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Predictors of plasma concentrations of polybrominated diphenyl ethers (PBDEs) among pregnant African American women in urban Atlanta: the CHERUB study

By

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Environmental Health

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B.A.
Sun Yat-Sen University
2016

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An abstract of
A thesis submitted to the Faculty of the
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2018

Abstract

Predictors of plasma concentrations of polybrominated diphenyl ethers (PBDEs) among pregnant African American women in urban Atlanta: the CHERUB study

By Yitong Guo

Background: Recent research suggests that prenatal exposure to PBDEs during critical periods of development may impair infant neurodevelopment. **Objective:** The present study aimed to assess the body burden of PBDEs among pregnant African American women living in urban Atlanta, as well as to examine the predictors of PBDE concentrations in maternal plasma. **Method:** To date, 108 eligible women have been enrolled in Characterizing Exposures and Outcomes in an Urban Birth Cohort (CHERUB). PBDE concentrations were measured using GC-MS/MS in maternal plasma. We ran univariate and multivariate linear models to assess the relations between demographic, lifestyle and dietary predictors and PBDE concentrations. **Results:** Only BDE-47, -99 and -100 had frequencies of detection over 50%. The medians (range) were 76.3 (20.7-772.1) pg/mL for BDE-47, 23.8 (< LOD-342.0) pg/mL for BDE-99 and 12.5 (< LOD-289.2) pg/mL for BDE-100. Adjusted for other variables, being married (β=0.38, p<0.01) and action of shaking rug (β =0.57, p<0.01) were predictors for a lower BDE-47 level in maternal plasma; BDE-99 concentration increased with recent consumption of canned meats (β =2.80, p=0.02); while being married (β =0.14, p<0.01) and action of shaking rug (β =0.33, p<0.01) were also inversely associated with BDE-100 concentration, achieving college or equivalent degrees (β =3.02, p=0.02) and recent consumption of canned meats (β =2.45, p=0.08) were found to increase BDE-100 concentration.

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I. Introduction

Polybrominated diphenyl ethers (PBDEs) are brominated flame retardants that have been widely used in plastics, textiles, upholstery and electronics since 1970's. At high temperature, PBDEs release bromine radicals to reduce the rate of combustion and dispersion of fire. Three commercial products were produce and sold in the market: penta-, octa- and decaBDE, among which decaBDE was the most widely used PBDE globally. In the United States, the manufacturers and importers of PBDE mixtures had successively launched voluntary phase-out plans of these compounds since the late 20th century. The production of octaBDE and pentaBDE ceased at the end of 2004, and decaBDE was later banned in 2013 (Birnbaum & Staskal, 2004). However, with extensive manufacture and usage over the past decades, PBDEs are found ubiquitous in the U.S. and worldwide population (Fromme, Becher, Hilger, & Volkel, 2016). Several biomonitoring studies suggest an overall decline in levels of human exposure to PBDEs since the domestic and global phase-out of these chemicals from the market (Zota et al., 2013), following by a plateau of concentrations in the recent years (Parry, Zota, Park, & Woodruff, 2018).

PBDEs are persistent, lipid-soluble and can bioaccumulate in both creatures and the environment, leading to growing concerns regarding the potential health effects they could have on human beings. Human PBDE toxicity is largely thought to be due to endocrine disruption, especially of thyroid hormone function. Pregnant women, in a special period of increased demand on the maternal thyroid gland, may suffer more from thyroid hormone dysregulation (Legler, 2008). PBDEs also post a threat on the brain development of infants because they can readily pass through blood-placenta barrier (Kim et al., 2009) and the blood-brain barrier, metabolize and accumulate in the central nervous system (Zhang, Bursian, Martin, Chan, & Martin, 2008), adversely affecting neuronal proliferation, migration, synaptogenesis, synaptic plasticity, and myelination (Dingemans, van den Berg, & Westerink, 2011). Additionally, prior animal studies show that PBDEs have reproductive toxicity, immunotoxicity, liver toxicity and pancreas effects. Limited evidence of carcinogenic potential is suggested for decaBDE (EPA, 2017).

Routes of potential exposure to PBDEs involve ingestion, inhalation and dermal contact, where inhalation of contaminated household dust accounts for majority of PBDE exposure (Lorber, 2008). Because of noncovalent binding of PBDEs to the surface of commercial products, these compounds can be readily leached into the household dust and soon attached to airborne particulate matter (Legler, 2008). In addition, food items including fish and meat from high trophic levels and dairy products with high fat contain elevated concentrations of PBDEs (Frederiksen, Vorkamp, Thomsen, & Knudsen, 2009).

