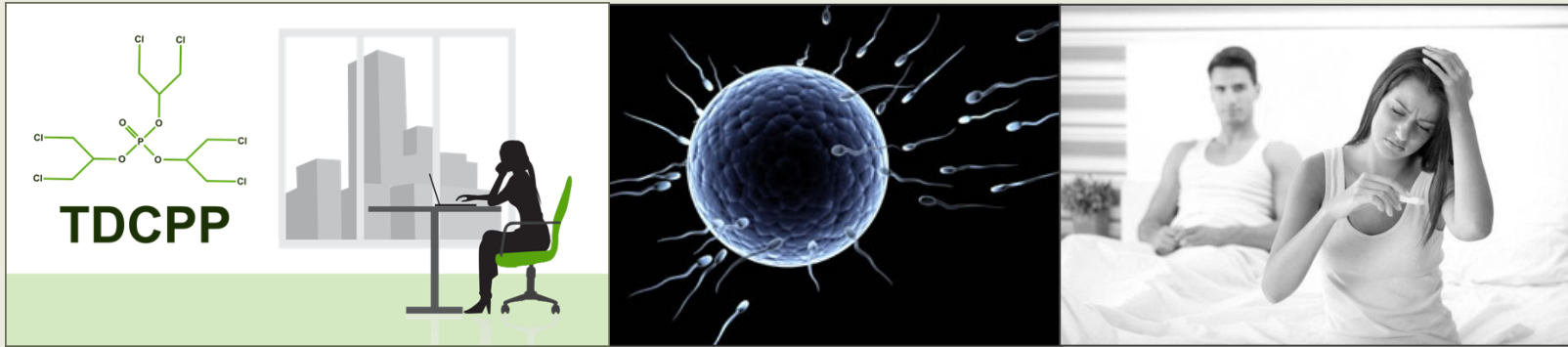


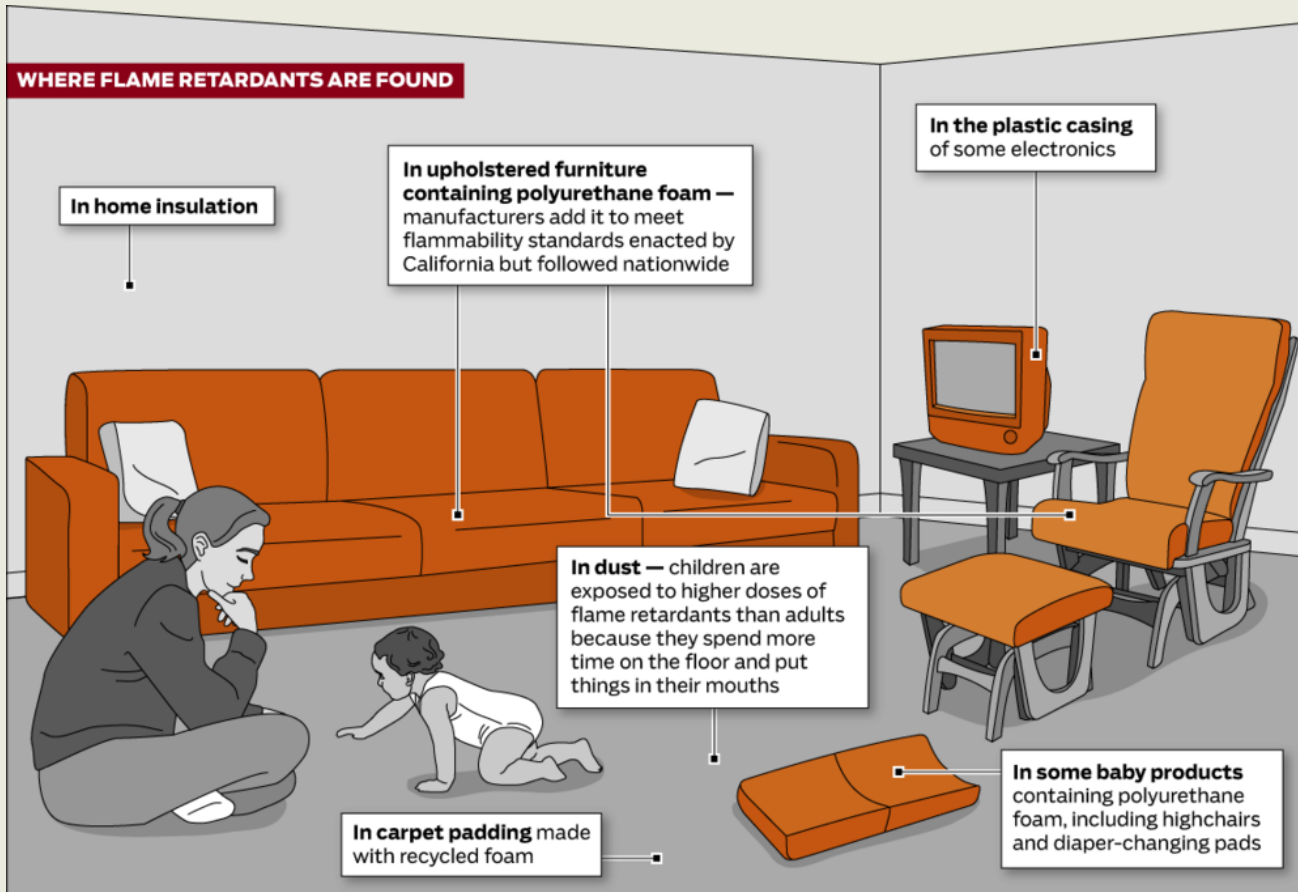
# Replacement Flame Retardants



Collaborative on Health and the Environment  
Pioneers Under 40 in Environmental Public Health  
October 24, 2017

