



## The association between local fish consumption and DDE, mirex, and HCB concentrations in the breast milk of Mohawk women at Akwesasne

EDWARD F. FITZGERALD,<sup>a</sup> SYNI-AN HWANG,<sup>a</sup> DEBRA A. DERES,<sup>b</sup> BRIAN BUSH,<sup>c</sup> KATSI COOK<sup>d</sup> AND PRISCILLA WORSWICK<sup>d</sup>

<sup>a</sup>Bureau of Environmental and Occupational Epidemiology, New York State Department of Health, Troy, New York

<sup>b</sup>Bureau of Occupational Health, New York State Department of Health, Troy, New York

<sup>c</sup>Laboratory of Organic Analytical Chemistry, Wadsworth Center, New York State Department of Health, Albany, New York

<sup>d</sup>Akwesasne Task Force on the Environment, Mohawk Nation at Akwesasne, New York

A study was conducted to assess the extent to which the consumption of local fish contaminated with *p,p'*-dichlorodiphenyl dichloroethylene (*p,p'*-DDE), mirex, and hexachlorobenzene (HCB) has impacted the concentrations of these compounds in the milk of nursing Mohawk women residing along the St. Lawrence River. From 1986 to 1992, 97 Mohawk women were interviewed, and each donated a one-time sample of at least 50 ml of breast milk. The comparison population consisted of 154 Caucasians from other rural areas in New York State. After adjustment for potential confounders, Mohawk mothers who gave birth from 1986 to 1990 had significantly higher geometric mean *p,p'*-DDE milk concentrations than did the control group, but no significant differences were observed from 1991 to 1992. In contrast, mirex was significantly elevated among the Mohawks throughout the study period, while HCB showed no difference at any point. Mohawk women with the greatest estimated cumulative lifetime exposure to *p,p'*-DDE from local fish consumption had a significantly higher geometric mean milk level of that compound relative to control women, but no differences in mirex or HCB concentrations in breast milk by local fish consumption were found. The reduction in breast milk *p,p'*-DDE concentrations among the Mohawk women from 1986 to 1990 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. Elevations in the concentrations of mirex in the breast milk of the Mohawks are consistent with the fact that it is a common contaminant in the region and throughout the Lake Ontario–St. Lawrence River Basin. *Journal of Exposure Analysis and Environmental Epidemiology* (2001) **11**, 381–388.

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### Introduction

Dichlorodiphenyl trichloroethane (DDT) is an organochlorine pesticide that was widely used in the USA prior to 1972 to control insects on agricultural crops and mosquitoes and other insects that transmit malaria and vector-borne diseases (ATSDR, 2001a). In mammals, it is metabolized by the liver into *p,p'*-dichlorodiphenyl dichloroethylene (*p,p'*-DDE). Mirex was used as an industrial flame retardant and as an insecticide until 1977 (ATSDR, 1995). Hexachlorobenzene (HCB) is a by-product of the manufacture of many chlorinated chemicals, and was used as a fungicide until 1984 (ATSDR, 2001b). All three are persistent, lipophilic compounds that bioaccumulate and

biomagnify in the food chain (Evans et al., 1991; Niethammer et al., 1984; Hebert et al., 1994). Ingestion of small amounts of these contaminants in the diet (especially meat, fish, and poultry) is the major route of exposure for the general population (ATSDR, 1995, 2001a,b). Groups who consume larger amounts of fish from contaminated waterways such as the Great Lakes may be at higher risk of such exposure (Hanrahan et al., 1999). These groups include Native American communities whose tradition and culture emphasise local fish consumption. However, very few studies have directly assessed body burdens of organochlorine pesticides and fish consumption among Native peoples in the USA, especially those who live on reservations and reside outside of Alaska (West, 1992). The purpose of this article is to assess the extent to which the consumption of local fish contaminated with DDE, mirex, and HCB has impacted the breast milk concentrations of these compounds among 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 ft

1. Abbreviations: *p,p'*-DDE, *p,p'*-dichlorodiphenyl dichloroethylene; HCB, hexachlorobenzene; ppm, parts per million; ppb, parts per billion

