

Low Birth Weight and Residential Proximity to PCB-Contaminated Waste Sites

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Previous investigations have shown that women exposed to polychlorinated biphenyls (PCBs) are at increased risk of giving birth to an infant with low birth weight (< 2,500 g), and that this relationship is stronger for male than for female infants. We have tested the hypothesis that residents in a zip code that contains a PCB hazardous waste site or abuts a body of water contaminated with PCBs are at increased risk of giving birth to a low-birth-weight baby. We used the birth registry of the New York State Vital Statistics to identify all births between 1994 and 2000 in New York State except for New York City. This registry provides information on the infant, mother, and father together with the zip code of the mother's residence. The 865 state Superfund sites, the 86 National Priority List sites, and the six Areas of Concern in New York were characterized regarding whether or not they contain PCBs as a major contaminant. We identified 187 zip codes containing or abutting PCB-contaminated sites, and these zip codes were the residences of 24.5% of the 945,077 births. The birth weight in the PCB zip codes was on average 21.6 g less than in other zip codes ($p < 0.001$). Because there are many other risk factors for low birth weight, we have adjusted for these using a logistic regression model for these confounders. After adjusting for sex of the infant, mother's age, race, weight, height, education, income, marital status, and smoking, there was still a statistically significant 6% increased risk of giving birth to a male infant of low birth weight. These observations support the hypothesis that living in a zip code near a PCB-contaminated site poses a risk of exposure and giving birth to an infant of low birth weight. *Key words:* birth registry, confounders, female, inhalation, male, very low birth weight. *Environ Health Perspect* 111:1352–1357 (2003). doi:10.1289/ehp.6053 available via <http://dx.doi.org/> [Online 18 March 2003]

Low birth weight is an important predictor of infant morbidity and mortality. About 75% of early neonatal mortality in the United States and Canada is associated with low birth weight. This condition is also related to increased infant and childhood morbidity because low-birth-weight infants are 5–10 times as likely to die in the first year of life (Kramer 1987).

Recent studies have shown that low birth weight increases risk of several chronic adult diseases, including cardiovascular diseases (Barker 1999; Rich-Edwards et al. 1997), hypertension (Law et al. 2001), renal failure (Lackland et al. 2000), and type 2 diabetes (Forsen et al. 2000; Rich-Edwards et al. 1999).

Conventionally, low-birth-weight infants are defined as those born weighing < 2,500 g. This low weight could be caused by shortened gestation (< 37 weeks) and/or inadequate fetal growth. Infants born weighing < 1,500 g are considered very low-birth-weight infants. Very low birth weight is usually a reflection of a more serious problem with pregnancy and thus has a different etiology (Kramer 1987), although there are some common risk factors. Several factors have been proven to be associated with increased risk of giving birth to low-birth-weight babies: mother's age, race, nutritional status and weight before pregnancy, socioeconomic status and educational level, and mother's smoking status. Premature birth is by far the most common cause of low

birth weight. Birth weight and gestational age are usually positively correlated (Kramer 1987). African-American women are twice as likely as white women to deliver a low-birth-weight infant (Goldenberg et al. 1997; Luke et al. 1993). Lack of education and low-income status are also associated with low birth weight (Bruce and Tchabo 1989; Olsen and Frische 1994; Williams 1998). The effect of maternal age on risk of having a low-birth-weight baby is U-shaped: Women at the youngest (≤ 18 years) and oldest (> 39 years old) ends of the child-bearing age spectrum are at greatest risk of having a low-birth-weight infant (Abel et al. 2002; Aldous and Edmonson 1993; Goldenberg et al. 1997; Herceg et al. 1994). Cigarette smoking affects birth weight by causing intrauterine growth retardation (Kramer 1987). Female infants are more likely to be of low birth weight than are male infants (Herceg et al. 1994; Goldenberg et al. 1997). Other risk factors include poor gestational nutrition (Bruce and Tchabo 1989; Haste et al. 1990), primiparity (Herceg et al. 1994), single motherhood (Holt et al. 1997), and mother's short stature (Goldenberg et al. 1997; Herceg et al. 1994).