Courtney Carignan, Ph.D.  
Assistant Professor  
Michigan State University

# Flame retardants



SOURCES: EPA, Tribune reporting

KATIE NIELAND/TRIBUNE

# Infants & Children Highly Exposed

## Total daily dose

Nanograms (billionths of a gram) of PBDE per kilogram of body weight, per day

Adults | 7.1

Ages 12-19 | 8.3

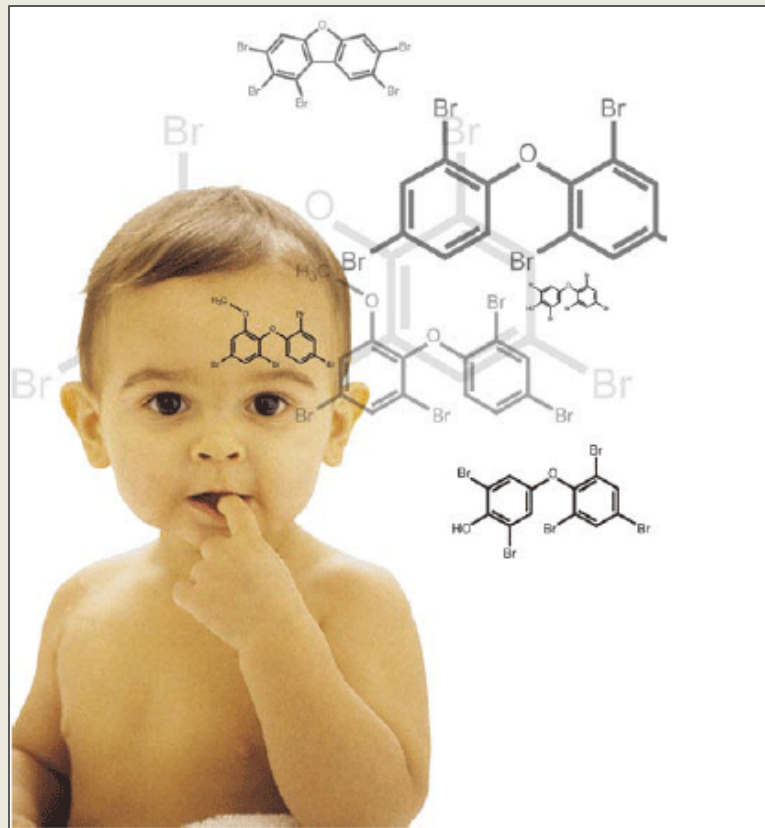
Ages 6-11 | 13

Ages 1-5 | 47.2

Infants | 141

Source: EPA  
Graphic: Chicago Tribune

© 2012 MCT

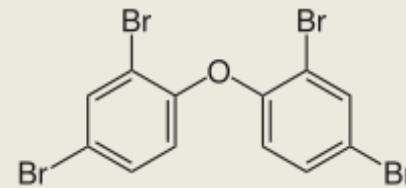


# Polybrominated diphenyl ethers (PBDEs)

---

- Thyroid Hormone

- Reduced TSH and T<sub>4</sub>






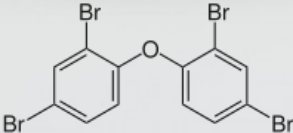
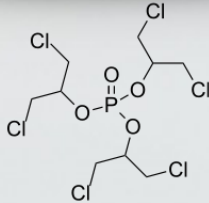
- Neurodevelopment

- Behavior, cognition and motor skills in birth cohorts

- Reproductive

- Increased time to pregnancy and failed implantation, decreased birth weight, altered growth trajectory

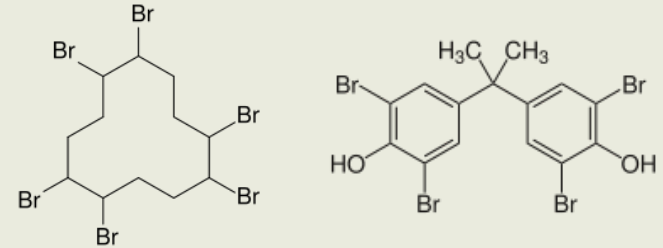
# Replacements in Foam

PentaBDE	TDCIPP	Firemaster	
Phased-Out (2005)		550 <sup>®</sup>	
			
		EH-TBB	TPHP
		BEH-TBPH	ITPs

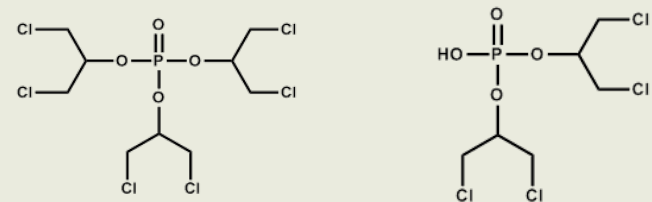
# Characterizing Human Exposure



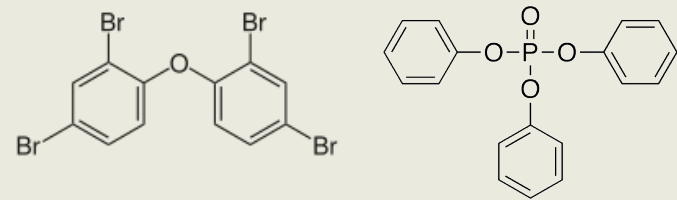
Nursing Mothers



Office Workers



Gymnasts

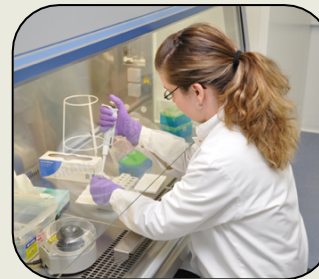


# Biomonitoring Study Framework

Data &  
Sample  
Collection

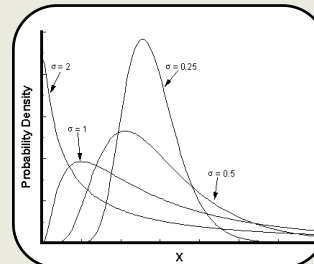


Data &  
Sample  
Processing  
& Storage



Data  
Analysis

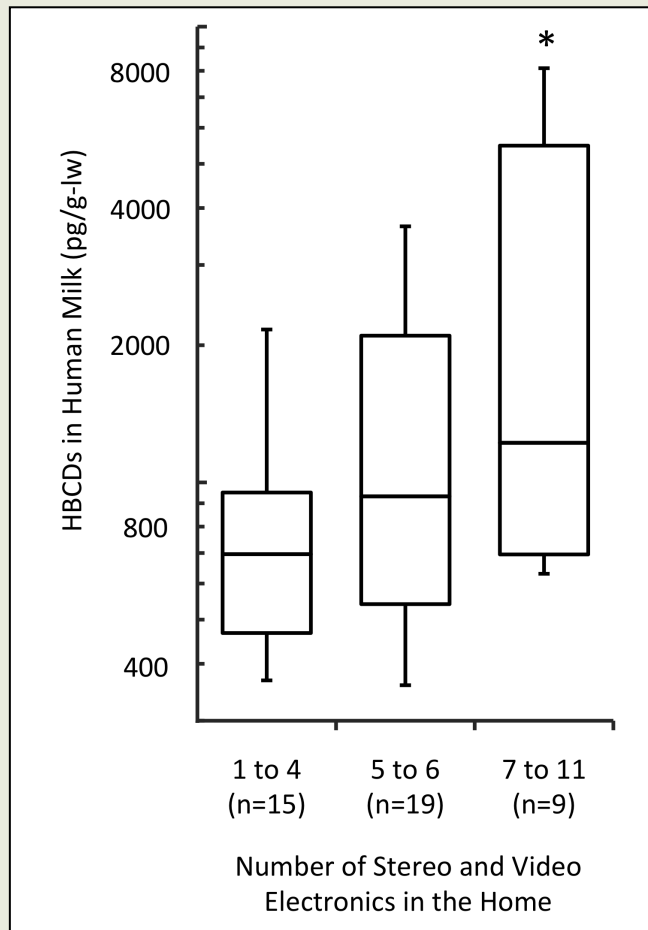
Normalize



$e^{\beta}$



# HBCD in Breast Milk



Mothers with 7 or more electronic items had average HBCD concentrations that were 153% higher than those who had 4 or fewer (95% CI=34-375%).

