Supporting Information

Polybrominated diphenyl ethers (PBDEs), hydroxylated PBDEs, and thyroid hormones in second trimester pregnant women in California

Ami R. Zota[1]*, June-Soo Park[2], Yunzhu Wang[2], Myrto Petreas[2], R.Thomas Zoeller[3], Tracey J. Woodruff[1]

Environmental Science and Technology

Total number of pages (including cover page): 9

[1]Program on Reproductive Health and the Environment, University of California, San Francisco, Oakland, California, USA

[2]Department of Toxic Substances Control, California Environmental Protection Agency, Berkeley, California, USA

[3]Biology Department, Morrill Science Center, University of Massachusetts at Amherst, Amherst, Massachusetts, USA

*Corresponding author: zotaar@obgyn.ucsf.edu, phone: 510.986.8928; fax: 510.986.8960

Table S1. List of PBDE congeners and OH-PBDEs measured in the serum of second trimester pregnant women from Northern and Central California by PBDE commercial mixture.[1]

	penta-BDE	octa-BDE	deca-BDE
PBDEs			
BDE-017	x		
BDE-028	x		
BDE-047	x		
BDE-066	x		
BDE-085	x		
BDE-099	x		
BDE-100	x		
BDE-153	x	x	
BDE-154	x	x	
BDE-183		x	
BDE-196		x	
BDE-197			
BDE-201		x	
BDE-202			
BDE-203		x	
BDE-206		x	x
BDE-207		x	x
BDE-208		x	x
BDE-209		x	x
OH-PBDEs			
6'-OH-BDE17			
4'-OH-BDE17			
2'-OH-BDE28			
6'-OH-BDE49			
2'-OH-BDE68			
6-OH-BDE47			
3-OH-BDE47			
5-OH-BDE47			
4'-OH-BDE49			
6-OH-BDE99			
5'-OH-BDE100			
6-OH-BDE90			
5'-OH-BDE99			
4'-OH-BDE101			
2-OH-BDE123			
6-OH-BDE85			
4'-OH-BDE103			
6-OH-BDE137			

[1] Congener composition of PBDE commercial mixtures adapted from La Guardia et al.[1]

Table S2. Average percent recoveries (± standard deviation) of labeled internal standards of PBDEs and OH-PBDEs and of QC materials analyzed together with serum.

	Percent recoveries ± standard deviation (%)		
	Labeled surrogate internal standards (n=45)	In-house matrix spike control (n=4)	NIST SRM 1589a (n=4)
BDE-28L*	94 ± 12	100 ± 5	93 ± 7
BDE-17		88 ± 5	
BDE-28		94 ± 5	
BDE-47L*	104 ± 9	109 ± 6	108 ± 9
BDE-47		89 ± 3	104 ± 4
BDE-99L*	110 ± 9	112 ± 9	111 ± 8
BDE-66		98 ± 7	
BDE-85		86 ± 12	
BDE-99		89 ± 5	136 ± 12
BDE-100		84 ± 9	108 ± 18
BDE-153L*	126 ± 14	128 ± 9	127 ± 15
BDE-153		80 ± 6	
BDE-154L*	122 ± 10	123 ± 7	121 ± 9
BDE-154		85 ± 2	
BDE-183L*	120 ± 15	121 ± 13	120 ± 15
BDE-183		94 ± 5	
BDE-196		95 ± 1	
BDE-197L*	105 ± 13	123 ± 9	108 ± 6
BDE-197		96 ± 5	
BDE-201		96 ± 1	
BDE-202		93 ± 1	
BDE-203		95 ± 1	
BDE-207L*	83 ± 16	108 ± 9	89 ± 9
BDE-206		96 ± 5	
BDE-207		96 ± 4	
BDE-208		98 ± 2	
BDE-209L*	55 ± 13	78 ± 8	59 ± 9
BDE-209		95 ± 2	
6-OH-BDE47L*	103 ± 15		

* $^{13}C_{12}$ labeled internal standards

Table S3. Descriptive statistics for PBDE chemicals expressed as ng/ml in the serum of second trimester pregnant women from Northern and Central California, 2008-2009 (N=25).

