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# PFAS AND PRECURSORS IN BELGIUM: CURRENT STATE AND DATA GATHERING

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Compilation of the information received: from FPS Environment.

# Foreword

This report is produced in the framework of the CIMES decisions of July 2021 which decided to prolong the mandate of the CCIEP PFAS working group. This reports builds on the report that has been published in July 2021 in line with the mandate given by the CCIEP-CIE in 2018 (state of affairs for short-chain PFAS; perspectives including consequences of inaction).

In contrast to the previous version (which focused on data and information of short-chain PFAS) this report has a broader scope to all PFAS substances.
Activities and policy developments are mentioned factually without valuation. The report also proposes some final discussions and perspectives.

This report is accompanied by two annexes: (1) data tables and figures referred to from the text; (2) Confidential information coming from the REACH dossiers than can only be distributed through the BCR.

# Content

# Tables

# 1 Summary

This report presents a non-exhaustive compilation and analysis of the available information and ongoing activities in Belgium about PFAS. The report considers available data on possible/recognized/expected exposures, quantifiable or expected but non-quantifiable risks, expected / possible/probable outcomes, as well as the balance of uncertainties, ambiguities and ignorance. Hazards are not specific to Belgium, so they are more briefly mentioned.

The PFAS regulatory landscape has evolved tremendously over the last years, with several legislations including PFAS norms in their text, up to the point that an EU-level general ban is being prepared. In consequence, this report is useful for recollecting the fragmented information available until now (Regions, Federal level, NEHAP) so BE positions at EU and international levels can be better prepared with up-to-date information, and federal/regional actions can be coordinated or serve as sources of inspiration. Moreover, as for example the water compartment shows, regions are interdependent in terms of PFAS pollution and PFAS measures to take at their level.

Since the developments in Zwijndrecht of 2021 many actions have been taken to increase the knowledge, clean-up and regulatory action on PFAS substances. The regional authorities of Belgium have been conducting many different studies and (bio)monitoring on PFAS, as well as a mapping exercise and risk management of polluted sites. It is of vital importance that this large amount of newly generated data will flow through to the EU-level decision-making under REACH and other PFAS-related regulations. Especially under the current and planned REACH restrictions on PFAS this data will prove to be valuable for the development of these risk management dossiers and to develop strong knowledge-based restriction proposals. This CCIEP working group plays an important role in this data sharing in the form of this report.

With the data and information collected and generated in this report we have identifies some main gaps in knowledge and understanding regarding the PFAS topic. This list can be consulted in the discussion and perspectives section of this report. Even though we list some main concerns, it is important to realize that the topic of PFAS is a large and complex one with many different aspects to be taken into account due to the large number of substances and their widespread uses, together with the specific concerning characteristics of PFAS as a group. Considering this complexity it is impossible to give an exhaustive overview of the challenges regarding these substances. It also clear that there is still a lot of work to be done to ensure that these substances are properly regulated and actions are taken to reduce the emissions and the exposure of these substances to humans and the environment. However, this report illustrates that many things are happening in Belgium to tackle the PFAS pollution.

# 2 PFAS Chemistry

Per- and poly-fluoroalkyl substances (PFAS) are composed of alkyl chains with fluorine substitutions and functional groups attached to them. The alkyl chain is either fully fluorinated (Per) or partly fluorinated (Poly). These fluorinated compounds can be polymerized, creating fluorinated polymers. This is a large group of substances with over 4700 substances described in the OECD[1] inventory, and ECHA inventory containing more than 6800 substances. ECHA's database contains information of over 2 000 individual PFAS on the EU market.

In a recent report by the OECD a new definition of PFAS was proposed:

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*"PFAS are defined as fluorinated substances that contain at least one fully fluorinated methyl or methylene carbon atom (without any H/Cl/Br/I atom attached to it), i.e. with a few noted exceptions, any chemical with at least a perfluorinated methyl group (–CF3) or a perfluorinated methylene group (–CF2–) is a PFAS."*

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All these substances share the common characteristic of a high C-F content. These C-F links are known to be very strong, which gives these substances high thermal and chemical stability, as well as high persistence, repellency to water, oil and grease, and many other properties.

This large group of substances can be divided into subgroups based on characteristics like chain length and the composition of the functional groups (Figure 1). The OECD is has recently published a factsheet which divides the known PFAS substances in 15 groups based on their structure and functional groups[2].

[1] The OECD has a Global PFC Group which has published several reports on PFAS, for more information on this group, see the OECD PFAS webportal (Risk reduction - OECD Portal on Per and Poly Fluorinated Chemicals)
[2] https://www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?cote=env/cbc/mono(2022)1&doclanguage=en


*Figure 1: A comprehensive overview of PFAS groups, their structural traits, examples and notes on whether corresponding common nomenclatures (including acronyms) exist. Source: OECD (2021), Reconciling Terminology of the Universe of Per- and Polyfluoroalkyl Substances: Recommendations and Practical Guidance, OECD Series on Risk Management, No. 61, OECD Publishing, Paris.*

# 3 PFAS Brief Hazards Overview

The present report focuses on the available PFAS information in Belgium, so the hazards aspects are only briefly mentioned here. Hazards are recognized legally under various regulations (see below point 4 ) for some substances (Carc, reprotoxic, lactation hazards, STOT RE, vPvP, PBT, ELOC HH+ENV, Aquatic tox.). An Excel-file containing information from 120 scientific papers on short-chain PFAS (per- and polyfluoroalkyl substances) is available in the Annex of this report (Table 16). The first sheet gives an overview of recently available information on short-chain PFAS from all over the world, regarding human biomonitoring (concentrations in blood, urine, tissues, …) and ecological monitoring (concentrations in air, groundwater, drinking water, soil, …). Information in the table is preceded by a number that refers to the scientific paper in which the information can be found. The numbers corresponding to the scientific papers can be seen in the second sheet. This table is updated each year with the most recent scientific papers and is thus constantly adapted and following the newest information.

There is growing scientific evidence of hazards for many other members of the PFAS group, e.g. :

- Immunotoxicity and developmental concerns (Liew, 2018, Grandjean,2018; DeWitt, 2019)
- Additive effects between PFAS are very likely. Wolf et al. 2014 tested mixtures of PFOA and either PFNA, PFHxA, PFOS, or PFHxS. In vitro response addition and concentration addition at low concentration were observed.
- Children chronic respiratory impairment (Qin, 2017; Timmermann,2017)
- Endocrine disruptors (see e.g. ENDO 2020 abstracts: obesity)
- Accumulation in some edible plants (Klenow et al., 2013; Brendel, 2018).
- Long-range transport potential (Hopkins et al., 2018)
- From correlations appearing in biomonitoring data (see biomonitoring in § 5.6 ) the following hazards rates as well proven, relevant, and significantly associated for PFOS, PFOA, and suspected for part of the short-chain PFAS: 1. Fertility and pregnancy 2. Weight of new-borns at birth 3. Lipid metabolism 4. Immunity after vaccination, immunological development 5. Hormonal development, age at puberty/menarche 6. Thyroid metabolism 7. Onset of menopause.

There are growing concerns that PFAS may increase the occurrence of COVID-19 risk factors because :

- Immunotoxicant activity: correlations to diminished vaccine antibody response to vaccines (Grandjean, 2017, Looker et al., 2014); may reduce infectious disease resistance (NTP, 2016).
- Endocrine-disrupting leading to COVID-19 risk factors (obesity, diabetes,…)

A comprehensive database on PFAS toxicity research[3] is publicly available. It lists relevant toxicity studies on 29 PFAS substances.

The EFSA has conducted an in depth assessment on the human health related risk profile of PFAS substances, which can be consulted on their website[4].

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[3] https://pfastoxdatabase.org/

[4] https://www.efsa.europa.eu/en/efsajournal/pub/6223

Recently the focus of PFAS toxicity research has been focussing on Endocrine Properties, low-dose effects and non-monotonic dose-response curves:

- PFAS ED properties
  - NAPED (see point 4 page 22)
  - Kar et al. 2017: PFASs can compete with T4 for binding to TTR in resulting endocrine disruption. Important structural attributes of PFASs for endocrine disruption were identified.
  - Vagi et al. 2014: Polycystic ovarian syndrome (PCOS) is an endocrine disorder affecting nearly 10% of women of childbearing age. Although the exact etiology of PCOS is unknown, it is characterized by hyperandrogenism, polycystic ovaries, and anovulation. The data suggest that PCOS case-patients may differ from controls in their environmental contaminant profile. PCOS subjects had higher serum concentrations of two PFCs, PFOA and PFOS Low dose effects.
  - Zota et al., 2018: investigated associations between prenatal exposures to polybrominated diphenyl ethers (PBDEs), hydroxylated PBDE metabolites (OH-PBDEs), polychlorinated biphenyls (PCBs), and per- and polyfluorochemicals (PFASs) with repeated biomarker measurements of inflammation and cellular aging in women during pregnancy and the postpartum period.
- Low dose effects:
  - Dixon et al. 2012: Assessed whether perfluorooctanoic acid (PFOA) is estrogenic or antiestrogenic. They use an immature mouse uterotrophic assay and histopathology. Uterine weights were significantly increased in the 0.01 mg/kg PFOA only group.
  - Tucker et al. 2015: Perfluorooctanoic acid (PFOA) is a developmental toxicant in mice, with varied strain outcomes depending on dose and period of exposure. The impact of PFOA on female mouse pubertal development at low doses (≤1 mg/kg) has yet to be determined. Therefore, female offspring from CD-1 and C57Bl/6 dams exposed to PFOA, creating serum concentrations similar to humans, were examined for pubertal onset, including mammary gland development. Pups demonstrated a shorter PFOA elimination half-life than that reported for adult mice. Prenatal exposure to PFOA caused significant mammary developmental delays in female offspring in both strains. Delays started during puberty and persisted into young adulthood; severity was dose-dependent. Also an evaluation of female serum hormone levels and pubertal timing onset revealed no effects of PFOA compared to controls in either strain. These data suggest that the mammary gland is more sensitive to early low level PFOA exposures compared to other pubertal endpoints, regardless of strain.
  - White et al. 2011: Prenatal exposure to perfluorooctanoic acid (PFOA), a ubiquitous industrial surfactant, has been reported to delay mammary gland development in female mouse offspring (F1) and the treated lactating dam (P0) after gestational treatments at 3 and 5 mg PFOA/kg/day. Gestational PFOA exposure induced delays in mammary gland development and/or lactational differentiation across three generations. Chronic, low-dose PFOA exposure in drinking water was also sufficient to alter mammary morphological development in mice, at concentrations approximating those found in contaminated human water supplies.
- Non-monotonic dose response curves
  - Meng et al., 2018: The influence of PFASs on preterm birth (PTB) appears to have a dose-dependent relationship contingent on the metabolite. The PFAS metabolites perfluorooctanoic acid (PFOA) and perfluorohexanesulfonate (PFHxS) had a non-monotonic dose relationship with increased odds for PTB at low to mid exposure ranges but decreased odds at higher exposure range.

- Kim et al. 2018: Many people are exposed to perfluoroalkyl substances (PFASs) because these substances are widely used as industrial products. Although epidemiological studies suggest that PFASs can disrupt thyroid hormones, the association between PFAS exposure and thyroid function remains inconclusive. Therefore, we performed a comprehensive meta-analysis to investigate the association between PFASs exposure and thyroid hormones. Our meta-analysis suggests that PFASs are negatively associated with total T4, and their effect can be different depending on the PFAS concentration. The effect of PFASs can be different according to the concentration. Therefore, we performed a subgroup analysis. Interestingly, PFOS showed a significant correlation with thyroid hormones in the intermediate concentration group (8–16 ng/mL). It was not a typical linear dose-response relationship. Such nonmonotonic or U-shaped dose response is considered to be one of the characteristics of endocrine-disrupting chemicals.