In the United States, both AA and Hispanic population are found to have higher levels of PBDEs (CDC, 2018). The reason for this disproportionate exposure remain uncertain. Given the potential adverse birth outcomes in children with prenatal exposure to PBDEs, it is of great importance to identify sources of PBDE exposures in women of childbearing age, to characterize vulnerable subpopulations, and to inform interventions to reduce exposure. The current study primarily investigates the extent of maternal exposure to PBDEs among pregnant AA women living in urban Atlanta, Georgia between 2015 and 2016, and characterizes demographic, behavioral, dietary and lifestyle predictors of PBDE exposures.

II. Method

Study sample

The study sample comprises 108 healthy pregnant women participating in the Characterizing Exposures and Outcomes in an Urban Birth Cohort (CHERUB), which is an ongoing cohort expecting to have complete data on ≥ 300 AA mother-infant pairs from urban Atlanta through an 18-month follow-up. Women who 1) self-identified as Black and were born in the United States, 2) had singleton pregnancy between 8-14 weeks of gestation (verified by clinical record), 3) were able to comprehend written and spoken English, 4) aged 18-35 years, and 5) had no chronic medical conditions or chronic medications (verified by prenatal record). Socio-demographic information was collected during 8-14 weeks of gestation using self-report and prenatal records, including maternal age, marital status (single, married), education level (high school or less, college or equivalent, graduate school), household income (<100%, 100-299%, ≥ 300% of poverty line). The institutional Review Board (IRB) of Emory University approved this study protocol. Written informed consent was obtained from all subjects and included a statement that all data presented for publication would be grouped, rather than individual.

Biological sample collection and laboratory analysis

Maternal blood (12 mL) was collected via venipuncture at 8-14 weeks of gestation at a routine prenatal care. Blood was drawn into EDTA tubes and transported on ice to the School of Nursing Biobehavioral Laboratory in Emory University. Blood samples were processed to extract plasma, aliquoted and stored at -80°C for subsequent analyses. Up to 3 mL of plasma of each participant was made available for this study. BDE-47, -85, -99, -100, -153 and -154 were later measured in plasma in Laboratory of Exposure Assessment and Development in Environmental Research (LEADER) in Emory University. Plasma samples were fortified with isotopically labeled analogues of the target chemicals, homogenized and deproteinated. Supernatant was extracted twice with hexane and dichloromethane, which then passed through activated silica gel column to remove residual biogenic material. Sample extracts were concentrated and analyzed using gas chromatography-tandem mass spectrometry (GC-MS/MS) with isotope dilution calibration. The limit of detection (LODs) were 2.5 pg/mL for BDE-47 and -99, 12.5 pg/mL for BDE-85, -100 and -153, and 62.5 pg/mL for BDE-154.

Exposure questionnaire data

Participants were given a structured questionnaire regarding determinants of PBDEs exposure administered by a trained researcher at a 30-minute home visit when they achieved 20-24 weeks' gestation. For lifestyle factors, participants were asked about the housing characteristics of the home they currently lived, including age of the home (<5 years, 5-10 years, 10-20 years, >20 years, or unknown), type of home (brick or concrete single family home, wood or siding single family home, brick or concrete multifamily home, apartment with single room, apartment with >1 rooms, mobile home, or others), and age of the couch (<5 year, or >5 years). Participants were also asked if they were the person in the household who usually cleaned the home (floors, bathrooms, kitchens) and methods of cleaning (mop, broom, and vacuum). Questions regarding dietary factors only involved times participants consumed canned meats in the last 48 hours prior to the home visit (none, 1-5, 6-10, 11-16, or >16).

