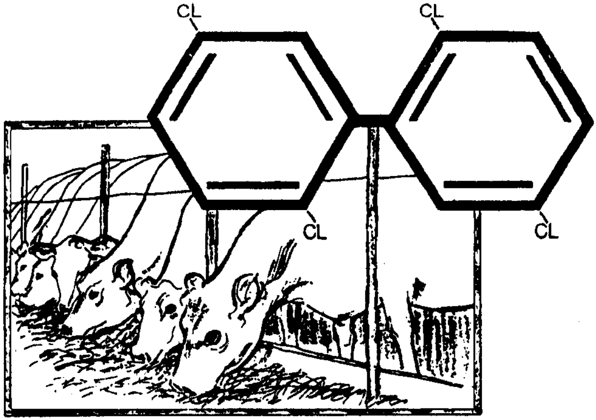


# PCB RESIDUES: THEIR SIGNIFICANCE TO ANIMAL AGRICULTURE

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POLYCHLORINATED biphenyls, more commonly known as PCB's, are chlorinated hydrocarbon compounds that have a variety of industrial uses. Residues of these compounds have been found to be widely distributed in the environment.

These residues have occurred in a number of foods but more frequently in seafoods than any other food product. Contamination of animal products has not been widespread, but several significant localized problems have arisen with poultry and dairy products.

It is my purpose to review the known incidents of poultry and milk contamination by PCB's and to discuss future problems that may arise.

*Background*

PCB's have been produced since 1930 but were not recognized as widespread environmental contaminants until 1966. The major use of PCB's has been as a dielectric in transformers and capacitors. Other significant uses have included heat transfer and hydraulic fluids. Minor uses, making up less than 6 percent of sales, have included such items as surface coatings, plasticizers, sealants, adhesives, and printing inks.

The sole producer of PCB's in the United States is the Monsanto Chemical Co.[1] whose production of these compounds peaked in 1970 at about 36,500 tons. The company has restricted sales of PCB's to use in sealed products such as a dielectric in transformers and capacitors. Foreign producers of PCB's

[1] Trade names are used in this publication solely for the purpose of providing specific information. Mention of trade names does not constitute guarantee or warranty of the product by the U.S. Department of Agriculture or an endorsement over other products not mentioned.

are not a significant factor in U.S. usage but are important when considering global contamination problems.

Polychlorinated biphenyls and polychlorinated triphenyls are sold by Monsanto under the trade name Aroclor. They are described by a four digit number. The first two digits indicate the chemical structure of the material, while the second two digits indicate the percent chlorine that the material contains. For example, Aroclor 1254 is a polychlorinated biphenyl containing 54 percent chlorine.

Aroclors are mixtures but do not contain all of the 210 theoretically possibly polychlorinated biphenyl compounds. A single formulation may contain as many as 40 individual PCB's.

Chemically and biologically, PCB's are similar to other chlorinated hydrocarbon compounds. PCB's can be isolated by the same analytical procedures used in routine surveying for chlorinated hydrocarbon pesticides. Some components have the same gas chromotographic retention times as chlorinated hydrocarbon pesticides. These interferences led to the discovery and identification of PCB's in the environment. Some values listed in the literature as DDT prior to 1966 may have been PCB's.

PCB's persist in the environment and resist degradation by organisms. However, in some species the less chlorinated components are degraded and converted to water soluble compounds. PCB's are stored in the body fat of animals where the concentrations undergo biological magnification. Thus, animals at the higher levels of the food chain will have the highest residue levels.

The toxicological significance of PCB residues has not been determined. The only clinical experience with acute human exposure occurred in Japan in 1968. About 1,000 persons had eaten rice oil contaminated with PCB's. They developed darkened skins, eye discharge, severe acne, and symptoms of what came to be called Yusho disease. Average intake was 2 grams of PCB, with symptoms appearing at a minimum dose of 0.5 g.

A variety of subacute effects at much lower intakes have been observed in many other species. The long-term significance of these effects and their implications for human health has not been determined.

Toxicological evaluation of PCB's is difficult because they all are mixtures. Proportions of the components are different among the various Aroclors. One cannot evaluate a single formulation and assume that the result applies to other formulations. There is also evidence that PCB's, particularly those of European and Japanese manufacture, may contain highly toxic impurities such as dibenzofurans.

The PCB problems in the United States involving animal agriculture have been of two distinct types. The poultry incidents were short-term, high-level exposures causing not only high residues in the product but also adverse effects on the birds. The milk incidents were chronic exposures involving only residues.

