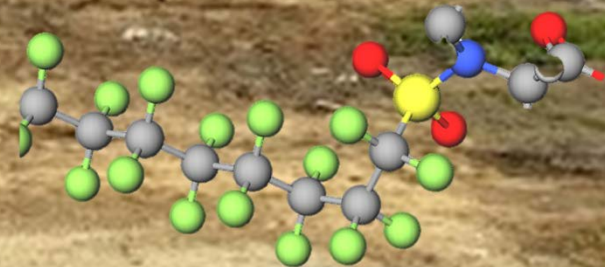
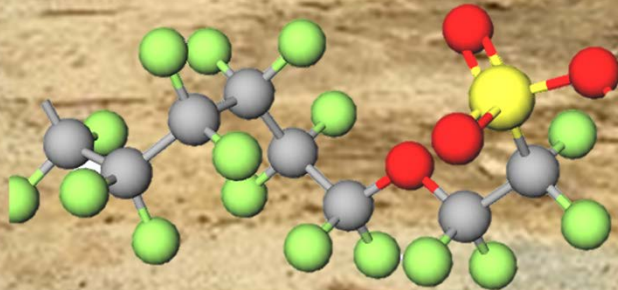
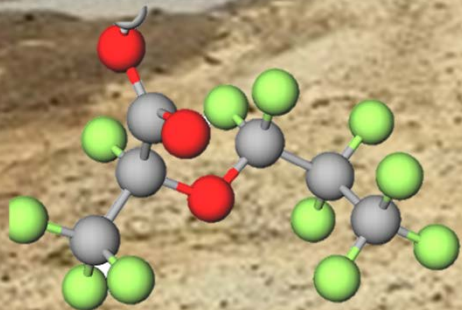


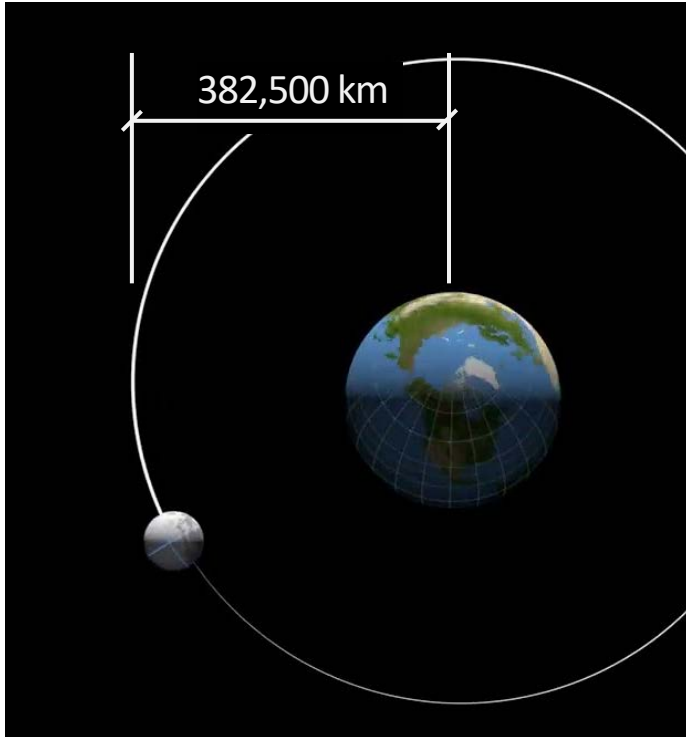
# PFAS in Common Materials of Sampling

**RAMBOLL** Bright ideas. Sustainable change.

The image shows an industrial or construction site under a cloudy sky. In the background, there is a chain-link fence and a building with a corrugated metal roof. Two billboards are visible on the left. The foreground is a dirt area with some sparse vegetation. Overlaid on the bottom half of the image are three 3D ball-and-stick molecular models of PFAS compounds. The first model on the left is a branched structure with a central carbon atom bonded to two fluorine atoms (green) and two hydroxyl groups (red and white). The middle model is a long, linear chain of carbon atoms (grey) with many fluorine atoms (green) and a terminal sulfonate group (yellow sulfur atom bonded to three red oxygen atoms). The third model on the right is a branched structure with a central carbon atom bonded to two fluorine atoms (green) and two hydroxyl groups (red and white), with a sulfonate group (yellow sulfur atom bonded to three red oxygen atoms) attached to one of the hydroxyl groups.



# What's a part-per-trillion?



## 1 part per trillion

$$= 1/1,000,000,000,000$$

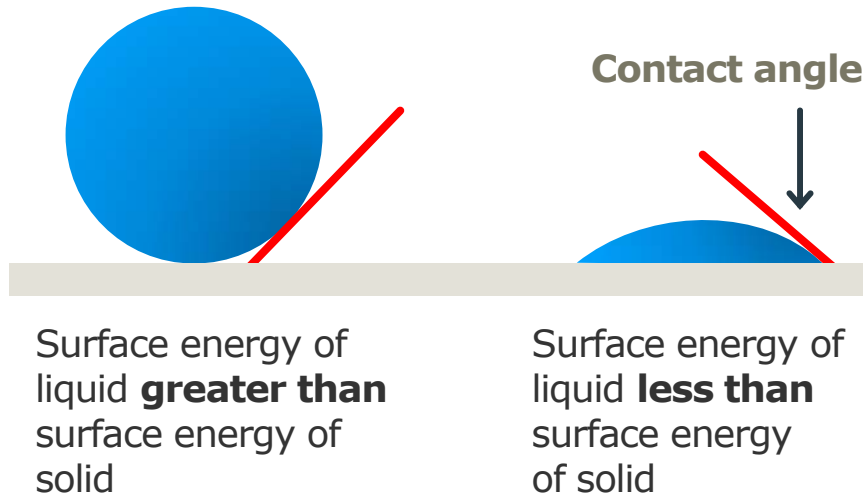
= **1/4<sup>th</sup> the thickness of a penny** in comparison to the orbit of **Earth and Moon**





## At solid-liquid interfaces, low energy “wins”

- If the solid surface has the lower surface energy, liquids have a very difficult time “wetting” the surface
- If the liquid has the lower surface energy, it coats the solid surface readily



**PTFE** (i.e., Teflon) has surface energy much lower than almost all liquids, and has excellent oil and water repellency, think:

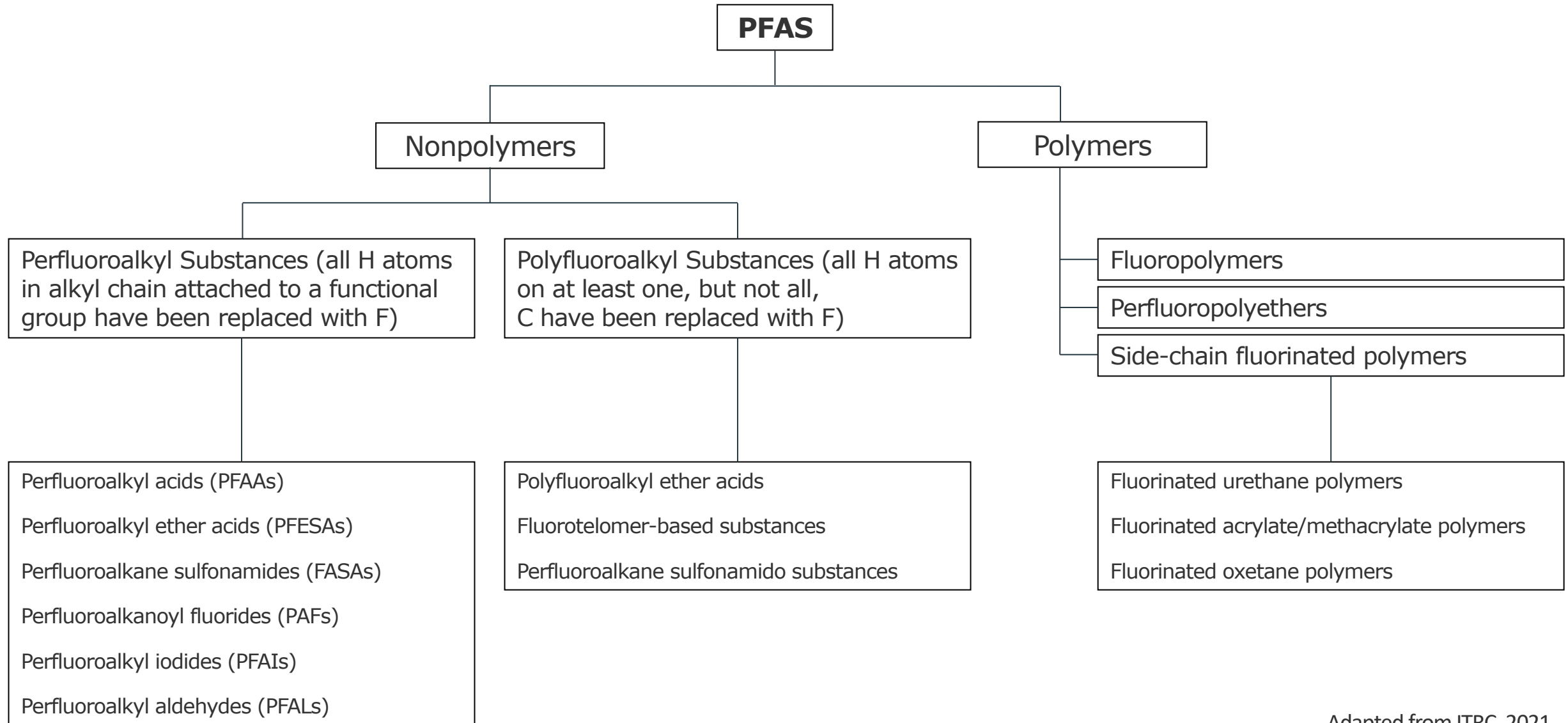
- Stain resistance (carpets, furnishings)
- All-weather performance (outerwear, outdoor stains)

**PFOA**, a fluorosurfactant imparts very low surface energy to liquids, making them extremely effective wetting agents, think:

- Detergents (lifting and suspending solids)
- Wetting agents (penetration of fine fractures and enhancements to aqueous surface chemistry)

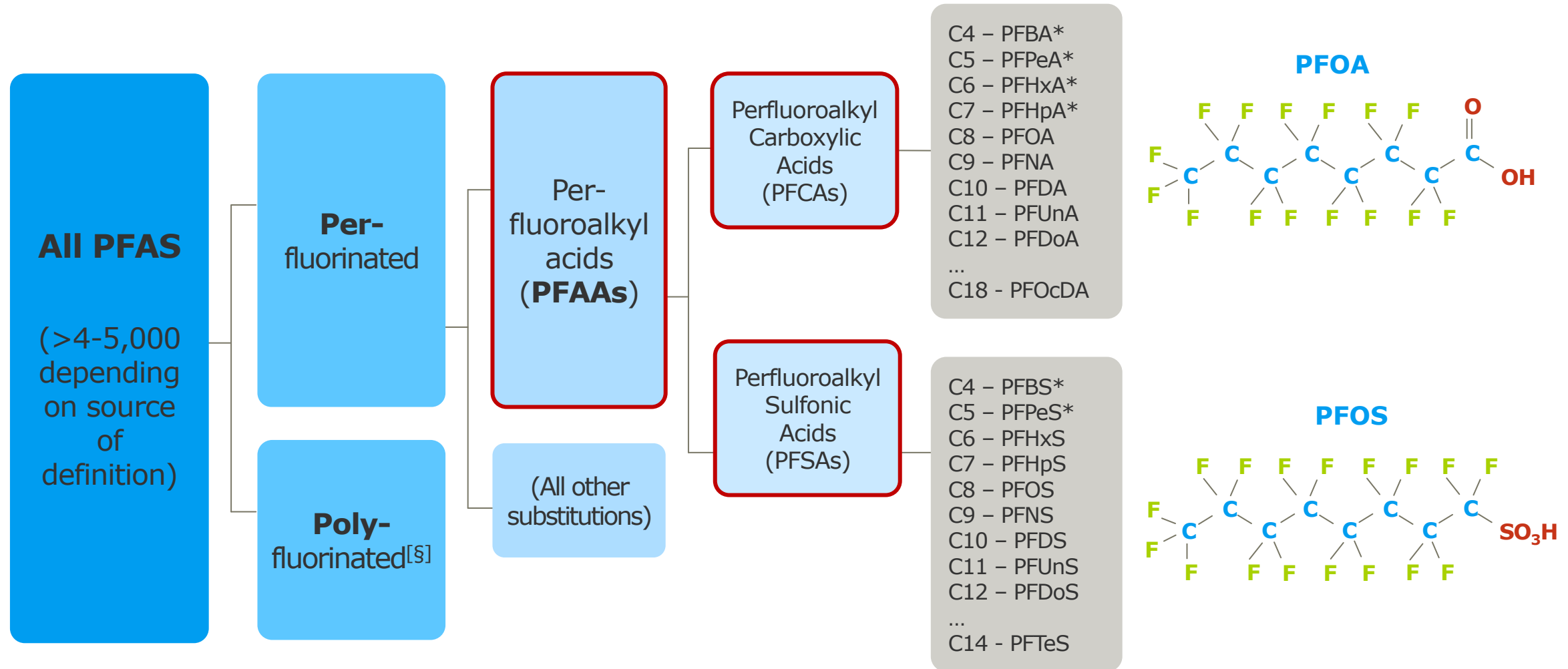
*Consider these desirable properties when conducting Due Diligence activities*

# Classification of PFAS



Adapted from ITRC, 2021

# A nomenclature primer



[§] Potential precursors

\* "Short-chain"

# Why do the PFAS in Common Materials of Sampling Study?

- To provide empirical information to parties performing and relying on PFAS sampling data
- To evaluate the potential for sample bias due to PFAS mass gain from commonly used products
- Assess relative types and concentrations of PFAS with an expanded analyte list
- Dispel or reinforce precautionary concerns of many guidance documents