	GM(GSD)	50th	95th
PBDEs (ng/ml)			
BDE-028	0.016 (1.76)	0.015	0.049
BDE-047	0.294 (1.74)	0.281	0.866
BDE-066	--	< MDL	0.005
BDE-085	0.006 (1.93)	0.005	0.019
BDE-099	0.079 (1.84)	0.066	0.194
BDE-100	0.061 (1.88)	0.061	0.175
BDE-153	0.105 (1.85)	0.106	0.349
BDE-154	--	< MDL	0.015
BDE-183	--	< MDL	0.008
BDE-196	--	< MDL	< MDL
BDE-197	--	< MDL	0.022
BDE-201	--	< MDL	< MDL
BDE-203	--	< MDL	< MDL
BDE-206	--	< MDL	< MDL
BDE-207	0.011 (1.6)	0.010	0.022
BDE-208	--	< MDL	0.021
BDE-209	--	< MDL	0.637
$\sum PBDE_5$	0.584 (1.63)	0.547	1.355

GM = geometric mean; GSD = geometric standard deviation. GM and GSD were only calculated for congeners with detection frequencies ≥ 50%.

Table S4. Median serum concentrations (ng/g lipid weight) of PBDEs and OH-PBDEs in pregnant women from different study locations

Location	Study period	N	∑PBDE	BDE-28	BDE-47	BDE-99	BDE-100	BDE-153	BDE-209	5-OH-BDE47	6-OH-BDE47	Ref
United States												
Northern and Central California[1]	2008-2009	25	85.8	2.3	43.1	11.5	9.0	15.5	<MDL	5.2	3.5	current study
NHANES (US)[1]	2003-2004	75	55.9	1.3	23.7	5.1	6.6	7.8				[2]
Indiana[2,3]	2003-2004	4	34	0.3	15	6.3	3.0	5.5		1.4	0.2	[3]
Southern California[4]	2003	28		1.3	18.8	6.5	5.1	6.9				[4]
New York City, New York	2002	100		0.65	9.7	1.5	1.8	1.8				[5]
Indiana[5]	2001	12	37		28	5.7	4.2	2.9				[6]
Salinas Valley, California[1]	1999-2000	270	25.2	0.5	15.0	4.0	2.4	2.1				[7]
Europe												
Copenhagen[2]	2007	51	1.8	0.03	0.38	<MDL	<MDL	1.1	1.7			[8]
France	2004-2006	91		0.12	2.8	1.9	0.37	0.72	5.8			[9]
Valencia, Spain[6]	2003-2005	174	9.6	<MDL	2.3	0.35	<MDL	2.1	<MDL			[10]
Madrid, Spain[7]	2003-2004	61	9.1	0.06	2.4	2.6	1.6	0.86	1.1			[11]
Netherlands	2001-2002	69			0.8	0.2	0.2	1.6			<MDL	[12]
Sweden[8]	2000-2001	15	2.07	0.07	0.83	0.19	0.17	0.56				[13]
Faroe Islands	1994-1995	57			1.3	0.33	0.51	1.0	0.77			[14]
Asia												
Korea	2008-2009	26									<MDL	[15]
Korea[9,10]	2007	20	5.5	0.74	3.0	2.5	1.9	4.0	16			[16]
China[2,4]	2007	25	0.02									[17]
Japan[11]	2005-2006	16	3.0	0.03	0.30	0.04	0.13	0.48	1.1		0.35	[18]

MDL = method detection limit (may also be reported as less than limit of detection (LOD) or limit of quantification (LOQ))

[1] ∑PBDE equal to the sum of BDE-28, BDE-47, BDE-99, BDE-100, BDE-153

[2] ∑PBDE equal to the sum of BDE-28, BDE-47, BDE-99, BDE-100, BDE-153, BDE-154

[3] Measured in plasma

[4] Control group only

[5] ∑PBDE equal to the sum of BDE-47, BDE-99, BDE-100, BDE-153, BDE-154, BDE-183

[6] ∑PBDE equal to the sum of BDE-17, BDE-28, BDE-47, BDE-66, BDE-71, BDE-85, BDE-99, BDE-100, BDE-138, BDE-153, BDE-154, BDE-183, BDE-190, BDE-209

[7] ∑PBDE equal to the sum of BDE-17, BDE-28, BDE-47, BDE-66, BDE-85, BDE-99, BDE-100, BDE-153, BDE-154, BDE-183, BDE-184, BDE-191

