DEPARTMENT OF HEALTH

Persistent, Ubiquitous, and Not Always Clear – Understanding PFAS Toxicity and Health Effects

James Kelly, MS – Manager, Environmental Surveillance & Assessment

December 15th, 2020

PROTECTING, MAINTAINING AND IMPROVING THE HEALTH OF ALL MINNESOTANS

CLEAN WATER LAND & LEGACY AMENDMENT

Outline

- General Overview of Health Risk Assessment
- Challenges of Per- and polyFluoroAlkyl Substances (PFAS)
- Health Effects
- MDH Mother-Child Model
- Conclusions

Key Takeaways

- PFAS have been in use for over seventy years, health science has lagged
- Assessing health risks requires lots of data!
  - Most PFAS, and there are thousands, have no available toxicity information
- PFAS are difficult to quantify, problematic to study in a laboratory, last nearly forever in the environment in some form, and are found in most people's blood (98% of the population)
- Linking human health effects to PFAS exposure is extremely difficult work
- Our current system - generating toxicity data in animal models and evaluating chemicals one at a time is poorly suited to address societal needs and concerns around PFAS

Role of Minnesota Department of Health (MDH)

- 1989 Groundwater Protection Act
  - Requires MDH to protect public health by developing human health-based guidance values for groundwater contaminants
- Goal is to protect the resource as a potential drinking water source
- Establishing Health Risk Limits (HRLs)
  - Concentration of a chemical likely to pose little or no risk to human health
- HRLs are not enforceable drinking water standards as specified in rule, but individual regulatory programs may use them in MN
- Promulgation through rulemaking is required for guidance to become HRL

General Overview of Health Risk Assessment

- Human Health Risk Assessment requires high quality toxicity data for multiple effects
  - Animal Studies
  - Human/Epidemiological Studies

- Publicly-available peer-reviewed studies
- Very expensive, often held back as trade secrets

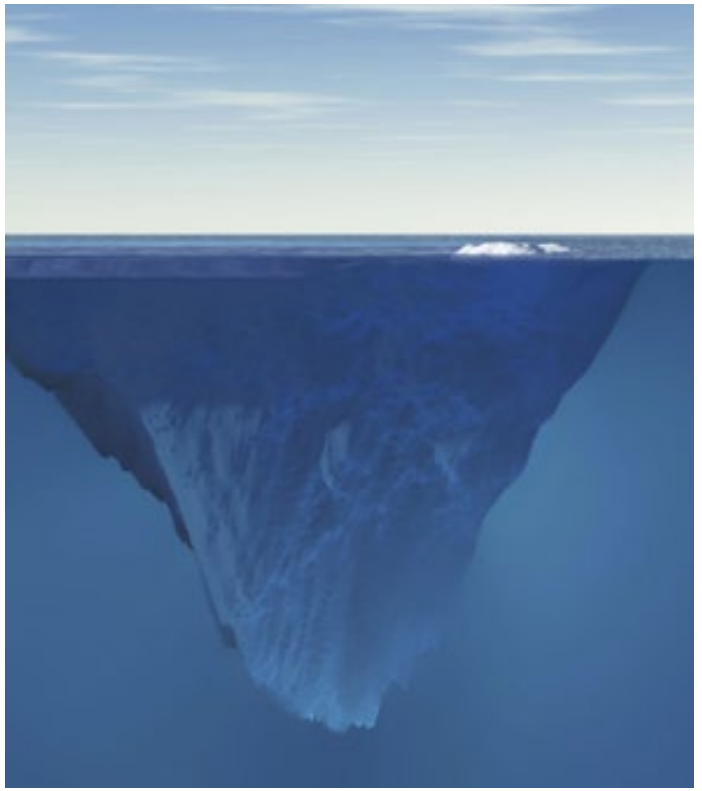
Evaluating the Available Data

- Scientists at the Minnesota Department of Health evaluate available studies
  - Toxicity and Exposure studies
- Study design: Doses, Durations, etc.
- Key (critical) effects
- Establish health protective daily dose and water concentration