# 4 Current regulatory risk management

*Table 1. PFAS hazards legally recognized*

| Substance | REACH SVHC | POP | CLH |
|---|---|---|---|
| **PFBS (C4) and its salts** | ELOC ENV+HH | | |
| **PFHxS Perfluorohexane-1-sulphonic acid and its salts (C6)<br>ammonium perfluorohexane-1-sulphonate<br>potassium perfluorohexane-1-sulphonate<br>tridecafluorohexanesulphonic acid, compound with 2,2'-iminodiethanol (1:1)** | vPvB | Being considered | |
| **PFHpA (C7)** | | | Being considered |
| **PFOA (C8) pentadecafluorooctanoic acid its salts and PFOA-related compounds** | PFOA: Toxic for reproduction, PBT | X | Carc. 2, Repr. 1B, Lact., Acute Tox. 4, Acute Tox. 4, STOT RE 1, Eye Dam. 1 |
| **PFOS (C8) and derivatives** | | X | perfluorooctane sulfonic acid + potassium perfluorooctanesulfonate (PFOS); and related diethanolamine perfluorooctane sulfonate; ammonium perfluorooctane sulfonate; ammonium heptadecafluorooctanesulfonate; lithium perfluorooctane sulfonate; lithium heptadecafluorooctanesulfonate<br><br>→ Carc. 2, Repr. 1B, Lact., Acute Tox. 4 *, Acute Tox. 4 *, STOT RE 1 liver, Aquatic Chronic 2 |
| **APFO – Ammonium pentadecafluorooctanoate (C8)** | Toxic for reproduction, PBT | | X |

| | | | |
|---|---|---|---|
| **PFNA Perfluorononanoic acid (C-9), and its sodium and ammonium salts PFN-S, PFN-A** | Toxic for reproduction, PBT | | Carc. 2; Repr. 1B; Lact.; Acute Tox. 4; Acute Tox. 4; STOT RE 1; Eye Dam. 1 |
| **PFUnDA henicosafluoroundecanoic acid (C11-PFCA); PFDoDA Tricosafluorododecanoic acid (C12); PFTrDA Pentacosafluorotridecanoic acid (C13); PFTeDA heptacosafluorotetradecanoic acid (C14-PFCA)** | vPvB | | |
| **PFDA nonadecafluorodecanoic acid (C-10) and its sodium and ammonium salts, PFD-A, PFD-S** | Toxic for reproduction, PBT | | Carc2, repr 1B, Lact. |
| **2,3,3,3-tetrafluoro-2-(heptafluoropropoxy)propionic acid, its salts and its acyl halides (HFPO-DA). (Ammonium salt = GENx)** | ELOC ENV+HH | | |

*Table 2 PFAS restrictions under REACH*

| substance | REACH restriction proposals under discussion | REACH restrictions in force |
|---|---|---|
| **perfluorooctanoic acid (PFOA), its salts and PFOA-related substances** | | X<br><br>Note: REACH restriction no more in force since the listing of PFOA in the POP regulation (COMMISSION DELEGATED REGULATION (EU) 2020/784) |
| **following perfluorinated carboxylic acids (C9-14 PFCAs) including their salts and precursors: perfluorononan-1-oic acid (PFNA); nonadecafluorodecanoic acid (PFDA); henicosafluoroundecanoic acid (PFUnDA); tricosafluorododecanoic acid (PFDoDA); pentacosafluorotridecanoic acid (PFTrDA); and heptacosafluorotetradecanoic acid (PFTDA).** | X | |
| **PFHxS, its salts and related substances** | X<br><br>Being considered as POP | |

| | | |
|---|---|---|
| **PFHxA, its salts and related substances**[5] | X | |
| **All PFAS except essential uses** | X (full proposal to be submitted in 2022) | |
| **PFAS in firefighting foams** | X | |
| **PFAS in textiles, leather, apparel** | X | |
| **(3,3,4,4,5,5,6,6,7,7,8,8,8-tridecafluorooctyl)silanetriol and any of its mono-, di- or tri-O- (alkyl) derivatives** | | x |

Presently hazards are legally recognized already for some substances (Table 1) and new proposals are being examined. Several PFAS restrictions are being prepared under REACH (see Table 2). PFAS in drinking water regulation now contains limits for all PFAS (0.5 µg/l) and a subgroup of PFAS. PFOA and PFOS both identified as POP are priority hazardous substances under the Water Framework Directive. Food contact materials regulations already reduced the rare authorisations for PFAS maximum levels for 4 PFAS in foodstuffs of animal origin have been included in a draft EU regulation voted in June 2022[6].

# 5 Available data and on-going studies relevant or specific to BE or by Belgian actors

An overview of the industrial production of PFAS substances, as well as the registered substances under REACH, can be found in Table 1 of the (confidential) Annex II.
In 2021 the 5 member states working on the broad PFAS restriction under REACH have published multiple reports in which they collected information on the different uses and production of PFAS. These reports can be found in the non-confidential annex 1.1.

ECHA has performed a search on its Text Analytics portal to identify all PFAS substances registered by Belgian companies. The complete results of this search can be found in Table 7 of the confidential Annex II.

*Table 3: Overview of EC numbers that have been registered by BE companies*

[5] For a list of the related substances, see the annex to the information note on the restriction proposal: https://echa.europa.eu/documents/10162/7da473c1-7f27-df34-9e6a-46152ef10d4b

[6] More information at: https://www.health.belgium.be/nl/europese-maximumgehalten-voor-pfas-verontreiniging-levensmiddelen

| File Owner Name | EC Number (RIT) | CAS Number (RIT) |
|---|---|---|
| **3M Belgium BVBA/SPRL** | 206-420-2 | 338-83-0 |
| | 206-792-6 | 375-72-4 |
| | 206-841-1 | 382-28-5 |
| | 207-019-5 | 422-61-7 |
| | 252-043-1 | 34454-97-2 |
| | 266-733-5 | 67584-55-8 |
| | 266-737-7 | 67584-59-2 |
| | 278-305-5 | 75768-65-9 |
| | 422-100-7 | 102061-82-5 |
| | 436-710-6 | 756-13-8 |
| | 473-390-7 | N/A |
| | 614-396-3 | 68298-12-4 |
| | 807-113-1 | 3709-71-5 |
| | 908-205-5 | N/A |
| | 920-778-3 | N/A |
| | 939-511-7 | N/A |
| **3M Europe N.V.** | 415-300-0 | 90076-65-6 |
| | 422-270-2 | N/A |
| | 436-710-6 | 756-13-8 |
| | 468-740-0 | N/A |
| **Agfa-Gevaert N.V.** | 940-889-0 | 1770781-13-9 |
| **Evonik Antwerpen NV** | 700-476-6 | 119895-68-0 |
| **Ferro Performance Pigments Bel-gium N.V.** | 201-806-7 | 88-17-5 |
| | 268-734-6 | 68134-22-5 |
| **Galco** | 200-871-9 | 75-45-6 |
| **Minakem High Potent s.a.** | 943-624-7 | N/A |

| | | |
|---|---|---|
| **N.V. Ajinomoto OmniChem S.A.** | 445-820-3 | N/A |
| | 638-777-9 | 376348-78-6 |
| | 638-778-4 | 376348-77-5 |
| | 642-947-8 | 415927-29-6 |
| | 943-624-7 | N/A |
| **NYCO-STPC** | 805-807-9 | 169051-76-7 |
| **SHAMROCK TECHNOLOGIES BVBA** | 204-126-9 | 116-14-3 |
| **Zoetis Belgium S.A.** | 202-635-0 | 98-08-8 |
| | 829-719-5 | 1190865-44-1 |

## 5.1 Import

Public information regarding the import of PFAS compounds into Belgium is limited. Import of articles containing PFAS is an important source of PFAS in Belgium, although numbers are lacking. Especially articles imported from countries outside of the EU not regulating PFAS may have several PFAS incorporated. Placing on the market (including import) of SVHC containing articles (above 0.1%) have to be notified to ECHA since 05/01/2021 using the SCIP database, therefore data on SVHC identified PFAS substances that are imported might become available soon.

There is some information available on the import of PFAS containing textiles and food products (see 6.2.4), however this is limited to PFHxA and its related substances no info is available for other PFAS substances in these textiles. The Annex XV report for the restriction of PFHxA has estimated that 58.7% of uses of PFHxA related substances are attributed to the import of clothing outside of the EU.

In some countries outside and within the EU, PFOA can be used in some specific applications including in textiles for the protection of workers, in invasive and implantable medical devices and in the production of polymers like PTFE as a processing aid. It has been estimated that around 3-16 tons of PFOA were imported into the EU this way (KEMI report 2015). These specific exemptions are now time-limited by the POP regulation  which bans  the placing on the market (including import) of PFOA, its salts and related compounds since July 2020.

The Netherlands has a GenX (which is a short-chain PFAS substance) production site, which is known to export GenX containing wastewater to Belgian to be treated in the Antwerp Indaver site. In 2019, a total of 15 tons of GenX contaminated water, produced in Italy by Chemours, has been treated by the Indaver at its Antwerp location.

## 5.2 Industrial Production, use and emissions

### 5.2.1 Industrial production

Since the phase-out of PFOS production by 3M in 2001, production of long-chain PFAS is estimated to have declined in Belgium to negligible amounts (Wang et al., 2014). Wang et al. (2014) estimated that 50-160 tons of PFOS based products were being produced in 2003 in Belgium, Germany, Italy and Japan, and 73-162 tonnes in 2005. They estimated that this production has since declined to negligible amounts due to ongoing legislative actions (i.e. REACH and the Stockholm convention).

Data on the production of short-chain PFAS in Belgium is scarce. In a report by the Norwegian government on PFHxS, 3M has stated they do not produce PFHxS or related substances on the Belgian site (BiPRO, 2018; Table 1 of confidential Annex). Whether they produce other short-chain PFAS is not known with high certainty (see Annex I for other possible production/uses). In the same report from Norway, Daikin and Solvay (also having BE production sites) have been contacted as well, with Daikin not responding and Solvay stating no production of the PFHxS or related compounds happening on the Belgian sites (BiPRO, 2018; Table 1 of confidential Annex).

A Recent study by Glüge et al. (2020) has listed some companies known to produce PFAS, being 3M, Chemours (DuPont), F2 Chemicals and Solvay. Apart from F2 chemicals, all the above-listed companies have production sites in Belgium, indicating they could be producing PFAS compounds. OVAM has stated in their report on PFAS pollution in soil that there are PTFE (known as Teflon) producing companies present in Mechelen (most likely Chemours) and Zwijndrecht (most likely 3M) (OVAM report on PFAS, 2018).

Chemours (DuPont) is a well-known producer of fluorinated products. This company also phased-out the production of C8 fluorinated compounds several years ago, which they have replaced with the production of 4:2 and 6:2 FTOH derived products. These new products are repellents and surfactants based on short-chain PFCAs (Danish Ministry of the Environment, 2015). It is not certain whether these substances are produced at the Belgian Chemours sites.

On the registered substances database, we also found the production of Tetrafluoroethylene, which is used and/or produced by Shamrock technologies (Tongeren) and SCAS Europe (Diegem). Furthermore, we found the production of trifluoromethane by Nippon Gases Belgium (Schoten). It must be noted that it is not certain whether these companies actually produce PFAS substances at the Belgian sites.

The annual production of PFAS identified as POP has to be reported pursuant article 13 of the POP regulation. Regional measures will be needed to get this info from manufacturers based in Belgium. Initiatives have already started in Brussels.

No producer of PFAS has been identified, to date, in Wallonia and Brussels.

Publicly available information (on the SIN-list of ChemSec) on the production of PFAS substances (other than polymers) in Belgium indicates the production of PFBS (CAS 29420-49-3), PTPA (CAS 338-83-0) and FC-3284 (CAS 382-28-5) at the Belgian 3M site in Diegem.

Other Belgian companies have registered several PFAS substances, some are only single representatives for importing substances on the European market.

In July 2021 the Member States working on the general PFAS restriction proposal have published several reports on a range of PFAS uses, including a report on the production of PFAS and PFAS polymers. In this report the authors have found that in 2018 up to 8% of the Global Market share in fluopolymer, F-gas and other PFAS is produced by Solvay in Belgium[7].

[7] Fluoroplastics - AGC Chemicals Europe (agcce.com)

**3M Zwijndrecht**

On the website of 3M, it is indicated that the production site of 3M in Zwijndrecht mainly produces semi-finished products for other 3M branches. Examples include adhesives for Scotch® tapes, high-quality synthetic rubbers for the automotive and chemical industries, and coolants for the electronics sector. The website also indicates that 3M Zwijndrecht has a production line for the Novec™ 1230, which is a fluorinated ketone that is used in firefighting foams.

In the environmental permit granted to 3M in 2020 (see section 6.2.3.1.), it is stated that 3M produces the following:

- Max 3.300 tonnes/year (crude) fluorinated organic chemicals in building 036 by electrofluorination
- Max 4.500 tonnes/year (crude) fluorinated organic chemicals in building 016 by electrofluorination
- Max 5.000 tonnes/year fluorinated organic chemicals in building 036 by batch processing for purification and/or reprocessing of (crude) products from electrofluorination
- Max 10.150 tonnes/year of fluorinated organic chemicals in building 016 and 003 by batch processing for purification and/or reprocessing of (crude) products from electrofluorination, ow which 9000 tonnes/year production of fluorinated organic compounds in building 003
- Max 4.000 tonnes/year production of fluoroelastomers in buildings 002, 032, and labs

The permit also mentions a storage capacity of 1000 tonnes of fluoroelastomers

Other potential production sites:

- Chemours Kallo: according to industry, this is only an administrative site
- Chemours Machelen:
  - preparation of mixtures imported from the Netherlands that are sold for coatings manufacturing

### 5.2.2 Industrial and professional uses

**Use of firefighting foams (AFFF)**

Because of the capacity to create a film layer with high repellent properties, which remains stable at high temperatures, PFAS are interesting compounds to use in firefighting foams in civil, aeronautic, and military settings. Since the use of PFOA and PFOS is now strictly regulated under the POP regulation, other (short-chain) PFAS substances have been used as substitutes.

VITO has been analyzing the presence of PFAS in firefighting foams imported from the UK, Spain and France since 2016. The detection limit for the compounds was set at 5 mg/kg from 2017 onward, however due to the restriction of PFOA at 25 µg/kg, the detection limit has been set at 10 µg/kg from 2018 onward. Up to 25 compounds have been measured, including short-chain compounds like PFHxS and PFHxA.

The Annex XV report on the restriction proposal of PFHxA substances has estimated that about 3000 t/a of PFHxA precursors are used in firefighting foams in the EU, which translates to roughly 77 t/a in Belgium.

**Industrial galvanization**

In Europe, PFOS can be used as mist suppressants for the non-decorative metal plating (hard chromium plating) industry to prevent worker exposure to chrome (VI). It was used in closed-loop systems until its phase-out in 2015 in Belgium (Stockholm Convention, 2016). The estimated use until then was 229 kg/year. PFOS has been substituted by fumetrol (6:2 FTS), which is a 6-carbon PFCA-precursor. Several salts of the 4-carbon PFBS are used as a spray mist inhibitor for the chromium galvanic industry (Lassen et al., 2017).

