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Persistent organic pollutants (POPs) and metals in primiparous women: a comparison from Canada and Mexico☆

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Abstract

Under the North American Commission for Environmental Cooperation (CEC) and its Sound Management of Chemicals (SMOC) program, a tri-national human contaminant monitoring initiative was completed to provide baseline exposure information for several environmental contaminants in Canada, Mexico and the United States (U.S). Blood samples were collected from primiparous women in Canada and Mexico, and were analysed for a suite of environmental contaminants including polychlorinated biphenyls (PCBs), dichlorodiphenyldichloroethylene(p,p′-DDE),beta-hexachlorocyclohexane (β-HCH), mercury and lead. A multiple stepwise linear

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regression analysis was conducted using data from Canadian and Mexican primiparous mothers, adjusting for ethnicity group, age, pre-pregnancy BMI, years at current city and ever-smoking status. Concentrations of p,p′-DDE, β-HCH, and lead were found to be higher among Mexican participants; however, concentrations of most PCBs among Mexican participants were similar to Canadian primiparous women after adjusting for covariates. Concentrations of total mercury were generally higher among Mexican primiparous women although this difference was smaller as age increased. This initial dataset can be used to determine priorities for future activities and to track progress in the management of the selected chemicals, both domestically and on a broader cooperative basis within North America.

Keywords

Primiparous women; Persistent Organic Pollutants (POPs); Metals; Canada; Mexico

1. Introduction

Prior to the initiation of the Trinational Biomonitoring study (CEC, 2011) there was relatively limited biomonitoring data available across parts of Canada and Mexico. In Canada, several targeted population and community-based based studies have been conducted among Aboriginal populations (Donaldson et al., 2010; Wheatley and Paradis, 1995), and in specific regions including the Great Lakes (Cole et al., 2002) and the St. Lawrence region (St. Lawrence Vision, 2000), and in certain provinces (Alberta Health and Wellness, 2008; INSPQ, 2004). More recently however, a number of comprehensive surveys have been conducted such as the Canadian Health Measures Survey, and several others described by Haines et al., (2012), that provide a nation-wide level of information on contaminants present in the population. In Mexico, biomonitoring data was relatively scarce except for a few contaminants such as lead and DDT (López-Carrillo et al., 1996a,1996b) although more recently, studies have been conducted that focus on environmental contaminants in suspected areas of higher levels (Dominguez-Cortinas et al., 2013; Meza-Montenegro et al., 2013; Trejo-Acevedo et al., 2012;Trejo-Acevedo et al., 2009) at specific sites (Orta-Garcia et al., 2014) and at sites in proximity to point sources of contaminants (Soto-Jimenez et al., 2011; Soto-Rios et al., 2010).

A tri-national human contaminant monitoring initiative was developed by the North American Commission for Environmental Cooperation (CEC) and its Sound Management of Chemicals (SMOC) program, which is tasked with implementing tri-national efforts to reduce the risks of exposure to toxic substances related to human health and the environment in the United States (U.S.), Canada and Mexico (CEC, 2011). The initiative was developed with two main objectives: 1) to obtain an initial profile of exposure to persistent organic pollutants (POPs) and selected metals in primiparous women for Canada and Mexico, and women of childbearing age in the U.S.; and 2) to enhance the capacity of Mexico to monitor Stockholm Convention POPs and selected metals, establishing the basis for the development of compatible and comparable databases of human biomonitoring results for the three countries. The data collected by this pilot biomonitoring study (Trinational Biomonitoring Study) provides a baseline profile of human exposure to environmental contaminants to help

track progress in managing select chemicals in the three countries (CEC, 2011) and assist in the prioritization of future monitoring activities.

The POPs and metals contaminants measured in the Trinational Biomonitoring Study are some of the most well studied contaminants and human health effects associated with their exposure has been studied by numerous researchers. Studies have linked lead exposure to neurodevelopmental (Boucher et al., 2012a,2012b; Cho et al., 2010; Wang et al., 2008a), cardiovascular (Glenn et al., 2003, 2006; Yazbeck et al., 2009), renal (Muntner et al., 2003, 2005) and reproductive effects (Cantonwine et al., 2010). Mercury exposure has been associated with neurotoxic effects in adults (Harada et al., 2005; Harada, 1995) and children (Grandjean et al., 2003), cardiovascular effects (Choi et al., 2009), and developmental effects in children from prenatal exposure (Boucher et al., 2012a,2012b). In addition, several studies have identified a number of potential health effects associated with exposure to persistent organic pollutants (POPs), including exposure to dichlorodiphenyldichloroethylene (p,p′-DDE) and PCBs (Dallaire et al., 2004, 2006), PCBs and dioxins (Weisglas-Kuperus et al., 2004) with immune system effects, and exposure to PCBs with cardiovascular effects (Huang et al., 2006; Sergeev and Carpenter, 2005), and neurodevelopment effects (Boucher et al., 2009; Grandjean et al., 2001; Jacobson and Jacobson, 2003; Muckle et al., 2004). An increasing number of studies are reporting increased risk of developing type II diabetes associated with exposure to POPs, such as PCBs and dioxins (Lee et al., 2010, 2006; Wang et al., 2008b;) and p,p′-DDE (Rignell-Hydbom et al., 2009). Few studies have investigated health effects associated with exposure to polybrominated compounds (Kicinski et al., 2012), although several toxicology studies have documented developmental, neurotoxic, and endocrine disruption effects (Costa et al., 2008; Darnerud, 2003).

Exposures for young children and the developing fetus carry the most cause for concern due to their rapid growth and physiological immaturity. Environmental chemicals can be passed on from the mother to the developing fetus through the placenta (Needham et al., 2011) and some contaminants such as mercury have been detected at higher concentrations in umbilical cord blood than in maternal blood (Ask et al., 2002; Sakamoto et al., 2004; Soria et al., 1992). Even after birth, when the body is still developing and young children do not have a fully formed blood–brain barrier, further exposure to contaminants can occur through breastfeeding (Anderson and Wolff, 2000; LaKind et al., 2001). For this reason, pregnant women were the target population for the CEC Trinational Biomonitoring Study. Primiparous women in particular, are an ideal population to study as they are not influenced by confounding variables such as parity and breast-feeding (James et al., 2002; Sarcinelli et al., 2003). Several studies have investigated changes in maternal blood volume, body mass index and other factors during pregnancy, however recent studies indicate that the last weeks of the third trimester is the most suitable time period for the measuring of organochlorines in blood samples (Hansen et al., 2010).

