Fish Consumption and Breast Milk PCB Concentrations among Mohawk Women at Akwesasne

Edward F. Fitzgerald, 1 Syni-An Hwang, 1 Brian Bush, 2 Katsi Cook, 3 and Priscilla Worswick 3

A study was conducted to determine the relation between the consumption of contaminated local fish and concentrations of total polychlorinated biphenyls (PCBs) and 68 PCB congeners in the milk of nursing Mohawk women residing near three hazardous waste sites. From 1986 to 1992, 97 Mohawk women were interviewed and donated at least 50 ml of breast milk. The comparison population consisted of 154 Caucasians. After adjustment for potential confounders, Mohawk mothers who gave birth in 1986–1989 had a geometric mean milk total PCB concentration of 0.602 ppm (fat basis) compared with 0.375 ppm for the control group (p = 0.009). These Mohawk women also had significantly higher geometric mean concentrations of nine congeners. Beginning in 1990, however, there were no significant differences between the Mohawk women and the comparison group. Estimated cumulative lifetime exposure from local fish consumption was significantly related to milk total PCB and to three congeners only among those Mohawks who gave birth from 1986 to 1989. The reduction in breast milk PCB concentrations parallels a corresponding decrease in local fish consumption and may be the result of the advisories that have been issued over the past decade recommending against the consumption of local fish by pregnant and nursing Mohawk women. Am J Epidemiol 1998;148:164–72.

Polychlorinated biphenyls (PCBs) are very persistent, lipophilic compounds that bioaccumulate and biomagnify in the food chain (1). Ingestion, including the consumption of contaminated sportfish (2), is consequently a major route of human exposure. Native American communities, particularly those around the Great Lakes and the Pacific Northwest, are believed to be at particularly high risk of such exposure, since they typically are more dependent on local fish and game as a food source than are other populations. However, very few studies have directly assessed PCB body burdens and fish consumption among Native American people, especially those who live on reservations and reside outside of Alaska (3). The purpose of this paper is to present data regarding the association between the consumption of local fish contaminated with PCBs from hazardous waste and the milk PCB concentrations of nursing Mohawk women at Akwesasne.

Akwesasne is a Native American community of more than 10,000 persons located along the St. Lawrence River in New York, Ontario, and Quebec (figure 1). Less than 100 feet (30.7 m) to the west of Akwesasne is the General Motors/Central Foundry Division Superfund hazardous waste site. This facility used Aroclor 1248 (Monsanto Industrial Chemical Co., St. Louis, Missouri), a commercial mixture of various PCB congeners, as a hydraulic fluid in its die-casting machines from 1959 to 1974 (4). When these machines leaked, the fluids were collected in the wastewater system and disposed of on the property. Concentrations of PCBs range up to 40,000 ppm in on-site soils and sludges and up to 5,700 ppm offshore in St. Lawrence River sediment (5). Reynolds Metals, Inc. and the Aluminum Company of America operate aluminum-processing facilities in the area and have used Aroclor 1248 in their heat-transfer equipment. These facilities also have released PCBs into the St. Lawrence River and its tributaries (6). The PCBs have entered the local food chain, with some species of fish, reptiles, amphibians, birds, and mammals having levels that exceed the US Food and Drug Administration’s tolerance limits for human consumption of 2 ppm (wet weight) for fish and 3 ppm (lipid weight) for...
poultry (7, 8). An interim clay cap and liner was placed on the General Motors/Central Foundry Division landfill in 1988, but removal of contaminated soils and sediments has only recently started at all three facilities.

