

# Environmental impact assessment of PFAS in ambient air

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Atmosf'Air 10 October 2024



# Agenda

1- PFAS – Sources and challenges

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2- How are we exposed to PFAS? The case of ambient air

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3- Indicative values for PFAS in ambient air

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4- PFAS and air – Emissions, ambient air monitoring and dispersion modelling

# PFAS : what are we speaking about?

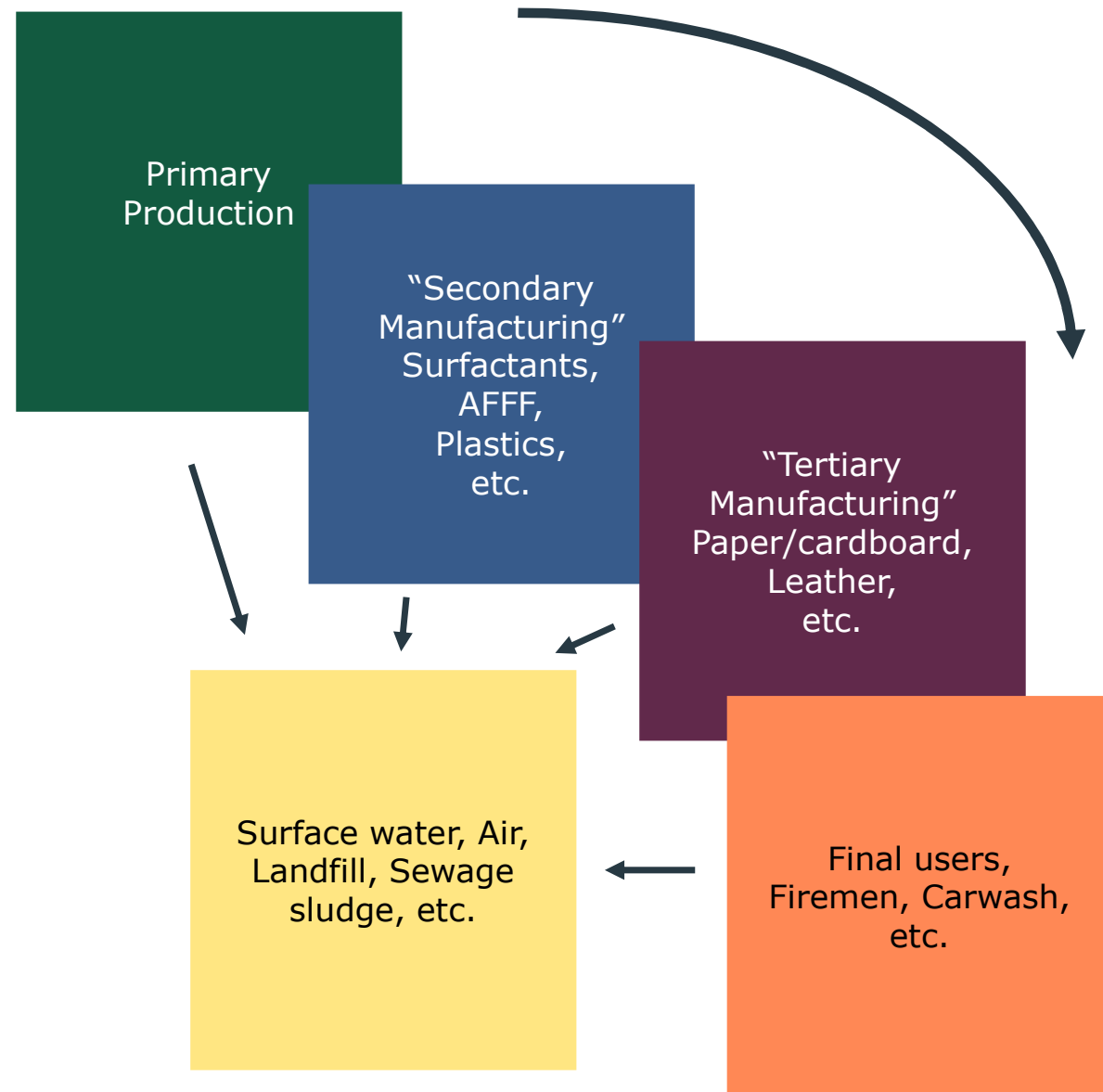


- Per- and polyfluoroalkylated substances (PFAS) are fluorinated molecules synthesised since the late 1940s.
- PFAS substances contain carbon-fluorine bonds, which are among the strongest chemical bonds in organic chemistry. This family includes several thousand substances. The best-known molecules are PFOA (perfluorooctanoic acid) and PFOS (perfluorooctane sulphonate).
- Appreciated for their surface-active properties and stability, these molecules are used in the chemical, textile, electronics, cosmetics and food packaging industries, and are also the main components of certain aqueous film forming foam (AFFF) used in military bases and airports.
- Discharges into the environment can be linked to atmospheric emissions, leaks, aqueous discharges or waste

# Potential sources of PFAS

- **PFAS manufacturers**
- **PFAS users**
  - Textile industry
  - Carpet manufacturers
  - Leather industry