Data on concentrations of chemicals in human populations are required by regulatory agencies to conduct risk assessments and for informing policy decisions. The monitoring of contaminant levels in human populations can provide information to track the effectiveness of regulations. In Canada, for example, a decline in blood lead concentrations has been observed over the last three decades, where 25% of Canadians aged 6 or older were found to

have blood lead concentrations above 10 μg/dL as measured in the Canada Health Survey (1978–79), while less than 1% of Canadians were above 10 μg/dl as measured in the Cycle 1 of Canadian Health Measures Survey 30 years later (2007–2009; Wong and Lye, 2008). This may reflect the phase-out of leaded gasoline, lead-containing paints, and lead solder in food cans (Health Canada, 2004). The concentrations of a number of organochlorines, such as DDT and β-HCH, have also been measured to be declining in human breast milk in Ontario and Quebec over several decades (Craan and Haines, 1998), the use of which has been reduced or eliminated due to either restricted use or production, voluntary bans or regulated bans.

Comparison of biomonitoring datasets from different geographic areas and countries can provide valuable information to compare and contrast contaminants concentrations in human populations (a result of exposures from various sources including consumer products, food and environmental media), as well as to help evaluate the effectiveness of global regulations and other risk management efforts. Challenges exist, however, when comparing biomonitoring studies due to the potential for lack of consistency in study design, sample populations, time period, laboratory analytical methods, and interpretation of the data. To ensure comparisons for human biomonitoring data are scientifically meaningful, it is essential to evaluate the methodological components of the biomonitoring surveys and their impact on the comparability of the data (LaKind et al., 2012). The CEC biomonitoring data collected in this pilot study was conducted using similar methods and designs in Canada and Mexico, which provides a unique opportunity to make a meaningful statistical comparison between these two populations. Due to the different recruitment/sampling strategy used for the collection of US data, the analysis was restricted to Canadian and Mexican data. A descriptive comparison of all three countries is however presented in the original report (CEC, 2011). The objective of this paper is to use statistical methods to compare the concentrations of select POPs and metals in the blood of primiparous women from Canada and Mexico after adjusting for covariates.

2. Methods and Materials

2.1. Study Design

The Canadian women selected for the study were pregnant women attending their first prenatal visit, while Mexican women selected for the study were pregnant women attending a later prenatal visit in their last trimester. In this study, only primiparous women (e.g., first birth) aged between 14 and 43 years and who were able to provide informed consent, were included in this study as participants. This age range allowed inclusion of primiparous women in the two countries, as women having their first child in Mexico were younger than women in Canada. Only primiparous women were included in the study to provide a consistent body burden of contaminant concentrations unaffected by lactation or *in utero* transfer from mother to a previous infant. Exclusion criteria for this study included women with pre-eclampsia, gestational diabetes, hypertension, diabetes, epilepsy, endocrine disorders or any other disease during pregnancy that may significantly affect maternal or child health. Each study participant completed a demographics questionnaire providing information on age, reproductive history, place of birth and residence, family income, and

self-reported cigarette smoking history at the time of enrollment. The Canadian study protocol was reviewed and approved by the research ethics boards of Health Canada and of each of the participating centers. The Mexican study protocol was reviewed and approved by the research, ethics and bio-security commissions of Instituto Nacional de Salud Pública (INSP).

Study subjects were recruited at five Canadian sites[1] between December 2005 and August 2007, and at 10 Mexican sites[2] between November 2005 and March 2006. These sites represent a mix of cities with different histories of industrial activity, agricultural practices and use of pesticides, types of employment, and also represent different geographic regions of each country (Foster et al., 2012; Rodriguez-Dozal et al., 2012). Primiparous women were recruited until the goal of twenty-five women from each of the sites was reached. Existing NHANES data on American women of childbearing age were presented in the CEC Tri-national Report (CEC, 2011); however, those data are not included in this analysis to allow us to more directly compare primiparous women from Canada and Mexico.

2.2. Sample collection and analysis

Due to the significant physical changes (including blood volume and lipid content) that occur during pregnancy, all blood samples from Canadian and Mexican primiparous women were collected in the third trimester, prior to delivery. Samples from all sites were collected according to the agreed upon sampling and laboratory protocols using sample containers supplied by the U.S. Centres for Disease Control and Prevention. Blood was collected from the antecubital vein into purple-top, EDTA-containing Vacutainer® tubes (two 7 mL tubes for trace metal measurements and two 10 mL tubes for POPs measurements). Anticoagulated whole blood was stored at 4 °C until required for analysis. Plasma, obtained by centrifugation of POPs tubes, was decanted into pre-cleaned vials and stored frozen. In Canada, duplicate samples were collected to allow further follow-up analyses, while in Mexico, duplicate samples were collected so that analyses could be completed by national laboratories in both countries, Centro Nacional de Investigación y Capacitación Ambiental (Cenica – metals) and Universidad Autónoma de San Luis Potosí (UASLP – POPs) in Mexico, and the Institut national de santé publique du Québec (INSPQ) in Canada.

The data presented in this paper from Canada and Mexico are the results from the INSPQ laboratory, Canada. The duplicate analyses undertaken at the two Mexican laboratories are discussed in the Trinational Biomonitoring Study (CEC, 2011). Metals were measured by either inductively-coupled mass spectrometry (lead and cadmium) or cold vapor atomic absorption (mercury) (Butler-Walker et al., 2006). Chlorinated pesticides and PCBs were measured using high-resolution gas chromatography/low-resolution mass spectroscopy (GC-MS) using an in-house, ISO-17025 accredited method adapted from Mes et al. (1990). Plasma samples (2 mL) were extracted on a solid phase extraction (SPE) column. The extracts were purified on a Florisil column, concentrated to a final volume of 100 μL, and analyzed by gas chromatography–mass spectrometry using electronic impact ionization (EI).

[1]Halifax, Vancouver, Hamilton, Ottawa, Calgary.
[2]Queretaro, Tultitlan, Merida, Salamanca, Monterrey, Guadalajara, Hermosillo, Cordoba, Coatzacoalcos and Ciudad (Cd.) Obregon.

Analytical details are explained in more detail in Foster et al., 2012 and Rodriguez-Dozal et al., 2012.

All metals concentrations are reported on a whole blood volume basis. The POPs data in plasma are reported on a lipid-adjusted basis. The total lipid concentration of each sample was calculated by summing the measured concentrations of plasma lipid components. All lipid components were measured by standard clinical chemistry enzymatic methods. INSPQ measured 4 components: total cholesterol (TC), free cholesterol (FC), triglycerides (TG) and phospholipids (PL) and calculated the total lipid (TL) concentration as described by Akins et al. (1989). Whole blood samples were analyzed for a total of nine metals: lead, mercury (total and inorganic), cadmium, cobalt, nickel, selenium, thallium and tin. In addition, a total of 37 POPs were measured and reported in this paper including: 20 polychlorinated biphenyl congeners (PCB 28, 52, 99, 101, 105, 114, 118, 123, 128, 138, 153, 156, 157, 163, 167, 170, 180, 183, 187, and 189), hexachlorohexanes (α-HCH, β-HCH, γ-HCH), aldrin, chlordane derivatives (α-chlordane, γ-chlordane, cis-nanachlor, transnonachlor, oxychlordane), hexachlorobenzene (HCB), Mirex, p,p′-DDT, p,p′-DDE, and polybrominated diphenyl ethers (PBDE 47, 99, 100, and 153).