The pollution is a major concern of the Mohawk people, since their tradition and culture emphasize the interdependence of man and the environment because many residents formerly depended on local fish, waterfowl, and mammals for food. An earlier article by Fitzgerald et al. (9) described fish PCB concentrations, consumption rates, species preference, fish preparation methods, and sociodemographic factors associated with fish consumption among 97 nursing Mohawk women from 1986 through 1992 and a rural comparison group of nursing Caucasians. That report noted a significantly greater average rate of local fish consumption among the Mohawks relative to the controls before pregnancy (respective annual means of 23.5 and 14.1 local fish meals for the period more than 1 year before pregnancy). However, 60 percent of all Mohawk women who had previously eaten local fish ceased consumption once they were pregnant compared with only 38 percent of the comparison women. These changes may be related to the advisories that have been issued over the past decade by Mohawk, state, and provincial authorities against the consumption of fish from that area of the St. Lawrence River by pregnant and nursing women, infants, and children.

The objective of this paper is to relate local fish consumption to breast milk concentrations of total PCB and 68 PCB congeners in the Mohawk and comparison women. Breast milk was chosen as the sampling fluid since monitoring the levels of chemical contaminants in human milk is a useful indicator of maternal exposure and because it is a major source of exposure to environmental pollutants among breast-fed infants (10). The project is a collaborative effort.
among the New York State Department of Health, the St. Regis Mohawk Tribe, the Mohawk Council of Akwesasne, the Akwesasne Task Force on the Environment, and the State University of New York at Albany.

MATERIALS AND METHODS

Interview

Detailed descriptions of ascertainment, interview, and dietary assessment are published elsewhere (9). Briefly, all nursing Mohawk women who lived at Akwesasne and who gave birth between March 1, 1988, and March 31, 1992, were eligible for inclusion. A total of 93 (78.2 percent) participated. As part of a pilot project, four other Mohawk mothers were interviewed from 1986 to 1987. They were added to the study to increase the number of participants who gave birth prior to 1990, resulting in total sample size of 97 Mohawk participants. The dietary assessment consisted of the participant’s report of her consumption of various foodstuffs, emphasizing local species of fish and game. The specific method combined a food frequency with a limited dietary history to estimate usual intake (11). It focused upon consumption at three points in time: 1) during the index pregnancy; 2) in the year before the pregnancy; and 3) more than 1 year before the pregnancy.

Comparative data were obtained from nursing mothers who lived in Warren or Schoharie County and gave birth during the same period. Like Akwesasne, these counties are primarily rural in character. However, a review of records maintained by the New York State Department of Health indicated that both counties were relatively free of PCB contamination, and according to studies performed by the New York State Department of Environmental Conservation, fish in both regions show only background contamination (12). The mothers were recruited through the local Women and Infant Care clinics and were not selected on the basis of their fish consumption habits. A total of 154 women (52.4 percent) participated. All were Caucasian. Detailed comparisons with the Mohawk mothers regarding other sociodemographic factors, physical characteristics, reproductive histories, and lifestyle variables are published elsewhere (9).

Breast milk analysis

After the interview was completed, project personnel instructed the mothers in the use of a breast pump/infant nurser. Mothers were asked to provide at least 50 ml of breast milk 1 month postpartum. The chemical analysis was performed by one of the coauthors (B. B.), using methods (including quality assurance and control, accuracy, and precision) published elsewhere (13). Briefly, the milk samples were extracted by using ethanol and hexane and then transferred to a Florisil clean-up column (US Silica Co., Berkeley Springs, West Virginia) containing 10 g 4 percent deactivated Florisil topped with 1 cm anhydrous sodium sulfate. The eluate was analyzed with a Hewlett-Packard 5890 gas chromatograph (Hewlett-Packard Co., Avondale, Pennsylvania) using a phenylmethyl-octadecyl, silyl-bonded, fused-silica capillary column and an electron-capture detector. A computerized data management system reported each of 68 PCB-containing zones or peaks and summed the congener concentrations to report total PCB. In some cases, the capillary column was unable to resolve two congeners, so the result was reported as their sum.

