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Children's Exposure to SVOCs in the Indoor Environment

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NICHOLAS SCHOOL OF THE ENVIRONMENT



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Chemical Use in Commercial Products

- Consumer products are often chemically treated to alter their performance or durability (e.g. plasticizers and flame retardants).

- Many of these chemical treatments use semi-volatile organic compounds (SVOCs) that escape from products over time and accumulate in indoor environments



Flame Retardants (FRs) Used to Meet California's TB 117

- Promulgated by California Bureau of Home Furnishing and Thermal Insulation, within the Department of Consumer Affairs

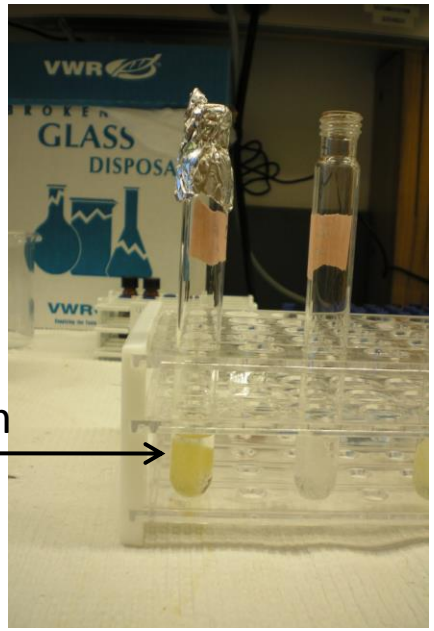
- Requires 12-second open flame testing for polyurethane inside furniture

Screening Consumer Products for FR Chemicals:

Project 1- Baby Products

Project 2- Residential Couches

Screening Consumer Products for FR Chemicals:



Foam

Gas Chromatograph Mass Spectrometer (GC/MS)



Flame Retardants (FRs) Used to Meet California's TB 117

- Previous research in our laboratory has focused on identifying FR chemical additives in polyurethane foam:
  - Baby Products (Stapleton et al. 2011)
  - Residential Sofas (Stapleton et al. 2012)

Sleep Positioners

- The most common FRs identified in furniture are:
  - PBDEs associated with PentaBDE
  - Tris (1,3-dichloro-isopropyl) phosphate (TDCPP)
  - Chemicals associated with Firemaster® 550 (FM 550)
  - Triphenyl phosphate (TPP) and isomers of tris(4-isobutyl) phenyl phosphate
  - Tris (1-chloro-isopropyl) phosphate (TCPP)

Table 1. Reported concentrations of organic contaminants in US house dust (ng/g or ppb).

Chemical (Class)	Year Sampled	Sample Number	% Detect	Min	Median/ Geomean	Max	Reference
Benzo(a)pyrene (PAH)	1999-2001	120	85	<MDL	712	18,100	Rudel et al. 2003
DEHP (phthalate)	1999-2001	120	100	16,700	340,000	7,700,000	Rudel et al. 2003
BBzP (phthalate)	1999-2001	120	100	3,870	45,400	1,310,000	Rudel et al. 2003
BDE 47 (flame retardant)	2009-2010	120	100	55	870	24,720	Stapleton et al. 2012
BDE 209 (flame retardant)	2009-2010	120	100	441	2574	76,130	Stapleton et al. 2012
BPA (phenol)	1999-2001	120	86	<MDL	821	17,600	Rudel et al. 2003
TPP (flame retardant & plasticizer)	2002-2007	50	98	<150	7,360	1,798,000	Stapleton et al. 2009
TDCPP (flame retardant & plasticizer)	2002-2007	50	96	<90	1,890	56,090	Stapleton et al. 2009
TBPH (flame retardant)	2010-2012	30	100	83	620	20,955	Stapleton unpublished data
PFOA (PFC)	2000-2001	102	96	<10	296	1960	Strynar and Lindstrom 2008
PFOS (PFC)	2000-2001	102	95	<9	761	12,100	Strynar and Lindstrom 2008
TBT (organotin)	2005-2006	24	75	<2	22	300	Kannan et al 2009
MBT (organotin)	2005-2006	24	100	320	2450	11,000	Kannan et al. 2009

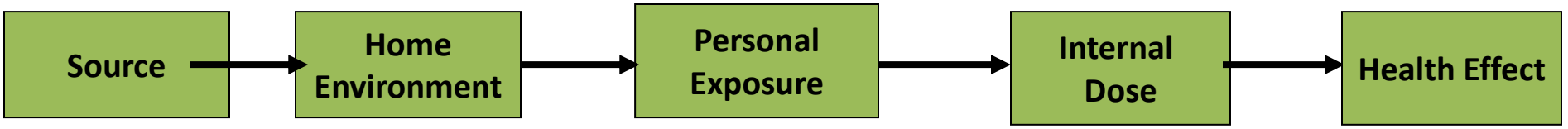


Children's Exposure Indoors

- Children spend a lot of time indoors
- Higher frequency of hand to mouth contacts
- Higher exposure to semi-volatile organic compounds (SVOCs) commonly detected in indoor dust