2.3. Statistical analysis

The Canadian population sample was divided into two sub-groups based on place of birth (Canadian–born and Canadian–foreign born). For the Mexico data, the samples were considered to be homogenous, in the sense that all primiparous women from these populations were native-born.

Data was presented using the geometric mean (instead of an arithmetic mean) and corresponding 95 percent confidence interval because most of the contaminants were log-normally distributed as shown by the Anderson-Darling test for normality. Further analysis to compare group means for each of the contaminant concentrations was conducted on only those groups where a minimum of 70 percent of the data were above the limit of detection (LOD). Values below the LOD were imputed with half the LOD.

Multiple stepwise linear regression analysis was performed to simultaneously determine the relationship between the concentrations of each contaminant and demographic factors. Ethnicity group, age, pre-pregnancy BMI, years at current city and ever-smoking status were included in the model selection process. Spearman correlation coefficients were used to identify significant correlations between continuous covariates in an effort to minimize multicollinearity. Stepwise procedures were implemented to simultaneously test for relationships among covariates and contaminants. The best predictive model was selected based on an overall F-test for goodness of fit, according to the Akaike Information Criterion (AIC) and adjusted R^2.

Final models included covariates with a p-value of less than $\alpha = 0.05$ as determined by the stepwise procedure. A residual analysis was implemented to verify the statistical assumptions of normality and constant variance. When the overall F-test for ethnicity differences in the final models was significant, Scheffé multiple pair-wise comparisons were used to determine which groups were significantly different from one another.

The analysis was completed using software packages SAS (Statistical Analysis System) Enterprise Guide 4.2 and R (R Core Development Team). Unless otherwise stated, a significance level of 5% ($\alpha = 0.05$) was assumed throughout.

3. Results

3.1. Descriptive statistics

Unadjusted data for POPs and metals among primiparous women from Canada and Mexico are presented in Tables 1 and 2. A geometric mean for p,p′-DDT was not calculated for Canadian–born and Canadian–foreign born primiparous women as detectable concentrations were found in only 1% and 16% of samples, respectively. In addition, gamma-hexachlorocyclohexane (γ-HCH) was only detected in 2% of Mexican samples, and therefore this data is not presented in Table 1. All other organochlorines, including p,p′-DDE (the main metabolite of p,p′-DDT), were detected in greater than 70% of primiparous women from each group. Due to the low detection of PBDEs among Mexican primiparous mothers, geometric means were not calculated. Among the PBDEs measured, only for PBDE 47 and PBDE 153 did 70% of Canadian primiparous women have detectable concentrations. Metals such as cadmium, lead, nickel and selenium were detected in all of the samples, however a geometric mean was not calculated for inorganic mercury as most of the samples were below the detection limit.

For the unadjusted data presented in Tables 1 and 2, differences in concentrations of several contaminants among the groups are observed. For example, Mexican primiparous women had four and six times higher concentrations of lead and p,p′-DDE, respectively, compared to Canadian-born primiparous women. It is worth noting that while only 38% of Mexican primiparous women had detectable concentrations of p,p′-DDT, the most highly exposed women had concentrations as high as 3210 μg/kg plasma lipid. Mexican and foreign-born Canadian primiparous women had similar concentrations of beta-hexachlorocyclohexane (β-HCH) that were nearly four times higher than Canadian-born primiparous women. Foreign-born Canadian primiparous women had higher concentrations of PCBs such as PCB 138, 153 and 180 than either Mexican or Canadian-born primiparous women. Mexican primiparous women had the lowest concentrations of PCBs among the three groups available.

3.2. Demographics

While several demographic variables were recorded from the questionnaires, due to missing information and inconsistent observations, only a select few remaining variables were comparable between Canadian and Mexican participants, and are presented in Table 3.

Mexican primiparous women were between 15 and 33 years of age with a mean age of 21. This was substantially lower than Canadian born and Canadian Foreign born primiparous women, who were between the ages of 18 and 40, and 25 and 41, respectively, with mean ages of 29 and 33. Pre-pregnancy BMI was similar among all groups although slightly higher among Canadian-born mothers. Canadian-born and foreign-born mothers had much higher monthly family income and maternal education level than Mexican mothers, although this is partially due to the fact that Mexican mothers were younger. In fact, Spearman rank

correlations among the continuous variables found that age and monthly family income had the highest correlation (r = 0.5122) as shown in Table 4.

3.3. Regression analysis

While there were several differences noted in concentrations of various contaminants observed in Tables 1 and 2, this data only describes the sample, and does not account for confounding variables which can influence blood concentrations of several POPs and metals. Multiple stepwise linear regression analysis was performed to simultaneously determine the relationship between the concentrations of each contaminant and demographic factors (Table 5). While data was available for smoking during pregnancy and current smoking status, these variables were not included in the analysis due to small sample size (within each category). Monthly family income was also not included to minimize the effects of multicollinearity among the continuous variables. Education was also not included due to the minimal overlap in education and small sample sizes in each category (23.4% of Mexican mothers had high school or higher education, compared to 94.6% and 100% of Canadian-born and foreign-born mothers who had completed a high school or higher education, respectively). Ethnicity group, age, pre-pregnancy BMI, years at current city and ever-smoking status were included in the model selection process, although the years at current city variable was not found to be significant for any contaminants ($p > 0.05$).

Table 5 shows that higher pre-pregnancy BMI was significantly associated with lower levels of PCB 153 and PCB 180 ($p = 0.0032$ and 0.0016, respectively). Age was significantly associated with all POPs and metals considered except cadmium and nickel. Older mothers had higher levels of POPs, lead and selenium, but also had lower levels of cobalt. Ever smoking status was significant only for cadmium, as the interaction term between ever smoking status and ethnicity group was found to be significant, indicating that differences in contaminant levels of ethnic groups depend on whether mothers ever smoked. Other interaction terms were found to be significant including between age and ethnicity for mercury and PCB 180 ($p = 0.0077$ and 0.0416 respectively). Ethnicity group (Canadian-born, Canadian foreign-born and Mexican mothers) was significant for all metals and all POPs except for PCB 138, 153 ($p = 0.3840$ and 0.0923 respectively), and oxychlordane ($p = 0.0565$). For the contaminants whose overall F-test for ethnicity group difference was significant, Scheffé multiple pair-wise comparisons were performed to determine differences between Canadian-born, foreign-born and Mexican mothers.