- Values are not enforceable standards, solely health considered

No Data, Often No Guidance

- When data are limited, so are guidance options
- Use data from another related chemical (maybe)
- Different types of guidance are possible
- #1 issue for PFAS is a lack of data
  - ~99% of PFAS, no data on toxicity



MDH's Long History with PFAS

- 2002 – First PFAS water guidance values developed
- PFOA and PFOS were first, then PFBA, PFBS, PFHxS
- Guidance values have decreased over time, as more information becomes available
  - Toxicological data
  - Just as important, human half-life information
- Major focus of efforts by many staff across multiple agencies from 2002 – present day

PFAS Challenges – Physical/Chemical Properties

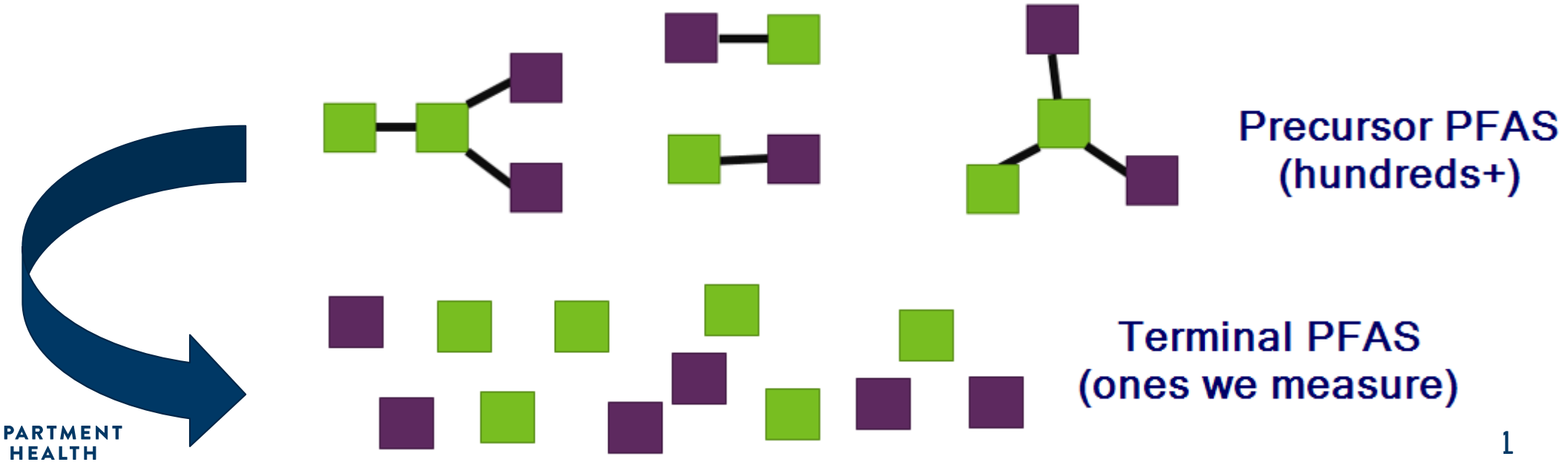
- PFAS behave differently than many other contaminants
- Water soluble, yet some are very bioaccumulative
  - Actively retained by our kidneys (mimic fatty acids)
- No metabolism – PFOA, PFOS, PFHxS, PFBS, PFBA
- Others are metabolically active, but poorly understood

Only a handful of PFAS can be reliably detected

- A good analytical method for PFAS will be able to detect about 30 different PFAS chemicals
- 10-15 years ago, that number was closer to just five PFAS
- New methods are being developed, but identifying all PFAS compounds is currently not possible

PFAS End Products and PFAS Precursors

- End products famous, commercial products mysterious
  - Stable end products: PFOA, PFOS, PFBS, PFHxA, PFHxS, etc
  - But Precursors are often the commercial product