Environmental permit data from Flanders has indicated that there used to be the use of PFOS in galvanization by Sabena Technics, Teneco, and Picanol. Environmental permits from Picanol have indicated that there were still emissions of PFOS in 2014, even though the company switched to non-PFOS alternatives in 2014. Emission data from VMM show that Picanol has emitted PFBA into surface water in 2020.

When the ban on PFOS use in Flanders was adopted, 3 companies indicated they used PFOS as a mist suppressant, Sabena Technics, Belcroom, and Tenneco. All these companies have indicated they now use PFOS-free alternatives.

**Use in building materials**

PFHxA are added in different kinds of building materials like paints (to improve flow, wetting, and leveling, PFAS can be present in concentrations up to 0.05% (ECHA 2018), in coatings, use in the protection of building materials against weather influences. Furthermore, glasses and transparent polymer panels used in the solar sector or in transparent building constructions are coated with perfluorinated substances according to the Annex XV report on PFHxA. PFAS are also used in coatings with fluorosurfactants on roofing and frontages on buildings, which indicates a direct exposure to the environment (stated in the Annex XV report of the PFHxA restriction). In the Annex XV report on PFHxA, it has been estimated that the tonnage range of PFHxA used in these applications is < 1000 tons per year for the EU. Other PFAS substances are used in construction as well, we refer to the German report on SVHCs in the environment (Knepper et al., 2020), which provides an overview of PFAS used in products of the building industry. Lassen et al. (2017) have estimated that a volume of 5-10 tonnes/year of PFBS-moieties are used in surface treatment of porous hard surfaces like concrete, grout and granite, which translates to roughly 0.13-0.26 tonnes/year for Belgium.

In April 2021, a report by the Green Science Policy Institute (Rojello et al., 2021) was published, which lists several PFAS uses in the building industry (roofing, coating, solar panels, flooring, glass, artificial turf, etc.).

**Electronic devices**

The company Advanced Circuit Boards (Dendermonde), which produces printed circuit boards, used PFOS in the past in several processes (through(-hole) metallization, electroless nickel dipped gold, chemical cleaning inner layers resist-assist, multiband, chemical tin/chemical silver, pre-treatment outer layers, acid cleaner line, and V-bond). The company now uses PFOS)-alternatives for these processes. The company 3M produces semi-finalised coatings used in electronics at its site in Zwijndrecht, these coatings most likely contain perfluorinated substances.

**Industrial use in Brussels**

In 2013, a study was conducted on the possibly still existing PFOS use in Brussels Industry (Belgium FOD Health, FC and Environment, 2018). The study contacted several companies that are known to use PFOS in the past. Companies producing anti-reflecting coatings, water vapor repellent treatment for galvanization, and companies producing and storing PFOS. The companies that replied stated they no longer use or store PFOS in their Brussels facilities.

### 5.2.3 Industrial emissions

Data on industrial emissions are scarce. Discharge data from textile companies from 2007 give an idea of emissions by these companies (Table 4). Emissions of the waste treatment company Indaver are provided as well (Table 5) although important to note here is that these data might be outdated and the permits have been reviewed.

*Table 4 Data on the discharge of PFAS substances by Flemish textile companies from 2007.Source: Derden et al. (2010).*

| parameter | concentratie [µg/l] | | | aantal waarnemingen |
|---|---|---|---|---|
| | minimum | maximum | gemiddelde | |
| **PFBS** | **0,3** | **50,5** | **23,0** | **5** |
| **PFHA** | **0,2** | **15,5** | **2,1** | **9** |
| **PFOA** | **0,3** | **11,6** | **3,8** | **21** |
| PFNA | 0,0 | 5,6 | 2,2 | 17 |
| PFHpA | 0,0 | 4,3 | 0,8 | 10 |
| PFuDA | 0,0 | 3,4 | 0,7 | 6 |
| **PFOS** | **0,0** | **3,0** | **0,7** | **6** |
| PFDA | 0,0 | 2,8 | 0,9 | 13 |
| PFC5A | 0,2 | 0,8 | 0,4 | 3 |
| PFC14A | 0,2 | 0,6 | 0,4 | 2 |
| PFDoA | 0,0 | 0,6 | 0,2 | 3 |
| PFHS | 0,3 | 0,3 | 0,3 | 2 |
| FOSA | 0,0 | 0,3 | 0,2 | 1 |
| PFBA | 0,1 | 0,2 | 0,2 | 3 |

BRON: Centexbel, 2009a

*Table 5 PFAS content of Wastewater from Indaver, for the MKN/IC/RC (environmental quality norm/criterion for classification/reporting limit) column, only PFOS and PFOA have values in the second and third column because only these substances have an MKN (environmental quality norm).*

| Substance | MKN/IC/RG (µg/l) | MKN max (µg/l) | Threshold value for permit (µg/l) | Yearly average (µg/l) | Max (µg/l) |
|---|---|---|---|---|---|
| **PFOA** | 0.00048 | - | 250 | 0.96 | 2.29 |
| **PFOS** | 0.00065 | 36 | 30 | 0.7 | 2.59 |
| **PFPeA** | - | - | 4000 | 4.51 | 8.54 |
| **PFHxA** | - | - | 60 | 4.43 | 10.50 |
| **PFHpA** | - | - | 20 | 0.73 | 1.38 |
| **PFBS** | - | - | 4000 | 24 | 109 |
| **PFBA** | - | - | - | 336 | 1326 |
| **PFHxS** | - | - | 20 | 0.71 | 1.43 |
| **PFOS-equivalent** | 0.00065 | 36 | | 9.9 | 34.77 |

Source: Environmental permit rapport from Indaver (2019)

**Global emissions**

Boucher et al (2019) have estimated the global emissions of several C4-C10 PFAS compounds into the environment. The authors calculate that, between 1958 and 2015, total emissions from PFHxS are 120-1022 metric tons. The same study predicts that emissions from PFHxS from product use and disposal will range between 1-21 tons, and degradation of precursors will be 1-66 tons between 2016 and 2030. Furthermore, they have sampled and modelled the PFHxS content in oceanic surface water and found that, for the Belgian latitude, concentrations range from 5-35 pg/l.

The OECD published a report[8] in 2015 providing data on Global and Regional emissions of several PFCA substances.

#### 5.2.3.1 Environment permits

[8] https://www.oecd.org/chemicalsafety/risk-management/Working%20Towards%20a%20Global%20Emission%20Inventory%20of%20PFAS.pdf

The VMM has data on PFAS emissions in water from industrial sites and WWTPs from Flanders, measured from 2018 through 2020. These measurements were conducted on treated wastewater streams, which either end up in the surface water or go to sewage.

Over 200 industrial locations have been sampled and found to emit PFAS substances. Of the more than 10 000 samples, over 60 measuring samples had PFAS concentrations exceeding the 36 µg/L maximum limits for PFOS in surface water. These high values were mainly PFBS and PFBA values from waste treatment, industrial textile treatment, and the production of glue. Over 500 measurements found PFAS levels exceeding 1 µg/L of one of 8 PFAS substances (PFBS, PFBA, PFHpA, PFHxA, PFHxS, PFOA, PFOS, and PFPA). The main activities at these sampling points are industrial washing, waste treatment, textile treatment, production of chemical compounds, and the production of glue. Over 1700 samples exceeded 0.1 µg/L for one PFAS, which is the drinking water norm for the sum of 20 PFAS.

Some of the wastewater streams that have been sampled go through sewage, which ends up in WWTP. However, since it is known that PFAS substances are not efficiently removed from water during WWTP treatment, we can say with high confidence that the measured concentrations of PFAS in all the samples go directly into the environment (as arrowhead degradation products).

These measurements on PFAS conducted by VMM from the period of 2018-2020 can be consulted in the Confidential Annex document (Table 6), as well as data on the annual emissions (Table 6 of the Confidential Annex).

When companies in Flanders have an emission level value for PFOS, PFOA, and 'sum PFAS' in their permit, they have to measure those components in their wastewater once a year on their budget (See Table 11 footnote for more detail).

**3M Zwijndrecht**

An environmental permit for the 3M site in Zwijndrecht has been granted in September 2020. The norms for emissions requested by 3M, and proposed by VMM can be found in the following table (Table 6). However, this permit has been modified in July 2021 with lower concentration limits.

*Table 6 emission norms as granted to 3M Zwijndrecht in September 2020*

| | Permit (µg/l) | Requested by 3M (µg/l) | Proposal by VMM (µg/l) |
|---|---|---|---|
| **PFBS** | / | 3700 | 3.700 µg/l until 31/06/2022 |
| **PFDA** | / | 10 | / |
| **PFHpA** | / | 15 | 15 µg/l until 31/06/2022 |
| **PFHxA** | / | 30 | 30 µg/l until 31/06/2022 |
| **PFHxS** | / | 40 | 40 µg/l until 31/06/2022 |
| **PFNA** | / | 8 | / |
| **PFOA** | 220 | 40 | 40 µg/l until 31/06/2022 |
| **PFOS** | 30 | 30 until 31/06/2022 – 2 from 01/07/2022 | 30 µg/l until 31/06/2022 – 1 from 01/07/2022 |
| **PFOSA** | / | 10 | 10 µg/l until 31/06/2022 |
| **PFPA** | / | 32 | 32 µg/l until 31/06/2022 |
| **PFUnA** | / | 10 | / |
| **PFBA** | / | 5000 | 5000 µg/l until 31/06/2022 |

#### *5.2.3.2 PRTR*

Presently only the following substances are on the register:

- Under inorganic compounds: Total fluorides (Total F)
    - See Tables 13 and 14 in Annex I

Under Greenhouse gasses: Perfluorocarbons (PFC)

- 19.6 tons were emitted into the air by 3M in 2017
- 5 tons of fluorides (as toral F) emitted by 3M in water in 2017

In the future, it could be considered to introduce PFAS in the PRTR registry.

### 5.2.4 Consumer uses

Per- and polyfluoroalkyl substances are produced for a multitude of industrial and consumer uses, due to their water, dirt, and fat repellent properties. The paper of Glüge et al. (2020) provides a comprehensive, global overview on the uses of PFAS. Some of the most important uses regarding Belgium are summed up below.

**Textiles**

PFAS are widely used as coatings on textile products to create a water, oil, and dirt-repellent layer on these products. Among others, they are being used in clothing, carpets, and umbrellas. A report by Sweden has shown that up to 15% of the total weight of synthetic carpets could be attributed to PFAS (KEMI, 2015). One commonly used product is the Gore-Tex®, which makes materials water repellent and breathable, which is interesting for use in outdoor clothing and tents.

The Annex XV report of the PFHxA restriction proposal (ECHA, 2019) has reported that about 45000 t/a of fluoropolymers are currently used in the EU, which can be extrapolated (based on population density) to an estimated 1161 t/a for Belgium. These polymers are mainly used as finishing agents, and repellents in textiles and papers and are important in the manufacturing of machine parts in the automotive- and aviation industry. The same report also estimated a total of 55 000 tons/year of PFHxA precursors (like for example 6:2 acrylates) originate from textile treatment. 75% of these used precursors can be found in imported textiles from outside of the EU. When we extrapolate this number to Belgium, we can estimate Belgium has an import of over 1000 tons per year of PFHxA precursors from outside of the EU.

Releases into the environment from use in textiles have been estimated in the Annex XV report (Table 7). Especially the release of PFHxA precursor substances from clothing is shown to be an important source of pollution. Emissions over the 20 years are expected to add up to 3240 – 68400 tons for the EU, which translates to 83.59 – 1764.72 tons for Belgium.

According to the Annex XV report on PFBS, the main application of PFBS-related substances is in the protection of leather, textiles, and carpets. The substances used mainly are side-chain fluorinated polymers as a replacement for the phased-out PFOS-related substances. The total tonnage of these PFBS-related substances has been estimated at 20-60 tons/ year for the EU (Lassen et al., 2017), which translates to 0.5-1.5 tons/year for Belgium.

The use of PFOA, its salts, and related compounds is still allowed for use in textiles for the protection of workers until 4 July 2023.

*Table 7 Releases of C6 fluoropolymers and related substances from textiles estimated for Belgium, based on data from the PFHxA Annex XV report.*

| Subsector | Release of C6 fluoropolymers (min-max t/a) | Release of C6-related substances (min-max t/a) |
|---|---|---|
| **Clothing and textiles except outdoor and occupational** | 0.69 – 1.72 | 3.94 – 83.83 |
| **Outdoor clothing** | 0.06 – 0.15 | 0.11 – 2.22 |
| **Occupational wear** | 0.04 – 0.1 | 0.07 – 1.41 |
| **Carpets and other textile floor coverings** | 0.08 – 0.2 | 0.06 – 0.77 |
| **Industrial textile fabrics** | 0.07 – 0.18 | 0 |

**Paper and Food contact materials**

In food packaging, PFAS are used to make materials water, fat, and dirt repellent. Products like backing papers, pizza boxes, etc. are known to contain PFAS substances. Apart from their use in food contact materials, these compounds are also used in photographic paper, post-its, etc.

For the Annex XV dossier of PFHxA (ECHA, 2019), data were evaluated from the UN Comtrade database, which showed that 47 000 tons of greaseproof paper were used in the EU in 2018, which translates to roughly 1212,6 tons for Belgium. The industry has stated that 0.3 -1.5% of these materials contain side-chain fluorinated polymers, which would mean a total of approximately 3.64 – 18.19 tons are imported into Belgium. It is estimated that, for the EU, 235 – 470 kg of PFHxA-related substances are emitted into the environment per year during the service life of these materials (which translates to 6 kg – 12 kg for Belgium), and an additional release of 2.5 tons per year via landfills (64.5 kg for Belgium). Similar estimations have been done for AFFF, cosmetics, printing ink, and chrome plating in the Annex XV dossier.