Data analysis

PBDE congeners had positively skewed distribution given histograms, Q-Q plots and Shapiro-Wilk test results. Medians and interquartile ranges were reported for PBDE concentrations as picograms per milliliter (pg/mL) plasma. Decile categories of PBDE exposure were presented according to the distribution of values in the dataset. PBDE values were log-transformed for subsequent analysis as distributions approximated lognormal than normal. Regression analyses were used to confirm residual homoscedasticity and normality. Pearson correlation coefficients were calculated using log-transformed PBDE values. We then fitted generalized linear regression models to examine univariate and multivariate associations between potentials predictors and log-transformed plasma PBDE concentrations at significance level of 0.1. Stepwise procedure was applied to select the best model with SLE=SLS=0.1. 12 predictors were examined including maternal age (continuous), marital status, maternal education level, household income, home age, home type, couch age, whether cleaning house by yourselves, using brooms, using vacuums, shaking rug, and consumption of canned meat in the last 48 hours preceding the interview. In these models, the estimated coefficient of predictor variables was exponentiated and interpreted as the ratio of geometric means in the outcome variable comparing either unit changes (for continuous variables) or categories compared to the reference category (for categorical variables), adjusted for other variates. The adjusted coefficient of determination R^2 was used to indicate the proportion of variability in the data that was accounted for by the statistical model with multiple predictors. All statistical analyses were conducted using SAS 9.4 (SAS Institute Inc, Cary, North Carolina).

III. Results

Population characteristics

Table 1 presents demographic, lifestyle and dietary characteristics of the AA mothers participating in this cohort. The mean maternal age was 26 (range 19-40) years. Most of them (86%) were unmarried. Around 60% of them achieved a high school education or less, and 35% obtained some college or had completed college at the time of enrollment. Five women (5%) received graduate education or degrees. 45% reported a total household income of 2014 below 100% of the federal poverty line. As for lifestyle characteristics, around 60% of our participants reported that the age of their current house was at least 10 years old. 40% lived in brick or concrete home and 25% lived in an apartment with more than 1 rooms. No participant reported living in mobile home. More than half of the women had relatively new couch (< 5 years). About 80% claimed they did house cleaning since being pregnant. Most women (90%) ever used brooms for cleaning, 74% ever used vacuums and about half would shake rugs. Only 7 women had consumed 1-5 times canned meats in the last 48 hours prior to the questionnaire, while the rest reported no intake of canned meats.

PBDE concentrations in maternal plasma

Descriptive statistics of PBDE concentrations in maternal plasma are showed in **Table 2**. At least one PBDE congener was detected in all the 108 plasma samples and only BDE-47, -99 and -100, with a frequency of detection over 50%, were included in the subsequent analysis. The median values for maternal plasma BDE-47, -99 and -100 concentrations were 76.3, 23.8 and 12.5 pg/mL respectively. 5% of participants had PBDE concentrations 4-23 times higher than the median. Ranges for the highest 5% of plasma PBDE concentrations were 314.1-772.1 pg/mL for BDE-47, 104.4-342.0 pg/mL for BDE-99, and 82.1-289.2 pg/mL for BDE-100. We also provided estimated lipid-adjusted concentrations of all 3 frequently detected PBDE congeners using the method and the estimated total lipid value published elsewhere (Bernert, Turner, Patterson, & Needham, 2007). Log-transformed concentrations of these 3 PBDE congeners were highly correlated with each other (Pearson's $r > 0.70$, $p < 0.001$).

Predictors of PBDE concentrations in maternal plasma

Table 3 presents results of univariate and multivariate regression analyses between predictors and plasma PBDE concentrations. Univariate estimations indicated that subjects using vacuums for house cleaning had lower maternal concentrations of both BDE-47 (p=0.06) and -100 (p=0.05), compared to those without vacuum usage. Consumption of canned meats in the last 48 hours was strongly positively associated with PBDE levels in maternal plasma. Subjects who consumed canned meats had concentrations 1.67 (p=0.03), 3.08 (p=0.01) and 4.02 (p=0.02) times, for BDE-47, -99 and -100 respectively, that of those who didn't. Additionally, concentrations of BDE-99 were found highest among women living in the apartment with a single room (p=0.02), and for both BDE-99 and -100, concentrations were found lowest among those living in a brick or concrete multifamily home (p=0.08-0.09).

We then identified unique multiple predictor patterns for each PBDE congener and calculated the total variance explained by the combination of predictors (adjusted R^2), ranging from 11.10% (BDE-99) to 39.38% (BDE-47). In final models, being married (GMR=0.38, p<0.01) and action of shaking rug (GMR=0.57, p<0.01) were predictors for a lower BDE-47 level in maternal plasma; BDE-99 concentration increased with recent consumption of canned meats (GMR=2.80, p=0.02); while being married (GMR=0.14, p<0.01) and action of shaking rug (GMR=0.33, p<0.01) were also inversely associated with BDE-100 concentration, achieving college or equivalent degrees (GMR=3.02, p=0.02) and recent consumption of canned meats (GMR=2.45, p=0.08) were found to increase BDE-100 concentration.