Scheffé multiple comparison (Table 6) show that with other factors held constant, Mexican mothers had higher levels of cobalt, lead, nickel, trans-nonachlor, p,p′-DDE and β-HCH than Canadian-foreign born and Canadian-born mothers. Canadian-foreign born mothers had similar levels as Canadian-born mothers for these contaminants, except p,p′-DDE and β-HCH for which levels were significantly higher among foreign-born mothers. Since the interaction term between ethnicity and ever smoking status for cadmium was significant, relationships between the 6 groups (non-smokers and ever smokers among Canadian-born, foreign born, and Mexican mothers) are also shown in Table 6. No significant difference was found between Mexican non-smoker and ever smoker mothers, or any significant difference between Canadian-foreign born non-smoker and ever smoker mothers. Canadian-foreign

born non-smokers however, were found to have significantly higher cadmium levels than Canadian-born non-smoker mothers. Interestingly, statistically similar cadmium levels were found among Canadian foreign-born non-smokers, Canadian foreign-born ever smokers, and Canadian-born ever-smokers.

Even though differences were observed between groups for PCB180 and total mercury, they are not presented in Table 6 due to the significant interaction term between age and ethnicity group. In other words, the group effect (i.e., place of birth) on contaminant levels depends on the mother's age. Instead, Fig. 1a and b summarize the estimated adjusted geometric means using ages of 19, 22, 28, 32, and 34 for PCB 180 and total mercury. While concentrations of total mercury remain higher among Mexican primiparous women of all ages, the difference in concentrations between Mexican and Canadian primiparous women became less in older age groups. We also note that while concentrations of PCB 180 are lowest among young Canadian born primiparous women, this trend reversed as the mother's age increased, with older Mexican primiparous women having lower concentrations of PCB 180 than Canadian-born primiparous women of the same age.

4. Discussion

Two recent papers have reported the analysis of data from this CEC study for Canada (Foster et al., 2012) and Mexico (Rodriguez-Dozal et al., 2012). In each case the analysis was restricted to comparisons between sites or regions within each country. The Canadian analysis by Foster et al. (2012) focused on concentrations of POPs and metals in primiparous women and found statistical differences between the 5 Canadian sites for several contaminants after adjusting for age and BMI, although no one site was consistently higher for all contaminants. The paper by Rodriguez-Dozal et al. (2012) did not look at concentrations of metals, but instead focused on POPs and pooled samples of di-oxins, furans and dioxin-like PCBs in primiparous women. Significant differences were observed for several contaminants between the 10 Mexican study sites and concentrations of some POPs at certain sites were higher than originally expected based on the hypothesized exposure scenario (Rodriguez-Dozal et al., 2012). The unique analysis presented here provides a direct statistical comparison between the concentrations of metals and POPs in the blood of primiparous women from both Canada and Mexico. Statistically significant differences in the concentrations of several contaminants were observed between participants from these two countries, after adjusting for age, ethnicity group, pre-pregnancy BMI, years at current city, and ever-smoking status.

The contaminants that were found at higher concentrations among Mexican primiparous women, compared to Canadian primiparous women (after adjusting for covariates), included trans-nonachlor, β-HCH, p,p′-DDE, cobalt, nickel, selenium, lead and mercury. These results are not unexpected for β-HCH (a byproduct of lindane [γ-HCH] production) and p,p′-DDE (a persistent metabolite of p,p′-DDT) in Mexico, as the higher concentrations are consistent with their more recent production and use. While most uses of p,p′-DDT were banned in Canada in the 70s and 80s, its use continued quite extensively in regions of Mexico for malaria vector control until it was banned in 2000 (Chanon et al., 2003). Despite the recent ban, studies in the past decade have reported high levels of p,p′-DDE in serum of the

Mexican population (Cupul-Uicab et al., 2010; De Jager et al., 2006; Torres-Sanchez et al., 2007). Higher concentrations of β-HCH may also reflect more recent use of lindane, which was also banned in Mexico in 2000.

Contrary to the above mentioned POPs, concentrations of PCBs appeared to be lowest among Mexican primiparous women (Table 1), however after adjusting for covariates, no significant difference was detected between Mexican and Canadian mothers (Canadian-born and foreign born) except for PCB 180 (Table 5 and Fig. 1a). It is interesting that only PCB180 was different between the three ethnicity groups as Foster et al., (2012) found place of birth (Canadian-born and foreign born) to be significant for PCB 138, 153, and 180. We found these three congeners to be highly correlated with each other when we conducted Pearson correlations (Table 7), although we also found that only PCB153 and 180 were significantly correlated with pre-pregnancy BMI among Canadian-born mothers, which may partially explain some of these differences among PCB congeners. These high correlations between PCBs do not imply that they have identical concentrations, but rather they display similar trends with respect to covariates in this sample. The two most highly detected PCB congeners in all population groups are PCB 138 and PCB 153. This appears to follow the trend seen in literature (Becker et al., 2002; Needham et al., 2005) which has shown that PCBs 138 and 153 continue to be the predominant PCB congeners in North America and Europe.

Unlike the majority of organochlorine contaminants, PBDEs were detected in very few Mexican primiparous women, with the most detected congeners (PBDE 47 and 153) measured in only 33% of Mexican women. This is in contrast to the higher detection rate of PBDEs in most of the Canadian primiparous women (PBDE 47 and 153 were detected in 82% and 86% of Canadian primiparous women). PBDEs are used as flame retardants in many household products. Other studies have highlighted higher concentrations of PBDEs among residents in regions with tighter flammability standards, such as in California (Eskenazi et al., 2011; Zota et al., 2008). In these studies, concentrations of PBDEs were twice as high among California residents compared with other US residents (Zota et al., 2008), and Mexican-American children who grew up in California had higher concentrations of PBDEs, due to post-natal exposure, than their Mexican counterparts (Eskenazi et al., 2011).

Unlike POPs, metals such as lead and mercury occur naturally in the environment, however these metals are also used or released during a number of different anthropogenic activities and human exposure can be due to different sources. This study did not examine or identify sources of exposure; however other studies have suggested that one of the major sources of lead in Mexico is lead-glazed pottery (Chaudhary-Webb et al., 2003; Hernandez-Avila et al., 1991; López-Carrillo et al., 1996a). Another potential source of exposure to lead found in other areas of Mexico is living in a vicinity of smelter complex (Carrizales L., et al., 2006; García-Vargas., et al., 2001; Soto-Jiménez and Fregal, 2011). Further research is needed to better explain the higher concentrations observed in Mexican mothers, relative to Canadian-mothers. For example, further research on identification of sources of lead exposure, using new tools such as lead isotopes ratios (Glorennec et al., 2010; Oulhote et al., 2011), would be beneficial to the interpretation of biomonitoring data. Total mercury concentrations were