**Cosmetics**

PFAS are used in various cosmetics products for making cremes and lotions water repellent, they are also used as anti-caking agents, solvents, and preservatives. The Annex XV dossier on PFHxA has reported that concentrations of up to 6500 µg/kg can be found in cosmetic products.

**Other articles and mixtures**

A study by Herzke et al. (2012) on the presence of PFAS in mixtures and articles, has found numerous PFAS in all but three of their sampled products. Furthermore, they found that PFBA (short-chain), PFHxS (short-chain), and PFOS were the most commonly found PFAS.

PFAS mixtures are possibly imported from the Netherlands that are sold for coatings manufacturing.

The above-mentioned uses in consumer products mainly focused on the use of PFHxA, however, a vast amount of other short-chain PFAS, which are not yet being regulated, are predicted to follow pathways similar to the PFHxA pathways. Data is available on PFHxS, which is undergoing a restriction process at the EU level (Final RAC and SEAC opinions were published 11/11/2020) and is being considered as a POP at the international level. It is shown that this substance is also omnipresent in numerous consumer products and articles (Table 8), therefore indicating this product is being emitted into the environment on a global scale due to its persistency and long-range transport as well.

PFBS and its salts are known to be used in a multitude of articles. The salt KPFBS is registered at 100-1000 tons/year manufacture and import in the EU. Its main application is as a flame retardant in polycarbonate, which is used in electrical and electronical equipment (Lassen et al., 2017). It has been estimated that a large portion of KPFBS enters the EU via the import of electronic equipment from Asia (Lassen et al., 2017). Furthermore, a PFBS-related substance (CAS 220689-12-3) is known to be used as an anti-static additive for plastics.

A well-known use of PFAS substances in articles is their use as coatings in cooking wares. The PFAS substances commonly used in these wares are the ammonium salts of hexafluoropropylene oxide dimer acid (known as HFPO-DA, or GenX) which is short-chain PFAS and is used for the production of PTFE, which is a fluoropolymer commonly sold under the name Teflon, which is used in non-stick cooking ware.

*Table 8 Overview of PFHxS detected in consumer products and articles, published in the SVHC restriction proposal of PFHxS under REACH.*

| Study | Product category | Product name | Unit | PFHxS | PFOS |
|---|---|---|---|---|---|
| Herzke et al. (2012) | Paints | Jotun wetroom filler | µg/kg | 0.53 | 5.8 |
| Herzke et al. (2012) | Paints | PCI Lastogum | µg/kg | 0.31 | 4.76 |
| Herzke et al. (2012) | Non-stick ware | Privilege pan | µg/kg | 0.8 | 24.9 |
| Herzke et al. (2012) | Non-stick ware | Rast camping pan | µg/kg | 14.1 | 213 |
| Herzke et al. (2012) | Non-stick ware | IKEA pan. 28 cm. Kavalkad | µg/kg | 1.86 | 14.2 |
| Herzke et al. (2012) | Non-stick ware | Eva cake form | µg/kg | 11.9 | 415 |
| Herzke et al. (2012) | Textiles, leather, carpets | Black shoe. leather | µg/m² | 4.81 | 21.2 |
| **Study** | **Product category** | **Product name** | **Unit** | **PFHxS** | **PFOS** |
| Herzke et al. (2012) | Textiles, leather, carpets | Carpet brown; Element | µg/m² | 0.08 | 1.04 |
| Herzke et al. (2012) | Electronics and electrics | PCB. Disney electronic toy | µg/kg | 0.06 | 0.4 |
| Norin and Schulze (2007) | Water proofing agents | Boston Raingard allover | ng/mL | 3.5 | 8.6 |
| Norin and Schulze (2007) | Water proofing agents | Kiwi select all protector | ng/mL | 3.6 | 8.9 |
| Norin and Schulze (2007) | Water proofing agents | Imprenex plus | ng/mL | 4.2 | 77.1 |
| Norin and Schulze (2007) | Water proofing agents | Springyard Waterproofer | ng/mL | 2.5 | 19.9 |
| Norin and Schulze (2007) | Water proofing agents | XT | ng/mL | 4.6 | 13.1 |
| Norin and Schulze (2007) | Water proofing agents | Atsko Waterguard | ng/mL | 0.9 | 4.2 |
| The Norwegian Pollution Control Authority (2006) | Textile | Children ski pants | µg/m² | 0.04 | 0.02 |
| The Norwegian Pollution Control Authority (2006) | Textile | Women all weather jacket | µg/m² | 0.38 | 30.1 |
| The Norwegian Pollution Control Authority (2006) | Textile | Jacket | µg/m² | 0.02 | 0.24 |
| (Greenpeace, 2014b) | Textile | Coat | µg/kg | 20-300 | <0.5-4.5 |
| (Greenpeace, 2014b) | Textile | Coat | µg/kg | 2.4 | <1.5 |
| (Greenpeace, 2014b) | Textile | Plastic pants | µg/kg | 21-2260 | <5 |

### 5.2.5 Other Uses in Belgium

Several uses of long-chain PFAS have been exempted from restrictions, we list them below:

- Use in medical devices
- In Europe, PFOA can be used in invasive and implantable medical devices until 4 July 2025.
- Use of PFOA in photolithography or etch processes in semiconductor manufacturing is allowed until 4 July 2025.
- Use of PFOA in photographic coatings applied to films allowed until 4 July 2025.

After these exemption periods have ended, these uses of long-chain PFAS could be substituted by short-chain alternatives as well.

During the consultation period on the PFHxA REACH restriction process, several companies have indicated they use PFAs substances in high-performance filtration and separation media. The companies stated that C6 fluorinated polymers are used in several applications (medical devices, Heating, Ventilation, Air Conditioning (HVAC), Air Pollution controls (APC), dust collectors, hydraulic systems coalescers, gas turbines, and fuel systems.

The OECD is working on a report on the commercial availability and current uses of alternatives for PFAS in coatings, paints, and varnishes. In this report, there is information on the function of PFAS in these products (Thermal Stability and Flame Resistance, Corrosion Resistance, Durability, Weather and UV-fade Resistance, etc.). This report also lists specific uses of PFAS in coatings (Powder Coating in Cable & Wiring, Powder Coating in Architectural Sector, Radiation Curable Coatings, etc.), paints (Architectural, Chemical Industry, and Household applications), and varnishes.

**Plant protection products**

Plant protection products (as surfactants): Full detailed composition is known and registered in a database with the competent authorities. In 2019, PFAS were only present in a very limited number of authorisations (3 out of about 1500) at very low concentrations. Contribution by plant protection products looks hence negligible.

**Fertilisers**

Fertilisers: Authorisation on EU level. Only national derogations for non-EU fertilisers. Composition is present in the national applications for derogation however not in a structured database. Hence, no information can be given concerning concentrations and presence in fertilisers on the Belgian market. However, only a few fertilisers contain synthetical components.

**Biocides**

See section 7.4.1. for more information on PFAS in biocides.

SCIP-database

The SCIP is the database for information on **S**ubstances of **C**oncern **I**n articles as such or in complex objects (**P**roducts) established under the Waste Framework Directive (WFD).

Companies supplying articles containing SVHCs in a concentration exceeding 0.1% w/w have to notify to ECHA via this database. A search on SVHC identified PFAS (i.e. PFHxS, PFBS, PFOA, APFO, PFNA, and PFDA) resulted in over 43000 results. However, when looking at the individual hits there was little additional information found on the type of article in which the PFAS are present. There was solely information available on general Article categories, of which for PFBS Article category SECTION XVI (84-85) was the most prevalent category, which corresponds to machinery and mechanical appliances. Other categories found were 86-89 (Vehicles, aircraft, vessels, and associated transport equipment) and specifically for PFHxS category 90-92 (optical, photographic, cinematographic, etc.).

## 5.3 Waste phase, End of Waste, recycling, and re-use

The previous chapters have illustrated that short-chain PFAS are used in a multitude of products, resulting in emissions of these products into the environment. The next paragraphs will discuss the effect of PFAS in the waste phase, as well as possibilities regarding the reuse, recycling, and disposal of these products. Apart from the projects described in the below paragraphs, there has been a call within the EU Green Deal Horizon 2020 (LC-GD-8-1-2020 'Innovative, systemic zero-pollution solutions to protect health, environment, and natural resources from persistent and mobile chemicals') for research on removal techniques for persistent and mobile substances like PFAS.

### 5.3.1 Waste: Landfills

A vast amount of PFAS are incorporated in numerous consumer products (protective films on textiles and papers, cosmetics, etc.), resulting in these compounds ending up in landfills. A study by Eschauzier et al. (2013) in the Netherlands has found that leachate and water draining from nearby landfills is a direct source of PFAS contamination in drinking water. Concentrations of up to 1.8 µg/l of PFOA and 1.2 µg/l for PFBA have been found in the groundwater from landfill leachate, with concentrations of total PFAA reaching up to 4.4 µg/l (Eschauzier et al., 2013). In Flanders, a study by OVAM (see 3.2.7.) has also found elevated concentrations of PFAS (short-chain and long-chain substances) in groundwater near landfills (OVAM, 2018). Both studies indicate that PFAS compounds are leaching out of products and articles in landfills, thereby contaminating the groundwater and soil.

### 5.3.2 Re-use and remediation

#### *5.3.2.1 Soil remediation*

There is limited availability of techniques for remediation of PFAS, mainly due to their low volatility and high persistence. Due to these characteristics, common techniques like compressed air injection, biological degradation, and soil air extraction are therefore not feasible for PFAS extraction (Pancras et al., 2018). One of the few known methods to remove PFAS from soil is excavation and groundwater abstraction, after which PFAS can be adsorbed to activated carbon or the soil can be incinerated (Pancras et al., 2018). Incineration of soil is the most commonly used and efficient technique according to OVAM, although it is a costly technique since the soil has to be heated to 1000 to 1200°C.

Regarding the possible emission of PFAS due to waste incineration, Aleksandrov et al. (2019) have found no statistical evidence for PFAS emission during the combustion of PTFE (a study funded by GORE, which is a PFAS-producing company). Other studies regarding this possible emission route could not be found.

Another used technique is the stabilization and solidification of PFAS by binding them to the soil matrix. Solidification is a technique for which cement mixtures are added to the soil, which prevents the water from flowing into the soil matrix and thus prevents the leaching of PFAS-contaminated water. Stabilization is achieved by adding additives (substances based on clay, minerals, or organic material) to the soil matrix, which will enhance the binding of PFAS to the soil (Pancras et al., 2018). In 2022 OVAM published a report on remediating techniques, in which it describes some new evolutions in the remediation and cleaning techniques of PFAS-contaminated soil[9].

Soil washing is another viable technique to use in certain soil types (sandy soils). By running water through the soil, PFAS can be concentrated in the water or sludge, leaving a clean sand fraction. The NVGP (Nederlandse vereniging voor procesmatige grondbewerkingsbedrijven) has conducted a study on this technique and found extraction efficiencies of up to 90% (NVPG, 2017, 2018).

#### 5.3.2.2 Water extraction

The most common technique used to extract PFAS from water is adsorption using activated carbon. However, activated carbon adsorption is less efficient for short-chain PFAS compared to long-chain compounds (Pancras et al., 2018). After adsorption of PFAS, the activated carbon is incinerated at 1000°C to ensure breakdown of PFAS. Other techniques are being explored to extract PFAS from water, including ion exchange systems, separation techniques (nanofiltration, reversed osmosis, etc.), and other adsorption media (Pancras et al., 2018).

In the past, sludge from wastewater treatment has been used as fertilizer in agricultural soils. A study in the Czech Republic has shown that this sludge can be contaminated with PFAS, which resulted in PFAS contamination of the agricultural soil and the crops grown on these soils (Semerád et al., 2020). OVAM has confirmed that sewage sludge is not being used on agricultural land in Flanders. However, it is possible that sludge is still being used on agricultural soils in the Walloon region.

## 5.4 Hazards/effects: BE data, research teams, projects

The following Belgium teams are involved in research on PFAS hazards:

- Vlaams steunpunt = Flemish Center of Expertise on Environment and Health
    - Biomonitoring = Flemish Environment and Health Study (FLEHS)

[9] https://ovam.vlaanderen.be/documents/177281/919410/OVAM_-_Grondreiniging_PFAS_ufuxbo.pdf/749b4204-70cf-7e48-3d5a-278c14cba44a?t=1648565011753

    - An Colles et al (2020) paper
    - Greet Schoeters et al. (2017) paper
- VUB / Pr Nick Vanlaerebeek
- UA: SPHERE research group / W.D'Hollander
    - Ecotoxicological research on PFAS at 3M site in Zwijndrecht
- ULg / Patrice Dufour, Catherine Pirard
    - Biomonitoring Walloon population
- Vito / C. Cornelis / A. Alves / Lieve Geerts / Greet Schoeters
    - PFAS in hair: https://doi.org/10.1016/j.talanta.2015.07.009
    - Fire Fighting Foams
- BE is involved in the future PARC project, where PFAS activities are foreseen (e.g. immunotoxicity)

## 5.5 Development of analytical methods

For the determination of PFAS concentrations in the soil and other solid compounds, the OVAM uses analytical methods developed by the emis (Energie- en milieu-informatiesysteem voor het Vlaamse Gewest) VITO and incorporated into the Compendium for sampling and analysis for the implementation of the materials and soil decree (CMA/3/D).