Carignan et al. ES&T (2012)



# EPA's Intervention

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- Alternatives Assessment
- Significant New Use Rule

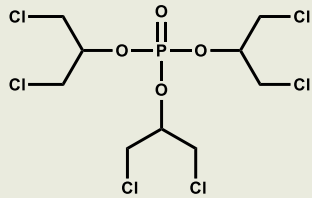




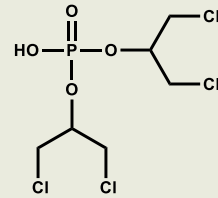
# Urinary TDCIPP Metabolite

29 Office workers

Parent Compound



Urinary Metabolite



100% Detection Frequency

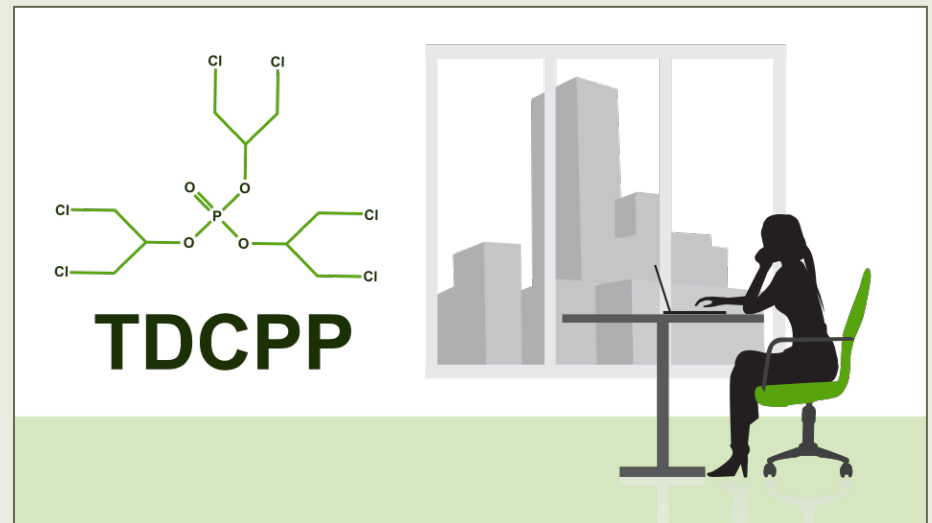
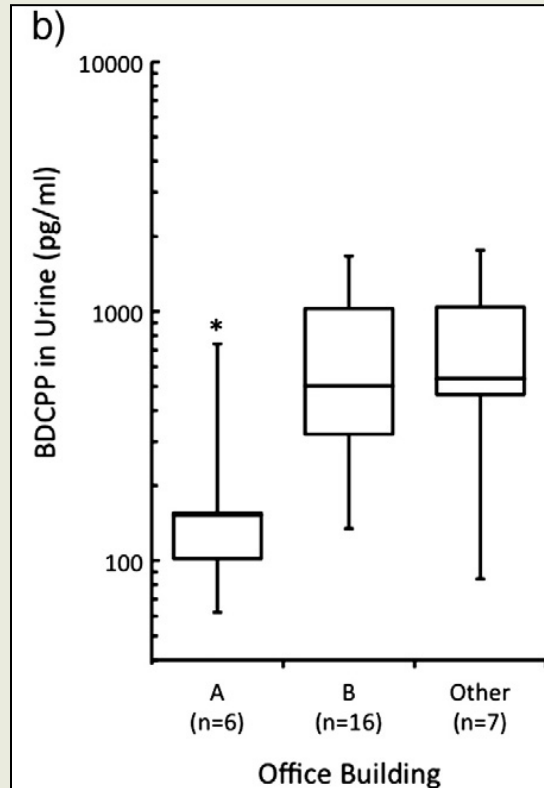
**TDCPP**

Carignan et al. Environ Int (2013)

Linear regression: Evaluate associations with demographic, dietary, and behavioral characteristics



# Predicted by Office Building



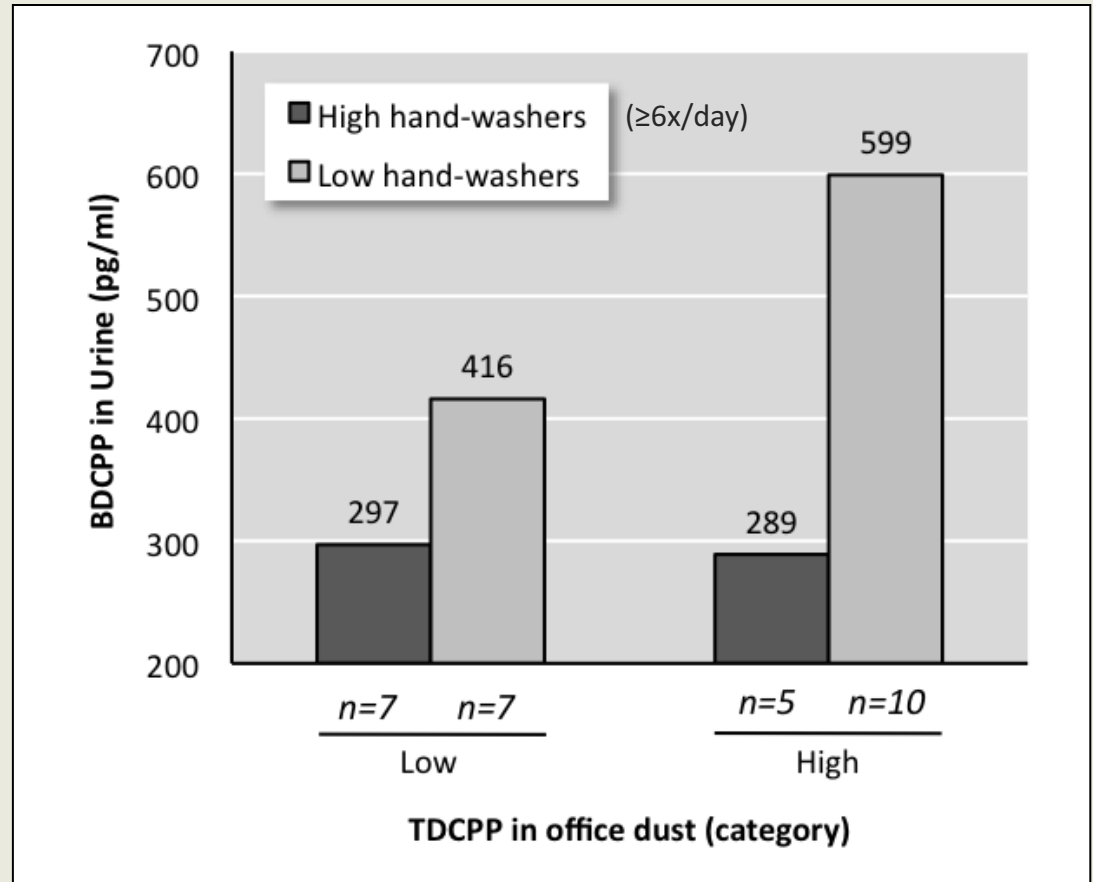
Carignan et al. Environ Int (2013)