  - Building materials
  - Paper and cardboard
  - Etc.
- **Fire tests areas**
  - Military sites
  - Airports
  - Refineries
  - Etc.
- **Others**
  - Landfills
  - Waste incineration plants
  - Sewage sludge spreading
  - Carwash stations

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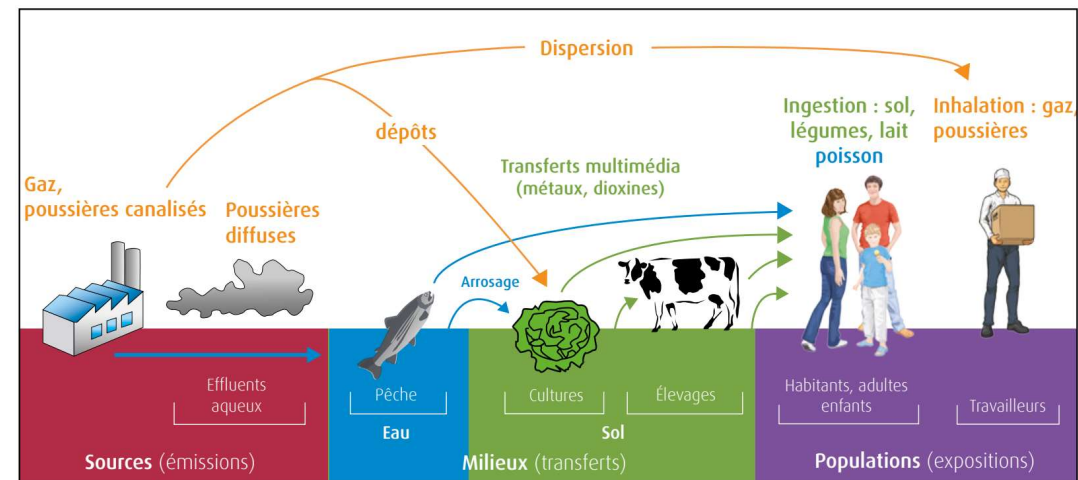


# PFAS and health

- Some PFAS compounds may be persistent in the environment and can bioaccumulate in organisms.
- PFAS are a family of substances, and not all of them represent the same types or levels of risk. The EFSA (European Food Safety Authority) has identified 4 PFAS of specific interest because they contribute most to exposure and potential health risk: PFOA, PFNA, PFHxS, PFOS.
- In December 2023, PFOA was classified as 'carcinogenic to humans' (Group 1) by the IARC, and PFOS was classified as 'possibly carcinogenic to humans' (Group 2B). According to the CLP classification, these two molecules are classified as C2 / R1B (Suspected human carcinogens, Presumed human reproductive toxicant).
- Studies indicate that PFOA and PFOS may have effects on reproduction and development, on the immune system, the liver, kidneys and thyroid in laboratory animals, and effects on reproduction and development to be confirmed in humans. Both PFOA and PFOS have caused tumours in animal studies.
- ANSES has published several reports on PFASs since 2014, particularly in relation to the issue of endocrine disruptors – Existing work in progress on this topic.