VITO developed a quantitative measuring method for per- and polyfluoroalkyl compounds in soil, sediment, sludge, dredging material, solid waste, and soil-enhancing products. The method is based on liquid chromatography and can be used to extract and analyse a multitude of PFAS compounds (Table 9) as well as indicate the presence of other PFAS. A known quantity of isotope-labeled fluorinated compounds is added to the sample. Samples are then extracted, purified, and concentrated if necessary. The sample extract is then added to a mobile phase and analysed using a LC-MS/MS system. The PFAS concentrations are determined by the internal standard method.

The emis (VITO) has also developed a method for the analysis of PFAS in water samples. The method is published in the Compendium for Water Analysis under WAC/IV/A/025. 12 different PFAS compounds (Table 9) can be quantified with a lower limit of 10 ng/l for surface water and drinking water, and 20 ng/l for wastewater. The presents of other PFAS can be indicated as well.

Known concentrations of isotope-labeled fluorinated compounds are added to water samples. The samples are extracted with a solid phase and the solid phase is eluted with methanol. The methanol extract is concentrated and the final extract is added to a known volume of the mobile phase and analysed using a LC/MS/MS system. The PFAS compounds are quantified by the internal standard method.

VITO is working on 4 different research initiatives on developing analytical methods for PFAS substances. 2 of these initiatives will start in 2021, the other 2 most likely in 2022. The first study started in 2021 will look at measuring methods for PFAS in air samples, and the second study will look at the optimalisation and validation of Total Oxidisable Precursor Assay (TOPA) for the detection of PFAS precursors in water. In 2022, one study will focus on the suspect and non-targeted screening (NTS) of PFAS in water, and the second one will investigate adsorbable organic fluorine (AOF) with combustion chromatography for complementary, non-specific total PFAS detection.

Table 9 List of substances that can be measured using the measuring methods described in the CMA and the WAC.

| *PFAS* | *Acronym* | *CAS n°* |
|---|---|---|
| **perfluoro-n-butanoic acid** | PFBA | 375-22-4 |
| **Perfluoro-n-pentanoic acid** | PFPA | 2706-90-3 |
| **perfluoro-n-hexanoic acid** | PFHxA | 307-24-4 |
| **perfluoro-n-heptanoic acid** | PFHpA | 375-85-9 |
| **perfluoro-n-octanoic acid** | PFOA | 335-67-1 |
| **perfluoro-n-nonanoic acid** | PFNA | 375-95-1 |
| **perfluoro-n-decanoic acid** | PFDA | 335-76-2 |
| **perfluoro-n-undecanoic acid** | PFUdA | 2058-94-8 |
| **perfluoro-n-dodecanoic acid** | PFDoA | 307-55-1 |
| **perfluoro-n-tridecanoic acid** | PFTrDA | 72629-94--8 |
| **perfluoro-n-tetradecanoic acid** | PFTeDA | 376-06-7 |
| **perfluoro-n-hexadecanoic acid** | PFHxDA | 67905-19-5 |
| **perfluoro-1-butanesulfonic acid** | PFBS | 375-73-5 |
| **Perfluoro-1-pentanesulfonic acid** | PFPeS | 2706-91-4 |
| **perfluoro-1-hexanesulfonic acid** | PFHxS | 355-46-4 |
| **perfluoro-1-heptanesulfonic acid** | PFHpS | 375-92-8 |
| **perfluoro-1-octanesulfonic acid** | PFOS | 1763-23-1 |
| **perfluoro-1-nonanesulfonic acid** | PFNS | 68259-12-1 |
| **4:2 fluorotelomer sulfonic acid** | 4:2 FTS | 757124-72-4 |
| **6:2 fluorotelomer sulfonic acid** | 6:2 FTS | 27619-97-2 |
| **8:2 fluorotelomer sulfonic acid** | 8:2 FTS | 39108-34-4 |
| **perfluoro-1-octane sulfonamide** | FOSA | 754-91-6 |
| **N-ethylperfluorooctanesulfonamido acetic acid** | MeFOSAA | 2355-31-9 |
| **N-methylperfluorooctanesulfonamido acetic acid** | EtFOSAA | 2991-50-6 |

| | | |
|---|---|---|
| **8:2 fluorotelomer phosphate diester** | 8:2 diPAP | 678-41-1 |
| **Hexafluoropropylene oxide dimer acid** | HFPO-DA (GenX) | 13252-13-6 |
| **4,8-dioxa-3H-perfluorononanoic acid** | ADONA | 919005-14-4 |
| **perfluoro-4-ethylcyclohexanesulfonic acid** | PFECHS | 646-83-3 |

*The following substances can only be measured indicatively (low uncertainty regarding the exact concentrations).*

| *PFAS* | *Acronym* | *CAS n°* |
|---|---|---|
| **perfluoro-n-octadecanoic acid** | PFODA | 16517-11-6 |
| **perfluoro-1-decanesulfonic acid** | PFDS | 335-77-3 |
| **perfluoro-1-dodecanesulfonic acid** | PFDoS | 79780-39-5 |
| **10:2 fluorotelomer sulfonic acid** | 10:2 FTS | 120226-60-0 |
| **N-methylperfluorooctane sulfonamide** | MeFOSA | 31506-32-8 |
| **N-ethylperfluorooctane sulfonamide** | EtFOSA | 4151-50-2 |
| **6:2 fluorotelomer phosphate diester** | 6:2 diPAP | 57677-95-9 |
| **6:2/8:2 fluorotelomer phosphate diester** | 6:2/8:2 diPAP | 943913-15-3 |
| **Perfluorooctanesulfonamido acetic acid** | FOSAA | 2355-31-9 |
| **6:2 fluorotelomer phosphate monoester** | 6:2 PAP | 57678-01-0 |
| **8:2 fluorotelomer phosphate monoester** | 8:2 PAP | 57678-03-2 |

Source: CMA/3/D. https://esites.vito.be/sites/reflabos/2021/Online%20documenten/CMA_3_D.pdf

Source: WAC/IV/A/025. https://esites.vito.be/sites/reflabos/2021/Online%20documenten/WAC_IV_A_025.pdf

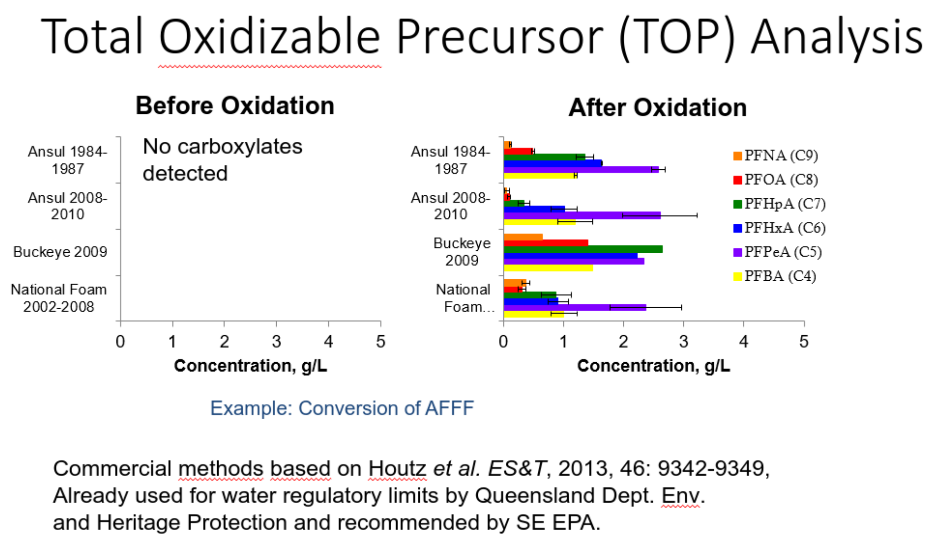


*Figure 2: Comparison of concentrations measured before and after oxidation using the TOP analysis.*

Analytical methods regarding the analysis of PFAS compounds are constantly evolving. Due to the large number of PFAS compounds used and the relatively low concentrations found in the environment, there still are hurdles to overcome. A review paper by Amin et al. (2020) has summarized several new developments regarding sample preparation, the recent emergence of nanoparticle and app-based sensors as well as developments in known technologies like TOP (total oxidizable precursors, Figure 2) and TF (Total fluorine). The paper has a comprehensive overview of PFAS compounds already analysed, as well as an overview of analysis techniques for different matrices (including solid, food, and air mediums). The paper concludes that LC-MS/MS with negative electrospray ionization (-ESI) mode is the most commonly used method for selective and sensitive analysis of PFAS. Nanoparticle-based sensing has been developed for on-site analysis by pre-screening and is evolving rapidly.

Even though there are a large amount of PFAS known to be produced by industry, only a small amount has been found in analysis studies. Non-targeted screening for PFAS, therefore, is an important analytical method to get a correct and full overview of the PFAS compounds present in our environment. Fragment ion flagging (FIF) is a method used for non-targeted screening and identification of novel PFAS substances. With this method up to 40 PFAS were (tentatively) identified in surface water samples throughout the Netherlands, of which 4 were not found in existing databases (Hensema et al., 2020).

A recent study by Groffen et al. 2021 has outlined a new method to determine the presence of up to 32 PFAS in bird feathers using liquid chromatography-tandem mass spectrometry (LC-MS/MS).

Sciensano has developed analytical methods for analysing many PFAS in several types of food.

## 5.6 Belgian studies on Occurrence, Monitoring, Exposure, and Fate

### 5.6.1 Biomonitoring and environmental monitoring by the Regions

#### 5.6.1.1 Flanders: PFAS action plan

The government of the Flemish region is working on a PFAS action plan, in function of the Flemish strategy against endocrine disrupters. It is a collaboration between the department of environment (dOMG), Flanders Environment Agency (VMM), and OVAM. The action plan encompasses the monitoring of PFAS in the environment (soil and water), human biomonitoring (via the Flemish Environment and Health Studies (FLEHS) and HBM4EU), and monitoring of PFAS in the drinking water.

**Departement Omgeving (dOMG): Human Biomonitoring**

Four different cycles in human biomonitoring have been conducted in Flanders by the Flemish Center of Expertise on Environment and Health (Steunpunt Milieu en Gezondheid) in the Flemish Environment and Health Studies (FLEHS). The 4th FLEHS cycle (2016-2020) measured 12 different PFAS in a Flemish reference group of 410 individuals (14-15 years old) to establish Flemish reference values and additionally in 173 participants of the same age group to answer specific research questions. The most commonly found PFAS in the FLEHS IV Flemish reference group were PFOS, PFOA, PFHxS, and PFNA, with quantification frequencies between 82% and 100%. PFDA was quantified in 42% of the participants in the FLEHS IV reference group. Furthermore, PFUNDA, PFHxA, PFHpS, and PFDODA were found in measurable concentrations in a limited number of participants (1.2% - 7.6%). PFBS and PFPEA were not found at quantifiable levels. Since PFOS and PFOA accumulate with older age, comparisons of body burdens over time are to be assessed in the same age group. It was found that PFOS and PFOA concentrations have been declining throughout the measuring periods: cord blood of FLEHS III new-borns (sampling period 2012-2015) showed 41% lower PFOS levels and 79% lower PFOA levels compared to levels in FLEHS II new-borns (sampling period 2007-2011) (Schoeters et al., 2017). Despite the older age, also lower concentrations were found in 3rd FLEHS cycle adults (age 50-65), compared to 2nd FLEHS cycle adults (age 20-40).

Colles et al. (2020) give an overview of the PFAS results of the 2$^{nd}$ and 3$^{rd}$ FLEHS cycles. They found that the PFAS levels in the blood were comparable to those in other Western countries. The study also found that 77% of adults (50-65 years old) sampled in 2014 exceeded the HBM I values for both PFOS and PFOA. The HBM-I values that were used were derived by the German HBM commission and were 5 ng PFOS/mL and 2 ng PFOA/mL blood plasma. Environmental factors that seemed to increase PFAS blood levels were the consumption of locally grown food, and a possible exposure route has been attributed to cosmetics. Differences between genders were found, with menstruation being a possible route of PFAS elimination from the body.

HBM I values for PFOA and PFOS were exceeded in 62%–81% of the participants, depending on the compound, the timing of sampling, and on the study population considered. Higher internal levels of PFAS were observed with increasing age, indicating cumulative exposure over time. Consumption of crustaceans, consumption of organ meat, potatoes, alcohol, locally produced vegetables, and eggs were identified as significant determinants of exposure. Sex differences could also be observed, with higher levels of PFOS, PFOA, and PFHxS in men than in women (Colles et al., 2020).

**Vlaamse Milieu Maatschapij (VMM): Biomonitoring of biota and surface water in Flanders**

The VMM has conducted monitoring studies of PFAS in Flemish surface waters, drinking waters, industrial wastewater, and effluent of WWTPs (an overview can be found in the Minaraad presentation, 2020). They found that the quality standard for PFOS in surface water (being 0.00065 µg/l yearly and 36 µg/l max) is exceeded at all the monitoring points (VMM, Teunen et al., 2017).

The VMM also has a measuring network on biota to look at the bioaccumulation capacity of PFAS. Perch and eel have been monitored for 15 PFAS substances (PFBA, PFPeA, PFBS, PFHxA, PFHpA, PFHxS, PFOA, PFNA, PFOS, PFDA, PFUDA, PFDS, PFDoA, PFTrA, and PFTeA). The report of 2019 (Teunen et al., 2019) has found that, for perch, PFOS is the most prevalent, with concentrations ranging from 7.9-78 µg/kg. With exception of one sampling pool, all the measured sampling pools had at least one exceedance of the 9.1 µg/kg standard (EQS). For PFBA and PFPeA, max concentrations of 0.14 and 0.25 µg/kg respectively have been found in perch. Furthermore, max concentrations of PFHxA and PFBS were found to be 0.3 and 0.25 µg/kg respectively. For eel, similar results were found, except for PFBS, of which no samples exceeded the detection limit.