significantly higher among Mexican primiparous women but the difference in adjusted geometric means became less as age increased (1. 1b). This measure of total mercury is assumed to be mostly organic mercury (such as methylmercury) as the inorganic mercury was not detectable in most of the mothers (Table 2). The low R^2 value in Table 4 for mercury suggests that there are additional variables not included in this analysis that would more accurately describe the distribution of mercury. In Mexico, mercury has several industrial applications in the chloralkali, cement, pharmaceutical, and coal and coke industries; however there is very little information (Soto-Ríos et al., 2010) on human exposures to mercury. A number of studies in Canada have shown that diet, particularly fish consumption, is associated with concentrations of mercury in blood (Clarkson and Magos, 2006; Donaldson et al., 2010) and may have better explained mercury concentrations, however due to incomplete or inconsistent collection of dietary and lifestyle data from Canada and Mexico, this data was not available to include in the analysis to assess any potential relationships. The results for cadmium in this paper indicate that ever smoking status was significant, since the interaction term between ever smoking status and ethnicity group was found to be significant, however the R^2 value was fairly low for cadmium which suggests other variables should be sought to better explain the variation in cadmium concentrations. Current-smoking status was also initially considered for the analysis but it could not be included due to sample size issues. As blood concentrations of cadmium usually reflect recent and cumulative exposures (CDC, 2005), current-smoking status may have been a better variable to include for blood samples.

Foster et al., (2012) found significant differences between Canadian-born and Canadian-foreign born mothers for several contaminants (cadmium, β-HCH, p,p′-DDE, PBDE 47, PCB138,153 and 180) and this was found to be similar in the analysis presented in this paper, but with a few exceptions. Specifically, concentrations of both PCB138 and PCB153 were not significantly different among these two groups, and cadmium was only significantly different among non-smokers in the analysis of this paper. Foster et al., (2012) also found age and pre-pregnancy BMI effect to be significant for several contaminants. While age was not significant for cobalt in Foster et al., (2012) it was significant in the present analysis ($p = 0.0244$). Pre-pregnancy BMI was also weakly significant for cobalt and trans-nonachlor ($p = 0.044$ and 0.049 respectively) in Foster et al., (2012) however they were not significant in the present analysis. It is also worth mentioning that while pre-pregnancy BMI was significant for PCB180 in this analysis and that of Foster et al., (2012), it was not significant among Mexican mothers in Rodriguez-Dozal et al., (2012). In addition, Rodriguez-Dozal et al., (2012) also found significant differences of p,p′-DDE between underweight and obese mothers, while pre-pregnancy BMI was not significant for p,p′-DDE in this analysis or in Foster et al., (2012). These small differences in p-values may be attributed to the differences in the statistical analysis, due to differences in the degrees of freedom and variance since data from two countries were included in the present analysis.

Among Canadian participants, it was noted that foreign born primiparous women had more than double the concentration of β-HCH found in their Canadian-born counterparts. The Canadian-foreign born primiparous women also had moderately elevated concentrations of p,p′-DDE compared to Canadian born primiparous women. These higher concentrations of persistent bioaccumulative chemicals are likely due to prior exposure in their country of

origin or in foods imported from these countries, although there is insufficient information on residential history to verify this conclusion. Higher concentrations of select contaminants among foreign born mothers has been observed previously in other studies (Butler-Walker et al., 2003; Wang et al., 2009) and is also described in greater detail by Foster et al. (2012). Foreign born mothers however, may also have lower concentrations of other contaminants, as demonstrated in the United States where one study found lower indicator PCB concentrations among pregnant Mexican-American women compared to non-Mexican American women (Wang et al., 2009).

It is also possible that the differences by country are due, not to geographic-specific attributes, but rather due to unobserved effects or exposures to these contaminants not captured by the variables used in this analysis.

5. Conclusion

Human biomonitoring data provides substantial information on human exposure to contaminants that is valuable for risk assessments (Smolders et al., 2009). One of the restricting issues regarding exposure characterization is the availability of reliable and comparable human biomonitoring data (Smolders et al., 2010). When comparing data from different countries, it is important to evaluate the methods used for analysis and sampling of participants, as there are several factors that may influence this comparisons such as analytical differences including limits of detection (LOD) for chemicals (LaKind et al., 2012). Other challenges that may exist when comparing biomonitoring data from different countries include gender, age, and time period in which samples were collected (Smolders et al., 2010).

While the results of the CEC Trinational Biomonitoring Study for Canada and Mexico are not nationally representative due to the non-probability sampling strategy used, it does provide an initial set of regional data on POPs and metals concentrations in primiparous women from both countries. Due to the design of the pilot study, which included implementation of similar methods for data collection (same target population and during same time period) and analysis (sample analysis conducted at same lab using same methods/instruments and thus the same LOD), a statistical comparison could be made between the data collected in Canada and Mexico, which eliminated many of the challenges described above. This information highlights significant differences of contaminant concentrations in primiparous women (particularly p,p′-DDE, β-HCH and lead) which provide important information for North-American risk-management efforts to limit and reduce human exposure to contaminants.

Since the completion of the CEC Trinational Biomonitoring study, a number of other larger scale biomonitoring studies have been conducted in Canada (Haines et al., 2012). Future activities could use this new data for comparative purposes to further highlight differences in a more comprehensive manner, both nationally and internationally. Comparing these biomonitoring studies with other similarly designed studies, may allow for detection of smaller differences in contaminant levels, account for other variables impacting contaminant levels, and provide a comparison that is representative of the population.

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HIGHLIGHTS

- Higher concentrations of p,p′-DDE, β-HCH, and lead among Mexican primiparous women.
- PCB concentrations similar among Mexican and Canadian primiparous women.
- Age, pre-pregnancy BMI, ethnicity group, and ever-smoked status were significant.

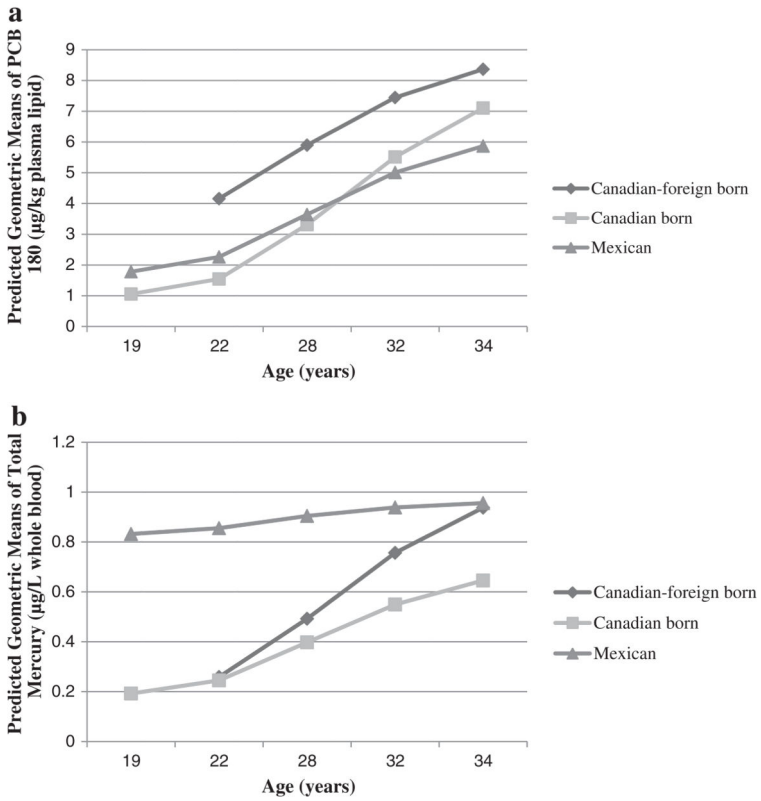

Fig. 1.