### *Milk Residues*

PCB residues in milk were first detected in 1970 in Ohio. The source was traced to a sealant used on the inside walls in the manufacture of concrete stave silos. Aroclor 1254 was included in the formula of this sealant which was used extensively by one company. All incidents of milk contamination have involved the silos of this company and its successors.

Other companies have in their files formulas for PCB-containing sealants. It has not been determined whether or not any of these were produced and used. However, no contaminated silos originating from other companies have been detected.

The sealant containing PCB's was developed in the 1930's and used until about 1968. Estimates of the number of silos in which it was used are not available. In addition to Ohio, contaminated silos exist in Kentucky, Tennessee, and adjacent States.

Scrapings from silo walls contain as much as 1 to 2 percent PCB. While PCB's are not very soluble in water, their concentrations as high as 100 p.p.m. in the silage dry matter can occur adjacent to the wall. Levels drop rapidly as the distance from the wall increases and significant residues are seldom found more than 2 or 3 feet from the wall. The diffusion towards the center is greater at lower levels in the silo.

Despite the relatively low transfer of PCB from the wall to the silage, there are two factors in addition to the high-wall concentrations that contribute to the milk residue problem. First, it is impractical to separate the high-residue silage adjacent to the wall from the other silage and second, PCB's are transferred very efficiently from the silage to the cows' milk.

We surveyed a number of farms that were using contaminated silos. Levels of PCB residues in milk fat were approximately 10 p.p.m. when the silage was fed. Other workers have found individual farms with residue levels as high as 28 p.p.m. The Food and Drug Administration (FDA) guideline for maximum PCB residue is equivalent to 2.5 p.p.m. in milk fat. Low-level silage feeding would theoretically allow production of milk within the guidelines, but the level is too low to be practical.

We have studied the metabolism of PCB's by cows both in the field and under controlled conditions in the laboratory. Transfer of PCB's from the feed to the milk fat and body fat is very efficient. Rates of transfer are approximately equal to the rates for DDE, the most persistent metabolite of DDT. The total diet of the cow must contain less than 0.5 p.p.m. PCB in order to prevent milk from exceeding FDA guidelines.

If excessive residues occur in milk the time required to return the herd to a marketable condition may be quite long. PCB's are removed from the body fat at a rate proportional to the concentration in the body fat. It takes approximately 6 to 8 weeks to reduce the concentration in milk fat by one-half. Thus, if the PCB concentration in milk fat is 10 p.p.m. (four times the FDA guideline), it will take approximately 16 weeks from the time the contaminated feed is removed from the cow's diet for the milk to be within the guideline.

Since the PCB concentration in the body fat is closely related to that in the milk fat, cows exceeding the guideline for milk would also exceed the guideline for meat. If the cows are producing milk with excessive PCB levels, one can either destroy the animal or wait until the residue level in milk returns within the guideline. In either case the loss to the dairyman can be substantial.

The number of contaminated silos detected by regulatory activity has been small compared to the estimated number of contaminated silos. This is largely due to problems of analysis and survey techniques that are followed by regulatory agencies. Generally the lower level of detection has been about 1 p.p.m. in milk fat. Thus, if the milk supply is surveyed using composite samples of many farms, it would be difficult to detect an individual farm with contaminated milk if the other farms in the sample produced clean milk.

The amount of PCB-contaminated milk produced is relatively small compared to the total milk supply of the country. The farms producing contaminated milk are scattered and it is greatly diluted by clean milk. Thus, there is no reason to be particularly concerned about the effects of the residues on the health of the general public.

However, there is one segment of the population that could receive significant exposures from this source: Farm families who drink milk from their own cows fed on contaminated silage. Using typical residue and milk consumption levels, intakes of PCB for over 15 to 20 years would approximate the level of short-term intakes that caused serious effects in Japan.

However, the problem is probably not as serious as implied since a dose consumed over a long period may be less serious than the same dose consumed in a very short period. Also the PCB in the contaminated silos was more chlorinated than the Japanese product which also may have contained highly toxic contaminants. Thus, the situations are not directly comparable.

### *Silo Decontamination*

ANY method devised to correct the PCB problem in milk should have two desirable characteristics: Effectiveness and economy. Because of the high efficiency of transfer of PCB's from a cow's diet to its milk there is no known effective remedy short of elimination of most PCB from the cow's diet. The most effective and most costly method of eliminating the problem would be complete abandonment of the contaminated silos.

Several alternatives to complete abandonment have been suggested and partially tested. The suggestions generally involve resealing the silo to block the diffusion of PCB's from the silage. In some cases the resealing may be preceded by partial removal of the PCB's.