**Openbare Vlaamse Afvalstoffenmaatschappij (OVAM): Presence of PFAS at possible contamination sites**

The OVAM has conducted an exploratory study on the presence of PFAS in soil, groundwater, and surface water at high-risk locations. High-risk locations were chosen based on the possible PFAS release (i.e., industry, firefighting exercise grounds, etc.). A total of 24 sites were sampled, with 35 soil samples and 40 groundwater samples, as well as one water sample.

71% of groundwater samples at the high-risk locations had a PFAS concentration exceeding the measurement threshold x100 (0,5 µg/l) and 42% of the locations had concentrations exceeding the x1000 value (5 µg/l). It was found that mainly PFOS and PFOA were present in the groundwater samples, however other PFAS were found as well, including 6:2 FTS, which is a precursor that can degrade to a more persistent, short-chain PFAS.

For soil samples, the locations which had the highest amounts of PFAS were found to be mainly firefighting training grounds. On these locations, PFOS was the most abundant PFAS. On grounds with a history of calamities (I.e. fires etc.), they also found high concentrations of PFAS, with in this case precursors (mainly 6:2-FTS) being more common. The highest concentrations of PFAS found (6200 µg/kg) far exceeded the 11 µg/kg limit proposed for soils by RIVM (Netherlands).

For groundwater samples, similar results were observed, with again firefighter training grounds showing the highest concentrations, with PFOS being the most abundant PFAS. For groundwater, it was found that sampling sites at textile industry, waste collection, and coating industry were also found to have higher concentrations of PFAS. In comparison with the soil samples, more perfluorocarbons were detected, as well as more short-chain PFAS, which were hardly present in soil samples.

OVAM recently conducted a study on PFAS concentrations in non-suspect areas and found that only PFBA, PFOA, PFOS, and 6:2 FTS were frequently found above the detection limit. Concentrations were generally low, with max concentrations not exceeding 2.6 µg/kg dw (Vanermen et al., 2020 draft).

#### 5.6.1.2 Wallonia

A study by Pirard et al., 2020 measured 11 PFAS in the serum of 242 adults in Liege. The study found that the levels of PFAS found were similar to those found in other countries, with half of the population containing PFOS and PFOA concentrations above the HBM-I values. Comparable with other studies, the age and gender of the individuals were important determinants for PFAS concentrations.

Since 2016 the Institut scientifique Wallon de surveillance, de sûreté et de recherche & développement en environnement (ISSeP) has been conducting a multitude of human end environmental monitoring studies on chemical substances, including PFAS[10]. Below we list 2 of these studies in which PFAS has been monitored. The Walloon region is planning to include PFAS in several of its planned projects.

**BIODIEN-project (2015-2018)**

The Walloon government has conducted a large-scale environmental monitoring study in the Walloon and Brussels region on a multitude of hazardous substances, including several PFAS. For surface water measurements from treatment plants, they found concentrations of PFHxS and PFOA in all samples. PFHpA and PFOS were found in 95% of all samples and PFHxS was found in 60% of the samples. The sum of these PFAS on average did not exceed 50 ng/l in the samples. However, at the wastewater treatment plant in Louvain-la-Neuve concentrations of PFAS were far higher compared to the other sites, with the highest concentrations found for PFHxA and PFHpA, max PFOS concentrations of 67 ng/l, and even max PFOA concentrations of up to 7 µg/l.

For groundwater levels, the Walloon government found PFHxA, PFHpA, and PFHxS in 75% of the samples and in 100% of the samples of the Brussels region. The sum of PFAS found in the samples was 5 ng/l on average and never exceeded 20 ng/l. Municipal wastewater was tested as well, with concentrations never exceeding 1 ng/l.

A study by Pirard et al. (2020) on the PFAS levels in the blood serum of individuals living in the Walloon region showed that for all participants, at least 4 PFAS were detected simultaneously, with levels close to those recently reported in other European or North American countries, but substantially lower than levels measured in the North of Belgium. However, only half of the population showed PFOS and PFOA levels below the peer-recognized health guidance values set by the German HBM Commission suggesting that for the other half, the sources of exposure should be investigated and minimized.

**CARIBOUH project (2017-2020)**

[10] https://www.issep.be/environnement-sante-be/

From 2017 to 2020 the Walloon government conducted a study on sewage sludge[11]. PFOA, PFOS, PFHxA, and PFHxS were measured in 29 WWTP sludge samples.

### 5.6.2 Monitoring by the Federal Government and EU

While environmental and human health monitoring is mainly being done on a regional level, official control relating to food safety is a federal responsibility exercised by the FAVV. At the moment, FAVV analyses the presence of PFOS and PFOA in drinking water, water used in food preparation, feed and fertilizers, and food. Before 2017, several other PFAS substances were measured as well (Table 10). According to a report by the scientific committee of the FAVV on POPs in 2017, there is a low reporting frequency of PFOA and PFOS in the measured samples, therefore indicating no need for concern regarding contaminations in food and feed (SciCom, 2020).

*Table 10 Overview of the results for PFAS in foodstuffs from the FAVV databank. Source: SciCom (2020).*

| Parameter | periode | # resultaten | | Maximale gerapporteerde concentratie |
|---|---|---|---|---|
| | | Totaal | > LOR [(1)] | |
| Perfluoroctaansulfonzuur (PFOS) | 2010-2018 | 341 | 9 [(a)] | 18 µg/kg |
| Perfluoroctaanzuur (PFOA) | | 341 | 2 [(a)] | 85 µg/kg |
| Perfluorbutaansulfonzuur (PFBS) | 2010-2016 | 309 | 0 | < 5 µg/kg |
| Perfluoroctaansulfonamide (PFOSA) | | 309 | 2 [(a)] | 13 µg/kg |
| Perfluorhexaansulfonzuur (PFHxS) | | 309 | 0 | < 5 µg/kg |
| Perfluorhexaanzuur (PFHxA) | | 309 | 1 [(a)] | 28 µg/kg |
| Perfluorheptaanzuur (PFHpA) | | 309 | 1 [(a)] | 16 µg/kg |
| Perfluornonaanzuur (PFNA) | | 309 | 0 | < 5 µg/kg |
| Perfluordecaanzuur (PFDA) | | 309 | 1 [(a)] | 15 µg/kg |
| Perfluoroundecaanzuur (PFUnDA) | | 309 | 0 | < 5 µg/kg |
| Perfluordodecaanzuur (PFDoDA) | | 309 | 1 [(a)] | 8,2 µg/kg |
| PFAS som (*i.e. profiel van verschillende PFAS)* | | 309 | 22 [(b)] | 165 µg/kg |

[(1)] In het algemeen bedraagt de LOR 5 µg/kg, met uitzondering van perfluoroctaansulfonamide en perfluorhexaanzuur waarvoor ook een LOR van 10 µg/kg gerapporteerd wordt, en van PFAS som waarvoor een LOR van 65 µg/kg gerapporteerd wordt.
[(a)] detectie in producten en bereidingen van de visserij of de aquacultuur; [(b)] detectie in producten en bereidingen van de visserij of de aquacultuur, maar ook in eieren, melk en vlees

As the competence for elaborating legislation such as maximum levels for contaminants in food (contributions of Belgium to elaborate EU legislation), is at the DG Animals, Plants and Foodstuffs of FPS Health, Food Chain Safety and

[11] https://www.issep.be/wp-content/uploads/Projet-Caribouh.pdf

Environment, this administration has commissioned studies and made contributions to issue European recommendations for monitoring/studies.

- Commission Recommendation of 17 March 2010 on the monitoring of perfluoroalkylated substances in food (2010/161/EU)
- Commission Recommendation (EU) 2022/1431 of 24 August 2022 on the monitoring of perfluoroalkyl substances in food

The occurrence data are collected in the EFSA database.

**PERFOOD, Kenlow et al 2013; D'Hollander et al., 2015**

A PERFOOD project commissioned by the FPS Health, Food Chain Safety and Environment studies in the period of 1/7/2007-30/6/2012 the PFAS in the food chain and analysed the risk. It was a huge challenge to analyse low levels and only in a few food samples, levels above 1 ng/g were found. PFOS and PFOA were found most often and at the highest levels. Foods with the highest levels were liver and paté. In shrimps and mussels originating from the Belgian coast, higher levels were found than in fishery products in the supermarket. According to a deterministic estimate of exposure of the Belgian population, there was a large margin with the tolerable intakes established by EFSA in 2008 with mean consumption data only 0.03% of the TDI of PFOA and 0.8% of the TDI of PFOS. Hence no concern was identified for the Belgian population from background dietary intake. However, risk was found for the consumption of some eggs from private gardens from hot spots. Further monitoring of food and other sources as well as biomonitoring was recommended. It has to be noted that the TDIs were at that time different from the current health-based guidance value of EFSA.

The Belgian PERFOOD project had a link with an EU PERFOOD project that assessed the origin of PFAS in our diet and the diet's contribution to the total human exposure to PFAS in four EU countries. This study looked at the reliability of measurements of PFAAs at very low concentrations (pg/g) in food items. Due to the low method detection limits (MDL) achieved in this study, previously undetectable PFAS could be measured in food products. Short-chained PFAS were indicated to transfer best to edible vegetative parts of plants.  For cattle, they found PFAA transfer from feed and water to meat and milk. For fish, it was found that farmed fish have lower PFAA content compared to feral fish. Two types of contact material were found to have a high potential transfer capacity of PFAS, namely baking paper and butter wraps.

However overall, the PERFOOD project, as well as several other studies conducted in Belgium, have found no concern about exceeding the EFSA tolerable intake in foodstuffs (D'Hollander et al 2015; Kenlow et al 2013). Several figures from the studies are provided in the annex of this document to give an overview of the PFAS analysed and their concentrations (Figures 4-6 and Table 15 in Annex I).

**FLUOREX**

A study called FLUOREX[12] has been commissioned by the FPS Health, Food Chain Safety and Environment (DG Animals, Plants, and Foodstuffs) to Sciensano to study the occurrence of PFAS in many food groups and to assess the background dietary exposure of the Belgian population to PFAS from food and bottled drinking water, and to compare this to the 2020 EFSA tolerable weekly intake of 4 ng/kg bw for the sum of PFOS, PFOA, PFHxS and PFNA.

**PFASFORWARD**

The Directorate of Food Safety of the FPS Health, Food Chain Safety and Environment has issued a call for tenders for a study called PFASFORWARD[13] to investigate a series of questions related to PFAS in the food chain, including topics such as: occurrence of a long list of PFAS in food in line with the Commission Recommendation (EU) 2022/1431 of 24 August 2022 on the monitoring of perfluoroalkyl substances in food (to complement data of FLUOREX where this is still needed); research into the behaviour and distribution of PFAS within a foodstuff (If for example PFAS are mainly present in the peel of potatoes, one could assume that peeling a potato could result in a lower exposure compared to what could be the exposure considering the actual original concentration of PFAS in the potato.); research into the fate of PFAS in food processing; research into relevant sources and pathways (including occurrence in feed and if possible transfer of PFAS in fertilising products and irrigation water to foodstuffs of vegetable origin).

**FAVV monitoring of foodstuffs in agricultural products**

Between August and November 2021 the FAVV conducted a monitoring study on the background levels of PFAS in foodstuffs[14]. 175 samples were taken from several agricultural businesses and tested for the 4 PFAS identified by EFSA to be of concern (i.e. PFOS, PFOA, PFNA, and PFHxS). None of the samples exceeded the FAVV limit values.

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[12] Exposure assessment of perfluoroalkyl substances as follow-up on the concerns raised in the recent draft opinion of EFSA | sciensano.be

[13] Research on PFAS contamination in the food chain

[14] https://www.favv-afsca.be/professionelen/publicaties/pers/2021/2021-12-22.asp

### 5.6.3 Academic (bio)monitoring studies in Belgium

The human biomonitoring and environmental monitoring studies of the regions clearly indicate some relevant exposure routes. In the next paragraph, we will mention some other studies conducted by other research institutes on Belgian soil.

**PFAS in home and office dust**

Several studies have shown that PFAS intake apart from the most common routes via dietary intake, happens due to inhalation of indoor dust from furniture. A study by D'Hollander et al. (2010) has found the presents of PFAS in dust of Flemish homes and offices. Total PFAS content ranged from 0.2 to 336 ng/g (median 3.0 ng/g). Levels found in office dust were higher, ranging between 2.2 and 647 ng/g (median 10ng/g). The most abundant PFAS found was PFOS, although other, short-chain compounds (i.e. PFHxS and PFHxA) were found as well. Outdoor inhalation exposure is also thought to occur close to PFAS-producing industry and firefighting exercise areas, as well as at landfills and water treatment plants.

**PFAS in eggshells of birds near chemical site**

To look at the legacy effect of PFAS production in Belgium, studies have been conducted in close vicinity to the 3M plant of Zwijndrecht (Antwerp), where PFOS used to be produced until its phase-out in 2001. A study by d'Hollander et al. (2011) found high concentrations of PFOS in chicken eggs, with maximum concentrations of up to 3500 ng/g. More Recent studies at the 3M site have looked at the bioaccumulative capacity of PFAS by sampling their occurrence in passerine bird eggs. Groffen et al. (2017) and Lopez et al. (2017) found extremely high concentrations of PFAS in eggs, with Lopez et al. finding the highest observed concentrations in eggs worldwide. Apart from PFOS, these studies also found the short-chain compound PFHxS at some sampling sites.

