PFAS: Bilan de 2 études de science participative en région Lyonnaise

Festival les Grands Bleus

Louis Delon, Directeur de l'IECTL

Présentation

2001-2005	2005-2007	2007-2011	2012-2014	…	2020-2025
Doctorat chimie (Université Montpellier 2)	Post-doctorat	CEO Azasynth	CEO Kallistem		Maraicher bio

Chimie des PFAS

Journal of Fluorine Chemistry

New synthesis of polyfluoroalkyl racemic α-amino acids

Journal of Fluorine Chemistry

New synthesis of polyfluoroalkanesulfonylureas

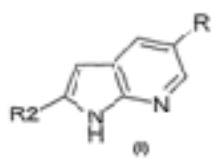
United States Patent

US 8,859,150 B2

Chimie Hétérocyclique

DEMANDE DE BREVET CANADIEN / CANADIAN PATENT APPLICATION

2 751 478



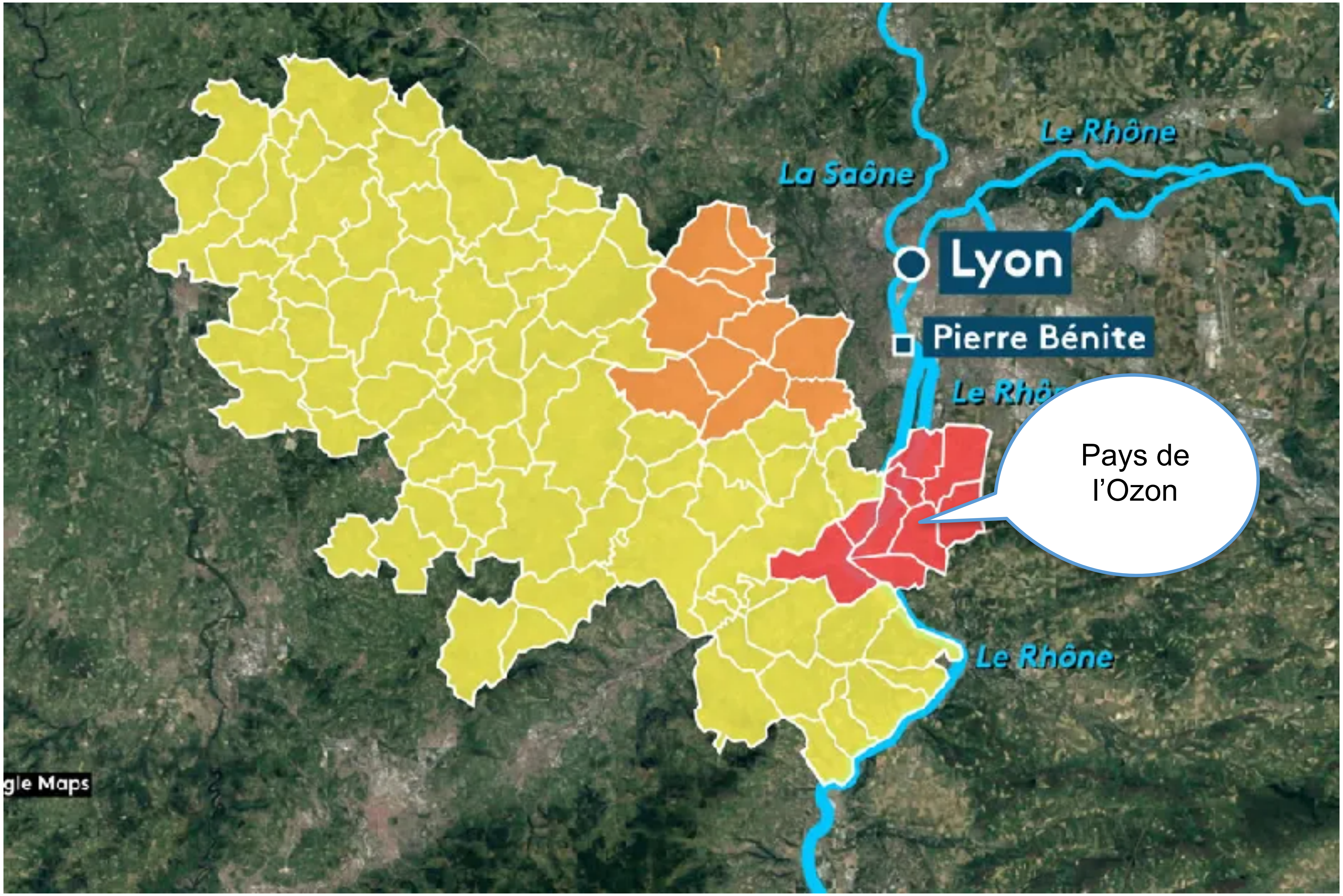
Toxicologie de la reproduction

KALLISTEM

OZON L'EAU SAINE

Collectif Citoyen

Origine du collectif



Mission du collectif

OZON L'EAU SAINE

Collectif citoyen formé en Novembre 2022

- Documenter / vulgariser le sujet des PFAS

- Interpeller les pouvoirs publics/Elus

- Améliorer la connaissance





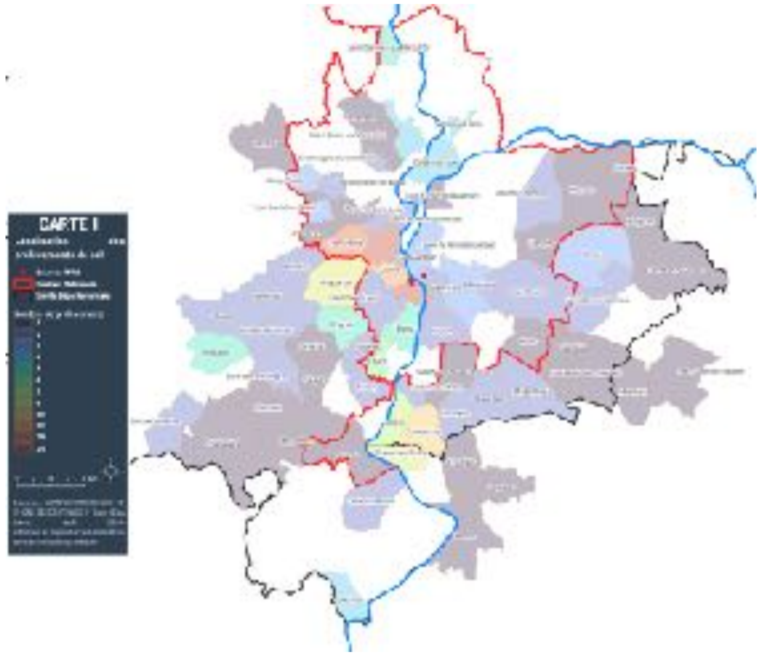
Science participative

3 études menées en collaboration avec l'Université de Montréal

- **2023**: 50 prélèvements d'eaux répartis sur le territoire (robinet, puits, rivières, irrigation, étangs de pêche)

- **2024**: Etude d'imprégnation des sols
  - 215 prélèvements
  - 90 bénévoles
  - 60 Communes

- **2025**: Etude poussières de maison

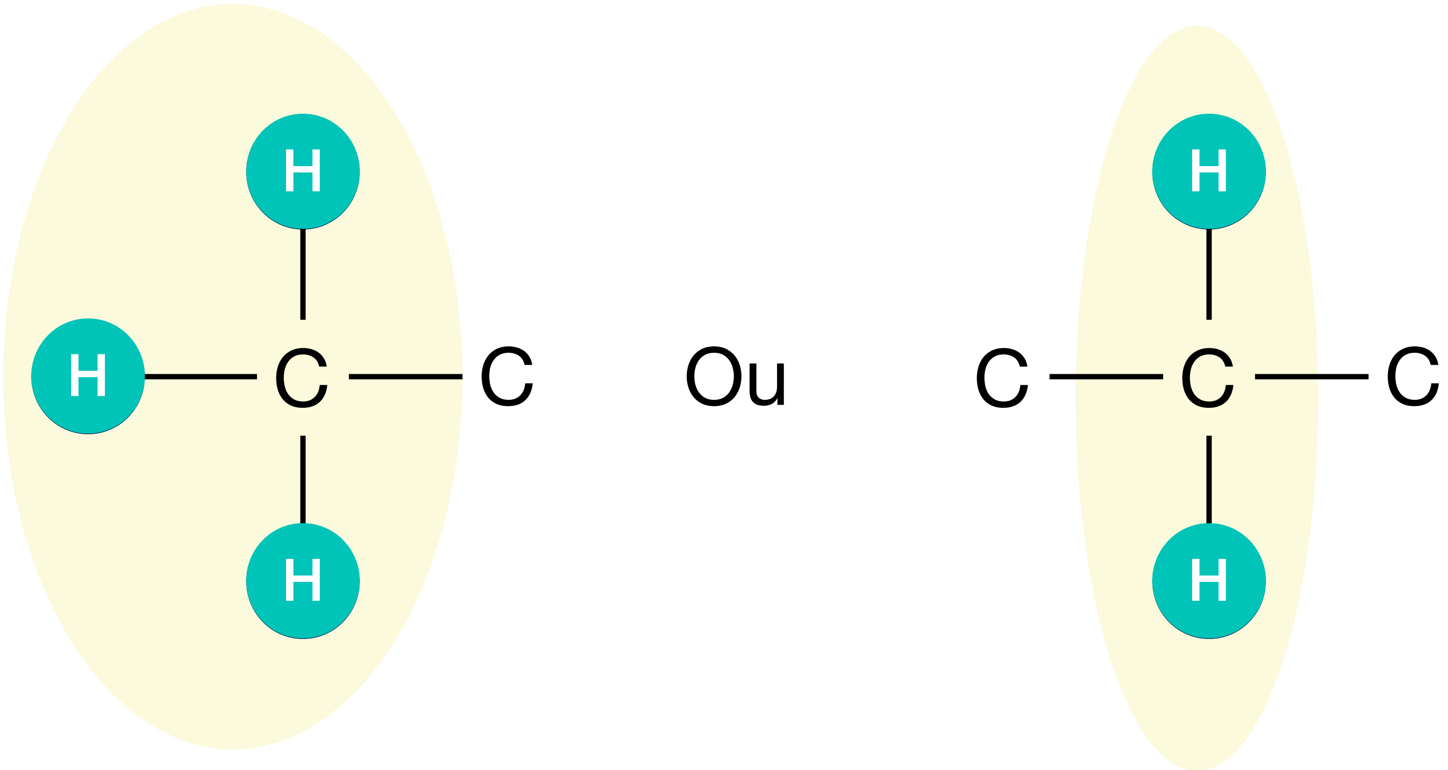


Qu’est ce qu’un PFAS ?

Définition

PFAS= **P**oly and **P**er**F**luoro**A**lkyl **S**ubstances

= Toute molécule qui dans sa structure chimique comprend un motif CF_2 ou CF_3 (à quelques exceptions)



Molécule organique « classique » (naturelle ou de synthèse)

A New OECD Definition for Per- and Polyfluoroalkyl Substances
Zhanyun Wang & al, *Environmental Science & Technology* **2021** *55* (23), 15575-15578
DOI: 10.1021/acs.est.1c06896

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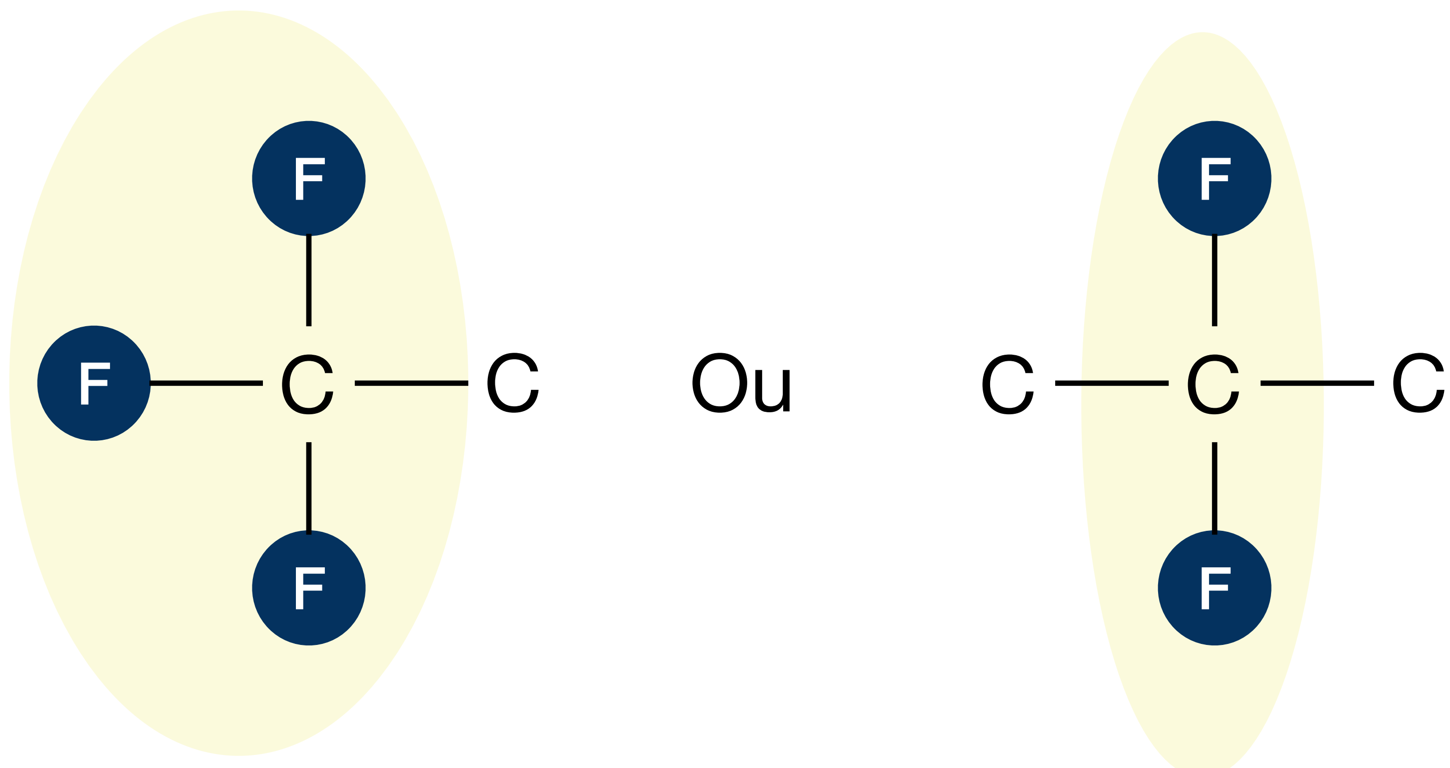
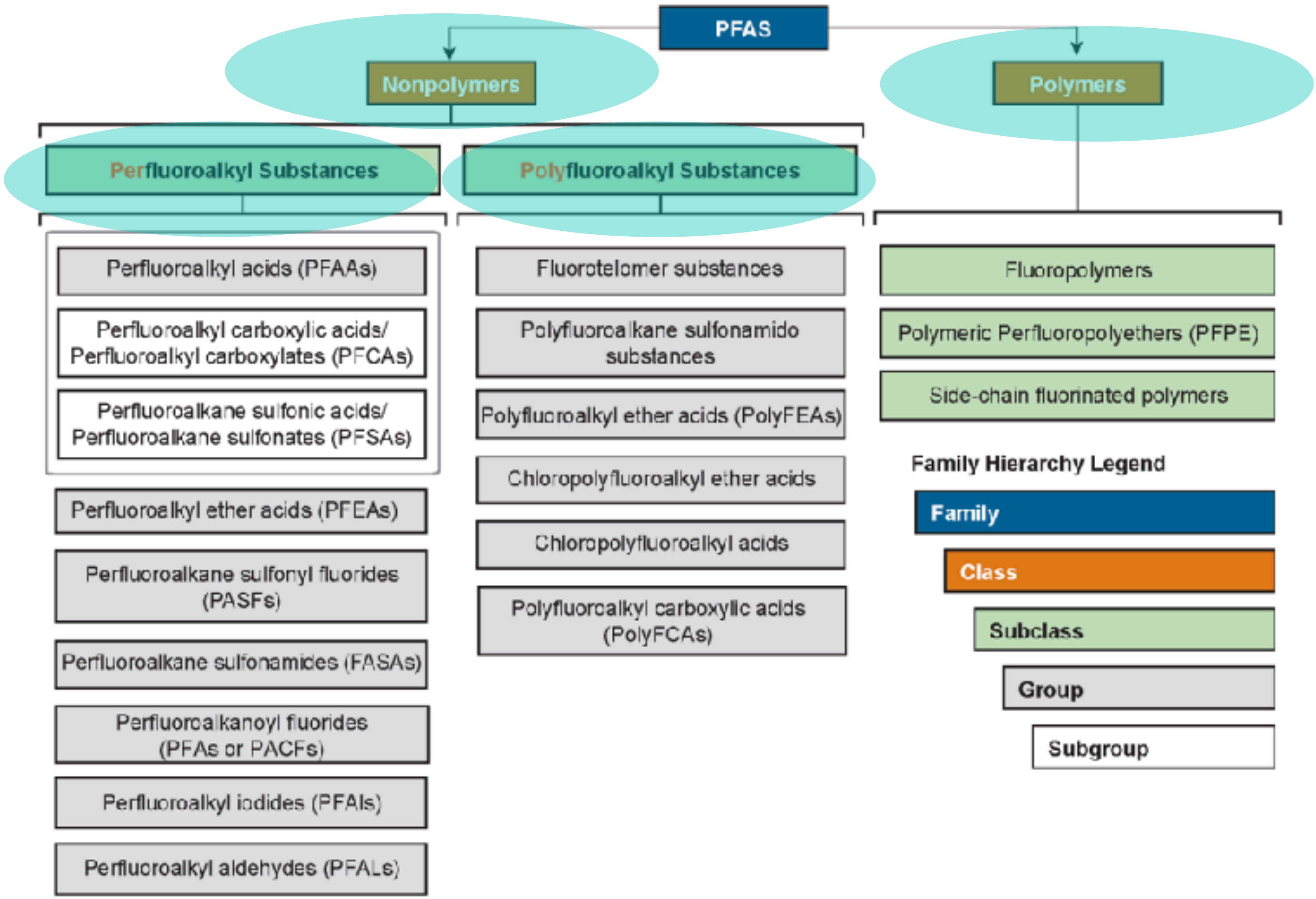


PFAS

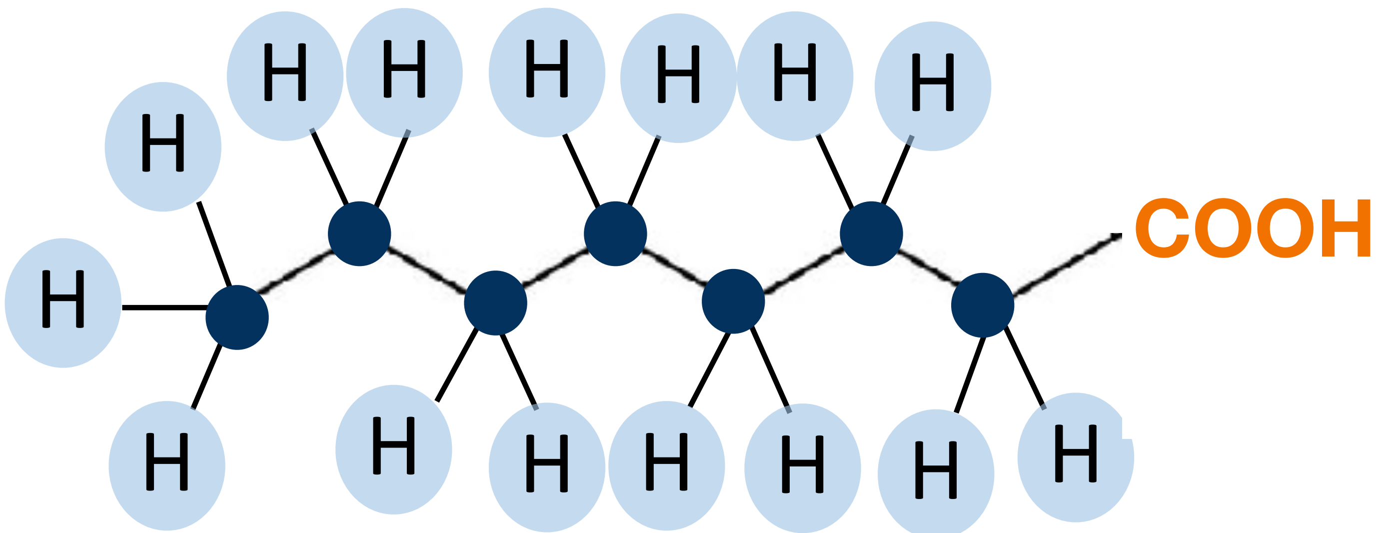
Des millions de combinaisons possibles
Des molécules très diverses: gaz, liquides, solides

A New OECD Definition for Per- and Polyfluoroalkyl Substances
Zhanyun Wang & al, *Environmental Science & Technology* **2021** *55* (23), 15575-15578
DOI: 10.1021/acs.est.1c06896

Classification

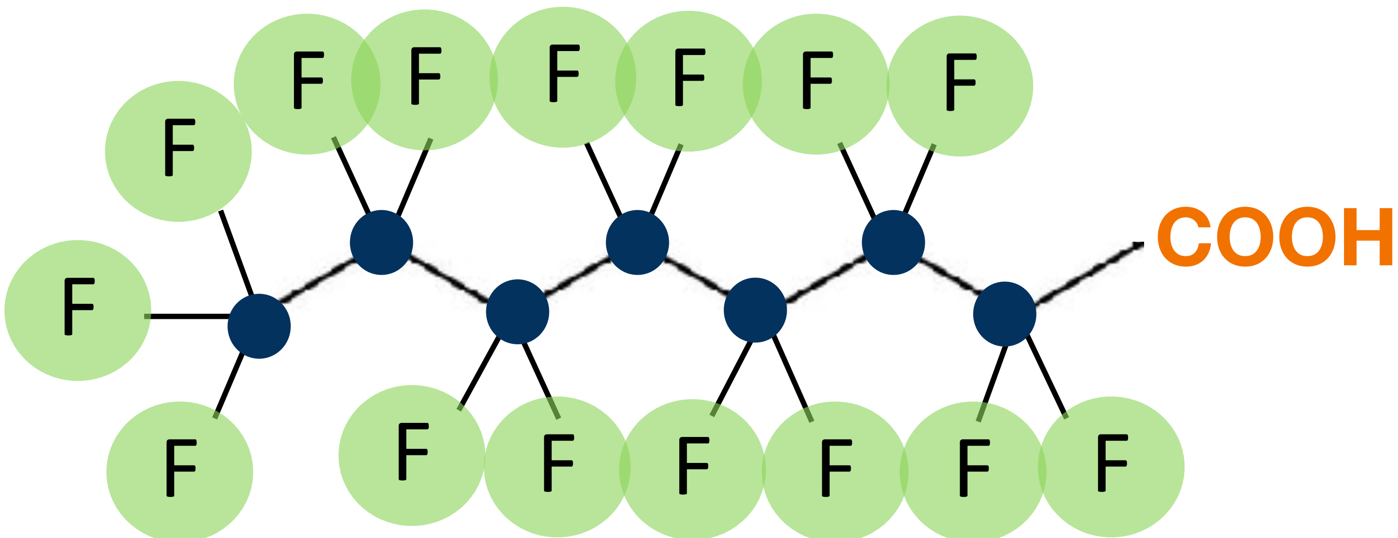


Non polymères: Les Perfluorés à chaine longue



Acide octanoïque (caprylique)

Non polymères: Les Perfluorés à chaine longue

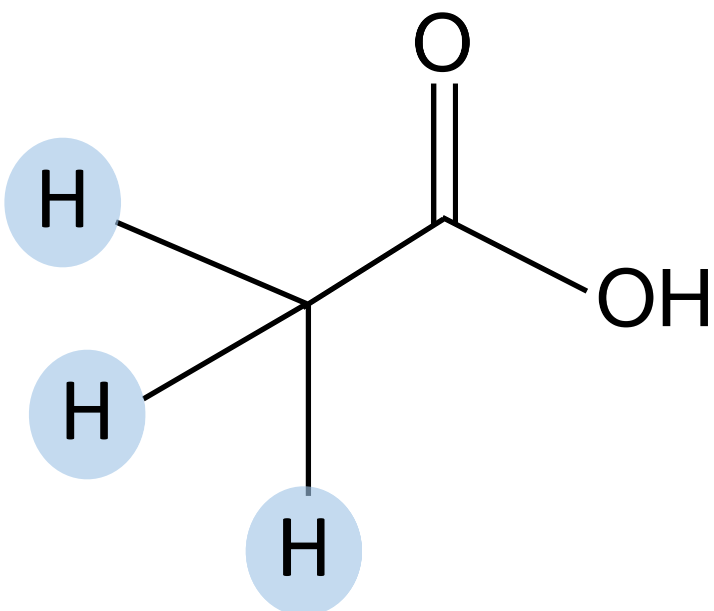


Acide perfluoroocta**noïque**

PFOA
(C8, Perfluorée)

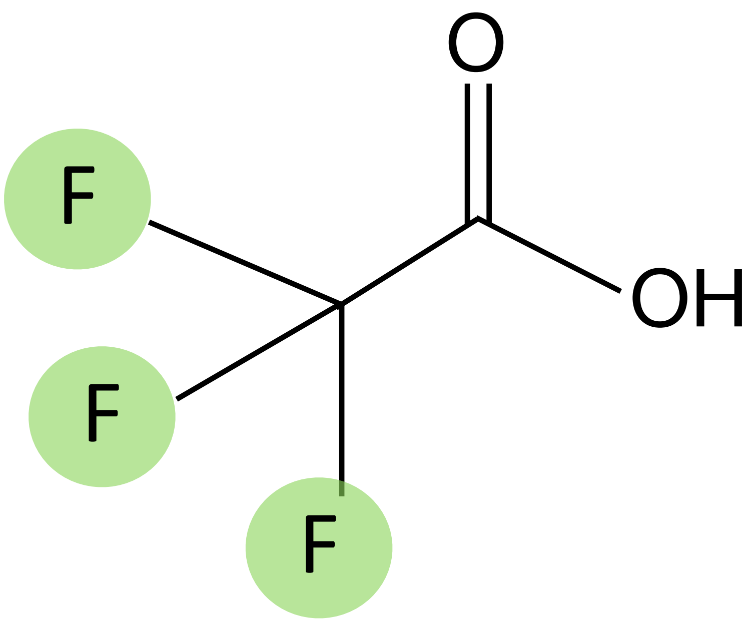
« **PF** » = Perfluoro = C-H ▶ C-F
« **O** » = « octanoique » = 8
« **A** » = « acide »

Non polymères: Les Perfluorés à chaine courte



Acide acétique (vinaigre)

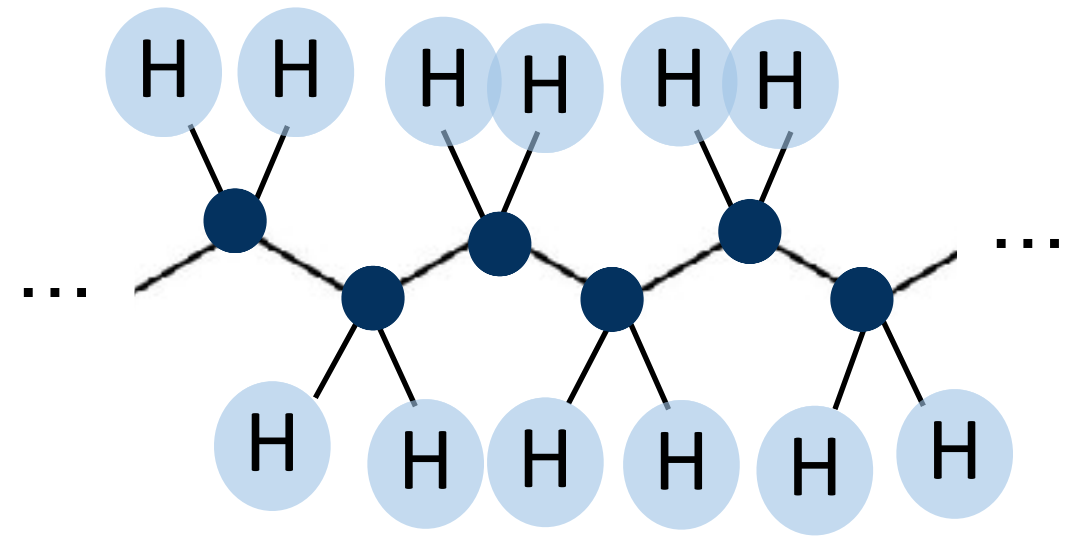
Non polymères: Les Perfluorés à chaine courte



Acide perfluoro**acétique (TFA)**

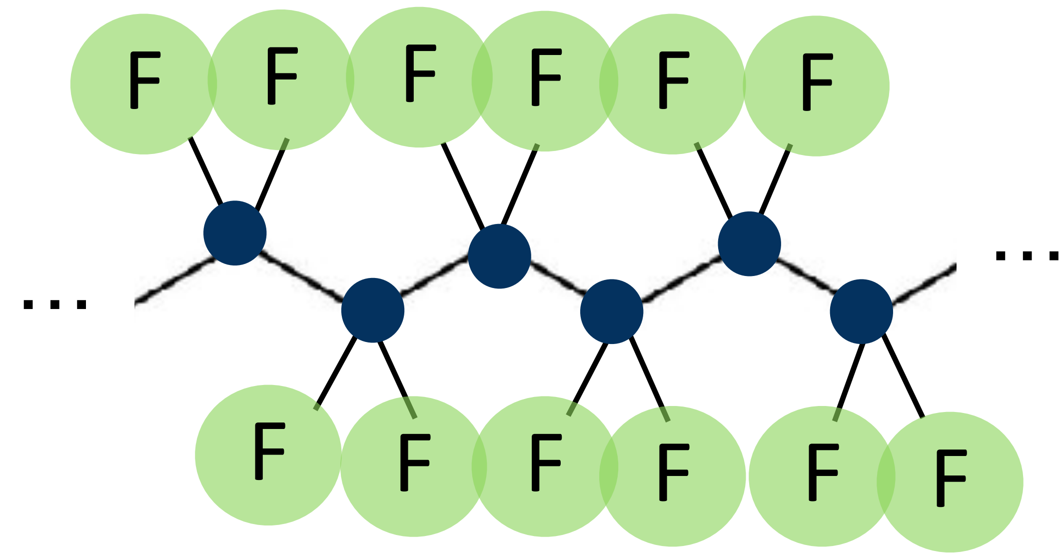
Acide trifluoroacétique 32 000 fois plus fort que l'acide acétique