Partial removal of PCB has been attempted by either sandblasting the surface or washing the surface with a suitable solvent. Sandblasting followed by resealing has been tried but no studies of its effectiveness have been made. The cost of this procedure is greater than half the cost of a new silo and may exceed the depreciated value of the silo.

Sandblasting has consequences that have not been fully explored. The operation is dusty and thus it is possible that other areas of the farm could be contaminated. The PCB's also penetrate quite deeply into concrete. It is not known how much of the surface would have to be removed to completely remove or reduce the PCB's to a satisfactory level.

Solvent washing has been tried on a few silos, but the cost of the procedure is not established. Presumably it would be similar to the cost of sandblasting. In field experiments we have found that the process of solvent washing and resealing has not been effective. Whether this was due to the specific procedure used has not been determined.

Resealing the silo without prior treatment would be a desirable method because of its lower cost. For this method to be effective the PCB should not penetrate the new sealant and the new sealant must adhere to the walls for the remainder of the silo's life. Several materials have been tested and some show promise. However, the work that has been reported has only covered the first years' experience. It is not known how well these materials will continue to seal.

Temporary expedients have been attempted on a few farms where contaminated silos were identified by regulatory agencies. Lining the interior of the silo with plastic was effective enough to keep the residue levels near the guideline. Discarding the silage within about 6 inches of the wall was less effective. Neither method is compatible with mechanized unloading of the silo and neither eliminates the problem.

### *Poultry*

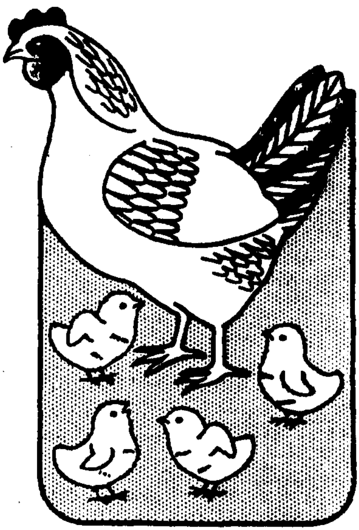
SOME of the most spectacular and publicized incidents of PCB contamination have involved poultry. In the past 2 years there have been serious incidents in North Carolina, New York, Maine, and Minnesota. The source of contamination was not established in all cases.

The North Carolina incident was the most extensive and is the best documented. A large poultry producer noted a severe decrease in hatchability of eggs. The problem was tracked to fishmeal contaminated by Aroclor 1242. The fishmeal was contaminated during processing when the PCB leaked from a corroded heat exchanger. In addition to this incident, contaminated feed from the same source had been shipped to 11 other States before the situation was brought under control. Significant numbers of broilers and eggs had to be destroyed because of the high residues.

Lowered hatchability is one of the more important toxicological effects of PCB's in birds. In contrast to some of the chlorinated hydrocarbons such as DDT, PCB's apparently have little or no effect on eggshell thickness. The effect on hatchability may occur at levels as low as 10 p.p.m. in the diet. Generally, there is full development of the embryo but the chicks are unable to break the shell. Subdermal edema is the most frequent abnormality.

Only the Aroclors with intermediate degrees of chlorination affect hatchability. We found that Aroclor 1232 has some effect, while the most severe effects are encountered with Aroclors 1242 and 1248. In contrast, Aroclors 1221 and 1254 have no effect at levels as high as 20 p.p.m. in the diet. No significant effects of PCB's on mammalian embryo development have been reported. This may indicate a species difference. However, most mammalian studies have used the more highly chlorinated PCB's and it is possible such effects could be obtained with the less chlorinated compounds.

The FDA has recently prohibited use of PCB's in feed plants and the use of recycled paper for feed



containers. Presumably these restrictions should eliminate short-term exposures of the type that have occurred with poultry. However, since PCB's have been so widely used and all of their possible uses have not been established, it is conceivable that a few incidents of this type will occur in the future.

### *Other Animal Products*

PCB contamination of poultry and dairy products suggests that contamination of other animal products may have occurred. However, there are circumstances that minimize its significance and chances for detection.

It is possible that some cattle raised for beef have received silage from contaminated silos. However, silage, particularly during fattening, is not as important a component of beef rations as it is of dairy rations. From levels in milk contamination, it can be assumed that some carcasses of surplus dairy animals have residue levels exceeding the FDA guideline. However, surplus dairy animals account for a small part of the meat supply. There would only be a small chance for a carcass of either type to be selected for routine analysis.

