Polychlorinated Biphenyl Contamination of Nursing Mothers' Milk in Michigan

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Abstract: The problem of environmental contamination by toxic substances and human exposure to these substances has attracted increased attention in recent years. Particular concern has centered on polychlorinated biphenyls (PCBs), which have become widespread environmental pollutants as well as contaminants of the human population. This paper reports data from a study of PCB contamination of nursing mothers' breast milk in Michigan.

During 1977 and 1978, breast milk samples of 1,057 nursing mothers residing in Michigan were tested for PCB residues. All of the 1,057 samples collected from 68 of the state's 83 counties contained PCB residues ranging from trace amounts to 5.100 parts per million (fat weight basis). The mean level was 1.496 parts per million (ppm), with 49.5 per cent of the samples having PCB levels of 1-2 ppm, 17.4 per cent had 2-3 ppm, and 6.14 per cent had more than 3 ppm. There was no consistent trend in the level of PCB contamination over the 24 months of monitoring. The mean PCB level for the eighth quarter of monitoring was slightly higher than for the first quarter. The public health significance of PCB contamination in human populations and its effects on breast-fed infants are unclear. However, an infant breast-fed for eight months by a woman with the average PCB level in this sample would have an estimated body burden of approximately 0.89 ppm of PCBs. The implications of PCB contamination of human milk with regard to current breast-feeding practices are discussed and several precautionary measures are recommended. (*Am J Public Health* 1981; 71:132-137.)

Introduction

Polychlorinated biphenyls (PCBs) are a group of chlorinated synthetic organic compounds. PCBs are thermally stable, resistant to many strong chemical agents, and have excellent dilectric (insulating) properties, making this class of compounds ideal for many industrial applications. PCBs have been used most widely in the electrical industry to produce electrical capacitors and transformers,[1] but have also been used in heat exchange systems and in hydraulic fluids and lubricants, as well as in other applications. Commercial PCB products have been manufactured in the United States under the trade name "Aroclor" and are identified by four digit numbering codes, e.g., 1242, 1254, 1260, with the last two digits representing the per cent by weight of chlorine in the mixture. Since 1976, the sale and use of these chemicals in the United States have been strictly controlled by federal law.

PCBs have long been known to produce toxic effects in prolonged industrial exposure. Skin lesions, edema of the face and hands, impotence, and systematic digestive disturbances have been reported.[2-4] Other evidence of PCB toxicity has come from human exposure and animal studies. In 1968, over 1,000 Japanese became seriously ill with "Yusho" (oil disease) from ingesting rich bran oil accidentally contaminated by PCBs.[5] Children born to mothers exposed to the contaminated oil were of low birth weight and exhibited hyperpigmentation of the skin.[6] In studies involving test animals PCBs have also been found to be associated with reproductive problems and liver tumors.[7-9]

However, findings from studies of Yusho patients as well as those from animal experiments should be interpreted cautiously. In the Yusho incident, the rice oil was contaminated by a high concentration of a PCB mixture that contained other highly toxic impurities.[10] Secondly, the characteristics of test animals may interact with the properties of PCBs to affect the outcome of experiments, making interpretation of the findings from these experiments difficult.[10] Despite what is known about the toxicity of PCBs, it is not as yet possible to assign with any certainty a level of risk or to identify a critical threshold of risk which may be associated with human exposure to these chemicals. For this reason, the long-range public health significance of PCB contamination in humans remains unknown.

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In the past the uncontrolled use of PCBs has led to widespread environmental contamination[11-13] including contamination of the human food chain.[14, 15] This contamination has resulted principally from the disposal and leakage of industrial fluids into rivers and coastal waters,[16, 17] often affecting the human food chain by the consumption of contaminated fish. Because PCBs are highly soluble in fat and tend to collect in the fatty tissues of animals, including man,[18, 19] they may be bioconcentrated in the food chain. Consequently predator fish near or at the top of the food chain coming from polluted waters may have greatly elevated levels of PCB residues, and fish are now considered to be the primary dietary source of PCBs.