The method detection limit for total PCB was 4.5 ppb (whole milk) or 180 ppb (fat basis, assuming a fat content of 2.5 percent and a volume of 50 ml). The median method detection limit for the 68 individual PCB congeners was 0.2 ppb (whole milk) or 8 ppb (fat basis). However, the instrument is capable of detecting signals in milk extracts as low as 0.001 ppb (whole milk) for each PCB congener. Concentrations between this instrument detection limit of 0.001 ppb and method detection limits were reported by the laboratory and included as such in the statistical analysis because many chemists and statisticians believe that a reported result, even if it is below the “criterion for detection,” remains the best available estimate of the true value and is preferable to assigning a zero or an arbitrary constant such as one-half the method detection limit (14). However, to prevent misconceptions regarding the level of certainty attached to the results, aggregate data are presented only if the geometric mean for all study participants equaled or exceeded the method detection limit for a given congener.

Dietary exposure assessment

The exposure of each Mohawk woman to total PCB through the consumption of local fish was estimated by multiplying the total number of local fish meals that she reported eating during each time period (during, 1 year before, and >1 year before the index pregnancy) for a particular species by the PCB concentration of that species and the duration of consumption. If a mother recalled from which of seven specific locations the fish was obtained, the data for that location were used. Otherwise, PCB concentrations for that species were averaged across all seven locations. The result was summed over all species, multiplied by an average of 200 g of fish per meal (the weight of a typical portion), and expressed as milligrams. The values for each time period were then combined to estimate each...
woman’s cumulative lifetime exposure. However, because maternal recall of diet is likely to be imprecise and because the mean PCB level of a composite sample may not be typical of the individual fish that a woman consumed, cumulative lifetime exposure was categorized into three ordinal levels for most statistical analyses: “none” for those Mohawks who reported never eating local fish, and “low” or “high” for all others, dividing along the median value.

In addition to total PCB, cumulative lifetime dietary exposures were estimated for the three leading congeners found in fish taken near General Motors/Central Foundry Division: 1) 2,4,4′-trichlorobiphenyl (IUPAC no. 28); 2) 2,5,2′,5′-tetrachlorobiphenyl (IUPAC no. 52); and 3) 2,4,3′,4′-tetrachlorobiphenyl (IUPAC no. 66). However, the exposure estimates for each of these three individual congeners were highly correlated with the estimates for total PCB (r = 0.99). The estimate for total PCB therefore was used as a proxy for a woman’s dietary exposure to individual congeners.

Statistical analysis

Multiple linear regression was used to test for the effect of fish consumption after evaluating the effect of 11 background variables, including maternal age, education, previous breastfeeding, body mass index, and occupation, that could potentially confound any association between exposure and breast milk PCB level (15). Models were first constructed for total PCB by using backward elimination to delete nonsignificant (p > 0.10) background variables one at a time. Then cumulative lifetime exposure from local fish consumption was added to estimate its effect after adjustment for all remaining background variables. The General Linear Model procedure of Statistical Analysis System (16) was used to calculate least-square means for every category of fish consumption after centering each covariate around its grand mean.

To determine whether there were changes in breast milk PCB concentrations during the course of the study period, the year of the index child’s birth was also entered as a variable in the regression models. To maximize cell frequencies, it was categorized a priori into three levels: 1986–1989, 1990, and 1991–1992. Interactions between time period and risk factors, such as cumulative lifetime exposure from local fish consumption, were also assessed by testing their cross-products.

The milk PCB concentrations were first fat adjusted by dividing the whole-milk level by the percent fat for a given sample. The result was micrograms of chemical per gram of milk fat (ppm). This adjustment was necessary because the concentration of these lipophilic compounds in whole milk is very dependent on the fat content of the milk (17). These fat-adjusted values were then transformed by using natural logarithms because their distributions were log-normal in shape. The results are presented as geometric means by taking the anti-log of the means of the log-transformed values after adjustment for potential confounders.

RESULTS

Breast milk total PCB

The breast milk total PCB data for the Mohawk and comparison women were similar when averaged across the entire study period. For example, the geometric mean concentration on a fat basis for the 97 Mohawk participants was 0.336 ppm (standard error = 0.026 ppm), while the geometric mean for the 154 controls was 0.372 ppm (standard error = 0.022 ppm). Approximately 19.6 percent of the Mohawks had a value of less than the method detection limit of 0.180 ppm; a milk level of less than the method detection limit was observed among 14.9 percent of the controls. The maximum levels were 2.39 ppm (Mohawks) and 2.34 ppm (controls).