[8] ∑PBDE equal to the sum of BDE-17, BDE-28, BDE-47, BDE-66, BDE-85, BDE-99, BDE-100, BDE-153, BDE-154, and BDE-183

[9] ∑PBDE equal to the sum of BDE-47, BDE-99

[10] Geometric means are presented

[11] ∑PBDE equal to the sum of BDE-15, BDE -28, BDE -47, BDE -49, BDE -66, BDE-85, BDE-99, BDE-100, BDE-153, BDE-154, BDE -197, BDE -207, BDE -209

Table S5. Spearman rank correlations between PBDE congeners and OH-PBDEs in the serum of second trimester pregnant women from Northern and Central California, 2008-2009 (N=25)

	BDE-028	BDE-047	BDE-085	BDE-099	BDE-100	BDE-153	BDE-207	4'-OH-BDE17	5-OH-BDE47	6-OH-BDE47
BDE-028	--									
BDE-047	**0.80****	--								
BDE-085	**0.53****	**0.84****	--							
BDE-099	0.28	**0.63****	**0.76****	--						
BDE-100	**0.64****	**0.83****	**0.81****	**0.45***	--					
BDE-153	0.16	0.26	0.27	-0.15	**0.56*****	--				
BDE-207	-0.07	-0.05	-0.02	0.17	-0.02	-0.09	--			
4'-OH-BDE17	0.13	0.10	0.05	0.19	0.02	0.01	0.08	--		
5-OH-BDE47	0.39	0.32	0.26	-0.01	0.33	**0.45***	-0.02	**0.46***	--	
6-OH-BDE47	0.32	0.06	-0.06	-0.15	0.04	0.09	-0.17	0.24	**0.55****	--
4'-OH-BDE49	-0.02	0.14	0.13	0.14	0.03	0.27	-0.25	**0.53****	**0.67****	0.30

*$p < 0.05$; **$p < 0.01$

Literature Cited

1. La Guardia, M. J.; Hale, R. C.; Harvey, E., Detailed polybrominated diphenyl ether (PBDE) congener composition of the widely used penta-, octa-, and deca-PBDE technical flame-retardant mixtures. *Environmental Science & Technology* **2006,** *40* (20), 6247-6254.

2. Woodruff, T. J.; Zota, A. R.; Schwartz, J. M., Environmental chemicals in pregnant women in the US: NHANES 2003-2004. *Environ. Health Perspect.* **2011,** *119* (6), 878–885.

3. Qiu, X. H.; Bigsby, R. M.; Hites, R. A., Hydroxylated metabolites of polybrominated fiphenyl rthers in human blood samples from the United States. *Environ Health Perspect* **2009,** *117* (1), 93-98.

4. Carmichael, S. L.; Herring, A. H.; Sjodin, A.; Jones, R.; Needham, L.; Ma, C.; Ding, K.; Shaw, G. M., Hypospadias and halogenated organic pollutant levels in maternal mid-pregnancy serum samples. *Chemosphere* **2010,** *80* (6), 641-646.

5. Wolff, M. S.; Teitelbaum, S. L.; Lioy, P. J.; Santella, R. M.; Wang, R. Y.; Jones, R. L.; Caldwell, K. L.; Sjödin, A.; Turner, W. E.; Li, W.; Georgopoulos, P.; Berkowitz, G. S., Exposures among pregnant women near the World Trade Center site on 11 September 2001. *Environ. Health Perspect.* **2005,** *113* (6), 739-748.

6. Mazdai, A.; Dodder, N. G.; Abernathy, M. P.; Hites, R. A.; Bigsby, R. M., Polybrominated diphenyl ethers in maternal and fetal blood samples. *Environ Health Perspect* **2003,** *111* (9), 1249-1252.

7. Chevrier, J.; Harley, K. G.; Bradman, A.; Gharbi, M.; Sjodin, A.; Eskenazi, B., Polybrominated diphenyl ether (PBDE) flame retardants and thyroid hormone during pregnancy. *Environ. Health Perspect.* **2010,** *118* (10), 1444-9.