(a) Adjusted Geometric Means by Mother's Age for PCB 180 (µg/kg plasma lipid).(b) Adjusted Geometric Means by Mother's Age for Total Mercury (µg/L whole blood).

Table 1

Descriptive statistics and summary results for POPs (μg/kg plasma lipid) in primiparous women in Canada and Mexico.

Contaminant	Group	N	Detection limit	Percent detected	Min	Max	Geometric Mean	95% CI for geometric mean	
Oxychlordane	Canadian –foreign born	20	0.67	100	1.1	12	2.9	2.2	3.8
	Canadian –born	102	0.64	100	0.83	10	2.1	1.9	2.3
	Mexican All	240	0.65	89	ND	15	1.6	1.5	1.8
trans-nonachlor	Canadian–foreign born	20	1.3	100	1.7	27	4.3	3.1	5.9
	Canadian–born	103	1.3	89	ND	24	2.4	2.2	2.7
	Mexican All	240	1.3	82	ND	21	2.4	2.2	2.7
p,p′-DDE	Canadian–foreign born	20	12	100	33	1705	162	107	246
	Canadian–born	103	12	100	14	295	53	48	58
	Mexican All	240	12	100	47	19753	336	295	382
p,p′-DDT	Canadian–foreign born	19	6.7	16	ND	58	NA	NA	NA
	Canadian–born	103	6.5	0.97	ND	7.7	NA	NA	NA
	Mexican All	240	6.5	38	ND	3210	7.1 *	NA	8.4 *
β - HCH	Canadian–foreign born	20	1.3	95	ND	989	7.7	3.8	16
	Canadian–born	103	1.3	84	ND	26	2.1	1.9	2.4
	Mexican All	240	1.3	98	ND	210	8.3	7.3	9.5
PCB 118	Canadian–foreign born	20	1.3	95	ND	7.3	2.5	2.0	3.1
	Canadian–born	103	1.3	89	ND	13	2.2	1.9	2.4
	Mexican All	240	1.3	46	ND	58	NA	NA	NA
PCB 138	Canadian–foreign born	20	1.3	100	2.2	22	6.0	4.7	7.7
	Canadian–born	102	1.3	100	ND	21	3.7	3.3	4.1
	Mexican All	240	1.3	82	ND	51	2.4	2.2	2.6
PCB 153	Canadian–foreign born	20	1.3	100	4.4	49	11	8.6	14
	Canadian–born	103	1.3	100	ND	20	5.7	5.1	6.3
	Mexican All	240	1.3	93	ND	73	3.6	3.3	4.0
PCB 170	Canadian–foreign born	20	1.3	90	ND	13	2.7	2.0	3.8
	Canadian–born	103	1.3	52	ND	17	NA	NA	1.4 *
	Mexican All	240	1.3	42	ND	7.0	NA	NA	NA
PCB 180	Canadian–foreign born	20	1.3	100	1.7	32	7.9	5.9	11

Contaminant	Group	N	Detection limit	Percent detected	Min	Max	Geometric Mean	95% CI for geometric mean	
	Canadian–born	103	1.3	89	ND	86	3.4	2.9	4.1
	Mexican All	240	1.3	74	ND	44	2.1	1.9	2.3
PCB 187	Canadian–foreign born	20	1.3	85	ND	9.1	2.5	1.8	3.5
	Canadian–born	103	1.3	48	ND	17	NA	NA	NA
	Mexican All	240	1.3	20	ND	23	NA	NA	NA
PBDE 47	Canadian–foreign born	20	4.0	85	ND	141	15	8.6	25
	Canadian–born	103	3.9	82	ND	232	9.2	7.5	11
	Mexican All	240	3.9	33	ND	85	NA	NA	NA
PBDE 99	Canadian–foreign born	20	2.7	60	ND	24	3.3*	NA	5.2*
	Canadian–born	103	2.6	28	ND	83	NA	NA	NA
	Mexican all	240	2.6	13	ND	25	NA	NA	NA
PBDE 100	Canadian–foreign born	20	2.7	55	ND	22	3.3*	NA	5.2*
	Canadian–born	103	2.6	35	ND	47	NA	NA	NA
	Mexican All	240	2.6	7.5	ND	13	NA	NA	NA
PBDE 153	Canadian–foreign born	20	1.3	80	ND	42	3.4	1.9	6.1
	Canadian–born	103	1.3	87	ND	117	3.7	3.0	4.7
	Mexican all	240	1.3	33	ND	13	NA	NA	NA

ND, Non-detects (value below the limit of detection).

NA, Data not available (not calculated due to high number of non-detect samples).

*Due to high percentage of non-detects, these results should be interpreted with caution.

Table 2

Descriptive statistics and summary results for metals (μg/L whole blood) in primiparous women in Canada and Mexico.

Contaminant	Group	N	Detection Limit	Percent Detected	Min	Max	Geometric Mean	95% CI for geometric mean	
Total mercury	Canadian–foreign born	16	0.10	94	ND	4.2	0.88	0.55	1.4
	Canadian–born	77	0.10	92	ND	2.8	0.40	0.32	0.50
	Mexican all	233	0.10	97	ND	18	0.86	0.75	0.97
Inorganic mercury	Canadian–foreign born	16	0.40	6.3	ND	0.96	NA	NA	NA
	Canadian–born	76	0.40	2.6	ND	0.90	NA	NA	NA
	Mexican all	233	0.40	24	ND	18	NA	NA	NA
Lead	Canadian–foreign born	16	0.21	100	3.5	33	7.8	5.7	11
	Canadian–born	77	0.21	100	2.7	12	5.7	5.3	6.1
	Mexican all	233	0.21	100	5.6	228	25	23	27
Cadmium	Canadian–foreign born	16	0.04	100	0.25	2.0	0.59	0.42	0.83
	Canadian–born	77	0.04	100	0.16	5.0	0.46	0.38	0.55
	Mexican all	233	0.04	100	0.16	1.7	0.36	0.34	0.37
Selenium	Canadian–foreign born	16	7.9	100	134	284	199	183	216
	Canadian–born	77	7.9	100	150	253	190	186	195
	Mexican all	233	7.9	100	118	245	164	161	167
Nickel	Canadian–foreign born	16	0.35	100	0.59	4.1	2.5	2.0	3.2
	Canadian–born	77	0.35	100	ND	5.6	2.1	1.9	2.4
	Mexican all	233	0.35	100	1.3	6.5	3.2	3.1	3.3
Cobalt	Canadian–foreign born	16	0.05	94	ND	0.41	0.23	0.16	0.32
	Canadian–born	77	0.05	97	ND	1.8	0.24	0.21	0.28
	Mexican all	233	0.05	100	0.17	3.0	0.41	0.38	0.43
Thallium	Canadian–foreign born	16	0.01	63	ND	0.04	0.02*	NA	0.02*
	Canadian–born	77	0.01	58	ND	0.04	NA	NA	0.02*
	Mexican all	232	0.01	64	ND	0.13	0.02*	0.02*	0.02*
Tin	Canadian–foreign born	16	0.24	81	ND	1.8	0.43	0.28	0.65
	Canadian–born	77	0.24	66	ND	12	0.32*	0.26*	0.41*
	Mexican all	233	0.24	60	ND	7.4	0.24*	NA	0.27*