Challenges of PFAS: Persistent and Bioaccumulative

- Longer chain PFAS bioaccumulate in the human body over many decades, and can take many years to leave the body after exposure stops
- PFAS can occur in sources of food (esp. fish/seafood), drinking water, house dust, and on articles (clothes, furniture)
- Dermal exposure – not well absorbed (good!)
- Inhalation exposures can occur, little is known

Challenges of PFAS: Unknown Production, Releases, Import

- Recently (2020) PFAS have been included in Toxics Release Inventory (172 PFAS chemicals)
- Amounts of PFAS produced, imported and released into the environment each year unknown
- Some more problematic PFAS like PFOA and PFOS are no longer made in the US
- New, approved, PFAS have taken their place – impact of revised TSCA unclear

PFAS Health Effects - Epidemiology

- Epidemiology Studies (associations, not causal)
  - Developmental (e.g., ↓ birth weight)
  - Endocrine (e.g., thyroid homeostasis)
  - Immune (e.g., ↓ vaccine response, ulcerative colitis)
  - Kidney (e.g., ↑ uric acid)
  - Liver (e.g., ↑ serum lipids and liver enzymes)
  - Cancer (e.g., testicular, kidney; mixed results positive/negative)

PFAS Health Effects – Animal Studies

- Laboratory Animal Studies (causal)
  - Developmental Effects (e.g., ↓ body weight, delayed puberty & mammary gland development, accelerated puberty, changes in lipid metabolism & liver histology)
  - Endocrine (e.g., ↓ thyroid hormones)
  - Immune (e.g., ↓ immune response, ↓ spleen & thymus weight)
  - Kidney and Liver effects (e.g., ↑ organ weight, ↓ cholesterol)
  - Cancer (PFOA - liver, pancreas, kidney)

Most Sensitive PFAS Health Effects

- Thyroid
- Immune System
- Cholesterol/Lipid (liver) effects
- Developmental Effects

Setting MDH Health-Based Values for PFAS in Water

Most Sensitive (subtle) Health Effects in Animals

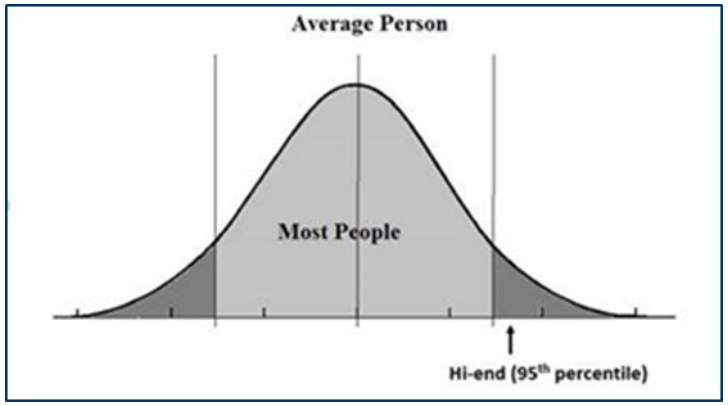
Identify Exposure Level ≠ Health Effects

Add Margins of Safety (100 to 300-fold)