The incidents involving poultry suggest that contamination of feeds for other livestock could also have occurred. Some of the fishmeal from the North Carolina incident may have been used for pigs, yet residues in pork have not been reported. Some of the fishmeal also was ultimately destined for catfish food.

To date there have been no severe losses of species other than poultry due to PCB's. This could indicate that other species are not as sensitive to PCB's as poultry and if exposure occurred, there was no noticeable effect on productivity.

### *Discussion*

PCB residues have been accumulating for 40 years but were not detected until 6 years ago. It can be assumed that other undetected contamination exists. It usually comes to light by one of two ways. One is the release of high levels of a material and subsequent observation of severe problems, as illustrated by the poultry incidents. The other, and more frequent, is the development of analytical instruments and methods capable of detecting smaller residues than was previously possible, as illustrated by the silo incidents.

PCB's have the two characteristics of a compound most likely to cause contamination problems. These are resistance to degradation and solubility in fat. Water soluble compounds, even if not degradable, would tend to disperse in the environment and would be of less potential hazard.

The poultry feed and silo problems also illustrate some practical problems associated with regulatory activities. With the poultry feed there was no question of the severity of the problem. Through an intensive short-term effort, regulatory agencies located all of the contaminated feed and products which were then removed from food marketing channels.

The situation involving silos is considerably different. Mixed samples of milk from several farms rarely show significant residues. Thus, only a small percentage of the affected farms have been identified in routine surveys.

In order to completely eliminate the problem it would be necessary to sample individual farms. This would involve a very large sample load and is probably beyond the capability of most regulatory laboratories. This problem could be overcome to a large extent if a preliminary survey was made and the individual samples were limited to the farms having the suspected type of silo. To my knowledge only Ohio is following such a program at the present time.

Regulatory efforts that are not completely effective raise a number of questions. The first is whether or not the undetected farms pose a threat to public health. They probably do not because dilution would reduce the residues to a negligible level. However, the "dilution principle" has not been acceptable to many regulatory agencies.

The second question is whether or not the occasional removal of a contaminated dairy from the market provides a sufficient incentive for other dairymen to determine whether they have silos that are contaminated and to correct the problem if it exists. Removal from the market is a major economic loss but the cost of correcting the problem without market loss can also be substantial. If a dairyman feels the chances of being detected are very small he may take the chance and ignore the possibility that he has contamination.

Problems are also posed for others, such as research and extension personnel, who may be aware



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of the nature of the situation but who have no direct responsibility for its resolution. They should not condone the production of milk with residue levels above the guidelines. On the other hand, it is difficult to recommend a large economic outlay to a dairyman unless it prevents a larger outlay in the future.

Also confusing the issue is the determination of responsibility for the contaminated silos. Litigation involving dairymen, the silo builder, and the PCB manufacturer is now in progress. When responsibility is established, it should be easier to decide upon and to implement a course of action.

## *ON ANSWERING "WHAT ARE YOU DOING, MR. RESEARCHER?"*

I sometimes imagine myself discussing my own (research) project with several kinds of people and they each ask the question, "What are you doing."

Let us say that this question is asked by a fellow scientist, a Texas beef cattle producer, a man in the street, and a member of the legislative Appropriations Committee.

To my fellow scientist I would say, "I have a theory based partially on a feedback control model that the regulation of internal temperature in cattle can be studied by treating the hypothalmus as a sensor-controller amenable to testing. To achieve such tests I have to install a camula permanently in the anterior hypothalmus to permit repeated entry. Thus the tissue can be heated artificially to put a step input into the controller or I can measure its temperature change in response to a step change in environmental temperature. In either case the data for entering the control model can be secured and from this the thermal time constant can be derived. Thus a small advance in our knowledge of bovine temperature regulation might be made."

To the beef cattle producer I would say, "I believe I have worked out a method for rapid identification of heat-tolerant individuals within a breed. These individuals should have better feeding efficiency in our climate, thus making your business more profitable."

To the man in the street I would say, "I am working on a scheme which, if successful, will give the consumer better beef at lower cost."

To the legislator I would say, "Texas cattle feeders can use this information to their economic advantage and thus contribute further to our industrial economy."

Now I know all of this sounds kind of awful. . . . trying to be everything to everybody, but every word of what I said, I think, is true and illustrates the idea that if the researcher cannot discuss these matters with people having all shades of opinion, then maybe he shouldn't be doing that kind of work.

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(From a talk at a workshop on research planning and decision making held in Washington, D.C. by the Cooperative State Research Service.)