As a result of environmental contamination, human exposure to PCBs has been unavoidable. Although the extent and distribution of PCB contamination in the human population are not precisely known, reports suggest that a significant proportion of the population has been affected. PCB residues of 1 part per million (ppm) were found in approximately 30 to 40 per cent of tissues analyzed in three national surveys conducted in the early 1970s.[20, 21] In a separate national survey conducted in 1975 involving analysis of 1,038 breast milk samples, PCB residues were found at detectable, but not quantifiable, levels in 69 per cent of the samples analyzed, while 30 per cent of the samples had PCB levels above 0.50 ppm (whole-milk basis), the lowest quantifiable level for the type of testing done.[22] Other studies, based on small samples, have also reported PCB residues in human milk and in adipose tissue.[23-28]

In Michigan, predominantly an industrial state, environmental contamination by PCBs, as well as other toxic substances, has been a widely reported problem. Reports of elevated levels of PCBs in fish in the Great Lakes[29] led to controls being placed on commercial fishing and to recommendations by public health officials that persons reduce or eliminate their consumption of such fish. In one study, consumption of Lake Michigan fish was found to be associated with increased blood PCB levels.[30] In order to assess more completely the extent and distribution of PCB contamination in the population in Michigan, we investigated the level of PCBs in the breast milk of Michigan nursing mothers.

Materials and Methods

In 1973 and 1974, several thousand Michigan dairy farms were contaminated with polybrominated biphenyl (PBB) as the result of an industrial accident. A survey conducted in 1976 showed that as many as 96 per cent of the nursing mothers in the Lower Peninsula of the state had PBB residues in their breast milk.[31] As a result of this finding, the Michigan State Health Department made available to Michigan nursing mothers a voluntary, no-cost Breast Milk PBB Determination Service, with the option that a PCB determination would also be made on the same milk specimen at the expense of the subject submitting the specimen. Environmental Research Group, Inc., in Ann Arbor, Michigan was selected to carry out the testing of the breast milk samples.

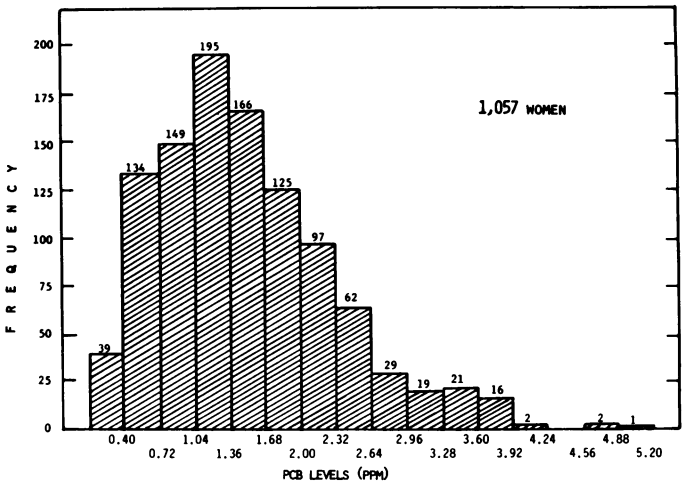

FIGURE 1—Histogram of PCB Residues in Breast Milk of 1,057 Women Tested during 1977 and 1978 in Michigan

In early December 1976, all physicians (MDs and DOs) licensed to practice in Michigan were advised of the program by the Michigan Health Department, and, at the same time, announcements of the service and the procedure to be followed in obtaining it were made through the media.

From January 1, 1977 to December 31, 1978, 2,584 nursing mothers residing in Michigan had their breast milk tested for PBB. Of this group, 1,057 (41 per cent) paid the extra fee and had their breast milk tested for PCBs. All 1,057 women whose breast milk was tested for PCBs were included in the study population. It should be stressed that this sample was not randomly selected and may not therefore be representative of the general population of Michigan. Nevertheless, the sample is large and provides an indication of the extent and distribution of PCB contamination in the population of Michigan.