Exposure to environmental contaminants also contributes to the increased risk of having a low-birth-weight baby. Numerous studies that looked at the relationship between exposure to environmental hazards and reproductive outcomes used residence in proximity to hazardous waste landfill sites as a surrogate

for exposure. A statistically significant association between the mother's residence near hazardous waste sites and risk of having low-birth-weight births was found in some (Berry and Bove 1997; Elliott et al. 2001; Goldberg et al. 1995; Goldman et al. 1985; Vianna and Polan 1984) but not all studies (Baker et al. 1988; Kharazi et al. 1997; Shaw et al. 1992). Most of these studies did not consider the chemical composition of the waste within the sites. Because most waste sites contain multiple chemical components, it is usually not possible to determine which chemicals are responsible for the observed health effects.

A key to understanding which contaminant(s) might cause these effects comes from the observation that low birth weight occurs more commonly among women who consume large amounts of fish contaminated with organochlorine compounds, including polychlorinated biphenyls (PCBs), persistent pesticides, and dioxins/furans (Fein et al. 1984; Rylander et al. 1998, 2000; Vartiainen et al. 1998). Fein et al. (1984) noted that PCB-exposed infants averaged 190 g less in weight and 4.9 days less in gestational age, and Taylor et al. (1984, 1989) also reported an increase of low-birth-weight babies and shortened gestational age among women occupationally exposed to PCBs. Rylander et al. (1995, 1996) and Hertz-Picciotto et al. (2000) found that in PCB-exposed populations, low birth weight is more pronounced in male infants than in female infants. Vartiainen et al. (1998) reported that low birth weight was more pronounced in boys than in girls prenatally exposed to dioxins and furans.

We have examined the effect of maternal residence in a zip code that contains or abuts a PCB-contaminated site on the birth weight of the baby. We used birth registry data without personal identifiers from the New York State Vital Statistics (New York State Department of Health 1994–2000) to test the hypothesis that living in a zip code that contains or abuts a PCB-contaminated site is a risk factor for

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giving birth to a low-/very low-birth-weight infant. Although zip code of residence is a very inexact indicator of exposure, some studies have shown that residential proximity to contaminated sites increases risk of several different diseases (Carpenter et al. 2001; Elliott et al. 2001; Gilbertson and Brophy 2001).

Materials and Methods

The New York State Department of Environmental Conservation has identified 865 hazardous waste sites in the state, and for each lists the chemicals of major concern and the geographical location, including zip code, census tract, and geographic longitude and latitude. Additional information is available for those waste sites listed on the U.S. Environmental Protection Agency (2003) National Priority List website. After scanning the list of the chemicals under each of the waste sites for the key words PCBs, PCB, Aroclor, and Pyranol, we have identified 128 zip codes in New York containing PCB-contaminated sites. In this study we excluded New York City, which reduced the PCB-contaminated zip codes to 117. We added all zip codes that directly abut bodies of water known to be contaminated with PCBs, including a major portion of the Hudson River and the six Areas of Concern in New York State (areas along the Great Lakes that have exceptional levels of contamination), as identified by the International Joint Commission. These are the Niagara River, Buffalo River, 18 Mile Creek, Oswego River, the Rochester Embayment and Genesee River, and the St. Lawrence River near Massena (Carpenter et al. 2001). The final number of zip codes identified to contain or abut PCB-contaminated sites was 187. Of these, 78 abut the Hudson River; the others were distributed throughout the state.

Data on outcomes and potential confounders/effect modifiers were derived from birth certificates collected and stored in New York State Department of Health Vital Statistics files for the years 1994–2000. To estimate socioeconomic status, we used the estimated mean per capita income for 1997 (midpoint between the beginning and the end of the study) in the zip code of the mother's residence. This information was obtained from the New York State Department of Health, which in turn uses data produced by Claritas Inc. (San Diego, CA).

Inclusion criteria. We analyzed all births recorded in New York State hospitals from years 1994 through 2000. There were 1,871,594 births recorded during this time span. We excluded all births to New York City residents (885,685) and to out-of-state residents (3,324), and all plural births (35,144). Observations where data on baby's sex were missing and births where the recorded baby's birth weight was < 500 g or > 7,500 g (these

values must be a result of miscoding) were also excluded (2,364). These exclusions produced a final sample size of 945,077 births.