2. Address all correspondence to: Dr. Edward F. Fitzgerald, Bureau of Environmental and Occupational Epidemiology, New York State Department of Health, Flanigan Square, 547 River Street, Room 200, Troy, NY 12180. Tel.: +1-518-402-7960. Fax: +1-518-402-7959. E-mail: eff02@health.state.ny.us

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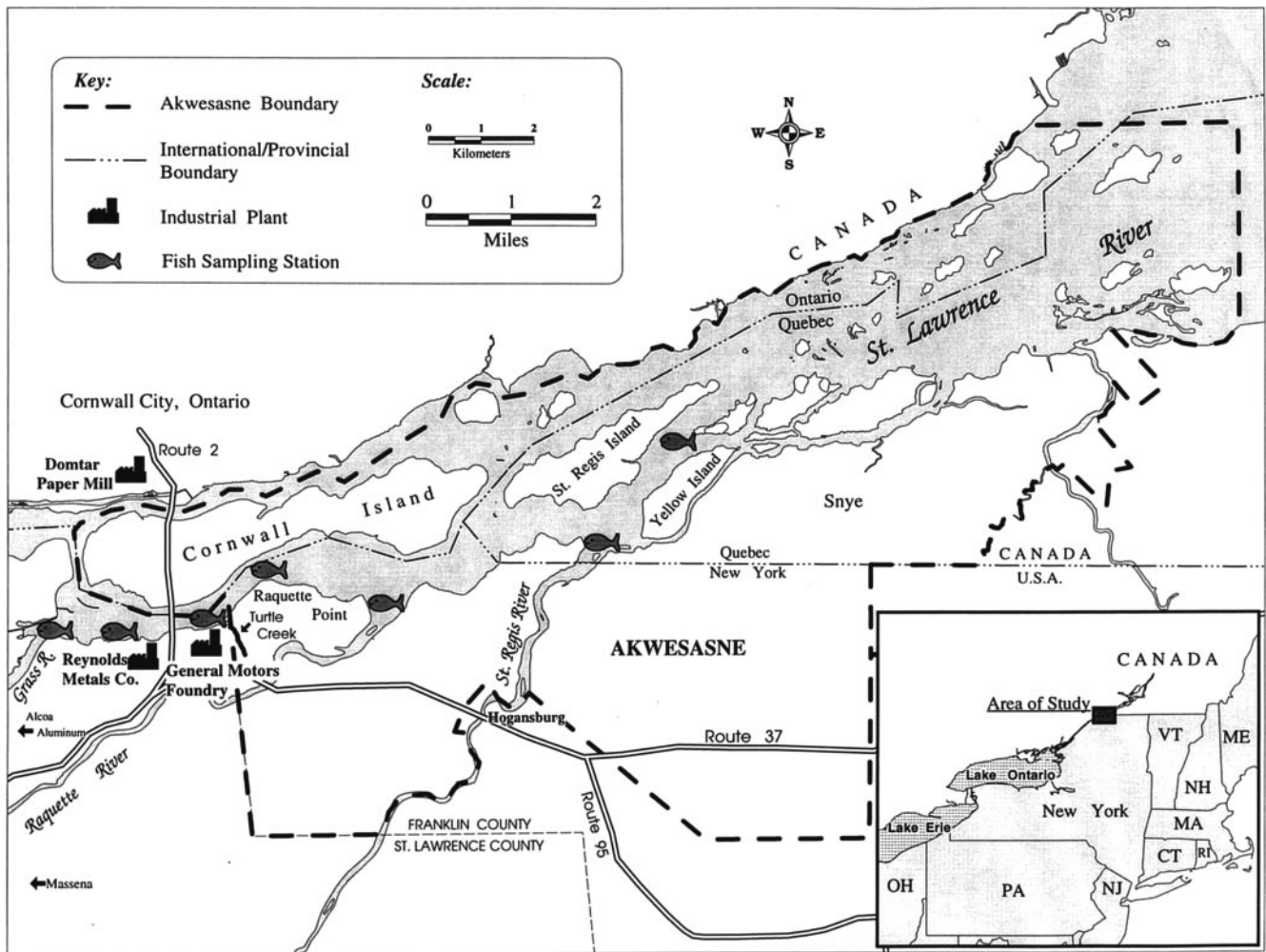


Figure 1. Map of the Mohawk Nation at Akwesasne.