# Materials of sampling



## 28 Unique Materials:

- 1/4" HDPE Tubing
- 3/8" HDPE Tubing, A
- 3/8" HDPE Tubing, B
- 5/16" HDPE Tubing, Imported
- Teflon Tubing
- Silicon Tubing, Generic
- Silicon Tubing, Brand A
- Bailer String, Brand A
- Bailer String, White, Imported
- Bailer String, Orange, Imported
- Braided Rope
- HDPE Bailer, A
- HDPE Bailer, B
- LDPE Bladder Geotech, A
- LDPE Bladder Geotech, B
- LDPE Bladder QED, A
- LDPE Bladder QED, B
- Silicon Bladder, A
- Silicon Bladder, B
- Teflon Bladder Geotech
- Teflon Bladder QED
- PPE, DuPont
- PPE, Trimaco
- PPE, International
- Blue Shop Wipes
- White Shop Wipes
- Brass Valve
- Plastic Valve

- Items procured from national equipment rental company, purchased from local home improvement center
- Intentionally attempted to incorporate imported items

# Sample pump sampling

## 5 Unique Pump Types:

- Geotech, Bladder
  - QED, Bladder
  - Geotech, 12V
  - Monsoon, 12V
  - Grundfos, 12V
- 
- Procured from national equipment rental company
  - Deconned equipment on receipt following Ramboll typical SOPs



"Wells" constructed of 2" PVC pipe, procured from home improvement center

Arrangement for sampling of Grundfos Rediflo pump



# Prior evaluations of PFAS in common field products

|                       | Denly et al. (2019)                                                                                                                                                                                                                                                                                              | Rodowa et al. (2020)                                                                                                                                                                                                                                                                                                                                                  | This Study                                                                                                                                                                                                                                                                                           |
|-----------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Methods and Materials | 24-hr leaching period using "commercially available bottled water" and shaken on a shaker table                                                                                                                                                                                                                  | Three rounds of leaching with methanol heated to 60-65°C for 10 min each for PFAS on product surfaces                                                                                                                                                                                                                                                                 | 1-hr leaching using alkaline-buffered lab-grade, PFAS-free water                                                                                                                                                                                                                                     |
|                       | 24 products (adhesive notes, aluminum foil, water level tape, waterproof field book paper)                                                                                                                                                                                                                       | 66 different materials (dryer sheets, PTFE tape, aluminum foil, marker ink, cold pack exterior)                                                                                                                                                                                                                                                                       | 28 products, 5 types of common rental pumps                                                                                                                                                                                                                                                          |
|                       | 24 target analytes; SPE, LC-MS/MS, with isotope dilution ("537 modified")                                                                                                                                                                                                                                        | 52 target analytes; SPE, LC-MS/MS, with isotope dilution ("537 modified")<br>Particle-induced gamma-ray emission (PIGE) quantitation of total fluorine                                                                                                                                                                                                                | 70 target analytes; SPE, LC-MS/MS, with isotope dilution ("537 modified")                                                                                                                                                                                                                            |
|                       | Testing in batches over 1-year period                                                                                                                                                                                                                                                                            | Combined results from different consultancies                                                                                                                                                                                                                                                                                                                         | Single study; one commercial lab but two physical laboratory sites (leachate vs. pump effluent)                                                                                                                                                                                                      |
| Findings              | <ul style="list-style-type: none"> <li>PFCAs were found to be the most common PFAS class detected</li> <li>PFCAs (no PFSAs) were found in PTFE and LDPE</li> <li>PFBA and PFPeA concentrations were particularly high in the LDPE tubing leachate</li> </ul>                                                     | <ul style="list-style-type: none"> <li>Only 5 PFCAs, 4 PFSAs, and 2 FTSs were detected</li> <li>PFOA was found the most, and at the highest concentrations, followed by PFBS</li> <li>PTFE tape; highest detections by PIGE, but ND for target analytes Similar for First aid adhesive wrapper, some plastic and paper packaging, and a reusable cold pack</li> </ul> | <ul style="list-style-type: none"> <li>PFCAs with highest detection frequency and highest detection values</li> <li>Several mono ethers and one di ether found with the next highest detection frequency, but at low detection values; PFSAs found with the next highest detection values</li> </ul> |
| Conclusions           | <ul style="list-style-type: none"> <li>Results were quite variable, with different batches of identical products yielding varying measured PFAS concentrations; Possibly due to process variability during manufacturing, possibly due to experimental design</li> <li>Additional studies recommended</li> </ul> | <ul style="list-style-type: none"> <li>Very poor PFAS analyte to PIGE correlation</li> <li>Additional studies recommended</li> </ul>                                                                                                                                                                                                                                  | <ul style="list-style-type: none"> <li>Potentially useful to repeat findings with some samples, possibly add new materials</li> </ul>                                                                                                                                                                |

# 70-Compound Analyte List

| CAS         | Analyte Name                          | Acronym    |
|-------------|---------------------------------------|------------|
| 422-64-0    | Perfluoropropanoic acid               | PFPrA      |
| 375-22-4    | Perfluorobutanoic acid                | PFBA       |
| 2706-90-3   | Perfluoropentanoic acid               | PFPeA      |
| 307-24-4    | Perfluorohexanoic acid                | PFHxA      |
| 375-85-9    | Perfluoroheptanoic acid               | PFHpA      |
| 335-67-1    | Perfluorooctanoic acid                | PFOA       |
| 375-95-1    | Perfluorononanoic acid                | PFNA       |
| 335-76-2    | Perfluorodecanoic acid                | PFDA       |
| 2058-94-8   | Perfluoroundecanoic acid              | PFUnA      |
| 307-55-1    | Perfluorododecanoic acid              | PFDoA      |
| 72629-94-8  | Perfluorotridecanoic acid             | PFTra      |
| 376-06-7    | Perfluorotetradecanoic acid           | PFTeA      |
| 67905-19-5  | Perfluorohexadecanoic acid            | PFHxDA     |
| 16517-11-6  | Perfluorooctadecanoic acid            | PFOcDA     |
| 423-41-6    | heptafluoropropane sulfonic acid      | PFPrS      |
| 375-73-5    | Perfluorobutyl sulfonic acid          | PFBS       |
| 2706-91-4   | Perfluoropentanesulfonic acid         | PFPeS      |
| 355-46-4    | Perfluorohexyl sulfonic acid          | PFHxS      |
| 375-92-8    | Perfluoroheptyl sulfonic acid         | PFHpS      |
| 1763-23-1   | Perfluorooctanesulfonic acid          | PFOS       |
| 68259-12-1  | Perfluorononane sulfonic acid         | PFNS       |
| 335-77-3    | Perfluorodecyl sulfonic acid          | PFDS       |
| 79780-39-5  | Perfluorododecanesulfonic acid        | PFDoS      |
| 356-02-5    | 3-Perfluoropropyl propanoic acid      | 3:3 FTCA   |
| 914637-49-3 | 3-Perfluoropentyl propanoic acid      | 5:3 FTCA   |
| 812-70-4    | 3-Perfluoroheptyl propanoic acid      | 7:3 FTCA   |
| 53826-12-3  | 2H,2H-Perfluorooctanoic acid          | 6:2 FTCA   |
| 27854-31-5  | 2H,2H-Perfluorodecanoic acid          | 8:2 FTCA   |
| 53826-13-4  | 2H,2H-Perfluorododecanoic acid        | 10:2 FTCA  |
| 70887-88-6  | 2H-Perfluoro-2-octenoic acid          | 6:2 FTUCA  |
| 70887-84-2  | 2H-Perfluoro-2-decenoic acid          | 8:2 FTUCA  |
| 70887-94-4  | 2H-Perfluoro-2-dodecenoic acid        | 10:2 FTUCA |
| 757124-72-4 | 4:2 Fluorotelomersulfonate, acid form | 4:2 FTS    |
| 27619-97-2  | 6:2 Fluorotelomersulfonate            | 6:2 FTS    |
| 39108-34-4  | 8:2 Fluorotelomersulfonate            | 8:2 FTS    |