Reference Exposure Level

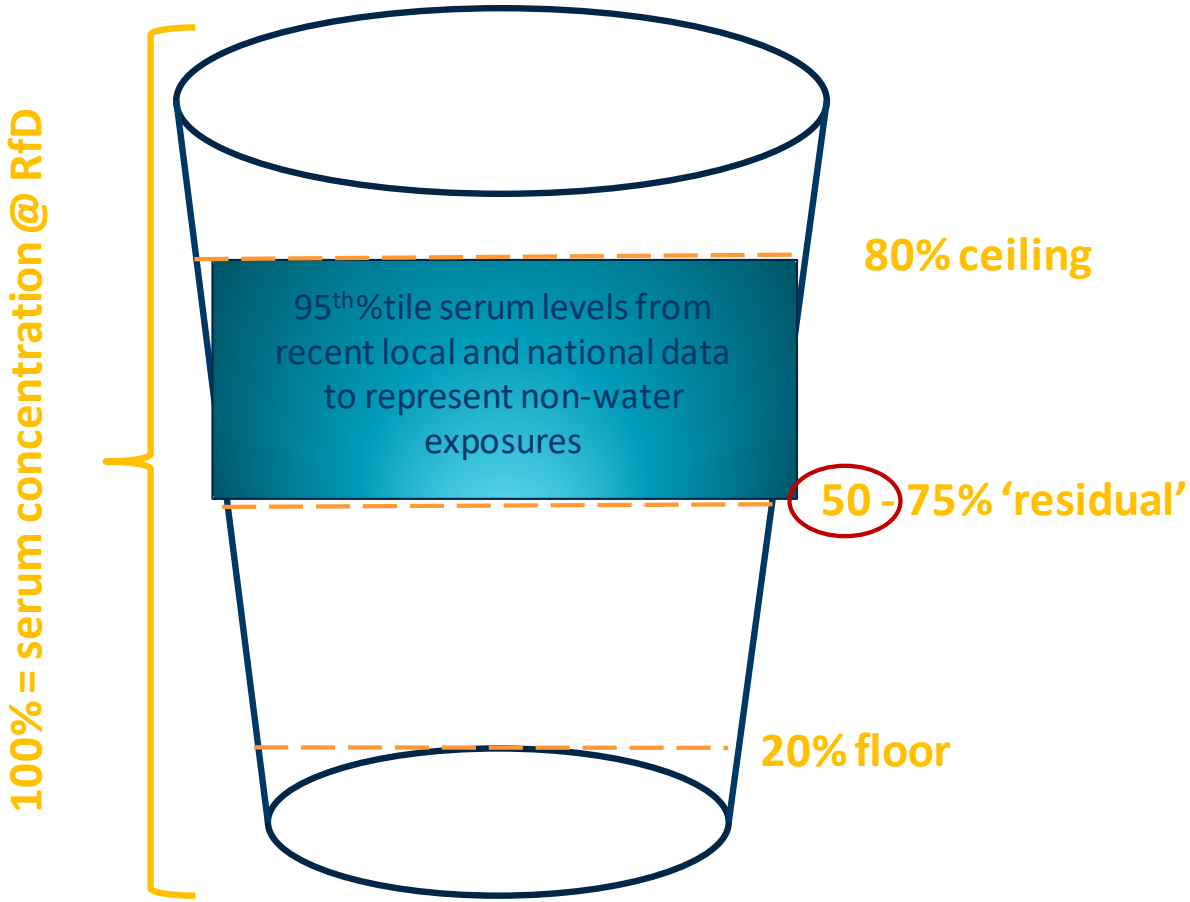
½ allowed to come from drinking water

High-End Water Intake Rate



Health-Based Value for Lifetime Exposure

Relative Source Contribution (RSC)



How PFAS Water Guidance has Changed

- MDH health-based guidance values have evolved over time as additional research becomes available
- Surrogate values were used when widespread detection of chemical in drinking water, but insufficient toxicological data to set an HBV
- Health Risk Index (HI): allows MDH to evaluate mixtures of similar chemicals
  - If HI > 1, considered an exceedance

	PFOA	PFOS	PFBA	PFBS	PFHxS
2002	7	1			
2006	1	0.6	1		
2007	0.5	0.3	7		
2009	0.3	0.3	7	7	
2013	0.3	0.3	7	7	0.3
2016	0.07	0.07	7	7	0.07
2017	0.035	0.027	7	3/2	0.027
2019	0.035	0.015	7	3/2	0.047

Blue = HRL; Red = HBV; Green = Surrogate

$$HI = \frac{PFOA_{[conc]}}{0.035} + \frac{PFOS_{[conc]}}{0.015} + \frac{PFBA_{[conc]}}{7} + \frac{PFBS_{[conc]}}{2} + \frac{PFHxS_{[conc]}}{0.047}$$

How does Minnesota compare?