to the west of Akwesasne is the General Motors — Central Foundry Division Superfund hazardous waste site. Polychlorinated biphenyls (PCBs) migrating from this site have contaminated local fish, and levels up to 81 parts per million (ppm) have been detected in brown bullhead (Sloan and Jock, 1990). Concentrations of organochlorine pesticides in local fish are generally lower than PCBs, but they have been detected in most species consumed by the Mohawks. For example, channel catfish had DDE levels up to 3.2 ppm and mirex levels up to 0.7 ppm. These chemicals probably reflect general Lake Ontario–St. Lawrence River exposures more than local point sources such as the General Motors facility. However, the pollution is a major concern of the Mohawk people, since their tradition and culture emphasize the interdependence of man and the environment and because many residents formerly depended on local fish, waterfowl, and mammals for food, and this concern led to the present investigation.

An earlier article explored the association between local fish consumption and concentrations of total PCB and selected PCB congeners in the breast milk of 97 nursing Mohawk women from 1986 through 1992 and a rural comparison group of nursing Caucasians (Fitzgerald et al., 1998). That report noted a geometric mean milk total PCB level of 0.602 ppm (fat-basis) after adjustment for potential confounders among Mohawk women who gave birth from 1986 to 1989. In comparison, the geometric mean for the control group was 0.375 ppm ( $p=0.009$ ). These Mohawk women also had significantly higher levels of nine congeners. Beginning in 1990, however, there were no significant differences between the Mohawk and comparison women. Estimated cumulative lifetime exposure to PCBs from local fish consumption was significantly related to milk PCB level only among those Mohawk women who gave birth from 1986 to 1989. The reduction in Mohawk breast milk PCB concentrations paralleled a corresponding

decrease in their local fish consumption, i.e., from an average of 8.5 meals during pregnancy from 1986 to 1989, 3.3 meals during pregnancy in 1990, and only 1.5 meals during pregnancy from 1991 to 1992. This decline may be the result of the advisories that have been issued over the past decade against the consumption of local fish by pregnant and nursing women.

To determine whether the pattern of results for organochlorine pesticides is similar to that observed for PCBs, this article relates local fish consumption to breast milk concentrations of *p,p'*-DDE, mirex, and HCB in the same populations of Mohawk and comparison women. Breast milk was chosen as the sampling fluid since monitoring the levels of chemical contaminants such as organochlorine pesticides 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 (Sim and McNeil, 1992). 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 University at Albany, State University of New York.

## Methods

### Interview

Detailed descriptions of ascertainment, interview, and dietary assessment are published elsewhere (Fitzgerald et al., 1995). 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. Ninety-three women (78.2%) of all such women identified 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 food-stuffs, emphasizing local species of fish and game. The specific method combined a food frequency with a limited dietary history to estimate usual intake (Willett, 1990). 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 Counties and gave birth during the same period. Like Akwesasne, these counties are primarily rural in character. According to studies performed by the New York State Department of Environmental Conservation, fish in both regions had little or no levels of organochlorine pesticides during the study period (NYS-DEC, 1989). The mothers were recruited through the local Women and Infant Care clinics and were not selected based

on their fish consumption habits. One hundred and fifty-four women (52.4%) of those identified participated. All were Caucasian. The comparison women were slightly older than the Mohawk women (means of 26.4 and 24.9 years, respectively), but, in general, the two groups were similar. Detailed comparisons with the Mohawk mothers regarding other sociodemographic factors, physical characteristics, reproductive histories, and lifestyle variables are published elsewhere (Fitzgerald et al., 1995).

### Breast Milk Analysis

After the interview was completed, project personnel instructed the mothers in the use of the Marshall 900 CP Kaneson breast pump/infant nurser. They were asked to provide a one-time sample of at least 50 ml of breast milk 1 month postpartum. The chemical analysis was performed using methods (including quality assurance and control, accuracy, and precision) published elsewhere (Bush et al., 1983a). Briefly, the chemical contaminants were extracted from the breast milk samples using ethanol and hexane, then transferred to a Florisil clean-up column containing 10 g 4% deactivated Florisil topped with 1 cm anhydrous sodium sulfate. The eluate was analyzed with a Hewlett-Packard 5890 gas chromatograph using a phenylmethyloctadecyl silyl-bonded fused-silica capillary column and an electron-capture detector. A computerized data management system reported each *p,p'*-DDE, mirex, and HCB-containing zone or peak.

