Prevalence of the Toxicokinetic Nature of Per- and Polyfluoroalkyl Substances (PFAS) on Human Development

Daniela Paolino and Dr.Salvador Tarun J.r

Department of Chemistry, State University of New York Geneseo, Geneseo 14454

They can be found in some…

- Tap and bottled water (e.g: Perrier, La Croix, Canada dry)
- Fire extinguishers
- Throughout blood streams
- Fast food packaging
- Dust
- Makeup
- Lotions
- Shampoos
- Cookware
- Clothes
- Floss
- Dirt
- Microwave Popcorn bags

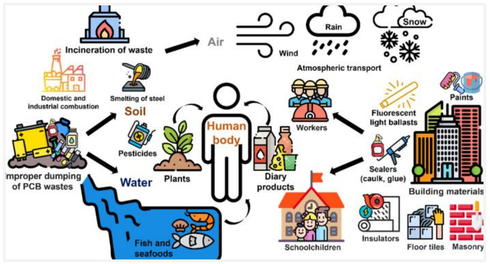

Figure 1. Cycling of PFAS chemicals in the environment (Environment: Occupational and Exposure Events)

How to avoid PFAS ingestion

- **Drink through a filtration system**
  -Reverse osmosis, Ion exchange, Activated carbon
- **Food**
  -Avoid non stick coated pans; stainless steel, cast iron, carbon steel, and ceramic are all options that tend to lack PFAS chemicals noted in non stick coatings.
  - Avoid using materials, such as metals, that could scrape off flakes of the coating your food
  -Become informed about what companies are processing your food and their history of chemical use
- **Absorb**
- Regular habit of dusting
- Avoid stain resistant clothes
- Choose clothing that doesn't have Gore-Tex or Teflon tags.
- Avoid care products that have "PTFE" OR "FLUORO" in it

EWG: Healthy Living app, supplies a guide on PFAS involvement in specific food and skin products

Legislative regulations

- Federal Safe Drinking Water Act:
  "maximum contaminant levels (MCLs) are set at 10 parts per trillion (or nanograms per liter) each for public water supplies"
- EPA is removing the availability of the De Minimis effective November 30, 2023
- Currently no legislations on land/nutrient based pollutions

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What are PFAS chemicals

Abstract: *Per- and poly-fluoroalkyl substances (PFAS) were created in the 1930s with the desire to monopolize their durable hydrophobic nature, attained through the fluorine-carbon bonding in the alkyl chain, and was quickly utilized in innumerable consumer products (e.g: makeup, lotion, nonstick pans, food containers, carpets, and shampoos). It wasn't until 1970 when traces of PFAS were found in blood tests, that concerns about its ability to endure biodegradation started to arise. Today people are constantly exposed to PFAS chemicals, whether it be through dust build-up in their homes, the products they are consuming, or the water they drink. Its often unbeknownst prevalence has become progressively concerning, affecting not only those interacting with it directly, but also transmitting from one affected individual to another during prenatal development. Research suggests that the internal accumulation of PFAS chemicals will not only become a prominent factor in stunting development, but has also been linked to the suppression of lymphatic and antibody-responsive cells, and the degradation of various organs such as the liver, kidney, and thyroid. Researchers are currently investigating means by which these "forever chemicals" can be broken down and analyzing the intricacies of their toxigenic nature, in order to create awareness and valid evidence towards the dismantling of PFAS in commercial use.*

Adverse toxicokinetic health effects

***Blood levels of PFOA in the U.S average out to* ng/mL *µg/L for the U.S. population, but this varies between location; Some individuals having levels as high as 32.9-1130* ng/mL**
(moderate risk: 2-20 ng/mL), (high risk: >20 ng/mL)

Immune response to acute and chronic exposure:

- Decrease in levels of IFN-gamma: A contributor for inducing pathogenic recognition, and is a major contributor in the stimulation of phagocytosis
- Decreased Ace2 mRNA: Vital contributor in homeostatic regulation (no significant effects observed in females)
- Irregularities in thyroid function: Increased organ size resulting from Swelling of cells or increase in cell quantity and decrease in thyroid hormone production, disrupting Pituitary function
- Increased susceptibility for liver and kidney diseases, obesity, reproductive malfunction, high cholesterol and cancer.
- Suppression of varies immune responses through a decrease in natural killer cell activity, lymphocyte proliferation, and T-cell-dependent antibody response and phenotypic distribution
- All forms of PFAS, other than PFBS, have been found capable of activating at least 8 nuclear receptors, one significantly decreasing production and secretion of testosterone

Genetics:

-Hormones, cytokines, and the expression of genes such as ACE2 have been linked to expression and severity of viral infections changes in mRNA and protein expression

Exposure in children:

- PFAS chemicals can be absorbed through in utero exposure through the placenta and continual exposure in breast milk
- Adipose percent fat mass increase in male offspring and decrease in females
- Correlations between in utero exposure to PFOS and insulin resistance in adult offspring have been recognized
- In utero exposure may result in the offspring having higher elevations of PFOS in the brain then that found in their mothers
- Decline in cognition resulting from neurotoxicity

Chemical composition

- Fluorine has a high electronegativity creating a strong bond between whatever element it is paired with
- PFAS and PFOS are fully fluorinated molecule compounds
- Both long-chain and short-chain PFAS are able to use proteins for circulatory transport and intracellular uptake into organ.

X	Y	Acronym	Name	Formula
B = buta (4 carbon)	A = Carboxylate or carboxylic acid	PFBA	Perfluorobutanoate	$C_3F_7CO_2^-$
			Perfluorobutanoic acid	C_3F_7COOH
	S = Sulfonate or sulfonic acid	PFBS	Perfluorobutane sulfonate	$C_4F_9SO_3^-$
			Perfluorobutane sulfonic acid	$C_4F_9SO_3H$
Pe = penta (5 carbon)	A = Carboxylate or carboxylic acid	PFPeA	Perfluoropentanoate	$C_4F_9CO_2^-$
			Perfluoropentanoic acid	C_4F_9COOH
	S = Sulfonate or sulfonic acid	PFPeS	Perfluoropentane sulfonate	$C_5F_{11}SO_3^-$
			Perfluoropentane sulfonic acid	$C_5F_{11}SO_3H$
Hx = hexa (6 carbon)	A = Carboxylate or carboxylic acid	PFHxA	Perfluorohexanoate	$C_5F_{11}CO_2^-$
			Perfluorohexanoic acid	$C_5F_{11}COOH$
	S = Sulfonate or sulfonic acid	PFHxS	Perfluorohexane sulfonate	$C_6F_{13}SO_3^-$
			Perfluorohexane sulfonic acid	$C_6F_{13}SO_3H$
Hp = hepta (7 carbon)	A = Carboxylate or carboxylic acid	PFHpA	Perfluoroheptanoate	$C_6F_{13}CO_2^-$
			Perfluoroheptanoic acid	$C_6F_{13}COOH$
	S = Sulfonate or sulfonic acid	PFHpS	Perfluoroheptane sulfonate	$C_7F_{15}SO_3^-$
			Perfluoroheptane sulfonic acid	$C_7F_{15}SO_3H$
O = octa (8 carbon)	A = Carboxylate or carboxylic acid	PFOA	Perfluorooctanoate	$C_7F_{15}CO_2^-$
			Perfluorooctanoic acid	$C_7F_{15}COOH$
	S = Sulfonate or sulfonic acid	PFOS	Perfluorooctane sulfonate	$C_8F_{17}SO_3^-$
			Perfluorooctane sulfonic acid	$C_8F_{17}SO_3H$
N = nona (9 carbon)	A = Carboxylate or carboxylic acid	PFNA	Perfluorononanoate	$C_8F_{17}CO_2^-$
			Perfluorononanoic acid	$C_8F_{17}COOH$
	S = Sulfonate or sulfonic acid	PFNS	Perfluorononane sulfonate	$C_9F_{19}SO_3^-$
			Perfluorononane sulfonic acid	$C_9F_{19}SO_3H$
D = deca (10 carbon)	A = Carboxylate or carboxylic acid	PFDA	Perfluorodecanoate	$C_9F_{19}CO_2^-$
			Perfluorodecanoic acid	$C_9F_{19}COOH$
	S = Sulfonate or sulfonic acid	PFDS	Perfluorodecane sulfonate	$C_{10}F_{21}SO_3^-$
			Perfluorodecane sulfonic acid	$C_{10}F_{21}SO_3H$