# How are we exposed to PFAS?

- According to the literature, ingestion is the main route of exposure via water and food.
- Given the presence of certain PFAS compounds in cosmetics, the cutaneous route may also be a route of exposure.
- Finally, inhalation is also a potential route of exposure, although not the main one.



Even if inhalation is low stake, it does not mean that there are no air issue regarding PFAS



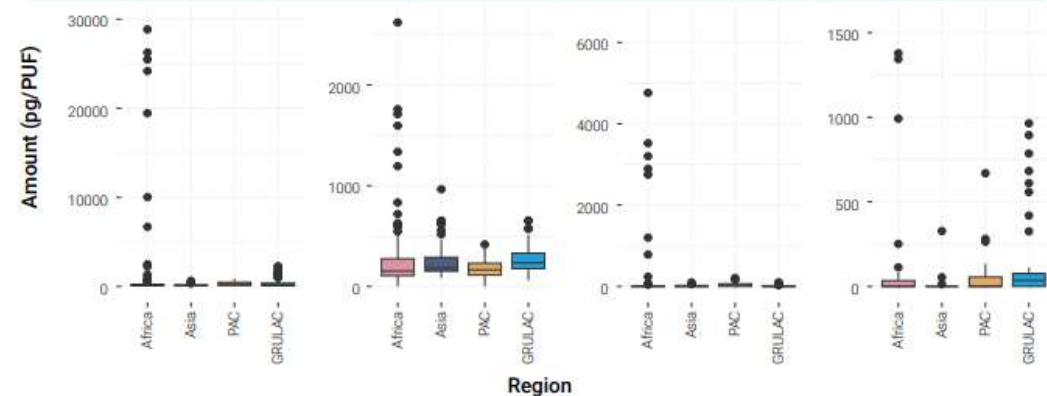
# PFAS in ambient air– UNEP monitoring (GMP2)

- Passive sampling – 317 samples from 40 countries non producers of PFAS – period 2017-2019
- Highest levels in Zambia, associated to work field in an airport
- At least 1 PFAS in almost all the samples :
  - PFOS and PFOA in 91 % and 92 % of the samples
  - PFHxS quantified in 37 % of the samples
  - PFOSA quantified in 17 % of the samples

Source : [United Nations Environment Programme \(2024\). Sectoral Report: Results of Air Monitoring of Persistent Organic Pollutants. Geneva](#)

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	Central tendencies	Africa (N=127)	Asia (N=46)	PAC (N=43)	GRULAC (N=101)	Overall (N=317)
PFOS	Mean (SD)	1640 (5940)	139 (122)	297 (219)	376 (497)	847 (3860)
	Median [Min, Max]	110 [0, 36000]	101 [27.3, 634]	266 [0, 827]	192 [0, 2260]	136 [0, 36000]
	Missing	5 (3.9%)	1 (2.2%)	3 (7.0%)	10 (9.9%)	19 (6.0%)
PFOA	Mean (SD)	305 (464)	271 (194)	181 (86.5)	257 (125)	268 (313)
	Median [Min, Max]	153 [0, 3180]	183 [83.1, 965]	165 [0, 417]	233 [58.9, 655]	192 [0, 3180]
	Missing	10 (7.9%)	2 (4.3%)	5 (11.6%)	5 (5.0%)	22 (6.9%)
PFHxS	Mean (SD)	224 (980)	13.4 (20.7)	41.6 (48.5)	9.72 (18.6)	101 (628)
	Median [Min, Max]	0 [0, 7880]	0 [0, 96.1]	34.7 [0, 206]	0 [0, 101]	0 [0, 7880]
	Missing	2 (1.6%)	2 (4.3%)	0 (0%)	1 (1.0%)	5 (1.6%)
PFOSA	Mean (SD)	132 (414)	24.6 (81.8)	68.5 (155)	138 (260)	112 (315)
	Median [Min, Max]	0 [0, 1890]	0 [0, 327]	0 [0, 669]	34.9 [0, 964]	0 [0, 1890]
	Missing	63 (49.6%)	30 (65.2%)	20 (46.5%)	56 (55.4%)	169 (53.3%)



