Similarity of a Polychlorinated Biphenyl (Aroclor® 1254) and DDE in Rate of Elimination from Cows

by G. F. Fries, G. S. Marrow, Jr., and C. H. Gordon
United States Department of Agriculture, ARS
Animal Science Research Division
Beltsville, Md. 20705

Polychlorinated biphenyls (PCB) are persistent chemicals that are widespread in the environment (1). One of the PCB's, Aroclor(R)* 1254, is of particular importance to animal agriculture because of its use in coatings for concrete silos. Feeding silage stored in these silos results in residues of Aroclor 1254 in milk of cows.

The parameters of PCB accumulation and elimination from cows are not established. The objective of this report is to demonstrate that the rates of reduction in milk concentration of DDE and Aroclor 1254 are similar when the cows were removed from the sources of contamination.

Materials and Methods

We examined milk from cows simultaneously contaminated with DDT, including related compounds, and Aroclor 1254. The cows were inadvertantly contaminated with DDT and related compounds by grazing on land with high DDT levels in the soil. The total concentration of DDT residue was about 15 µg/g milk fat with a ratio of DDE to DDT of about 5:1 when we first observed the herd.

The herd was removed from the source of DDT contamination on June 15, 1970. When a clean cow was introduced to the herd about July 1, we found other gas chromatographic peaks that we originally assumed were DDD and DDT. The peaks were later identified as Aroclor 1254.

At this time the cows were being fed corn silage from a silo later established as the source of PCB contamination. In late July corn silage was fed from an uncontaminated silo. It is not possible in retrospect to determine the precise date that this change occurred.

Milk samples from individual cows were obtained at 3-week intervals from July 27 through December 1. Concentrations of DDE in milk fat were determined by electron capture chromatography (2). As will be noted, Aroclor 1254 did not interfere with the

*Aroclor(R), Monsanto Co., registered trade name for polychlorinated biphenyls.

Bulletin of Environmental Contamination & Toxicology, Vol. 7, No. 4, 1972. © by Springer-Verlag New York Inc.

G.W.

MONS 087232

analysis of DDE. However, PCB did interfere with DDD and DDT and the concentrations of these compounds were not routinely determined.

Concentrations of PCB in milk fat were determined by somewhat arbitrary methods. PCB's are a complex mixture of compounds, and authentic standards for the individual components of the mixture are not available. This poses no problem in silage analysis since material recovered was identical to Aroclor 1254 in gas and thin layer chromatographic behavior (3).

However, many of the peaks of Aroclor 1254 with retention times equal to DDE or less did not appear in milk (3). Similar findings have been reported for other samples of animal origin. Since PCB's are resistant to alkaline dehydrochlorination, the samples were treated with alcoholic KOH to convert DDT and DDD to the corresponding dehydrochlorination products with retention times equal to DDE or less. This eliminated interferences of DDT or DDD with the analysis for PCB. Concentrations of PCB were calculated as Aroclor 1254 based on the heights three major peaks with gas chromatographic retention times greater than the retention time of DDE. The column used was 10% DC-200 on 80/100 mesh Gas-Chrom Q and detection was by electron capture.

Results

Concentrations of PCB in the milk fat of the uncontaminated cow introduced to the herd July 1 are shown in Figure 1. The concentration of PCB rose rapidly after the cow was introduced.

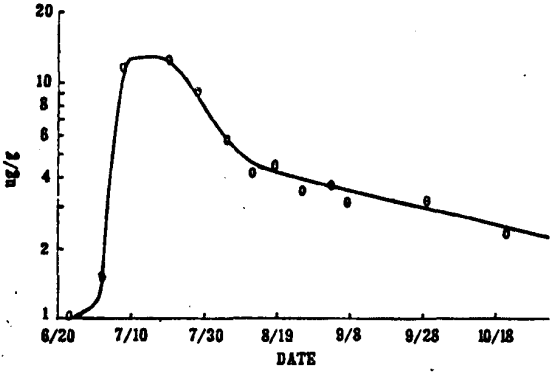

Figure 1. PCB concentration in milk fat of a cow fed contaminated silage from about July 1 to July 27.

MONS 087233

The peak level was reached on July 20th with a small decrease by July 28. This suggests that the herd was removed from the contaminated silage during this period. However, the remaining cows were not sampled between July 1 and July 27, and it is not possible to establish the date of change.

The concentration of PCB in milk fat declined rapidly after the cow was removed from the contaminated silage. Two weeks after the removal, the rate of decline was much less. When plotted on semilog paper, the concentration curve was similar to the two-component first-order curves that we have suggested for the reduction of DDE levels in milk fat after feeding of DDE stopped (2).

The average concentration of PCB in milk fat of the remaining cows declined from 19.3 to 10.3 µg/g from July 27 to August 17. Without intervening points and exact knowledge of when feeding stopped, it is not possible to make estimates of rates of decline for the first component. The slower second component was the component of importance after August 17.