Statistical methods. We performed bivariate analysis to look at the distribution of potential confounders between exposed (defined as residence in a PCB zip code) and unexposed groups (defined as residence in a zip code that doesn't have PCBs). Then two separate multiple logistic models were fitted for two outcomes: low birth weight and very low birth weight. Low birth weight was defined as infants weighing between 1,500 and 2,500 g at birth, and very low birth weight was defined as infants weighing < 1,500 g. Finally, the model for probability of having a low-birth-weight baby was stratified by sex of the baby.

Potential confounders and effect modifiers. Variables that have been reported to be independent risk factors for low birth weight/very low birth weight were considered potential confounders/effect modifiers in our regression models. The most important risk factor for the outcomes of interest is short gestational age. We input the number of completed weeks of gestation as a continuous variable in both models. The rest of the variables were categorized before being included in the model, and all are adjusted for gestational age. Mother's age was stratified into three groups: ≤ 18 years or younger, 19–39 years old, and ≥ 40 years. Because paternal age has also been identified by some researchers (Abel et al. 2002) as a risk factor, a variable indicating father's age was included into the model and was classified as ≤ 18 years and ≥ 19 years. The mothers were grouped by race into white, African American, and other. Mother's education was classified as less than or up through high school or having some postsecondary education. We used the lowest 10th percentile of distribution of mother's prepregnancy weight and mother's height in the study sample to define the cutoff point for low maternal weight before pregnancy and maternal short stature. They were found to be 110 lb for maternal weight and 61 inches for maternal height. We estimated parent's socioeconomic status on the basis of two variables: mean per capita income in the zip code of the mother's

residence, and the primary payer for birth. The mean per capita income was classified as < \$15,000 and \geq \$15,000. The primary payers for birth were categorized as Medicaid/self-paid and other, which is expected to indicate parents of lower and higher socioeconomic status, respectively, because "other" is assumed to mean coverage by health insurance. The information on mother's smoking was obtained from the birth certificate and had two categories: yes/no. Single motherhood was defined as absence of any information on the father in the birth certificate.

Results

Among the total of 945,077 births, the PCB zip code group constituted 24.5% (231,583) and the non-PCB group was 75.5% (713,494) of the study sample. The mean birth weight in the PCB group was 3,386.7 g, whereas in the non-PCB group it was 3,408.3 g. The difference of 21.6 g was statistically significant, with a p -value < 0.0001. There was no significant difference in rates of very low-birth-weight infants between the two groups. The low-birth-weight rates were 5.7% and 5.0% and very low-birth-weight rates were 0.94% and 0.85% in the PCB group and non-PCB groups, respectively. The yearly distribution of low-birth-weight and very low-birth-weight rates showed a slight upward trend and followed the same pattern among the PCB and non-PCB groups (Figure 1). The upward trend is consistent with national statistics (Centers for Disease Control and Prevention 1994).

Table 1 presents the distribution of potential confounders among the PCB and non-PCB groups. There was no difference in the sex ratio between the PCB and non-PCB sites. Several variables do have a different pattern of distribution between these two groups. The PCB-contaminated zip codes have a higher percentage of African-American population (13.4 vs. 9.6%), teenage mothers (6.9 vs. 4.6%), and teenage fathers (1.7 vs. 1%) and a higher percentage of people with mean per capita annual income < \$15,000 (28.5 vs. 18.9%) compared with the non-PCB group. There was also a larger proportion of women for whom Medicaid is the primary payer (32.4 vs. 24.5%).

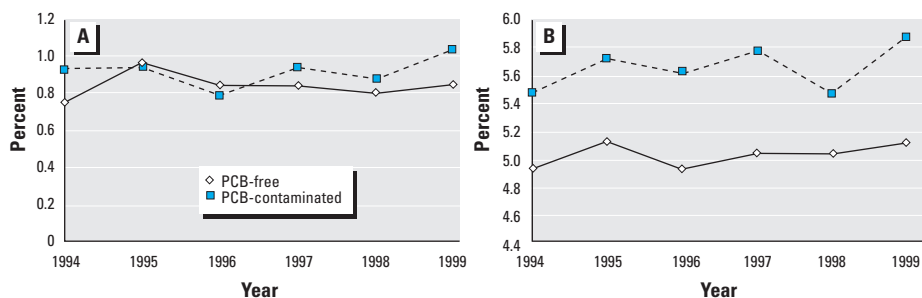


Figure 1. Very low birth weight (A) and low birth weight (B): incidence rate trend by year in PCB-contaminated and PCB-free ZIP codes.