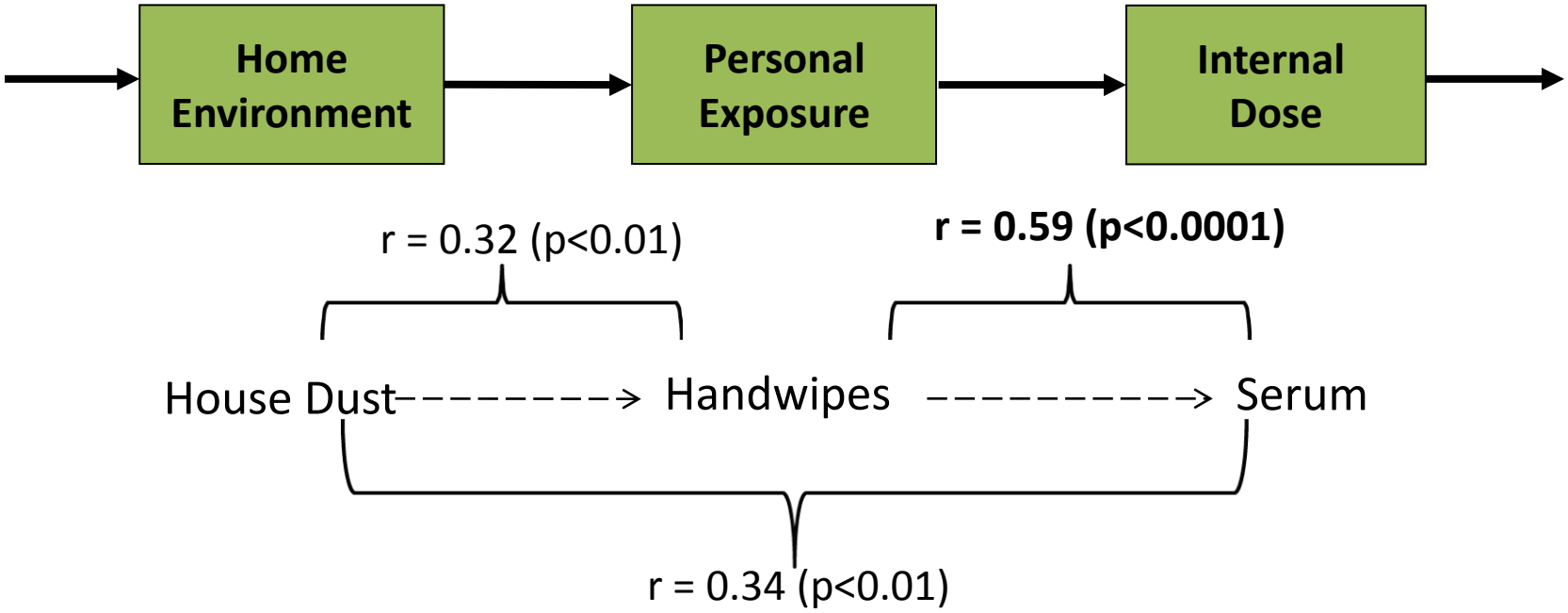
From Source to Dose



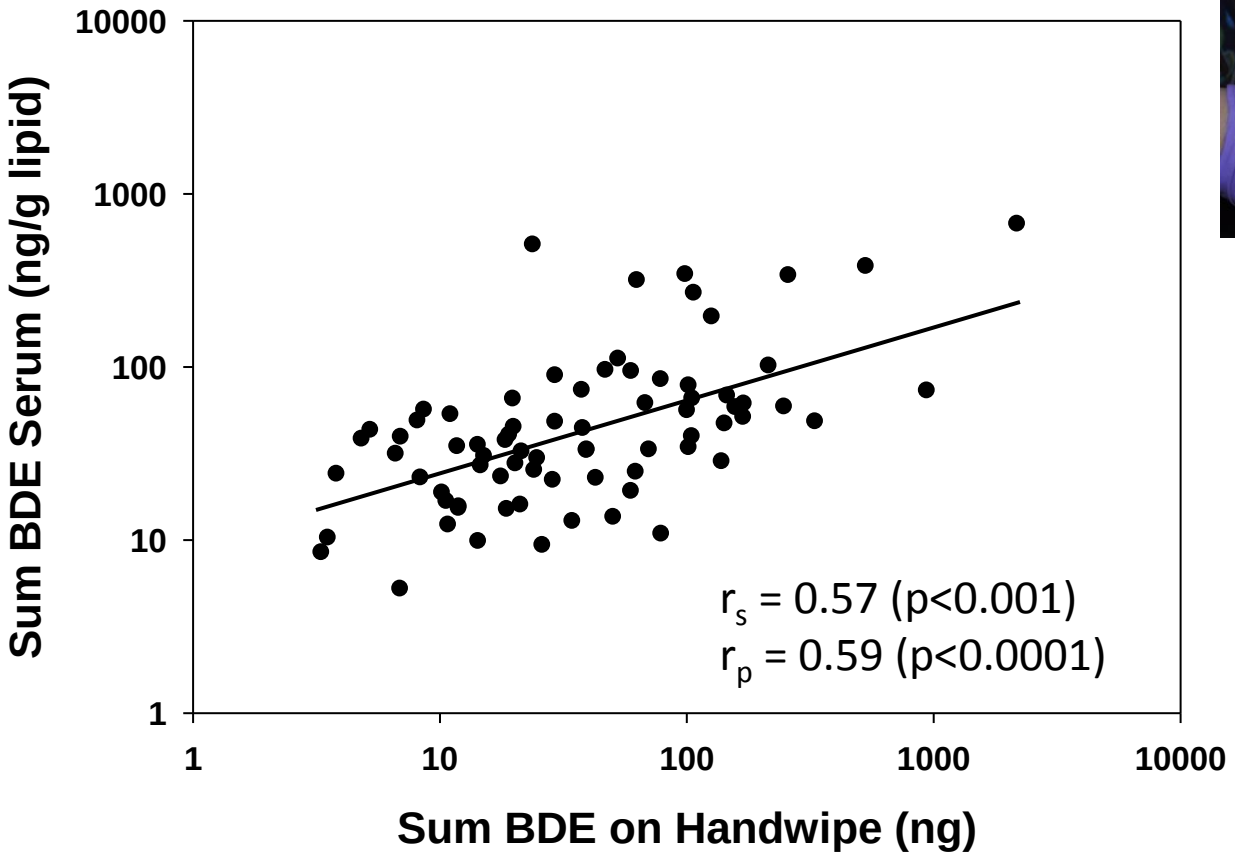
Source	Home Environment	Personal Exposure	Internal Dose	Health Effect
TV Flooring Furniture Insulation	Air or Dust	Inhalation? Hand to mouth? Dermal absorption?	Level in Body	Asthma ADHD Obesity

<u>Goal of Study</u>: To improve our understanding of pathway from "source" to "Internal Dose"

PBDE Exposure Pathway: (Stapleton et al. 2012)



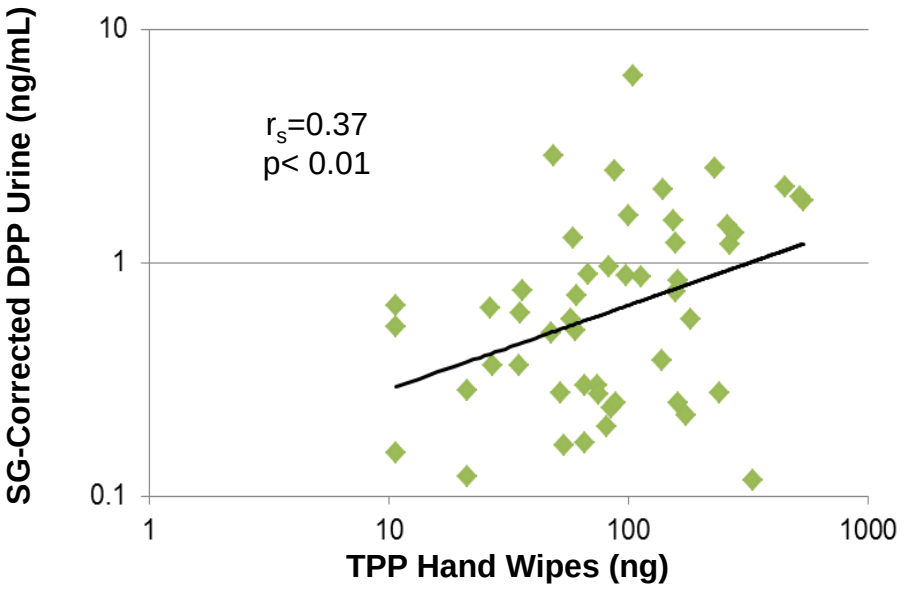
What's On Your Hands Predicts What's in Your Body!



Human Exposure to TDCPP & TPP

(Hoffman et al. 2015)

- TDCPP and TPP Levels in house dust did not predict handwipe or urine levels.
- However, TPP levels measured in handwipes did predict urinary metabolite levels (see Figure); trends for TDCPP were suggestive (p=0.06)
- ICC values: BDCPP = 0.81, DPP = 0.51
- BDCPP and DPP decreased 2-3%/year with increasing age (p<0.05)





Research Aims

1. Characterize SVOC applications in products common to home environment (e.g. furniture, TVs, insulation, flooring, etc)

1. Measure young children's exposure to SVOCs using hand wipes and determine if they predict internal dose (i.e. serum and urinary levels) using targeted and non-targeted approaches

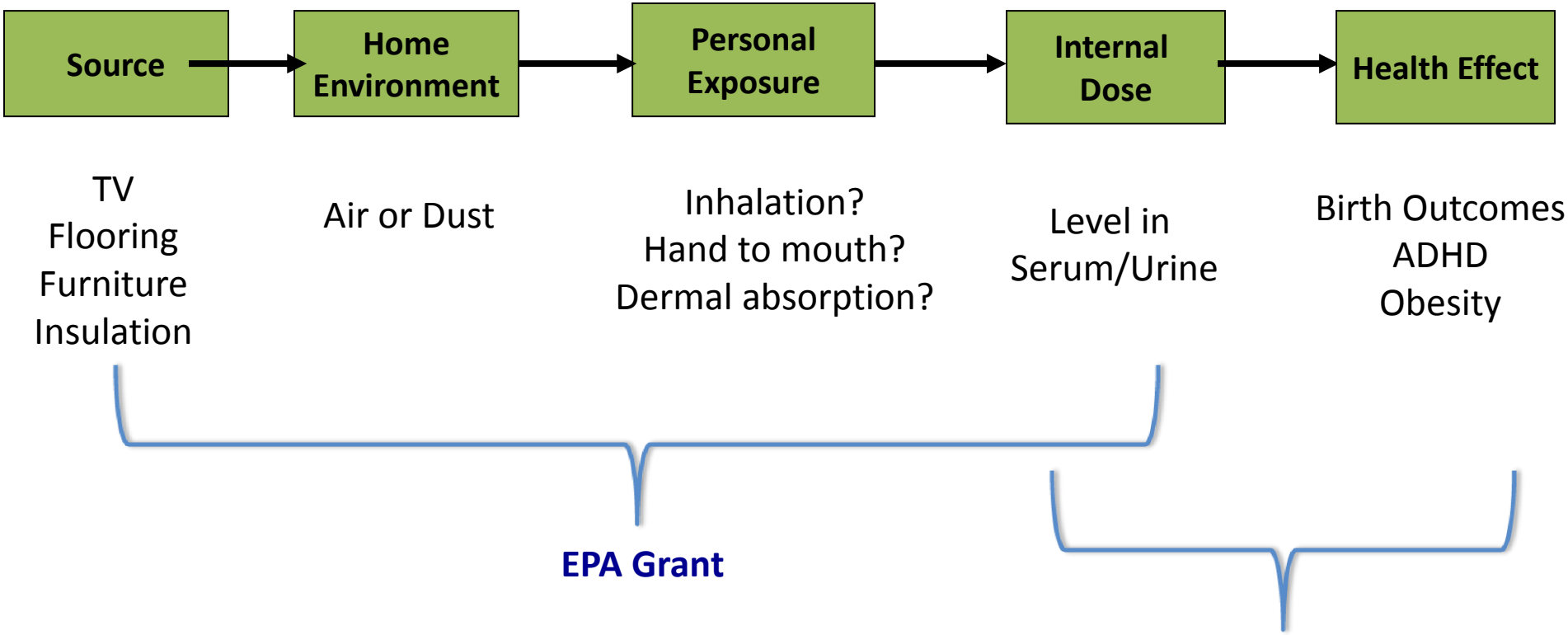
1. Examine modifiers of hand wipe levels (e.g. hand washing, behavior, etc)

1. Examine patterns of co-exposure to SVOCs

1. Compare empirical results with predictions by indoor models



From Source to Dose





Toddlers Exposure to SVOCs in Indoor Environments "TESIE"

Recruitment:

- Targeted families with children between the ages of 2-5 years who are residing in central North Carolina;
- Currently enrolled in the NEST study (see below);
- Living in the same residence since birth of their child
- Target number of participants = 200

http://sites.duke.edu/nest

The Newborn Epigenetic STudy (NEST) is a federally-funded research project that studies how environmental exposures and nutrition, in the womb and during childhood, affect how genes work. The genes we are studying are believed to play a role in obesity and other diseases, disorders, and conditions. We would like to thank all the mothers and children that participate in the NEST study. This is a relatively new and exciting area of research which will have an impact on the health of our children in the future!

