PFAS Vapor Intrusion Potential and Inhalation Exposure

Challenges, Options, Application

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Toxicological Criteria: Inhalation

Ingestion-based (RfDo) tox criteria available for only about a dozen PFAS; **there are no federally-promulgated inhalation-based (RfC/Unit Risk[i]) tox criteria**.

The **predominant worker exposures are inhalation-based** – with doses, generally, **orders** of magnitude higher than drinking water exposures – predicated on volatiles, aerosols and particulate exposures.

Current driving concerns surround **infant and young child exposures** - reduced vaccine efficacy – **basis for OELs?**

While PFAS are unique in being managed as noncarcinogens, despite having recognized carcinogenic activity, it is likely that **cancer will take precedence in future toxic tort/litigation** and liability assessments (PFOA).

Definition of PFAS: “[F]luorinated substances that contain at least one fully fluorinated methyl or methylene carbon atom (without any H/Cl/Br/I atom attached to it), with a few noted exceptions, any chemical with at least a perfluorinated methyl group (–CF3) or a perfluorinated methylene group (–CF2–) is a PFAS” (OECD 2021).

Trends/Phenomena

PFAS Vapor Intrusion

- Is possible - often complete when contraindicated – and occurring to a significantly larger degree than standard USEPA VOC models would have predicted (VP, H', MW, … Fugacity?)

- In groundwater: PFHxA (100%), PFBA (95%), PFOS and PFHxS (89%), PFOA, PFPeA, PFHpA, PFBS, PFNA, PFDA (>84%) – FTs on the rise
- Avg VP: PFPeA>PFBA>GenX>4:2FTOH>PFMPA>PHHpA>PFOA>6:2 FTOH>PFHxA>PFBS>8:2FTOH>PFOS>PFNA ….
- PFCAs (e.g., PFOA):
  - PFOA (predicted) limited volatility.
  - >8C, consistently have VP below threshold.
  - Exists in deprotonated (anionic) form in solution – should be negligible yet commonly found in soil gas investigations above impacted WBUs – New Jersey/EPA.
- PFSAs (e.g., PFOS):
  - Deprotonated form in solution (negative charge at environmental pH)
    - H' does not take this into account and likely overpredicts volatility ...
  - Over 3 OoM less than predicted VP threshold, and yet ...
- FTOHs: Volatile functional grouping, remains uncharged in GW – Highest potential for VI
- Fluorotelomers:
  - FTCAs – Protonated state – above VP threshold
  - FTSAs – Deprotonated state, yet above VP threshold
- Co-contaminant Effects:
  - Affect F&T/geochemistry; particularly true for petro compounds, transform precursor compounds in terminal PFAAs through oxidation. Possible mitigation of deprotonation/ionization (inc. volatility potential).

Options → Progression

- Options:
  - Route-to-Route extrapolation
    - Absorption, Distribution, Metabolism, Excretion
    - No portal of entry effects
  - PBPK Modeling?

ITEM	COMMENT
GI absorption efficiency	>95% PFOA; respiratory system; no adjustment
Dusts	Impacted upper airways, ciliary action, ultimately swallowed
Distribution	Inhalation/ingestion, same (consistent blood, extravascular tissues, liver)
No metabolism	Toxic metabolites
Portal of entry effects	No evidence; low lung irritation, ingestion/inhalation
Route-to-Route extrapolation (for screening)	No contraindication