IV. Discussion

Our cohort comprised pregnant African-American women age 19-40 enrolled from suburban Atlanta area, where PBDE exposure was widespread. The levels of BDE-47 and -100 in this cohort were about 50% lower than those reported among the U.S. women in the 2009-2010 National Health and Nutrition Examination Survey (NHANES), while the BDE-99 level was equivalent. In NHANES, PBDE levels, in general, were higher in non-Hispanic blacks than in non-Hispanic whites or Mexican Americans. Parry (2018) reported some of the highest levels of PBDEs in the country in participants in 2008 and 2010 in California, an area known to have higher PBDE exposure because of strict fire safety laws. Despite the observed decline in PBDEs over the course of this study, levels from 2013-2014 were still about 2.5 times higher than the levels in our study. A cohort of predominantly non-Hispanic black pregnant women living in North Carolina between 2008 and 2010 had serum PBDE levels up to 4.5 times higher than those measured in our cohort (Buttke, Wolkin, Stapleton, & Miranda, 2013). Vuonge (2015) also reported high PBDE levels, similar to those in the BUTTKE study, in a predominantly non-Hispanic white cohort of pregnant women in Ohio in 2003. Levels and patterns of PBDEs measured in an African American and Dominican cohort of pregnant women in New York City between 2009 and 2010 were comparable to those reported in our study (Horton et al., 2013). Though generally lower than others reported in the United States, PBDE levels in our study were still up to 8 times higher those measured in Australia (Stasinska et al., 2014), Netherlands and Sweden (Foster et al., 2011), consistent with estimates that North Americans have the highest global body burden of PBDEs. Early restrictions and bans on use of penta- and octa-BDEs may account for lower levels of PBDE exposure in Europe.

In most studies, BDE-47, -99, -100 and -153 accounts for the majority of PBDE body burden, however, BDE-153 was detected with low frequency in our study. The low frequency of detection of BDE-153 may result from exposure to “weathered” PBDEs in the environment where BDE-153 is declining. BDE-47 is the predominant congener, which may be due to its higher potential of bioaccumulation (Burreau, Zebuhr, Broman, & Ishaq, 2006). Consistent with other literature, BDE-47, -99 and -100 were highly correlated with each other in this study. They are all components of the penta-BDE technical mixture. Environmental penta-BDE congeners are likely to originate from the off gassing of products containing these mixtures such as couches, mattresses and other foam items and/or from the degradation of deca-BDE (Soderstrom, Sellstrom, De Wit, & Tysklind, 2004).

In Herbstman (2017), younger maternal age was predictive of higher levels of PBDEs in cord blood, while being married, achieving higher income and education levels were associated with lower PBDE levels. Weight gain during pregnancy, parity and smoke status were also associated with PBDE levels, though these factors were not included in our study. Similarly, Horton (2013) found that levels of BDE-47 and -99 were lower in women with higher education. BDE-153 levels were weakly associated with prepregnancy BMI. A predominantly Mexican immigrant cohort of pregnant women in California revealed that serum PBDE levels also increased with years residing in the United States. In our study, the effects of income/marital status on PBDE levels were comparable to those in the previous studies. However, we observed an inverse association between age and PBDE levels, though it was insignificant. BDE-47 and -99 levels were highest among women with graduate degree compared to those with lower education, while BDE-100 level was highest among women with college or equivalent degree, compared to those with lower education and those with higher education. The trends in our cohort was inconsistent with those reported in the previous studies, which may be associated with the time of sample collection, the catchment areas of the enrollment and the different demographic distribution of the cohorts.

Several studies have considered the number of electronics (i.e., large-screen TV, computers) in home a significant predictor of PBDE levels in maternal blood (Buttke et al. 2013; Horton et al. 2013; Stasinka et al. 2014). Household electronics would influence levels of PBDEs in house dust, which was thought to be the major source of indoor PBDE exposure (Allen, McClean, Stapleton, & Webstert, 2008). House dust contributes to PBDE body burden either through oral intake of the dust or via dermal absorption. The number of stuffed furniture (Castorina et al., 2011) or new furniture (Buttke et al. 2013) were associated with higher blood PBDE levels among pregnant women, which may be due to extensive use of penta-BDE in polyurethane foam in furniture. Other household factors such as type of home, age of home and use of carpet were also examined in the previous studies, though none was reported as significant predictor (Buttke et al. 2013; Stasinka et al. 2014). In our study, we only observed significant differences on plasma BDE-47 and -100 levels between pregnant women who had shaken rugs and those who did not, adjusted for other variables. The movement of rug shaking appears to be an effective way to get rid of dust. Similarly, Rose et al. (2010) found that children living in larger homes were associated with lower levels of BDE-209. This may be because all electronics (i.e., TV, computers, ect.) and furniture had to be put in the same room, leading to more frequent and lasting exposure to upholstery.

