Cod: 4.4008

PRECURSOR PFAS MOLECULES (FTOHS AND MEFOSAS) IN AIR PREDICT SERUM PFOA AND PFOS LEVELS IN PREGNANT WOMEN.

C.M. Makey[1], T. Webster[1], J. Martin[2], M. Shoeib[3], T. Harner[3], A. Desilva[4], L. Dix-Cooper[5], G.M. Webster[6]

[1]*Department of Environmental Health, Boston University School of Public Health, Boston, MA. USA*

[2]*Division of Analytical & Environmental Toxicology, Department of Laboratory Medicine & Pathology, University of Alberta, Edmonton, AB Canada*

[3]*Air Quality Processes Research Section, Environment and Climate Change Canada, Toronto, ON Canada*

[4]*Water Science Technology Directorate, Environment Canada, Burlington, ON Canada*

[5]*Environmental Health Services, BC Centre for Disease Control, Vancouver, BC Canada*

[6]*Faculty of Health Sciences, Simon Fraser University, Burnaby, BC Canada; Child and Family Research Institute, Vancouver, BC Canada*

Introduction:
Per- and polyfluoroalkyl substances (PFASs) are a class of synthetic, fluorinated, organic chemicals that are distinct because they repel oil, grease and water. They have been widely used in consumer products[1]. Two perfluorocarboxylates (PFCAs) called perfluorooctonoate (PFOA) and perfluorononanoate (PFNA), and perfluorooctane sulfonate (PFOS) are among the major chemicals of concern due to their persistence in the environment, ability to bioaccumulate and ubiquity in human serum[1]. In epidemiological studies, PFOA and PFOS have been associated with altered thyroid hormone levels[2], decreased birth weight[3] and increased risk of ADHD[4], in some but not all studies.

Human exposure can occur directly through PFASs in contaminated food, drinking water[5], and in indoor dust or air[6,7]. Indirect exposure through PFAS precursors [e.g. disubstituted polyfluoroalkyl phosphates (diPAPs), fluorotelomer alcohols (FTOHs), fluorinated sulfonamides (FOSAs), sulfonamidoethanols (FOSEs)] may also be a source of human exposure, but evidence is limited[6,8,9]. Recent studies report higher levels of precursors than parent PFAS in indoor air and dust, suggesting that PFAS precursors may be an important but poorly recognized source of PFAS exposure.

The goal of our study is to determine to what extent precursor PFAS compounds such as diPAPs, FTOHs and FOSE/As in indoor air and dust are predictors of serum PFAS levels in a cohort of pregnant women.

Materials and Methods:
The Chemicals, Health and Pregnancy (CHirP) Study was conducted in Vancouver, Canada in 2007-08 and has been previously described[10]. Researchers collected environmental home samples (e.g. vacuum cleaner dust and air), exposure assessment information (a dietary and pregnancy history questionnaire), and serum samples from 152 participants during the 2nd trimester of pregnancy. Levels of parent PFASs were measured in sera, air and dust. Precursors were analyzed in environmental samples (i.e. FTOHs, FOSA/E in air and dust; diPAPs in dust only).

We used Spearman's correlation coefficients to assess associations and potential collinearity between chemicals in air and dust. We used general linear models (GLMs) to assess univariate associations between chemicals in environmental samples and the relevant PFASs in maternal serum. Significant univariate predictors were then included together in a multivariate model, which included multiple precursor and PFASs in environmental samples and parity, for each serum PFAS.

Results and Discussion:
PFAS and/or precursor levels were available in 102 dust samples and 58 air samples from CHirP study participants; 50 participants had dust, air and serum PFAS and PFAS precursor measures available.

PFOA, PFNA and PFOS were detected in 98%, 62% and 100% of serum samples, respectively. Similar to other studies, these PFASs were highly ($rho>0.55$) and significantly ($p<0.001$) correlated in serum.

The most frequently detected precursors (>60%) in air and dust were, for PFCAs: (6:2 diPAP, 8:2 diPAP, 10:2 diPAP; 6:2 FTOH, 8:2 FTOH, 10:2 FTOH), and for PFOS: (MeFOSA, EtFOSA, MeFOSE, EtFOSE).

PFCAs (PFOA and PFNA) and their precursors: Levels were higher for PFCA precursor compounds in air and dust (diPAPs in dust, FTOHs in air and dust) than for PFCAs themselves (PFOA, PFNA). In univariate models, diPAPs in dust were not associated with serum PFCAs. However, 8:2 and 10:2 FTOH in air were positive predictors of serum PFOA; 10:2 FTOH in air and PFNA in dust were positive predictors of serum PFNA. 10:2 FTOH in air explained 12% and 14% of the total variance in serum PFOA and PFNA levels, respectively. In multivariate models, 10:2 FTOH in air and parity explained 38% of the variance in serum PFOA levels (data not shown). In multivariate models, PFNA in dust was a stronger predictor than 10:2 FTOH in air, and explained 19% of the total variance in serum PFNA (data not shown).