NEST

Newborn Epigenetics Study



Sample Collections During Home Visit

Home

- Passive Air Sampler (n=50) for 2-3 week deployment
- Product Wipe Samples
- Dust Sample from child's play area

Child

- Height/weight, waist circumference
- Hand wipe
- Forehead wipe

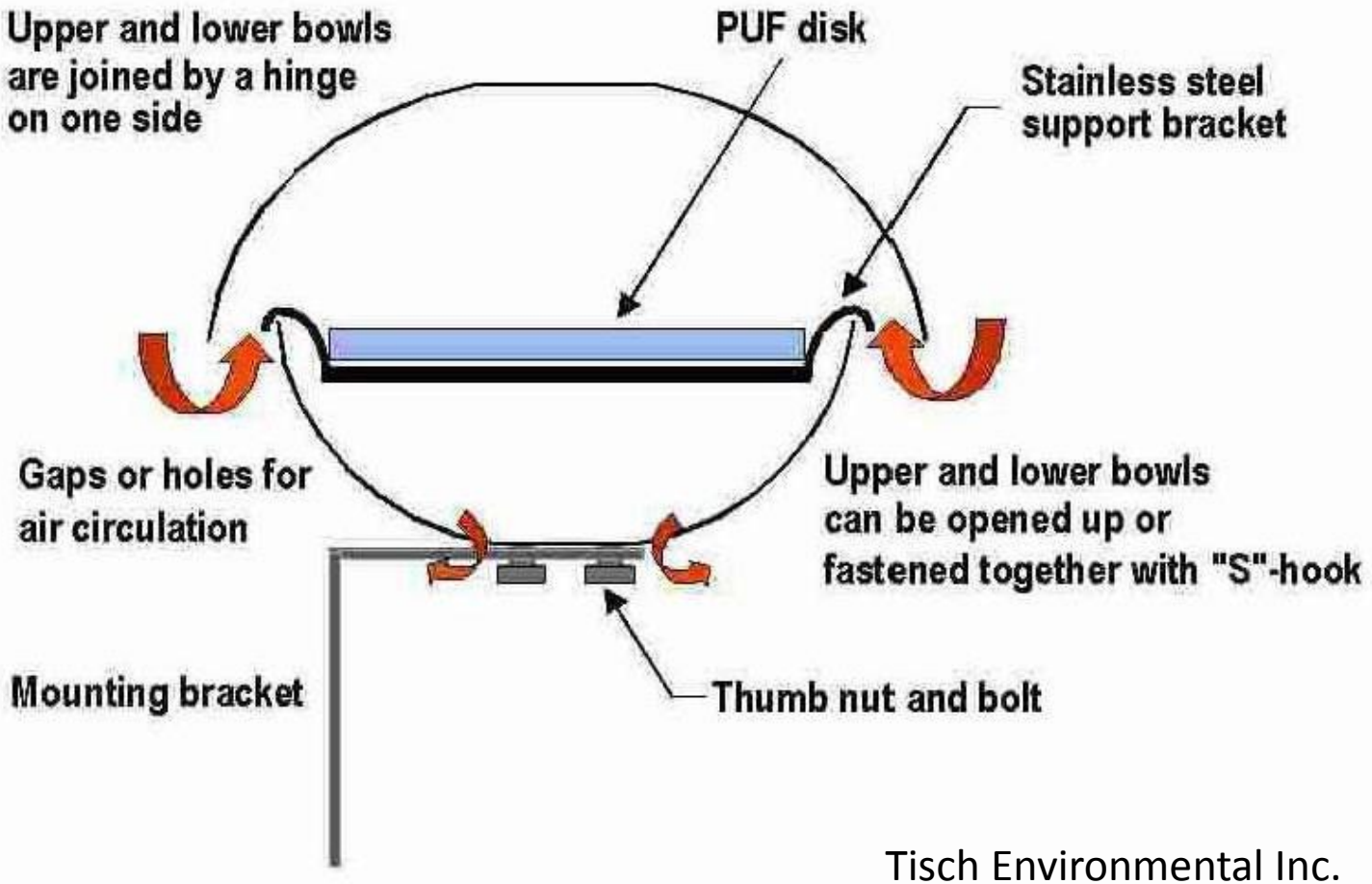
- Urine (over 2 days- then freeze)
- Blood
- Fecal sample

Parent

- Consent Form (prenatal blood)
- Questionnaire
- Activity recording sheet (to be mailed in)

Passive Air Samplers (50 Homes)

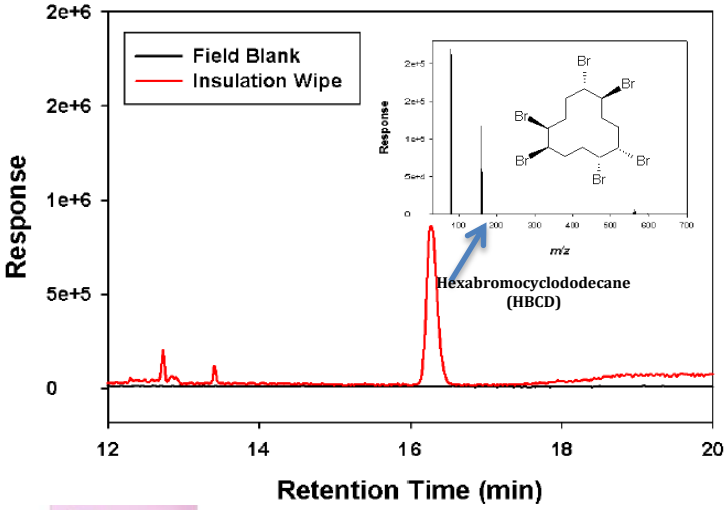
(Collaboration with Dr. Mahiba Shoeib)

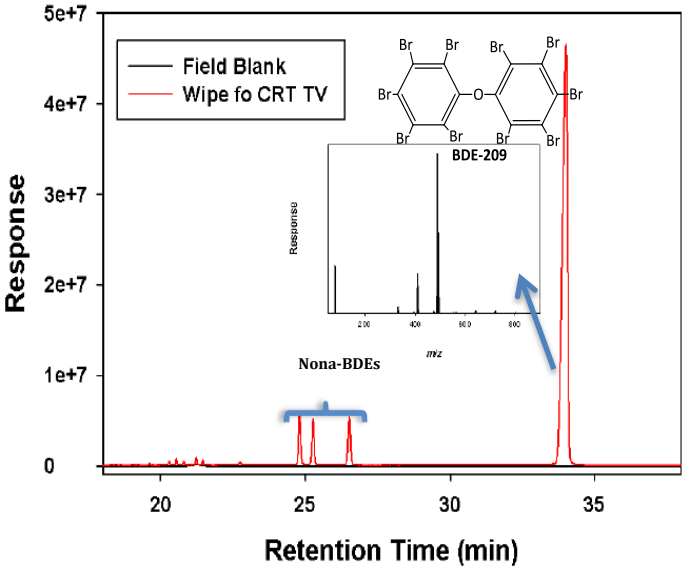


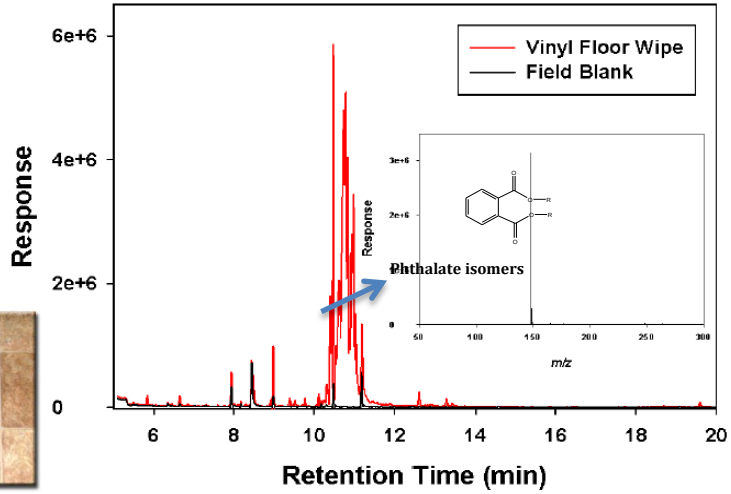
Tisch Environmental Inc.