Differences between the Mohawks and the controls were evident, however, when milk total PCB concentrations were evaluated by year of the index child’s birth. The results are displayed in table 1, after adjustment for previous breastfeeding, maternal age, alcohol

<table>
<thead>
<tr>
<th>Time period</th>
<th>Mohawk</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>19</td>
<td>52</td>
</tr>
<tr>
<td></td>
<td>0.602*</td>
<td>0.375</td>
</tr>
<tr>
<td>1990</td>
<td>38</td>
<td>57</td>
</tr>
<tr>
<td></td>
<td>0.352</td>
<td>0.404</td>
</tr>
<tr>
<td>1991–1992</td>
<td>40</td>
<td>45</td>
</tr>
<tr>
<td></td>
<td>0.254</td>
<td>0.318</td>
</tr>
</tbody>
</table>

* p < 0.01 for Mohawk versus control in 1986–1989, F_1,341 = 0.18, p = 0.674 for Mohawk or control; F_2,341 = 9.75, p < 0.001 for time period; F_1,341 = 4.94, p = 0.008 for M or C × time period.
† Adjusted for maternal age, antibiotic use before pregnancy, previous breastfeeding, and alcohol consumption before pregnancy.
‡ PCB, polychlorinated biphenyl.
consumption before pregnancy, and antibiotic use before pregnancy. The latter variables were the only background factors found to be significantly related to milk total PCB in the multiple regression analyses. The coefficients were $-0.0031$ ($p < 0.001$) for previous breastfeeding (weeks), $0.0370$ ($p < 0.001$) for maternal age (years), $0.0202$ ($p = 0.050$) for alcohol consumption before pregnancy (drink-years), and $0.5935$ ($p < 0.001$) for antibiotic use before pregnancy (yes vs. no).

The adjusted geometric-mean breast milk total PCB concentration of the Mohawk mothers who gave birth in 1986–1989 was 0.602 ppm, compared with 0.375 for the controls who participated during the same period ($p = 0.009$ for pairwise contrast). No significant difference was noted between mothers who participated later in the study. This time-dependent association was represented statistically in the analysis of variance as a significant interaction between whether the mother was a Mohawk or a control and the time period ($p = 0.008$). The Mohawks showed a significant and monotonic decline in their adjusted geometric mean breast milk PCB level over time was evident for the controls.

As noted previously, cumulative lifetime PCB exposure from local fish consumption among the Mohawks was categorized as 1) none, 2) low, or 3) high, with the 80 women in the latter two groups divided according to their median exposure of 8 mg. Table 2 shows the adjusted geometric mean total PCB concentrations for these three categories by the year of the index child's birth and with the inclusion of the controls.

The analysis of variance indicated that the interaction between cumulative lifetime dietary exposure and the year when the woman gave birth was significant, i.e., the effect of fish consumption varied according to time period. An examination of the cell means revealed that milk total PCB levels increased with cumulative lifetime PCB exposure from local fish consumption between 1986 and 1989 ($p = 0.009$ for test of linear trend including the controls). In comparison, among women who participated in 1990 or 1991–1992, no significant associations were observed. Regarding pairwise contrasts, the adjusted geometric mean for the high exposure category was significantly greater than that for the controls in 1986–1989 ($p = 0.011$). No other pairwise contrast was statistically significant. Similar results were observed when local fish consumption during or in the year before pregnancy was examined (data not shown).

**Breast milk congener-specific PCB**

Of the 17 congeners with geometric means that exceeded their method detection limits, nine were significantly greater among the Mohawk women who gave birth in 1986–1989 relative to control mothers after adjustment for previous breastfeeding, maternal age, alcohol consumption before pregnancy, and antibiotic use before pregnancy (table 3). The congeners found to be elevated ranged in degree of chlorination from tetra- to octachlorobiphenyls. Consistent with the results for total PCB, the Mohawk women who gave birth in 1990 or 1991–1992 had geometric mean milk concentrations for most congeners that equaled or were less than those of the controls (data not shown).