PAC: Pacific Islands

GRULAC: Group of Latin American and Caribbean countries

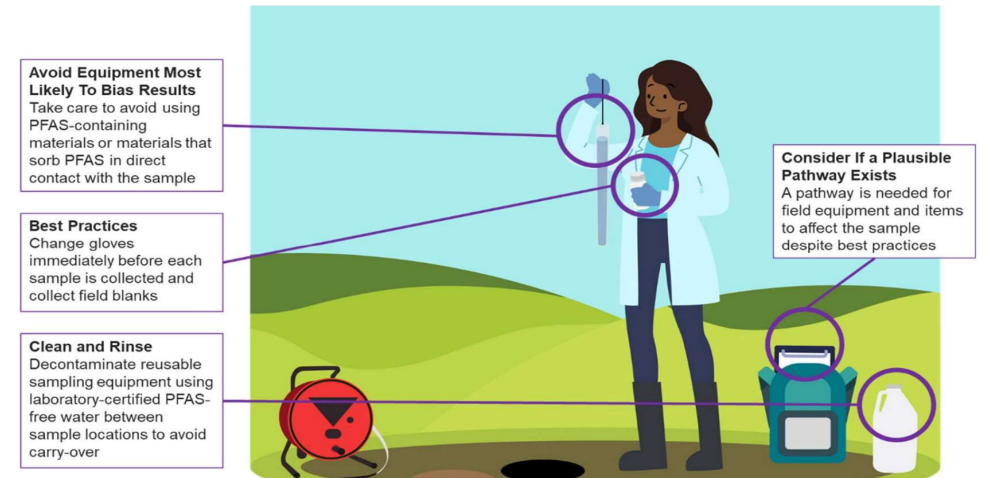
## Indicative values in ambient air

- Currently, there are no regulatory values in France or Europe.
- At federal level, no values defined in the USA and Canada, but values defined by certain States/Provinces
- No “VTR” (Valeurs Toxicologiques de Référence - Toxicological Reference Value) for the inhalation route defined in the priority databases cited in the French technical note of 31 October 2014
- Derivation approaches from ingestion route to inhalation route are sometimes implemented:
  - TCEQ (Texas Commission on Environmental Quality) (an organisation not listed in the NT of 31/10/2014) has defined inhalation reference values thanks to this method
  - “Temporary air thresholds derived from EFSA, 2020” have also been defined by the Flanders region (Belgium)



# PFAS sampling – Specific precautions

- Specific sampling protocol to be implemented to avoid cross-contamination (PFAS-free equipment, sampler's clothing and gloves, specific bottles, etc.): use of appropriate equipment and materials mandatory
- Commonly used sampling equipment (pumps, etc.) may contain PFAS!
- Thoroughly clean the equipment used, using a 'PFAS-free' protocol and products.
- Provide quality control samples