The method detection limits (MDL) for *p,p'*-DDE, mirex, and HCB were, respectively, 0.30, 0.02, and 0.06 parts per billion (ppb) (whole milk), and 12, 1, and 4 ppb (fat basis, assuming a fat content of 2.5%). Of the 251 breast milk samples analyzed, 97% had a *p,p'*-DDE concentration that exceeded the MDL. Similarly, 73% and 84% of the samples had concentrations of mirex and of HCB, respectively, that exceeded the MDL. Concentrations quantified by the laboratory but below the MDL were included as the actual reported value in the statistical analysis. This decision reflects the fact that many chemists and statisticians believe that a reported result, even if it is below the "criteria for detection," remains the best available estimate of the true value, and is preferable to assigning an arbitrary constant such as one-half the MDL (ASTM, 1989). Relatively few milk samples had a zero concentration (0.2% for *p,p'*-DDE, 8% for HCB, and 9% for mirex).

### Dietary Exposure Assessment

Each Mohawk woman's exposure to *p,p'*-DDE, mirex, and HCB through the consumption of five species 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 more than 1 year before the index pregnancy) for a particular species by

the contaminant 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, *p,p'*-DDE, mirex, and HCB concentrations for that species were averaged across all seven locations. Detailed discussions of the fish sampling scheme and fish contaminant levels are given elsewhere (Fitzgerald et al., 1995 and Sloan and Jock, 1990).

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 first were evaluated separately and then were combined to estimate each woman's cumulative lifetime exposure. However, since maternal recall of diet is likely to be imprecise and because the mean contaminant level of a composite sample may not be typical of the individual fish that a woman consumed, exposure was categorized into three ordinal levels for most statistical analyses. These included: (1) "none" for those Mohawks who reported never eating local fish, and (2) "low" or (3) "high" for all others by dividing along the median value.

*Statistical Analysis*

Multiple linear regression was used to test for the effect of fish consumption after evaluating the effect of 10 background variables (maternal age, education, alcohol consumption, cigarette smoking, antibiotic use, duration of breast-feeding (current and previous), parity, body mass index, and occupation) that could potentially confound any association between exposure and DDE, mirex, and HCB in breast milk. These variables were selected because previous studies suggest that they may be correlates of organochlorine pesticides (Albers et al., 1996; Dewailly et al., 1996; Harris et al., 1999; Nakagawa et al., 1999). Separate models were constructed for *p,p'*-

DDE, mirex, and HCB using backward elimination to delete nonsignificant ( $p > 0.10$ ) background variables one at a time. Exposure from local fish consumption during, 1 year before, and more than 1 year before the index pregnancy, as well as cumulative lifetime exposure, were then added individually to these models to estimate their effects after adjustment for all remaining background variables. The general linear model (GLM) procedure of Statistical Analysis System (SAS) was used, which calculated least square means for every category of fish consumption after centering each covariate around its grand mean (SAS, 1985). In addition to fish consumption, residential location at Akwesasne, defined according to six locally recognized regions, was examined as a potential environmental risk factor.

To determine if there were changes in breast milk contaminant concentrations during the course of the study period, the year of the index child's birth also was entered as a variable in the regression models. The number of births per year was too small to examine each year individually, so they were grouped into three periods: 1986 to 1989, 1990, and 1991 to 1992. The use of three categories permitted a test for linear trend, with the ranges defined in a manner that most balanced the number per group and without prior knowledge of the milk contaminant concentrations. Interactions between time period and risk factors such as exposure from local fish consumption also were assessed by testing their cross-products.

The milk *p,p'*-DDE, mirex, and HCB 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 since the concentration of these lipophilic compounds in whole milk is very dependent on the fat content of the milk (Jensen and Slorach, 1991). These fat-adjusted values were then transformed using natural logarithms because their distributions were lognor-

**Table 1.** Adjusted<sup>a,b,c</sup> geometric mean breast milk pesticide concentration (ppb — fat basis) by time period — Mohawk and control.