GM concentration 26% lower among workers in Building A ( $p=0.01$ )

Office environment a source of exposure



# Predicted by Handwashing



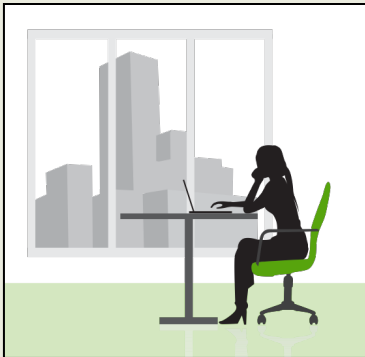
Carignan et al. Environ Int (2013)

# Public Health Interventions

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1. Hand-washing



2. Change in Boston Fire Codes negating requirement for flame retardants in upholstered furniture for public spaces

# Foam in Gymnastics Safety Equipment

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# Loose Foam Pit



# Elevated in Gym Air and Dust

---

Dust: 200x higher in gym compared to residences (371 vs 1.69 ug/g)

Air: 400x higher in gym compared to residences (120 vs 0.29 ng/m<sup>3</sup>)

Consistent with first gym and with a second study (Laguardia et al. 2014)

Carignan et al. ES&T (2013)

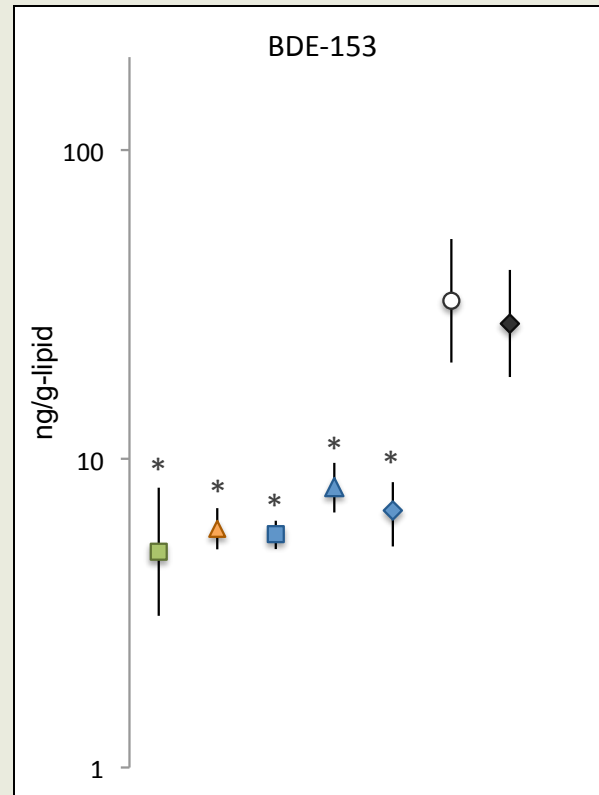


# Light Degrades Foam into Dust

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# Elevated in Gymnast Serum

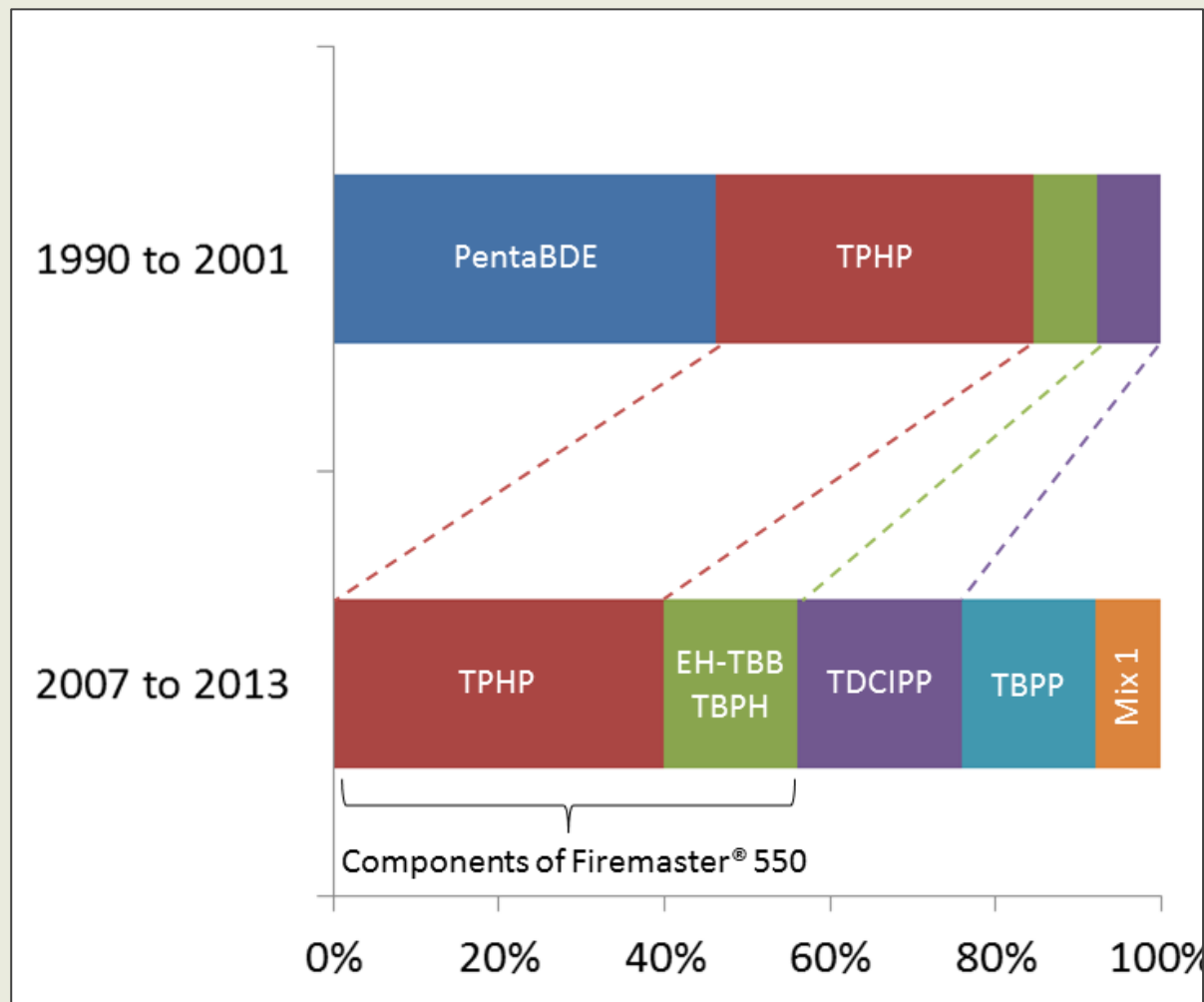


- ◆ Foam recyclers and carpet installers (2006) (Stapleton et al. 2008)
- Gymnasts (2012) (Our Sample)
- ◆ NHANES, Californians (2003-04) (Zota et al. 2008)
- ▲ NHANES, Ages 12-19 (2003-04) (Sjödín et al. 2008)
- NHANES, Full Dataset (2003-04) (Sjödín et al. 2008)
- ▲ Pregnant Women (2008-2010) (Stapleton et al. 2011)