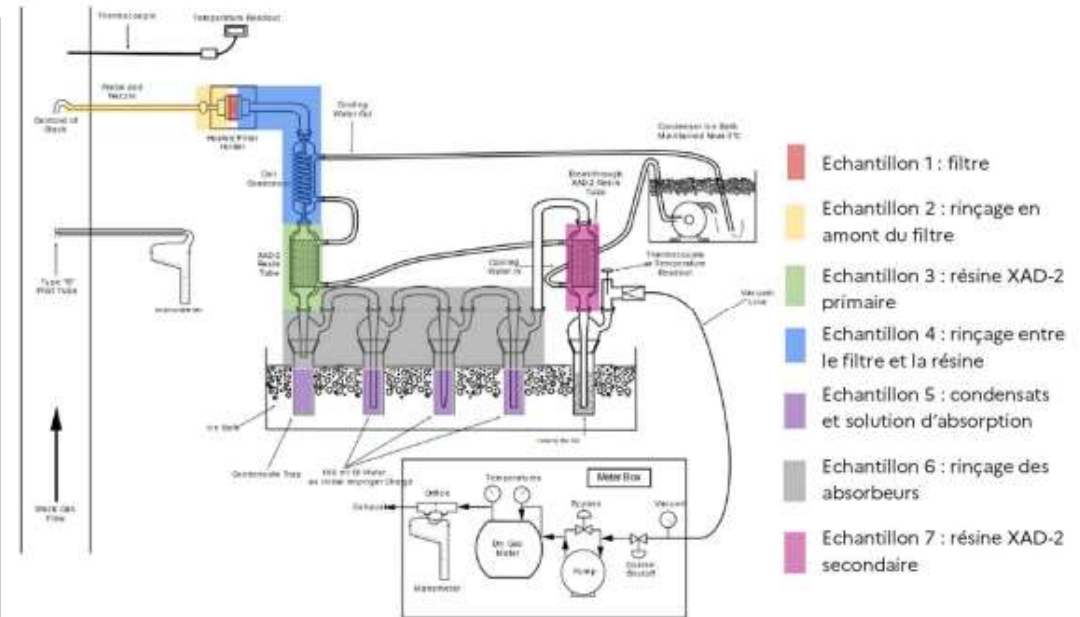
**Figure 2-2.** Science-based guidelines for field equipment and materials used during PFAS sample collection



**Figure 4-1.** Tips for collecting representative samples of bulk surface water

# PFAS sampling – Stack measurements

- **Note dated 7<sup>th</sup> March 2024** of the French Environnement Ministry for the approved emission laboratories specifies the requirements for emission measurements
- US-EPA method OTM-45, validated for 50 semi-volatile PFAS, is the basis for the method to be used in France, with a few specific features
- Isokinetic sampling (Filter + XAD-2 resins)
- Use of resins marked of with PFOA and PFBA isotopes to check trapping and recovery efficiency.
- Minimum sampling volume of 3 m<sup>3</sup>