| CAS          | Analyte Name                                                                                               | Acronym        |
|--------------|------------------------------------------------------------------------------------------------------------|----------------|
| 120226-60-0  | 10:2 Fluorotelomersulfonic acid                                                                            | 10:2 FTS       |
| 133201-07-7  | Perfluoro(perfluoroethyl)cyclohexanesulfonic acid                                                          | cHxPFETa       |
| 754-91-6     | Perfluorooctanesulfonamide                                                                                 | PFOSA          |
| 31506-32-8   | N-Methylperfluorooctanesulfonamide                                                                         | NMeFOSA        |
| 4151-50-2    | N-Ethylperfluorooctanesulfonamide                                                                          | NEtFOSA        |
| 24448-09-7   | N-Methyl perfluorooctane sulfonamidoethanol                                                                | N-MeFOSE       |
| 1691-99-2    | N-Ethyl-N-(2-hydroxyethyl)perfluorooctanesulfonamide                                                       | N-EtFOSE       |
| 2355-31-9    | 2-(N-Methylperfluorooctanesulfonamido)acetate, acid                                                        | N-MeFOSAA      |
| 2991-50-6    | 2-(N-Ethyl-perfluorooctanesulfonamido)acetate                                                              | N-EtFOSAA      |
| 377-73-1     | Perfluoro-3-methoxypropanoic acid                                                                          | PFMOPrA        |
| 801209-99-4  | 2-(1,2,2,2-Tetrafluoroethoxy)perfluoroethanesulfonic acid                                                  | TeEoPFETs      |
| 863090-89-5  | Perfluoro-4-methoxybutanoic acid                                                                           | PFMOBA         |
| 113507-82-7  | Perfluoro(2-ethoxyethane)sulphonic acid                                                                    | PFEESA         |
| 756426-58-1  | 9-Chlorohexadecafluoro-3-oxanone-1-sulfonic acid                                                           | 9Cl-PF3ONS     |
| 763051-92-9  | 11-Chloroeicosafluoro-3-oxaundecane-1-sulfonic acid                                                        | 11Cl-PF3OUdS   |
| 93449-21-9   | 3-Methoxytetrafluoropropionic acid                                                                         | MTP            |
| 674-13-5     | Difluoro (perfluoromethoxy)acetic acid                                                                     | PFMOAA         |
| 13140-29-9   | Perfluoro-2-methoxypropanoate                                                                              | PMPA           |
| 267239-61-2  | Perfluoro-2-ethoxypropanoate                                                                               | PEPA           |
| 13252-13-6   | Hexafluoropropylene oxide-dimer acid, acid                                                                 | HFPO-DA        |
| 801212-59-9  | Perfluoro-4-isopropoxybutanoic acid                                                                        | PFECA G        |
| 2416366-22-6 | 4-(2-Carboxy-1,1,2,2-tetrafluoroethoxy)-perfluoropentanoic acid                                            | R-EVE          |
| 2416366-21-5 | 1,1,2,2-Tetrafluoro-2-[(1,1,1,2,3,3,4,4-octafluorobutan-2-yl)oxy]ethane-1-sulfonic acid                    | Nafion BP6     |
| 2416366-18-0 | Perfluoro-4-(2-sulfoethoxy)pentanoic acid                                                                  | Nafion BP4     |
| 39492-88-1   | Perfluoro-3,5-dioxahexanoic acid                                                                           | PFO2HxA        |
| 151772-58-6  | Perfluoro-3,6-dioxahexanoic acid                                                                           | PFO2HxA        |
| 919005-14-4  | Ammonium 4,8-dioxa-3H-perfluorononanoate, acid                                                             | ADONA          |
| 773804-62-9  | 2,2,3,3-Tetrafluoro-3-[(1,1,1,2,3,3-hexafluoro-3-(1,2,2,2-tetrafluoroethoxy)propan-2-yl)oxy]propanoic acid | Hydro-EVE Acid |
| 749836-20-2  | Perfluoro-2-[[perfluoro-3-(perfluoroethoxy)-2-propanyl]oxy]ethanesulfonic acid                             | Nafion BP2     |
| 69087-46-3   | Perfluoro-3-[[1-(ethenyl)oxy]propan-2-yl]oxy]propanoic acid                                                | EVE Acid       |
| 29311-67-9   | 1-(Trifluorovinyl)oxy)-2-(2-sulfotetrafluoroethoxy)hexafluoropropane                                       | Nafion BP1     |
| 2416366-19-1 | Fluoro[perfluoro-2-(perfluoro-2-sulfoethoxy)propoxy]acetic acid                                            | Nafion BP5     |
| 39492-89-2   | Perfluoro-3,5,7-trioxaoctanoic acid                                                                        | PFO3OA         |
| 39492-90-5   | Perfluoro-3,5,7,9-butaoadecanoic acid                                                                      | PFO4DA         |
| 39492-91-6   | Perfluoro-3,5,7,9,11-pentaoadecanoic acid                                                                  | PFO5DA         |