- Office Workers (2009) (Watkins et al. 2011)
- \* Significantly different from gymnast GM at the  $\alpha=0.05$  level

Carignan et al. ES&T (2013)

# Pit Cubes and Replacement FRs

89% contained flame retardants



Carignan et al. Environ Int (2016)



[FR in Gyms](#)

[FR in Gymnasts](#)

[Take Action](#)

[Health Effects](#)

[Resources](#)

[Stay Updated](#)



# The Gymnast Flame Retardant Collaborative

addressing concerns regarding flame retardants in gymnastics equipment

[www.gymnastcollaborative.org](http://www.gymnastcollaborative.org)



## The Collaborative

[About Us](#)



## Flame Retardants

[The Data](#)



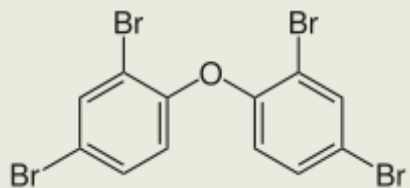
## Take Action

[Reducing Gymnast Exposure](#)

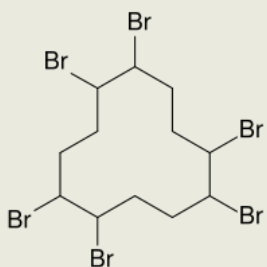
## Stay Updated

[By Email or Social Media](#)

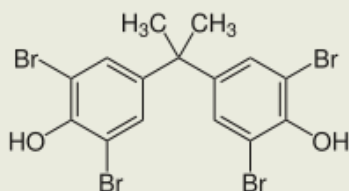
# Flame Retardants Act on the Hypothalamic Pituitary Thyroid Axis



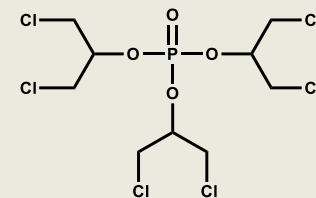
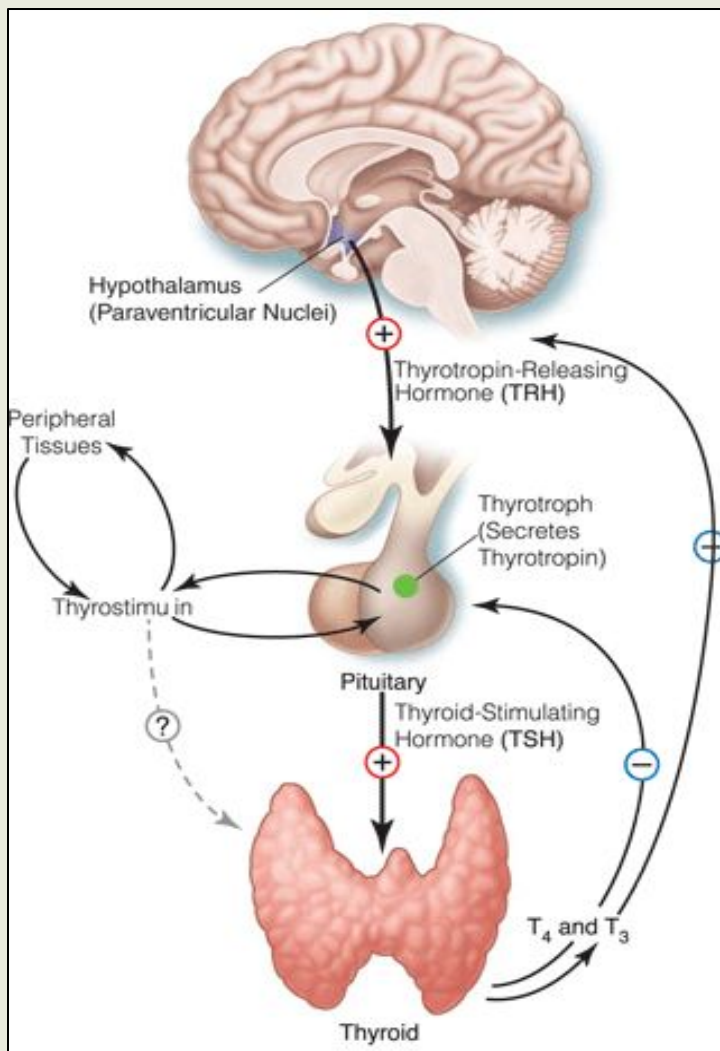
polybrominated diphenyl ethers (PBDEs)



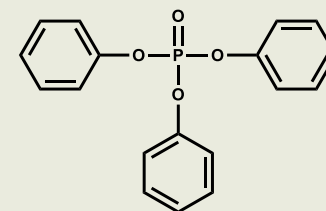
hexabromocyclododecane (HBCD)



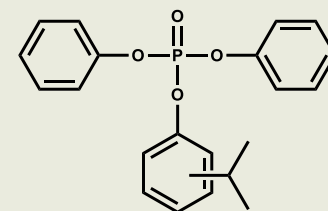
tetrabromobisphenol-A (TBBP-A)



tris(1,3-dichloro-2-propyl) phosphate (TDCIPP)



triphenyl Phosphate (TPHP)



isopropyl triphenyl phosphate (mono-ITP)