As PBDEs are lipophilic and bioaccumulative, lipid-rich food such as fish, meats and dairy products is another important source of exposure to PBDEs (Costa, Giordano, Tagliaferri, Caglieri, & Mutti, 2008). Schecter et al. (2010) quantified levels of PBDEs in commonly consumed foods in the United States and showed that the highest levels of PBDEs were in butter and fish, while lowest levels of PBDEs were in other liquid dairy products (milk and yogurt) and vegetables. Fraser (2009) used NHANES data to examine the association between food items and serum PBDE levels and showed that intake of poultry and red meat contributed significantly to PBDE body burden in the United States. Although fish had the highest PBDE levels, most dietary PBDE intake of the average American comes from meat, then dairy and fish (Schecter et al. 2008). In our study, women with higher levels of BDE-99 and -100 were likely to report recent consumption of canned meats, which was consistent to the association reported in the Horton study.

Our study has several limitations. With respect to the questionnaire data, demographic characteristics including years residing in the United States, prepregnancy BMI, weight gain during pregnancy, parity and smoke status, household/lifestyle characteristics regarding electronics and furniture, and dietary characteristics regarding consumption of fish and dairy products are not included in our study. Several studies have suggested difference on PBDE body burden by these characteristics. Further, we do not have environmental monitoring data on PBDE concentrations in house dust, nor assessment of dermal absorption. Additionally, with respect to data analysis, we do not adjust our PBDE levels for lipid contents.

V. Conclusion

In conclusion, prenatal exposure to PBDE congeners is prevalent among this African American cohort of healthy pregnant women living in suburban Atlanta, while plasma PBDE levels are low compared to those reported in other cohorts of pregnant women in the United States. We identified that married women were likely to have lower levels of BDE-47 and -100; movements of shaking rug tended to lower levels of BDE-47 and -100. Consumption of canned meats is a predictor of higher levels of BDE-99 and -100. There is still much uncertainty about metabolism mechanisms, toxicity and interactions of PBDE congeners. These findings require further investigation in a study with a large sample size and with collection of more demographic, household/lifestyle and dietary characteristics.

VI. Reference

Allen, J. G., McClean, M. D., Stapleton, H. M., & Webstert, T. F. (2008). Linking PBDEs in house dust to consumer products using X-ray fluorescence. *Environmental Science & Technology, 42*(11), 4222-4228. doi:10.1021/es702964a

Bernert, J. T., Turner, W. E., Patterson, D. G., & Needham, L. L. (2007). Calculation of serum "total lipid" concentrations for the adjustment of persistent organohalogen toxicant measurements in human samples. *Chemosphere, 68*(5), 824-831. doi:https://doi.org/10.1016/j.chemosphere.2007.02.043

Birnbaum, L. S., & Staskal, D. F. (2004). Brominated flame retardants: cause for concern? *Environmental Health Perspectives, 112*(1), 9-17.

Burreau, S., Zebuhr, Y., Broman, D., & Ishaq, R. (2006). Biomagnification of PBDEs and PCBs in food webs from the Baltic Sea and the northern Atlantic Ocean. *Sci Total Environ, 366*(2-3), 659-672. doi:10.1016/j.scitotenv.2006.02.005

Buttke, D. E., Wolkin, A., Stapleton, H. M., & Miranda, M. L. (2013). Associations between serum levels of Polybrominated Diphenyl Ether (PBDE) flame retardants and environmental and behavioral factors in pregnant women. *Journal of exposure science & environmental epidemiology, 23*(2), 176-182. doi:10.1038/jes.2012.67

Castorina, R., Bradman, A., Sjodin, A., Fenster, L., Jones, R. S., Harley, K. G., . . . Eskenazi, B. (2011). Determinants of serum polybrominated diphenyl ether (PBDE) levels among pregnant women in the CHAMACOS cohort. *Environ Sci Technol, 45*(15), 6553-6560. doi:10.1021/es104295m

Costa, L. G., Giordano, G., Tagliaferri, S., Caglieri, A., & Mutti, A. (2008). Polybrominated diphenyl ether (PBDE) flame retardants: environmental contamination, human body burden and potential adverse health effects. *Acta Biomed, 79*(3), 172-183.