# All results – 37 Compounds detected at least once

|                  | GW Pumps    |                 |                 | Brass       |                 |                 | Fabric      |                 |                 | HDPE        |                 |                 | LDPE        |                 |                 | Nylon       |                 |                 | Silicon     |                 |                 | Teflon      |                 |                 | Field Blank<br>ng/L | Total<br>Detections |
|------------------|-------------|-----------------|-----------------|-------------|-----------------|-----------------|-------------|-----------------|-----------------|-------------|-----------------|-----------------|-------------|-----------------|-----------------|-------------|-----------------|-----------------|-------------|-----------------|-----------------|-------------|-----------------|-----------------|---------------------|---------------------|
|                  | Max<br>ng/L | Average<br>ng/L | Detections<br># | Max<br>ng/L | Average<br>ng/L | Detections<br># | Max<br>ng/L | Average<br>ng/L | Detections<br># | Max<br>ng/L | Average<br>ng/L | Detections<br># | Max<br>ng/L | Average<br>ng/L | Detections<br># | Max<br>ng/L | Average<br>ng/L | Detections<br># | Max<br>ng/L | Average<br>ng/L | Detections<br># | Max<br>ng/L | Average<br>ng/L | Detections<br># |                     |                     |
| PFBA             | 14          | 10.9            | 5               | 16          | 11.7            | 2               | ---         | ---             | ---             | 2.5         | 2.50            | 1               | ---         | ---             | ---             | 100         | 100             | 1               | 1.7         | 1.70            | 1               | 41          | 28.4            | 3               | 9.5                 | 14                  |
| PFPeA            | ---         | ---             | ---             | ---         | ---             | ---             | 9.1         | 9.10            | 1               | 2.8         | 1.88            | 5               | 0.98        | 0.98            | 1               | 7           | 7               | 1               | 1.1         | 0.89            | 2               | 210         | 104             | 4               | ---                 | 14                  |
| PFHxA            | ---         | ---             | ---             | ---         | ---             | ---             | 20          | 15.0            | 3               | 1.2         | 1.20            | 1               | ---         | ---             | ---             | 8           | 8               | 1               | 1.6         | 1.60            | 1               | 14          | 10.5            | 3               | ---                 | 9                   |
| PFHpA            | 0.28        | 0.28            | 1               | ---         | ---             | ---             | 6.9         | 6.10            | 3               | 1.3         | 0.84            | 4               | ---         | ---             | ---             | ---         | ---             | ---             | 1.2         | 0.94            | 2               | 66          | 31.9            | 4               | ---                 | 14                  |
| PFOA             | 0.31        | 0.28            | 4               | ---         | ---             | ---             | 11          | 7.40            | 3               | 0.84        | 0.84            | 1               | ---         | ---             | ---             | ---         | ---             | ---             | 1.8         | 1.50            | 2               | 6.7         | 4.28            | 4               | ---                 | 14                  |
| PFNA             | 0.23        | 0.23            | 1               | ---         | ---             | ---             | 2.3         | 1.24            | 3               | 0.56        | 0.45            | 2               | ---         | ---             | ---             | ---         | ---             | ---             | 0.84        | 0.69            | 2               | 20          | 10.4            | 4               | ---                 | 12                  |
| PFDA             | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | 0.31        | 0.31            | 1               | ---         | ---             | ---             | ---         | ---             | ---             | 0.48        | 0.48            | 1               | 3.6         | 2.36            | 4               | ---                 | 6                   |
| PFUnA            | 0.27        | 0.27            | 1               | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | 6.7         | 5.47            | 3               | ---                 | 4                   |
| PFDoA            | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | 2.6         | 2.60            | 1               | ---                 | 1                   |
| PFTra            | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | 2.3         | 2.30            | 1               | ---                 | 1                   |
| PFTeA            | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | 2.1         | 2.10            | 1               | ---                 | 1                   |
| PFHxDA           | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | 2.5         | 2.50            | 1               | ---                 | 1                   |
| PFOcDA           | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | 2.2         | 2.20            | 1               | ---                 | 1                   |
| PFBS             | 0.41        | 0.34            | 3               | 0.67        | 0.64            | 2               | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | 0.37                | 6                   |
| PFOS             | 1.2         | 0.79            | 6               | 5.9         | 5.90            | 1               | ---         | ---             | ---             | 0.46        | 0.46            | 1               | 1.5         | 1.5             | 1               | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | ---                 | 9                   |
| PFDS             | 0.48        | 0.40            | 9               | 0.63        | 0.56            | 2               | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | ---                 | 11                  |
| PFDoS            | 0.59        | 0.42            | 9               | 0.88        | 0.70            | 2               | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | ---                 | 11                  |
| 6:2 FTCA         | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | 2           | 1.95            | 2               | 1.4         | 1.40            | 1               | ---                 | 3                   |
| 8:2 FTCA         | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | 1.3         | 1.25            | 2               | ---         | ---             | ---             | ---                 | 2                   |
| 6:2 FTUCA        | ---         | ---             | ---             | ---         | ---             | ---             | 1.6         | 1.55            | 2               | ---         | ---             | ---             | ---         | ---             | ---             | 6.2         | 3.39            | 2               | 0.69        | 0.69            | 1               | ---         | ---             | ---             | ---                 | 5                   |
| 6:2 FTS          | 0.93        | 0.83            | 3               | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | 2.3         | 2.3             | 1               | ---         | ---             | ---             | 3           | 2.85            | 2               | 1           | 1.00            | 1               | ---                 | 7                   |
| PFOSA            | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | 1.2         | 1.2             | 1               | 0.51        | 0.51            | 1               | ---         | ---             | ---             | ---                 | 2                   |
| N-EtFOSA         | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | 4.3         | 4.3             | 1               | ---         | ---             | ---             | ---         | ---             | ---             | ---                 | 1                   |
| N-MeFOSE         | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | 9.9         | 9.9             | 1               | ---         | ---             | ---             | ---         | ---             | ---             | ---                 | 1                   |
| N-EtFOSE         | 0.39        | 0.39            | 1               | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | 7.8         | 7.8             | 1               | ---         | ---             | ---             | ---         | ---             | ---             | ---                 | 2                   |
| PFMOPra          | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | 3.3         | 3.05            | 2               | ---                 | 2                   |
| PFMOBA           | ---         | ---             | ---             | ---         | ---             | ---             | 0.21        | 0.21            | 1               | ---         | ---             | ---             | ---         | ---             | ---             | 1.6         | 1.6             | 1               | ---         | ---             | ---             | 0.71        | 0.69            | 2               | ---                 | 4                   |
| MTP              | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | 25          | 25              | 1               | ---         | ---             | ---             | ---         | ---             | ---             | ---                 | 1                   |
| PFMOAA           | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | 18          | 13.70           | 2               | 2.7         | 1.8             | 3               | ---         | ---             | ---             | 1.8         | 1.55            | 2               | 2700        | 1326            | 4               | ---                 | 11                  |
| PMPA             | 55          | 13.3            | 8               | 6.3         | 5.0             | 2               | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | 940         | 540             | 3               | ---         | ---             | ---             | 43          | 41.5            | 2               | 2.9                 | 16                  |
| PEPA             | 10          | 5.43            | 4               | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | ---                 | 4                   |
| PFECA G          | 0.69        | 0.69            | 1               | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | ---                 | 1                   |
| R-EVE            | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | 14          | 14              | 1               | ---         | ---             | ---             | ---         | ---             | ---             | ---                 | 1                   |
| PFO2HxA          | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | 12          | 11.5            | 2               | ---                 | 2                   |
| EVE Acid         | 1.2         | 1.20            | 1               | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | ---                 | 1                   |
| PFO3OA           | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | 2.9         | 2.90            | 1               | ---                 | 1                   |
| PFO4DA           | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | ---         | ---             | ---             | 1.7         | 1.35            | 2               | ---                 | 2                   |
| Total Detections | 57          |                 |                 | 11          |                 |                 | 16          |                 |                 | 18          |                 |                 | 10          |                 |                 | 16          |                 |                 | 23          |                 |                 | 55          |                 |                 | 3                   | 209                 |