# Health Effects of Replacements

---

- Potential carcinogen (TDCIPP)
- Neurologic
  - Neurotoxicity: in vitro effects similar to chlorpyrifos (TDCIPP)
  - Neurodevelopment: Increased anxiety (FM550)
- Reproductive
  - Reduced egg quality, spermiation, and fecundity in zebrafish (TDCIPP, TPHP)
  - Decreased semen quality in adult men (TDCIPP)

# Preconception Cohort Study Design

Pre-conception

Pregnancy

Early Life

Childhood

Adolescence



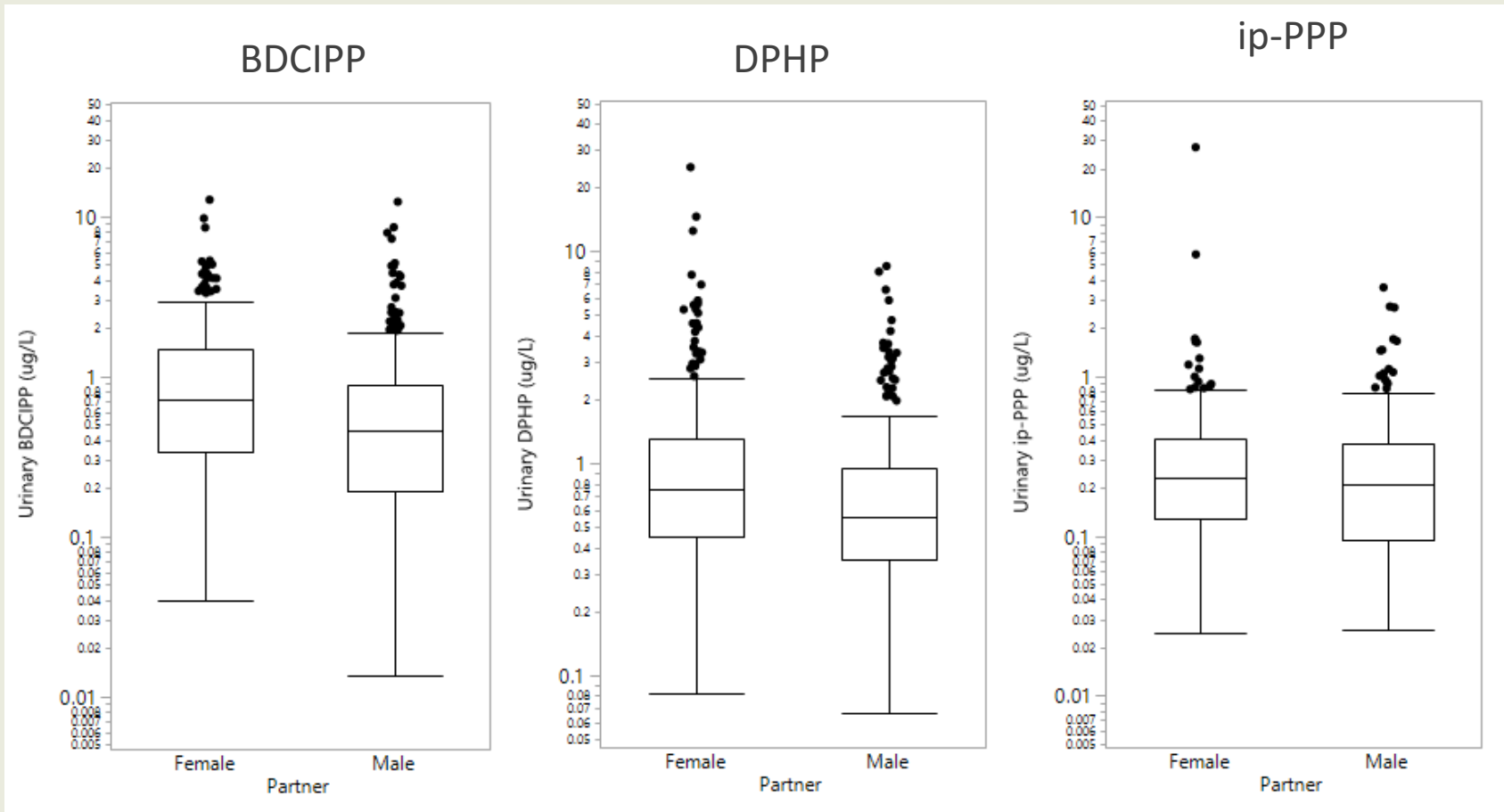
Infertility clinic  
population

## Benefits:

- Measure exposure preconception (sensitive)
- Include infertile couples (susceptible)
- Include male partner (important)
- Measure early developmental endpoints