Product Surface Wipes









Children's Activity Logs

As children develop and learn to eat on their own they often eat with their fingers and hands.

How does your child eat?

Please observe your child during **one meal**. On the chart, please mark a box each time your child touches their mouth with a fork or spoon, their hands, or their fingers. Please include each item and each time that it contacts your child's mouth in a separate row. Additional space is provided on the back of this sheet.

Please answer the questions below.

What did they use to eat?			
Fingers 	Whole Hand 	Fork or Spoon 	Other

Targeted SVOCs in Air, Dust and Handwipes

FLAME RETARDANTS

BDE 17
BDE 28
BDE 47
BDE 49
BDE 66
BDE 99
BDE 85
BDE 99
BDE 100
BDE 153
BDE 154
BDE 183
BDE 203
BDE 209

TBB
TBPH
HBCD
BTBPE
TBBPA

V6

TCEP	Tris (2-chloro-ethyl) phosphate
TCPP	Tris (1-chloro-isopropyl) phosphate
TDCPP	Tris (2,4-dichloro-isopropyl) phosphate
TPP	triphenyl phosphate
TBPP	tris (4-butyl-phenyl) phosphate
TiBP	Tri-iso-butyl-phosphate
TnBP	Tri-n-butyl-phosphate
TBOEP	Tri-(2-butoxyethyl)-phosphate
TBPDP	Tert-buty-phenyl, diphenyl phosphate
DEHP	diethyl hexyl phthalate
DBP	dibutyl phthalate
DINP	di-isononyl phthalate
DiBP	di-isobutyl phthalate
BBP	benzyl butyl phthalate
DMP	di-methyl phthalate
DEP	di-ethyl phthalate

PARABENS

BUTYL PARABEN
ETHYL PARABEN
METHYL PARABEN
N-PROPYL PARABEN

PHENOLS

BPA	bisphenol A
2,4 DBP	2,4 dibromophenol
2,4,5 TBP	2,4,5-tribromophenol
2,3,5 TBP	2,3,5-tribromophenol
2,4,6 TBP	2,4,6-tribromophenol

Triclosan

PAHS

Acenapthene
Anthracene
Benzo(a)pyrene
Fluoranthene
Fluorene
Phenanthrene
Pyrene
1,2 Benzanthracene
Chrysene
Benzo[b,k,j]fluoranthene
Benzo[e]pyrene
Benzo[a]pyrene
Perylene

PESTICIDES

Lindane
Chlorpyrifos

Permethrin
Fipronil
chlordane*
cypermethrin*

PERFLUORINATEd COMPOUNDS

PFCAs (C4-C12)
PFBS
PFHxS
PFOS
PFDS
FTOHs
FTACs (fluorotelomer acrylates)
diPAPs (4:2, 4:2/6:2)

Samples Collected To Date

(Sept. 2014- present)

Mother:

Prenatal Blood n=46

Home Environment:

Dust = 46

Surface Wipes n=46

Sofa Foam n=27

Air n=10

Child:

Blood n=23

Urine n=43

Feces n=4

Hand Wipes n=45

Forehead Wipes n=45

Activity Logs n=36

Pilot Studies

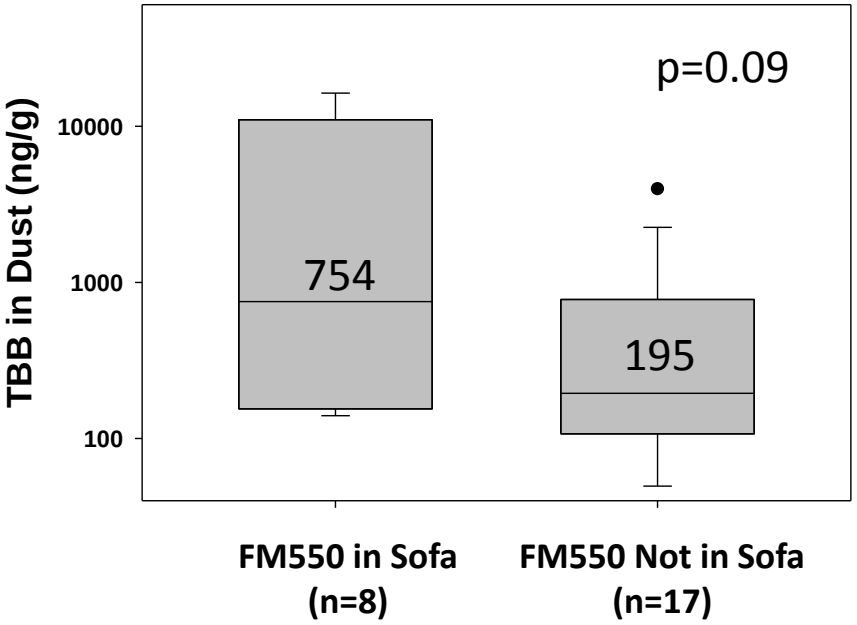
Pilot Project: Predicting FR Levels in Dust

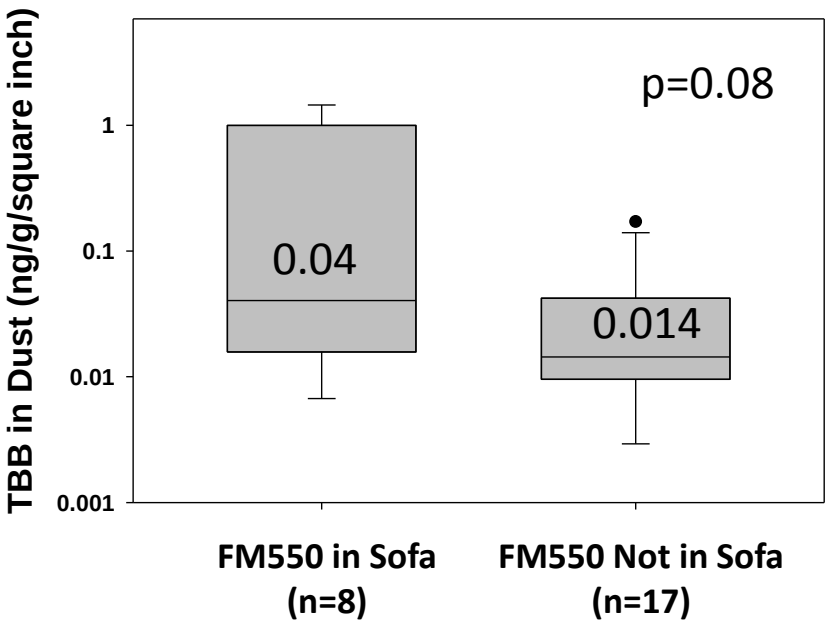
- Home visits conducted April –November 2014
- Collected investigator collected house dust
- Collected a sample of polyurethane foam from sofa in main living area

Foam Collection

Dust Collection

Pilot Project: Predicting FR Levels in Dust



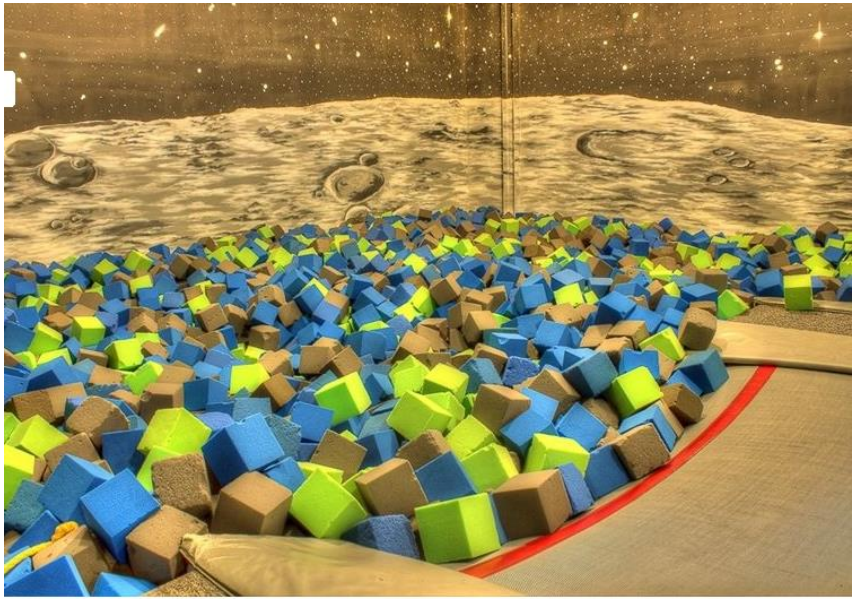


- Carpet vs wood flooring affects dust loading, but not FR dust concentrations
- Age of furniture does not appear correlated with dust concentrations

Non-Targeted Analysis of Hand Wipe Samples

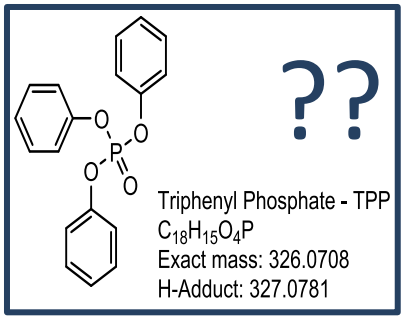
- Question: Can hand wipes identify recent exposures in a specific micro-environment?