# PFAS sampling – Stack measurements

Common Name <sup>a</sup>	Abbreviated Name	CAS <sup>b</sup> Registry Number
<b>Perfluoroalkylcarboxylic acids (PFCAs)</b>		
Perfluorobutanoic acid <sup>1,3,4</sup>	PFBA	375-22-4
Perfluoropentanoic acid <sup>1,3,4</sup>	PFPeA	2706-90-3
Perfluorohexanoic acid <sup>1,2,3,4</sup>	PFHxA	307-24-4
Perfluoroheptanoic acid <sup>1,2,3,4</sup>	PFHpA	375-85-9
Perfluorooctanoic acid <sup>1,2,3,4</sup>	PFOA	335-67-1
Perfluorononanoic acid <sup>1,2,3,4</sup>	PFNA	375-95-1
Perfluorodecanoic acid <sup>1,2,3,4</sup>	PFDA	335-76-2
Perfluoroundecanoic acid <sup>1,2,3,4</sup>	PFUnDA	2058-94-8
Perfluorododecanoic acid <sup>1,2,3,4</sup>	PFDoA	307-55-1
Perfluorotridecanoic acid <sup>1,2,3,4</sup>	PFTriDA	72629-94-8
Perfluorotetradecanoic acid <sup>1,2,3,4</sup>	PFTeDA	376-06-7
Perfluoro-n-hexadecanoic acid	PFHxDA	67905-19-5
Perfluoro-n-octadecanoic acid	PFODA	16517-11-6
<b>Perfluorinated sulfonic acids (PFSA)</b>		
Perfluoro-1-butanedisulfonic acid <sup>1,2,3,4</sup>	PFBS	375-73-5
Perfluoro-1-pentadisulfonic acid <sup>1,3</sup>	PFPeS	2706-91-4
Perfluoro-1-hexadisulfonic acid <sup>1,2,3,4</sup>	PFHxS	355-46-4
Perfluoro-1-heptadisulfonic acid <sup>1,3</sup>	PFHpS	375-92-8
Perfluoro-1-octadisulfonic acid <sup>1,2,3,4</sup>	PFOS	1763-23-1
Perfluoro-1-nonadisulfonic acid <sup>3</sup>	PFNS	68259-12-1
Perfluoro-1-decadisulfonic acid <sup>3</sup>	PFDS	335-77-3
Perfluorododecane sulfonate	PFDoS	79780-39-5
<b>Perfluorinated sulfonamides (FOSAs)</b>		
Perfluoro-1-octanesulfonamide <sup>1,3</sup>	FOSA	754-91-6
N-Methylperfluorooctanesulfonamide <sup>5</sup>	MeFOSA	31506-32-8
N-ethylperfluorooctanesulfonamide <sup>5</sup>	EtFOSA	4151-50-2
<b>Perfluorinated sulfonamide ethanols (FOSEs)</b>		
2-(N-methylperfluoro-1-octanesulfonamido)-ethanol <sup>5</sup>	N-MeFOSE	24448-09-7
2-(N-ethylperfluoro-1-octanesulfonamido)-ethanol <sup>5</sup>	N-EtFOSE	1691-99-2
<b>Perfluorinated sulfonamidoacetic acids (FOSAA)</b>		
N-methyl perfluorooctanesulfonamidoacetic acid <sup>2,3</sup>	MeFOSAA	2355-31-9
N-ethyl perfluorooctanesulfonamidoacetic acid <sup>2,3</sup>	EtFOSAA	2991-50-6