TABLE 1: State and US Environmental Protection Agency guidelines for PFAS in drinking water[a]

	Long chain (ng/L)							Short chain (ng/L)			
	PFOA	PFOS	PFNA	PFHxS	PFHpA	PFDA	Total	PFBA	PFHxA	PFBS	GenX
No. of carbons	8	8	9	6	7	10		4	6	4	6
USEPA	70	70	—	—	—	—	Yes (2)[b]	—	—	—	—
CA	10	40	—	—	—	—	No[c]	—	—	—	—
CT	70	70	70	70	70	—	Yes (5)[b]	—	—	—	—
MA	20	20	20	20	20	20	Yes (6)[b]	—	—	2000	—
MI	8	16	6	51	—	—	No	—	400 000	420	370
MN	35	15	—	47	—	—	No	7000	—	2000	—
NH	12	15	11	18	—	—	No	—	—	—	—
NJ	14	13	13	—	—	—	No	—	—	—	—
NY	10	10		—	—	—	No	—	—	—	—
NC	—	—	—	—	—	—	—	—	—	—	140
OH	70	70	21	140	—	—	Yes (2)[d]	—	—	140 000	700
VT	20	20	20	20	20	—	Yes (5)[b]	—	—	—	—
WA	10	15	14	70	—	—	—	—	—	1300	—

Source: Environmental Toxicology and Chemistry, 2020;00:1–14—G.B. Post

Why the Difference?

TABLE 3: Toxicological basis of state and US Environmental Protection Agency Reference Doses for perfluorooctane sulfonate

	MN/NH/WA	MI	NJ/NY	MA	VT/USEPA
Critical effect	Decreased antibody response to foreign antigen			Developmental—decreased offspring body weight	
Species	Mouse			Rat	
Study	Dong et al. (2011)	Dong et al. (2009)		Luebker et al. (2005)	
Serum PFOS metric	Measured			Modeled average	
Point of departure[a] (ng/mL)	2620 (NOAEL)	674 (NOAEL)		6260 (NOAEL)	
Uncertainty factor					
Intraspecies[b]	10				
Interspecies[c]	3				
Shorter-than-chronic	1[d]				
LOAEL-to-NOAEL	1				
Database[e]	3	1		3	1
Total[f]	100	30		100	30
Clearance factor[g]	0.00013 L/kg/d (Human $t_{1/2}$ 3.4 yr; Li et al. 2018)		0.000081 L/kg/d (Human $t_{1/2}$ 5.4 yr; US Environmental Protection Agency 2016b)		
Reference Dose (ng/kg/d)	3	2.9	1.8 or 2[h]	5	20

