularly OCDD/F. However, on a whole weight basis, congener-specific

bioconcentration factors were highest for adipose tissue and lowest for liver. Within each tissue type, the same influence of the degree of chlorination was observed. A small concentration effect on BCFs was observed for all congeners except OCDD and OCDF. Fortified congeners in the high dose group showed slightly higher BCFs as compared to the same congeners in the low dose group. BCFs for the non-spiked congeners appeared similar in the two groups. BCFs can be used to examine the relationship between soil levels of PCDD/Fs and their concentrations in edible parts of chickens or other grazing animals. Under the conditions and assumptions of this study, low ppt levels would give rise to egg and thigh concentrations that would exceed the ADI.

REFERENCES

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TABLE 1
2,3,7,8-PCDD/F concentrations (ppt) in soil

CONGENER	LEVELS IN SOIL		
	CONTROL	LOW	HIGH
+ 2,3,7,8 TCDD	NA	< 0.7	12.9
+ 1,2,3,7,8 PeCDD	< 0.3	11.8	243
+ 1,2,3,4,7,8 HxCDD	< 0.5	16.4	415
1,2,3,6,7,8 HxCDD	3.2	54.3	89.0
1,2,3,7,8,9 HxCDD	< 1.7	40.0	56.0
1,2,3,4,6,7,8 HpCDD	20.0	707	1090
+ OCDD	105	4250	109000
+ 2,3,7,8 TCDF	< 1.0	6.8	82.0
1,2,3,7,8 PeCDF	< 0.1	1.1	1.0
+ 2,3,4,7,8 PeCDF	< 0.1	4.4	134
1,2,3,4,7,8 HxCDF	< 0.1	45.0	97.5
+ 1,2,3,6,7,8 HxCDF	< 0.4	10.1	370
1,2,3,7,8,9 HxCDF	< 0.2	< 0.1	< 0.1
2,3,4,6,7,8 HxCDF	< 0.1	20.3	21.5
1,2,3,4,6,7,8 HpCDF	2.7	178	347
+ 1,2,3,4,7,8,9 HpCDF	< 0.4	40.5	1130
+ OCDF	6.2	250	9860
CA-TEF	0.6	58.0	579
I-TEF	0.5	41.9	458

+ = Isomer spiked in the High exposure group

TABLE 2
Bioconcentration factors after 80 days in the Low Exposure group

	LIVER	ADIPOSE	THIGH	EGG YOLK
2,3,7,8 TCDD	*	*	*	*
1,2,3,7,8 PeCDD	0.71	7.87	1.11	1.27
1,2,3,4,7,8 HxCDD	0.57	6.71	0.85	1.46
1,2,3,6,7,8 HxCDD	0.57	8.27	0.99	1.62
1,2,3,7,8,9 HxCDD	0.43	4.07	0.50	1.05
1,2,3,4,6,7,8 HpCDD	0.38	1.78	0.22	0.98
OCDD	0.18	0.36	0.04	0.47
2,3,7,8 TCDF	0.56	1.79	0.92	0.46
1,2,3,7,8 PeCDF	*	*	*	*
2,3,4,7,8 PeCDF	0.84	8.63	1.20	2.50
1,2,3,4,7,8 HxCDF	0.70	6.89	0.86	1.89
1,2,3,6,7,8 HxCDF	0.61	6.29	0.73	1.68
1,2,3,7,8,9 HxCDF	*	*	*	*
2,3,4,6,7,8 HxCDF	0.40	2.84	0.39	0.54
1,2,3,4,6,7,8 HpCDF	0.25	1.41	0.18	0.68
1,2,3,4,7,8,9 HpCDF	0.22	1.19	0.16	0.49
OCDF	0.13	0.30	0.07	0.30
I-TE	0.48	4.57	0.62	1.23

* = Uncertainty in BCFs due to low concentrations

$$BCF = \frac{[TISSUE\ (wet\ wt)]}{[FEED]}$$

FIGURE 1: BIOAVAILIBILTY OF PCDD/FS
HIGH EXPOSURE GROUP

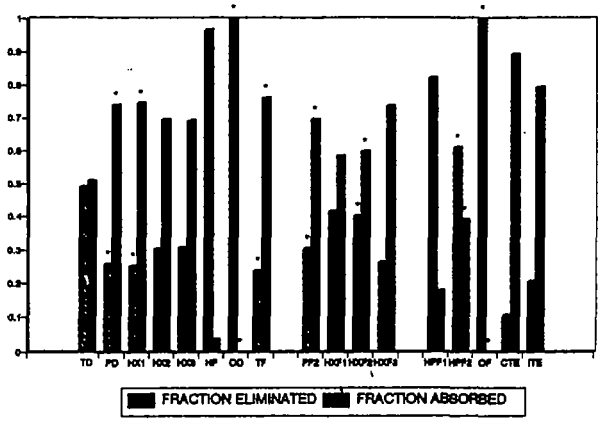

FIG.2 PeCDD IN TISSUES AND EGGS
HIGH EXPOSURE GROUP

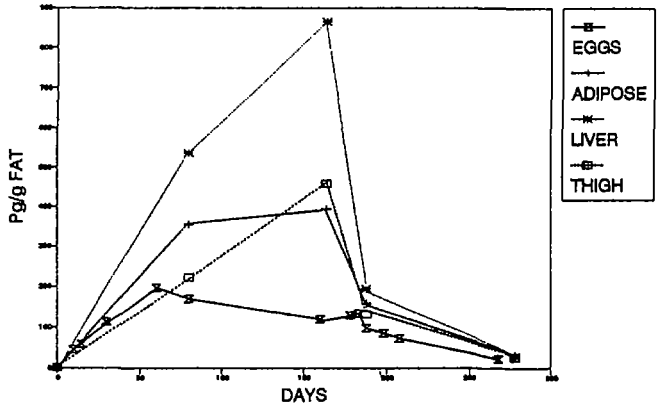

FIG.3 MASS BALANCE
HIGH EXPOSURE GROUP