In addition, women in the PCB zip codes were less likely to have postsecondary education (49.6 vs. 56.4%) and more likely to smoke (18.7 vs. 14.2%) and to be single mothers (16.9 vs. 11.6%).

The logistic regression models for both low and very low birth weight had 15 terms, including intercept. Overall, the fit of the model was good with concordance of 87% for the low-birth-weight model and 95% for the very low-birth-weight model. Table 2 shows the estimated odds ratios (ORs) for giving birth to an infant with low birth weight, with 95% confidence interval (CI) for each variable, calculated on the basis of the estimates of β -coefficients and standard errors given by the model. The OR for weeks of gestation is not included in Table 2, because this variable was modeled as a continuous variable, and all other variables are adjusted for gestational age. However, gestational age was found to be a very significant risk factor for the outcome of interest. The OR for gestational age given by the model was 0.6, which means that each additional week of gestation lowers the risk of having a low-birth-weight baby by 1.7 times. Other risk factors for having a low-birth-weight baby in order from the strongest to the weakest are maternal smoking (OR = 2.08; 95% CI, 2.02–2.14), maternal weight before pregnancy < 110 lbs (OR 1.66; 95% CI, 1.61–1.71), African-American race of the mother (OR = 1.63; 95% CI, 1.58–1.68), female sex of the baby (OR = 1.43; 95% CI, 1.40–1.46), maternal age > 39 years (OR 1.38; 95% CI, 1.30–1.47), maternal height < 61 inches (OR = 1.29; 95% CI, 1.25–1.33), nonwhite race of the mother (OR = 1.29; 95% CI, 1.22–1.37), Medicaid or self-paid births (OR = 1.12; 95% CI, 1.08–1.14), and teenage (\leq 18 years) motherhood (OR = 1.08; 95% CI, 1.03–1.13). Living in zip codes contaminated by PCB waste sites was found to be a weak but statistically significant risk factor for having a low-birth-weight baby (OR = 1.04; 95% CI, 1.02–1.07). The mother's educational and income level did not show a strong association with the risk of having a low-birth-weight baby. Single motherhood and young father's age seem not to have any effect on the risk of having a low-birth-weight baby in our study sample.

We then stratified the low-birth-weight model by the baby's sex. A mother's residence in a PCB zip code showed a statistically significant increased risk of giving birth to a low-birth-weight male infant (OR = 1.06; 95% CI, 1.02–1.10) but not for female infants (OR = 1.03; 95% CI, 0.99–1.07).

Table 3 shows the estimated ORs with 95% CIs for the risk of having a very low-birth-weight baby for the same variables. There was no relation between PCB zip codes and very low-birth-weight infants for either sex

(OR = 0.95; 95% CI, 0.88–1.02) or for non-white race of the mother or single motherhood. Several variables that were predictors of low birth weight remain strong risk factors for very low birth weight, including African-American race of the mother (OR = 1.60; 95% CI, 1.48–1.74), maternal height < 61 inches

(OR = 1.59; 95% CI, 1.746–1.72), maternal weight < 110 lbs (OR = 1.39; 95% CI, 1.28–1.51), maternal smoking (OR = 1.25; 95% CI, 1.15–1.35), and female sex of the baby (OR = 1.22; 95% CI, 1.15–1.30). Interestingly, mother's age \leq 18 years, low mother's educational level, and Medicaid or

Table 1. Distribution of potential confounders between exposed and unexposed groups.