ND, Non-detects (value below the limit of detection).

NA, Data not available (not calculated due to high number of non-detect samples).

* Due to high percentage of non-detects, these results should be interpreted with caution.

Table 3

Descriptive Statistics of demographic variables for Canadian and Mexican Mothers.

Group	Sample size	Mean	Standard deviation	Minimum	25th percentile	75th percentile	Maximum
Maternal age							
Canadian–foreign born	20	33	3.8	25	31	35	41
Canadian–born	101	29	4.9	18	26	31	40
Mexican	240	21	4.0	15	18	23	33
Pre-pregnancy body mass index (BMI)							
Canadian–foreign born	20	23	2.7	19	22	25	29
Canadian–born	93	25	6.2	17	21	26	47
Mexican	234	23	4.7	13	20	26	42
Monthly family income[a]							
Canadian–foreign born	17	7215	5540	1900	5000	7000	27500
Canadian–born	65	5353	2932	0.0	3400	7000	15000
Mexican	231	254	193	25	166	331	1657
Years residing in current city							
Canadian–foreign born	20	17	12	0.8	6.8	25	40
Canadian–born	98	15	10	0.1	5.5	23	36
Mexican	235	18	6	0.0	15	21	33

History of smoking – ever smoking status

Group	Ever smoking status	Sample size	Percent (%)
Canadian–foreign born	Yes	9	45
	No	11	55
Canadian–born	Yes	39	41
	No	55	59
Mexican	Yes	95	40
	No	145	60

Smoking during pregnancy[b]

Group	Smoking during pregnancy	Sample size	Percent (%)
Canadian–foreign born	Yes	NR	NR

Smoking during pregnancy[b]			
Group	**Smoking during pregnancy**	**Sample size**	**Percent (%)**
	No	NR	NR
Canadian–born	Yes	13	34
	No	25	66
Mexican	Yes	16	17
	No	79	83

Current smoking status[b]			
Group	**Current smoking status**	**Sample size**	**Percent (%)**
Canadian–foreign born	Yes	NR	NR
	No	NR	NR
Canadian–born	Yes	7	19
	No	30	81
Mexican	Yes	NR	NR
	No	NR	NR

Highest level of maternal education						
Group	**Canadian–foreign born**		**Canadian–born[c]**		**Mexican**	
	Frequency	**Percent**	**Frequency**	**Percent**	**Frequency**	**Percent**
Elementary, incomplete	0	0	0	0	12	5
Elementary completed	0	0	0	0	37	15
Middle School, incomplete	0	0	0	0	29	12
Middle School, completed	0	0	0	0	68	28
High School, incomplete	0	0	5	5.4	37	15
High School, completed	0	0	13	14	25	10
Technical degree, completed	NR	NR	16	17	10	4.2
Bachelor’s degree, incomplete	NR	NR	6	6.5	16	6.7
Bachelor’s degree, completed	13	68	36	39	6	2.5
Postgraduate degree, completed	NR	NR	16	17	0	0

NR = Not reported to protect participant confidentiality.

[a]Income for Mexican mothers was converted from pesos to Canadian dollars using the conversion factor of 1 = peso 0.08287 Canadian dollars (as of Feb. 18, 2014).

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[b] Only ever smokers were included in the above table.

[c] One Canadian-born mother was omitted due to a coding error.

Table 4

Spearman rank correlations between demographic variables.

	Age	Pre-pregnancy BMI	Monthly Family Income (CDN $)[a]	Years residing in Current City
Age	1.0000	0.2673 (p < 0.0001)	0.5122 (p < 0.0001)	0.1578 (p = 0.003)
Pre-pregnancy BMI		1.0000	0.1100 (p = 0.0547)	0.0721 (p = 0.1844)
Monthly family Income			1.0000	−0.1537 (p = 0.0070)
Years residing in current city				1.0000

[a]Income for Mexican mothers was converted from pesos to Canadian dollars using the conversion factor of 1 peso = 0.08287 Canadian dollars (as of February 18, 2014).

Table 5

Final multiple regression models of natural log concentrations.

Contaminant	Parameter	Estimate	P-value	R^2
Cadmium	Intercept	−0.9647	<.0001	0.155
	Ethnicity: Canadian-foreign born (reference – Mexican)	0.1713	<.0001	
	Ethnicity: Canadian–born (reference – Mexican)	0.5169		
	Ever smoked (reference – Yes)	−0.1018	0.5813	
	Ethnicity: Canadian–foreign born*non-smoker	0.5343	0.0007	
	Ethnicity: Canadian Mothers*non-smoker	−0.3808		
Cobalt	Intercept	−0.5812	<.0001	0.195
	Ethnicity: Canadian–foreign born (reference – Mexican)	−0.4057	<.0001	
	Ethnicity: Canadian–born (reference – Mexican)	−0.4083		
	Age	−0.0151	0.0244	
Lead	Intercept	2.8660	<.0001	0.546
	Ethnicity: Canadian–foreign born (reference – Mexican)	−1.3648	<.0001	
	Ethnicity: Canadian–born (reference – Mexican)	−1.5933		
	Age	0.0167	0.0303	
Nickel	Intercept	1.1729	<.0001	0.215
	Ethnicity: Canadian–foreign born (reference – Mexican)	−0.2609	<.0001	
	Ethnicity: Canadian–born (reference – Mexican)	−0.4131		
Selenium	Intercept	4.9269	<.0001	0.273
	Ethnicity: Canadian–foreign born (reference – Mexican)	0.0898	0.0003	
	Ethnicity: Canadian–born (reference – Mexican)	0.0900		
	Age	0.0083	<.0001	
Total mercury	Intercept	−0.1958	0.5608	0.135
	Ethnicity: Canadian–foreign born (reference – Mexican)	−3.4679	0.0001	
	Ethnicity: Canadian–born (reference – Mexican)	−3.0044		
	Age	0.0019	0.0053	
	Age* Ethnicity: Canadian–foreign born (reference – Mexican)	0.1041	0.0077	
	Age* Ethnicity: Canadian–born (reference – Mexican)	0.0791		
PCB 138	Intercept	−0.3053	0.0920	0.224
	Ethnicity: Canadian–foreign born (reference – Mexican)	0.2399	0.3840	
	Ethnicity: Canadian–born (reference – Mexican)	0.0099		
	Age	0.0564	<.0001	
PCB 153	Intercept	0.3000	0.1792	0.299
	Ethnicity: Canadian–foreign born (reference – Mexican)	0.2481	0.0923	
	Ethnicity: Canadian–born (reference – Mexican)	−0.0990		
	Age	0.0713	<.0001	
	Pre-pregnancy BMI	−0.0212	0.0032	
PCB 180	Intercept	−0.3228	0.2517	0.37
	Ethnicity: Canadian–foreign born (reference – Mexican)	1.0722	0.0178	
	Ethnicity: Canadian–born (reference – Mexican)	−1.4287		