Breast milk samples were obtained by manual expression and collected in chemically clean 125 ml glass jars. The samples were then sent to Environmental Research Group Laboratory where they were given identification numbers and stored at −20° C until testing. Women submitting breast milk specimens for testing were asked to provide information about their age and current residence in Michigan.

A Tracor Model 560 dual column gas chromatograph with a nickle-63 detector was used for the analysis; the extraction process was that of Price.* Standards of Aroclor 1242, 1254 and 1260 were injected before and after each set of samples. Quantification was based upon a match of all the major peaks of PCB in the sample with the standard. Most of the PCBs in the breast milk samples were isomers contained in 1254 and 1260. Quantification was made on the basis of peak height. The lowest quantifiable level was 0.3 ppm on a fat weight basis. Standards were run before and after all analysis, and blanks were run after each tenth sample. Every

*Price Harold A: Analytical Procedure for PBB in Milk, Procedure B. Michigan Department of Public Health, Lansing, MI.

TABLE 1—Incidence of PCB Contamination in Breast Milk in Michigan

Range of PCB Contamination	Number	%
<1 PPM	285	27.0
1 – <2 PPM	523	49.5
2 – <3 PPM	249	17.4
>3 PPM	65	6.1
TOTAL	1057	100.0

tenth sample was a duplicate and was spiked with PCB to ensure valid recovery.

Results

The 1,057 women who provided breast milk samples for PCB testing ranged in age from 17 to 44; the mean age was 29 (S.D. 3.99). The majority of the study population, 57 per cent, resided in the populous urban counties of southeast Michigan near Detroit; the remaining 43 per cent resided in other counties located throughout the state. On the average, women had lived in their county of residence for 13 years prior to having their breast milk tested (S.D. 11; range, 1-38). This figure underrepresents the number of years of residence in Michigan as a whole to an unknown degree, however, as women provided information only about their current county of residence.

All of the 1,057 breast milk samples tested during 1977 and 1978 contained PCB residues ranging from trace amounts to 5.100 ppm (fat weight basis). The mean PCB level was 1.496 ppm (S.D. 0.796 ppm); the median PCB level was 1.354 ppm. Out of 1,057 breast milk samples, 523 (49.5 per cent) had PCB residues of 1-2 ppm, 249 (17.4 per cent) had 2-3 ppm, and 65 (6.14 per cent) had over 3 ppm. PCB residues in four samples exceeded 4 ppm. Figure 1 depicts the distribution of PCB residues in the breast milk samples, while Table 1 shows the per cent distribution of cases.

The distribution of PCBs in our study population was not geographically uniform. Michigan has 83 counties in its Upper and Lower Peninsulas. All but 15 counties were represented by at least one case, while 37 counties had three or more cases. Mean PCB levels in counties having more than one case ranged from 0.700 ppm to 3.300 ppm. Figure 2 shows the geographical distribution of PCB contamination in Michigan by county. There appears to be no distinct pattern to this distribution. The PCB level in several counties in the western part of the Lower Peninsula as well as in three counties in the rural Upper Peninsula exceeded 2 ppm. This may reflect a high dietary intake of PCB-contaminated fish from the nearby Great Lakes.

PCB levels in the breast milk samples exhibited some variation during the two years of testing. Figure 3 depicts the mean PCB level of the samples for each quarter of 1977 and 1978. As can be seen in Figure 3, no consistent trend is shown over time. The mean level for the eighth quarter is slightly higher than that of the first quarter. The reason why PCB levels should vary seasonally is unclear. It may be related to the nonrandom nature of the sample or to when public media announcements about the testing program occurred; testing activity generally increased after media announcements, and women who suspected they had higher PCB levels may have been more responsive to these announcements.