Only the rate for the second component was estimated. The rate constants were calculated for individual cows by least squares using the linear form of the first-order equation:

$$\ln C = \ln C_o - kt$$

where C is the concentration at any time, C_o is the initial concentration, k is the rate constant, and t is time in days.

The first order rate constants calculated for the individual cows are summarized in Table 1. The cows have been separated into three groups. The mid-lactation cows are those that were milking on August 17 and continued in lactation through December 1. Late-lactation cows are those that were milking August 17 but ended their lactation before December 1. Early-lactation cows are those that were not lactating on August 17 but began lactating before December 1. With mid-lactation cows, the rate constants were

TABLE 1

Average rates of decline of DDE and PCB concentration in milk fat of cows in various stages of lactation

Group	Cows	DDE	PCB
	(No.)	(day^{-1})	(day^{-1})
Mid lactation	16	0.0145	0.0147
Early lactation	9	0.0107	0.0106
Late lactation	6	0.0147	0.0140
All	31	0.0134	0.0134

MONS 087234

C.W.

calculated using 6 points. With the early or late lactation cows, a minimum of 3 points were used and more if they were available.

The overall average rate constant for DDE is very similar to the 0.013 day^{-1} that we have previously found for DDE (2). The average rate constants for PCB, both overall and within groups, were practically identical to the averages for DDE. The cows in late lactation were similar to cows in mid-lactation, but the cows in early lactation had lower rate constants than the other two groups. The lower rate for early lactation is consistent with earlier work on DDT (4,5).

The relationship of the rate constants for DDE and PCB within individual cows are presented in Figure 2. The correlation ($r = 0.82$) between the rate constants for the two compounds was significant ($P<0.01$). The usual linear regression was calculated and the intercept did not differ significantly from zero (6). Therefore, the regression in Figure 2 was recalculated forcing the intercept through zero. The regression coefficient, 0.974, was essentially unity.

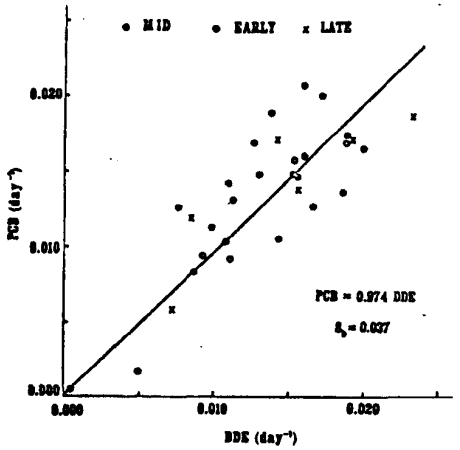

Figure 2. Relationship of the rates of decline of DDE and PCB concentration in milk fat of individual cows. Mid, early, and late are the stages of lactation described in the text.

MONS 087235

C.W.

In some cases there was considerable variation between the rate constant for DDE and for PCB within a given cow. The rate constants for the two compounds within a given cow were tested statistically (6), but differences were not significant.

Discussion

The components of Aroclor 1254 that occur in the milk are apparently the more highly chlorinated compounds (7). Our data suggests that DDE and the highly chlorinated components of PCB have identical behavior in cows. Until further data on PCB's are obtained, the established values relating DDE exposure to milk or meat contamination could be used as a first approximation for the components of PCB resistent metabolic degradation.

DDE is one of the most resistent organochlorine compounds to metabolic degradation. Thus, it is probably a good assumption that the more highly chlorinated PCB's are similarly resistent to metabolic degradation by the animal. Contamination of cows by PCB's of a lower average chlorination could occur because of their wide distribution in the environment (1). However, the residue of PCB in milk or meat should be at levels no greater for a given exposure than that established for DDE.

Similarity of DDE and the more highly chlorinated PCB's also has wider environmental implications. PCB's are biologically magnified in the environment (1). Unless there are marked differences between species in handling of the highly chlorinated PCB's, one can assume that the relative biological magnification of the highly chlorinated PCB's in the environment will be about the same magnitude as the magnification of DDE.

References

1. PEAKALL, D. B. and LINCER, J. L., BioScience 20, 958 (1970).

2. FRIES, G. F., MARROW, Jr., G. S., and GORDON, C. H. J. Dairy Sci. 52, 1800 (1969).

3. FRIES, G. F. Advan. Chem. Ser., In press.

4. FRIES, G. F., FLATT, W. P., and MOORE, L. A. J. Dairy Sci. 52, 684 (1969).

5. LABEN, R. C., ARCHER, T. E., CROSBY, D. G., and PEOPLES, S. A. J. Dairy Sci. 48, 701 (1965).

6. SNEDECOR, G. W. and COCHRAN, W. G. Statistical Methods, 6th ed., Iowa State University Press, Ames (1967).

7. ZITKO, V., HUTZINGER, O., and SAFE, S. Bull. Environ. Contam. Toxicol. 6, 160 (1971).

MONS 087236