PFAS: les polymères perfluorés



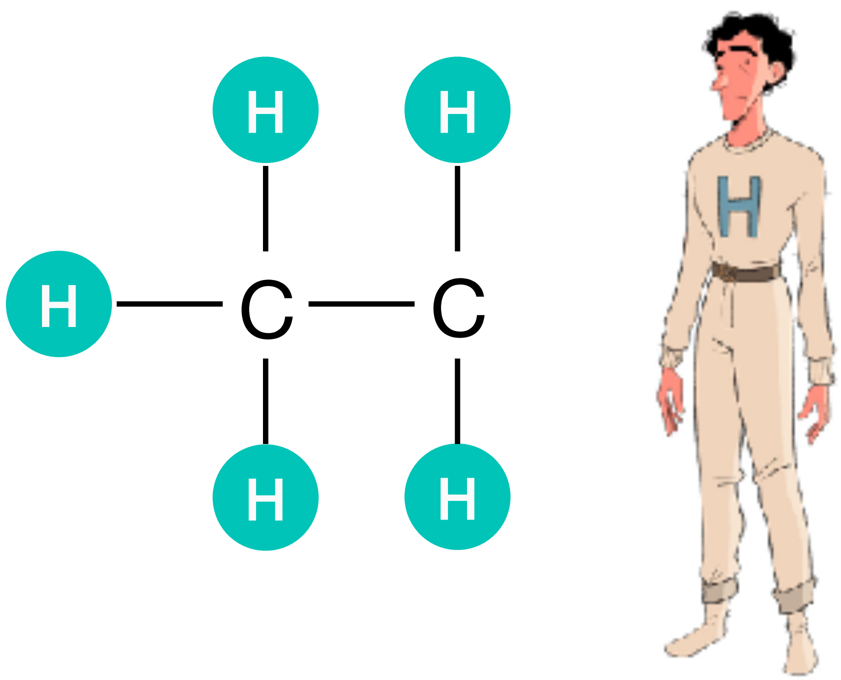
Polyéthylène

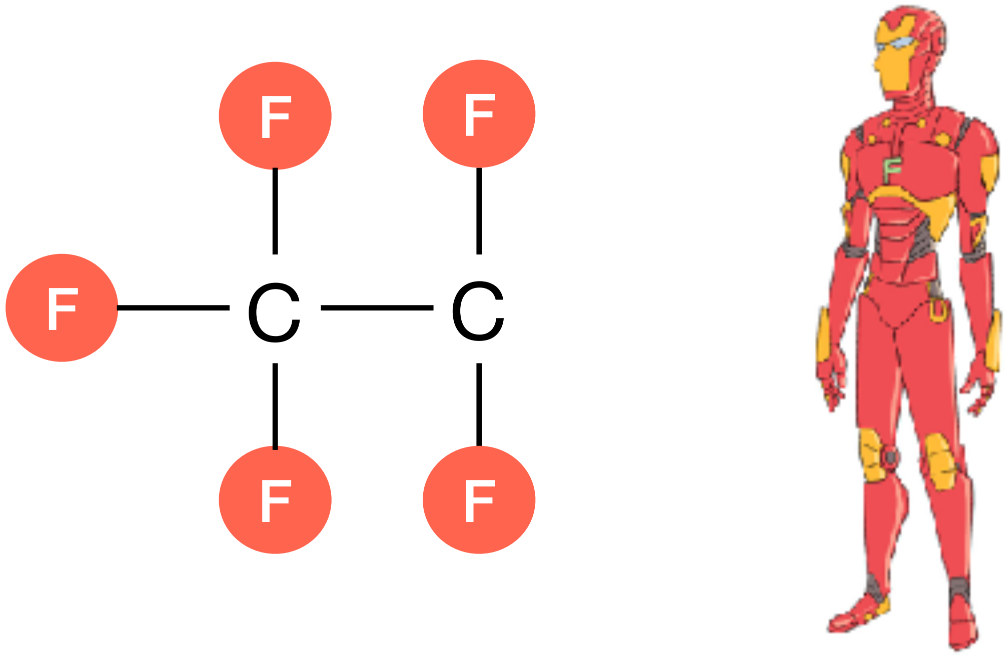
PFAS: les polymères perfluorés



Polytétrafluoroéthylène (PTFE)

Persistance





- Liaison C-F : La plus forte de la chimie organique
- Création de molécules très stables
- Pas de biodégradation => Persistance dans l'environnement (« polluants éternels »)

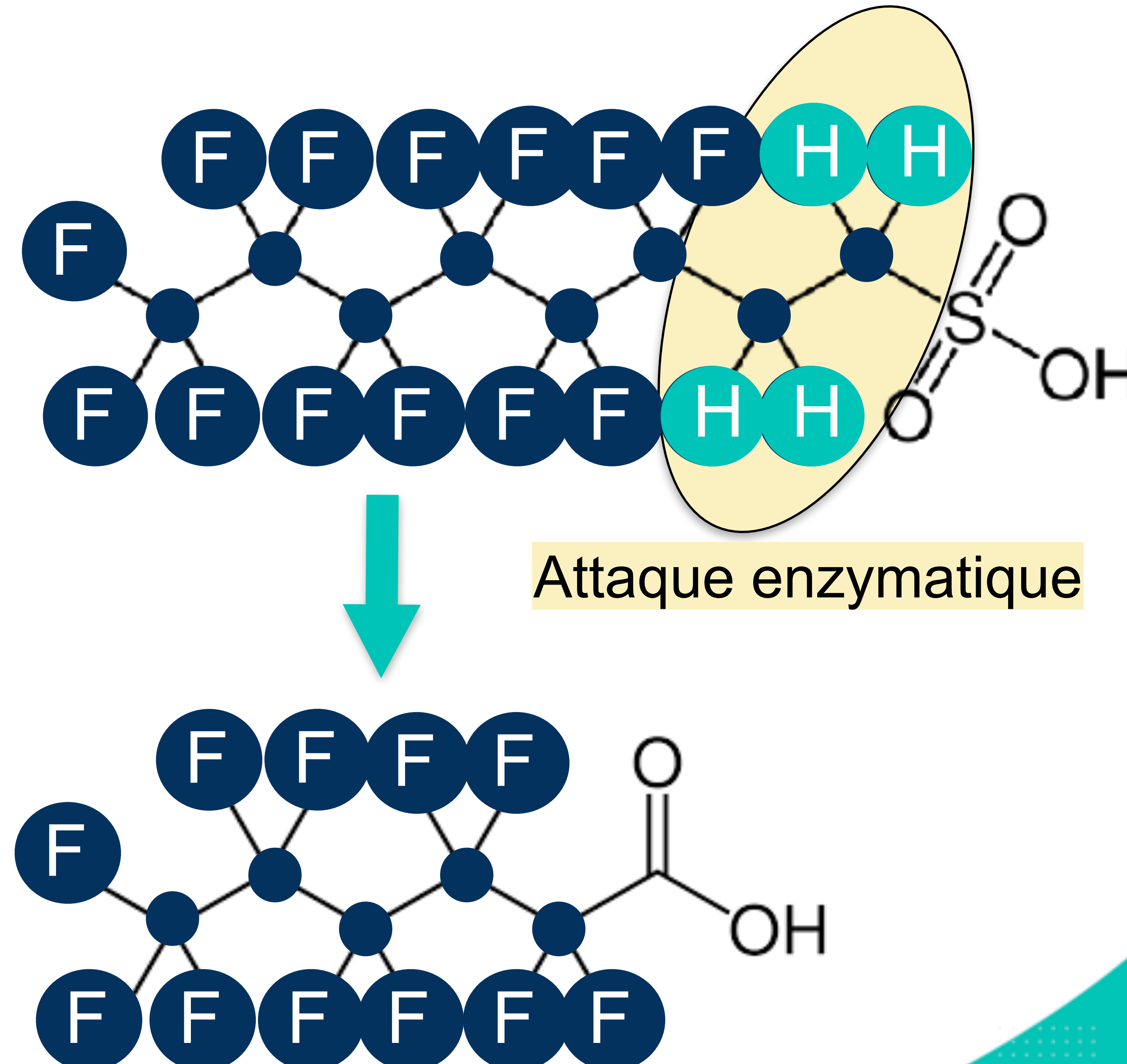
Perfluorés vs polyfluorés

6,2-FTS

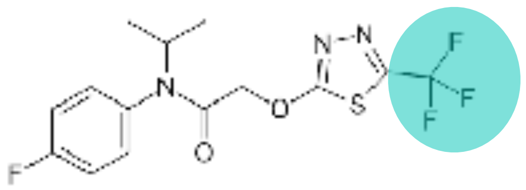
Molécule de substitution d'Arkema depuis 2017:

PFHxA (chaine courte)

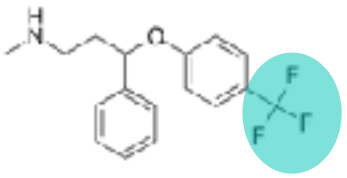
=> Produit de dégradation majoritaire



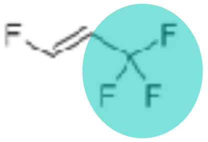
Quizz: Poly ou per?



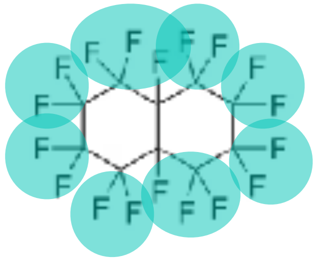
Flufénacet®



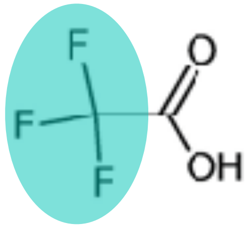
Fluoxetine®



HFO-1234z

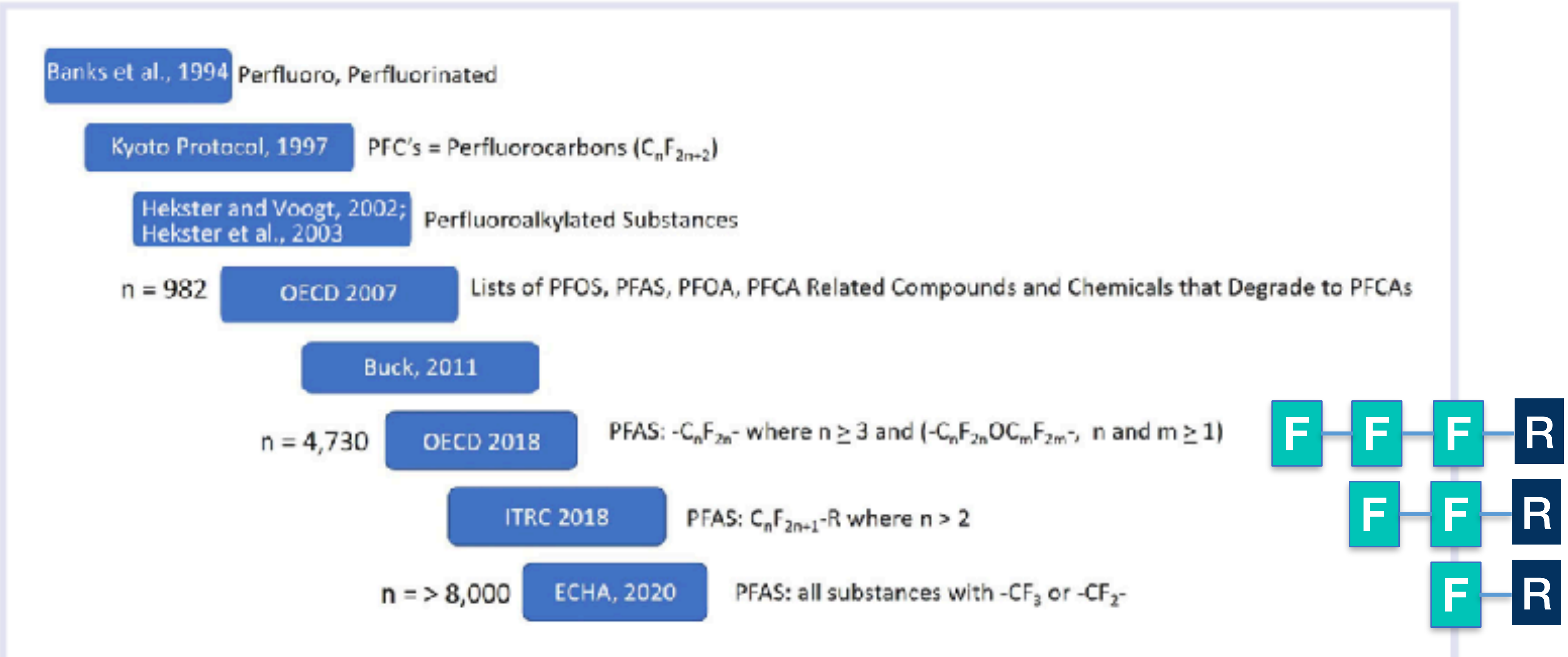


Perfluorodecaline



TFA

Combien de molécules PFAS



- ✓ Définition des PFAS qui a évolué dans le temps
- ✓ Nombre de molécules totale dépend de la définition
- ✓ Sujet toujours discuté dans la communauté scientifique
- ✓ Plusieurs milliers de molécules, quelques centaines produites à l'échelle industrielle

Source: Buck & al, Integrated Environmental Assessment and Management — Volume 17, Number 5—pp. 1045–1055

Production industrielle

Series	Structure category	No.	%
100	Perfluoroalkyl carbonyl compounds	514	11
200	Perfluoroalkane sulfonyl compounds	629	13
300	Perfluoroalkyl phosphate compounds	23	1
400	Fluorotelomer-related compounds	1872	40
500	Per- and poly-fluoroalkyl ether-based compounds	365	8
600	Other PFAA precursors and related compounds—perfluoroalkyl ones	314	7
700	Other PFAA precursors or related compounds—semifluorinated	746	16
800	Fluoropolymers	267	6
		4730	100

		Substance class	No.		%	
Non-polymer (NP)	1	NP perfluoro	78		32	
	2	NP polyfluoro	111	189	46	78%
Polymer	3	Fluoropolymer	38		16	
	4	Perfluoropolyether polymer	8	52	3.3	22%
	5	Side-chain fluorinated polymer	6		2.5	
			241		100	

AGC Chemicals
Chemours
Daikin

256 molécules répertoriées par les 3 principaux producteurs de PFAS comme étant produite à une échelle industrielle

Source: https://academic.oup.com/ieam/article/17/5/1045/7726990?guestAccessKey=

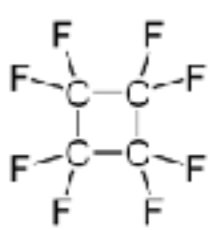
REACH

515 substances enregistrées dans le cadre de Reach (229 intermédiaires)

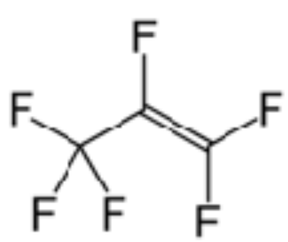
354 C1 PFAS (61%) — **CF3** — R

161 C2 PFAS (39%) — **CF3** — **CF2** — R

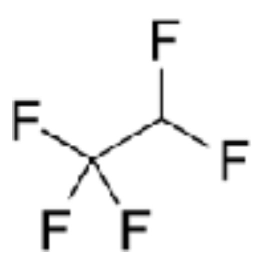
4 substances enregistrées > 10 000 T/an (gaz fluorés) => 87% (production / importation)



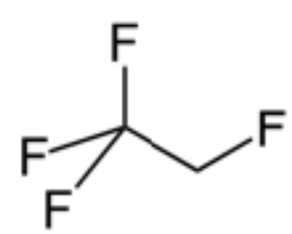
Octafluorocyclobutane



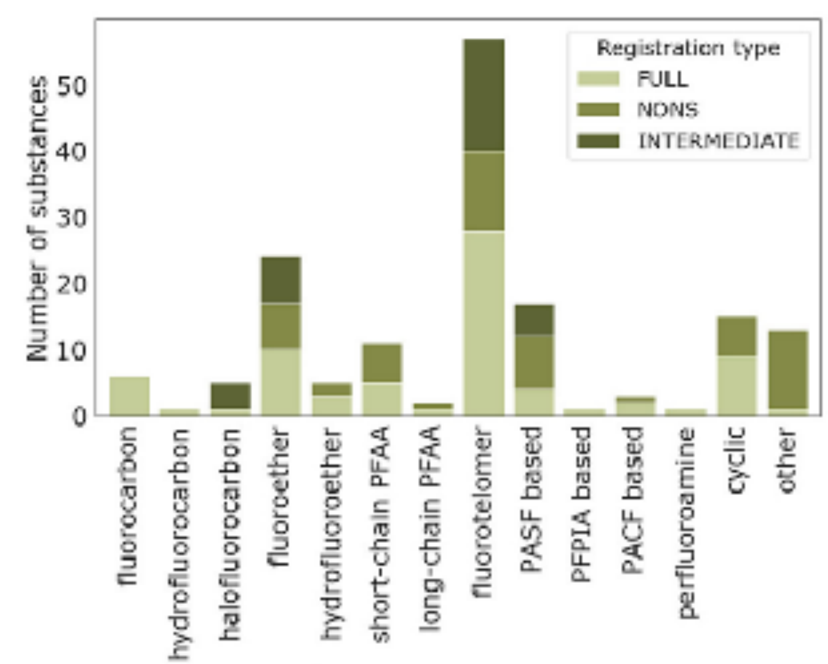
HFP



Pentafluoroethane



Norflurane



PFAS: une très bonne stabilité

Thermique
Supportent des températures élevées

Chimique
Résistants aux acides, bases, oxydants…

Photochimique
Résistants aux UV

Propriétés exceptionnelles

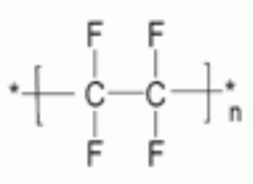
Oléophobes =
Repoussent la graisse

Hydrophobes =
Repoussent l'eau

- ✓ **Produits antitâche**
- ✓ **Vêtements Hydrofuges**
- ✓ **Emballages alimentaires**

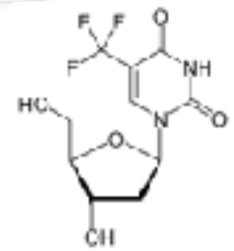
Applications Grand public

PTFE (Teflon)

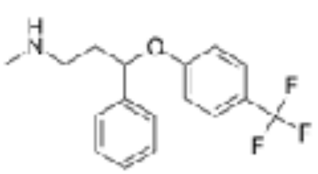


PTFE (Teflon)

Side chain polymers

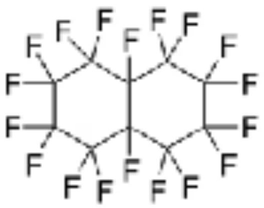


Trifluridine



Fluoxetine

PFOS



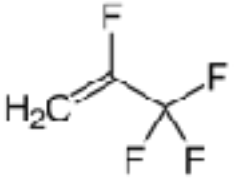
Perfluorodecaline

PFOA

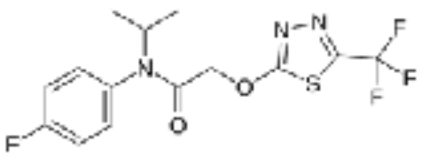
Shuhong & al, Environ. Sci.: Processes Impacts, 2020, 22, 2142

Couteau & al, Food and Chemical Toxicology 187 (2024) 114625

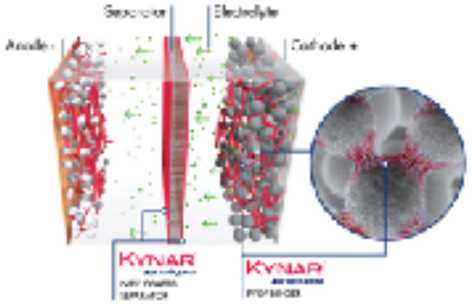
Applications Professionnelles/industrielles



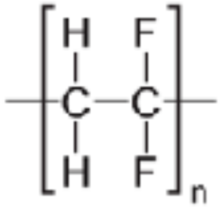
HFO-1234yf



Flufénacet



PVDF (Kynar)



PFOS

Sources primaires de contamination

AAAF: Site d'extinction des feux d'hydrocarbures

- Bases militaires
- Aéroports
- Sites Seveso

Usines/Industriels:

- Qui produisent des PFAS (ex: Arkema à Lyon)
- Qui utilisent des PFAS (Tefal, Ahstrom)

Epandage
pesticides (PFAS)

Sources secondaires de contamination

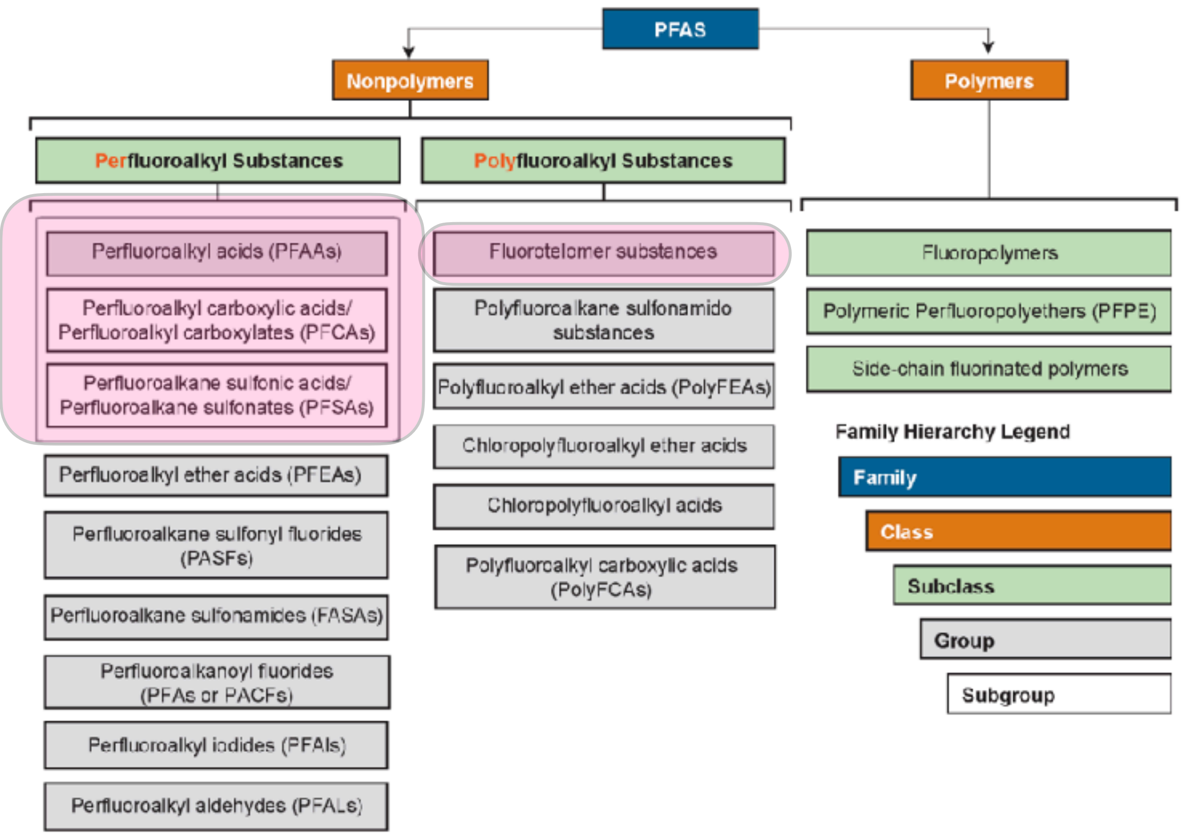
Rejets station d’épuration
dans les cours d’eau

Sites d’enfouissement de déchets
(ménagers, boues de station…)

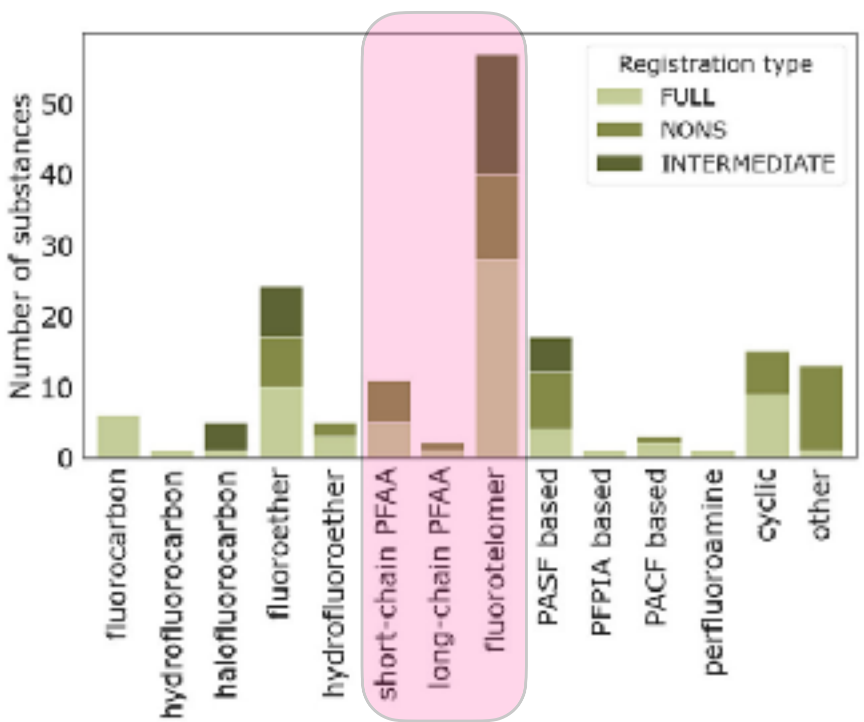
Epandage de boues
de station d’épuration

Irrigation

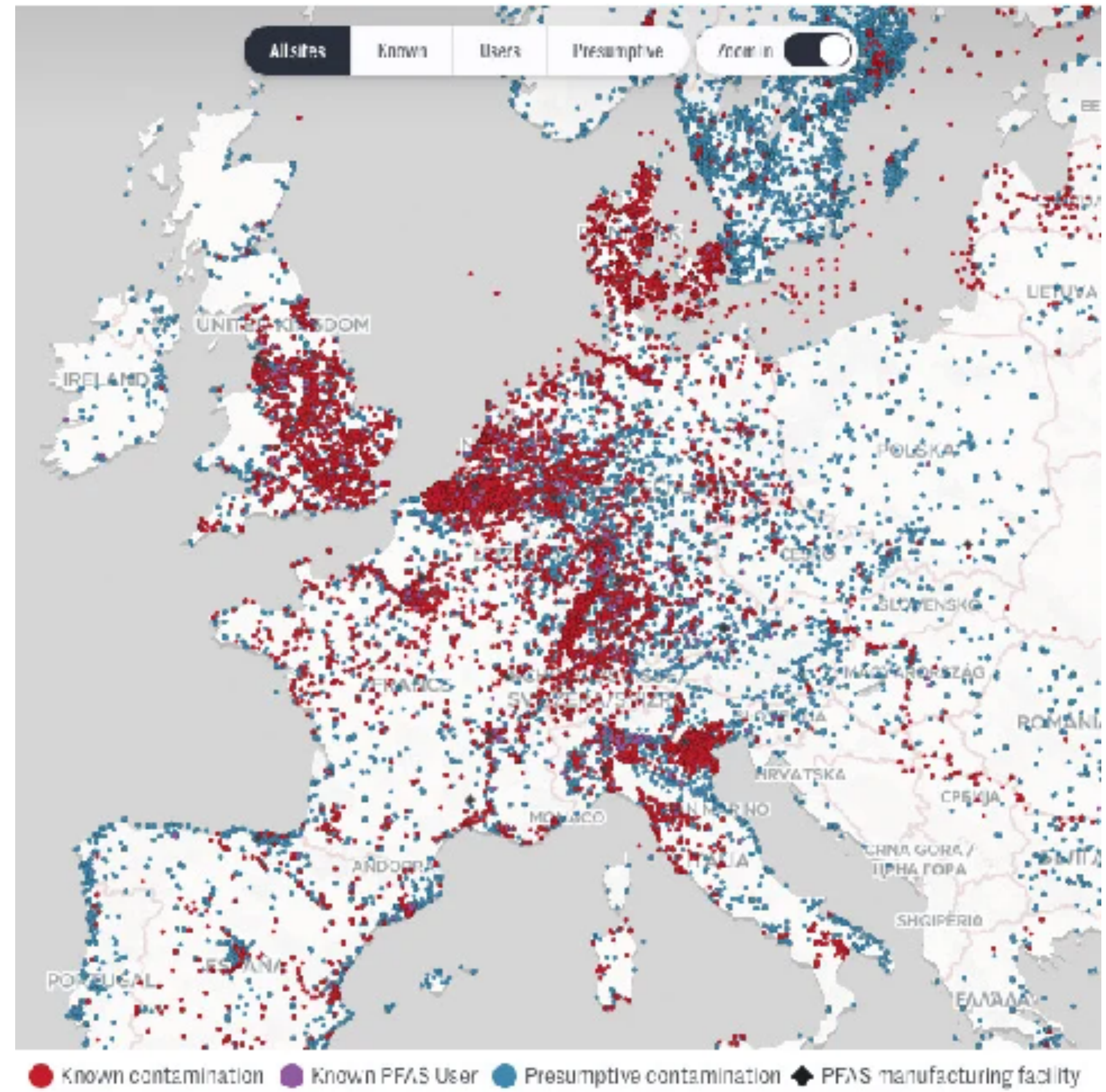
Incinérateurs



PFAS
Nonpolymers
Polymers
Perfluoroalkyl Substances
Polyfluoroalkyl Substances
Perfluoroalkyl acids (PFAAs)
Perfluoroalkyl carboxylic acids/ Perfluoroalkyl carboxylates (PFCAs)
Perfluoroalkane sulfonic acids/ Perfluoroalkane sulfonates (PFSAs)
Perfluoroalkyl ether acids (PFEAs)
Perfluoroalkane sulfonyl fluorides (PASFs)
Perfluoroalkane sulfonamides (FASAs)
Perfluoroalkanoyl fluorides (PFAs or PACFs)
Perfluoroalkyl iodides (PFAIs)
Perfluoroalkyl aldehydes (PFALs)
Fluorotelomer substances
Polyfluoroalkane sulfonamido substances
Polyfluoroalkyl ether acids (PolyFEAs)
Chloropolyfluoroalkyl ether acids
Chloropolyfluoroalkyl acids
Polyfluoroalkyl carboxylic acids (PolyFCAs)
Fluoropolymers
Polymeric Perfluoropolyethers (PFPE)
Side-chain fluorinated polymers
Family Hierarchy Legend
Family
Class
Subclass
Group
Subgroup