| Pesticide        | Time period |           |         |           |        |           |         |           |           |           |         |           |
|------------------|-------------|-----------|---------|-----------|--------|-----------|---------|-----------|-----------|-----------|---------|-----------|
|                  | 1986–1989   |           |         |           | 1990   |           |         |           | 1991–1992 |           |         |           |
|                  | Mohawk      |           | Control |           | Mohawk |           | Control |           | Mohawk    |           | Control |           |
|                  | N           | $\bar{X}$ | N       | $\bar{X}$ | N      | $\bar{X}$ | N       | $\bar{X}$ | N         | $\bar{X}$ | N       | $\bar{X}$ |
| <i>p,p'</i> -DDE | 19          | 420**     | 52      | 198       | 38     | 198**     | 57      | 113       | 40        | 183       | 45      | 190       |
| Mirex            | 19          | 2.6*      | 52      | 1.2       | 38     | 2.3***    | 57      | 1.0       | 40        | 3.0       | 45**    | 1.4       |
| HCB              | 19          | 1.8       | 52      | 1.7       | 38     | 8.7       | 57      | 11.0      | 40        | 12.5      | 45      | 14.4      |

\* $p < 0.10$  for Mohawk vs. control within time period.

\*\* $p < 0.05$  for Mohawk vs. control within time period.

\*\*\* $p < 0.01$  for Mohawk vs. control within time period.

<sup>a</sup>*p,p'*-DDE adjusted for maternal age and previous breast feeding.

<sup>b</sup>Mirex adjusted for maternal height.

<sup>c</sup>HCB adjusted for previous breast feeding and antibiotic use before pregnancy.

**Table 2.** Adjusted<sup>a,b,c</sup> geometric mean breast milk pesticide concentration (ppb — fat basis) by estimated lifetime exposure from local fish consumption among Mohawks, with controls.

| Fish consumption        | p,p'-DDE |           | Mirex |           | HCB |           |
|-------------------------|----------|-----------|-------|-----------|-----|-----------|
|                         | N        | $\bar{X}$ | N     | $\bar{X}$ | N   | $\bar{X}$ |
| Controls                | 154      | 159       | 154   | 1.2       | 154 | 5.8       |
| Mohawks — none          | 17       | 213       | 17    | 2.4       | 20  | 7.3       |
| Mohawks — low exposure  | 40       | 191       | 40    | 2.3       | 39  | 6.5       |
| Mohawks — high exposure | 40       | 260       | 40    | 3.1       | 38  | 8.4       |

$F(3, 243)=1.69, p=0.170$  for p,p'-DDE.

$F(3, 246)=5.85, p<0.001$  for mirex.

$F(3, 245)=0.52, p=0.671$  for HCB.

<sup>a</sup>p,p'-DDE adjusted for previous breast feeding and maternal age.

<sup>b</sup>Mirex adjusted for maternal height.

<sup>c</sup>HCB adjusted for previous breast feeding and antibiotic use pre-pregnancy.

mal in shape. The results are presented as geometric means by taking the antilog of the means of the log-transformed values after adjustment for potential confounders.

## Results

Differences between the Mohawk and control women in their geometric mean milk pesticide concentrations were examined by time period (Table 1). After adjusting for maternal age and previous breast-feeding, Mohawk mothers who gave birth from 1986 to 1990 had a significantly elevated mean concentrations of p,p'-DDE compared to the controls, but no difference was evident for those who gave birth in 1991 to 1992. Mohawk women also had a significantly higher mean mirex concentration after controlling for maternal height than the controls in every year, whereas for HCB, there was no difference for any year after adjusting for previous breast-feeding and antibiotic use before pregnancy. Regarding time trends, the Mohawks evidenced a monotonic decline in p,p'-DDE ( $p=0.020$  for linear trend), whereas the comparison group did not. Neither group varied in the level of mirex in breast milk over time, while both groups showed significant monotonic increases in their geometric means for HCB in breast milk (test for linear trend  $p<0.001$  for Mohawks and controls).

Table 2 gives geometric mean milk levels by estimated cumulative lifetime exposure to each contaminant from local fish consumption among the Mohawks, after adjustment for relevant background variables. The controls are included to provide an external comparison and to maximize power by increasing sample size. Only mirex showed a significant overall difference among the four groups. This difference resulted from the finding that every Mohawk group, regardless of its lifetime dietary exposure, had a significantly elevated adjusted geometric mean concentration of mirex in breast milk relative to the comparison

group. Pairwise contrasts also showed that the Mohawk women who had the highest cumulative lifetime exposure to DDE from fish consumption had a greater adjusted geometric mean milk p,p'-DDE level than the controls ( $p=0.032$ ). No significant pairwise differences were observed for HCB. The results were similar for exposure from local fish consumption during, 1 year before, and more than 1 year before the index pregnancy, although the strength of the association was generally less than that for cumulative lifetime exposure (data not shown). The interaction between fish consumption and time period was not significant for any pesticide.