Variable	PCB-contaminated sites		PCB-free sites	
	No.	Percent	No.	Percent
Sex of babies				
Male	118,909	51.3	365,000	51.2
Female	112,674	48.7	348,494	48.8
Race				
White	192,191	83.5	618,065	87.0
African American	30,955	13.4	68,482	9.6
Other	7,091	3.1	23,698	3.3
Length of gestation (weeks)				
< 37	20,080	9.0	56,919	8.2
\geq 37	204,193	91.0	634,062	91.8
Mother's age (years)				
\leq 18	16,009	6.9	33,042	4.6
19–39	210,214	90.9	658,534	92.6
\geq 40	4,987	2.2	19,511	2.7
Father's age (years)				
\leq 18	3,178	1.7	6,516	1.0
\geq 19	188,484	98.3	621,591	99.0
Mother's education				
No education	308	0.1	618	0.1
High school only	114,267	50.5	305,323	43.5
Postsecondary education	112,543	49.6	396,023	56.4
Mother's weight before pregnancy (lbs)				
< 110	16,686	7.7	49,737	7.5
\geq 110	200,325	92.3	612,758	92.5
Mother's height (inches)				
< 61	17,043	7.9	46,342	7.3
\geq 61	198,866	92.1	587,274	92.7
Average annual per capita income in the ZIP code of residence				
\$0–15,000	60,058	28.5	134,493	18.9
\$15,000–34,999	161,124	69.6	532,262	73.3
\geq \$35,000	4,401	1.9	55,718	7.8
Primary payer for birth				
Medicaid	72,965	32.4	167,970	24.5
Self-paid	3,861	1.7	13,599	2.0
Other	148,517	65.9	505,170	73.6
Mother's smoking				
Yes	42,899	18.7	99,502	14.2
No	186,540	81.3	599,910	85.8
Single motherhood				
Yes	39,222	16.9	82,471	11.6
No	192,361	83.1	631,023	88.4

Table 2. Estimated ORs (95% CIs) for risk of having low-birth-weight babies.

Variables ^a	OR (95% CI)
PCB	1.04 (1.02–1.07)
Female sex of the baby	1.43 (1.40–1.46)
African-American race of the mother	1.63 (1.58–1.68)
Nonwhite race of the mother	1.29 (1.22–1.37)
Mother's age \leq 18 years	1.08 (1.03–1.13)
Mother's age > 39 years	1.38 (1.30–1.47)
Father's age \leq 18 years	1.01 (0.92–1.12)
Mother's educational level less than or equal to high school grades	1.06 (1.04–1.09)
Parents annual per capita income < \$15,000	1.03 (1.00–1.06)
Medicaid/self-paid births	1.12 (1.08–1.14)
Maternal weight before pregnancy < 110 lbs	1.66 (1.61–1.71)
Maternal height < 61 inches	1.29 (1.25–1.33)
Single motherhood	1.04 (0.95–1.14)
Maternal smoking	2.08 (2.02–2.14)

^aAll variables are adjusted for gestational age (in weeks).

self-payment as the primary payer for births seem to exert a slight protective effect against the risk of having very low-birth-weight baby.

Discussion

Our results show that maternal residence in a zip code that contains or abuts a PCB-contaminated hazardous waste site results in a statistically significant 6% increased risk of giving birth to a male infant of low birth weight, after adjustment for other known risk factors. There was also a 3% increased risk of low birth weight for female infants, a value that almost reached statistical significance. These results suggest that simply living near a PCB-contaminated site poses a risk of exposure and of health impact, probably secondary to airborne spread of the PCBs. Although many PCB-contaminated sites also have other types of contaminants present, the disproportionate impact on male infants supports the conclusion that it is the PCBs that are responsible. A selective effect of PCB or dioxin/furan exposure on male infants has previously been reported in several other studies (Rylander et al. 1995, 1996; Vartiainen et al. 1998; Hertz-Picciotto et al. 2000).

Limitations. The main limitation of this study is the exposure assessment. The exposure was measured on a group level that cannot correctly represent the true level of individual exposure. Very little is known about the extent to which residents living near a waste site are exposed to PCBs (Stehr-Green et al. 1988). In general, the use of surrogate measures such as residence close to a waste site can lead to non-differential misclassification of exposure and decrease the sensitivity of the study to find a true effect (Vrijheid 2000). Moreover, exposure to PCBs from landfills or contaminated bodies of water, if such exposure exists, would be expected to be at very low concentrations. Associations with such low-level environmental exposures in the general population are by their nature hard to establish. Low-dose exposures are generally expected to generate small increases in relative risk that will be difficult to

distinguish from noise introduced by confounding factors and biases.