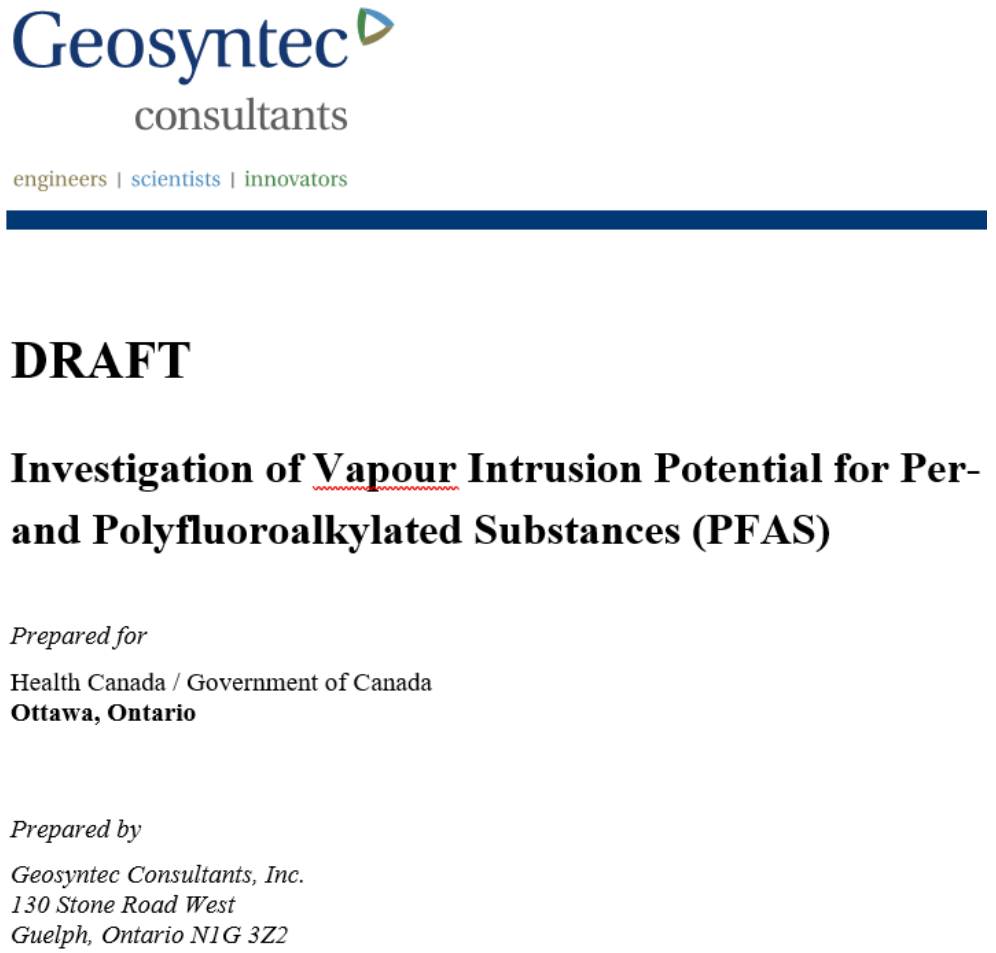
- Extant and Future Potential Liability Assessments
  - Risk Management: Implementation of IC/LUCs, Phase-in of replacement chemistries

- States:
  - MI, NJ, MN, TX, CA … HI EALs
  - NYS PFOA Annual Guideline Level of 5.3 ng/m^3
  - MI AQD: PFOA, PFOA, 6:2 FTS (RtR, Hinderliter et al. 2006)

	ACGIH TLVs		DFG MAKs (Germany)	
Occupational Exposure Values:	TWA (mg/m^3)	STEL/Ceil (C) (mg/m^3)	TWA (mg/m^3)	PEAK/CEIL (mg/m^3)
Perfluorobutylethylene (PFBE)	1023			
Perfluoroisobutylene		0.082 (C)		
Perfluorooctanesulfonic acid (and salts) (PFOS)			0.01	

Health Canada – PFAS VI Guidance

- Geosyntec PFAS Experts Selected
  - Route-to-Route Extrapolation, BMD modeling – inhalation tox criteria (adopted by several states)
  - RPF Model (options)
  - Critical review of study applicability


Geosyntec consultants

engineers | scientists | innovators

DRAFT

Investigation of Vapour Intrusion Potential for Per- and Polyfluoroalkylated Substances (PFAS)