The only significant finding regarding residential location was for Cornwall Island residence and concentration of mirex in breast milk. That is, women who lived on Cornwall Island for at least one of the past 10 years had a higher geometric mean level of mirex in breast milk than other Mohawk mothers (4.0 and 2.1 ppb, respectively,  $p=0.022$ ), and this difference persisted after adjusting for local fish consumption. Mirex concentrations in breast milk also rose significantly with increasing duration of residence on Cornwall Island (Table 3). There was no significant interaction between Cornwall Island residence and time period, nor was there a significant difference in mirex levels

**Table 3.** Adjusted<sup>a</sup> geometric mean for breast milk mirex concentration (ppb — fat basis) by duration of residence on Cornwall Island among Mohawks, with controls.

| Duration of residence on Cornwall Island | N   | $\bar{X}$ |
|--|-----|-----------|
| Controls                                 | 154 | 1.2       |
| Mohawks — 0 years                        | 68  | 2.2       |
| Mohawks — 1 to 5 years                   | 14  | 3.2       |
| Mohawks — 6+ years                       | 15  | 4.7       |

$F(3, 246)=6.91, p<0.001$ .

$p<0.001$  for test of linear trend.

<sup>a</sup>Adjusted for maternal height.

in breast milk according to whether the mother was a current or former resident at the time of interview.

## Discussion

Caution must be exercised when comparing milk contaminant levels across studies, given differences in analytical methods, time periods, and populations. In general, however, both the Mohawks and controls had milk concentrations of  $p,p'$ -DDE and HCB that are in the range typically observed in most studies of the USA and other industrialized countries (Jensen, 1991). There are few studies of mirex available for comparison. Bush et al. (1983b), however, did find mirex levels similar to the Mohawks on a whole milk basis in their study of maternity clinic patients, especially among women from the cities of Rochester and Oswego, NY, which border Lake Ontario. Much higher concentrations of all three organochlorines have been observed among Inuit women in Arctic Quebec (Dewailly et al., 1993). 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 (Kinloch et al., 1992).

The findings for milk  $p,p'$ -DDE showed that levels among the Mohawks were highest from 1986 to 1989, with a geometric mean for women who gave birth during that period twice that of the controls. The Mohawk concentrations decreased significantly over time while the controls remained relatively constant; consequently, by 1991 there was no difference between the two groups. These results paralleled those found for milk PCB levels in the same populations (Fitzgerald et al., 1998). Like PCB, this decline in milk  $p,p'$ -DDE over time may be the result of the decrease in local fish consumption by the Mohawk mothers. Consistent with this hypothesis are the facts that the Mohawk women with the higher cumulative lifetime exposure to  $p,p'$ -DDE from local fish consumption had a significantly greater adjusted geometric mean than the controls, and that the estimated average daily dose of 1.3 ng/kg body weight of  $p,p'$ -DDE from local fish consumption more than 1 year before the pregnancy was second only to PCB among the chemicals examined. Other studies have also found positive correlations between fish consumption and levels of  $p,p'$ -DDE in breast milk (Noren, 1983; Newsome et al., 1995). The decrease in milk  $p,p'$ -DDE concentrations over time is consistent with trends reported for the past 10 to 20 years in Canada (Craan and Haines, 1998), Germany (Schade and Heinzow, 1998), and Sweden (Vaz et al., 1993). This general decline in body burden is probably the result of the ban on the use of DDT in industrialized countries, although it is still employed in agriculture and for vector control in some tropical countries (ATSDR, 2001a).