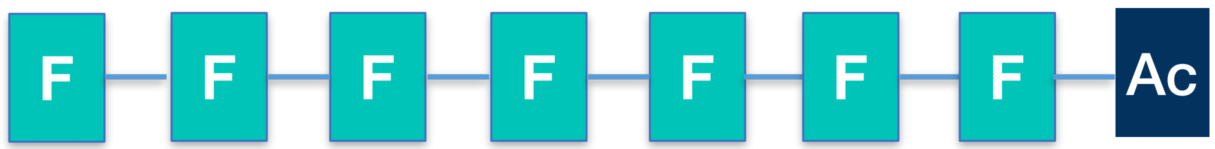


Number of substances
0
10
20
30
40
50
Registration type
FULL
NONS
INTERMEDIATE
fluorocarbon
hydrofluorocarbon
halofluorocarbon
fluoroether
hydrofluoroether
short-chain PFAA
long-chain PFAA
fluorotelomer
PASF based
PFPIA based
PACF based
perfluoroamine
cyclic
other



All sites
Known
Users
Presumptive
UNITED KINGDOM
IRELAND
POLSKA
ROMANIA
HRVATSKA
MONACO
ANDORRA
SHQIPERIA
Known contamination
Known PFAS User
Presumptive contamination
PFAS manufacturing facility

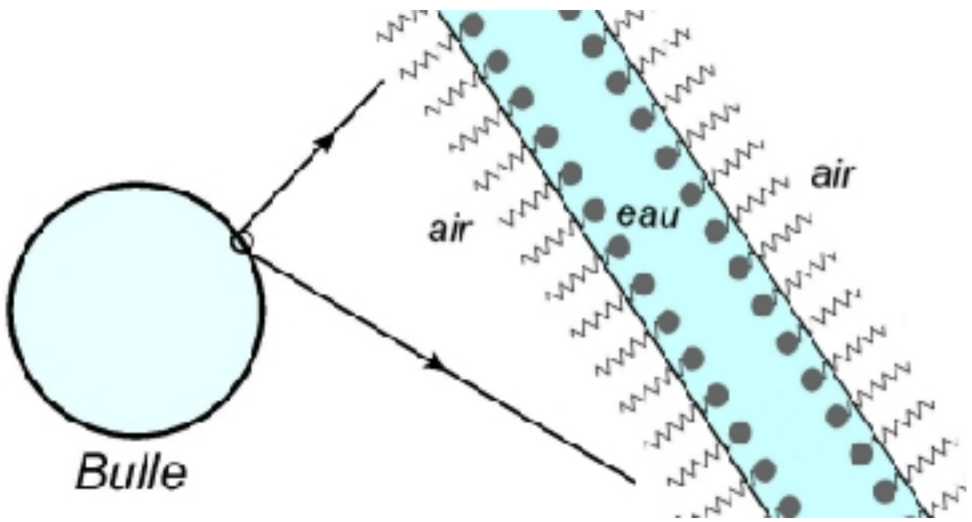
Propriété de fluorosurfactant



PFOA (C8)

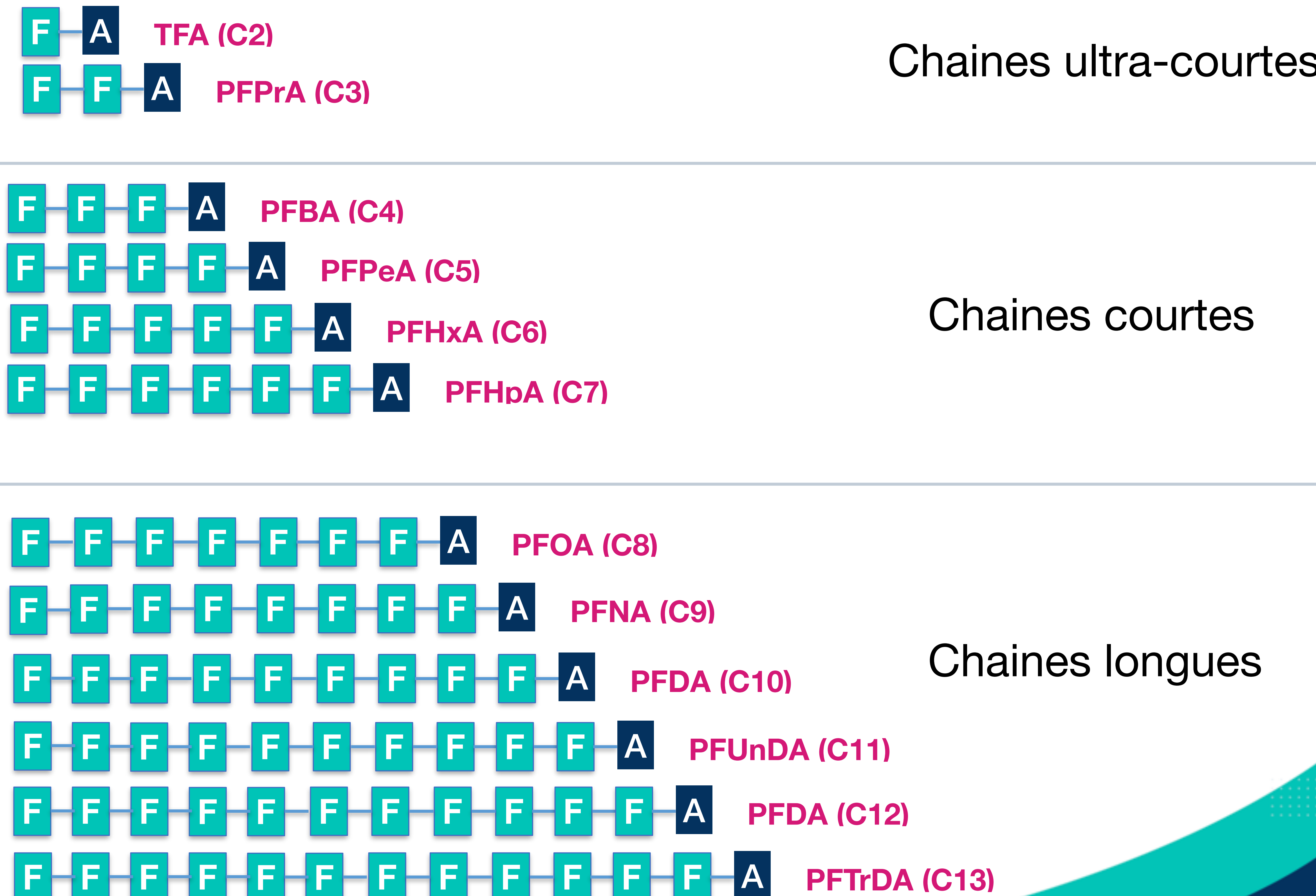
Chaine hydrophobe

Tête hydrophile



Des molécules solubles dans l'eau !
Diffusion dans les milieux et dans le biote

Chaînes courtes / Chaînes longues



Inquiétude à partir des années 1970

1973

Organic Fluorocompounds in Human Plasma: Prevalence and Characterization

W. S. GUY, D. R. TAVES, and W. S. BREY, JR.

1993

Mortality Among Employees of a Perfluorooctanoic Acid Production Plant

Frank D. Gilliland, MD, PhD
Jack S. Mandel, PhD, MPH

Perfluorooctanoic acid (PFOA) has been found at low levels (10 to 100 parts per billion) in sera of the general population and at higher levels in occupationally exposed workers. Although PFOA has been reported to be a promoter of rodent hepatocarcinogenesis and to alter reproductive hormones in humans and rodents, there is little information on human health effects associated with PFOA exposure. The present study examined the relationship between PFOA and mortality using a retrospective cohort mortality design. The cohort consisted of 2788 male and 749 female workers employed between 1947 and 1983 at a plant that produced PFOA. The all-causes standardized mortality ratio was .75 (95% confidence interval [CI], .56 to .99) for women and .77 (95% CI, .69 to .86) for men. Among men the cardiovascular standardized mortality rate was .68 (95% CI, .58 to .80) and the all-gastrointestinal diseases was .57 (95% CI, .29 to .99). There was no significantly increased cause-specific standardized mortality ratio for either men or women. Ten years of employment in exposed jobs was associated with a 3.3-fold increase (95% CI, 1.02 to 10.6) in prostate cancer mortality compared to no employment in PFOA production. There were only six prostate cancer deaths overall and four among the exposed workers; thus, the results must be interpreted cautiously. If prostate cancer mortality is related to PFOA, PFOA may increase prostate cancer mortality by altering reproductive hormones in male workers.

Perfluorooctanoic acid (PFOA) and its salt, ammonium perfluorooctanoate, are perfluorinated surfactants. Because of their unique surface active properties they are used in a large number of industrial applications and consumer products including plasticizers, lubricants, wetting agents, and emulsifiers.[1-3] Despite their widespread use, little is known about potential adverse health effects.

PFOA induced marked hepatomegaly and peroxisome proliferation in rodent livers.[3-8] The chemically diverse group of xenobiotics that induce peroxisomes is of concern because of its association with nongenotoxic hepatocarcinogenesis.[3-10] PFOA did not produce an increased number of hepatocellular carcinomas in a 2-year rat feeding study.[8] However, biphasic (initiation and promotion) and triphasic (initiation, selection, and promotion) hepatic carcinogenesis studies in rodents have shown significantly increased numbers of carcinomas in the PFOA-treated rats.[10,11] It has been

1998

An Epidemiologic Investigation of Reproductive Hormones in Men with Occupational Exposure to Perfluorooctanoic Acid

Olsen, Geary W. DVM, PhD; Gilliland, Frank D. MD, PhD; Burlew, Michele M. MS; Burris, Jean M. MPH; Mandel, Jack S. PhD; Mandel, Jeffrey H. MD

Author Information

Journal of Occupational & Environmental Medicine 40(7):p 614-622, July 1998.

Une prise de conscience internationale à partir des années 2000

DANS LE MONDE

- Prise de conscience internationale
- Pollution de grande ampleur des écosystèmes aquatiques/Eau potables
- Lien prouvé entre une exposition au **PFOA** et 6 maladies sérieuses

1998 — **Affaire DuPont de Nemours**
Parksburg (USA)
film "dark water"
DUPONT

2013 — PFOA
Affaire Miténi
(Italie)

2017 — PFOA
Affaire DuPont de Nemours
Dordrecht (Hollande)
DUPONT

2021 — PFOS
Affaire 3M
Zwijndrecht (Belgique)
3M

1998 | 2011 | 2013 | 2014 | 2017 | 2019 | 2020 | 2021

EN FRANCE

2011 — anses
Champs captant de Ternay: **180ng/L**
(10 PFAS)

2014 — Santé publique France
Etude ESTEBAN
Imprégnation de la population française aux PFAS

100 % des personnes sont contaminées au PFAS

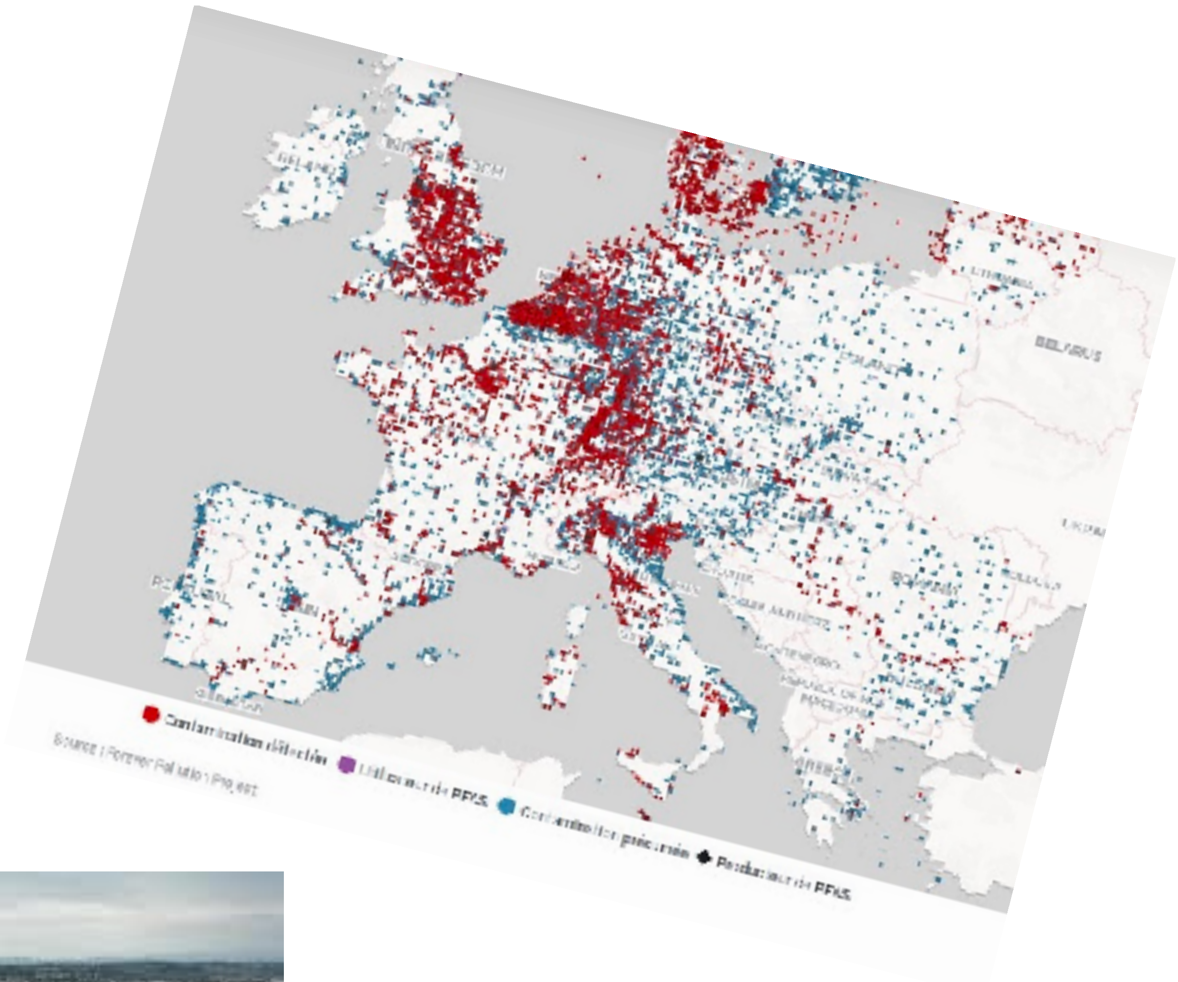
2019

2020

1ère enquête journalistique

En France, sujet médiatisé par Martin Boudot

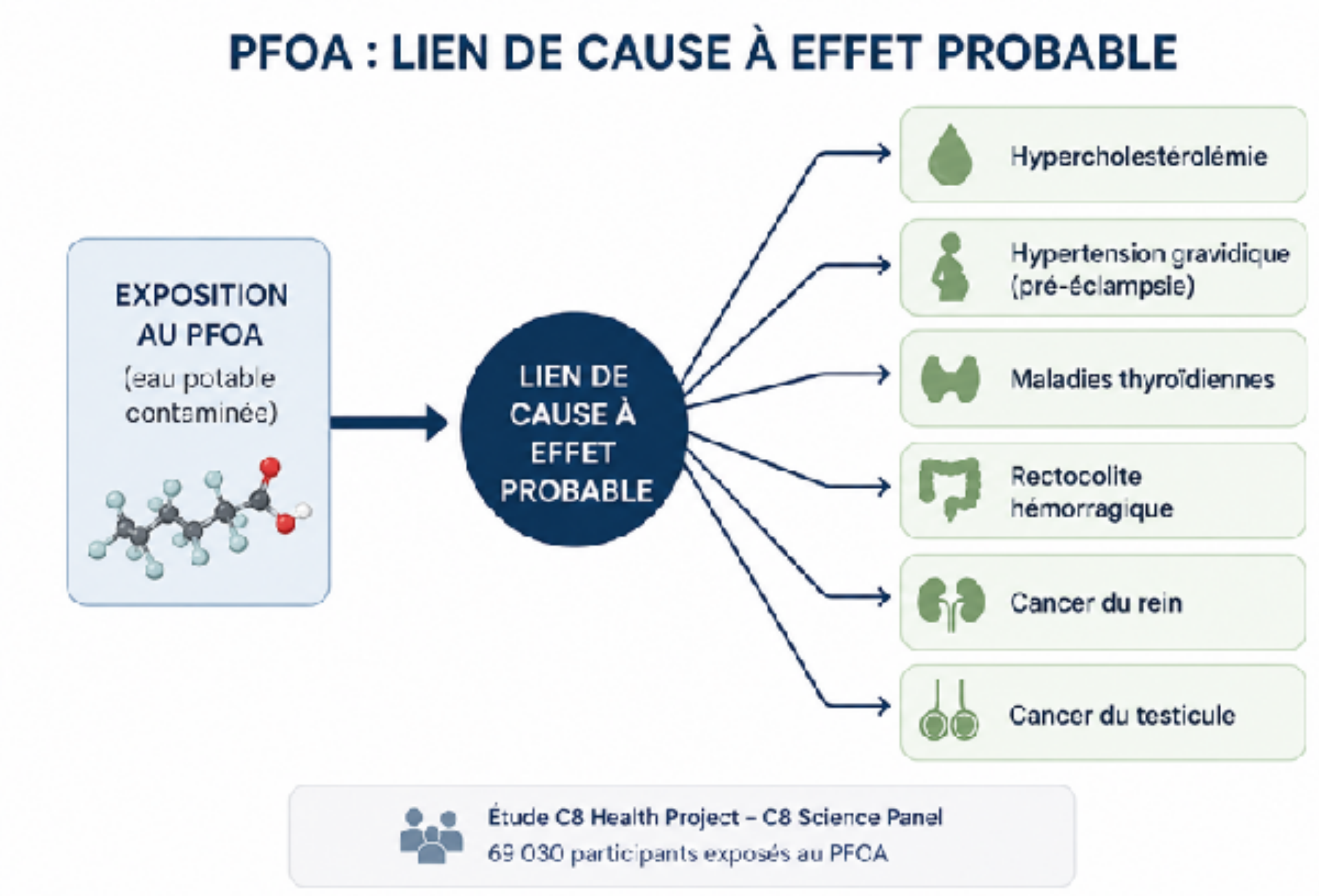
Puis relayé par de très nombreux médias (France 3, le Monde, …)



Toxicité et impact sanitaire

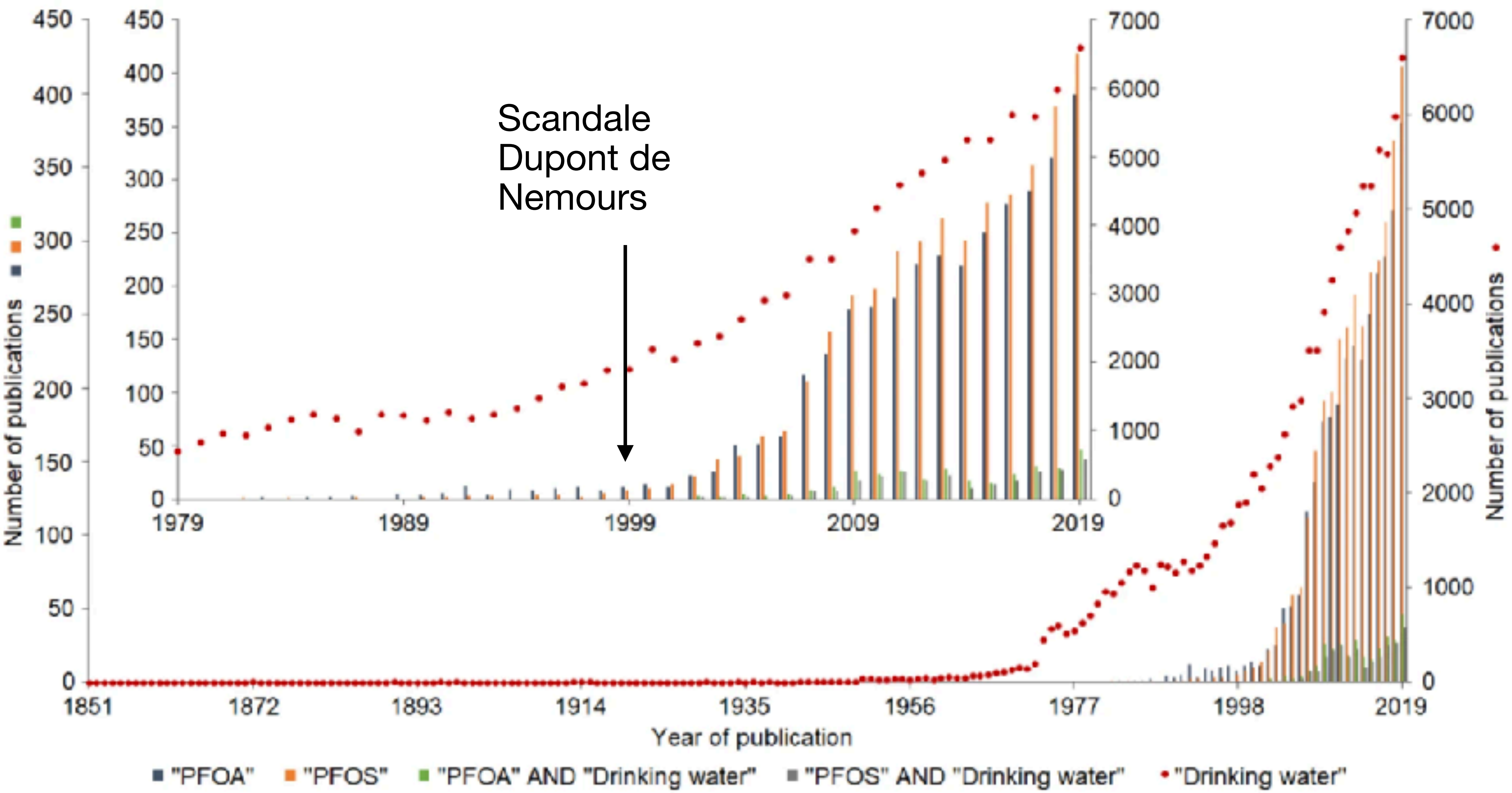
Première étude épidémiologique de grande ampleur

- ✓ Plus grande étude épidémiologique jamais réalisée sur les PFAS (69 000 personnes)
- ✓ 6 districts concernés (eau potable contaminé)
- ✓ 2005-2006: Prélèvements sanguins
- ✓ 2012: Publication des résultats



https://pmc.ncbi.nlm.nih.gov/articles/PMC2799461
https://pmc.ncbi.nlm.nih.gov/articles/PMC12014533/pdf/fpubh-13-1532277.pdf

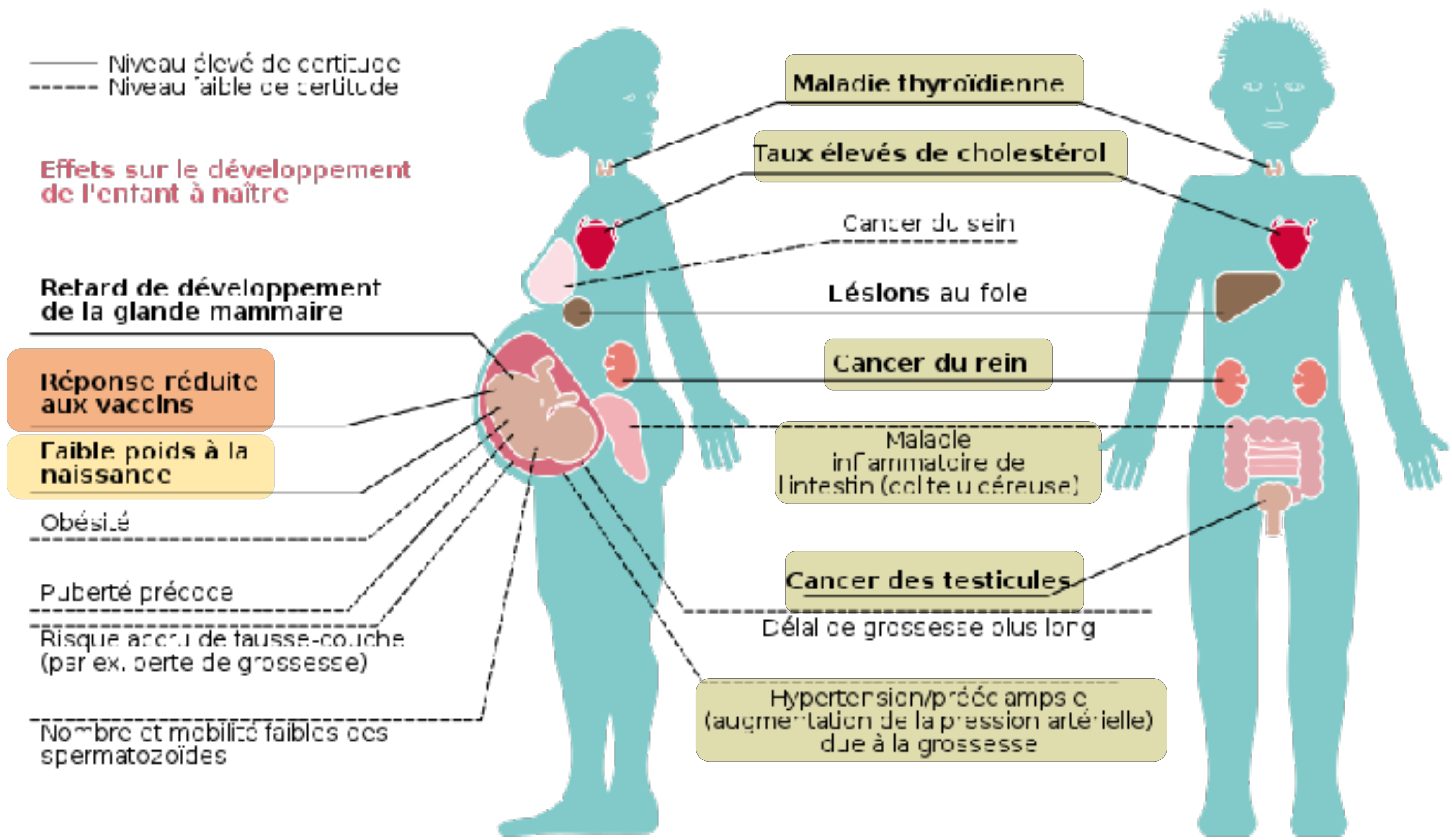
Intensification de la recherche scientifique



Source: https://www.nature.com/articles/s41545-023-00274-6

Risques sanitaires

Molécules Historiques ou « chaines longues »
(**PFOA, PFOS, PFNA, PFHxS**)



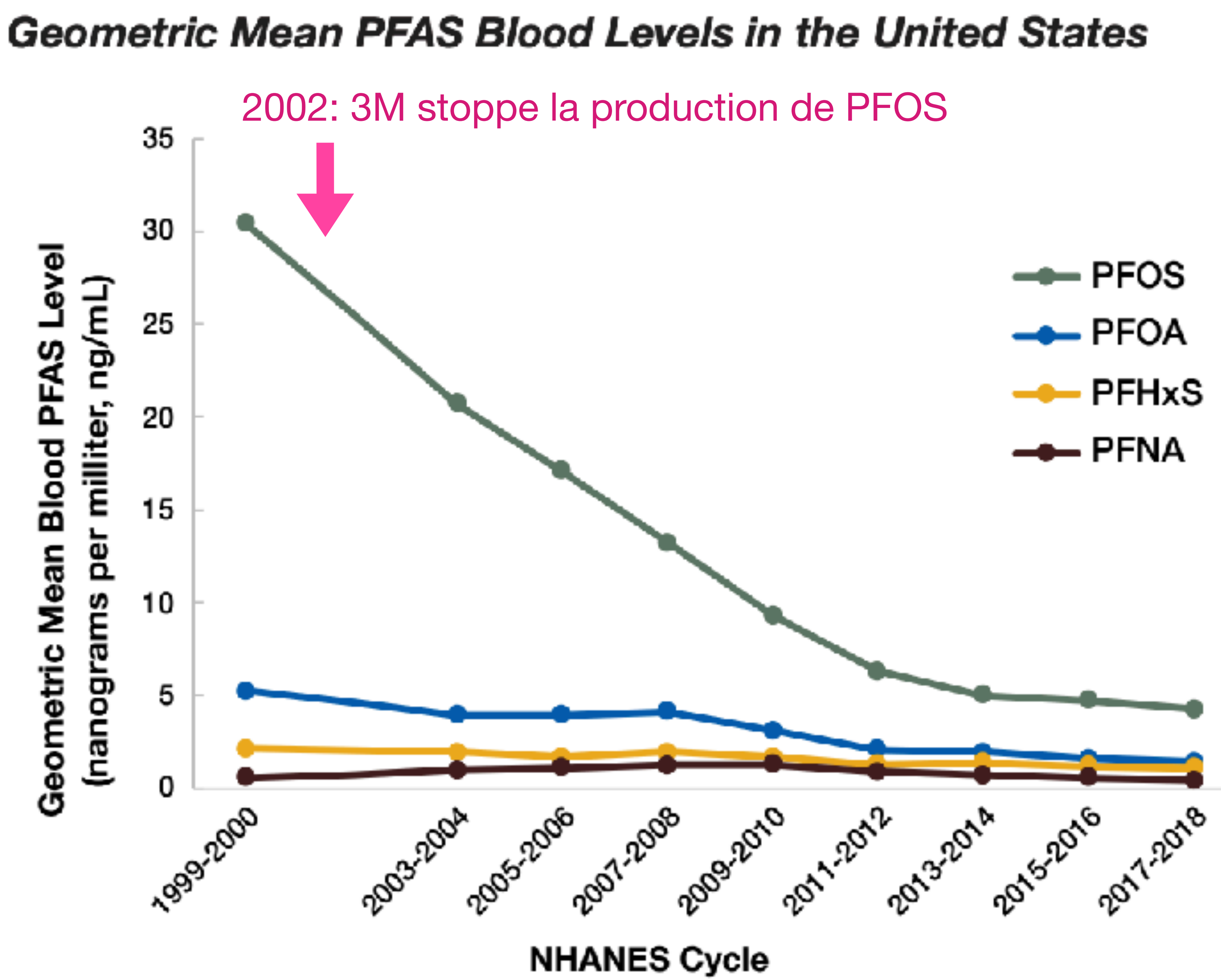
Premières restrictions

- 2002: Sous la pression de l'USEPA, 3M stoppe la production de **PFOS**

- 2005: USEPA signe un engagement des industriels à supprimer l'utilisation de PFAS à chaines longues d'ici à 2015 (**PFOS, PFOA, PFNA**). Elimination progressive des procédés et usages.