Lastly, it is of interest to observe the fat content found in the breast milk of women in our study population. The

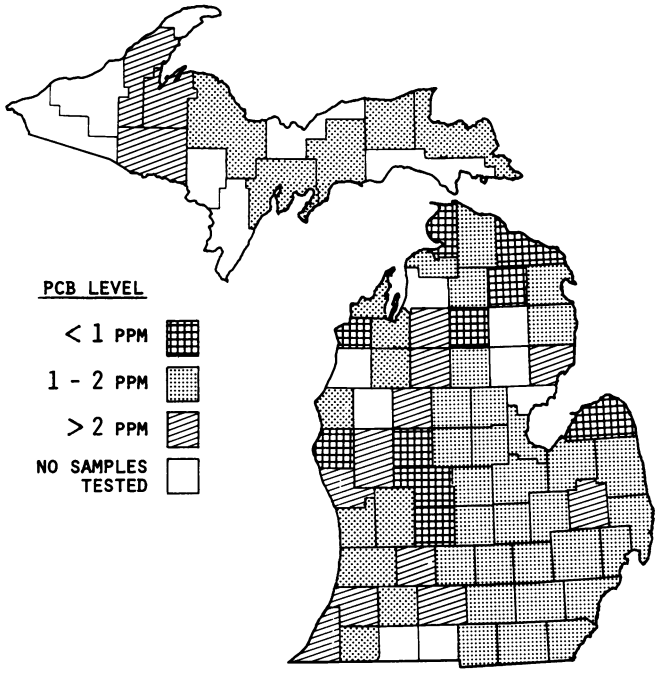

FIGURE 2—PCB Levels in Breast Milk in Michigan by County

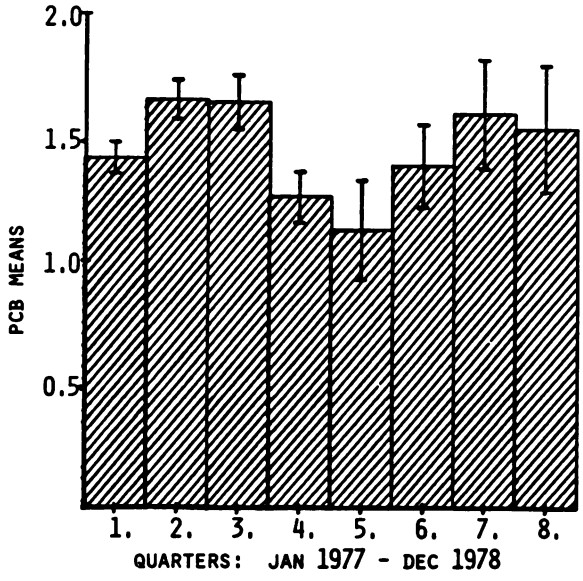

FIGURE 3—90 per cent Confidence Intervals about the Mean for 1,057 Breast Milk Samples Tested in Michigan during 1977 and 1978

mean fat content of the breast milk samples was 3.16 g/100 ml (S.D. 1.63 g/100 ml; range, 2.20 g/100 ml–17.0 g/100 ml). Cost considerations, however, allowed only two extraction procedures to be done on each breast milk sample resulting in the recovery of approximately 90 per cent of the fat content. Adjusting for this would yield an estimated mean fat content of 3.48 g/100 ml. It is likely that this relatively low fat concentration reflects the fact that the breast milk samples were collected at the beginning of feeding when the fat content of milk is lower. Mature human milk is generally thought to contain closer to 4.5 g/100 ml of fat.[32, 33]

Discussion

The present study has provided an opportunity to assess the extent and distribution of PCB contamination in breast milk of a self-selected sample of 1,057 nursing mothers in Michigan. PCB residues ranging from trace amounts to 5.100 ppm were found in all 1,057 breast milk samples tested during 1977 and 1978. On the average, the breast milk samples contained 1.496 ppm of PCBs; 49.5 per cent of the samples had PCB levels of 1-2 ppm, 17.4 per cent had 2-3 ppm, and 6.14 per cent had over 3 ppm.