Figure 2. *(*Department of Health.January 2024)

Analysis methodology

- Solid phase extraction method
- lye and dimethyl sulfoxide help break some of their atomic bonds
- Membrane filtration treatment methods: microfiltration (MF), ultrafiltration (UF), nanofiltration (NF), and reverse osmosis (RO)

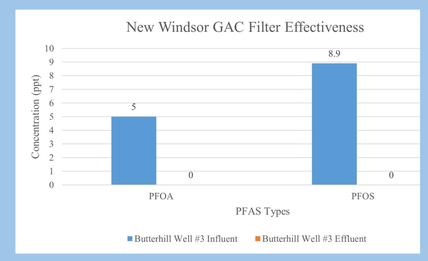

Figure 3: *Examples of the effectiveness of GAC filters in removing six types of PFAS' in Hoosick Falls (April 2021)*

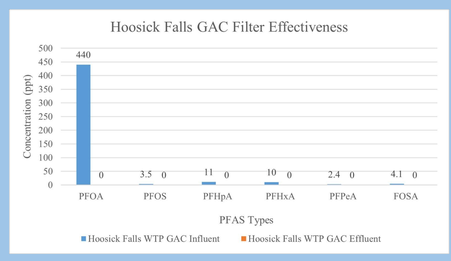

Figure 4: *Effectiveness of the New Windsor GAC filter in removing two types of PFAS' (December 2019)*

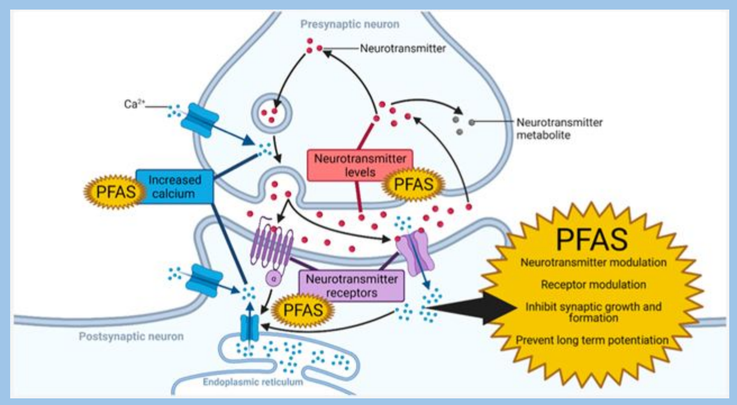

Figure 5: *Showing how correlations between global cognitive ability and PFAS update occur. Neurotoxicity has been noted to accrue via dopamine and calcium transport through synaptic transduction*
*(*Brown-Leung and Cannon 2022)

Limitations in current research:

- Obtaining necessary equipment and support
- Contamination of Lab equipment
- "safe" levels of PFAS has led to an increased disregard for results from studies of high level exposure;"Gas or liquid chromatography (GC or LC) tandem mass spectrometry (MS/MS), methods that are expensive, time consuming and require samples to be sent to a centralized laboratory for analysis."
- Detection of PFAS chemicals
- High variability of results due to varying levels of exposure on humans, type of exposure/ vehicle of administration , type of animal used in studies, geographical and temporal exposure, sex, and/ or type and length of PFAS strain.

Hypothesised significance to long-term exposure

The adverse health effects of high PFAS concentration would likely continue to rise as a result of sustained commercial use and preexisting PFAS concentrations during gestational development; An increased prominence in the effects of these teratogens can alter our epigenetic programming, through the interruption of synaptic communication and organogenesis, if left unchecked.