In addition to local fish consumption, previous breast-feeding and maternal age were related to milk  $p,p'$ -DDE — women who had nursed their previous children had lower milk concentrations, and older mothers had higher levels. Previous lactations are likely to deplete the adipose stores, resulting in lower levels in the milk fat (Jensen and Slorach, 1991). The increase with age probably reflects the greater cumulative lifetime exposure of older women to  $p,p'$ -DDE and the long biological half-life of this compound (Morgan and Roan, 1971). These findings are similar to the results of other studies (Dewailly et al., 1996; Harris et al., 1999; Nakagawa et al., 1999).

In contrast to  $p,p'$ -DDE, the concentrations of mirex in the breast milk of the Mohawks remained relatively constant over the study period, with average levels among the Mohawk mothers between 2.3 and 3.0 ppb, or approximately twice the range of 1.0 to 1.6 ppb for the controls regardless of when the index child was born. This difference between the two groups does not appear to be due to local fish consumption, since even Mohawk women who never ate local fish had a significantly greater adjusted geometric mean than did the controls. In addition, concentrations of mirex in the breast milk of the Mohawks remained high despite their decreased fish consumption over time. Mirex also showed an association with duration of Cornwall Island residence, with women who had lived on the Island for six or more of the past 10 years having a twofold elevation in their adjusted geometric mean concentration of mirex in breast milk compared to Mohawk mothers who had not lived there (4.7 vs. 2.2 ppb, respectively).

The general elevation in the concentration of mirex in the breast milk of the Mohawks relative to the comparison group is not surprising, given the contamination of Lake Ontario and the St. Lawrence River with mirex by Hooker Chemical (Kaiser, 1978). The apparent lack of a relationship with local fish consumption, however, was unexpected. The results suggest an ongoing exposure, especially among Cornwall Island residents. Further environmental sampling is necessary to identify likely pathways.

Among the background characteristics, only maternal height was significantly associated with concentrations of mirex in breast milk in the multiple regression analysis. Taller mothers had lower concentrations. One study has shown an inverse relationship between organochlorines in human milk and body mass index (Albers et al., 1996), but none have reported such an association with height. It may be a chance finding.

Breast milk levels of HCB were negatively associated with previous breast-feeding and positively related to antibiotic use before pregnancy. The association with antibiotic use may indicate that either antibiotics or the underlying infections for which they were prescribed affect the distribution, biotransformation, or excretion of HCB. Unlike the other contaminants, however, average concen-

trations of HCB in breast milk did not differ between the Mohawks and controls at any time period, and this pesticide was not related to any exposure variable. The lack of an association with local fish consumption is consistent with the low levels of HCB detected in fish samples at Akwesasne (generally less than 0.001 ppm). HCB has been detected at higher concentrations in the fat of snapping turtles and common mergansers at Akwesasne (Skinner, 1992), but the lack of consumption of these species by the Mohawk mothers in the study precluded such an exposure.

The significant increase over time in the geometric mean milk concentrations of HCB for both the Mohawks and controls was unexpected. It is inconsistent with other studies that suggest a worldwide decrease in breast milk levels of this compound (Vaz et al., 1993; Craan and Haines, 1998; Schade and Heinzow, 1998). It more likely reflects the fact that levels were low among women who participated in 1986 through 1989 than it does concentrations were high among mothers who gave birth from 1990 to 1992. For example, in a 1992 survey of Canadian women, Newsome et al. (1995) reported a median level of HCB in breast milk of 13 ppb (fat basis), and in a 1991–1993 study of New York State anglers and their wives, Kostyniak et al. (1999) found a mean milk concentration of 9.6 ppb (fat basis). Both values closely agree with the geometric means of 8.7 to 14.4 ppb (fat basis) observed in the current study from 1990 to 1992, but are an order of magnitude greater than the values of 1.8 and 1.7 ppb found for Mohawks and controls, respectively, from 1986 to 1989. The low levels in the early period may be an artifact or a chance finding.

Caution must be exercised regarding health implications, and the possibility of subtle, long-term effects such as disruption of the endocrine system (Birbaum, 1994) cannot be ruled out. The greater sensitivity of the infant to environmental insult is also a consideration (Bearer, 1995). However, since the period of exposure is relatively short, nursing is estimated by the World Health Organization to account for less than 5% of the total lifetime intake of these chemicals (Grandjean et al., 1988). As the natural foodstuff for newborn and small infants, breast milk also has well-recognized immunologic, psychologic, nutritional, and economic benefits (Hofvander, 1991). 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 (Rogan, 1996).

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