Another potential source of exposure misclassification involves the assumption that the zip code at the time of birth reflects the residence where a woman lived before and during the critical period of her pregnancy. If a woman moved during pregnancy, then the zip code of her latest residency does not represent her exposure status. It appears that as many as 25% of women change residence between conception and the end of the first trimester (Khoury et al. 1988; Shaw and Malcoe 1991; Shaw et al. 1992). This type of misclassification error is also nondifferential with respect to outcome and tends to reduce the magnitude of the estimated effects (Copeland et al. 1977; Shaw et al. 1992).

Information on exposure and confounders derived from birth certificates is not always accurate and complete. Almost all study variables have some percentage of missing data. For some variables this percentage was relatively low (0.5% for race, 0.3% for mother's age, and 1.7% for mother's education and smoking). For other variables the percentage of missing data was higher (3.2% for gestational age, 6.9% for maternal prepregnancy weight, and 10% for maternal height). If the data are randomly missing, it does not distort the effect estimates but could affect the standard error. We also cannot rule out some percentage of data miscoding.

With respect to potential confounders, we were limited to those that are present on the birth certificate. Several other variables in the birth certificate, such as maternal alcohol and drug use and mother's comorbid conditions, were not included in our analysis because these variables had a high percentage of missing and miscoding data. Although we cannot completely rule out a contribution of these and possibly other unknown confounders, the fact that the relationship between low birth weight and PCB sites was stronger for male than for female infants supports the conclusion that PCB exposure was the critical factor.

No evidence indicates that other confounders would selectively affect male infant birth weight.

Overall, our results confirm previous observations on a number of risk factors for giving birth to an infant with low/very low birth weight.

PCBs and low birth weight. We have found that infants born to mothers who reside in PCB-contaminated zip codes give birth to infants who are on average 21.6 g lighter than those born to mothers who do not live in PCB-contaminated zip codes. This value should be compared with the reports of Fein et al. (1984), who found that mothers who ate contaminated Lake Michigan fish had infants 160–190 g lighter than those of controls, and of Taylor et al. (1984), who reported that women occupationally exposed to PCBs have infants 153 g lighter than those of controls. After adjustment for most known confounders, we find that maternal residence in proximity to waste sites contaminated by PCBs increases by 6% the risk of having a low-birth-weight male baby, whereas the risk of having a low-birth-weight female infant narrowly misses being significant, and there is no elevated risk of having a very low-birth-weight baby of either sex. Even though the added risk of giving birth to low-birth-weight male babies by women residing in proximity to PCB-contaminated zip codes is small, the observation is consistent with the hypothesis that living next to a PCB-contaminated site constitutes a risk of exposure and of adverse health effects. The sex-specific effect is important support for the conclusion that the risk is due to PCB exposure, because most other confounders are not known to exhibit selective effects on male infants, and we have controlled for the added general risk of low birth weight in female infants.

Several points are worth noting. We have no direct exposure assessment other than zip code of residence. Zip codes are of irregular shape, and residence in a zip code near a PCB site is certainly not the optimal indicator of exposure. Previous studies of this type (Shaw et al. 1992; Sosniak et al. 1994) found that merging a large population database with environmental data is an innovative but not very efficient method of assessing the risks of low birth weight related to the environment. On the other hand, the benefits of such investigations are that they are economical, they may be useful for identifying large risks not previously known, and they may be used as hypothesis-generating studies (Shaw et al. 1992). Use of birth records for a large geographic area such as New York State over several years provides sufficient power to detect relationships that would otherwise not be apparent. Furthermore, the inadequacy of the exposure assessment should obscure the relationship, which suggests that the true relationship between PCB exposure

Table 3. Estimated ORs (95% CIs) for risk of having very low-birth-weight babies.