# Detection summary

## Detected, >10 ng/L (12 compounds)

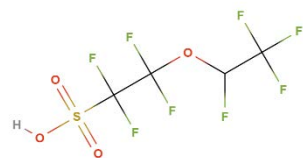
|         |   |                  |
|---------|---|------------------|
| PFBA    | } | Carboxylic acids |
| PFPeA   |   |                  |
| PFHxA   |   |                  |
| PFHpA   |   |                  |
| PFOA    |   |                  |
| PFNA    |   |                  |
| MTP     | } | Mono ethers      |
| PFMOAA  |   |                  |
| PMPA    |   |                  |
| PEPA    |   |                  |
| R-EVE   |   |                  |
| PFO2HxA |   | Di ether         |

## Detected, <10 ng/L (25 Compounds)

|          |           |
|----------|-----------|
| PFDA     | 6:2 FTUCA |
| PFUnA    | 6:2 FTS   |
| PFDoA    | PFOSA     |
| PFTra    | N-EtFOSA  |
| PFTeA    | N-MeFOSE  |
| PFHxDA   | N-EtFOSE  |
| PFOcDA   | PFMOPrA   |
| PFBS     | PFMOBA    |
| PFOS     | PFECA G   |
| PFDS     | EVE Acid  |
| PFDoS    | PFO3OA    |
| 6:2 FTCA | PFO4DA    |
| 8:2 FTCA |           |

## Not Detected (33 Compounds)

|            |              |                |
|------------|--------------|----------------|
| PFPrS      | 4:2 FTS      | Hydro-EVE Acid |
| PFPeS      | 8:2 FTS      | Nafion BP1     |
| PFHxS      | 10:2 FTS     | Nafion BP2     |
| PFHpS      | ADONA        | Nafion BP4     |
| PFNS       | HFPO-DA      | Nafion BP5     |
| 3:3 FTCA   | cHxPFEtA     | Nafion BP6     |
| 5:3 FTCA   | N-MeFOSA     | PFEESA         |
| 7:3 FTCA   | N-MeFOSAA    | PFDOHxA        |
| 10:2 FTCA  | N-EtFOSAA    | PFO5DA         |
| 8:2 FTUCA  | 9Cl-PF3ONS   |                |
| 10:2 FTUCA | 11Cl-PF3OUdS |                |



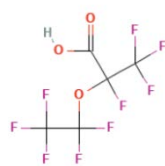
MTP



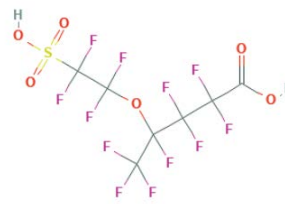
PFMOAA



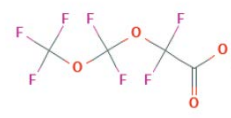
PMPA



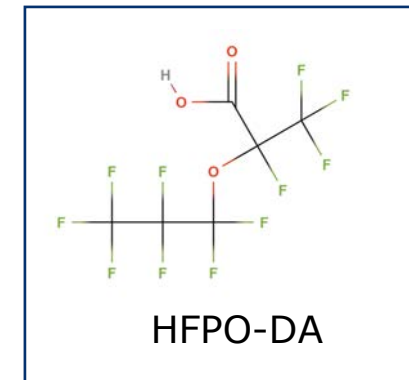
PEPA



R-EVE



PFO2HxA

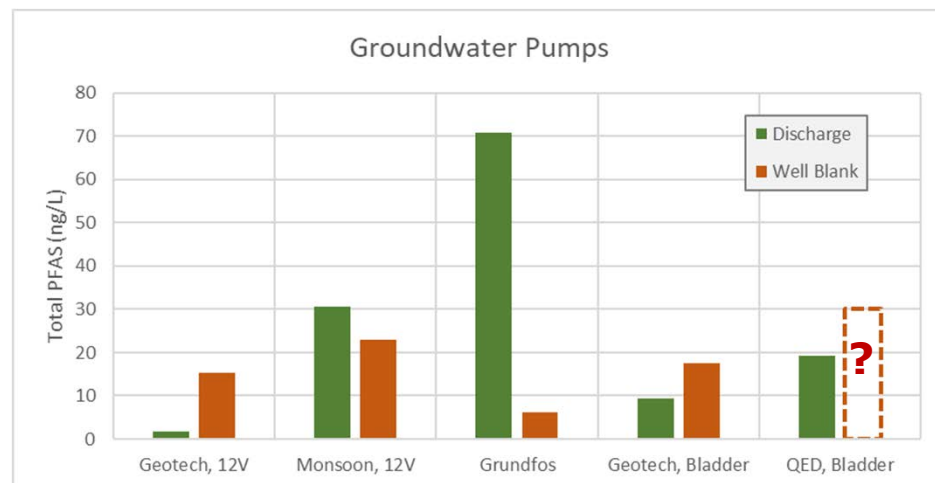


# Detection frequency

| Analyte | Detections | Detected, >10 ng/L | Media    | Detections |
|---------|------------|--------------------|----------|------------|
| PMPA    | 16         | PFBA               | GW Pumps | 57         |
| PFBA    | 14         | PFPeA              | Brass    | 11         |
| PFPeA   | 14         | PFHxA              | Fabric   | 16         |
| PFHpA   | 14         | PFHpA              | HDPE     | 18         |
| PFOA    | 14         | PFOA               | LDPE     | 10         |
| PFNA    | 12         | PFNA               | Nylon    | 16         |
| PFDS    | 11         | MTP                | Silicon  | 23         |
| PFDoS   | 11         | PFMOAA             | Teflon   | 55         |
| PFMOAA  | 11         | PMPA               | Field    | 3          |
| PFHxA   | 9          | PEPA               |          |            |
| PFOS    | 9          | R-EVE              |          |            |
| 6:2 FTS | 7          | PFO2HxA            |          |            |