PFOS and its precursors: Serum PFOS was positively associated with levels of the precursors MeFOSA/E in both air and dust, but not with PFOS in dust. PFOS levels in air were below the level of detection in all samples. In univariate models, MeFOSA and MeFOSE in air explained 21% and 16% of the variance in serum PFOS levels, respectively (data not shown). In multivariate models, MeFOSA in air and parity explained 47% of the variance in serum PFOS levels (data not shown).

Conclusions: PFAS precursors (FTOHs and MeFOSE/As) in household indoor air and dust of pregnant study participants in BC, Canada were positively predictive of serum PFOA and PFOS levels, respectively. PFOA and PFOS in air and dust were not predictive of PFAS serum levels. PFNA in dust was a stronger predictor of serum PFNA than PFNA precursors in air or dust. This suggests that some PFAS precursors - largely overlooked in most human and environmental exposure assessments - may be an important but unrecognized source of PFAS exposure in pregnant women and likely other populations.

Acknowledgements:
Data collection for the CHirP study was funded by Health Canada, the British Columbia Environmental and Occupational Health Research Network (BCEOHRN), and the UBC Centre for Health and Environment Research (CHER). Data analysis was funded by the National Institute of Environmental Health Sciences (NIEHS).

References:
1) Lindstrom AB, Strynar MJ, Libelo EL. (2011) Environ Sci Technol, 19, 7954-61.
2) de Cock M, de Boer MR, Lamoree M, Legler J, van de Bor M. (2014) Environ Health, 10, 103-106.
3) Bach CC, Bech BH, Brix N, Nohr EA, Bonde JP, Henriksen TB. (2015) Toxicol, 45(1):53-67.
4) Hoffman K, Webster TF, Weisskopf MG, Weinberg J, Vieira VM. (2010) Environ Health Perspect,18(12):1762-7
5) Trudel D, Horowitz L, Wormuth M, Scheringer M, Cousins IT, Hungerbühler K. (2008) Risk Analysis, 28(2):251-69
6) Fraser AJ, Webster TF, Watkins DJ, Nelson JW, Stapleton HM, Calafat AM, Kato K, Shoeib M, Vieira VM, McClean MD. (2012) Environ Sci Technol, 46(2):1209-15
7) Shoeib M, Harner T, M Webster G, Lee SC. (2011) Environ Sci Technol. 45(19):7999-8005
8) Martin JW, Asher BJ, Beesoon S, Benskin JP, Ross MS. PFOS or PreFOS? (2010) J Environ Monit, 12(11):1979-2004
9) De Silva AO, Allard CN, Spencer C, Webster GM, Shoeib M. (2012) Environ Sci Technol, 46(22):12575-82
10) Webster GM, Teschke K, Janssen PA. (2012) Journal of Maternal Child Health, 16(2):430-8

Table 1. Univariate associations between precursor or parent PFCA levels in air and dust, and PFCA levels (PFOA and PFNA) in serum (n=48[A]).

Chemicals in Air or Dust	PFOA (serum, ng/mL)		PFNA (serum, ng/mL)	
	Beta	p-value	Beta	p-value
Air[B]				
8:2 FTOH	0.0001	0.037	0.00002	0.155
10:2 FTOH	0.0002	0.011	0.00005	0.010
PFOA	0.0001	0.500	n/a*	
PFNA	n/a*		0.00002	0.773
Dust[C]				
PFOA	0.0004	0.330	n/a*	
PFNA	n/a*		0.00107	0.005

* comparison not applicable
[A] Only 48 women had parent PFCAs measured in the air samples.
[B] pg/m^3
[C] ng/g

Table 2. Univariate associations between PFOS or its precursors in air and dust, and PFOS levels in serum (n=50).

Chemicals in Air and Dust	PFOS (serum, ng/mL)	
	Beta	p-value
Air[A]		
MeFOSA	0.011	0.001
MeFOSE	0.00086	0.004
Dust[B]		
MeFOSA	0.35	0.028
MeFOSE	0.0023	0.059
PFOS	-0.00026	0.589

[A] pg/m^3
[B] ng/g

Table 1. Univariate associations between precursor or parent PFCA levels in air and dust, and PFCA levels (PFOA and PFNA) in serum (n=48[A]).

Chemicals in Air or Dust	PFOA (serum, ng/mL)		PFNA (serum, ng/mL)	
	Beta	p-value	Beta	p-value
Air[B]				
8:2 FTOH	0.0001	0.037	0.00002	0.155
10:2 FTOH	0.0002	0.011	0.00005	0.010
PFOA	0.0001	0.500	n/a*	
PFNA	n/a*		0.00002	0.773
Dust[C]				
PFOA	0.0004	0.330	n/a*	
PFNA	n/a*		0.00107	0.005

* comparison not applicable
[A] Only 48 women had parent PFCAs measured in the air samples.
[B] pg/m^3
[C] ng/g

Table 2. Univariate associations between PFOS or its precursors in air and dust, and PFOS levels in serum (n=50).

Chemicals in Air and Dust	PFOS (serum, ng/mL)	
	Beta	p-value
Air[A]		
MeFOSA	0.011	0.001
MeFOSE	0.00086	0.004
Dust[B]		
MeFOSA	0.35	0.028
MeFOSE	0.0023	0.059
PFOS	-0.00026	0.589

[A] pg/m^3
[B] ng/g