- 2009: **PFOS** est devenu le premier PFAS inscrit à la Convention de Stockholm (POP), en Annexe B (restriction), en raison de sa persistance, de sa bioaccumulation et de sa toxicité.

Taux sanguins aux Etats-Unis

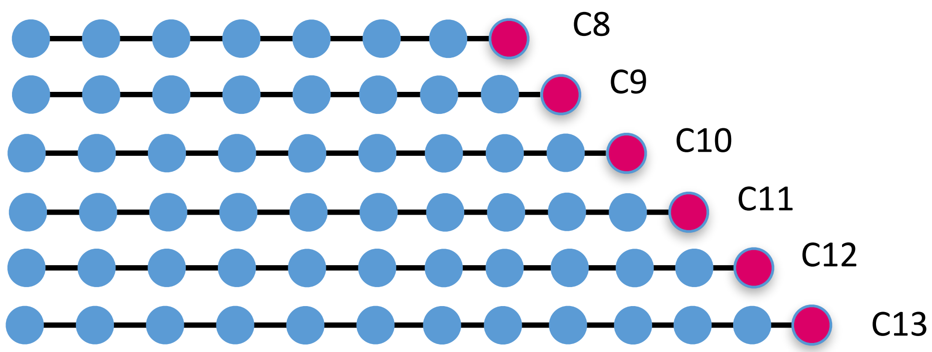


Source: https://www.ncbi.nlm.nih.gov/books/NBK584691/

PFAS de nouvelle génération

Chaines longues (Historiques)

PFOA
PFNA
PFDA
PFunDA
PFDoDA
PFTrDA

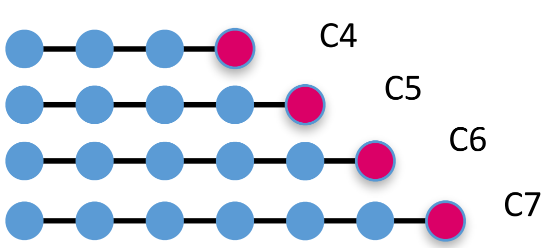


+ Bio-accumulables
+ Toxiques

Toutes sont persistantes

Chaines courtes + émergents (Nouvelles génération)

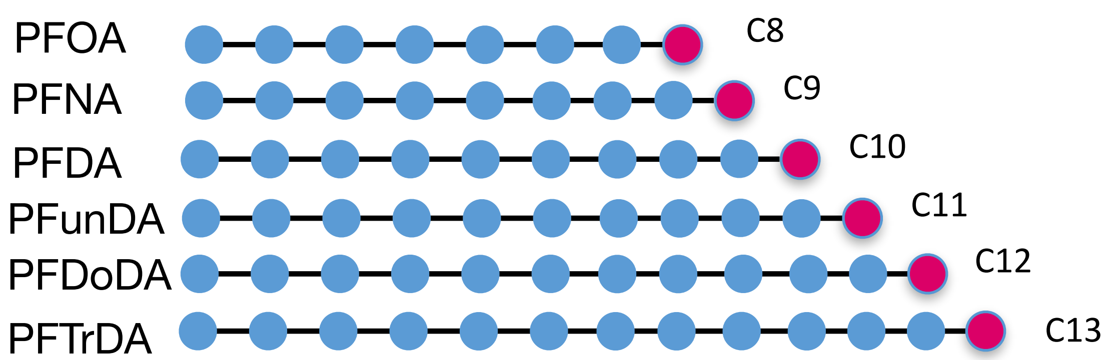
PFBA
PFPeA
PFHxA
PFHpA



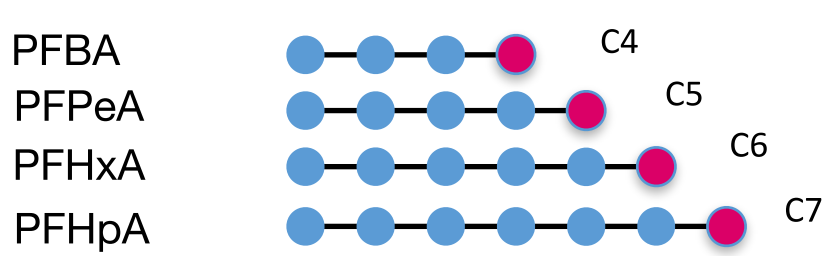
- Bio-accumulables
- Toxiques

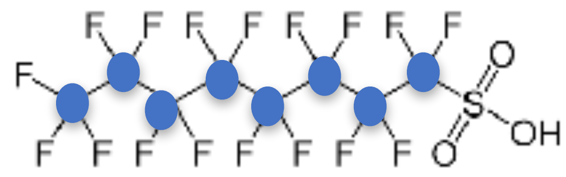
PFAS de nouvelle génération

Chaines longues (Historiques)

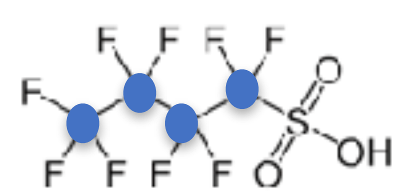


Chaines courtes + émergents (Nouvelles génération)



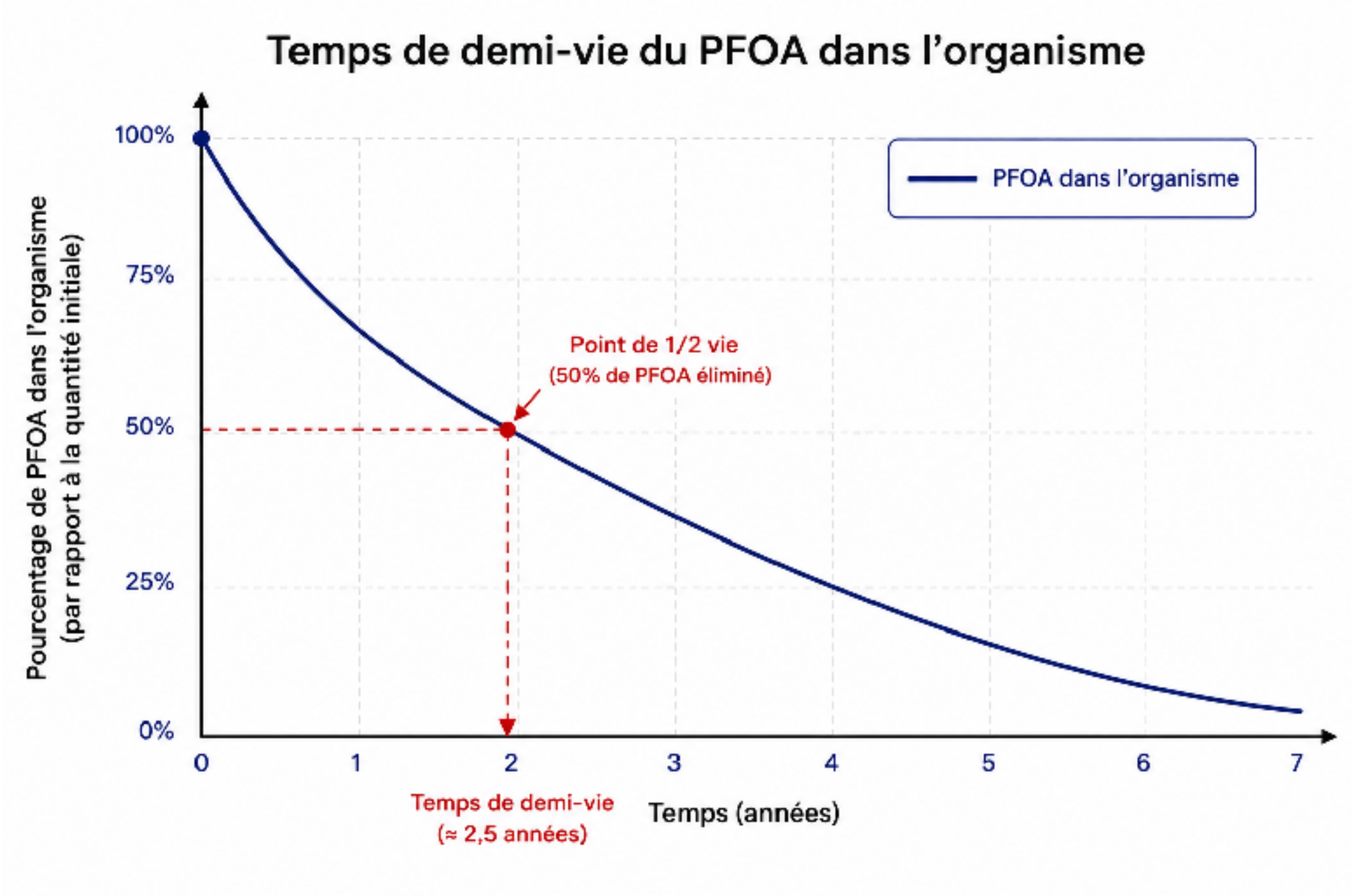


PFOS (8 carbones)



PFBS (4 carbones)

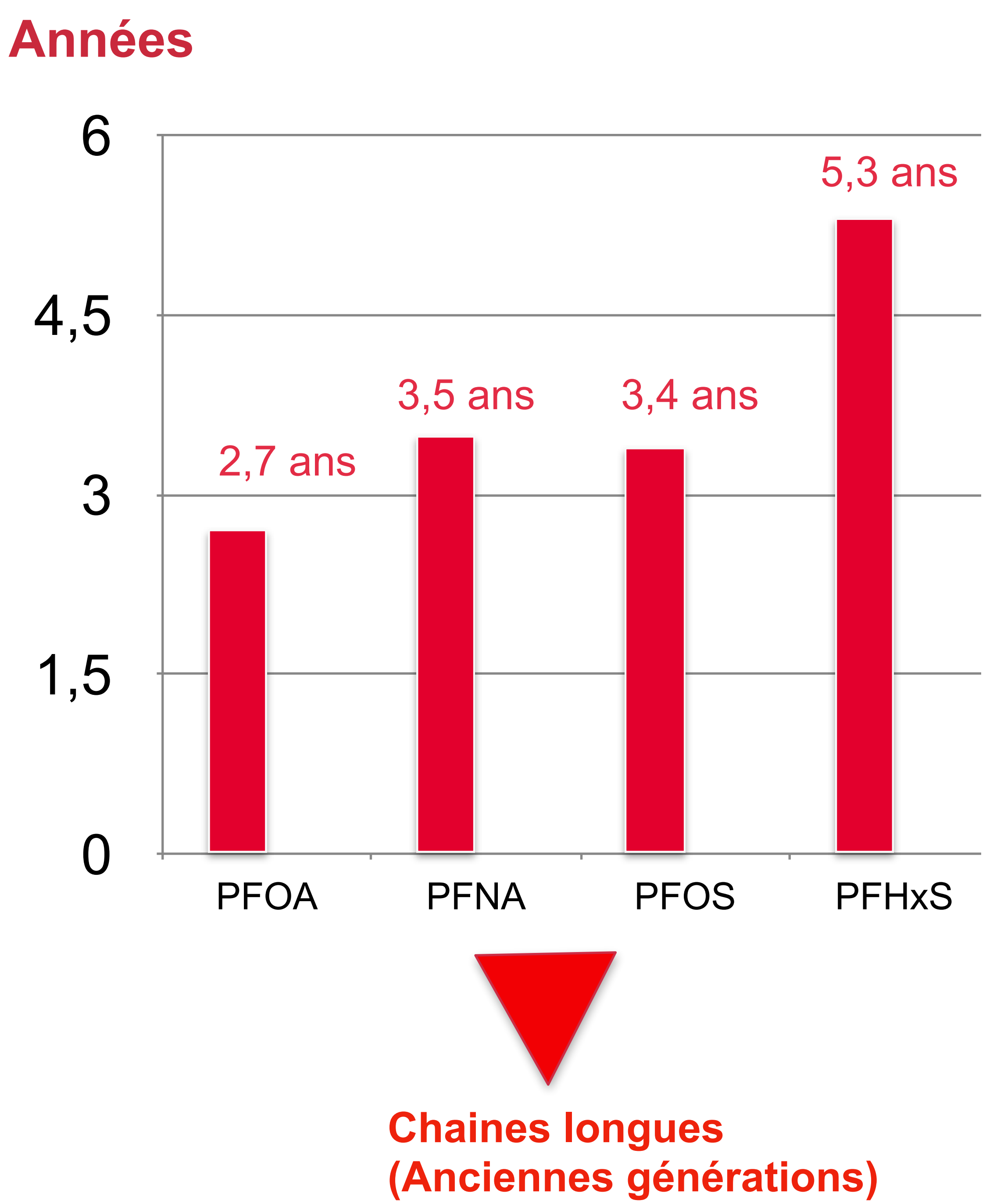
Temps de 1/2 vie (homme)



Temps de Demi-vie dans l'organisme très long pour les perfluorés "historiques"
(≈ 2-3 ans pour le PFOA)

Bioaccumulation: chaînes longues vs chaines courtes

Temps de 1/2 vie



Sources

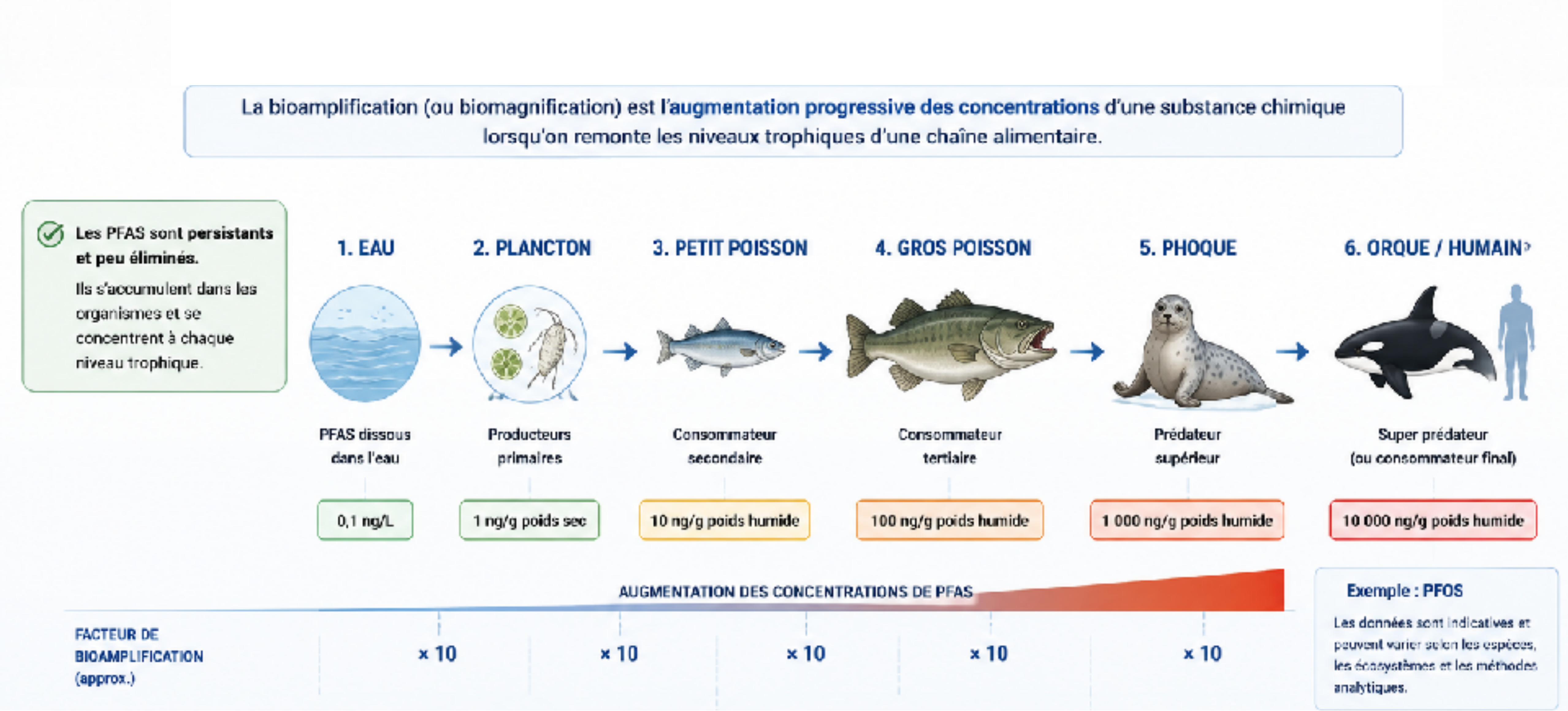
https://ehp.niehs.nih.gov/doi/10.1289/EHP6785

https://oem.bmj.com/content/75/1/46

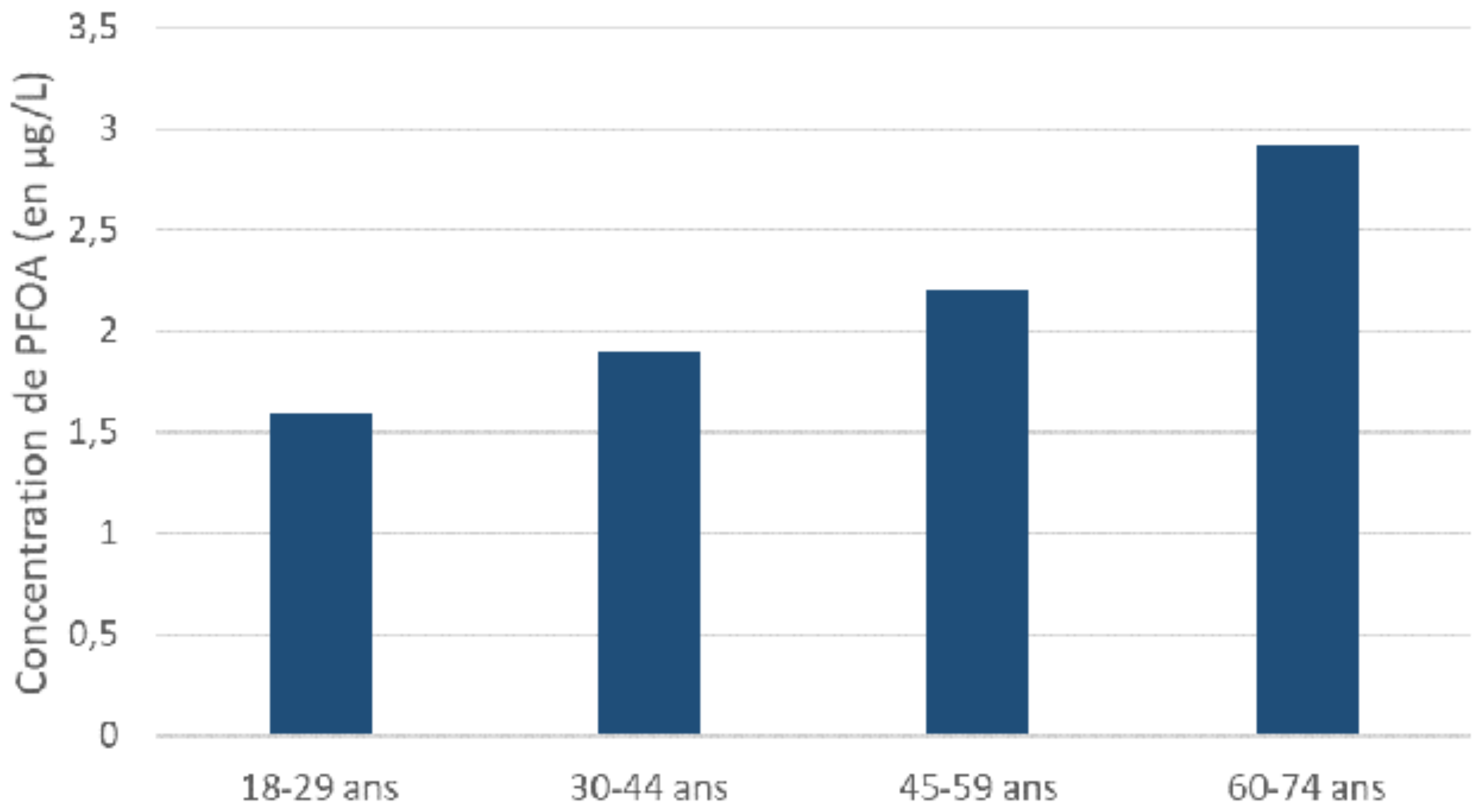
Temps de 1/2 vie

F–A TFA (C2) F–F–A PFPrA (C3)	~12h	Chaines ultra-courtes
F–F–F–A PFBA (C4) F–F–F–F–A PFPeA (C5) F–F–F–F–F–A PFHxA (C6) F–F–F–F–F–F–A PFHpA (C7)	~1 mois	Chaines courtes
F–F–F–F–F–F–F–A PFOA (C8) F–F–F–F–F–F–F–F–A PFNA (C9) F–F–F–F–F–F–F–F–F–A PFDA (C10) F–F–F–F–F–F–F–F–F–F–A PFUnDA (C11) F–F–F–F–F–F–F–F–F–F–F–A PFDA (C12) F–F–F–F–F–F–F–F–F–F–F–F–A PFTrDA (C13)	~2-3 ans	Chaines longues

Bioamplification



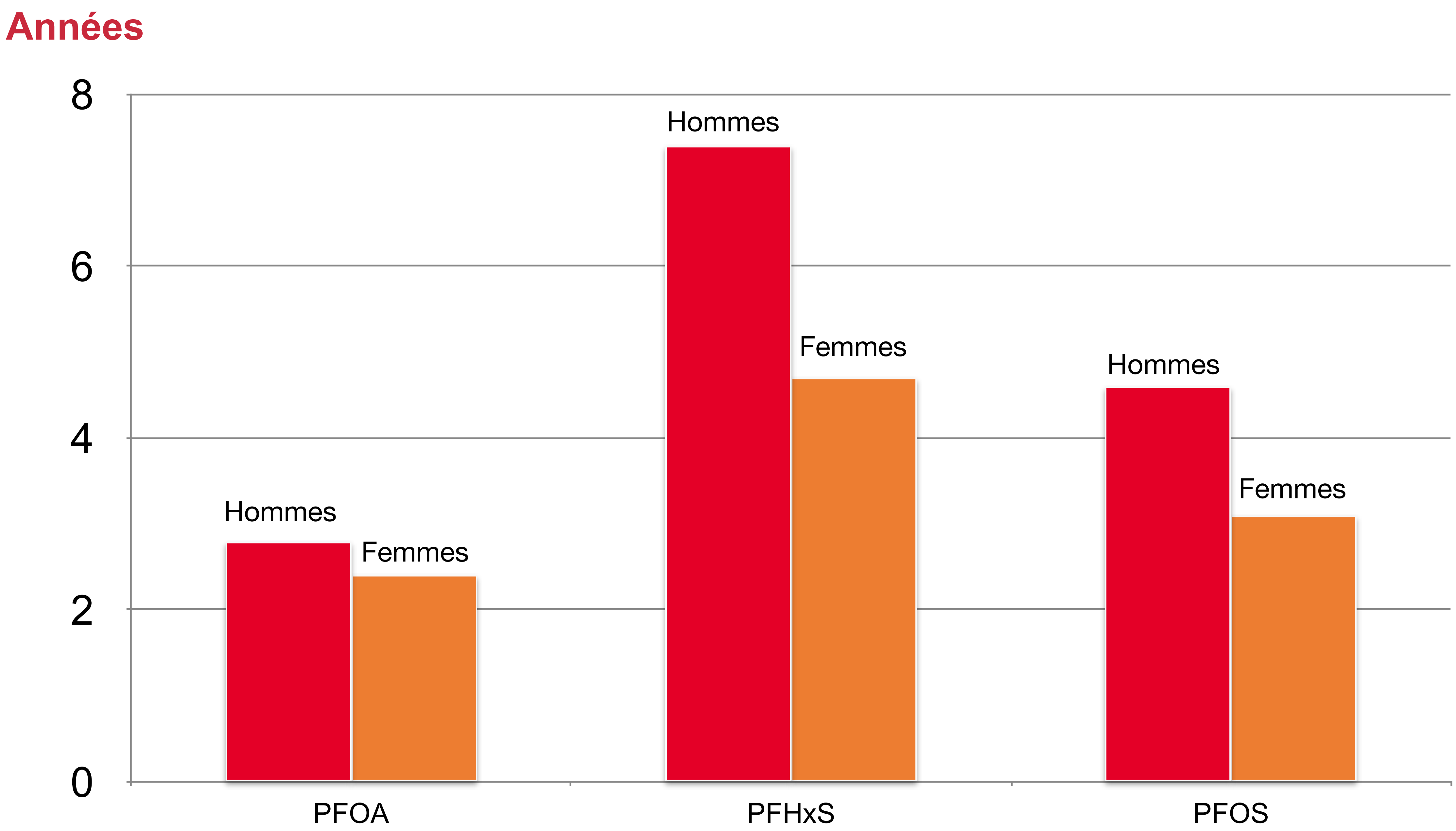
Imprégnation des populations (chaines longues)



La concentration de PFAS dans le sang augmente avec l'âge des individus

Source: Etude Esteban: 2014-2016

Différences Hommes/Femmes



Différences Hommes / Femmes = Cycles menstruels + Allaitement

Source: https://oem.bmj.com/content/75/1/46

Toxicité des PFAS

Valeur Toxicologique de Référence (VTR)

- Valeur seuil en dessous de laquelle une exposition sur le long terme peut être considéré comme sans effet pour la santé

- Dépend du poids de l'individu (Exprimée en µg/kg pc/j)

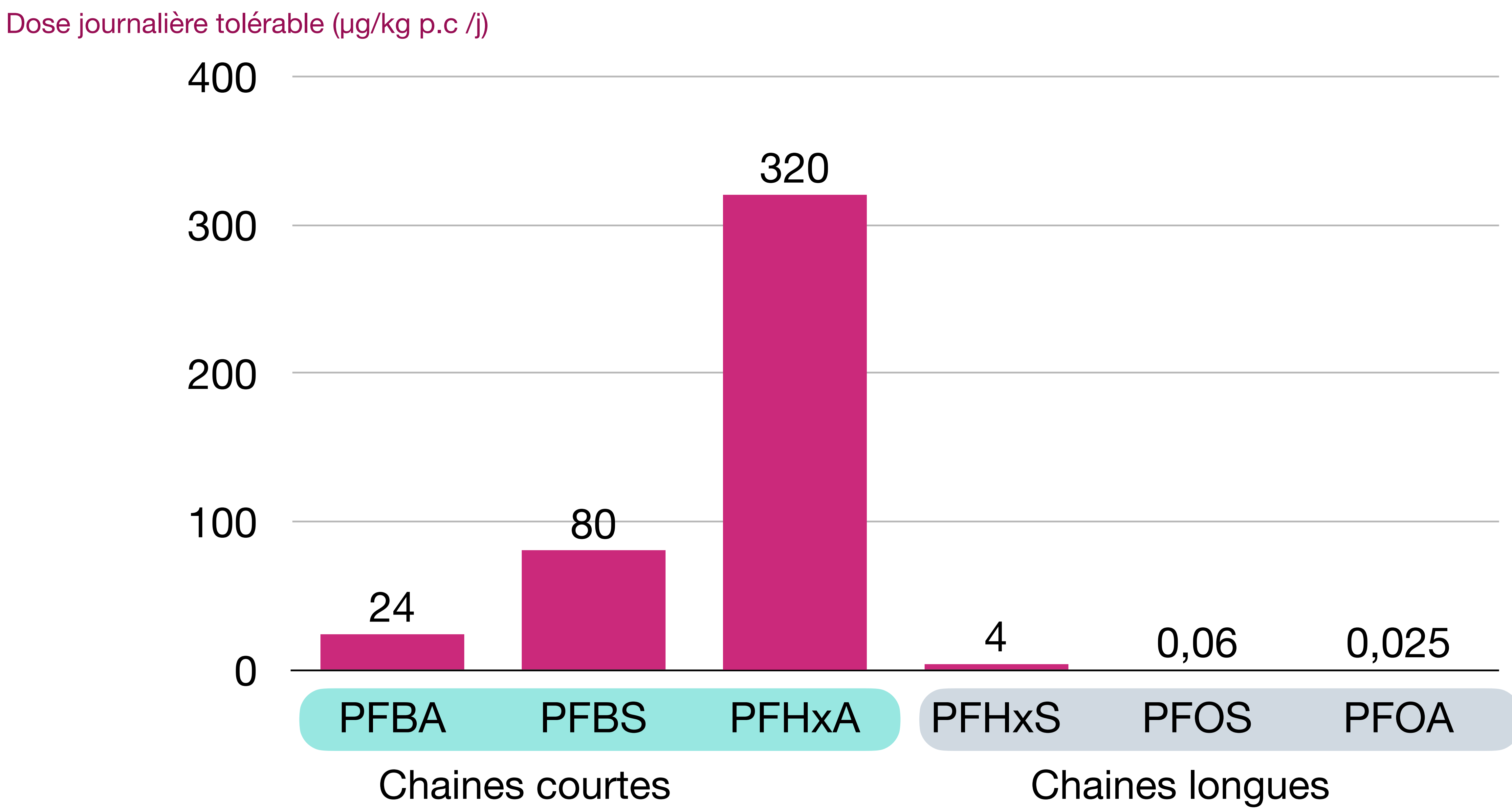
- En France, l'ANSES est en charge de l'établissement de ces valeurs

- **Sources principales:**

  - Etudes épidémiologiques (Homme)
  - Etudes toxicologiques (Animal)
  - Test *in vitro (Cellule)*