- List of the 50 semi-volatile PFAS included in the OTM-45 method

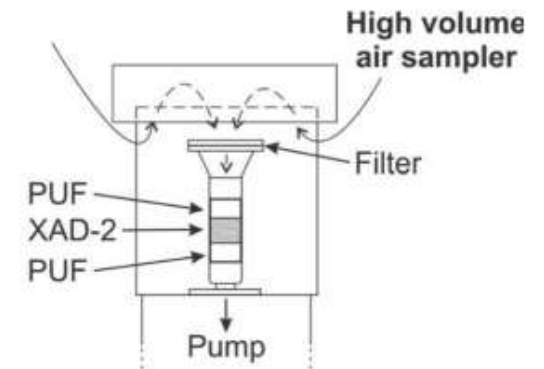
<b>Fluorotelomer sulfonates (FTS)</b>		
1H,1H,2H,2H-Perfluorohexane sulfonic acid <sup>1,3</sup>	4:2 FTS	757124-72-4
1H,1H,2H,2H-Perfluorooctane sulfonic acid <sup>1,3</sup>	6:2 FTS	27619-97-2
1H,1H,2H,2H-Perfluorodecane sulfonic acid <sup>1,3</sup>	8:2 FTS	39108-34-4
1H,1H,2H,2H-perfluorododecane sulfonate (10:2)	10:2 FTS	120226-60-0
<b>Fluorinated Replacement Chemicals</b>		
4,8-Dioxo-3H-perfluorononanoic acid	ADONA <sup>1</sup>	919005-14-4
Hexafluoropropylene Oxide Dimer Acid	HFPO-DA (GenX) <sup>1</sup>	13252-13-6
9-Chlorohexadecafluoro-3-oxanonane-1-sulfonic acid	9Cl-PF3ONS (F-53B Major) <sup>1</sup>	756426-58-1
11-Chloroeicosafluoro-3-oxaundecane-1-sulfonic acid OR 11-Chloroeicosafluoro-3-oxaundecane-1-sulfonate <sup>a</sup>	11Cl-PF3OUdS (F-53B Minor) <sup>1</sup>	763051-92-9 83329-89-9
<b>Additional Targets</b>		
Nonafluoro-3,6-dioxahexanoic acid <sup>1,5</sup>	NFDHA	151772-58-6
Perfluoro(2-ethoxyethane)sulfonic acid <sup>1,5</sup>	PFEESA	113507-82-7
Sodium perfluoro-1-dodecanesulfonate <sup>5</sup>	PFDoS	1260224-54-1
Perfluoro-4-methoxybutanoic acid <sup>1,5</sup>	PFMBA	863090-89-5
Perfluoro-3-methoxypropanoic acid <sup>1,5</sup>	PFMPA	377-73-1
Decafluoro-4-(pentafluoroethyl)cyclohexanesulfonate <sup>4</sup>	PFecHS	67584-42-3
2H-perfluoro-2-decenoic acid <sup>4</sup>	8:2 FTUCA or FOUEA	70887-84-2
2-perfluorodecyl ethanoic acid <sup>4</sup>	10:2 FDEA	53826-13-4
2-perfluorooctyl ethanoic acid <sup>4</sup>	8:2 FTA or FOEA	27854-31-5
2H-perfluoro-2-octenoic acid <sup>4</sup>	6:2 FHUEA	70887-88-6
2-perfluorohexyl ethanoic acid <sup>4</sup>	6:2FTCA or 6:2 FHEA	53826-12-3
3:3 Fluorotelomer carboxylic acid <sup>5</sup>	3:3 FTCA	356-02-5
5:3 Fluorotelomer carboxylic acid <sup>5</sup>	5:3 FTCA	914637-49-3
7:3 Fluorotelomer carboxylic acid or 3-perfluoropropyl propanoic acid <sup>4,5</sup>	7:3 FTCA or FHPA	812-70-4

# PFAS sampling – Ambient air monitoring

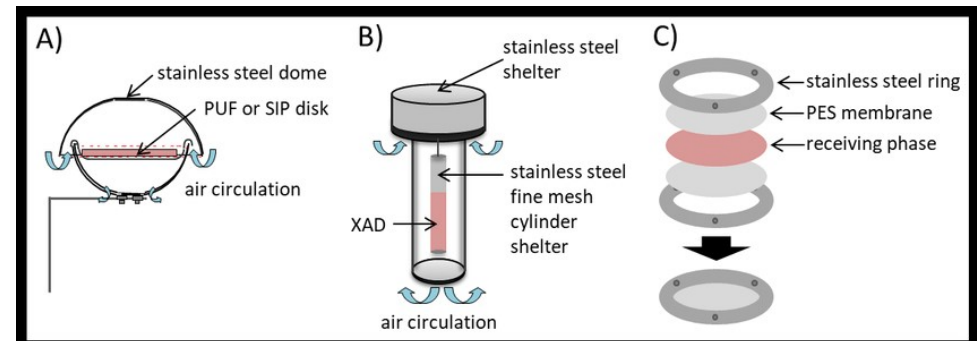
- Searching for trace compounds (in the  $\text{pg}/\text{m}^3$  range)
  - Searching for 1  $\text{pg}/\text{m}^3$  is like searching for 1 cell in the volume of an Olympic-sized swimming pool. 
  - Need to sample large quantities of air to obtain enough PFAS in the sample and therefore sufficient sensitivity
- PFAS may be particulate, volatile or semi-volatile: combination of filter + adsorbent medium (PUF foam, resin, or both)
- Both active and passive methods exist

# PFAS sampling – Ambient air monitoring

- Active sampling:
  - Sampling volume more accurate
  - Limited duration (96 h)
  - Higher risk of cross-contamination
- Passive sampling:
  - Indicative sampling volume
  - Good sensitivity, due to sampling time (up to three months)
  - Easy to use for mapping (no need for electricity, etc.)