Dingemans, M. M., van den Berg, M., & Westerink, R. H. (2011). Neurotoxicity of brominated flame retardants: (in)direct effects of parent and hydroxylated polybrominated diphenyl ethers on the (developing) nervous system. *Environ Health Perspect, 119*(7), 900-907. doi:10.1289/ehp.1003035

EPA. (2017). Technical Fact Sheet - Polybrominated Diphenyl Ethers (PBDEs).

Foster, W. G., Gregorovich, S., Morrison, K. M., Atkinson, S. A., Kubwabo, C., Stewart, B., & Teo, K. (2011). Human maternal and umbilical cord blood concentrations of polybrominated diphenyl ethers. *Chemosphere, 84*(10), 1301-1309. doi:10.1016/j.chemosphere.2011.05.028

Fraser, A. J., Webster, T. F., & McClean, M. D. (2009). Diet contributes significantly to the body burden of PBDEs in the general U.S. population. *Environ Health Perspect, 117*(10), 1520-1525. doi:10.1289/ehp.0900817

Frederiksen, M., Vorkamp, K., Thomsen, M., & Knudsen, L. E. (2009). Human internal and external exposure to PBDEs--a review of levels and sources. *Int J Hyg Environ Health, 212*(2), 109-134. doi:10.1016/j.ijheh.2008.04.005

Fromme, H., Becher, G., Hilger, B., & Volkel, W. (2016). Brominated flame retardants - Exposure and risk assessment for the general population. *Int J Hyg Environ Health, 219*(1), 1-23. doi:10.1016/j.ijheh.2015.08.004

Herbstman, J. B., Sjoedin, A., Apelberg, B. J., Witter, F. R., Patterson, D. G., Halden, R. U., . . . Goldman, L. R. (2007). Determinants of prenatal exposure to polychlorinated biphenyls (PCBs) and polybrominated diphenyl ethers (PBDEs) in an urban population. *Environmental Health Perspectives, 115*(12), 1794-1800. doi:10.1289/ehp.10333

Horton, M. K., Bousleiman, S., Jones, R., Sjodin, A., Liu, X., Whyatt, R., . . . Factor-Litvak, P. (2013). Predictors of serum concentrations of polybrominated flame retardants among healthy pregnant women in an urban environment: a cross-sectional study. *Environmental Health, 12*(1), 23. doi:10.1186/1476-069x-12-23

Kim, T. H., Lee, Y. J., Lee, E., Patra, N., Lee, J., Kwack, S. J., . . . Kim, H. S. (2009). Exposure assessment of polybrominated diphenyl ethers (PBDE) in umbilical cord blood of Korean infants. *J Toxicol Environ Health A, 72*(21-22), 1318-1326. doi:10.1080/15287390903212436

Legler, J. (2008). New insights into the endocrine disrupting effects of brominated flame retardants. *Chemosphere, 73*(2), 216-222. doi:10.1016/j.chemosphere.2008.04.081

Lorber, M. (2008). Exposure of Americans to polybrominated diphenyl ethers. *J Expo Sci Environ Epidemiol, 18*(1), 2-19. doi:10.1038/sj.jes.7500572

Parry, E., Zota, A. R., Park, J. S., & Woodruff, T. J. (2018). Polybrominated diphenyl ethers (PBDEs) and hydroxylated PBDE metabolites (OH-PBDEs): A six-year temporal trend in Northern California pregnant women. *Chemosphere, 195*, 777-783. doi:10.1016/j.chemosphere.2017.12.065

Rose, M., Bennett, D. H., Bergman, A., Fangstrom, B., Pessah, I. N., & Hertz-Picciotto, I. (2010). PBDEs in 2-5 year-old children from California and associations with diet and indoor environment. *Environ Sci Technol, 44*(7), 2648-2653. doi:10.1021/es903240g

Soderstrom, G., Sellstrom, U., De Wit, C. A., & Tysklind, M. (2004). Photolytic debromination of decabromodiphenyl ether (BDE 209). *Environmental Science & Technology, 38*(1), 127-132. doi:10.1021/es034682c