Toxicité: Chaines longues vs chaines courtes

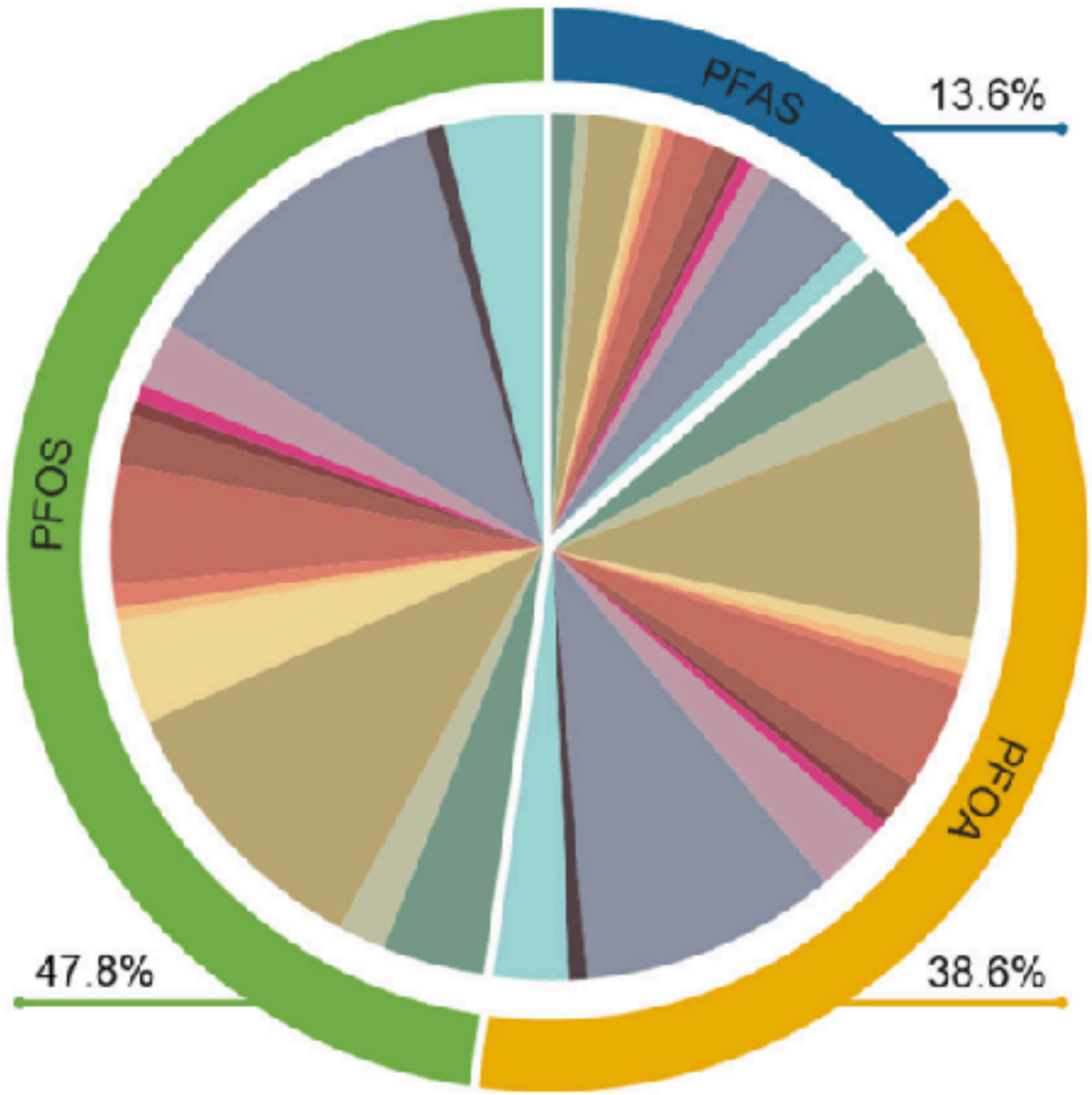
Dose journalière tolérable (DJT)



Plus DJT ↗ Moins la molécule est toxique

Source: ANSES 2017

Une généralité à nuancer



Number of publications

	PFAS	PFOA	PFOS
Body weight	44	159	184
Cancer	25	112	86
Cell	107	438	506
Heart	14	38	188
Bone	17	27	23
Nervous	22	23	41
Endocrine	73	191	216
Immune	43	67	89
Respiratory	13	20	27
Skin	24	26	31
Kidney	41	123	115
Metabolism	179	467	581
Genotoxicity	3	32	35
Reproductive	48	135	178

Près de 90% des études ont porté sur le PFOA/PFOS

Source: https://www.nature.com/articles/s41545-023-00274-6

Evolution des VTR

Les VTR évoluent avec les connaissances nouvelles du sujet

Dose journalière tolérable

(EFSA: Autorité européenne de la sécurité alimentaire)

(2008)

Métabolisme
Foie
Thyroïde

150 ng/kg/j PFOS

1 500 ng/kg/j PFOA

European Food Safety Authority

(2018)

1,85 ng/kg/j PFOS ÷ 80

0, 85 ng/kg/j PFOA ÷ 1 760

(2020)

Immunotoxicité

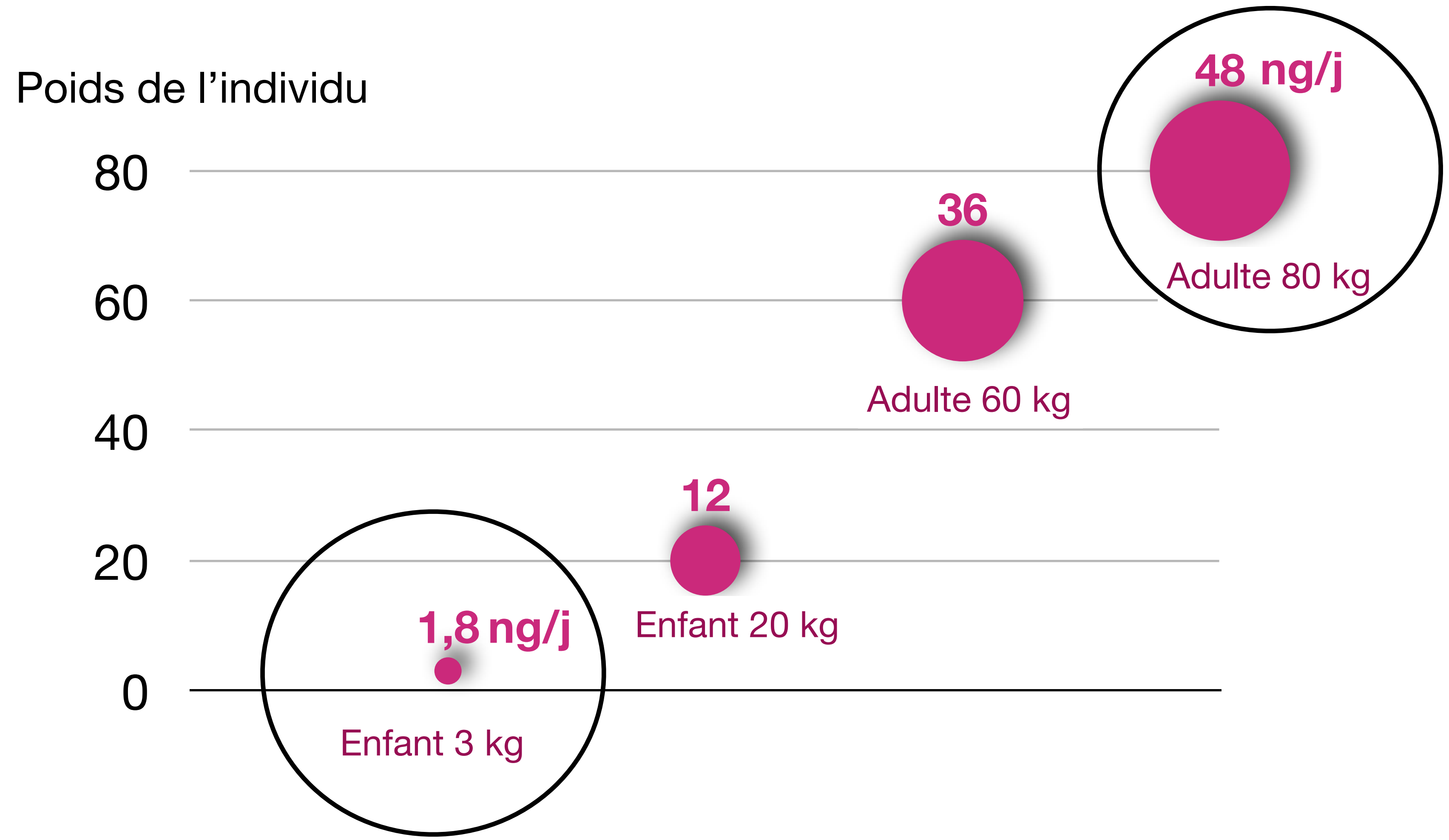
0,6 ng/kg/j

(PFOS, PFOA, PFHxS, PFNA)

Les enfants: un public particulièrement vulnérable

Recommandation EFSA

0,6 ng / kg pc / j => PFOA / PFNA / PFHxS / PFOS



Règlementation sur les denrées d'origine animale

2016-2020: Analyse de milliers d'échantillons à l'échelle européenne de denrées alimentaires

Présence majoritaire de 4 PFAS **(chaines longues)**:

PFOA
PFOS
PFNA
PFHxS

	P95 (2016-2020)	Réglementation
	50 ng/Kg	40 ng/Kg
	850 ng/Kg	1 300 ng/Kg
	1 550 ng/Kg	1 700 ng/Kg
	1 800 ng/Kg	2 000 ng/Kg
	2 600 ng/Kg	5 000 ng/Kg
	39 000 ng/Kg	40 000 ng/Kg

Situation Lyonnaise

Reportage vert de rage (Mai 2022)

Point de départ d’une prise de conscience sociétale du problème

Des sources diverses

Rejets Aqueux

Rejets Aériens

Rejets Terrestres

Volumes des rejets

ARKEMA et **DAIKIN**

PFOA (C8)
Surflon (C9 + C11 + C13)

PFHxA (C6)
6:2 FTS (C6)

~ 40-100 Tonnes PFAS déversées dans le Rhône (Arkema)

+

? PFAS dans l'air / les sols

INCENDIE du Port Edouard Herriot (1987)

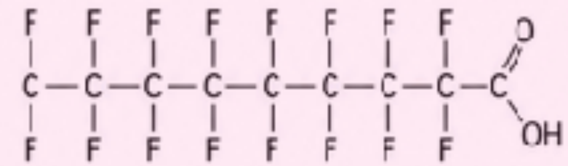
6:2 FTAB (C6)

~ 1-2 Tonnes PFAS déversées dans les sols (port Edouard héraut)

Historique des rejets

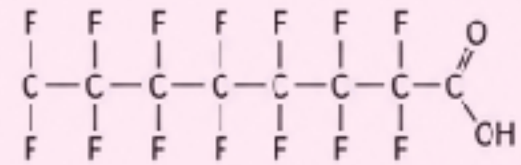
2004-2008 (Daikin)
1965-1986 (Arkema)

PFOA
C8



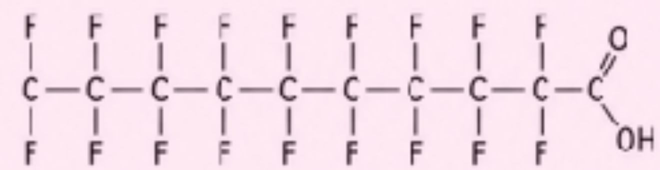
2003-2016 (Daikin)

PFHxA
C6

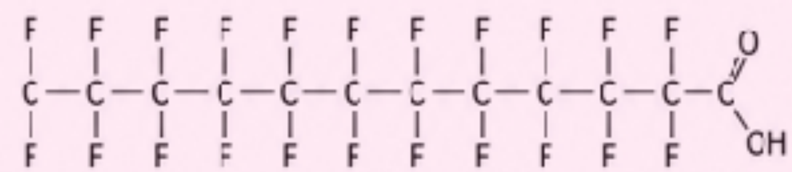


2003-2016 (Surflon, Arkema)

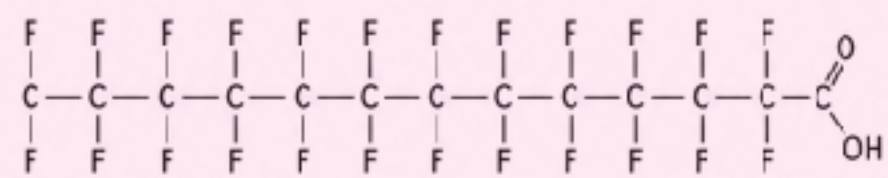
PFNA
C9



PFunDA
C11

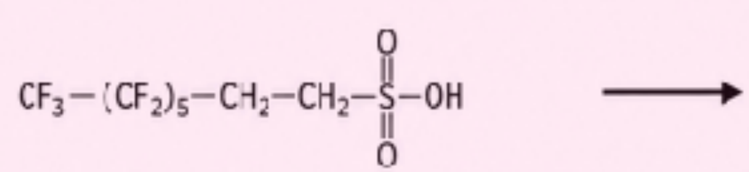


PFTrDA
C13



1974-2023 (Arkema)

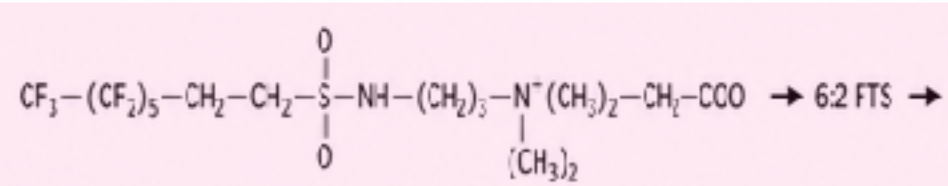
6:2 FTS



PFBA C4
PFPeA C5
PFHxA C6
PFhpA C7

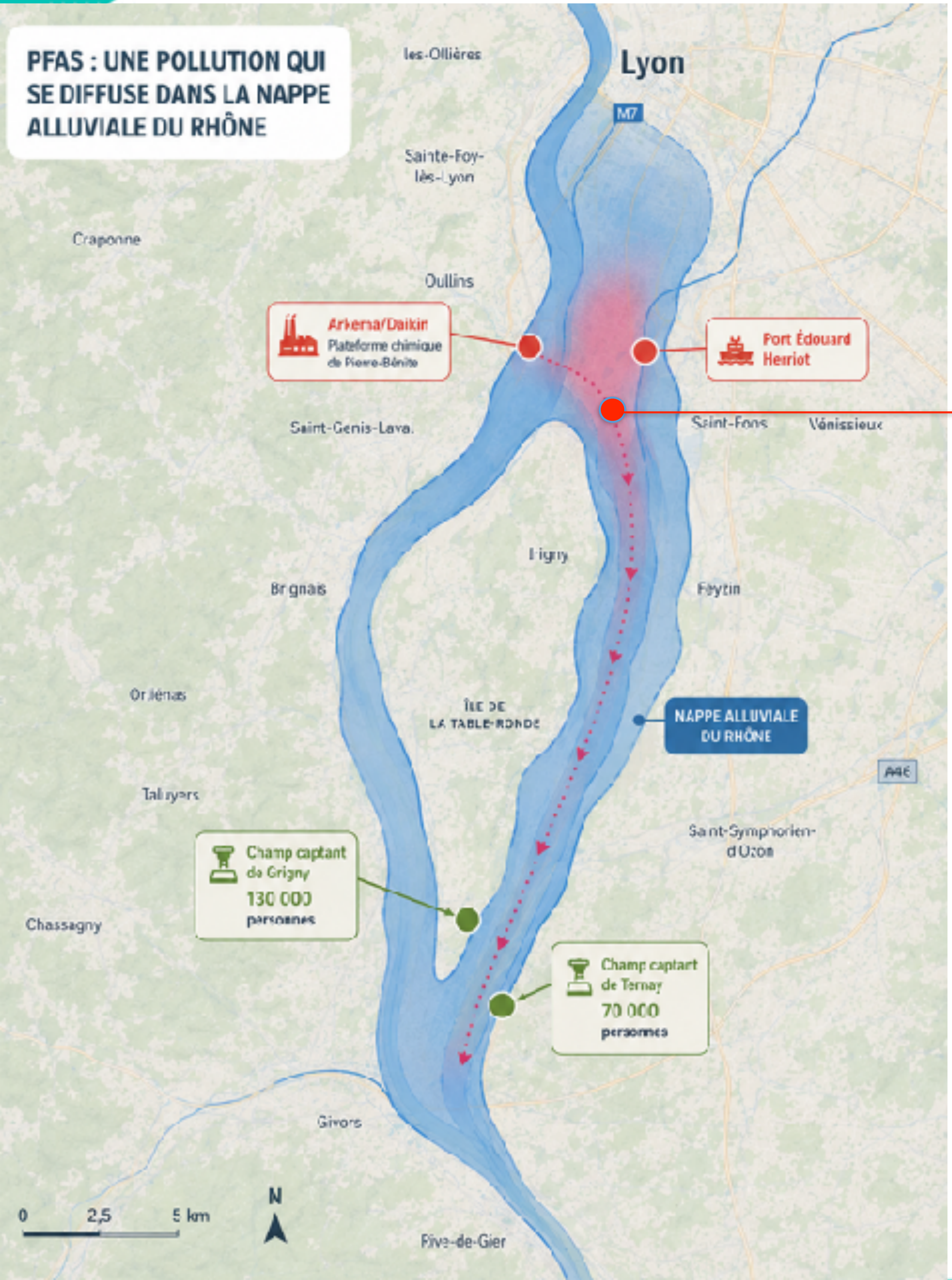
1987 (port Edouard Herriot)

6:2 FTAB



PFBA C4
PFPeA C5
PFHxA C6
PFhpA C7

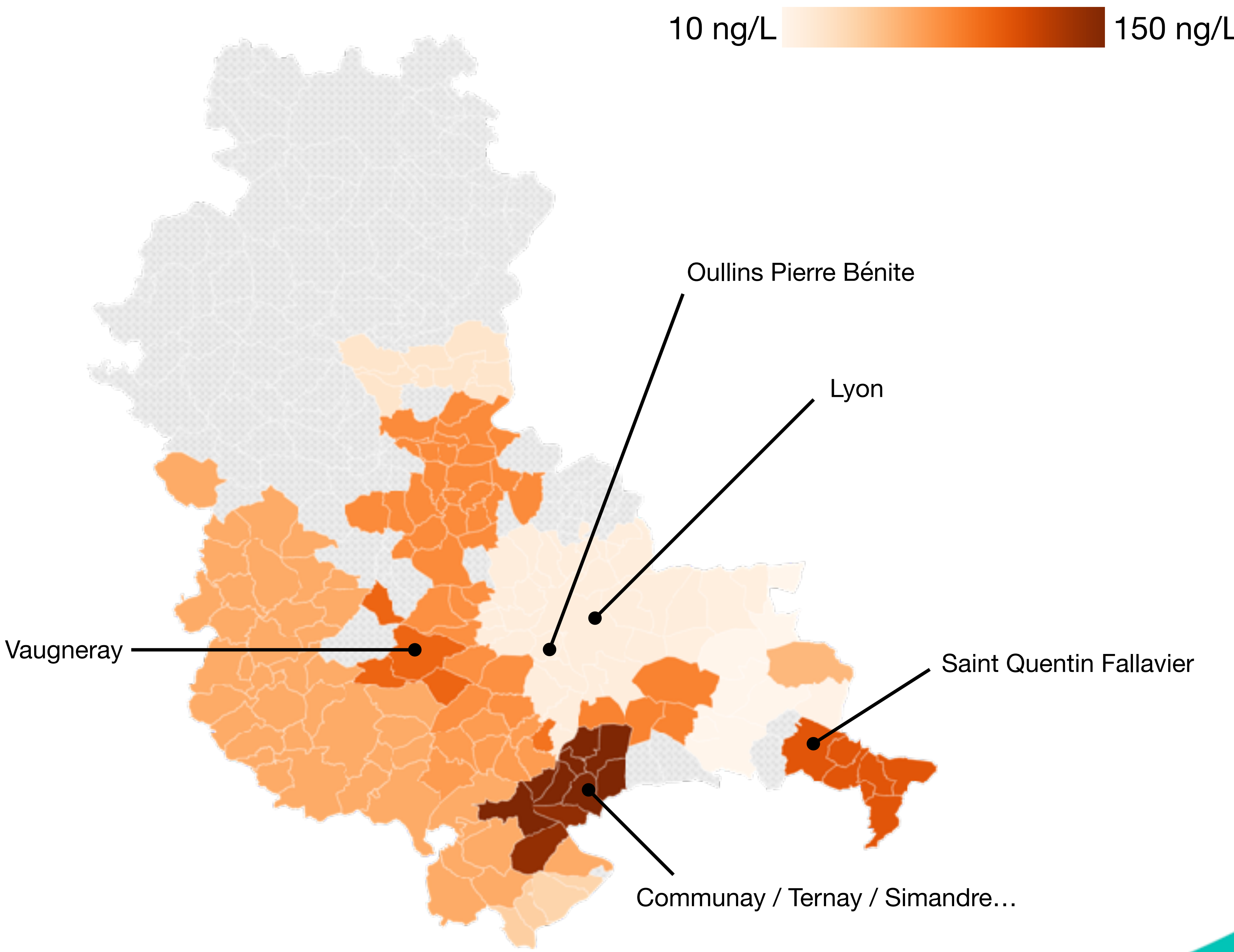
Contamination de l'eau potable



Source photo: Dreal

- Des nappes polluées en connexion directe avec les champs captant de Ternay/Grigny
- Des rejets d'Arkema directement dans le Rhône

Carte contamination eau du robinet



Cocktail majoritairement constitué de chaines courtes

Règlementation eau 2023

PFAS	
Σ 20 PFAS ➡	100 ng/L
Tous les PFAS ➡	500 ng/L

Pesticides	
1 pesticide ➡	100 ng/L
Tous les pesticides ➡	500 ng/L

Valeurs définies dans les années 80: Lié à la sensibilité des méthodes d'analyse de l'époque

Norme de qualité ≠ Valeur sanitaire

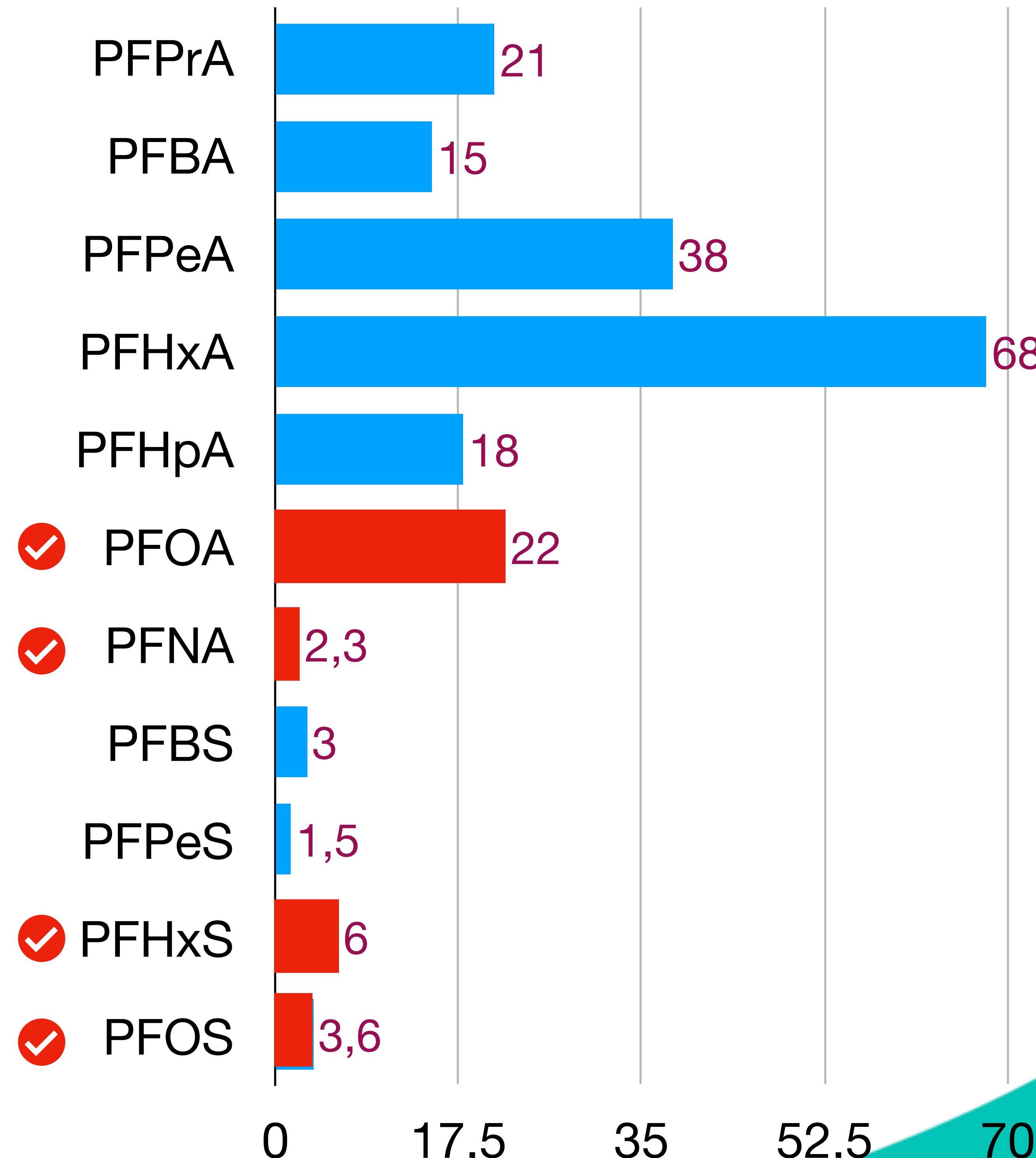
source: https://eur-lex.europa.eu/legal-content/FR/TXT/HTML/?uri=CELEX:32026L0805#ntc26-L_202600805FR.006301-E0026