After adjustment for maternal age, antibiotic use before pregnancy, previous breastfeeding, and alcohol consumption before pregnancy, six congeners showed a significant monotonic trend in 1986–1989, with cumulative lifetime exposure to total PCB from local fish.
DISCUSSION

Caution must be exercised when comparing reported PCB levels across studies, given differences in analytic methods, time periods, and populations. In general, however, the milk total PCB concentrations of both the Mohawk and control mothers are within the 0.5–1.5 ppm range for average levels in breast milk from other studies in the United States (18). Much higher concentrations have been observed among Inuit women of Hudson Bay, Quebec, Canada (19). Atmospheric transport of organochlorines and movement in ocean currents have contaminated the Arctic food chain, including the fish, seal, walrus, beluga, caribou, and narwhal that the Inuit people are heavily dependent upon as food sources (20).

Women who reported nursing their previous children had lower milk total PCB levels. Previous lactations are likely to deplete the adipose stores, resulting in lower levels in the milk fat (17). Breast milk total PCB concentrations also increased with maternal age and alcohol consumption prepregnancy, probably reflecting the greater cumulative lifetime exposure of older women to PCBs and the adverse effect of alcohol on the liver’s ability to metabolize PCBs. These findings are similar to the results of other studies (21). In addition, breast milk total PCB increased with antibiotic use before the index pregnancy. An inspection of the responses of the 16 women who reported antibiotic use revealed that they were primarily short-term users who took a broad range of antibiotics shortly before pregnancy. One other study has reported such a relationship (22). Although such an association may reflect chance, it may also indicate that either antibiotics or the underlying infections for which they were prescribed affect distribution, biotransformation, or excretion.

When the data were examined according to the year in which the index child was born, Mohawk mothers who delivered in 1986–1989 had a significantly elevated geometric mean milk total PCB concentration relative to the comparison women. This difference between study groups in 1986–1989 was directly associated with estimated cumulative lifetime exposure to PCBs from the consumption of local fish. In fact, the adjusted mean for those Mohawk women who never ate local fish was not significantly different from that for the control mothers.

Mohawk mothers who gave birth in 1986–1989 had significantly higher geometric means for nine PCB congeners relative to the controls. One was a coeluting peak that is a major constituent of Aroclor 1248, i.e., 2,3,4,4'- and 3,4,2',3'-tetrachlorobiphenyl (IUPAC no. 60 and no. 55). Two others, (IUPAC no. 99 and no. 118), are also found in Aroclor 1248. The remainder are exclusively Aroclor 1254/1260 congeners (23). They probably do not reflect exposure to PCBs from the local industrial facilities, but are consistent with more general Lake Ontario and St. Lawrence River exposures (24). IUPAC no. 99 and no. 118 were also

significantly elevated among Mohawk fish eaters from 1986 to 1989. Each congener accounted for 2 to 3 percent of the total PCB residue in yellow perch caught offshore from General Motors/Central Foundry Division. The third congener associated with local fish consumption, IUPAC no. 146, was not detected in any appreciable level in fish caught near the General Motors/Central Foundry Division. It is more typical of Aroclors 1254 and 1260 than of 1248 and may again reflect more general Lake Ontario and St. Lawrence River contamination. Other congeners prevalent in local fish, e.g., IUPAC nos. 28, 52, and 66, were also elevated among Mohawk participants relative to the controls but are not reported in tables 3 or 4 because the method detection limits for these congeners were greater than the concentrations observed in half or more of the milk samples.

The decline in milk PCB levels among the Mohawk mothers according to when they gave birth parallels a secular trend in local fish consumption, i.e., Mohawk women who participated after 1989 were less likely to eat local fish, especially during pregnancy, than were mothers who gave birth earlier (9). No such trend was apparent among the controls. It is unlikely that changes in fish PCB levels contributed to the reduction in milk PCB concentrations, since, in contrast to the fish consumption rates, the levels of PCBs in the fish remained relatively constant over time.