Stasinska, A., Heyworth, J., Reid, A., Callan, A., Odland, J. O., Duong, P. T., . . . Hinwood, A. (2014). Polybrominated diphenyl ether (PBDE) concentrations in plasma of pregnant women from Western Australia. *Science of the Total Environment, 493*, 554-561. doi:10.1016/j.scitotenv.2014.06.001

Zhang, S., Bursian, S., Martin, P. A., Chan, H. M., & Martin, J. W. (2008). Dietary accumulation, disposition, and metabolism of technical pentabrominated diphenyl ether (de-71) in pregnant mink (Mustela vison) and their offspring. *Environ Toxicol Chem, 27*(5), 1184-1193. doi:10.1897/07-487.1

Zota, A. R., Linderholm, L., Park, J. S., Petreas, M., Guo, T., Priyalsky, M. L., . . . Woodruff, T. J. (2013). Temporal Comparison of PBDEs, OH-PBDEs, PCBs, and OH-PCBs in the Serum of Second Trimester Pregnant Women Recruited from San Francisco General Hospital, California. *Environmental Science & Technology, 47*(20), 11776-11784. doi:10.1021/es402204y

VII. Tables

Table 1

Demographic, lifestyle and dietary characteristics of 108 healthy pregnant AA women living in urban Atlanta area between 2015 and 2016

Characteristics		N (%)*
Demographic		
Maternal age (years, range)		26 (19 to 40)
Marital status		
	Single	88 (86.3%)
	Married	14 (13.7%)
Education		
	High school or less	61 (59.8%)
	College or equivalent	36 (35.3%)
	Graduate school	5 (4.9%)
Income		
	<100%	46 (45.1%)
	100-299%	38 (37.0%)
	>= 300%	18 (18.0%)
Lifestyle		
Age of home (years)		
	<5	5 (9.3%)
	5-10	11 (20.4%)
	10-20	15 (27.8%)
	>20	16 (29.6%)
	Unknown	7 (13.0%)
Type of home		
	Brick or concrete single family home	21 (38.9%)
	Wood or siding single family home	4 (7.4%)
	Brick or concrete multifamily home	3 (5.6%)
	Apartment with single room	5 (9.3%)
	Apartment with >1 rooms	13 (24.1%)
	Mobile home	0 (0.0%)
	Other	8 (14.8%)
Age of couch (years)		
	<5	27 (58.7%)
	≥5	19 (41.3%)
House cleaning		
	No	12 (22.2%)
	Yes	42 (77.8%)
Use brooms		
	No	5 (9.3%)
	Yes	49 (90.7%)
Use vacuums		
	No	14 (26.4%)
	Yes	39 (73.6%)
Shake rugs		
	No	28 (51.9%)
	Yes	26 (48.2%)
Dietary		
Canned meats (times)		
	0	47 (87.0%)
	1-5	7 (13.0%)

* Number of missing values for characteristics: maternal age (6), marital status (6), education (6), income (6), age of home (54), type of home (54), age of couch (62), house cleaning (54), use brooms (54), use vacuums (54), shake rugs (54), canned meats (54).

Table 2

PBDE concentrations in maternal plasma (pg/mL) from 108 pregnant women, CHERUB study

				Percentile				Median		GM (GSD)	
Congener	LOD	% > LOD	Min	25th	75th	95th	Max		Estimated ng/g lipid *		Estimated ng/g lipid
BDE-47	2.5	100.0	20.7	54.5	130.1	314.1	772.1	76.3	12.0	86.5 (2.0)	13.6 (0.3)
BDE-85	12.5	5.6	< LOD	< LOD	< LOD	17.9	172.5	< LOD	NA	< LOD	NA
BDE-99	6.25	74.1	< LOD	< LOD	38.2	104.4	342.0	23.8	3.7	19.7 (3.0)	3.1 (0.5)
BDE-100	2.5	58.3	< LOD	< LOD	29.4	82.1	289.2	12.5	2.0	8.7 (4.4)	1.4 (0.7)
BDE-153	12.5	32.4	< LOD	< LOD	53.3	160.4	271.6	< LOD	NA	< LOD	NA
BDE-154	62.5	24.1	< LOD	< LOD	< LOD	167.2	478.2	< LOD	NA	< LOD	NA

Abbreviations: LOD, limit of detection; GM, geometric mean; GSD, geometric standard deviation; NA, not available.