Eau secteur Ternay

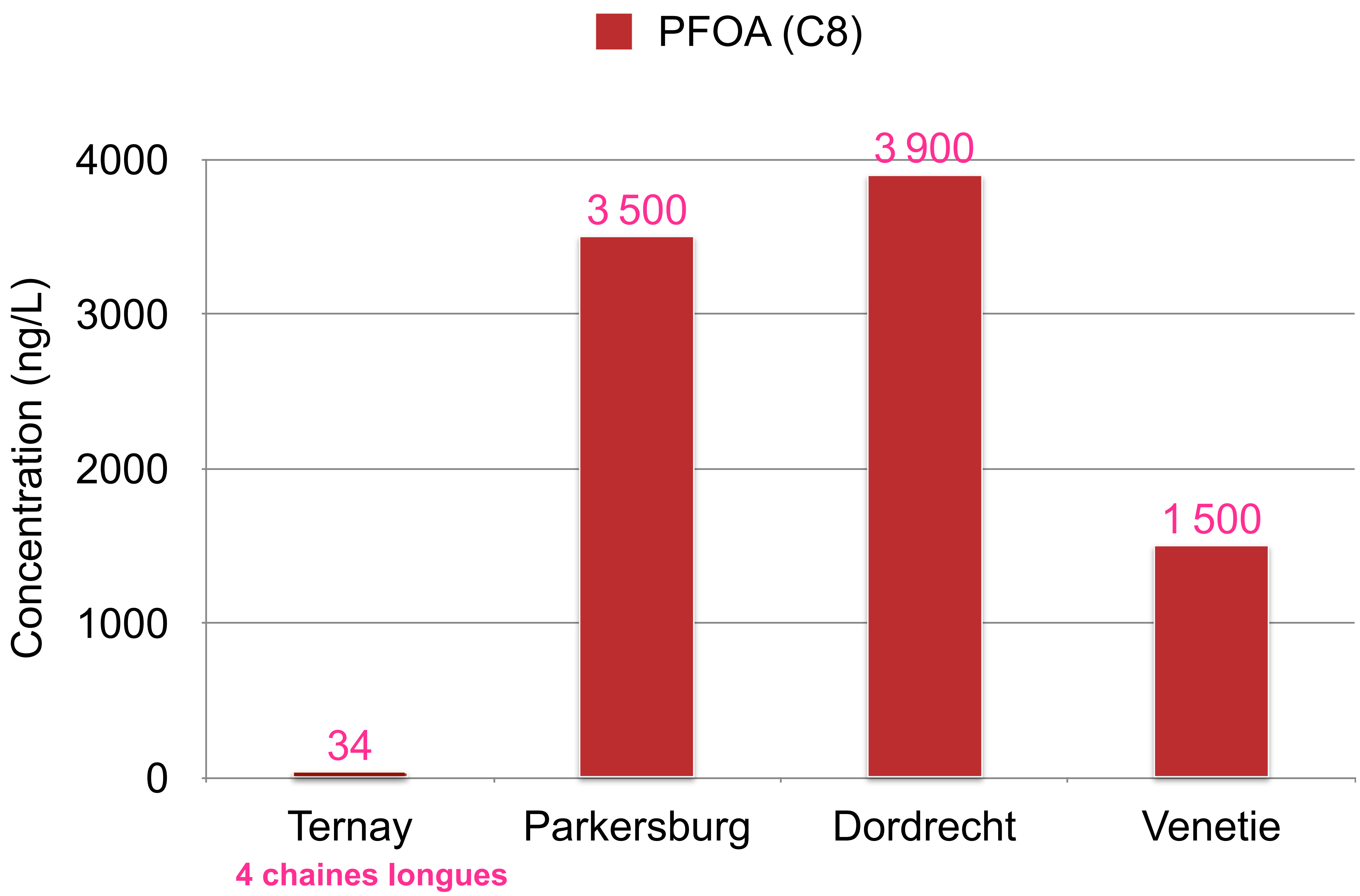
200 ng/L

Cocktail de 11 molécules

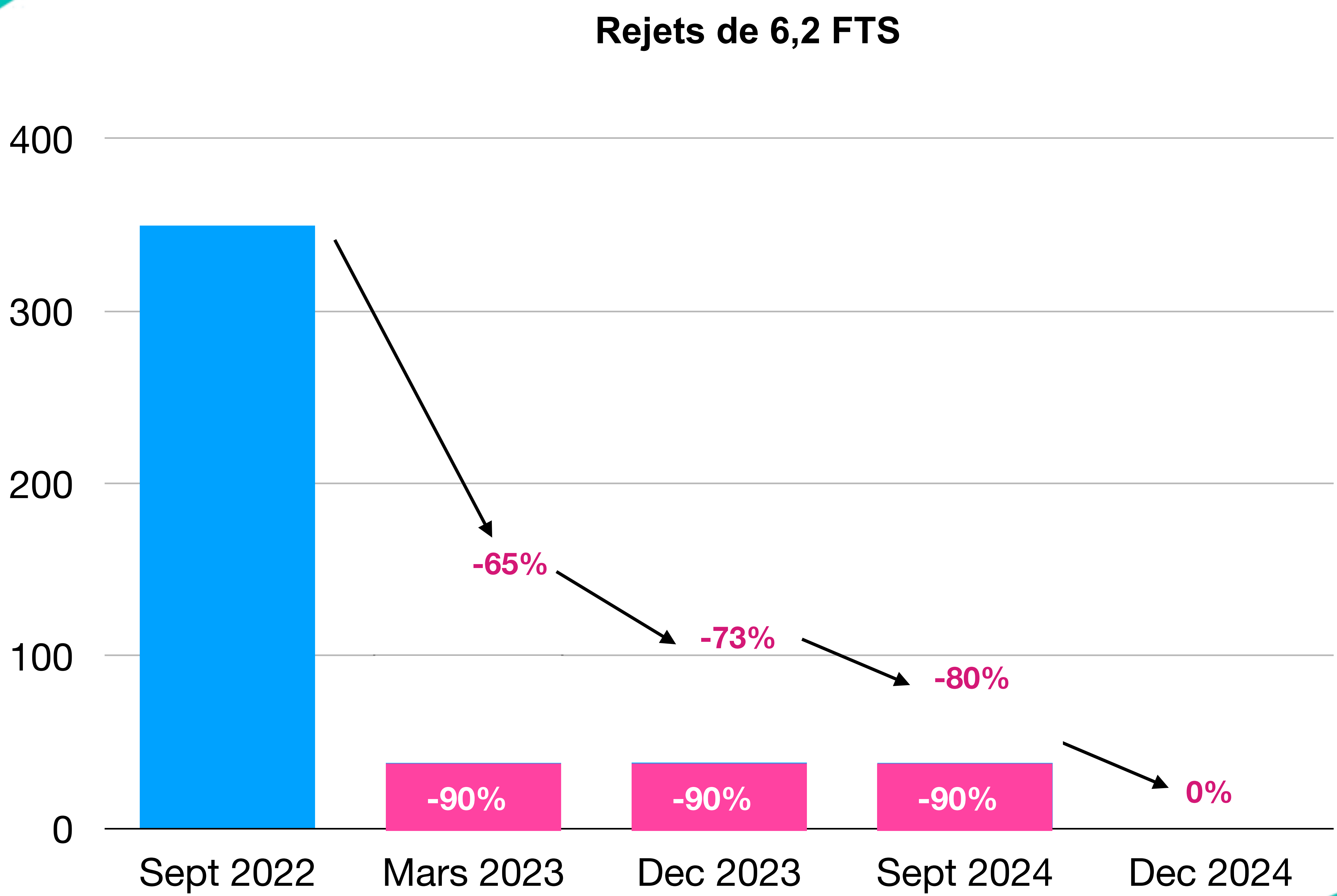
Chaines longues ~ 34 ng/L



Comparaison chaines longues

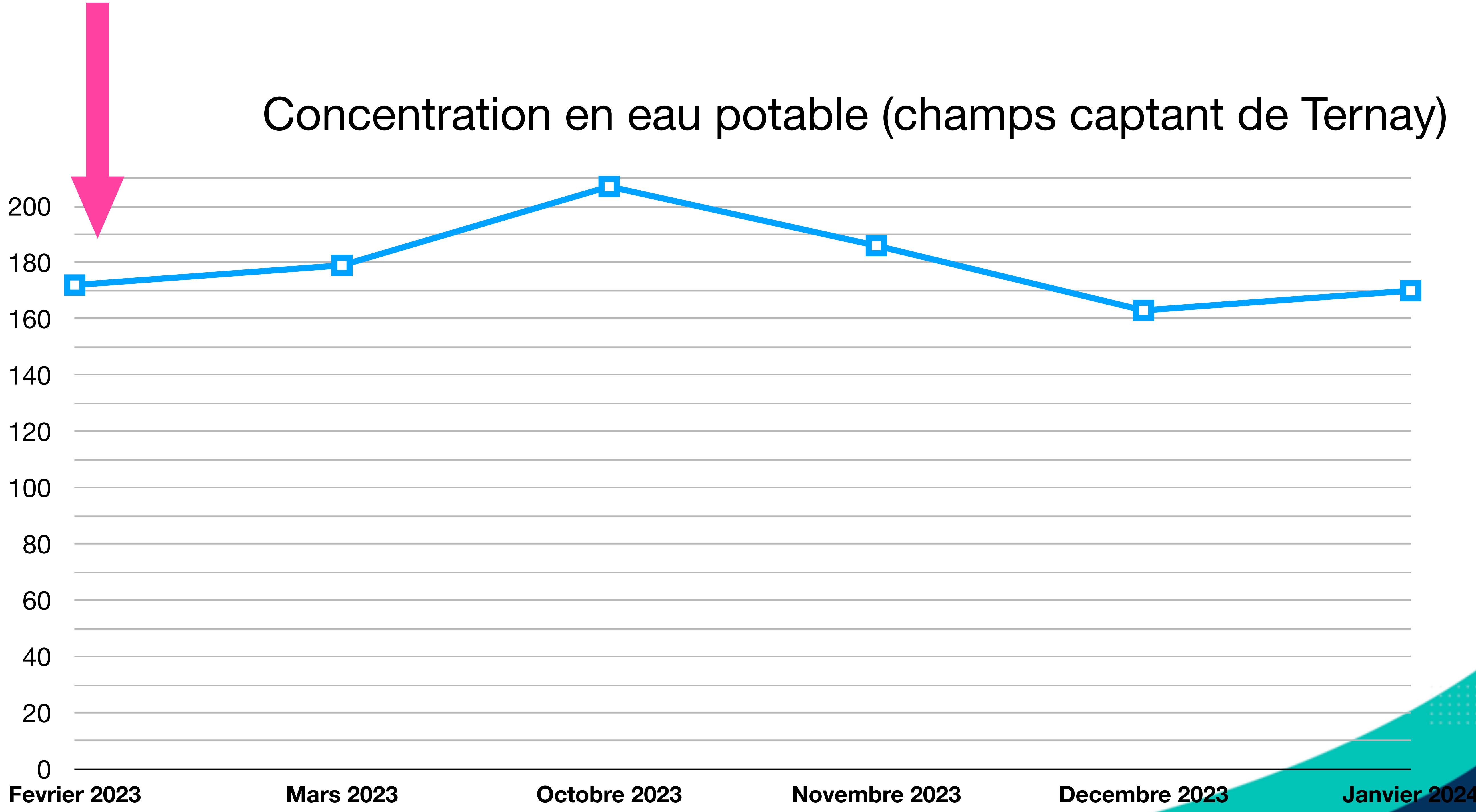


Arrêté préfectoral (Sept 2022)

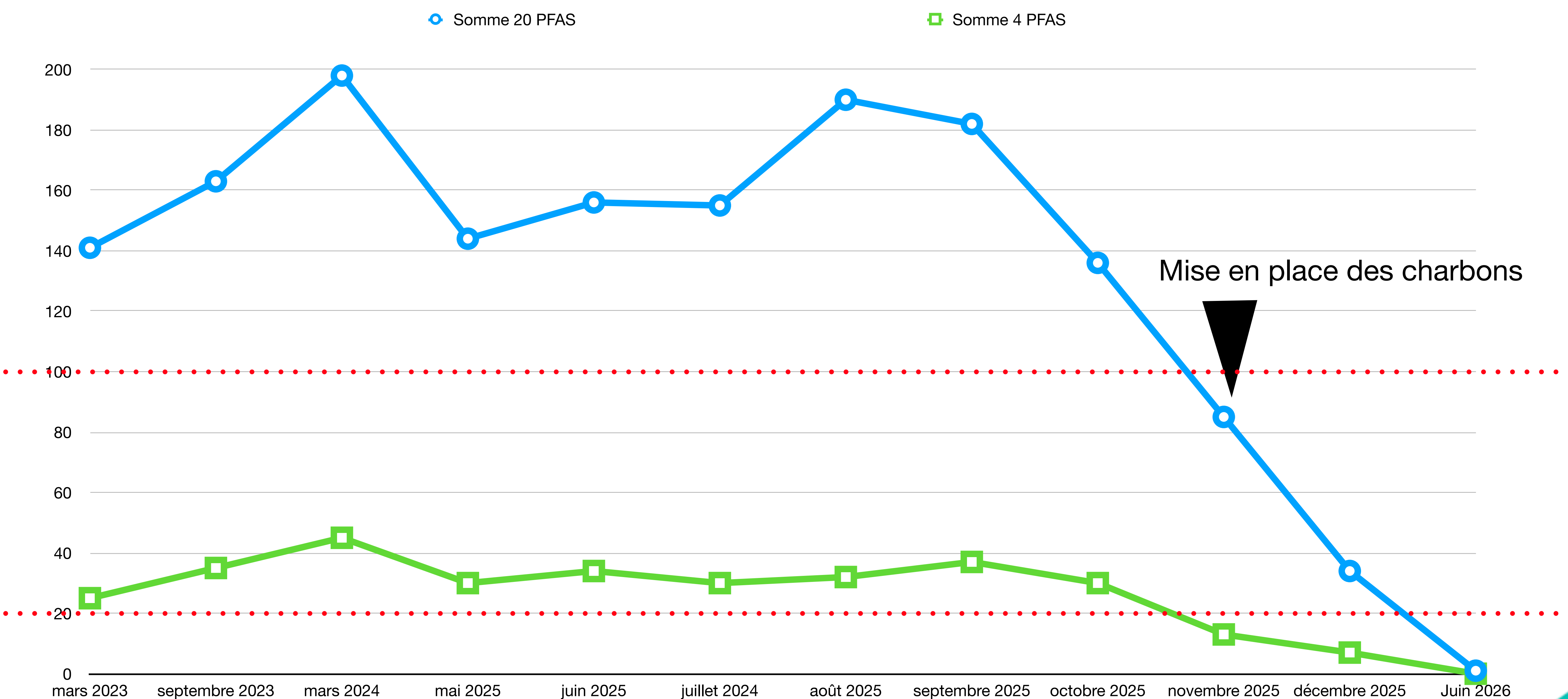


Eau secteur Ternay (campagne OES)

Début 2023= **- 90%**



Eau de Ternay



Contamination des oeufs

Air

Sols

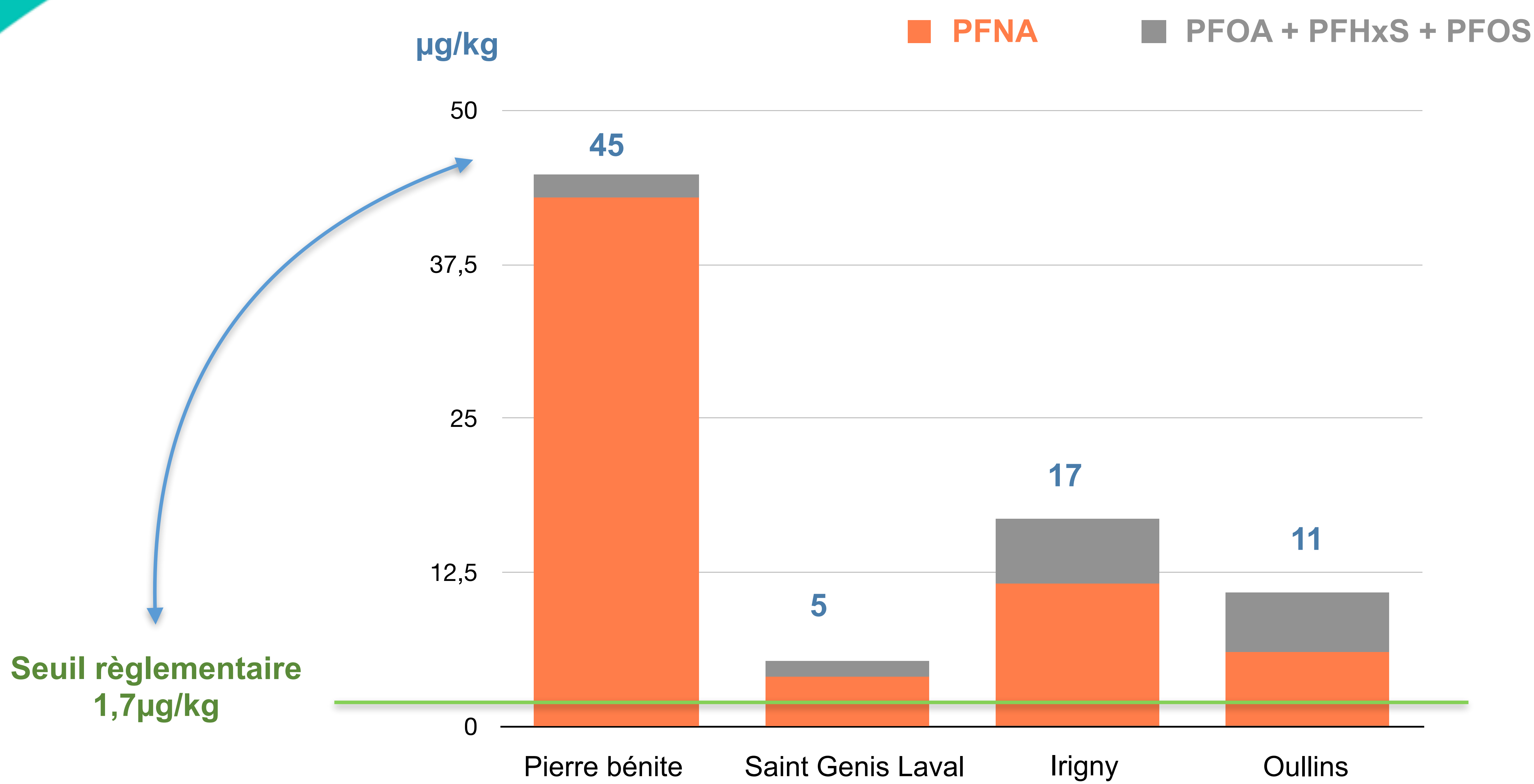
Oeufs

Recommandation sanitaire

Source: Le progrès

L'ARS recommande aux particuliers habitant ces communes de ne plus consommer les oeufs de leurs poules

Contamination des oeufs

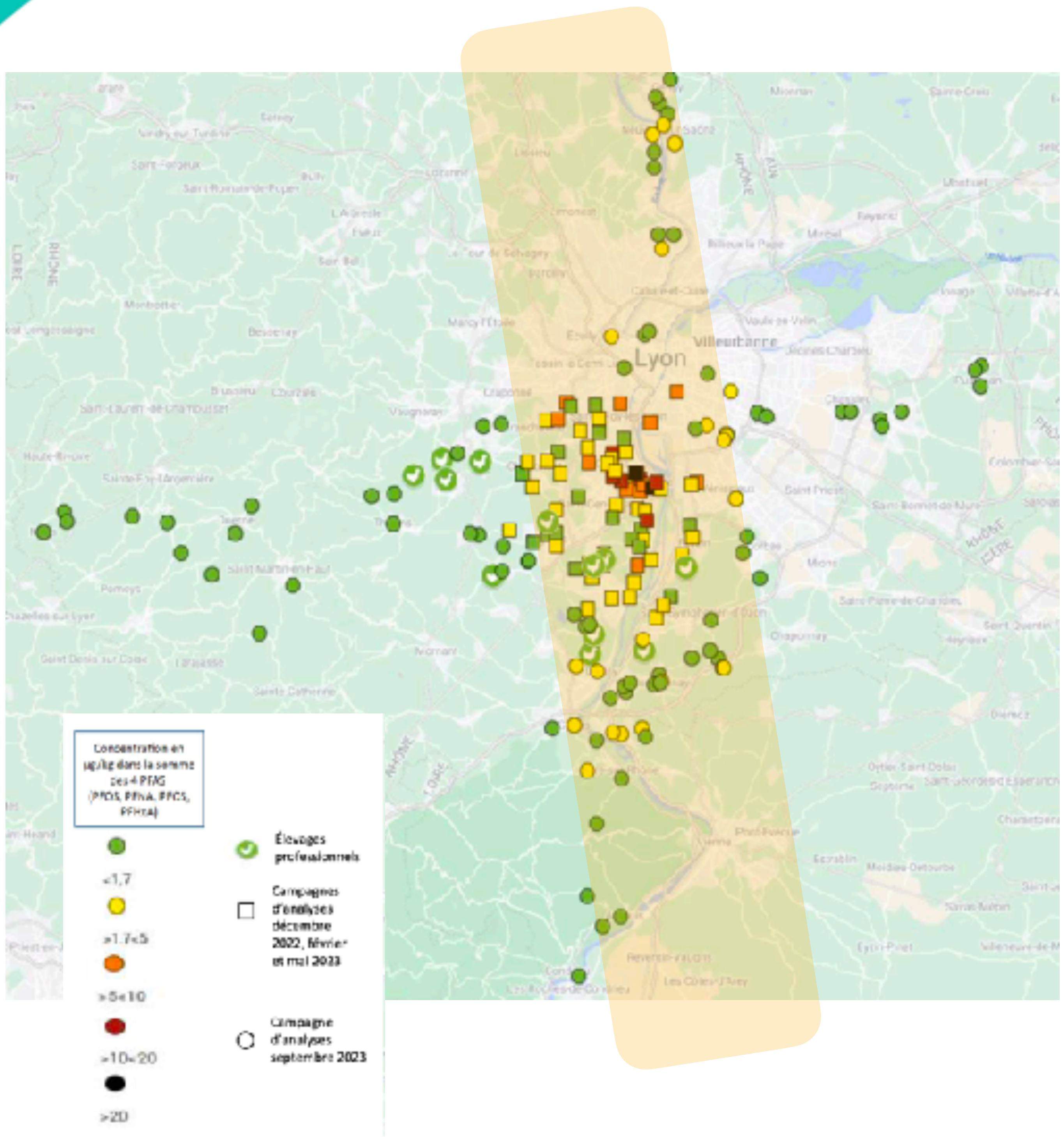


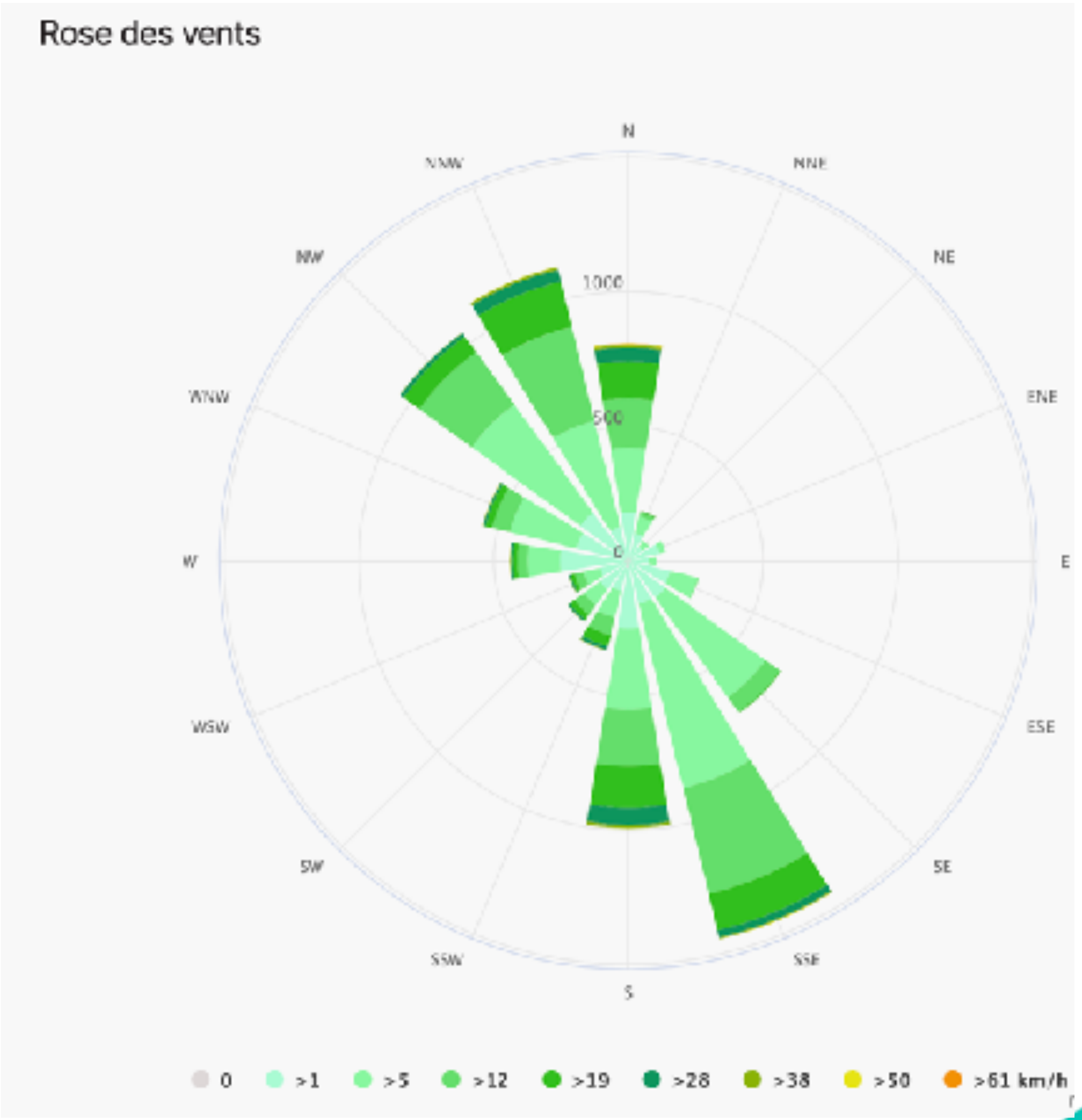
Jusqu'à 26 fois la norme réglementaire (2023)

PFNA = Molécules rejetée par Arkema (2003-2016)

Contamination des oeufs: Quelles zones touchées?

Couloir de contamination

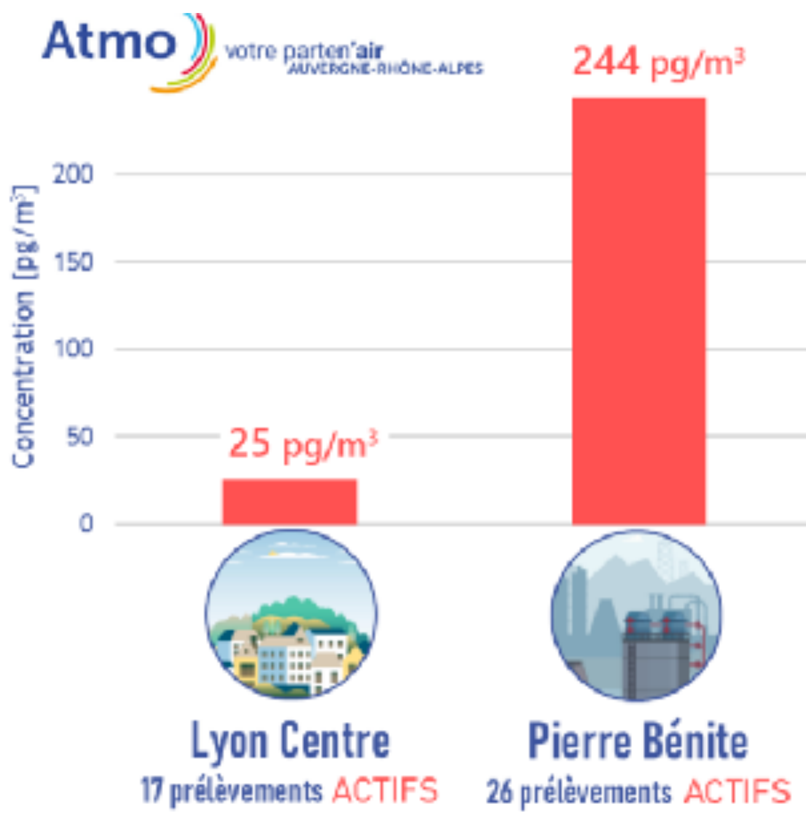


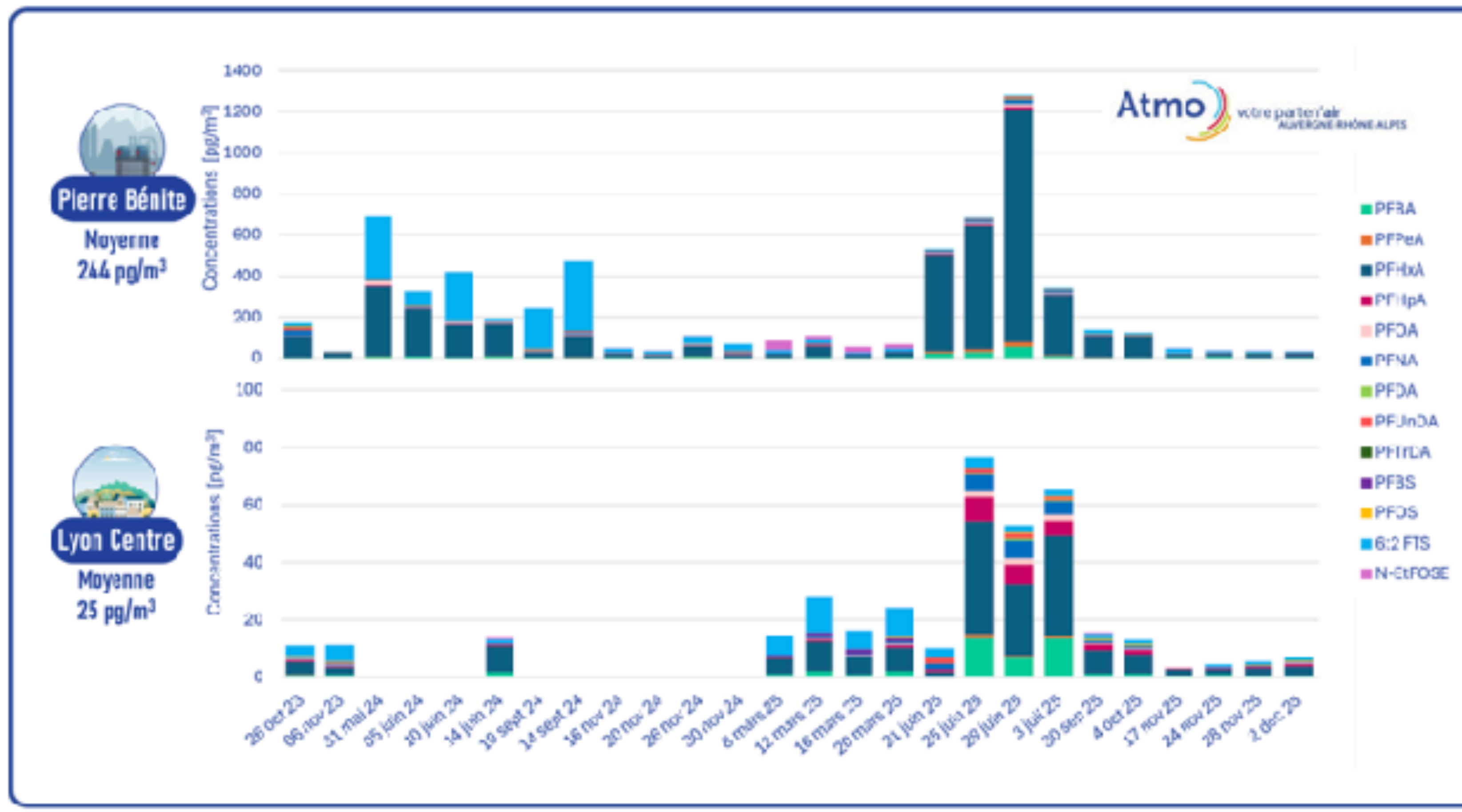


Faible imprégnation des légumes

- 56 prélèvements de légumes effectuées à l'automne 2022 puis au printemps 2023
- Contamination parfois significative des légumes aux abords de l'usine
- Absence de contamination des PFAS à chaine longue dans la majorité des légumes

Pollution de l’air (2023-2025)





- Chaines courtes majoritaires
- Concentration 10 fois plus élevée à Pierre Bénite qu’au centre de Lyon
- Pas de VTR d’inhalation validées à date

Source: https://www.atmo-auvergnerhonealpes.fr/sites/aura/files/medias/documents/2026-04/260408_RapportFinal_PFAS_1erResultatsEnAuRA_1.pdf

Bilan de 2 études de sciences participatives

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Letter

Target and Suspect Screening Reveal PFAS Exceeding European Union Guideline in Various Water Sources South of Lyon, France

Published as part of Environmental Science & Technology Letters special issue "Non-Targeted Analysis of the Environment".

Termeh Teymoorian, Louis Delon, Gabriel Munoz, and Sébastien Sauvé*

Cite This: Environ. Sci. Technol. Lett. 2025, 12, 327−333 Read Online

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ABSTRACT: Lyon, a major hub for chemical industries in France, has been identified as a contamination hotspot of per- and polyfluoroalkyl substances (PFAS). Major chemical companies in the Pierre-Bénite area have used PFAS in the production of fluoropolymers and fluorotelomers, with effluents discharged into the Rhône River. This together with other contamination sources such as firefighting foam use at a vicinal harbor oil depot, likely resulted in a complex PFAS signature. This study investigated PFAS contamination in various water sources in southern Lyon, including ponds, rivers, factory channels, wells, springs, and tap water. Out of 47 samples, 22 had a Σ_{20}PFAS above 100 ng/L (maximum: ~700 ng/L), and 67% of the tap water samples exceeded the European guideline of 100 ng/L for Σ_{20}PFAS. Target PFAS profiles were dominated by perfluoroalkyl carboxylates (particularly C4 to C8), in agreement with their historical or current industrial usage. Suspect screening also revealed the occurrence of electrochemical fluorination precursors such as N-sulfopropyldimethylammoniopropyl perfluorohexanesulfonamide acetic acid (N-SPAmP-FHxSAA) and bistriflimide (used in the composition of ionic liquids). Certain fluorotelomers, including ESI+ (e.g., 6:2 fluorotelomer sulfonamidopropyl betaine (6:2 FTAB)) and ESI- (e.g., 6:2 FTS, 6:2 FTSAS-sulfone) compounds, were more prevalent in surface water than in tap or groundwater.