- Hand wipes and urine (n=4) collected before and after spending one hour playing in a foam pit filled with flame retarded treated pit cubes



TIC of Before, After and Field Blank

Exact Mass: 327.0778



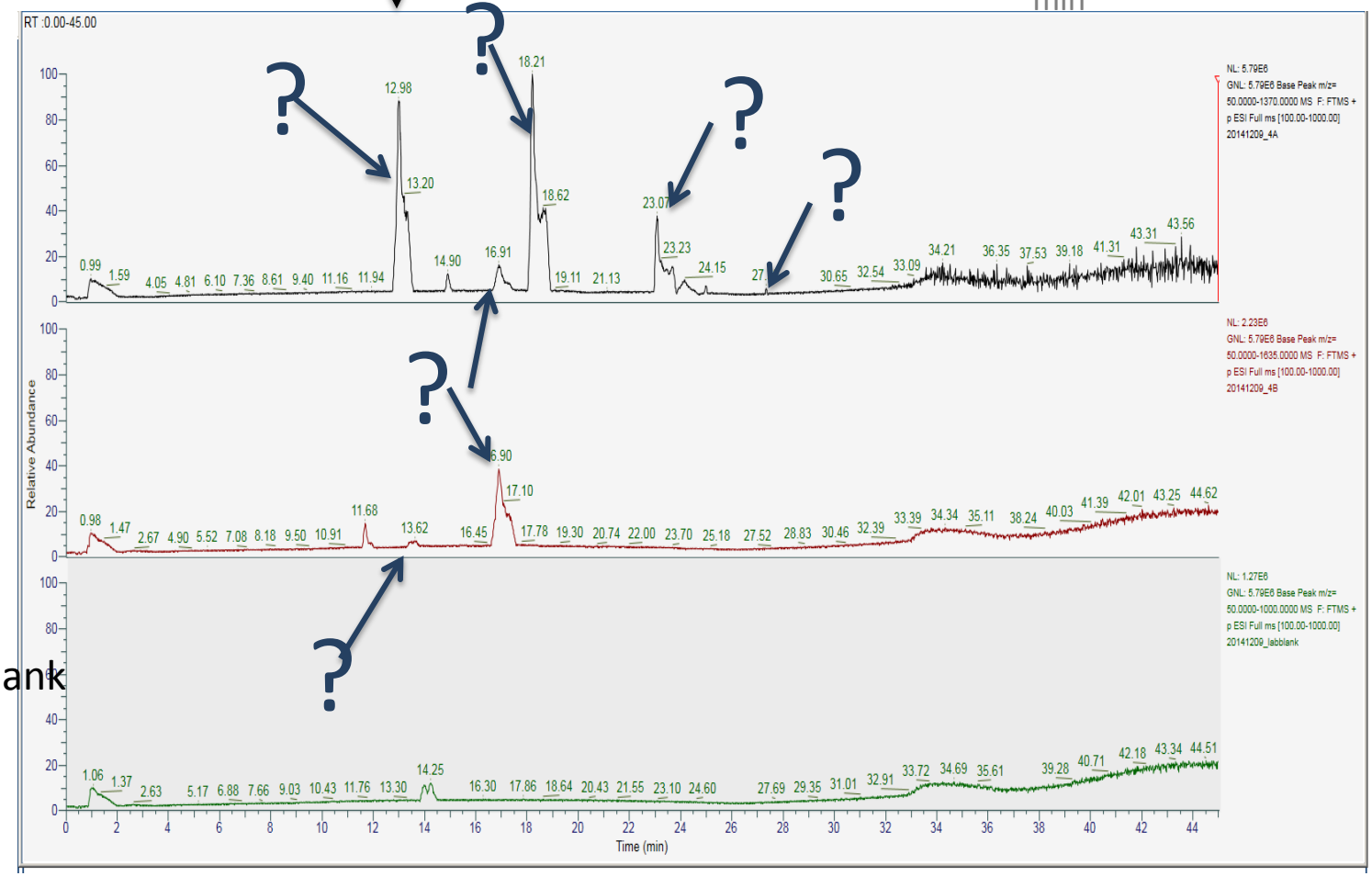
Sample preparation and Liquid Chromatography
1:9 Dilution in H_2O; centrifuged at 15,000 rpm at 4˚C

Hypersil Gold: 100 x 2.1 mm; 1.9 µm particle size
0.5 ml/min
10 % ACN in H_2O to 95 % ACN in 45 min