Source: Environmental Toxicology and Chemistry, 2020;00:1–14—G.B. Post

Human Health Effects – digging deeper

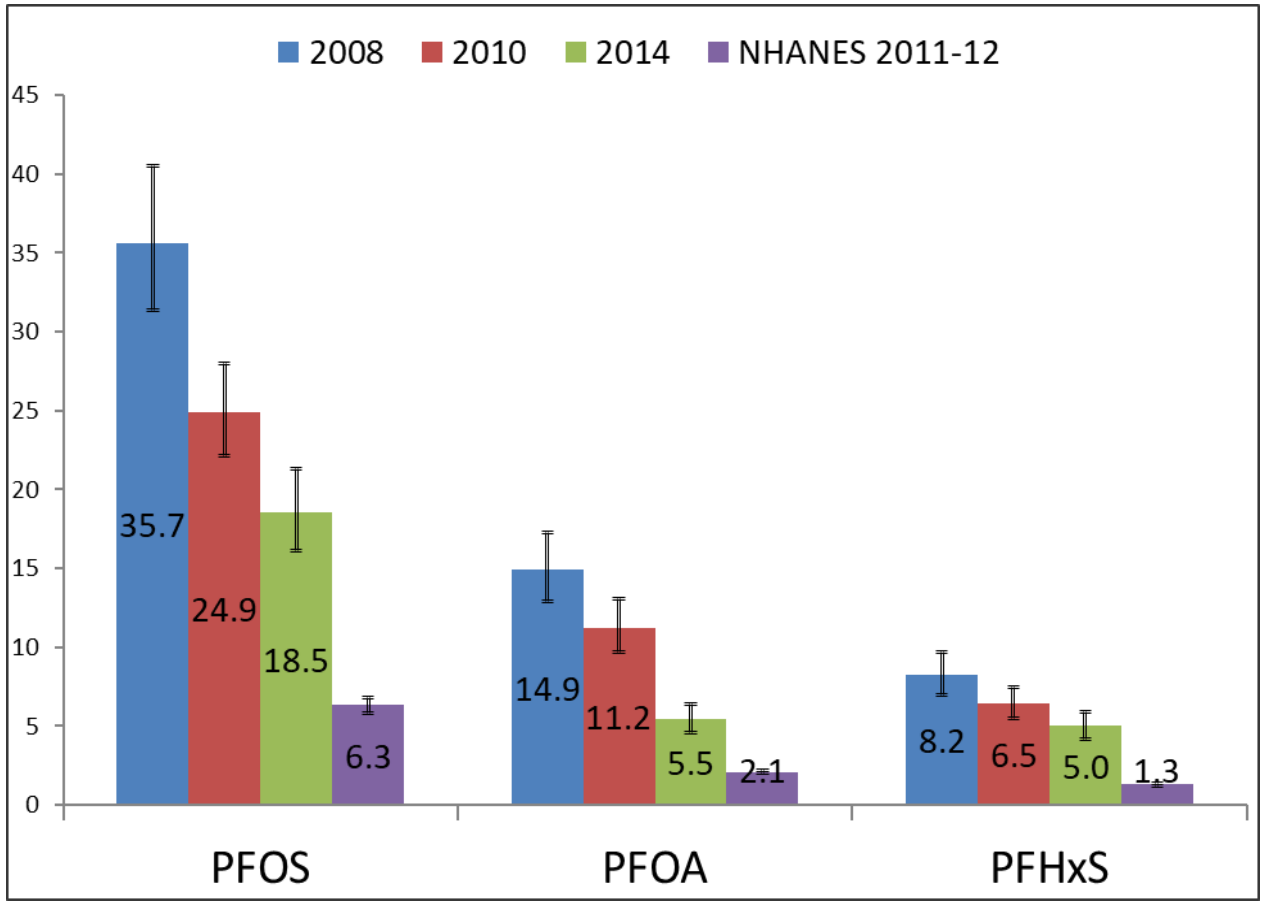
- Determining a specific exposure caused a specific health effect is very difficult
  - Mesothelioma/asbestos, bone cancer/radium
- Numerous PFAS are found in blood – Mixture effect
- No unexposed control group to compare
  - Only more exposed and less exposed

Blood/Serum Levels of PFAS

- PFAS in humans is nearly universal
- PFAS blood levels are the best metric for exposure for most
- Interpretation of individual blood PFAS levels in the context of population-wide exposures
- No bright line threshold for any one individual
- Many unidentified PFAS could also be present

Biomonitoring in Minnesota - General Population

- Exposure to well-known PFAS such as PFOA, PFOS, and PFHxS is declining according to biomonitoring
- Individuals with contaminated water have higher PFAS levels in their body
- Intervention/Treatment of drinking water works to reduce PFAS blood levels (studies in adults)
- Minnesota data confirm this