Prepared for

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Ottawa, Ontario

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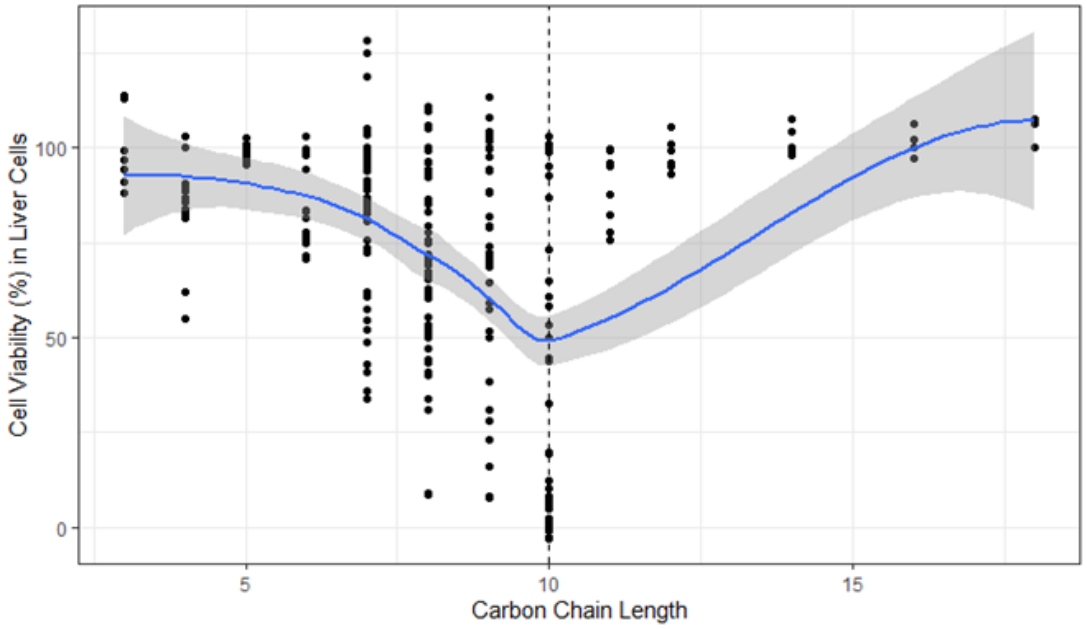
Application:

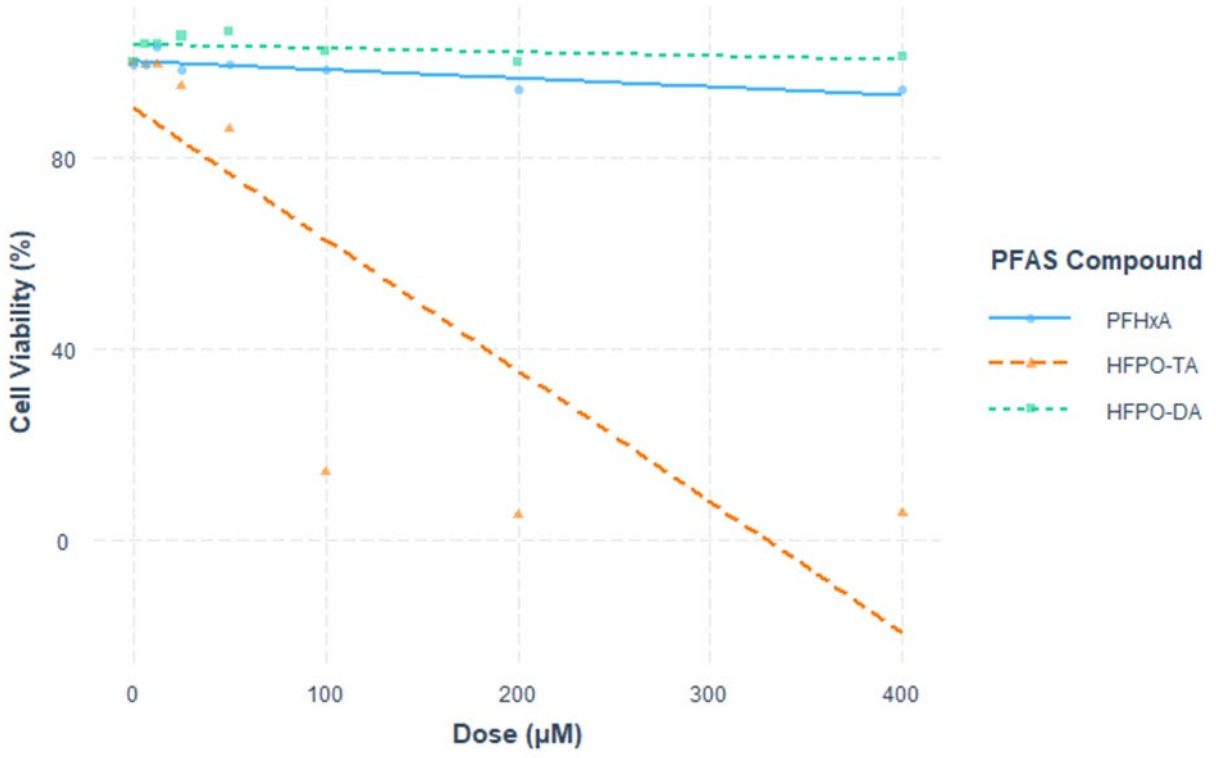
- **Due Diligence, Liability Assessment, Toxic Tort Defense, Re-Openers under CERCLA/RCRA/State Programs**