8. Frederiksen, M.; Thomsen, C.; Froshaug, M.; Vorkamp, K.; Thomsen, M.; Becher, G.; Knudsen, L. E., Polybrominated diphenyl ethers in paired samples of maternal and umbilical cord blood plasma and associations with house dust in a Danish cohort. *International Journal of Hygiene and Environmental Health* **2010,** *213* (4), 233-242.

9. Antignac, J. P.; Cariou, R.; Zalko, D.; Berrebi, A.; Cravedi, J. P.; Maume, D.; Marchand, P.; Monteau, F.; Riu, A.; Andre, F.; Le Bizec, B., Exposure assessment of French women and their newborn to brominated flame retardants: determination of tri- to deca-polybromodiphenylethers (PBDE) in maternal adipose tissue, serum, breast milk and cord serum. *Environmental Pollution* **2009,** *157* (1), 164-173.

10. Vizcaino, E.; Grimalt, J. O.; Lopez-Espinosa, M. J.; Llop, S.; Rebagliato, M.; Ballester, F., Polybromodiphenyl ethers in mothers and their newborns from a non-occupationally exposed population (Valencia, Spain). *Environment International* **2011,** *37* (1), 152-157.

11. Gomara, B.; Herrero, L.; Ramos, J. J.; Mateo, J. R.; Fernandez, M. A.; Garcia, J. F.; Gonzalez, M. J., Distribution of polybrominated diphenyl ethers in human umbilical cord

serum, paternal serum, maternal serum, placentas, and breast milk from Madrid population, Spain. *Environmental Science & Technology* **2007,** *41* (20), 6961-6968.

12. Meijer, L.; Weiss, J.; Van Velzen, M.; Brouwer, A.; Bergman, A.; Sauerf, P. J. J., Serum concentrations of neutral and phenolic organohalogens in pregnant women and some of their infants in the Netherlands. *Environmental Science & Technology* **2008,** *42* (9), 3428-3433.

13. Guvenius, D. M.; Aronsson, A.; Ekman-Ordeberg, G.; Bergman, A.; Noren, K., Human prenatal and postnatal exposure to polybrominated diphenyl ethers, polychlorinated biphenyls, polychlorobiphenylols, and pentachlorophenol. *Environ Health Perspect* **2003,** *111* (9), 1235-1241.

14. Fangstrom, B.; Hovander, L.; Bignert, A.; Athanassiadis, I.; Linderholm, L.; Grandjean, P.; Weihe, P.; Bergmant, A., Concentrations of polybrominated diphenyl ethers, polychlorinated biphenyls, and polychlorobiphenylols in serum from pregnant Faroese women and their children 7 years later. *Environmental Science & Technology* **2005,** *39* (24), 9457-9463.

15. Wan, Y.; Choi, K.; Kim, S.; Ji, K.; Chang, H.; Wiseman, S.; Jones, P. D.; Khim, J. S.; Park, S.; Park, J.; Lam, M. H. W.; Giesy, J. P., Hydroxylated polybrominated diphenyl ethers and bisphenol A in pregnant women and their matching fetuses: placental transfer and potential risks. *Environmental Science & Technology* **2010,** *44* (13), 5233-5239.

16. Kang, C. S.; Lee, J. H.; Kim, S. K.; Lee, K. T.; Lee, J. S.; Park, P. S.; Yun, S. H.; Kannan, K.; Yoo, Y. W.; Ha, J. Y.; Lee, S. W., Polybrominated diphenyl ethers and synthetic musks in umbilical cord serum, maternal serum, and breast milk from Seoul, South Korea. *Chemosphere* **2010,** *80* (2), 116-122.

17. Zhang, J. Q.; Jiang, Y. S.; Zhou, J.; Wu, B.; Liang, Y.; Peng, Z. Q.; Fang, D. K.; Liu, B.; Huang, H. Y.; He, C.; Wang, C. L.; Lu, F. N., Elevated body burdens of PBDEs, dioxins, and PCBs on thyroid hormonehomeostasis at an electronic waste recycling site in China. *Environmental Science & Technology* **2010,** *44* (10), 3956-3962.

18. Kawashiro, Y.; Fukata, H.; Inoue, M. O.; Kubonoya, K.; Jotaki, T.; Takigami, H.; Sakai, S. I.; Mori, C., Perinatal exposure to brominated flame retardants and polychlorinated biphenyls in Japan. *Endocr. J.* **2008,** *55* (6), 1071-1084.