While the long-range public health significance of PCB contamination in humans at levels such as we found in Michigan is unclear, it is of interest to note that the median PCB level of 1.354 ppm found in the breast milk of our sample of 1,057 women is only slightly less than the Food and Drug Administration's present tolerance limit of 1.50 ppm (fat weight basis) for PCBs in cow's milk and dairy products. This means that one-half of the total study population—or 528 out of 1,057 women—has a PCB level nearly equal to or above the present FDA tolerance limit for cow's milk.

A further question raised by the findings of this study is the effect of PCB contamination on breast-fed infants. The infants of nursing mothers in our sample continued to consume PCB-contaminated milk in some cases for as long as one year. If we make several assumptions concerning the volume and content of the breast milk and the duration of breast-feeding, it is possible to characterize a hypothetical "average" infant for the purpose of estimating the PCB body burden which may have resulted from breast-feeding. These assumptions include:

1. that infants consume 700 ml of milk for the first six months of nursing and 500 ml thereafter;[34]
2. that the breast milk contains 4 g/100 ml of fat;
3. that the breast milk contains 1.5 ppm PCBs (the average level found in our tested samples);
4. that infants follow the 50th percentile of weight for age growth; and
5. that infants retain 85 per cent of the PCBs contained in the breast milk.

These assumptions are reasonable and consistent with current medical knowledge about the composition of human milk and about the metabolic properties of PCBs.

Based on these assumptions, this "average" infant might have consumed approximately 9.36 mg of PCBs in the first eight months of life, of which approximately 7.96 mg would be retained. If we then divide this by the infant's weight, we obtain the body burden of PCBs in mg/kg (ppm). An infant weighing 8.97 kg at 8 months, the 50th percentile of weight for age growth, whose mother had a breast milk concentration of PCBs equal to the mean value in our sample, would therefore have an estimated body burden of 0.89 ppm—more than one-half of the PCB concentration in his mother's milk.

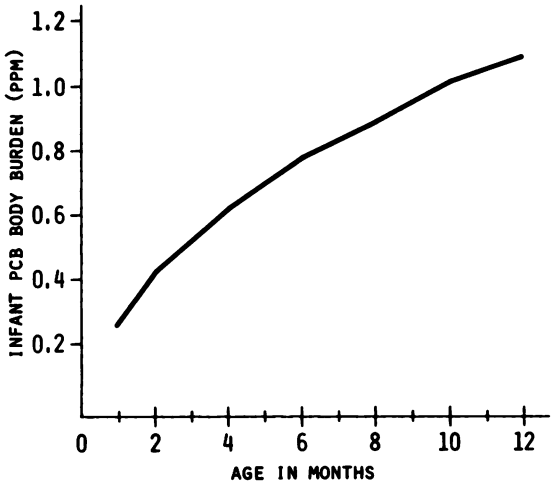

FIGURE 4—Estimated Accumulation of PCB Body Burden in Infants

The accumulation of PCB body burden over time for a hypothetical infant, based on the above assumptions, is shown in Figure 4. As can be seen in Figure 4, an infant's PCB body burden could be expected to increase steadily with ingestion of contaminated milk for the entire period in which breast-feeding is likely to occur. Blood PCB levels in infants have been found to rise with ingestion of PCB-contaminated breast milk[35] and may exceed those of the mother by as much as sixfold.[36]

Table 2 shows what the distribution of PCB body burden would be for the entire group of infants born to women in our study population, based on the assumptions noted above. As Table 2 shows, approximately 35 per cent of the infants would have a body burden of 1 ppm or more of PCBs at age 9 months. What effects this chemical contamination would have on infantile growth and development are at present unknown. Several clinical studies are currently being conducted to determine the risk factors associated with the transfer and accumulation of PCBs in breast-fed infants.[37]

The advantages of breast-feeding in terms of infant nutrition, health, and psychological aspects have been widely reported,[38–40] and both the incidence and duration of breast-feeding have been increasing in recent years.[41] However, public health officials and pediatricians have become increasingly concerned about PCB contamination of breast milk and its potential adverse effects on breast-fed infants.[37, 42, 43] Nonetheless, in the absence of any clear indication of unwarranted risk and, given the known benefits of breast-feeding, authorities have understandably been reluctant to recommend changes in current breast-feeding practices.