**PFAS in the North Sea and Scheldt**

A study by Van de Vijver et al. (2009) measured the amount of PFOS in soft tissue of shrimp, crab, and starfish captured in the North Sea and Scheldt river. The study found a PFOS pollution gradient along the Western Scheldt estuary, with the highest concentrations found near Antwerp. Furthermore, they found slightly higher PFOS levels in shrimp and crab captured in coastal regions compared to open water. The concentrations found in the tissue reached a maximum of 877 ng/g in crab tissue. We did not find any studies or data on short-chain PFAS in estuarine or marine environments.

**Association between PFAS in cord blood and thyroid function in newborns and mothers.**

This study by Dufour et al. (2018) sampled the presence of PFAS in 221 cord blood samples collected in Belgium between 2013 and 2016. The study found that the residual contamination by PFAS in cord blood is correlated with thyroid hormone in newborns and the risk of hypothyroid in mothers. 7 different PFAS were analysed (PFOS, PFOA, PFHxS, PFNA, PFDA, PFHpA, and PFUdA). The following median concentrations were determined; 0.73 µg/l for PFOS, 0.68 µg/l for PFOA, 0.16 µg/l for PFHxS, 0.12 µg/l for PFNA.

**PFAS accumulation in indigenous and translocated aquatic organisms from Belgium, with translation to human and ecological health risk.**

This monitoring study by Teunen et al., 2021 measured the PFAS concentrations in indigenous fish, European perch, and European eel and translocated freshwater mussels at 44 sampling locations within the main water basins of Flanders. Human health risk and ecological risk were assessed based on accumulated concentrations in fish muscle. The authors observed biomagnification of PFDA, PFUnDA, and PFOS, and bio dilution of PFOA and PFTeDA. It was concluded that the mean concentrations in fish posed a health risk for eel. Tolerable daily intake for perch was close to the reported daily consumption rates in Belgium and even exceeded them in highly contaminated locations. The European Environmental Quality Standard for biota (EQS biota) of PFOS was exceeded at 44% of locations for perch and 58% of locations for eel.

**PFAS in snails, nettles, and soil**

In a recently published paper by Rijnders et al. (2021), PFAS concentrations were measured in snails, nettles, and the soil around the 3M site along a distance gradient. For snails it was also investigated whether the presence of PFAS affects the physiology of the snails, more specifically they looked at the oxidate status, which indicates a stress response. The study showed that high concentrations of PFOA and PFOS are present around the 3M site, but no concentration gradient was observed. The PFOS concentration found in snails was related to the PFOS concentrations in soil and nettles, which was not found for PFOA. Furthermore, the study showed that short-chain PFAS are more dominantly accumulated by nettles, while soil and snails accumulate mostly long-chain PFAS. The study also concluded that there was a significant relationship between the presence of PFAS and the oxidative stress response from snails, indicating that PFAS contamination affects the snails that are exposed.

## 5.7 Risks, forecasts, modelling, and foreseen evolutions in BE

The estimations on the industrial emissions of these substances, in combination with the above-mentioned biomonitoring studies, indicate that short short-chain PFAS have already contaminated the environment and human bodies, with a constant background concentration present in soil and water. This in combination with the hazardous properties of these substances indicates that short short-chain PFAS could pose a significant risk to human and environmental health.
Risks were considered in a broad sense and in a weight of evidence approach for the recent RMOA, restriction proposals, SVHCID and in the EU PFAS strategy proposed by BE and other countries. In consequence, we list here how those risks translate into the Belgian situation:

### 5.7.1 Accumulation in plants

In all the above studies, it was found that the highest exposure to PFAS is dietary intake. Furthermore, several studies have shown that short short-chain PFAS accumulate in plant material, therefore posing a risk to the dietary intake of home-grown plants. There is a need for clear monitoring of the exposure risk via plant uptake, especially in contaminated areas.

### 5.7.2 Exposure via inhalation

There is a need for monitoring PFAS concentrations in the atmosphere to get a clear picture of all the possible exposure routes.
Health risks of lesser lesser-known PFAS
Only a few PFAS have been studied regarding their potential toxicity, and this is mainly because of their relatively large occurrence in the environment. Lesser-known PFAS might at the moment pose few risks due to their low

concentrations, however due to their persistent nature, these other PFAS might become more dangerous if they keep being emitted into the environment. The health effects of this lesser lesser-known PFAS must be studied to assess their possible risk in the future.

### 5.7.3 Summary of the Belgian PFAS risk

To summarize the data from the above-mentioned studies and monitoring projects, we can conclude that PFAS substances are present throughout the environment and the human body. Human biomonitoring studies have indicated that PFAS substances are present in the whole Belgian population. The major exposure routes are drinking water and food intake. The correlation between specific food types and serum concentrations indicates an important effect of diet on PFAS exposure. Higher levels of long-chain PFOS and PFOA in elders indicate a legacy effect of when these substances were still produced in Belgium. Even though PFOS and PFOA still are the most commonly detected PFAS substances, we see that several short-chain substances are emerging in sampling as well. Understanding the hazards of these short-chain PFAS will thus become increasingly important.
Apart from human health effects, PFAS substances are shown to be present throughout the environment. Their presence in the groundwater, surface water, and soil showcases their persistence and their environmental mobility. Overall, PFOS and PFOA concentrations have been decreasing since their phase-out. However, short-chain alternatives are emerging in emission sampling as well, especially PFHxS, PFHxA, PFBS, and PFBA are being detected in emission samples from industry and monitoring studies.
The persistence of fluorinated compounds in the environment, in combination with the difficulties in removing them from the environment, indicate that exposure to these substances will increase and could pose a significant risk to human health and the environment in the future.

## 5.8 Importance of the PFAS in BE

Economic importance, essential uses Industry did not provide information on the importance of the PFAS industry in Belgium.

# 6 State of Play on BE regulation and policy initiatives

*Table 11 Overview of (proposed) threshold and background values from Belgium and the EU*

| Medium | Concentration | Source of the value | Type of value |
|---|---|---|---|
| **HBGV (serum)** | 6.9 ng/mL for the sum of PFOS, PFOA, PFNA, and PFHxS (adults) | EFSA 2020 | Health-Based guidance Values |
| **HBM I (blood serum)** | PFOS: 2 ng/L<br>PFOA: 5 ng/L | German HBM-commission, Umweltbundesambt, 2016 | Health-Based guidance Values<br>(concentration of a compound in human biological material |

| | | | |
|---|---|---|---|
| | | HBM Commission, 2016 | below which no adverse health effects are expected) |
| **HBM II** | **Women of childbearing age**<br><br>PFOA: 5 ng/mL blood plasma<br><br>PFOS: 10 ng/mL blood plasma<br><br>**All other population groups**<br><br>PFOA: 10 ng/mL<br><br>PFOS: 20 ng/mL | German HBM-commission, Umweltbundesambt, 2018<br><br>https://doi.org/10.1016/j.yrtph.2021.104868 | Health Based Guidance Values (concentration in human biological material which, when exceeded, may lead to health impairment) |
| **Proposed Soil remediation values (20/10/2020)** | **Urban:**<br><br>PFOS: 18 µg/kg dw<br><br>PFOA: 89 µg/kg dw<br><br>**Recreation:**<br><br>PFOS: 110 µg/kg dw<br><br>PFOA: 643 µg/kg dw<br><br>**Industry:**<br><br>PFOS: 1949 µg/kg dw<br><br>PFOA: 643 µg/kg dw<br><br>**Groundwater**<br><br>PFOS: 120 ng/L<br><br>PFOA: 120 ng/L | OVAM | Provisional limit values for soil remediation, as described in the draft report by VITO (commissioned by OVAM) |
| **Target values Soil** | PFOS: 1.50 µg/kg dw<br><br>PFOA: 0.96 µg/kg dw<br><br>PFBA: 1.25 µg/kg dw | VITO/OVAM | Based on the study conducted by VITO (commissioned by OVAM) on the presence of PFAS at non-suspect locations (Vanermen et al., 2020 draft). |
| **Soil limit values** | PFOS: 2,6 µg/kg dw<br><br>PFOA: 0,7 µg/kg dw | Walloon Region | Based on ISSeP and SPAQuE determination ; minimum value between human health limit value and groundwater leaching limit value |

| | | | |
|---|---|---|---|
| **Limit values for soil excavation** | PFOS: 2,1 µg/kg dw<br><br>PFOA: 0,6 µg/kg dw | Walloon Region | 80 % of soil limit values |
| **Drinking water** | Sum PFAS[15]: 100 ng/L<br><br>Total PFAS[16]: 500 ng/L | EU | Values determined for the European Drinking Water Directive (2020/2184) |
| **Wastewater** | PFOS and PFOA: the emission limit value in the permit is set as low as possible[17] | EU | Starting points for these permits are the EU Directive on priority substances (2013/39/EU) and the Industrial Emissions Directive (2010/75/EU) |
| **Inland surface water** | PFOS<br><br>Annual average (AA) = 0.00065 µg/L<br><br>Maximum allowable concentration (MAC) = 36 µg/L | EU | Environmental Quality Standard (EQS) for PFOS in surface water, as determined in the Water Framework Directive (2013/39/EU).<br><br>Inland surface waters encompass rivers and lakes and related artificial or heavily modified water bodies. |
| **Other surface water** | PFOS<br><br>AA = 0.00013 µg/L<br><br>MAC = 7.2 µg/L | EU | Environmental Quality Standard (EQS) for PFOS in other surface water, as determined in the Water Framework Directive (2013/39/EU). |
| **Biota** | PFOS: 9.1 µg/kg fw | EU | Environmental Quality |

[15] From EU2020/2184: 'Sum of PFAS' means the sum of per- and polyfluoroalkyl substances considered a concern as regards water intended for human consumption listed in point 3 of Part B of Annex III. This is a subset of 'PFAS Total' substances that contain a perfluoroalkyl moiety with three or more carbons (i.e. –CnF2n–, n ≥ 3) or a perfluoroalkylether moiety with two or more carbons (i. e. –CnF2nOCmF2m–, n and m ≥ 1).

[16] From EU2020/2184: 'PFAS Total' means the totality of per- and polyfluoroalkyl substances. This parametric value shall only apply once technical guidelines for monitoring this parameter are developed in accordance with Article 13(7). Member States may then decide to use either one or both of the parameters 'PFAS Total' or 'Sum of PFAS'.

[17] There is no single limit value for these permits. The value can differ between permits. Starting points for these permits are the EU Directive on priority substances (2013/39/EU) and the Industrial Emissions Directive (2010/75/EU). The Directive on priority substances states that Priority substances (like PFOS), have to be phased out. This means that, when possible, the quantification limit will be set in permits. The IED states that BAP have to be used, with the norm for substances being based on these BAP.

| | | | |
|---|---|---|---|
| | | | Standard (EQS) for PFOS in biota, as determined in the Water Framework Directive (2013/39/EU). |
| **Food** | **Meat**<br>PFOS: 50 µg/kg<br>PFOA: 500 µg/kg<br>**Milk**<br>PFOS: 6 µg/kg<br>PFOA: 60 µg/kg<br>**Eggs**<br>PFOS: 100 µg/kg<br>PFOA: 1000 µg/kg<br>**Fish**<br>PFOS: 150 µg/kg<br>PFOA: 1500 µg/kg | FAVV (SciCom,2020) | Limit values determined by the FAVV in December 2020 report (no EU limits available) |
| **Daily intake** | 0.63 ng/kg for sum of PFNA,PFOA,PFOS and PFHxS | VITO | Value extracted from VITO Minaraad presentation, 16 October 2020. |
| **Weekly intake** | 4.4 ng/kg for sum of PFNA,PFOA,PFOS and PFHxS | VITO | Value extracted from VITO Minaraad presentation, 16 October 2020. |
| **Blood Serum** | 6.9 ng/L for sum of PFNA,PFOA,PFOS and PFHxS | VITO | Value extracted from VITO Minaraad presentation, 16 October 2020. |
| **Mother milk** | 0.133 ng/L for sum of PFNA,PFOA,PFOS and PFHxS | VITO | Value extracted from VITO Minaraad presentation, 16 October 2020. |
| **Tolerable weekly intake** | 4.4 ng/kg bw for the sum of PFOS, PFOA, PFHxS, and PFNA | EFSA | 2020 |
| **Draft maximum level in food** | see point 6.2.4. and more info in | European Commission, voted on text | 2022 |

| | | | |
|---|---|---|---|
| | website communication[18] | | |
| **Indicative level of PFAS in food above which research of sources is recom-mended** | See the published recommendation (EU) 2022/1431 on the monitoring of PFAS in foodstuffs [19] | European Commission recommendation | 2022 |
| | | | |

*Footnote: Please note there is a difference in interpretation of target values and limit values between the different regional values listed in this table. The values listed in this table are thus not for comparison but for information. Some of the values in this table are under revision and could therefore change in the near future.*

## 6.1 Regional level

Apart from the monitoring studies described above, the Flanders PFAS action plan is focusing on creating legislation to react to the ongoing environmental pollution of PFAS. There is special focus on determining threshold values to ensure the safe use of soils and water, thereby preventing further pollution of the environment. Table 11 gives an overview of the existing and proposed threshold values. The table also contains health-based guidance values for PFAS in serum. For levels above these guidance values, an increased risk of health effects cannot be excluded, based on current available knowledge.