Contaminant	Parameter	Estimate	P-value	R^2
	Age	0.0794	<.0001	
	Pre-pregnancy BMI	−0.0258	0.0016	
	Age*Ethnicity: Canadian–foreign born (reference – Mexican)	−0.0211	0.0416	
	Age*Ethnicity: Canadian–born (reference – Mexican)	0.0476		
Oxychlordane	Intercept	−0.7857	<.0001	0.225
	Ethnicity: Canadian–foreign born (reference – Mexican)	−0.1681	0.0565	
	Ethnicity: Canadian–born (reference – Mexican)	−0.2103		
	Age	0.0607	<.0001	
p,p′-DDE	Intercept	4.2736	<.0001	0.523
	Ethnicity: Canadian–foreign born (reference – Mexican)	−1.6310	<.0001	
	Ethnicity: Canadian–born (reference – Mexican)	−2.4274		
	Age	0.0742	<.0001	
trans-Nonachlor	Intercept	−0.7423	<.0001	0.237
	Ethnicity: Canadian–foreign born (reference – Mexican)	−0.3843	<.0001	
	Ethnicity: Canadian–born (reference – Mexican)	−0.5961		
	Age	0.0783	<.0001	
β-HCH	Intercept	−0.0020	0.9934	0.406
	Ethnicity: Canadian–foreign born (reference – Mexican)	−1.3189	<.0001	
	Ethnicity: Canadian–born (reference – Mexican)	−2.1614	<.0001	
	Age	0.1022	<.0001	

Table 6

Scheffé multiple pair-wise comparison results for ethnicity groups.

Contaminant	Group	Similar group	Adjusted Geometric Mean (95% CI)
Cadmium	Canadian–foreign born*Non-smoker	A	0.70 (0.52, 0.93)
	Canadian–foreign born*Ever smoker	AB	0.45 (0.31, 0.66)
	Canadian–born*Non-smoker	B	0.39 (0.34, 0.46)
	Canadian–born*Ever-smoker	A	0.64 (0.54, 0.76)
	Mexican*Non-smoker	B	0.34 (0.32, 0.37)
	Mexican *Ever-smoker	B	0.38 (0.35, 0.42)
Cobalt	Canadian–foreign born	A	0.26 (0.20, 0.35)
	Canadian–born	A	0.26 (0.23, 0.30)
	Mexican	B	0.39 (0.37, 0.42)
Lead	Canadian–foreign born	A	6.6 (4.8, 9.2)
	Canadian–born	A	5.3 (4.5, 6.1)
	Mexican	B	26 (24, 28)
Nickel	Canadian–foreign born	A	2.5 (2.1, 2.9)
	Canadian–born	A	2.1 (2.0, 2.3)
	Mexican	B	3.2 (3.1, 3.4)
Selenium	Canadian–foreign born	A	183 (170, 197)
	Canadian–born	A	183 (177, 183)
	Mexican	B	167 (164, 170)
p,p′-DDE	Canadian–foreign born	A	81 (53, 123)
	Canadian–born	B	37 (30, 44)
	Mexican	C	415 (367, 469)
trans-Nonachlor	Canadian–foreign born	A	2.1 (1.5, 2.8)
	Canadian–born	A	1.7 (1.4, 1.9)
	Mexican	B	3.0 (2.8, 3.3)
β-HCH	Canadian–foreign born	A	3.0 (1.9, 4.7)
	Canadian–born	B	1.3 (1.0, 1.6)
	Mexican	C	11 (9.8, 13)

Table 7

Pearson Correlations between PCB 138, 153, 180 and demographic covariates (p-value).

All mothers	**PCB 153**	**PCB 180**	**Age**	**Pre-BMI**
PCB 138	0.9262 (p < .0001)	0.8198 (p < .0001)	0.4686 (p < .0001)	0.0277 (p = 0.6072)
PCB 153		0.8943 (p < .0001)	0.5227 (p < .0001)	−0.0300 (p = 0.5776)
PCB 180			0.5641 (p < .0001)	−0.0420 (p = 0.4355)
Age				0.2156 (p < .0001)
Canadian–foreign born	PCB 153	PCB 180	Age	Pre-BMI
PCB 138	0.9451 (p < .0001)	0.7249 (p = 0.0003)	0.4103 (p = 0.0724)	0.1553 (p = 0.5132)
PCB 153		0.8826 (p < .0001)	0.4536 (p = 0.0445)	−0.0131 (p = 0.9564)
PCB 180			0.3293 (p = 0.1562)	−0.2031 (p = 0.3903)
Age				0.0877 (p = 0.7130)
Canadian born	PCB 153	PCB 180	Age	Pre-BMI
PCB 138	0.8165 (p < .0001)	0.7376 (p < .0001)	0.4869 (p < .0001)	−0.1304 (p = 0.2152)
PCB 153		0.8783 (p < .0001)	0.6487 (p < .0001)	−0.2489 (p = 0.0161)
PCB 180			0.6755 (p < .0001)	−0.2057 (p = 0.0479)
Age				−0.0708 (p = 0.5049)
Mexican	PCB 153	PCB 180	Age	Pre-BMI
PCB 138	0.9370 (p < .0001)	0.8354 (p < .0001)	0.2879 (p < .0001)	0.0255 (p = 0.6980)
PCB 153		0.8944 (p < .0001)	0.3043 (p < .0001)	−0.0089 (p = 0.8920)
PCB 180			0.3372 (p < .0001)	−0.0118 (p = 0.8574)
Age				0.3338 (p < .0001)