KEYWORDS: *Fluoropolymer manufacture, PFAS, Precursors, France, Lyon, Drinking water framework directive*

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Occurrence of PFAS in Lyon soils: contribution and impact of industrial activities

Toyin Dunsin Saliu,* Darianne Pepin,* Louis Delon,* Justine Fontaine* and Sébastien Sauvé

As the environmental impact of per- and polyfluoroalkyl substances (PFAS) increases, understanding their deposition to soils near chemical industries is vital to mitigate health and ecological risks. Lyon (France) is a hub of chemical production and faces concerns about PFAS releases into the environment. This study assessed the extent of PFAS deposition from chemical industries located in central Lyon to different parts of Lyon. Through a target analysis using UHPLC-MS, we investigated the concentration of 80 PFAS in 205 Lyon soil samples collected around a fluoropolymer industrial complex. PFAS contamination of eggs in Lyon has been reported by local public health; hence, we evaluated PFAS in soils from a few selected chicken-feeding areas and free-range chicken eggs. High PFAS concentrations (3.5–175 μg kg^{-1}) were observed in soils near fluorochemical industries, with levels declining as distance from the industrial site increased. Long-chain PFCAs (C ≥ 8) and PFSAs (C ≥ 6) showed high detection rates, with PFUnDA, PFTrDA, PFOS, PFHxS, PFNA and PFDA being the predominant PFAS. The $\sum$34 PFAS detected in soils from chicken-feeding areas ranged from 5.5–10.5 μg kg^{-1} and 2.1–19.1 μg kg^{-1} in eggs. This confirmed that the chickens are exposed to PFAS from the surrounding soils and other sources through their diet and foraging. Generally, the detection of elevated levels of PFNA, PFUnDA, and PFTrDA suggests an industrial input from the production of Surflon® at the Pierre-Bénite site. A significant negative correlation (p-value < 0.03) was observed between PFAS concentrations across the zones and their distance from the chemical industry. The variability in PFAS distribution may be influenced by wind direction, which has likely transported airborne PFAS from its source near the industrial complex and extending towards other parts.

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rsc.li/esadvances

Environmental significance

This study provides clear evidence of ambient PFAS deposition in a dataset of 205 Lyon soils, with contamination levels changing based on proximity to a major chemical industrial site using and producing PFAS. The observed soil PFAS concentrations are associated with prevailing wind patterns, thus indicating a direct atmospheric deposition of PFAS to Lyon soils.

Soil–Water Distribution Coefficients (Kd) of PFAS in Field-Collected Contaminated Soils from Lyon, France

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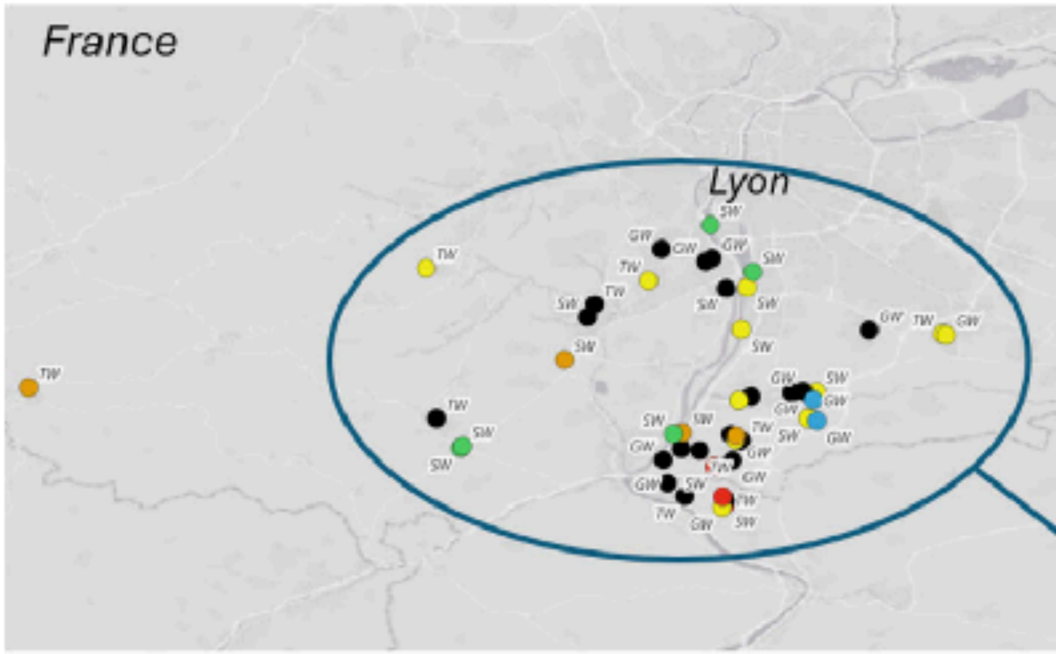
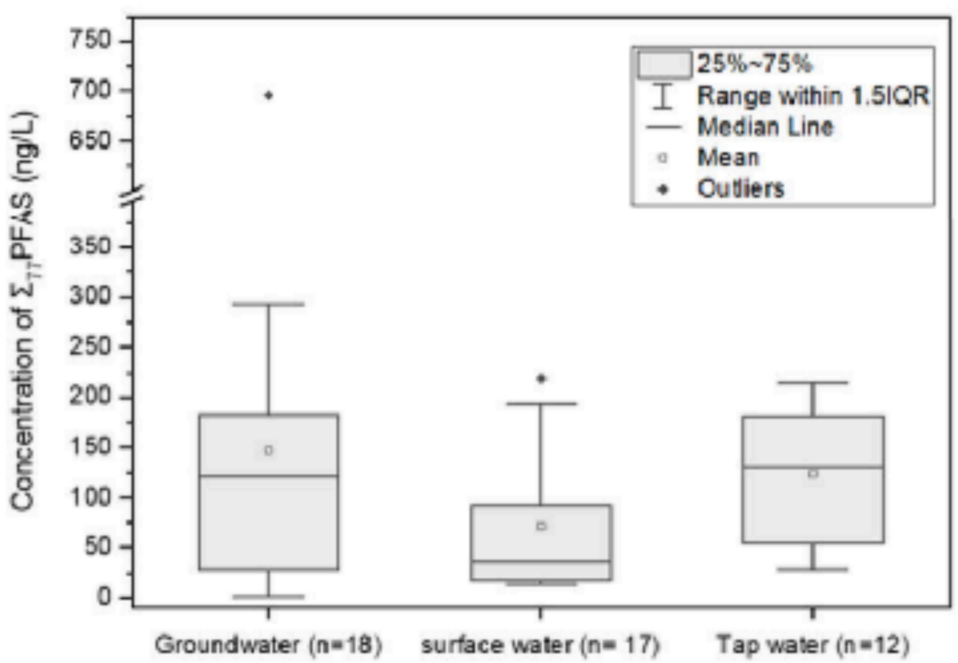
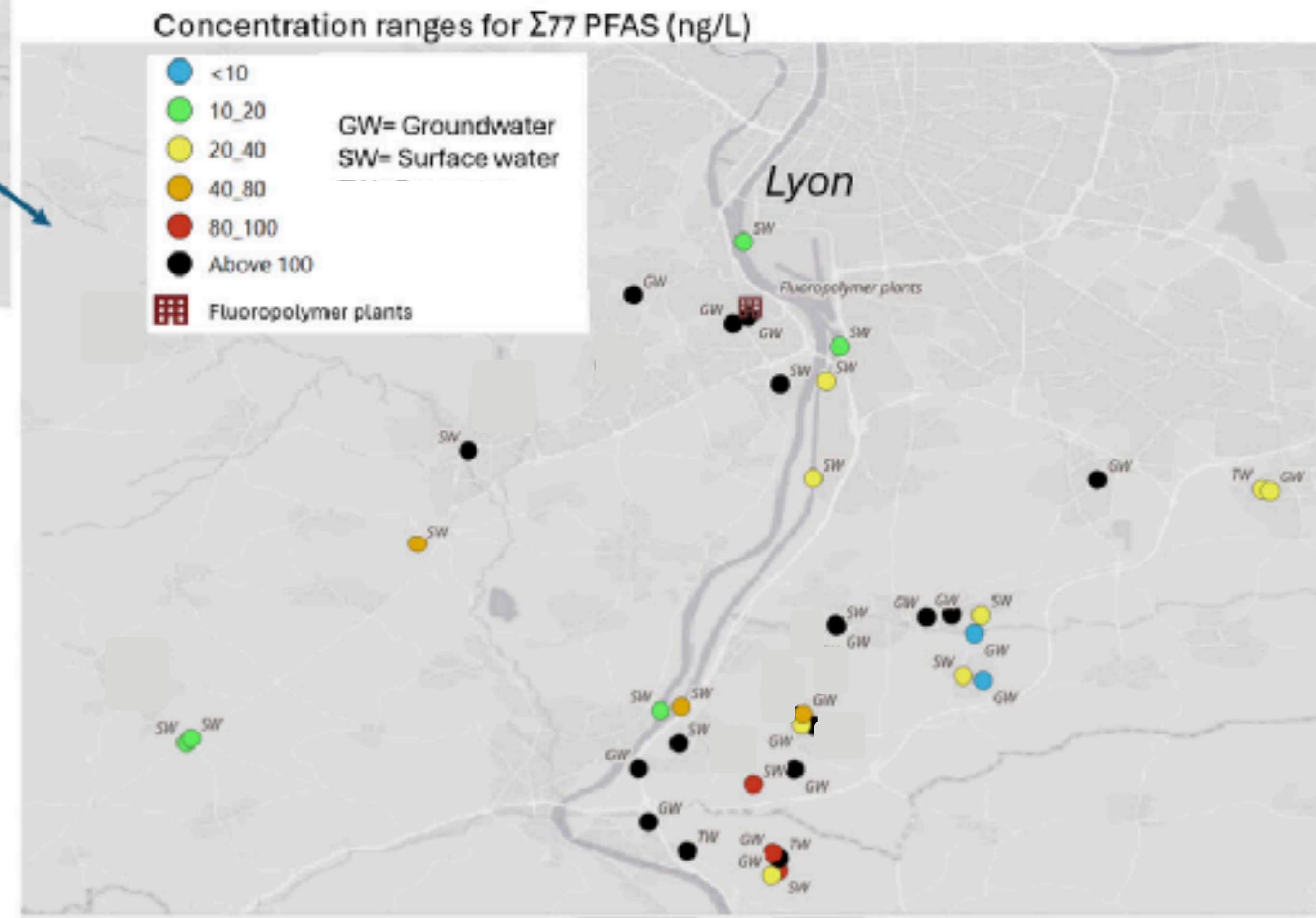
Abstract

The distribution coefficients (log Kd) of per- and polyfluoroalkyl substances (PFAS) were investigated in 84 soils from around Lyon, France. This area is located adjacent to an industrial facility that uses various PFAS in its production processes and that has been known to emit PFAS. A total of 77 target PFAS were analyzed in soil leachates using ultra-high-performance liquid chromatography coupled with high-resolution mass spectrometry (UHPLC–Orbitrap Q Exactive). While total PFAS concentrations in soil ranged from 3.8–175 μg kg-1 dry weight, the corresponding concentrations transferred to the aqueous phase ranged from 3.0-1235 ng L-1. A clear predominance of perfluoroalkyl carboxylic acids (PFCAs), including PFHxA, PFHpA, PFNA, PFPeA, and PFOA, was observed in the aqueous phase following soil-water equilibration across all soil types. The data were used to determine solid-liquid partitioning coefficients that can be used to model downward mobility of the PFAS. The resulting log Kd for the PFCAs (C3-C11) varied from 1.08 to 3.47 mL g-1, while values for PFSAs (specifically PFBS (C4), PFHxS (C6), and PFOS (C8)) varied between 0.80 and 4.54 mL g-1. Spearman's rank correlations between Kd values and soil properties (pH and SOC) for the 14 detected PFAS revealed that soil pH is a primary factor influencing PFAS partitioning, with statistically significant negative correlations for PFHxA and PFOA and highly significant negative correlations for PFBA, PFNA, PFUnDA, and

Carte des prélèvements



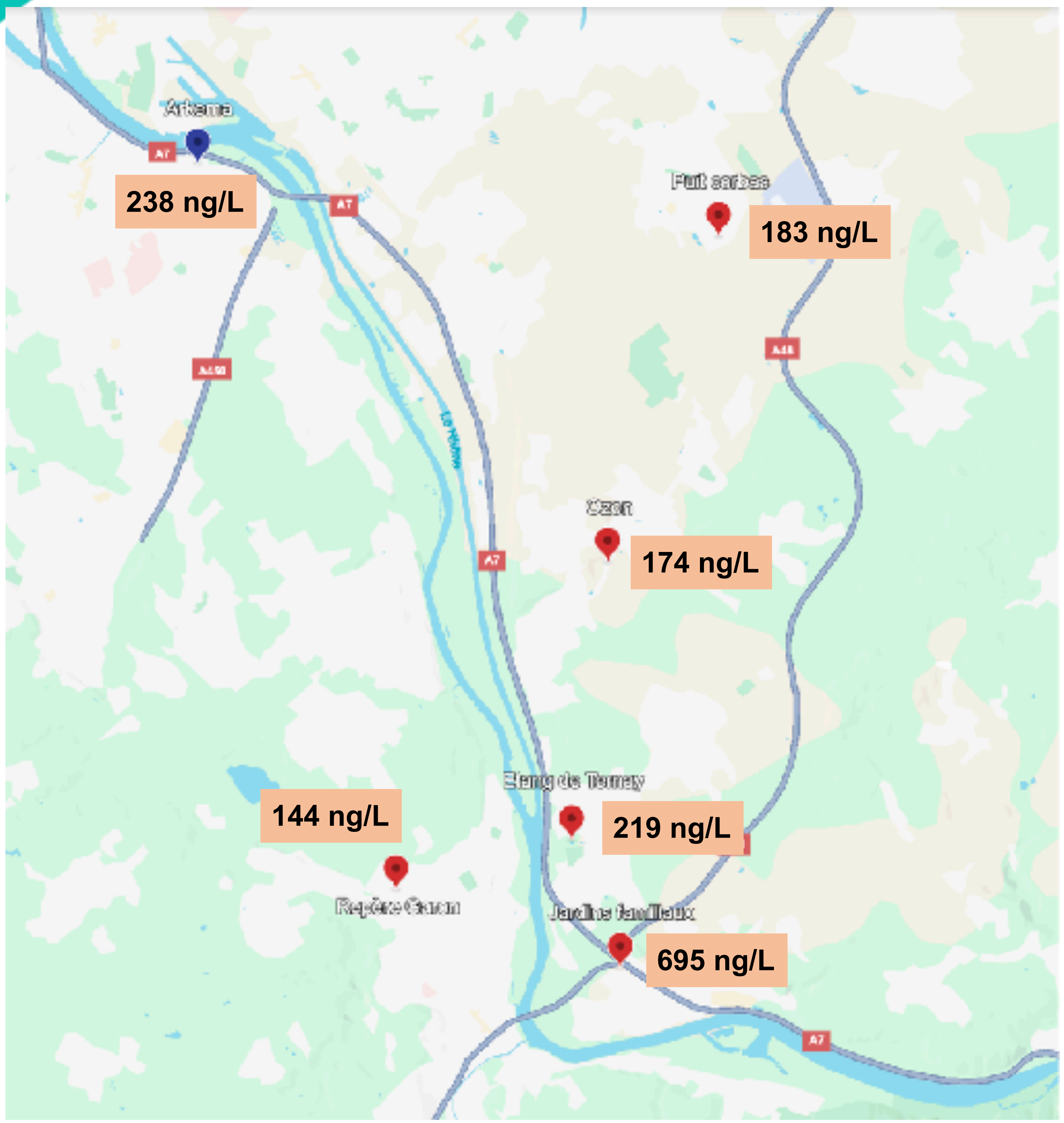




46 prélèvements réalisés (300 km2)
2/3 des eaux souterraines contaminées > 100 ng/L

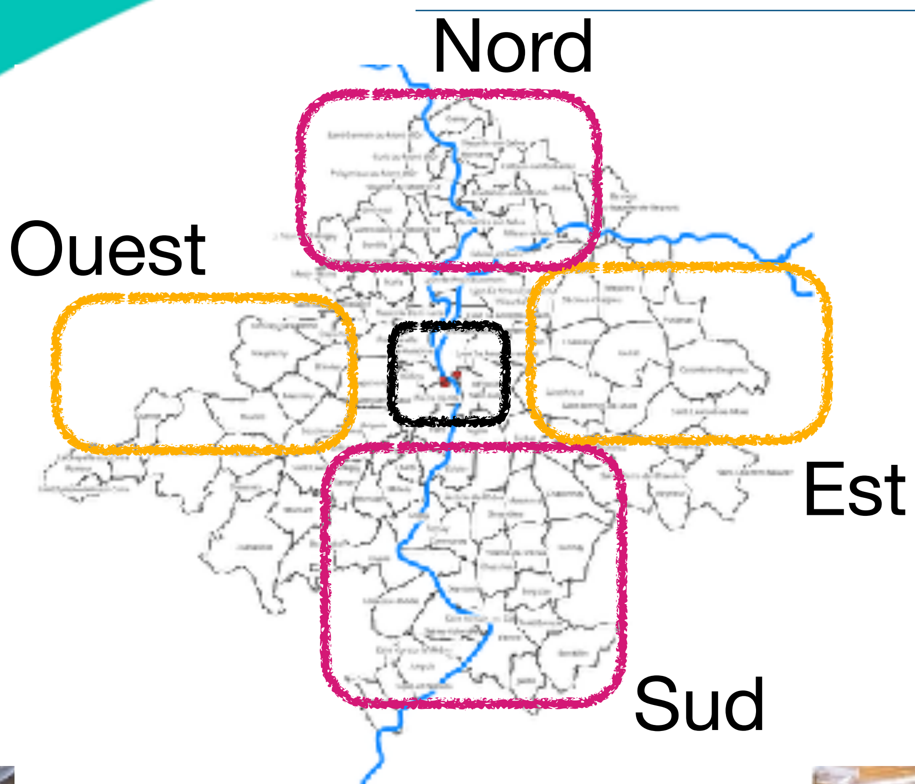
Source: S. Sauvé & al

Eaux territoriales (surface + souterraines)



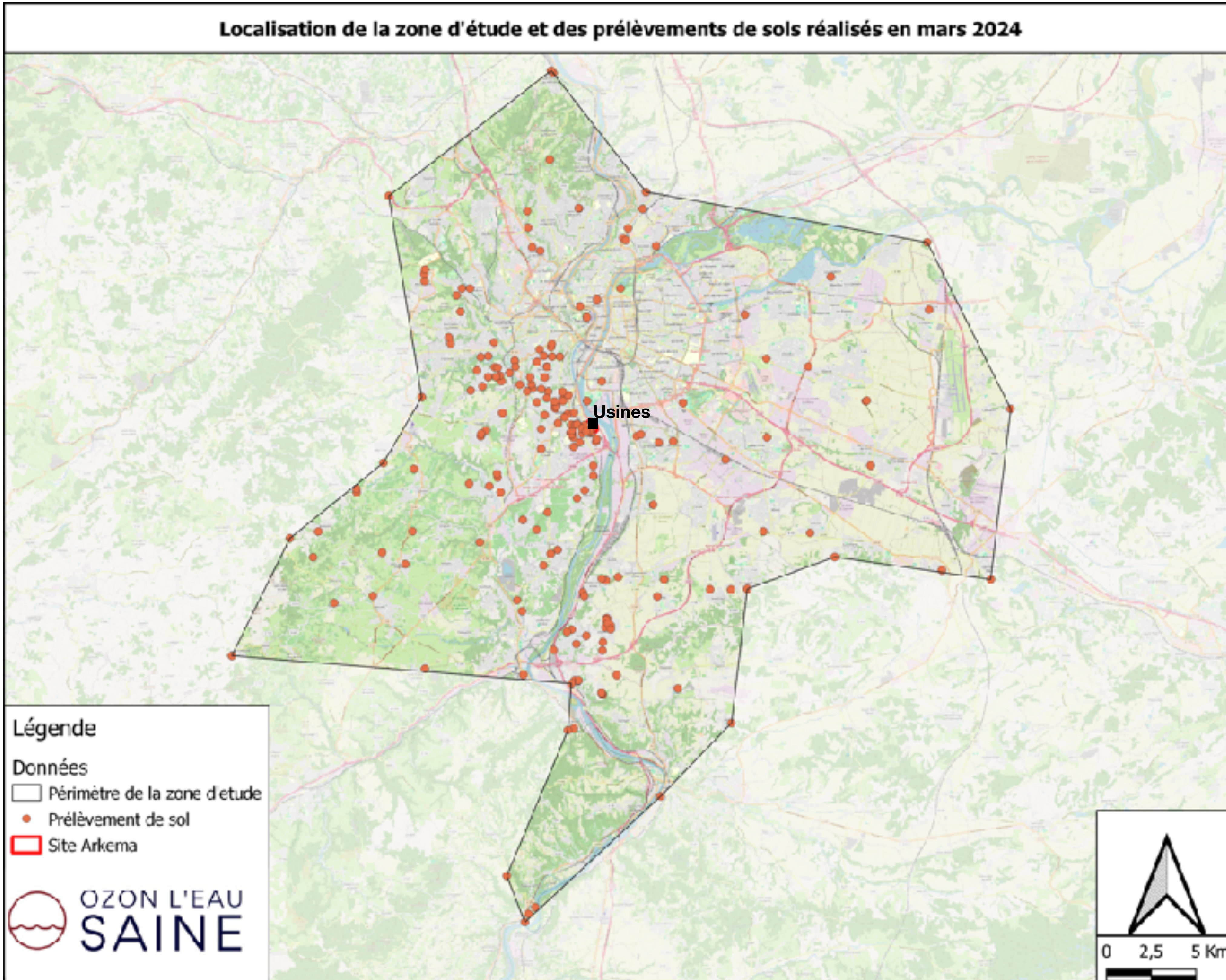
- **Une contamination diffuse qui ne se limite pas à PB**
- **Certains points > Normes de qualité eau potable (100 ng/L)**
- **70% de la contamination par des chaines courtes**

Etude d'imprégnation des sols



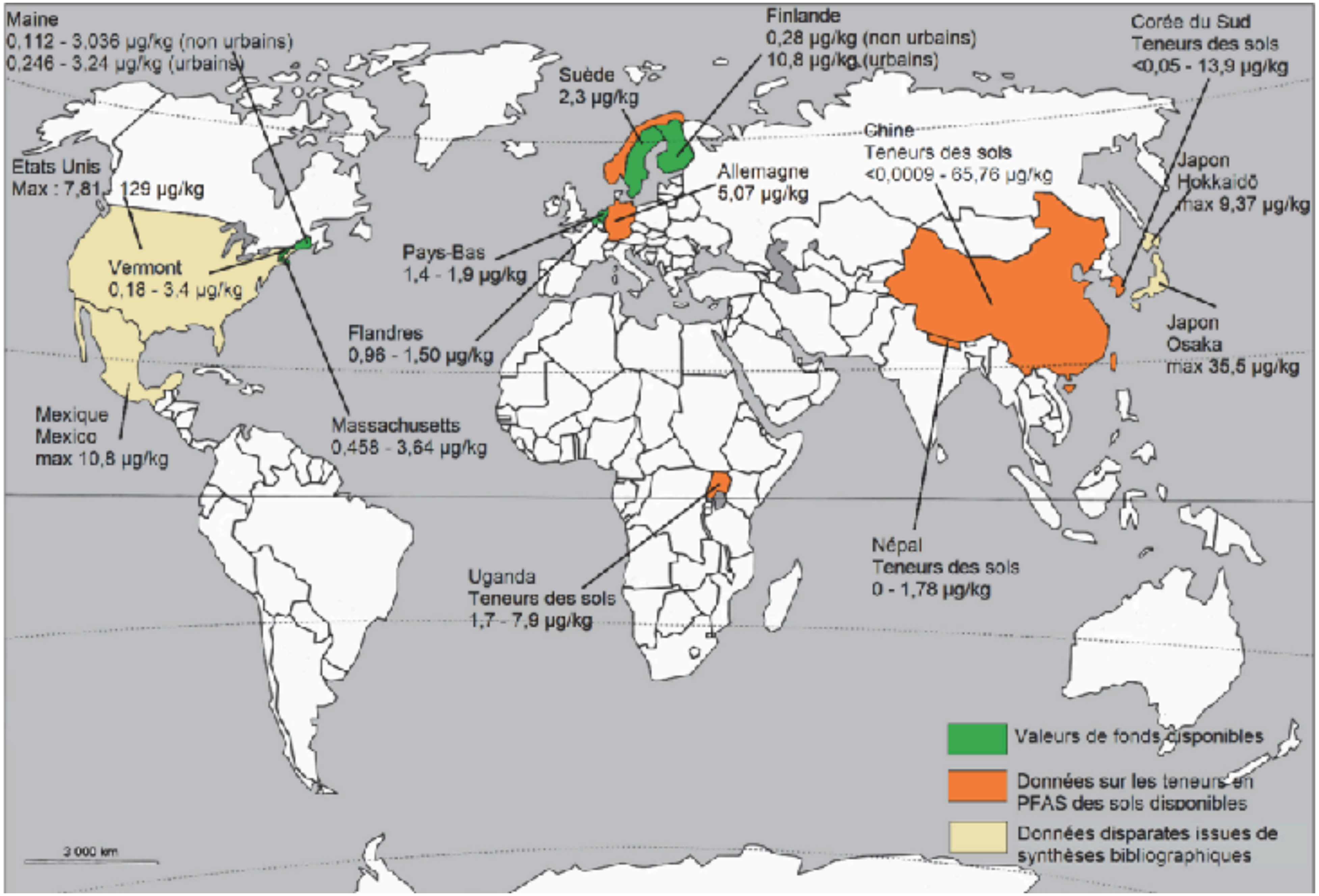
90 bénévoles
60 communes (1000 km2)
260 prélèvements

Carte des prélèvements



1000 km2

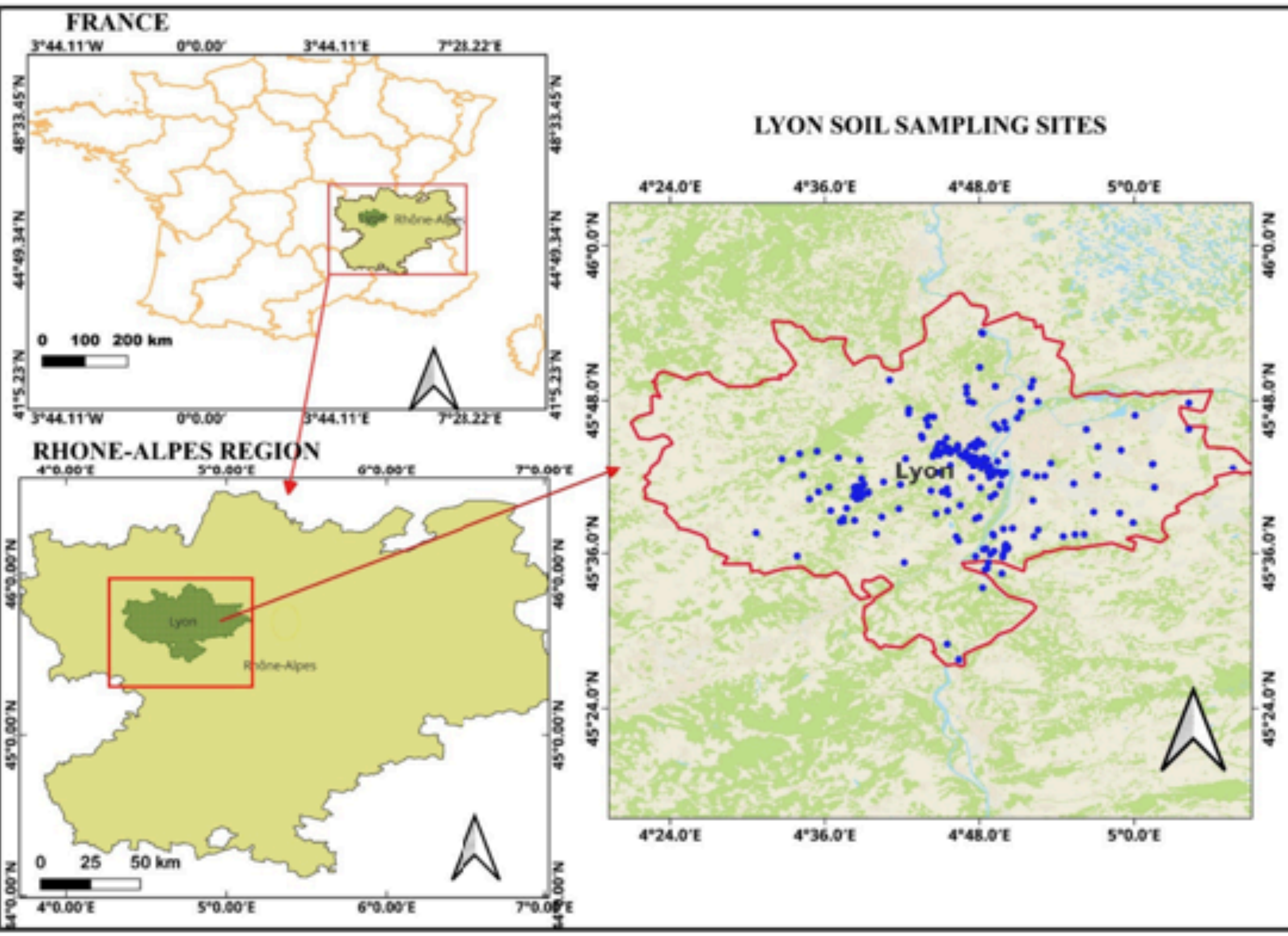
Evaluation du bruit de fond

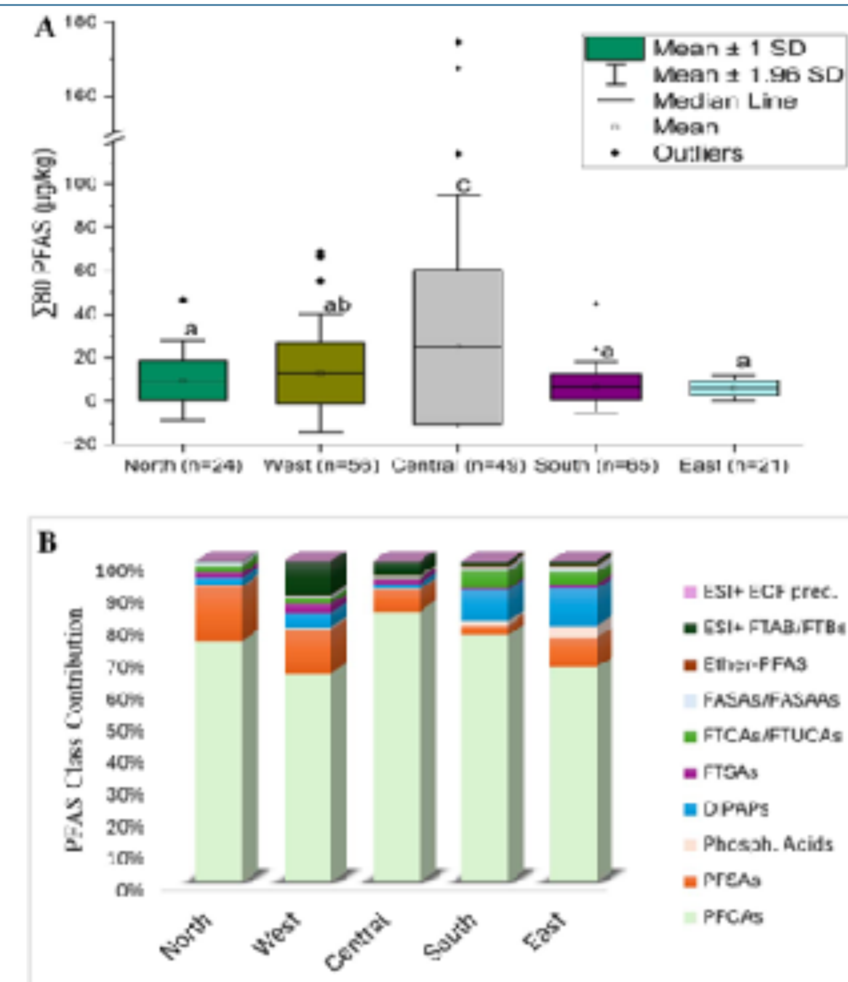


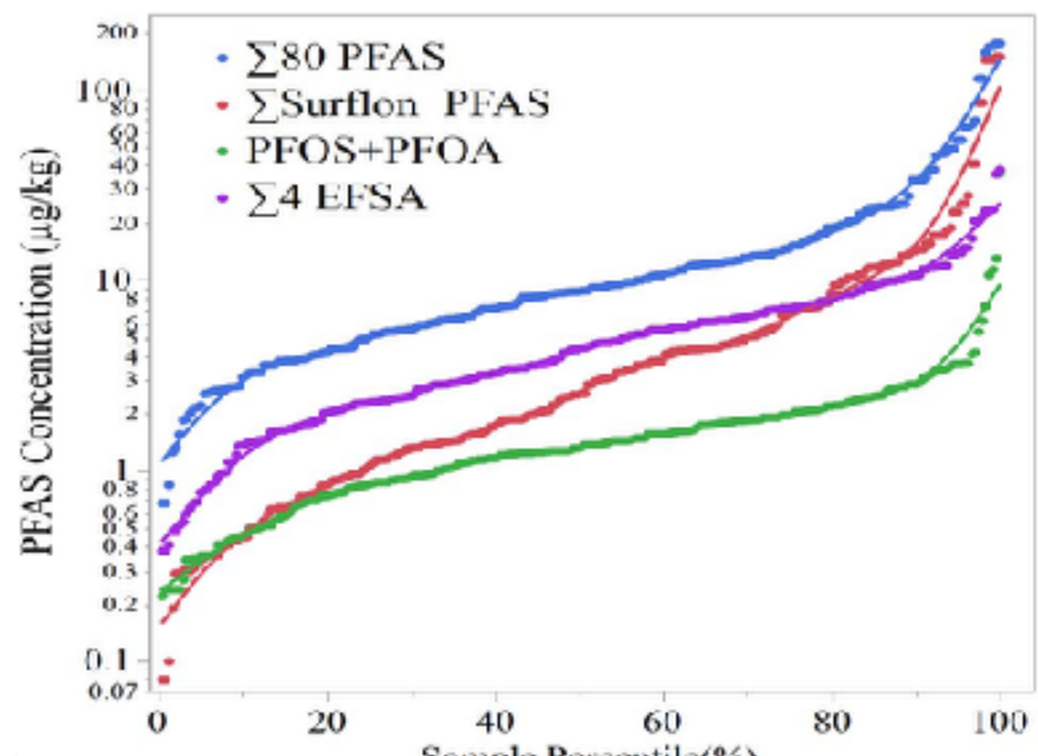
Sols « propres »: 0-2 µg/kg
Sols urbains: 10 µg/kg
Sols non urbains: 6 µg/kg