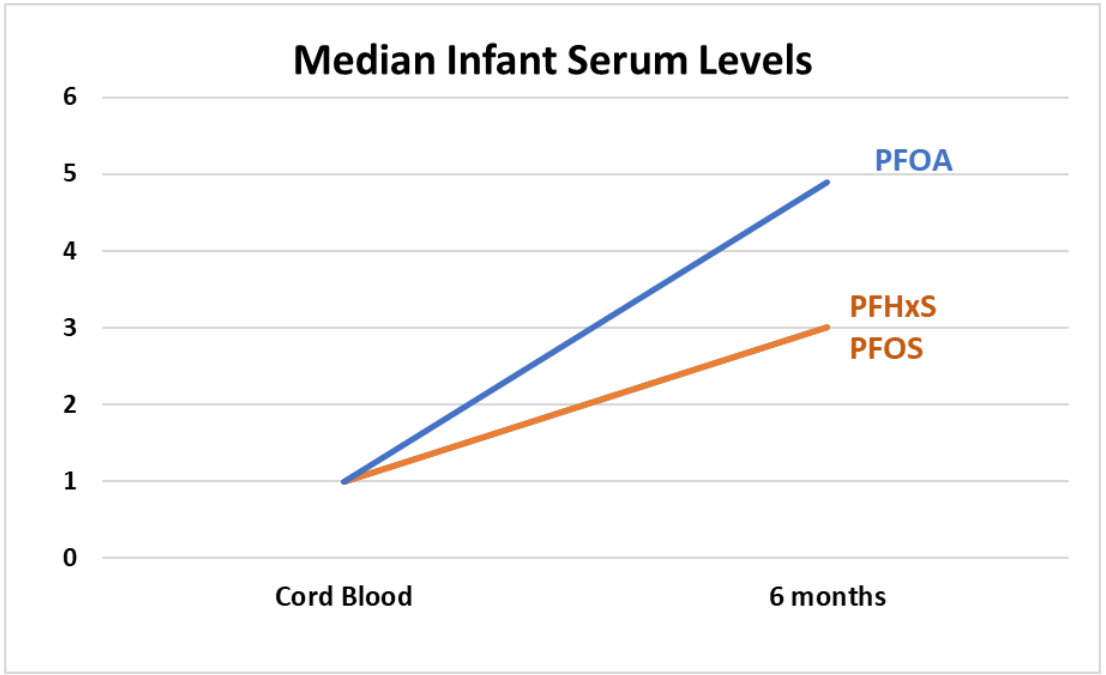
PFAS Exposure - Infants

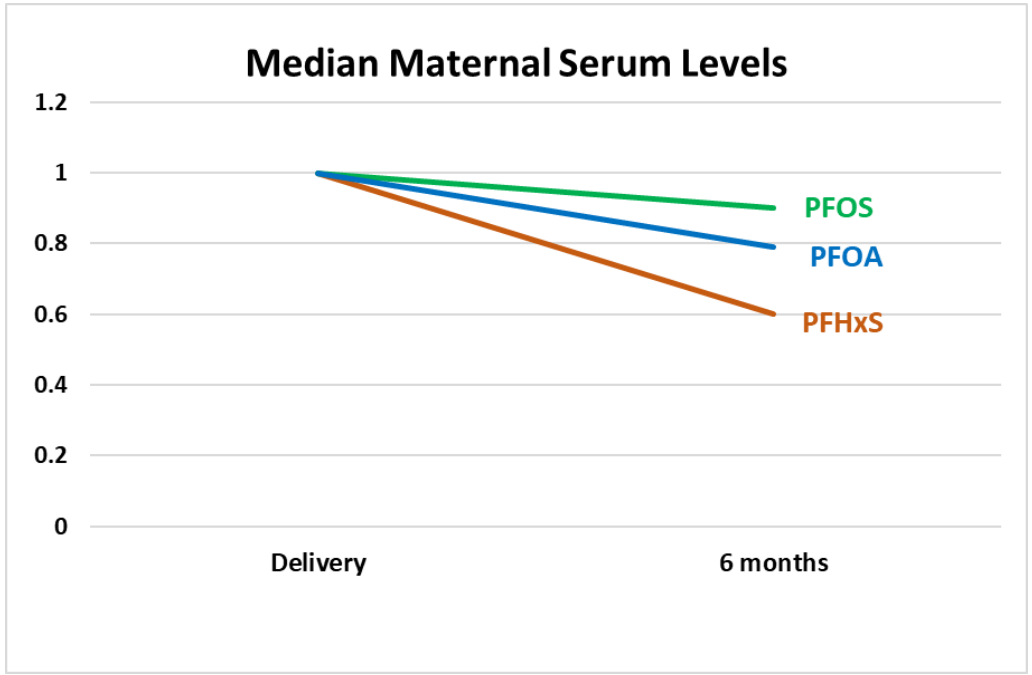
- Bioaccumulative PFAS can cross the placenta and be found in breast milk
- Babies from exposed mothers are born with a body burden of PFAS
- Additional PFAS can be transferred through breastmilk, increasing infant PFAS levels
- Referred to as “indirect exposure”