* Estimated total lipids = 6.36 g/L.

Table 3

β coefficients from univariate and multivariate regression models for selected PBDE congeners

	BDE-47				BDE-99				BDE-100			
	Crude β	90% CI	Adjusted β	90% CI	Crude β	90% CI	Adjusted β	90% CI	Crude β	90% CI	Adjusted β	90% CI
Demographic												
Maternal age (years, range)	0.99	(0.97 , 1.02)			1.01	(0.97 , 1.06)			0.97	(0.92 , 1.03)		
Marital status												
Single	1.00		1.00		1.00				1.00		1.00	
Married	0.82	(0.59 , 1.15)	0.38	(0.27 , 0.55)	0.96	(0.56 , 1.64)			0.61	(0.30 , 1.24)	0.14	(0.05 , 0.42)
Education												
High school or less	1.00				1.00				1.00		1.00	
College or equivalent	0.89	(0.69 , 1.13)			1.05	(0.71 , 1.55)			1.11	(0.66 , 1.87)	3.02	(1.43 , 6.38)
Graduate school	1.33	(0.77 , 2.29)			1.85	(0.78 , 4.39)			0.54	(0.17 , 1.70)	0.68	(0.17 , 2.72)
Income												
<100%	1.00				1.00				1.00			
100-299%	0.96	(0.74 , 1.24)			0.85	(0.57 , 1.28)			0.92	(0.53 , 1.58)		
>= 300%	0.91	(0.65 , 1.26)			0.75	(0.44 , 1.25)			0.68	(0.34 , 1.35)		
Lifestyle												
Age of home (years)												
<5	1.00				1.00				1.00			
5-10	1.04	(0.61 , 1.77)			0.72	(0.28 , 1.87)			0.70	(0.18 , 2.64)		
10-20	1.29	(0.78 , 2.14)			1.35	(0.54 , 3.35)			0.81	(0.23 , 2.92)		
>20	1.41	(0.85 , 2.33)			1.22	(0.49 , 3.02)			0.74	(0.21 , 2.63)		
Unknown	1.03	(0.58 , 1.83)			0.79	(0.28 , 2.23)			0.37	(0.09 , 1.56)		
Type of home												
Brick or concrete single family home	1.00				1.00				1.00			
Wood or siding single family home	0.91	(0.54 , 1.55)			1.15	(0.46 , 2.84)			0.76	(0.20 , 2.81)		
Brick or concrete multifamily home	0.56	(0.31 , 1.02)			0.34	(0.12 , 0.94)			0.22	(0.05 , 0.98)		
Apartment with single room	1.41	(0.87 , 2.28)			3.20	(1.40 , 7.31)			2.53	(0.77 , 8.38)		
Apartment with >1 rooms	1.01	(0.72 , 1.42)			0.83	(0.46 , 1.50)			0.92	(0.39 , 2.16)		
Other	0.81	(0.54 , 1.21)			1.01	(0.51 , 2.01)			0.74	(0.27 , 2.00)		
Age of couch (years)												
<5	1.00				1.00				1.00			
≥5	1.23	(0.91 , 1.66)			1.41	(0.83 , 2.38)			1.74	(0.86 , 3.55)		
House cleaning												
No	1.00				1.00				1.00			
Yes	0.81	(0.59 , 1.12)			0.83	(0.47 , 1.48)			0.53	(0.24 , 1.16)		
Use brooms												
No	1.00				1.00				1.00			
Yes	0.86	(0.54 , 1.36)			0.70	(0.31 , 1.60)			0.62	(0.20 , 1.95)		
Use vacuums												
No	1.00				1.00				1.00			
Yes	0.71	(0.53 , 0.95)			0.81	(0.47 , 1.40)			0.41	(0.20 , 0.85)		
Shake rugs												
No	1.00		1.00		1.00				1.00		1.00	
Yes	0.78	(0.60 , 1.02)	0.57	(0.44 , 0.73)	0.83	(0.51 , 1.34)			0.93	(0.48 , 1.81)	0.33	(0.17 , 0.63)
Dietary												
Canned meats (times)												
0	1.00				1.00		1.00		1.00		1.00	
1-5	1.67	(1.14 , 2.44)			3.08	(1.58 , 5.99)	2.80	(1.40 , 5.59)	4.02	(1.58 , 10.25)	2.45	(1.07 , 5.65)
Adjusted R^2			39.4%				11.1%				33.5%	