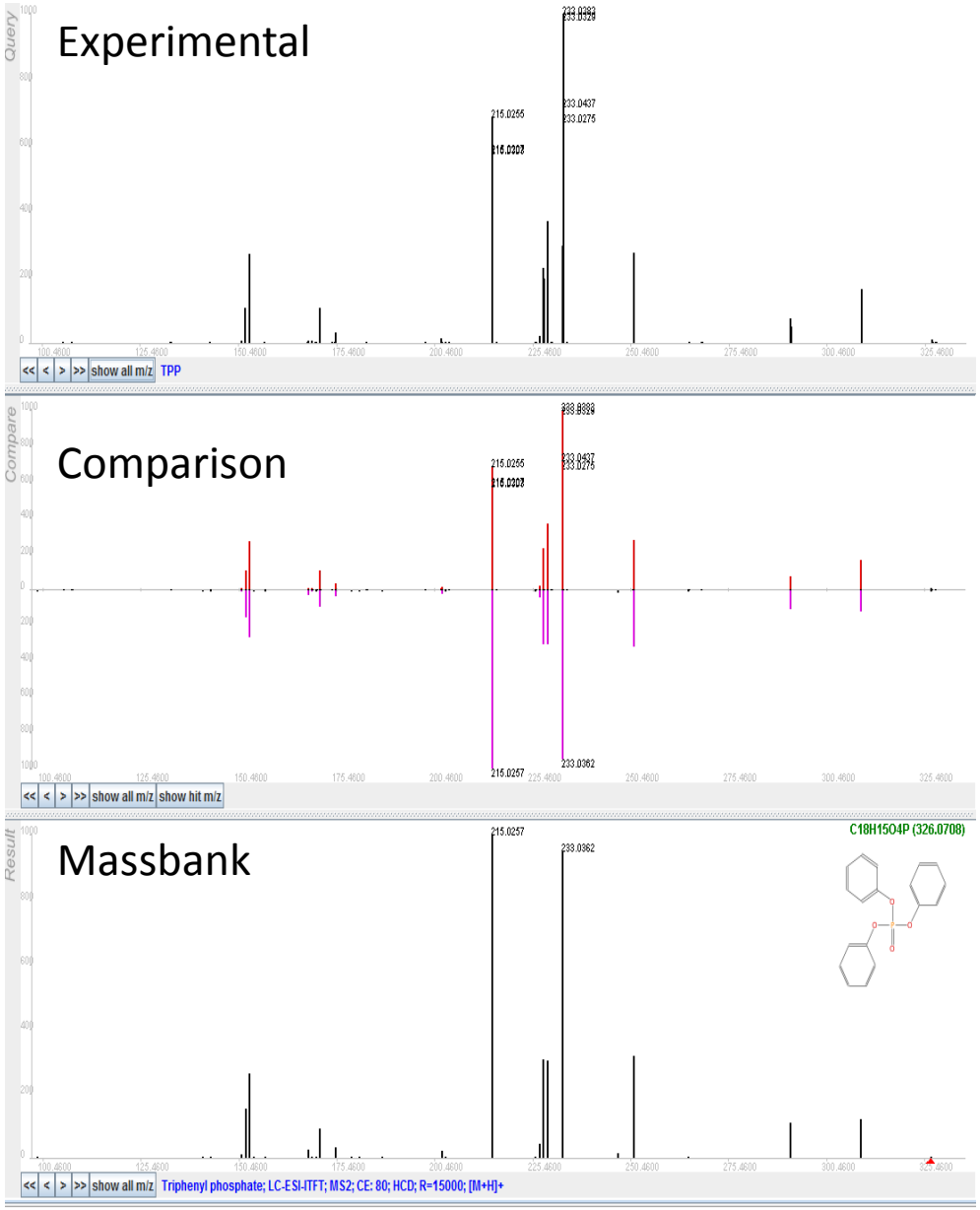
After

Before

Field blank



MSMS Spectra Comparison with Massbank



TIC of Before, After and Field Blank

Sample preparation and Liquid Chromatography

1:9 Dilution in H_2O; centrifuged at
m at 4˚C

Gold: 100 x 2.1 mm; 1.9 µm
ze
n
in H_2O to 95 % ACN in 45

Triphenyl Phosphate - TPP
$C_{18}H_{15}O_4P$

di-tertbutyl TPP
$C_{26}H_{31}O_4P$

Exact Mass: 383.1400

Exact Mass: 439.2025

Exact Mass: 495.2667

+ 56.02
C_4H_8 unit

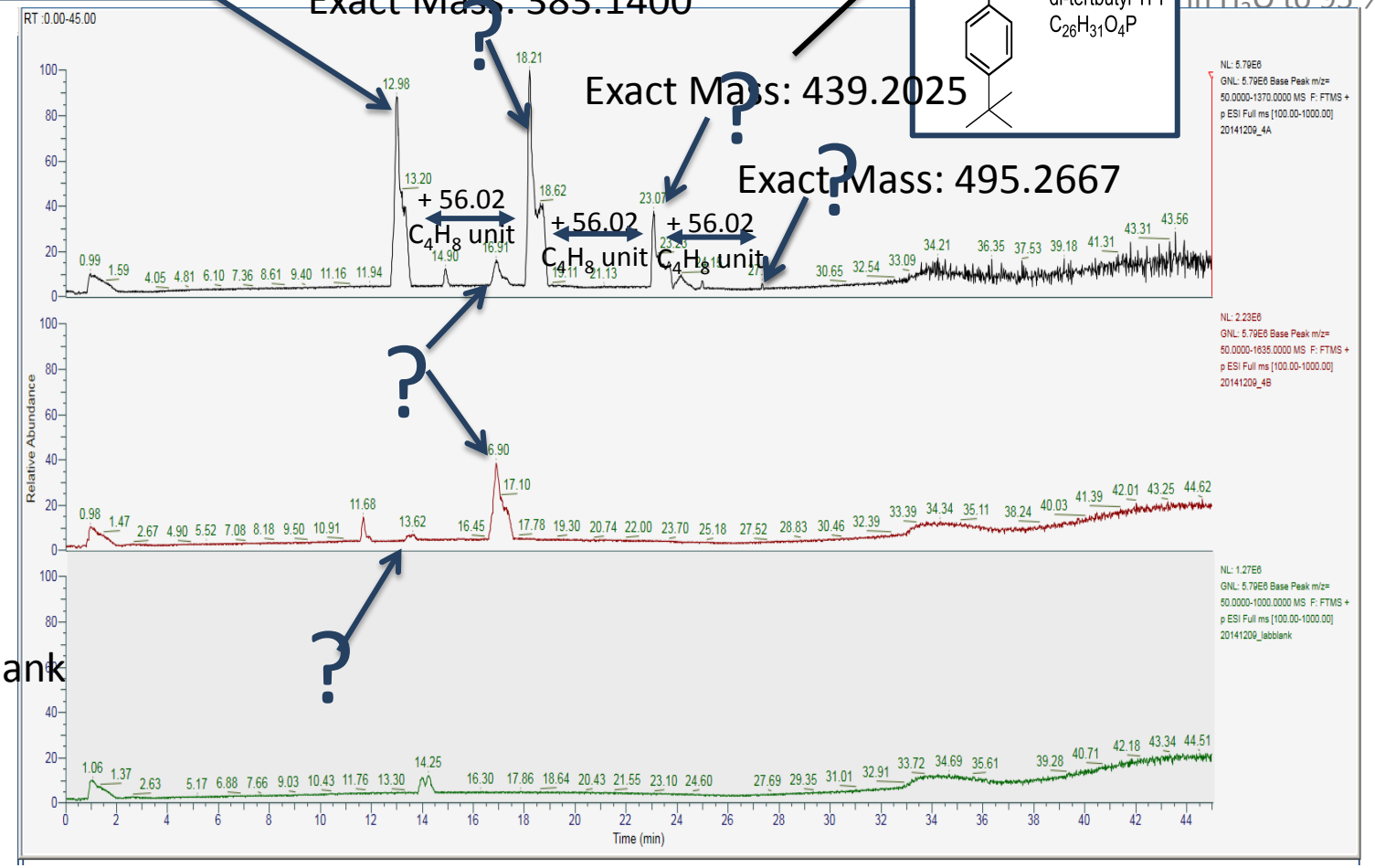
+ 56.02
C_4H_8 unit

+ 56.02
C_4H_8 unit

After

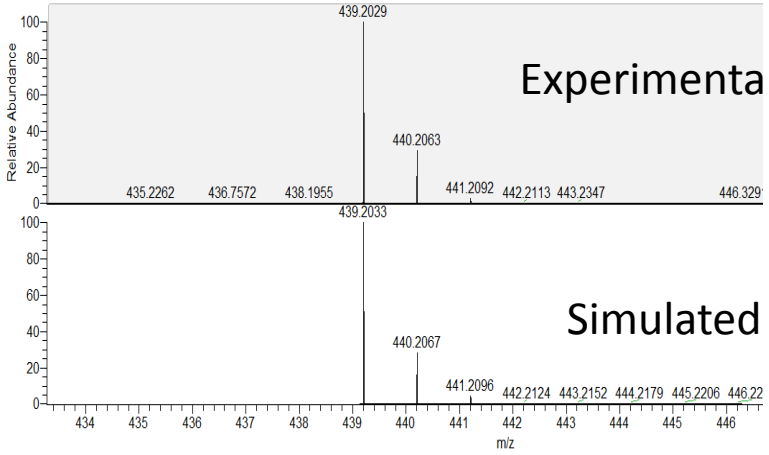
Before

Field blank

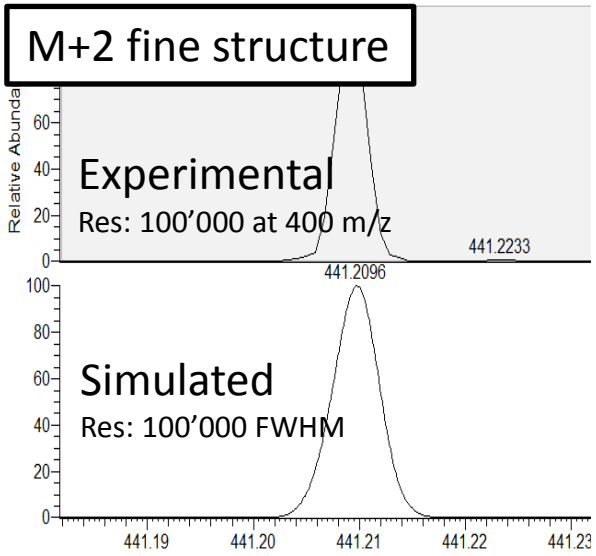


Spectra of 439.2025

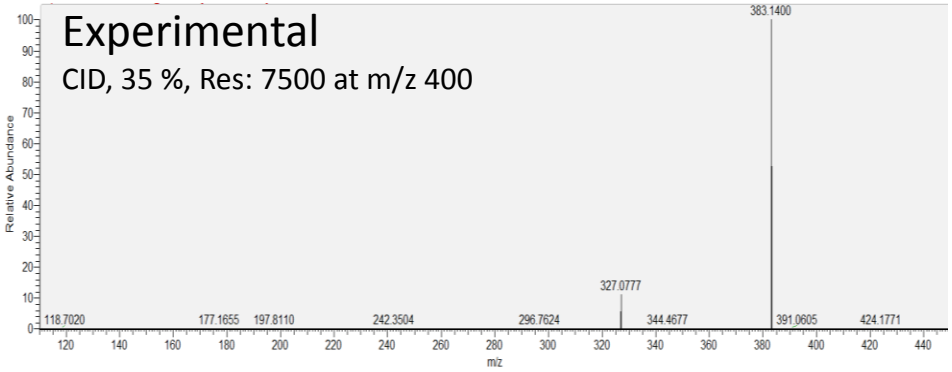
Isotopic pattern



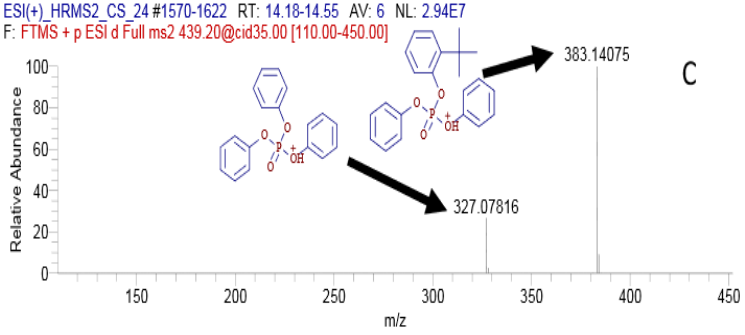