Significance of Indirect Exposure Routes

Accumulated levels can be passed onto offspring

Transferred to breastmilk *[breastmilk level can be > drinking water level]*





Based on data from Table 1, Fromme et al 2010

Mother-Child PFAS Model Concept

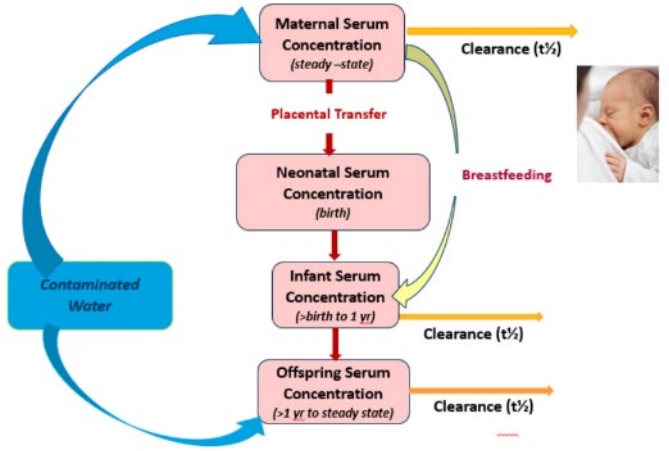
single-chemical,

two-compartment (maternal & infant),

Excel-based,

simulate serum levels from birth through adulthood (attainment of steady-state conditions)

- Start at birth with body burden from placental transfer from mother at steady-state
- Daily intake and elimination
  - Breastfeeding
  - Water Consumption
- 55-year simulation period



- Include maternal loss during breastfeeding
- Run iteratively, adjusting water concentration based on serum concentrations produced

Goeden et al. JESEE 2019

Model Highlights/Conclusions

- Model performs well, accounts for indirect exposure
- Guidance is protective for susceptible, highly exposed populations
- Breastfeeding can be a significant exposure pathway
  - However, breastfeeding has many health benefits and MDH recommends breastfeeding for those currently or planning to breastfeed

Conclusions

- Reducing possible risks has been done through reducing exposures, changing out PFAS used
- Toxicity information required to better inform hazard and risk is still lacking for most PFAS
- Hazard + Exposure = Risk
- Currently impossible to quantify exact risk
    - Lack Hazard and Exposure information for most PFAS

Thank you.
Questions?

James Kelly

james.kelly@state.mn.us; 651-201-4910

Additional Resources:

PFAS homepage - https://www.health.state.mn.us/communities/environment/hazardous/topics/pfcs.html

Water Guidance - https://www.health.state.mn.us/communities/environment/risk/guidance/gw/table.html

Goeden et al JESEE 2019 - https://www.nature.com/articles/s41370-018-0110-5

Attribution and thanks: James Jacobus, PhD and Health Risk Assessment Unit Staff

Breastmilk Transfer + Placental Transfer - *PFOA*