Variables ^a	OR (95% CI)
PCB	0.95 (0.88–1.02)
Female sex of the baby	1.22 (1.15–1.30)
African-American race of the mother	1.60 (1.48–1.74)
Nonwhite race of the mother	0.98 (0.81–1.17)
Mother's age ≤ 18 years	0.81 (0.71–0.93)
Mother's age > 39 years	1.16 (0.98–1.37)
Father's age ≤ 18 years	0.94 (0.73–1.21)
Mother's educational level less than or equal to high school grades	0.90 (0.83–0.96)
Parents annual per capita income < \$15,000	1.08 (1.00–1.17)
Medicaid/self-paid births	0.88 (0.81–0.95)
Maternal weight before pregnancy < 110 lbs	1.39 (1.28–1.51)
Maternal height < 61 inches	1.55 (1.46–1.72)
Single motherhood	0.79 (0.66–1.10)
Maternal smoking	1.23 (1.15–1.35)

^aAll variables are adjusted for gestational age (in weeks).

and low birth weight of male infants (and probably female infants as well) is actually greater than we have demonstrated. To identify the risk of maternal residence in selected zip codes, more detailed studies measuring the actual serum level of PCBs in women living in these zip codes are needed.

If living in a PCB-contaminated zip code indeed poses a risk of low birth weight in male infants, there is a question of the route of exposure to the mother. Consumption of PCB-contaminated fish is the best-documented route of exposure (Fein et al. 1984; Jacobson JL et al. 1990; Jacobson SW et al. 1985; U.S. Department of Health and Human Services 2000), but sport fishers are not defined by the zip code in which they live. The most likely route of exposure is airborne (Currado and Harrad 1998), either through inhalation of volatile PCBs or PCBs bound to particulates or through ingestion of PCB-contaminated particulates with foodstuffs. Inhalation as a route of exposure has not received much attention, but there is considerable evidence that PCBs volatilize, especially from contaminated bodies of water (Chiarenzelli et al. 2000) and wet sediments (Bushart et al. 1998; Chiarenzelli et al. 1996). Volatile PCBs can be absorbed through inhalation (Casey et al. 1999). PCBs are widely distributed in the food chain (U.S. Department of Health and Human Services 2000), and even remote places will have measurable PCBs in the air (Lohmann et al. 2001). Therefore, there is no unexposed population, and our results reflect only the effects of gradients of exposure. This fact also suggests that the risks of low birth weight that we have demonstrated are underestimations of the actual risk.

We did not find as strong a relationship between residence in a PCB-contaminated zip code and gestational age as others have reported (Fein et al. 1984; Taylor et al. 1984, 1989), who have suggested that gestational age is the major cause of low birth weight after PCB exposure. The reason for this is not clear, but it most likely reflects a lack of accuracy in the reporting of gestational age (from last menstrual period) in the vital statistics database. Animal studies have demonstrated that PCBs stimulate contraction of pregnant rat uterine muscle (Bae et al. 1999a, 1999b), which is likely the mechanism by which PCBs cause a shortened gestational age. It is interesting that this is a property of lower chlorinated, non-dioxin-like congeners, not the dioxin-like congeners (Tsai et al. 1996). Such congeners are more volatile and less persistent, but still may have health effects.

A separate issue raised by the present study is the inequity of locating hazardous waste sites and hazardous materials. The analysis of distribution of potential risk factors for giving birth to a low-birth-weight/very low-birth-weight baby indicates that the PCB group has a higher

risk not only because of proximity to waste sites but also because of race and income level (Table 1). This means that hazardous waste sites and the locations of hazardous materials are either disproportionately situated near minority communities, especially African-American communities and low-income communities, or that such places are unattractive to those who can afford to choose to live elsewhere.

These studies have confirmed several known risk factors for low birth weight and have also found 6% increased risk associated with living near a PCB-contaminated site and giving birth to a male infant of low birth weight. Because low birth weight is itself a risk factor for infant morbidity and mortality and a number of chronic diseases in adulthood, even a small increased risk has important public health implications. Furthermore, because zip code of residence is an inexact exposure assessment, it is likely that our results significantly underestimate the true risk from PCB exposure. Perhaps the most significant conclusion from these observations is that they provide additional support for the hypothesis that simply living near a PCB-contaminated site is a risk of exposure and of adverse health effects. The fact that the relationship was found only for male infants is consistent with this effect being secondary to PCB exposure, because most other confounders are not known to have a sex-specific effect.

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