- **International Paper/Filter Manufacturer**
  - **PFHxS**
  - **Particulate, aerosol, volatile phases**
- **Petro holding tank fire**
  - **AFFF/PFOS: Construction Worker Exposure**
- **Construction/site remediation**
  - **Multiple PFAS**
  - **Particulate phase-only → PM10 Stand-in**
- **PFAS Contaminated soil remediation site**
  - **Multiple PFAS**
  - **Workforce Steward (no regulatory driver, save OSHA General Duty Clause)**
  - **Liability Mitigation**
- **Proprietary Risk Management Levels – Oil and Gas Industry**
  - **Multiple PFAS**
  - **Workforce Steward (no regulatory driver)**
  - **Liability Mitigation**

- **Toxic Tort Defense:**
  - **Drinking water: VI and showering**
  - **Biosolids: Dust from agricultural activities**
  - **Indoor dust: A function of fugitive releases from consumer and cleaning products (25% of PFOA ADD)**

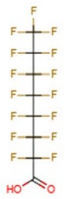
PFAS Toxicity Trends





PFCAs $F-[CF_2]_n-COOH$

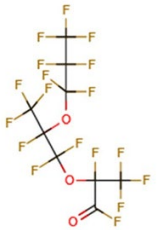
n	PFCA
5	PFPeA
6	PFHxA
7	PFHpA
8	PFOA
9	PFNA
10	PFDA
11	PFUnDA
12	PFDoDA
14	PFTeDDA
16	PFHxDA
18	PFODA