M+2 fine structure



MSMS of 439.2025



Literature

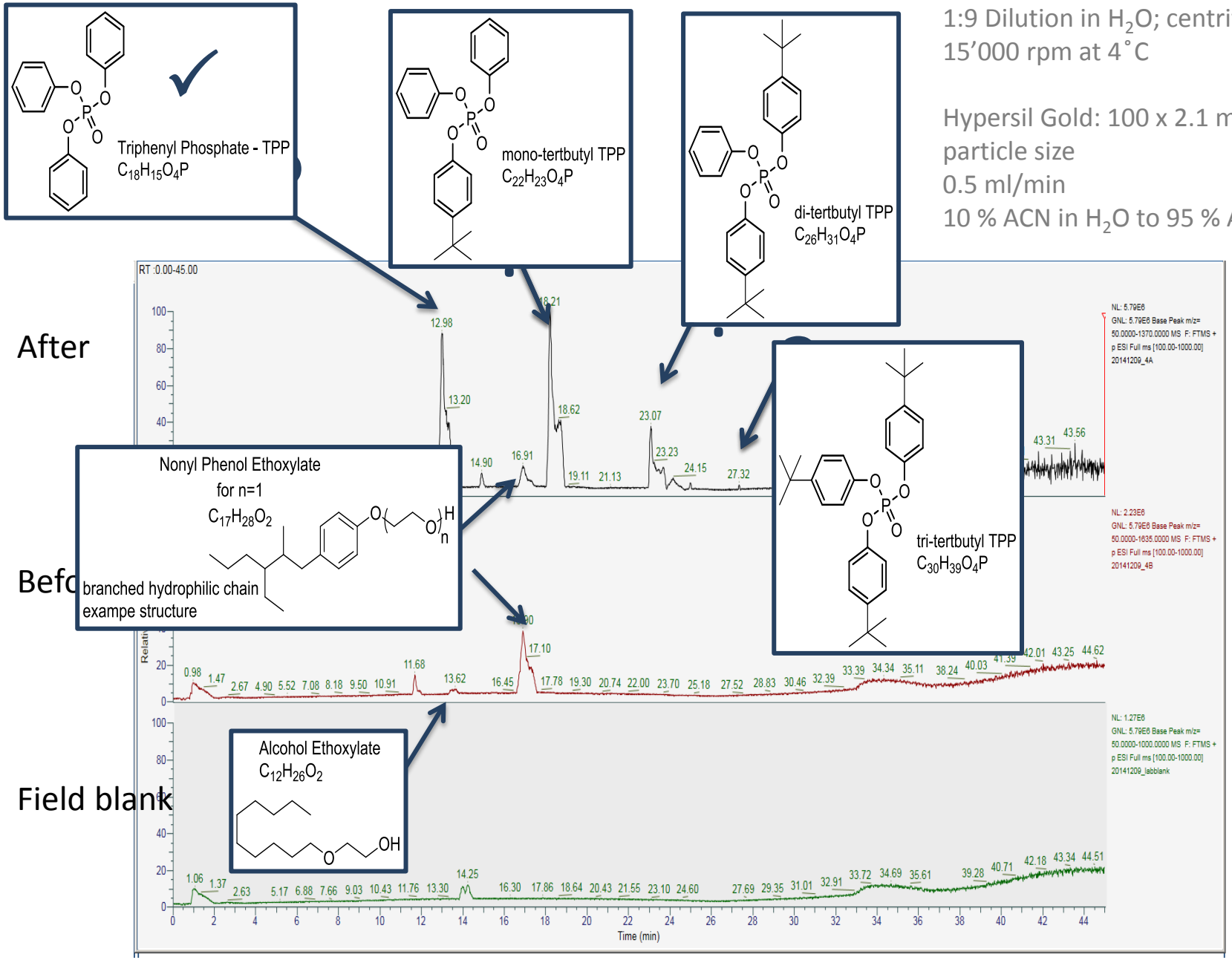


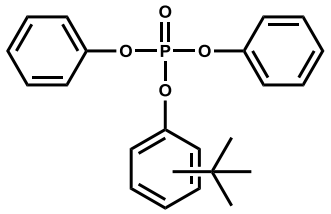
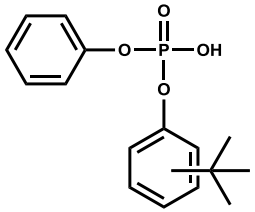
H. Stapleton et al., *Environmental Science and Technology*, **2012**, *46* (24), 13432-13439

TIC of Before, After and Field Blank

Sample preparation and Liquid Chromatography
1:9 Dilution in H_2O; centrifuged at 15'000 rpm at 4˚C

Hypersil Gold: 100 x 2.1 mm; 1.9 µm particle size
0.5 ml/min
10 % ACN in H_2O to 95 % ACN in 45 min

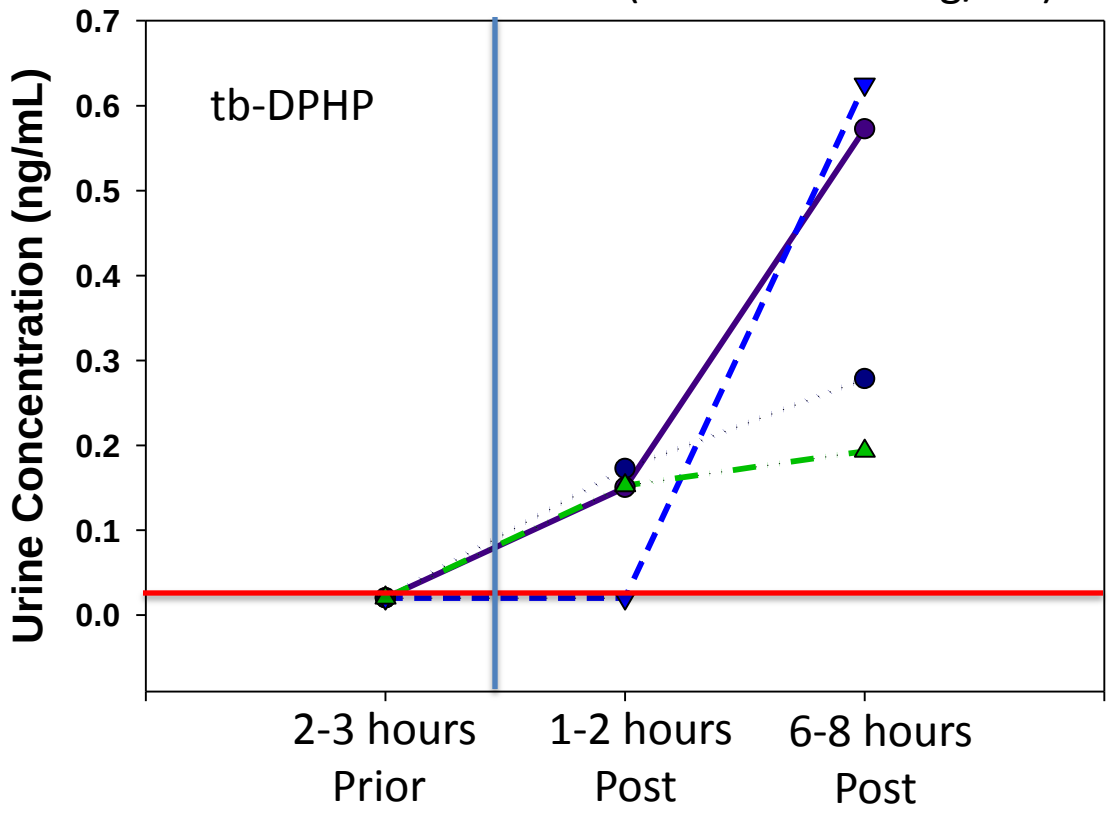


Parent	Hypothesized metabolite
	
t-butyl triphenyl phosphate (tb-TPHP)	t-butyl diphenyl phosphate (tb-DPHP)

Butt et. al 2014 (n=22 pairs)

Moms: 5% Detection (<MDL to 0.13 ng/ml)

Toddlers: 19% Detection (<MDL to 0.48 ng/mL)