# Higher Among Women

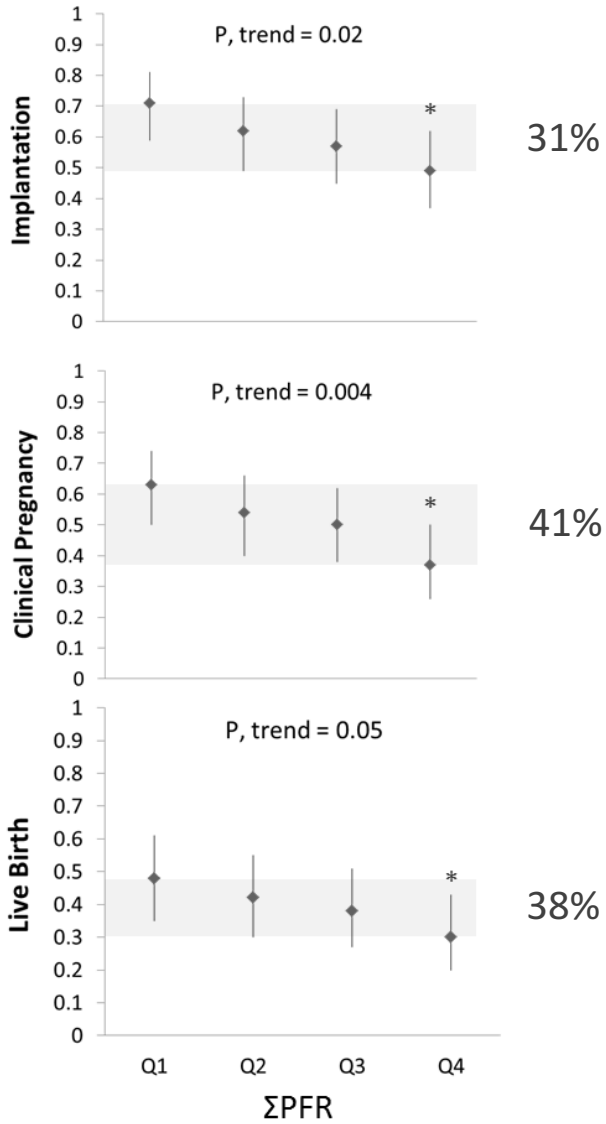




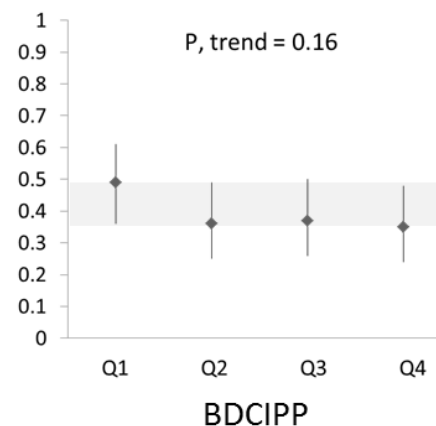
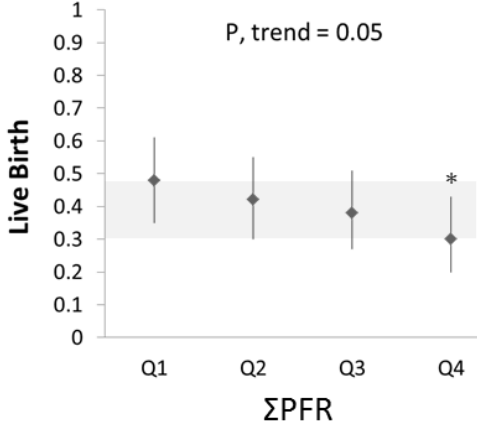
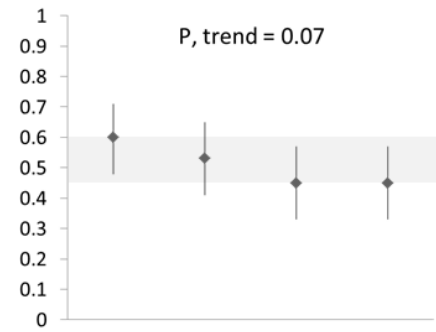
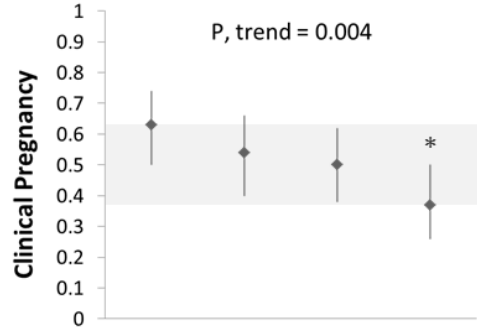
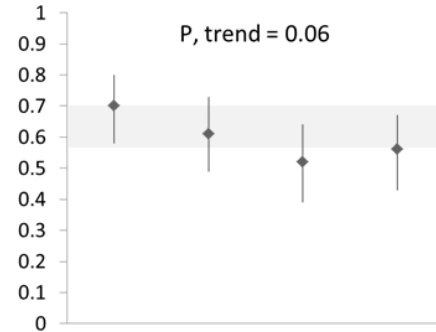
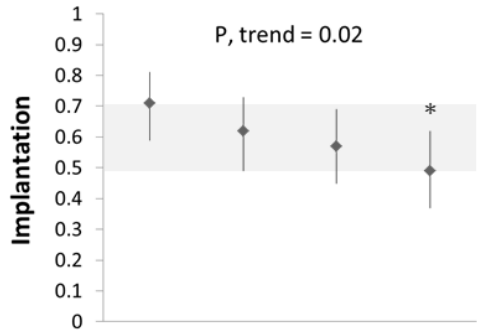
# Predictors and Trends

---

- Decreased with Age
- Increased with BMI
- Varied with time (year and season)
- Weak to Moderately Correlated ( $r_s=0.19$  to  $0.25$ ;  $p<0.05$ )
- $ICC_{\text{months}}=0.34$  to  $0.37$ ;  $ICC_{\text{week}}=0.44$  to  $0.53$



Quartiles of Organophosphate Flame Retardant Metabolites



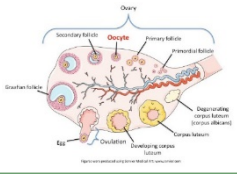

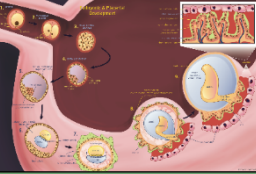


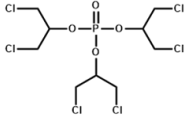
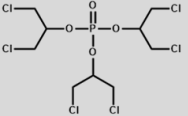
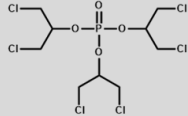
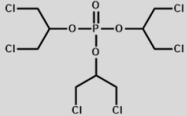
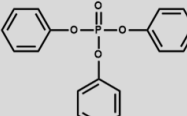
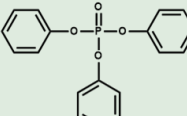
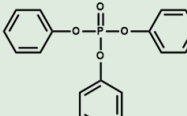
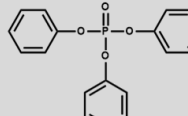
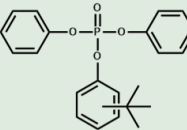
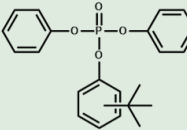
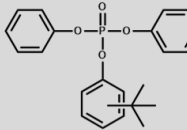
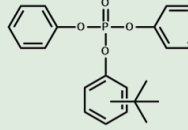
Quartiles of Organophosphate Flame Retardant Metabolites

# Clinically Relevant

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18% Decline in the proportion of live births

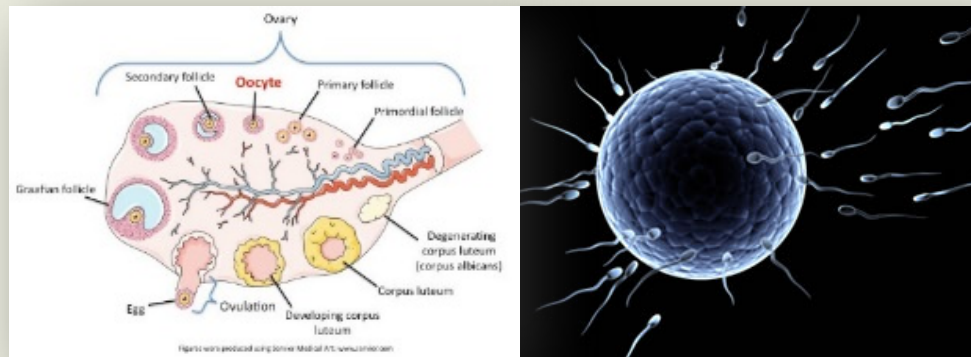


Oocyte Count	Fertilization	Implantation	Pregnancy	Live Birth
				
	ΣPFRs	ΣPFRs	ΣPFRs	ΣPFRs
 <p>TDCIPP</p>		 <p>TDCIPP</p>	 <p>TDCIPP</p>	 <p>TDCIPP</p>
	 <p>TPHP</p>	 <p>TPHP</p>	 <p>TPHP</p>	 <p>TPHP</p>
	 <p>Mono-ITP</p>	 <p>Mono-ITP</p>	 <p>Mono-ITP</p>	 <p>Mono-ITP</p>
Positive association (p<0.05)	Negative association (p<0.05)		Negative association, p<0.20	