PFOA

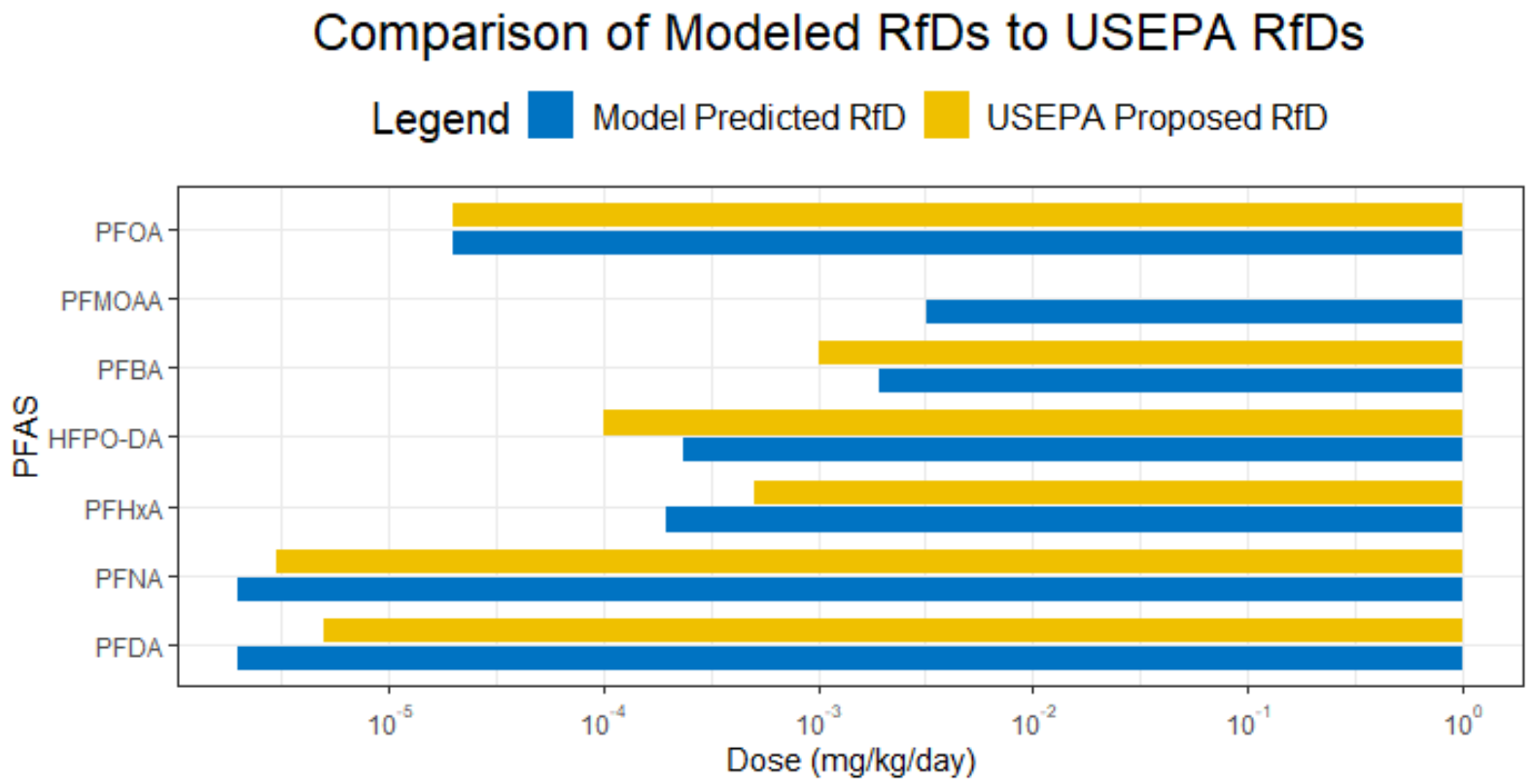


HFPO-DA

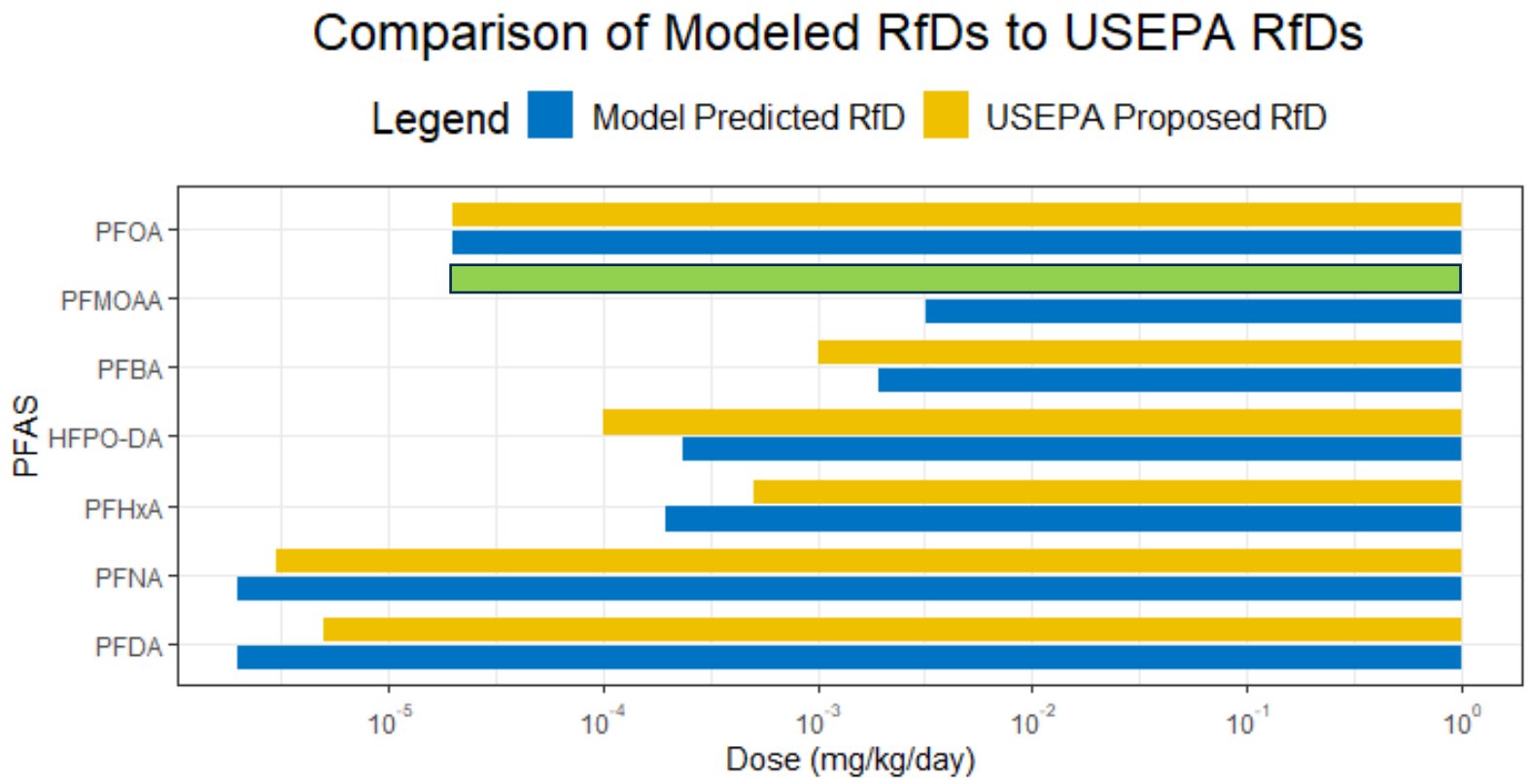


HFPO-TA

Calculate Reference Doses (RfDs)



Calculated Reference Doses (RfDs)



Green bar presupposes equivalent toxicity to PFOA, potentially overestimating PFMOAA human relevant toxicity by 2 orders of magnitude

Convert to Reference Concentrations (RfCs)

PFAS	Max Concentration	Units	KB Predicted RfD (mg/kg-day)	RfC (mg/m3)	RfC (ng/m3)	Resident Air SL
PFBA	681.6	ng/dscm	1.9E-03	7.8E-03	7.8E+03	337,716
PFHpA	65.8	ng/dscm	1.2E-05	4.6E-05	4.6E+01	2,007
PFOA	13.7	ng/dscm	2.0E-05	8.0E-05	8.0E+01	3,476
PFNA	19.1	ng/dscm	1.9E-03	7.8E-03	7.8E+03	337,716