# Sampling pump evaluation

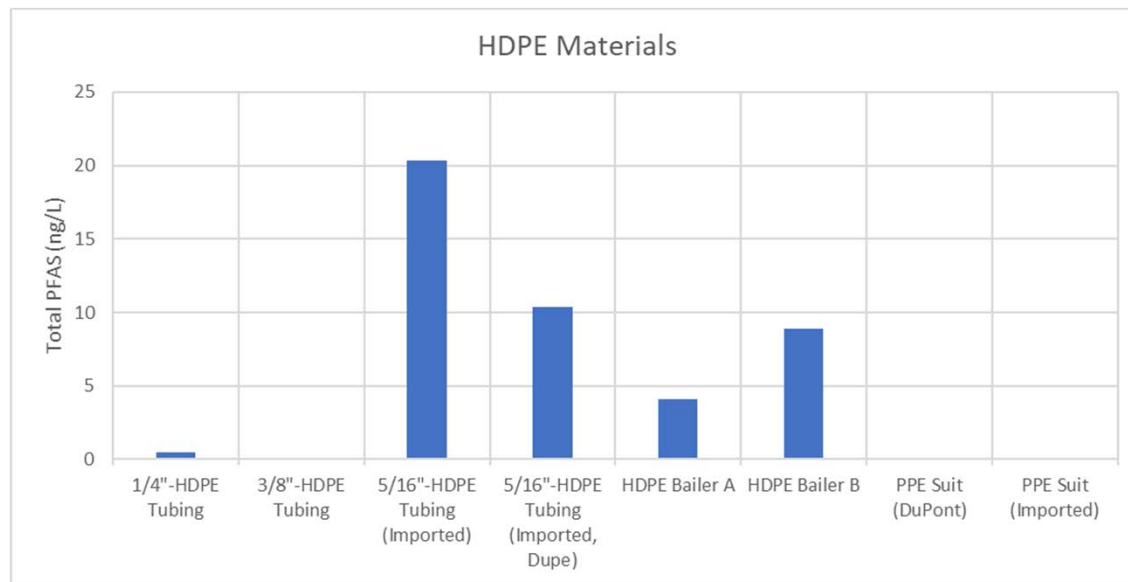
| Analyte        |             | Geotech, 12V<br>Discharge | Geotech, 12V<br>Well Blank | Monsoon, 12V<br>Discharge | Monsoon, 12V<br>Well Blank | Grundfos<br>Discharge | Grundfos<br>Well Blank | Geotech, Bladder<br>Discharge | Geotech, Bladder<br>Well Blank | QED, Bladder<br>Discharge |
|----------------|-------------|---------------------------|----------------------------|---------------------------|----------------------------|-----------------------|------------------------|-------------------------------|--------------------------------|---------------------------|
| PFBA           | ng/L        | ---                       | 8.9                        | 9.4                       | 12                         | 14                    | ---                    | ---                           | ---                            | 10                        |
| PFHpA          | ng/L        | ---                       | ---                        | ---                       | ---                        | 0.28                  | ---                    | ---                           | ---                            | ---                       |
| PFOA           | ng/L        | ---                       | 0.27                       | ---                       | ---                        | 0.28                  | ---                    | ---                           | ---                            | 0.31                      |
| PFNA           | ng/L        | ---                       | ---                        | ---                       | ---                        | ---                   | ---                    | ---                           | ---                            | 0.23                      |
| PFUnA          | ng/L        | ---                       | 0.27                       | ---                       | ---                        | ---                   | ---                    | ---                           | ---                            | ---                       |
| PFBS           | ng/L        | ---                       | 0.32                       | ---                       | ---                        | ---                   | ---                    | ---                           | ---                            | 0.41                      |
| PFOS           | ng/L        | 1                         | 1.2                        | ---                       | 0.43                       | 0.54                  | 0.47                   | ---                           | ---                            | ---                       |
| PFDS           | ng/L        | 0.48                      | 0.35                       | 0.43                      | 0.35                       | 0.42                  | ---                    | 0.44                          | 0.41                           | 0.36                      |
| PFDoS          | ng/L        | 0.33                      | 0.31                       | 0.59                      | 0.48                       | 0.29                  | 0.42                   | 0.53                          | 0.31                           | ---                       |
| 6:2 FTS        | ng/L        | ---                       | ---                        | 0.79                      | 0.93                       | ---                   | ---                    | ---                           | ---                            | ---                       |
| N-EtFOSE       | ng/L        | ---                       | 0.39                       | ---                       | ---                        | ---                   | ---                    | ---                           | ---                            | ---                       |
| PMPA           | ng/L        | ---                       | 3.4                        | 8.8                       | 5.5                        | 55                    | 5.3                    | 7.3                           | 13                             | 7.9                       |
| PEPA           | ng/L        | ---                       | ---                        | 10                        | 3.2                        | ---                   | ---                    | ---                           | 3.7                            | ---                       |
| PFECA G        | ng/L        | ---                       | ---                        | 0.69                      | ---                        | ---                   | ---                    | ---                           | ---                            | ---                       |
| EVE Acid       | ng/L        | ---                       | ---                        | ---                       | ---                        | ---                   | ---                    | 1.2                           | ---                            | ---                       |
| <b>Totals:</b> | <b>ng/L</b> | <b>1.8</b>                | <b>15.4</b>                | <b>30.7</b>               | <b>22.9</b>                | <b>70.8</b>           | <b>6.2</b>             | <b>9.5</b>                    | <b>17.4</b>                    | <b>19.2</b>               |



- PFCAs and PFBA especially associated with all pumps except the bladder pump
- PFSAs associated with all pumps
- $10^{-1}$  to  $10^0$  ng/L of various PFAS in discharged leachate of all pumps
- Highest PMPA and PFBA detected in discharge from Grundfos Rediflow (Teflon parts)

# HDPE materials

|                |             | 1/4"-HDPE<br>Tubing | 3/8"-HDPE<br>Tubing | 5/16"-HDPE Tubing<br>(Imported) | 5/16"-HDPE Tubing<br>(Imported, Dupe) | HDPE Bailer A | HDPE Bailer B | PPE Suit<br>(DuPont) | PPE Suit<br>(Imported) |
|----------------|-------------|---------------------|---------------------|---------------------------------|---------------------------------------|---------------|---------------|----------------------|------------------------|
| PFBA           | ng/L        | ---                 | ---                 | ---                             | ---                                   | ---           | 2.5           | ---                  | ---                    |
| PFPeA          | ng/L        | ---                 | ---                 | 1.8                             | 1                                     | 2.8           | 2.2           | ---                  | ---                    |
| PFHxA          | ng/L        | ---                 | ---                 | ---                             | ---                                   | ---           | 1.2           | ---                  | ---                    |
| PFHpA          | ng/L        | ---                 | ---                 | 0.56                            | ---                                   | 0.96          | 1.3           | ---                  | ---                    |
| PFOA           | ng/L        | ---                 | ---                 | ---                             | ---                                   | ---           | 0.84          | ---                  | ---                    |
| PFNA           | ng/L        | ---                 | ---                 | ---                             | ---                                   | 0.33          | 0.56          | ---                  | ---                    |
| PFDA           | ng/L        | ---                 | ---                 | ---                             | ---                                   | ---           | 0.31          | ---                  | ---                    |
| PFOS           | ng/L        | 0.46                | ---                 | ---                             | ---                                   | ---           | ---           | ---                  | ---                    |
| PFMOAA         | ng/L        | ---                 | ---                 | 18                              | 9.4                                   | ---           | ---           | ---                  | ---                    |
| <b>Totals:</b> | <b>ng/L</b> | <b>0.5</b>          | <b>0</b>            | <b>20.4</b>                     | <b>10.4</b>                           | <b>4.1</b>    | <b>8.9</b>    | <b>0</b>             | <b>0</b>               |



- Very low ( $10^{-1}$  to  $10^0$  ng/L) of PFCAs and PFSAAs found in leachate of HDPE materials
- PFMOAA (a mono ether) found at  $\sim 10^1$  ng/L in leachate of imported HDPE materials
- White PPE suits non-detect for all PFAS in leachate