TABLE 2—Per Cent Distribution of PCB Body Burden in Breast-Fed Infants at 9 Months of Age in Michigan

Body Burden	Per Cent
<1 PPM	64.6
1 – <2 PPM	31.4
>2 PPM	4.0

Until more is known about the risks of breast-feeding in relation to the contamination of human milk by PCBs, it would seem premature to recommend any major changes in current breast-feeding practices. However, as a precaution it is recommended that pregnant women and nursing mothers reduce or eliminate consumption of fish from PCB-contaminated waters and avoid excessive weight reduction, as this may mobilize chemicals stored in fat tissues.[10] While this will help to avoid excessive risk, it will not solve the problem because PCB body burden accumulates over time.

For this reason, it is recommended that nursing mothers who have had potentially high exposure to PCBs, i.e., those who have been occupationally exposed or those whose diet has included large quantities of fish from PCB-contaminated waters, have a breast milk sample submitted for testing. This would provide a determination of the milk's PCB level as well as its fat content. Because PCBs are fat soluble, the fat content of milk is a primary determinant of the transmission of these chemicals by breast-feeding. The fat content of milk can vary from lactation to lactation, from day to day, and even at a single nursing;[44, 45] therefore, if breast milk testing is to be done, it is important that the correct procedure be used to obtain a representative sample of the milk.[44, 46] Otherwise, the testing may not provide an accurate determination of the milk's fat content or PCB level.

Should the breast milk test reveal that the woman's milk has an elevated PCB level and an above average fat content, or a lower PCB level but a very high fat content, then it may be advisable for her to limit the duration of breast-feeding. Since the risk factors of PCB contamination of human milk are unknown, however, there is no clinical basis to judge what may constitute an elevated breast milk PCB level. An "advisory" level of 2.5 ppm (fat basis) has been adopted by one state health department.[10] The distribution of PCB levels in our sample of nursing mothers also provides a basis for assessing what might constitute an elevated breast milk PCB level. The PCB level equal to one standard deviation above the men in our sample is 2.3 ppm; PCB levels above this might be considered elevated.

While providing the infant with some of the benefits of breast-feeding, limiting the duration of nursing would reduce the potential risk of PCBs being transmitted through breast milk. Estimates of PCB body burden accumulation in the infant (see Figure 4) suggest that halving the duration of breast-feeding could reduce the accumulation of infant PCB body burden by as much as 30 per cent.

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Reye's Syndrome is Topic of NIH Consensus Development Seminar

"The Diagnosis and Treatment of Reye's Syndrome" will be the subject of a National Institutes of Health Consensus Development Conference to be held March 2-4, 1981, in Masur Auditorium, in the NIH Clinical Center (Building 10), Bethesda, MD.

This Consensus Development Conference will bring together biomedical research scientists, practicing physicians, consumers, and experts in fields relevant to a thorough discussion of the diagnosis and treatment of Reye's syndrome. The purpose of the conference is to reach agreement on a scientific evaluation of the criteria for diagnosis and treatment of Reye's syndrome. In considering this condition, key questions to be addressed include:

- What is Reye's syndrome?
- What symptoms should alert parents?
- What other conditions may present similar symptoms?
- When should parents seek medical evaluation of their child?
- Which tests are helpful in diagnosing Reye's syndrome?
- What early treatments are useful for noncomatose patients?
- What are the indications for and risks of intensive care?
- What are the indications for monitoring intracranial pressure?
- Is barbiturate coma useful?

For technical information, contact: Dr. Joseph S. Drage, Chief, Developmental Neurology Branch, NDP, NINCDS, Room 816, Federal Building, 7550 Wisconsin Avenue, Bethesda, MD 20205, (301) 496-6701.