# Consistent with other studies

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- Promotion of oocyte maturation but reduction in egg quality, reduced spermiation, and decreased fecundity in zebrafish (Wang et al. 2015)
- Decreased sperm motility in adult men (Meeker et al. 2010)



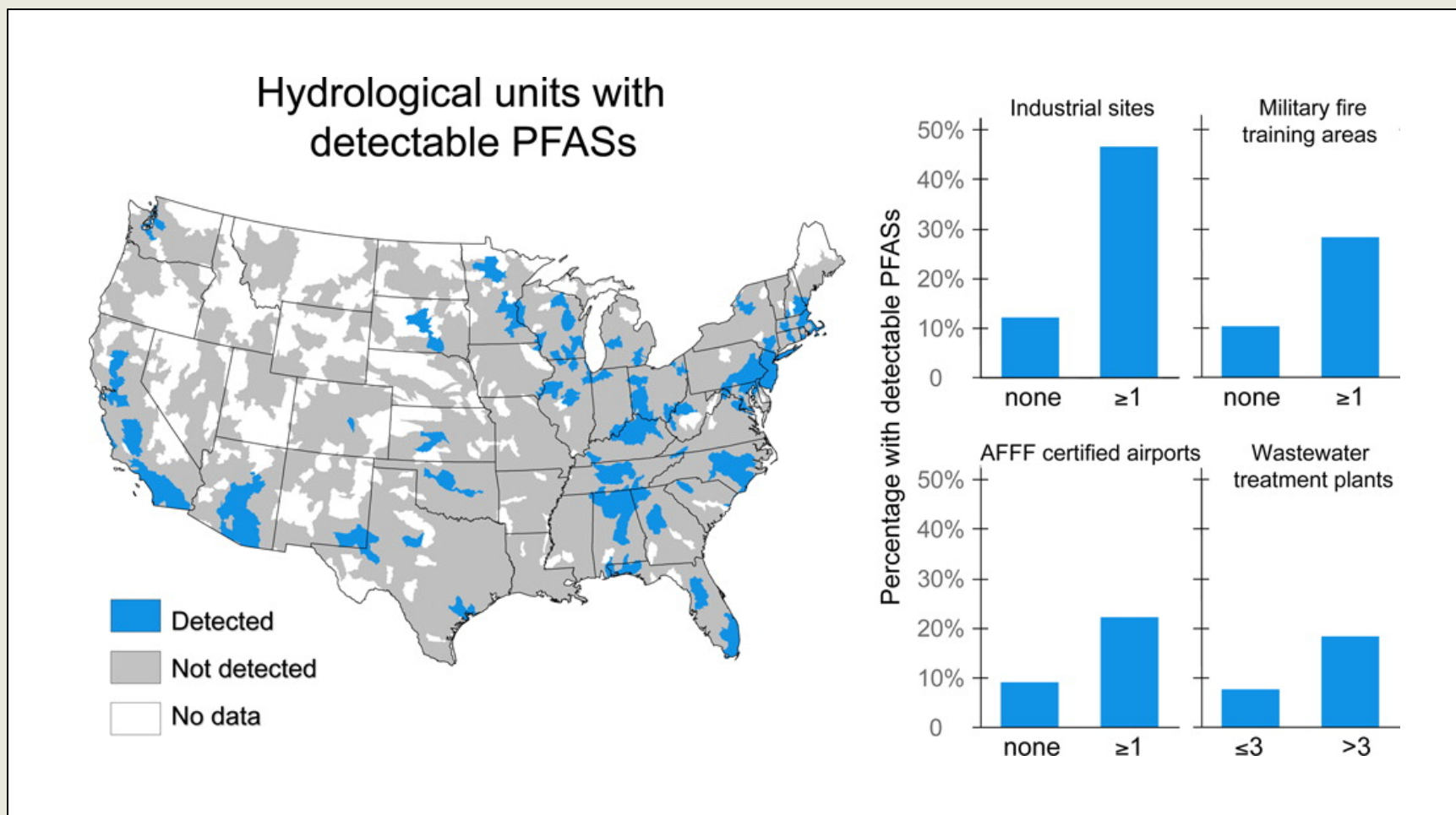
# Tips for Reducing Exposure

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- Support programs like EPA's Safer Choice
- Opt for FR-free products ([www.greensciencepolicy.org](http://www.greensciencepolicy.org))
- Limit electronic items (AV)
- Avoid installing carpet padding that uses recycled foam
- Wash hands before eating

# Poly- and Perfluoroalkyl Substances





# Acknowledgements

## Exposure Studies

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Tom Webster  
Mike McClean  
Wendy Heiger-Bernays  
Alicia Fraser  
Deb Watkins  
Nerissa Wu



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Ellen Cooper  
Simon Roberts  
Mingliang Fang  
Craig Butt



Andreas Sjödin



Mohamed Abdallah  
Stuart Harrad



**National Institute of  
Environmental Health Sciences**

T32ES014562, R01ES015829,  
R01ES016088



Study Participants

# Acknowledgements

## Fertility Study

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Russ Hauser  
Paige Williams  
Lidia Minguez Alarcon  
Jennifer Ford & Staff



John Meeker



Thomas Toth & Clinicians



Heather Stapleton  
Craig Butt



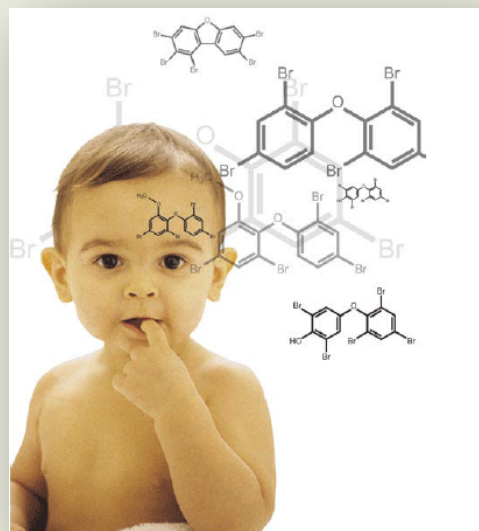
**National Institute of  
Environmental Health Sciences**

T32ES007069, R01ES009718,  
R01ES022955, R01ES000002



# Thank You!

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