# Silicone materials

| Analyte        |             | Silicone Tubing, Generic | Silicone Tubing, Brand A | Silicone Bladder, A | Silicone Bladder, B |
|----------------|-------------|--------------------------|--------------------------|---------------------|---------------------|
| PFBA           | ng/L        | ---                      | ---                      | ---                 | 1.7                 |
| PFPeA          | ng/L        | ---                      | ---                      | 0.67                | 1.1                 |
| PFHxA          | ng/L        | ---                      | ---                      | ---                 | 1.6                 |
| PFHpA          | ng/L        | ---                      | ---                      | 0.68                | 1.2                 |
| PFOA           | ng/L        | ---                      | ---                      | 1.2                 | 1.8                 |
| PFNA           | ng/L        | ---                      | ---                      | 0.54                | 0.84                |
| PFDA           | ng/L        | ---                      | ---                      | ---                 | 0.48                |
| 6:2 FTCA       | ng/L        | ---                      | ---                      | 2                   | 1.9                 |
| 8:2 FTCA       | ng/L        | ---                      | ---                      | 1.2                 | 1.3                 |
| 6:2 FTUCA      | ng/L        | ---                      | ---                      | ---                 | 0.69                |
| 6:2 FTS        | ng/L        | ---                      | ---                      | 2.7                 | 3                   |
| PFOSA          | ng/L        | ---                      | ---                      | ---                 | 0.51                |
| PFMOAA         | ng/L        | ---                      | ---                      | 1.8                 | 1.3                 |
| <b>Totals:</b> | <b>ng/L</b> | <b>0</b>                 | <b>0</b>                 | <b>10.8</b>         | <b>17.4</b>         |

- Silicone tubing non-detect for all PFAS in leachate
- Silicone bladders, different story!
- Why??

# Teflon materials

| Analyte        |             | Tubing, Teflon | Tubing, Teflon (Dupe) | Bladder, Teflon, Brand A | Bladder, Teflon, Brand B |
|----------------|-------------|----------------|-----------------------|--------------------------|--------------------------|
| PFBA           | ng/L        | 41             | 38                    | 6.1                      | ---                      |
| PFPeA          | ng/L        | 200            | 210                   | 3.8                      | 0.56                     |
| PFHxA          | ng/L        | 13             | 14                    | 4.5                      | ---                      |
| PFHpA          | ng/L        | 57             | 66                    | 4.2                      | 0.46                     |
| PFOA           | ng/L        | 5.6            | 6.7                   | 3.9                      | 0.91                     |
| PFNA           | ng/L        | 17             | 20                    | 4                        | 0.59                     |
| PFDA           | ng/L        | 2.5            | 2.8                   | 3.6                      | 0.52                     |
| PFUnA          | ng/L        | 6              | 6.7                   | 3.7                      | ---                      |
| PFDoA          | ng/L        | ---            | ---                   | 2.6                      | ---                      |
| PFTTrA         | ng/L        | ---            | ---                   | 2.3                      | ---                      |
| PFTeA          | ng/L        | ---            | ---                   | 2.1                      | ---                      |
| PFHxDA         | ng/L        | ---            | ---                   | 2.5                      | ---                      |
| PFOcDA         | ng/L        | ---            | ---                   | 2.2                      | ---                      |
| 6:2 FTCA       | ng/L        | ---            | ---                   | 1.4                      | ---                      |
| 6:2 FTS        | ng/L        | ---            | ---                   | ---                      | 1                        |
| PFMOPrA        | ng/L        | 2.8            | 3.3                   | ---                      | ---                      |
| PFMOBA         | ng/L        | 0.66           | 0.71                  | ---                      | ---                      |
| PFMOAA         | ng/L        | 2700           | 2600                  | 1.8                      | 1.5                      |
| PMPA           | ng/L        | 43             | 40                    | ---                      | ---                      |
| PFO2HxA        | ng/L        | 11             | 12                    | ---                      | ---                      |
| PFO3OA         | ng/L        | ---            | 2.9                   | ---                      | ---                      |
| PFO4DA         | ng/L        | 1              | 1.7                   | ---                      | ---                      |
| <b>Totals:</b> | <b>ng/L</b> | <b>3,101</b>   | <b>3,025</b>          | <b>49</b>                | <b>6</b>                 |

- Good agreement between dupes!
- 200 ng/L PFPeA, 60 ng/L PFHpA, 40 ng/L PFBA in leachate of Teflon tubing
- 2,700 ng/L (!) PFMOAA in Teflon tubing (same mono ether PFAS in HDPE tubing)
- $\sim 10^0$  ng/L PFCAs in leachate of Teflon bladders
- A “replacement chemistry” for Teflon manufacturing? From the extrusion process?

# Fabrics

| Analyte        |             | Blue Shop Wipes | Blue Shop Wipes, Dupe | White Shop Wipes |
|----------------|-------------|-----------------|-----------------------|------------------|
| PFPeA          | ng/L        | ---             | ---                   | 9.1              |
| PFHxA          | ng/L        | 13              | 12                    | 20               |
| PFHpA          | ng/L        | 6.9             | 5.5                   | 5.9              |
| PFOA           | ng/L        | 11              | 8.3                   | 2.9              |
| PFNA           | ng/L        | 2.3             | 1.2                   | 0.23             |
| 6:2 FTUCA      | ng/L        | 1.6             | 1.5                   | ---              |
| PFMOBA         | ng/L        | ---             | ---                   | 0.21             |
| <b>Totals:</b> | <b>ng/L</b> | <b>34.8</b>     | <b>28.5</b>           | <b>38.3</b>      |

- Reasonable dupe agreement
- $\sim 10^1$  ng/L PFHxA in shop wipe leachate
- $\sim 10^0$  to  $10^1$  ng/L PFOA and PFHpA in leachate
- Actual PFAS mass gain due to sample contact is likely low

# Key take-aways

## **Conclusions:**

- PFAS continue to show up in surprising settings
- Expanded PFAS analyte lists (i.e., Method 1633) present greater probability of increasing the number of detections
- Blanks, blanks, blanks!! (And good sampling design... next slides)
- Be mindful of origin of manufactured goods being used in the field
- Potentially useful to repeat some of the findings of this study
- Include untested materials in further studies

# Quality control: Trip Blanks

## Trip Blank

Field Blank

Equipment Blank

Field Duplicates

Matrix Spike and Matrix Spike Duplicates

Temperature Blank

**TB: Was the cooler or the lab contaminated; did anything happen in transit?**



# Quality control: Field Blanks

Trip Blank

Field Duplicates

**Field Blank**

Matrix Spike and Matrix Spike Duplicates

Equipment Blank

Temperature Blank

**FB: Were any  
environmental factors  
compromising sample  
integrity?**



# Quality control: Equipment Blanks

Trip Blank

Field Duplicates

Field Blank

Matrix Spike and Matrix Spike Duplicates

**Equipment Blank**

Temperature Blank

**EB: Have any systematic errors throughout the sampling event compromised sample integrity?**



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