The Mohawk mothers who participated in 1986–1989 were also less likely to remove the skin or trim the fat from any fish they did eat before they cooked it (33 percent compared with 95 percent for mothers who gave birth in 1990 or later). These methods of preparation help reduce the contaminant levels of many species of fish before they are consumed (25). Such changes in fish consumption patterns are probably in response to the local health advisories. As a result, even those Mohawk women who ate local fish in recent years may have reduced their exposures to levels that are insufficient to cause a detectable increase in body burden when compared with the general population. The finding that most of the controls also had detectable levels of PCBs in their breast milk probably reflects the facts that PCBs are ubiquitous pollutants and that even commercially available meats and other foodstuffs are contaminated (26).

The lack of an association between local fish consumption and breast milk PCB concentrations after 1989 has implications for research that relies on fish consumption as a surrogate measure of PCB internal dose or body burden (27, 28). The data suggest that validation studies are necessary, especially when fish consumption rates are relatively low or when the fish are commonly prepared in ways that reduce their contaminant burden.

It is unlikely that the declines in fish consumption rates and breast milk PCB levels among the Mohawks by year of the index child’s birth reflect a selection bias, since the same procedures and staff were used to recruit participants throughout the study period and because the staff were unaware of the participant’s exposure status and PCB body burden at the time of recruitment. Some differences were observed in age and education among the Mohawk participants over time, but controlling for them did not alter the results. The Mohawk women were more likely than the comparison mothers to participate in the study, perhaps because they were more aware of and concerned about fish contamination. These differences in awareness and concern may result, in turn, in differences in recall and reporting between the Mohawk and comparison groups. The findings that the fish consumption rates and the breast milk PCB levels of the Mohawk mothers declined over time while both variables remained constant among the controls, however, help to validate the dietary histories.

Declines in the PCB milk levels over time are consistent with the results of other cross-sectional studies. For example, the PCB levels detected in this study are approximately 50 percent lower than those previously reported by Bush et al. (24) in their 1977 investigation of 40 women recruited as walk-in cases from maternity facilities in Albany, Rochester, and Oswego, New York. Similar declines in milk PCB concentrations over the past 10–20 years have been reported in Canada (29), Sweden (30), and Norway (31). This decrease in human body burden parallels declines in environmental compartments and may be attributed to the ban on PCB production in most industrialized countries and the imposition of stricter regulations concerning their use and disposal (32).

The health risks to the infant of pre- or postnatal exposure to PCBs at the level observed in this study are controversial (33). For instance, some studies have reported a negative association between maternal exposure to PCBs and birth weight (34, 35), whereas others have not (36, 37). No differences in mean birth weight were observed between the Mohawks and controls in our study, but our power to detect a difference of 200 g (the magnitude of the effect cited by Fein et al. (34)) was only 0.133, given the small sample size.

Caution must be exercised regarding health implications, and the possibility of subtle, long-term effects such as disruption of the endocrine system (38) cannot be ruled out. However, since the period of exposure is relatively short, nursing is estimated by the World Health Organization to account for less than 5 percent...
of the total lifetime intake of these chemicals (39). As the natural foodstuff for newborn and small infants, breast milk also has well-recognized immunologic, psychologic, nutritional, and economic benefits (40). The World Health Organization, the American Academy of Pediatrics, and other responsible bodies have concluded that these benefits outweigh the risks from chemical contaminants at the low levels found in this and most other studies (41).

ACKNOWLEDGMENTS

Funding for this project was provided in part by the Agency for Toxic Substances and Disease Registry (grant H75/ATH290026) and the National Institute of Environmental Health Sciences (grant P42 ES04913). The authors express their appreciation to the following persons for their past and present help: Ann Casey, Susan Dzurica, Patricia Roundpoint, Kenneth Jock, Trudy Lauzon, F. Henry Lickers, Judith Quinn, and Bao-zhu Yang.

REFERENCES