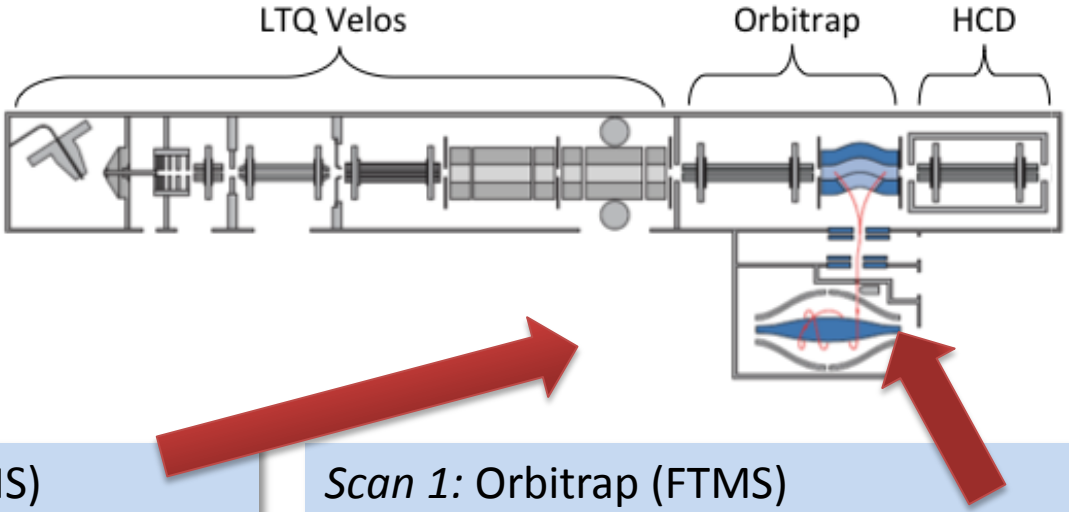
Non-targeted analysis by HRMS/MS

Chromatography:

- Accela UHPLC system
- RP C18 column (100x2.1mm)
- ACN/H_2O Gradient (~45min)

Mass Spectrometry:

- Thermo LTQ Orbitrap Velos
- **HESI(+)**, HESI(-), APPI/APCI(+)
- Full-scan HRMS + FTMS/MS



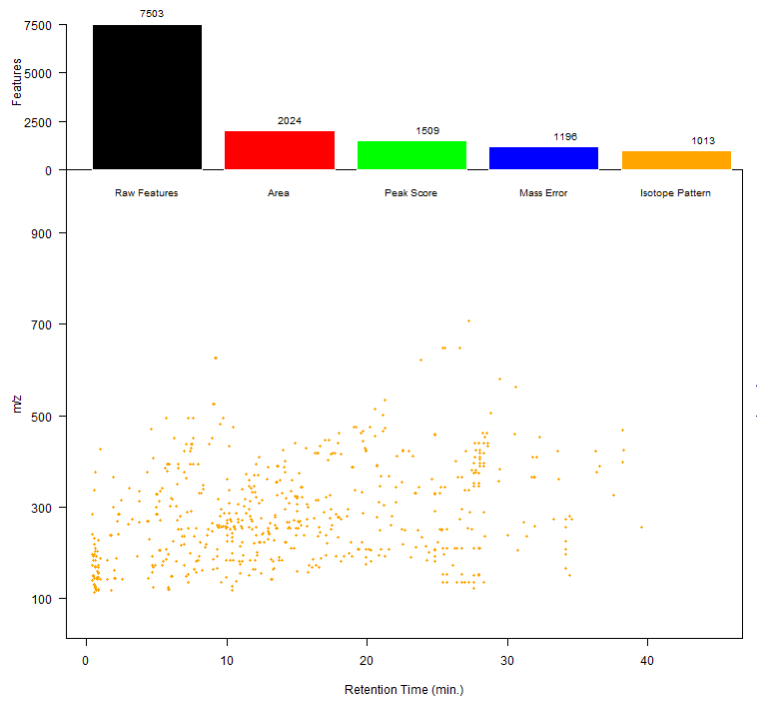
Scan 2-4: Orbitrap (FTMS/FTMS)

- Data-dependent top 3 $HRMS^2$ R=7500
- Accurate mass CID spectra of most intense ion from Scan 1

Scan 1: Orbitrap (FTMS)

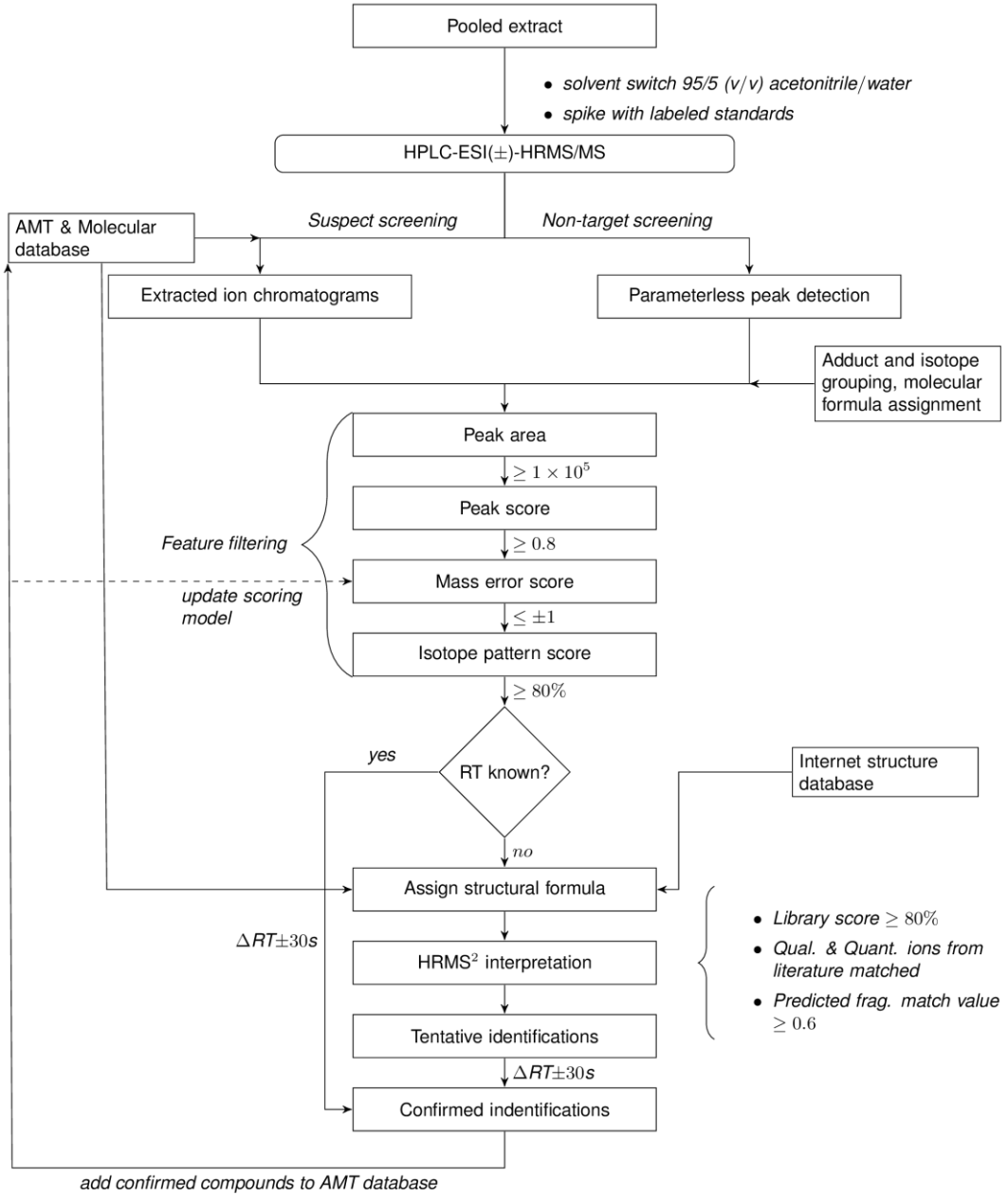
- Full-scan
- Accurate mass (<2ppm by external cal.)
- High-resolution (R=100,000 FWHM)

Workflow for non-targeted data analysis



Two suspect databases:

1. Thermo EFS database (1,004 substances with MS/MS library)
2. Compiled from literature including PBT, occurrence, and pharm. analytics (4,475 substances)



Non-target analysis objectives:

- Utilize 1D and 2D HPLC separations coupled to HRMS to resolve and characterize a broad range of polar and semivolatile pollutants in house dust, children's hand wipes, and urine/serum samples.
- Employ APCI, APPI, and ESI ionization methods to broaden the range of pollutants detected.
- Perform differential (subtractive) data analysis among dust, hand wipe, and urine/serum samples to prioritize contaminants with highest exposure and accumulation potential.
- Identify prioritized contaminants using customized databases and libraries of POPs, polymer additives, and consumer chemicals, together with authentic standards.

Future Plans & Directions

- Recruitment phase will take another year to complete
- Begin chemical analyses in Summer/Fall 2015
- Conduct hand washing experiments during Summer 2015
- Characterize additive chemical applications in insulation, flooring and wiring components

Thank You For Your Attention!

Questions?