Arhens et al. 2011

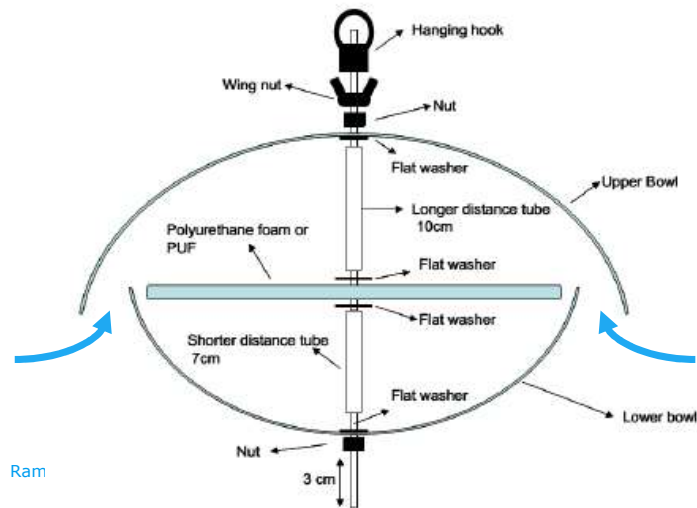


Yin Lai et al. 2018



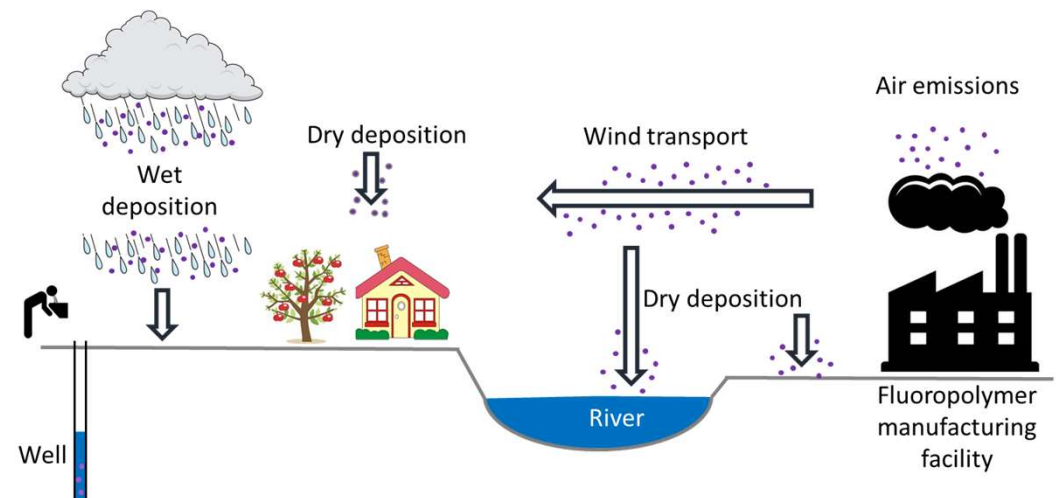
# PFAS sampling – Ambient air monitoring

- Installation of a foam (support) that adsorbs PFAS inside a metal enclosure (sampler)
- Free movement of air in the sampler
- Support protected from the sun and precipitation
- Air flow rate estimation based on meteorological conditions (a few  $\text{m}^3/\text{day}$ )



# Dispersion modelling of PFAS

- Possibility of carrying out atmospheric dispersion studies using standard dispersion software
- Main challenges :
  - Need to characterise the source term (cf. emission measurements)
  - Different behaviours of PFAS depending on their particulate/gas/semi-particulate nature → to be incorporated into model parameterisation



Adapted from Davis et al.,  
Chemosphere, 2007



# Thank you for your attention!

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