Source: https://infoterre.brgm.fr/rapports/RP-73455-FR.pdf

Résultats analyses sols

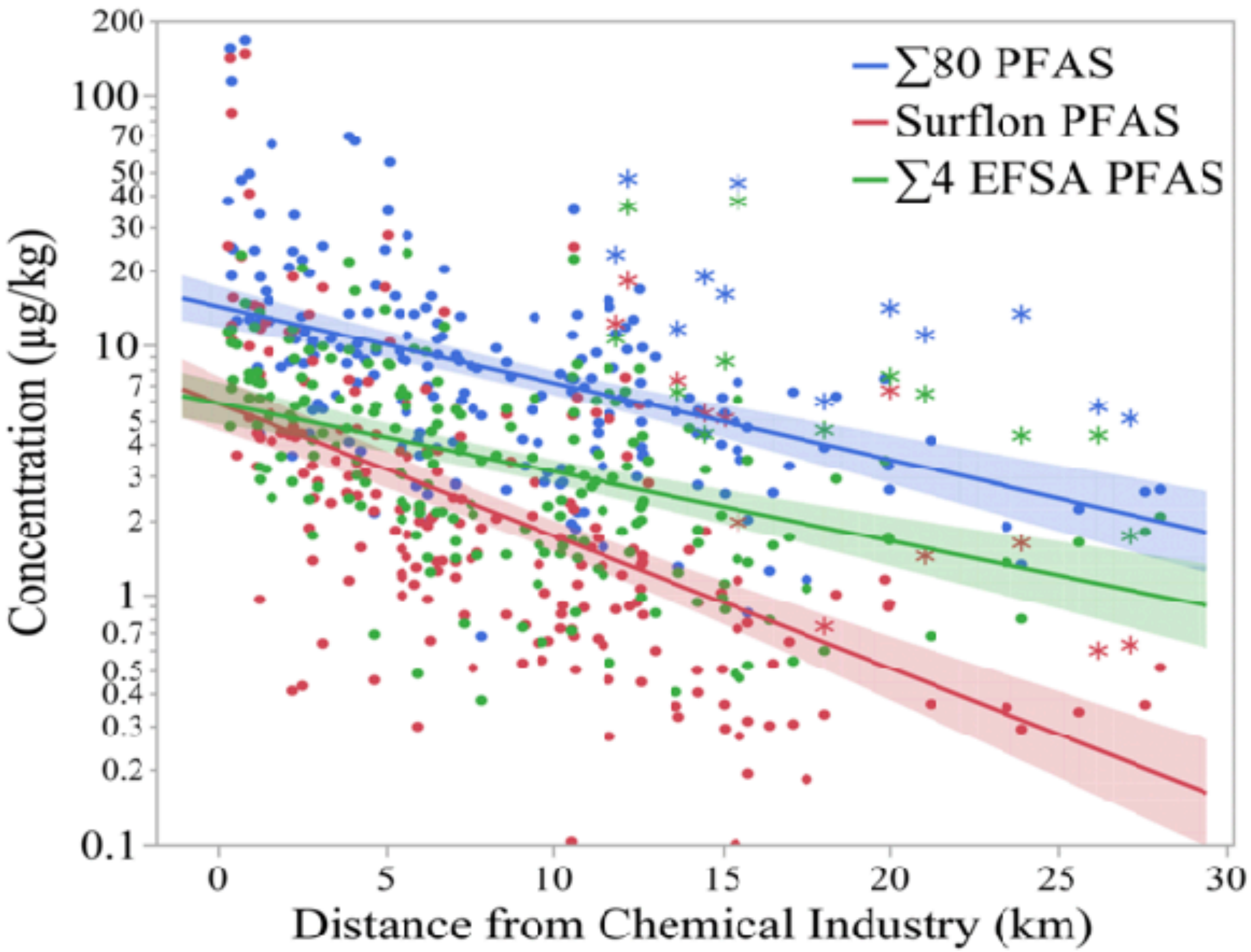






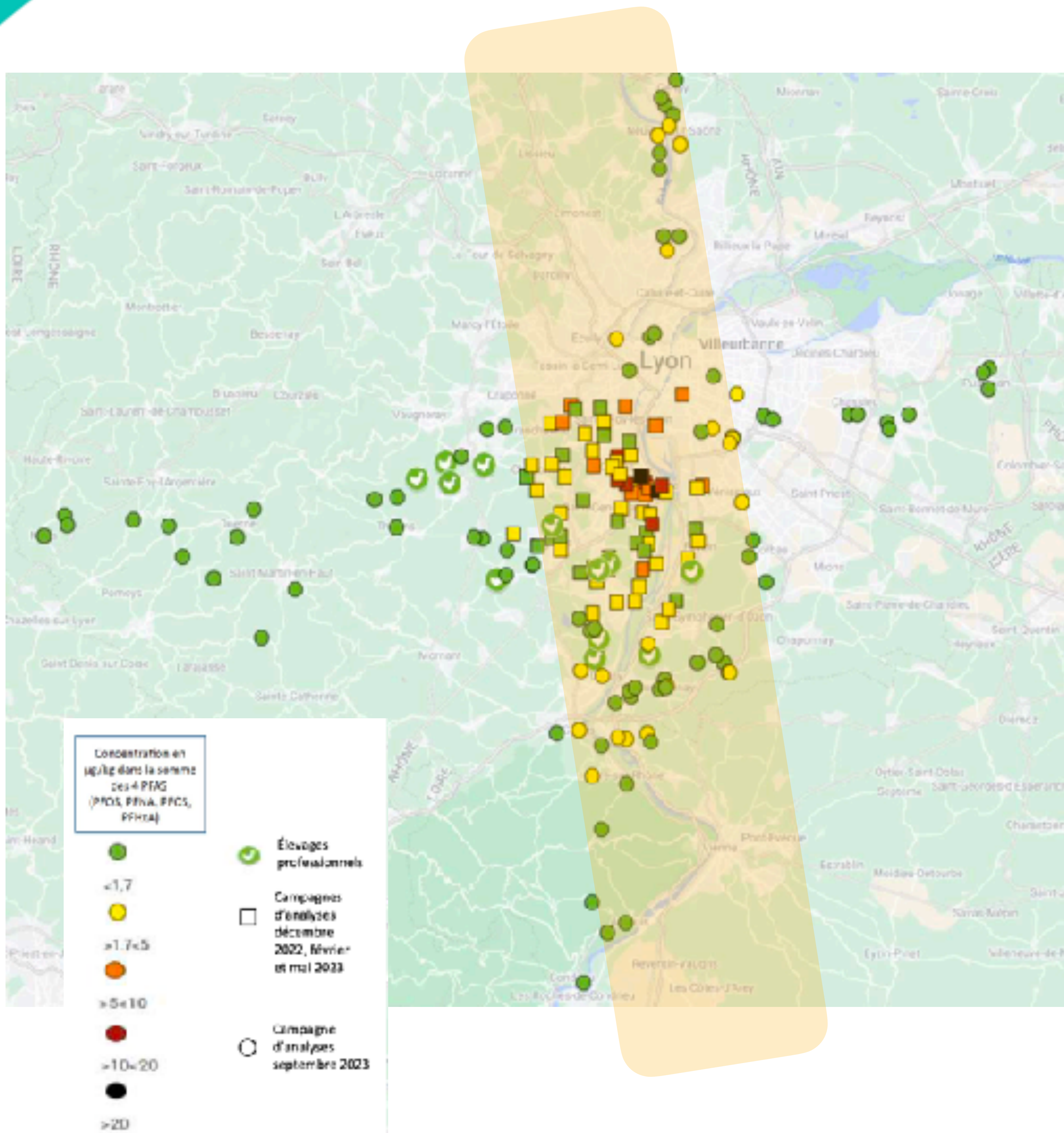
- **40% des échantillons > 10µg/kg**
- **Sols contaminé aux majoritairement par des chaines longues**
- **Contamination importante aux molécules de surflon® en particulier en proximité des usines**

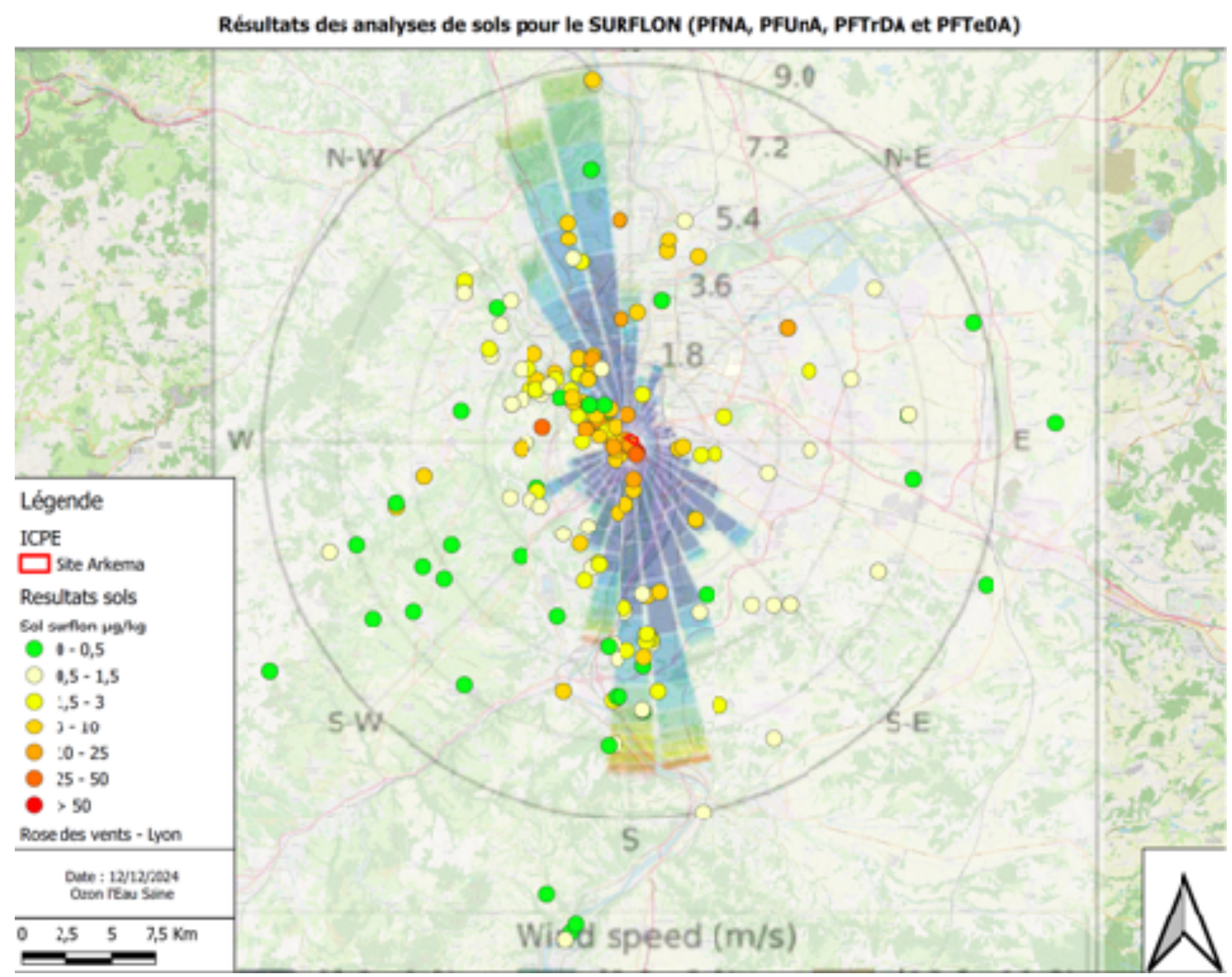
Concentration des sols en fonction de la distance aux usines



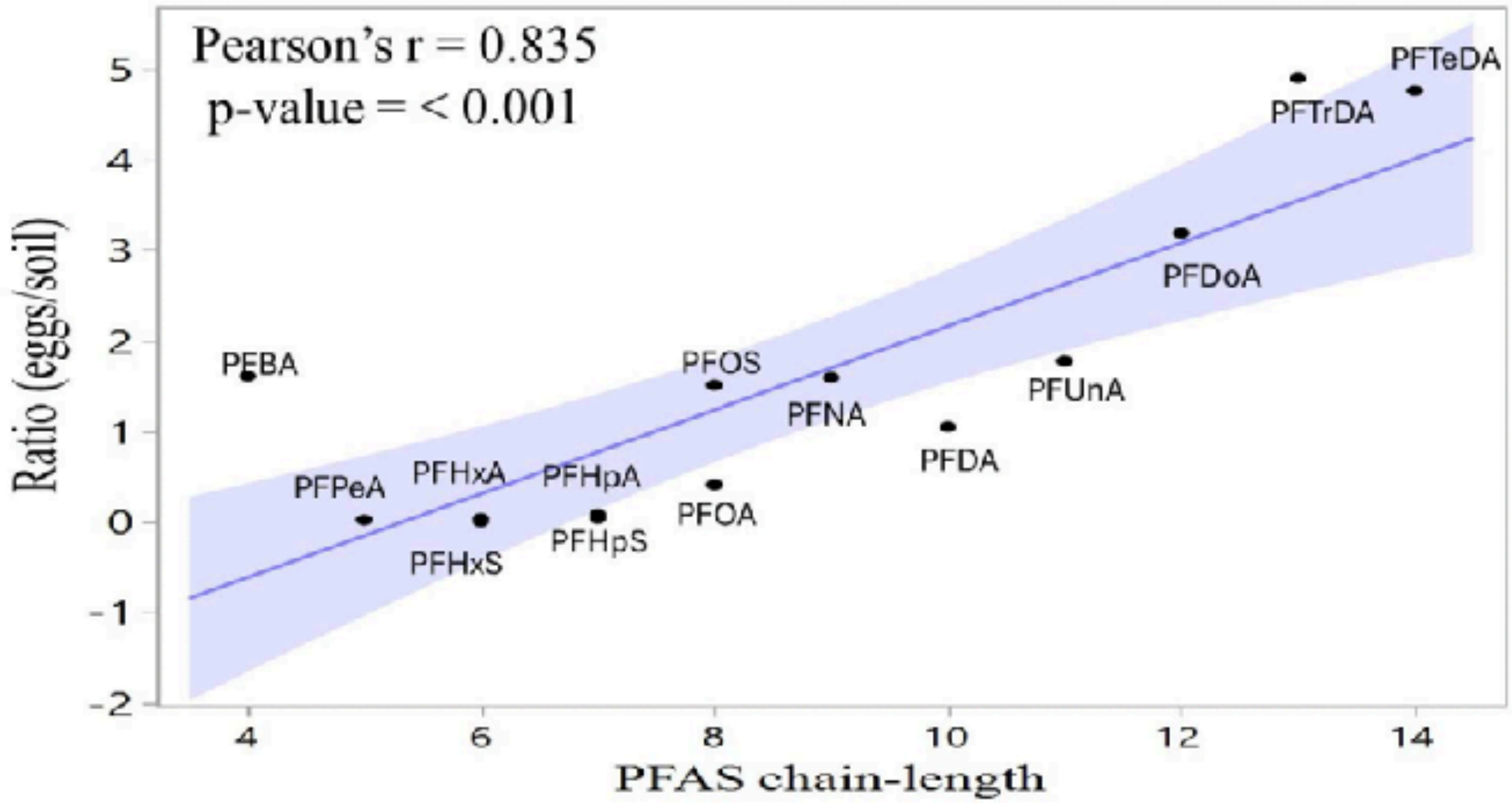
La concentration en Surflon® (chaines longues) diminue avec la distance

Comparaison oeufs /sols





Facteur de bioaccumulation (oeufs)



Plus la longueur de chaine augmente
Plus les PFAS s'accumulent dans les oeufs

Transfert sol-plante

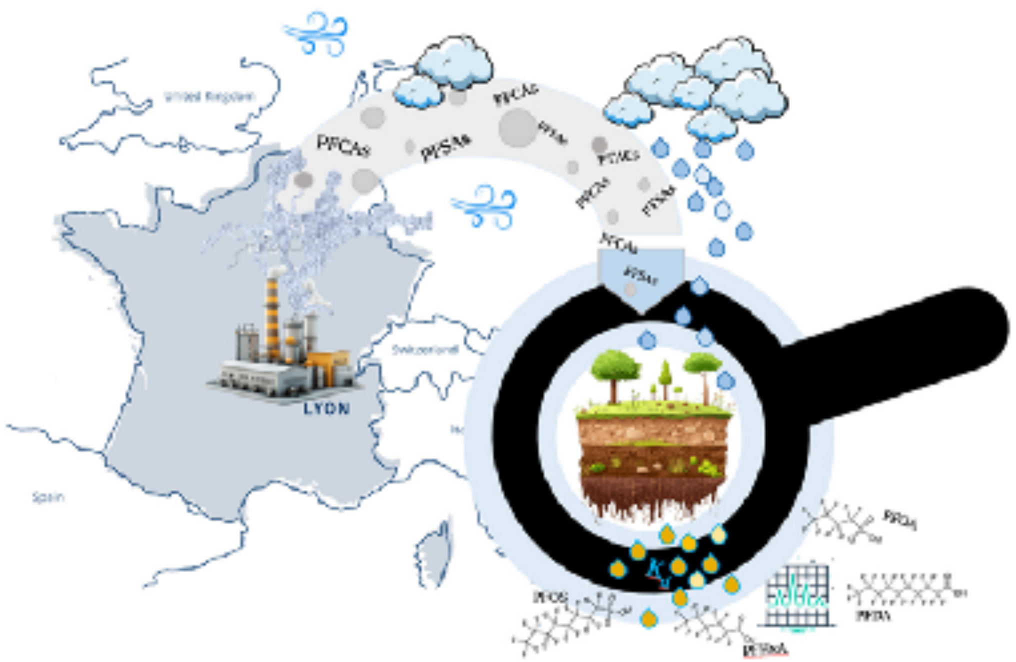
Table 1. Bioaccumulation factors of dominant PFAS (n =79)

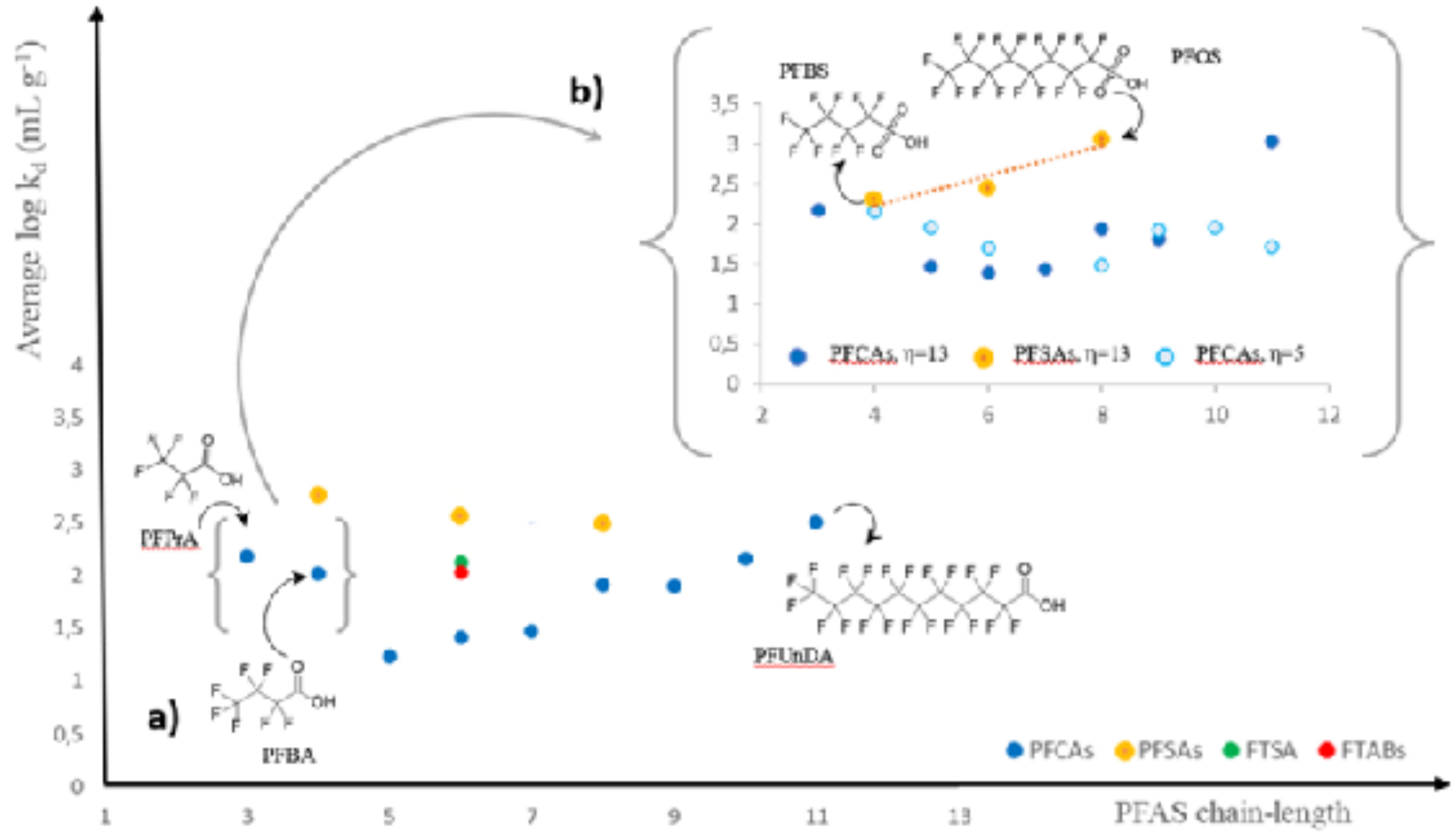
	PFAS	BAF Range	Average BAF
Chaines courtes	PFPrA	0.03–150.2	15.8 ± 26.6
	PFBA	0.5–245.7	10.1 ± 27.3
	PFPeA	0.1–726.8	21.9 ± 107.0
	PFBS	0.01–6.2	0.5 ± 0.9
	PFHxA	0.01–185.6	8.9 ± 28.3
Chaines longues	PFOA	0.3–21.4	2.0 ± 3.1
	PFHxS	0.01–36.4	2.2 ± 5.2
	PFNA	0.02–113.6	3.3 ± 12.9
	PFOS	0.04–49.7	2.7 ± 7.4
	PFUnA	0.0–35.5	1.3 ± 4.7

Plus la longueur de chaine est petite,
plus les PFAS s’accumulent dans les végétaux

Source: Sauvé & al

Mobilité des PFAS (sols)

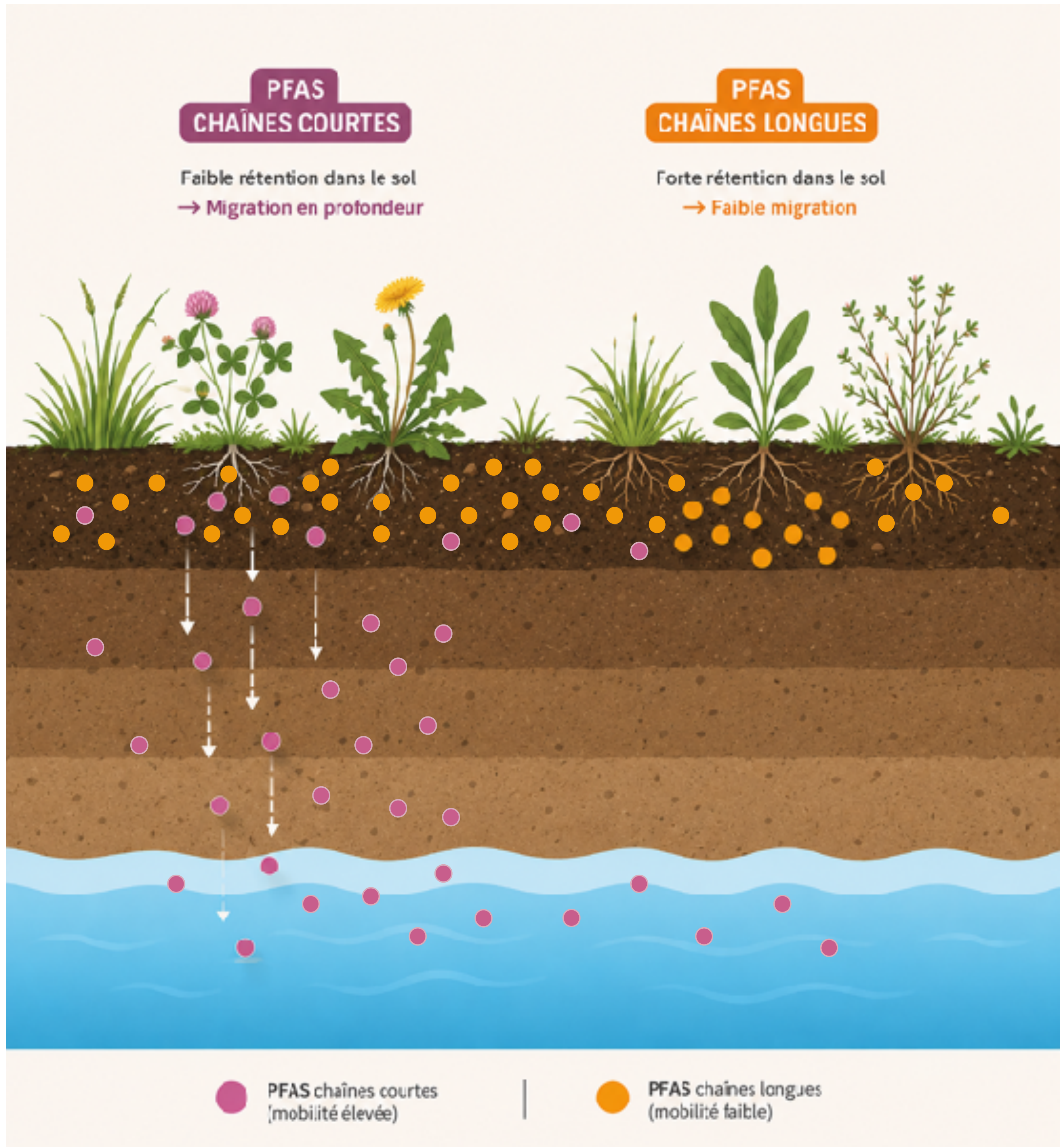




Plus la longueur de chaine augmente, moins les PFAS migrent en profondeur

$$Kd = \frac{[C]_{sol}}{[C]_{eau}}$$

Comportement des PFAS dans les sols



Création d'un institut écocitoyen des pollutions du territoire Lyonnais

Objectifs:

Produire des connaissances scientifiques sur les pollutions, leur mode de diffusion et leurs impacts sur la santé des écosystèmes et des individus.

Rendre ses connaissances actionnables par les parties prenantes

Espace de dialogue entre les acteurs du territoire

Gouvernance collective: Un conseil d'administration structuré autour de différents collèges:

- Scientifiques
- Travailleurs
- Associations
- Praticiens de santé
- Acteurs économiques
- Collectivité

Adhérer à l'institut ?

→ institut.ecocitoyen.lyon@gmail.com