At the regional, provincial, community, and communes levels, the following competencies are relevant for the PFAS:

- water, soil, air protection
- nature protection & conservation
- industrial activities control & environmental permits
- water production
- prevention for health (risk factors)
- interventions on indoor air quality
- waste policy and definition of end of waste status
- regional recovery plans about chemicals
- regional inspection services

[1818] https://www.health.belgium.be/nl/europese-maximumgehalten-voor-pfas-verontreiniging-levensmiddelen
[19] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32022H1431&qid=1662025579330

## 6.2 Federal and mixt competence

### 6.2.1 REACH & CLP

The Belgian REACH committee (BCR) has been consulted on SVHCID dossiers, PMT, vPvM concepts, etc.

**REACH Substance Evaluation**

The following substances have been evaluated by the Belgian Competent Authority:

- Reaction mass of 2,2,3,3,5,5,6,6-octafluoro-4-(1,1,1,2,3,3,3-heptafluoropropan-2-yl)morpholine
    - EC: 473-390-7
    - Status: follow-up
    - Concern: Suspected PBT/vPvB, Exposure to the environment, Wide dispersive use
- Perfluamine
    - EC: 206-420-2
    - Status: ongoing
    - Concern: Suspected PBT/vPvB, Exposure of environment
- Amphoteric Fluorinated Surfactant
    - Status: ongoing
    - Concern: Suspected PBT/vPvB, Exposure of environment, Wide dispersive use
- Ammonium salts of mono- and bis[3,3,4,4,5,5,6,6,7,7,8,8,8-tridecafluorooctyl and/or poly (substituted alkene)] phosphate
    - EC: 700-403-8
    - Status: ongoing
    - Concern: Suspected PBT/vPvB, consumer use, wide dispersive use

**CLH**

One fluorinated substance CLH dossiers have been worked on by the Belgian Competent Authority:

- Perfluoroheptanoic acid (EC: 206-798-9) is under opinion development for Repr. 1B, H360D and STOT RE 1, H372.

**WCSR advices**

The Scientific Committee REACH (WCSR) is a committee of Belgian experts which produces advices on chemical risk management. At the time of writing, there is one advice in preparation regarding a fluorinated substance.

The Belgian Competent Authority for REACH follows several regulatory processes on the EU and international level, see section 7.4 for more information.

### 6.2.2 POP

The Federal government is responsible for the implementation of the POP regulation which covers :

- Perfluorooctane sulfonic acid (PFOS) and its derivatives
- PFOA its salts and PFOA-related compounds

Furthermore, the federal government is active in preparatory meetings of the POPRC, COP, and follow-up of the proposal to include PFHxS into POPs. See section 7.4 for more info on international processes.

### 6.2.3 Ecolabel

This is a federal competency where the federal parliament is requesting to include additional product categories for which PFAS are banned (presently: textile, furniture). The FPS of Health -, Food Safety and Environment has proposed to Belgian Committee for granting EU Ecolabels to encourage the restriction of PFAS when developing new EU Ecolabel criteria.

### 6.2.4 Food regulations

**Food Contact Materials**

PFAS in food contact materials are regulated in Belgium (in addition to EU regulations) in paper and cardboard and varnishes in contact with food through 2 specific royal decrees.

- The Royal Decree of 11 May 1992 regarding materials in products destined to come in contact with food. This Decree has a list of substances on paper and cardboard. In this list there are 2 fluorinated compounds (Table 12).
- The Royal Decree of 25 September 2016 regarding varnish and coatings destined to come in contact with food. This Decree refers to a positive list of substances from the EU regulation 10/2011 from 14 January 2011[20] regarding materials and products in plastic. Substances listed in this regulation can be used in FCM as well (see table 17 in Annex I for an overview of the fluorinated compounds in this list).

[20] https://www.health.belgium.be/nl/verordening-102011-betreffende-materialen-en-voorwerpen-van-kunststof-bestemd-om-met-levensmiddelen

*Table 12* Fluorinated compounds that are allowed in paper and board for contact with aqueous and fatty foods, according to the Royal Decree of 11 May 1992. Source: Trier et al. (2018).

| Substance | $Q_M$ |
|---|---|
| Ammonium-bis- (N-ethyl-2-perfluoralkylsulfonamidoethyl) phosphate cannot contain more than 15 % ammoniummono(N-ethyl-2-perfluoralkylsulfonamidoethyl) phosphate | 8,3 mg/dm², 4,4 mg F/dm² |
| Diethanolaminosalts of mono- and bis (1H, 1H, 2H, 2H-perfluoroalkyl) phosphates | - |

**Food**

Aanbeveling 2010/161/EU van 17 maart 2010: Betreffende monitoring van perfluoralkylverbindingen in levensmiddelen (Stockholm dossier p41).

EFSA[21] in Sept.2020 issued an opinion on perfluorooctanoic acid (PFOA), perfluorooctane sulfonate (PFOS), perfluorononanoic acid (PFNA), perfluorohexane sulfonic acid (PFHxS) with a threshold – a group tolerable weekly intake (TWI) of 4.4 nanograms per kilogram of body weight per week. This will be taken into account in food regulation. Experts considered the decreased response of the immune system to vaccination to be the most critical human health effect when determining the TWI. This differs from EFSA's previous opinion on PFAS in 2018, which used increased cholesterol as the main critical effect. It is to be highlighted that the 4 PFAS considered in the 2020 EFSA opinion are rather known long-chain PFAS, while it does not consider the short ones.

In 2021, the Commission/DG SANTE has started discussions with the other Member States to establish maximum levels of PFAS in foodstuffs within the framework of the Contaminants EU Regulation. DGAPF is actively participating in this work on behalf of Belgium. On 22 June 2022 the European Regulatory Committee (Standing Committee on Plants, Animals, Food and Feed) voted in favour of the following regulatory texts concerning perfluoroakylated substances:

- Regulation amending Regulation (EC) No 1881/2006 as regards maximum levels of PFAS in certain foodstuffs.

- Commission Recommendation (EU) 2022/1431 on the monitoring of perfluoroalkyl substances in food: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32022H1431&qid=1661872588477

- Commission Implementing Regulation (EU) 2022/1428 laying down the methods of sampling and analysis for the control of perfluoroalkyl substances in certain foodstuffs: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32022R1428

[21] https://www.efsa.europa.eu/en/news/pfas-food-efsa-assesses-risks-and-sets-tolerable-intake

### 6.2.5 Parliament resolutions

Two resolutions have been voted and discussed by the federal parliament regarding PFAS:

**Voted:**
Resolution on the transparency of production and use of PFAS: **https://www.dekamer.be/FLWB/PDF/55/1546/55K1546002.pdf**

**Under discussion:**
Resolution regarding the prevention of PFAS contamination of food packaging materials and health risks due to exposure thereof: **https://www.dekamer.be/FLWB/PDF/55/2260/55K2260001.pdf**

### 6.2.6 CIMES and CCIEP

- A common position was taken on 3/10/2019, asking for a PFAS strategy aiming at keeping only essential uses and a range of measures, to be proposed to the COM in a joint letter with other MS under a SE initiative.
- A new position from CIMES was decided in July 2021, with actions for coordination aiming at the ban of all PFAS except essential uses.

Because of the growing international concern regarding PFAS – especially regarding the regrettable substitution of restricted long-chains by short-chain alternatives – a sub-group of the CCIEP Chemicals group was created to specifically tackle short-chain PFAS. This working group's main task consisted of gathering information on short-chain PFAS in Belgium. The first version of this report was one of the actions under this working group.

After the major pollution of PFOS around the 3M site in Zwijndrecht (Antwerp) gained public attention, the Joint-Interministerial Conference on Environment and Health (JICEH) decided in its meeting in July 2021 that this short-chain PFAS group should be expanded to all PFAS and that the existing mandate should be prolonged and that health competences should be included in the group (as CCIEP groups traditionally only encompass environmental dossiers). This resulted in a new mandate starting from December 2021.

### 6.2.7 NAPED

Within the National Action Plan for Endocrine Disruptors (NAPED) there are several actions planned that cover PFAS substances, including the addition of new criteria to the Ecolabel, possible labelling of PFAS-containing products, as well looking at conducting in-vitro toxicological research on PFAS substances.

### 6.2.8 Federal environmental inspection services

Competence on the placing of the market, under the Products norm law.

## 6.3 Overview of EU and International policy actions including BE positions

In this section, we give an overview of the EU and international activities in which BE actors are involved.

**Policy discussions**

- Council, June 2019: conclusions asking the COM to develop an action plan for PFAS, keeping only essential uses
- Letter and strategy proposed to the Commission (CIMES decision in 2019)
- HBM4EU PFAS biomonitoring, and autumn 2020 PFAS stakeholders workshop (UAntwerp, VITO)

Per-/polyfluorinated compounds | HBM4EU - science and policy for a healthy future

- EU Council 10/2020
- EU Council 03/2021 (about the EU Commission Chemicals for sustainability strategy, including a PFAS strategy).

**REACH & CLP regulations**

See tables 1 and 2 for an overview of the current and ongoing REACH and CLP-related dossiers on PFAS. Section 7.2.2 gives an overview of REACH and CLH dossiers which have been worked on by the Belgian competent authority.

The RMOA (regulatory management option analysis) list includes a total of 9 PFAS substances (Table 19 in Annex I). Furthermore, 10 PFAS substances have been listed on the Candidate list (Annex I, Table 20). No PFAS substances are listed on the authorization list (Annex XIV of REACH).
A total of 21 PFAS substances are listed in the Rolling Action Plan (CoRAP, Annex I, table 22) and several CLH intentions are within the scope of the PFAS definition (Annex I, Table 23).

**POP/Stockholm convention:**

Long-chain PFAS PFOS and PFOA are already regulated under the Stockholm Convention. PFOS has been identified as a persistent organic pollutant (POP) and was included in Annex B (restrictions) of the Stockholm Convention. This inclusion in the POPs convention overrules the REACH restriction on PFOS, which has been deleted from AnnexXVII. In the EU POPs regulation, the definition of the scope is “Perfluorooctane sulfonic acid and its derivatives (PFOS) $C_8F_{17}SO_2X$ (X = OH, metal salt (O-M+), halide, amide, and other derivatives including polymers)”. This definition thus also includes derivatives that can degrade to PFOS. The PFOS ban under the Stockholm Convention was re-examined in 2019, resulting in all exemptions granted until then in the EU being deleted (except for the use as spray suppressant for non-decorative hard chrome plating (chromium VI) in closed-loop systems).

PFOA, its salts, and related substances have been included in Annex A of the Stockholm Convention since May 2019, which resulted in inclusion into the EU POPs Regulation in April 2020. Same as with PFOS, this overrides the REACH restriction, which has been deleted.

Lastly, PFHxS, its salts and related substances have been nominated as POP candidates and will be included in 2022. A restriction proposal has been made by Norway and has been through opinion-making at ECHA. At its fifteenth meeting, the POPRC adopted the risk management evaluation on perfluorohexane sulfonic acid (PFHxS), its salts, and PFHxS-related compounds and recommended to the Conference of the Parties that it consider listing the chemicals in Annex A to the Convention without specific exemptions. The COP will decide on the listing of the substance at its 10th meeting in June 2022. The eventual listing under the Convention would enter into force one year after the date of the communication of its adoption by the depositary for the Convention.

**Montreal protocol**

CFCs and HCFCs are covered by the Montreal Protocol, these are partly or fully halogenated substances with a core ranging from C1-C3. Several substances such as chlorofluorocarbon 113 (CFC113) and hydrochlorofluorocarbon 22 (HCFC22) are derogated from this protocol, however, these are used as intermediates in the production of fluoropolymers.

**F-gases Regulation (EU) No 517/2014**

This is a specific regulation on fluorinated greenhouse gasses, which aims to reduce the 2030 emissions from industry by 70% compared to those in 1990. The annex of this regulation lists a number of HFCs and PFCs.

**OECD global PFC group**

Exchange of information about PFAS taxonomy, uses, and alternatives. Promotion stewardship programs and regulatory approaches to reduce emissions and the content of relevant perfluorinated chemicals of concern in products and to work toward global elimination, where appropriate and technically feasible.

**EFSA**

EU recommandation 2010/161/EU --> PFAS in food

EFSA has set a new threshold for the main PFAS (PFOA, PFOS, PFNA, and PFHxS). The threshold is set at a tolerable weekly intake (TWI) of 4.4 ng/kg of body weight per week for the 4 substances combined (DOI:

10.2903/j.efsa.2020.6223).

https://www.efsa.europa.eu/en/news/pfas-food-efsa-assesses-risks-and-sets-tolerable-intake

**OSPAR convention**

It is also to be mentioned that the OSPAR convention for the protection of the North-East Atlantic includes the North Sea. This is a federal competency, and the convention includes a list of PFAS in its list of potential substances of concern, as well as a polluter-pays principle and obligations regarding pollution coming from land-based sources.

**Rotterdam Convention (PIC)**

Federal competence, implemented in regulation (EU) No 649/2012. Includes a list of chemicals subject to export notification procedure including PFOS. Under the PIC regulation export outside the EU of PFOS and their related compounds (whether in substance, mixtures, and certain articles) are subject to various provisions defined in the PIC regulation including obtention of a positive import consent from the importing country's competent authority. It must be noted that the export of waste is not covered by the PIC regulation. At the time of writing it is being considered to add PFOA and related compounds to the PIC list.

**SAICM (Strategic Approach and sound management of chemicals and waste)**

Shared competence between the federal government and the regions.

Perfluorinated chemicals and the transition to safer alternatives were recognized as an issue of concern under SAICM (ICCM2, May 2009), calling for their eventual elimination, but instead, their production and use has increased, including short-chains in the EU.

**UN SDGs**

SDGs particularly relevant for PFAS:

- SDG 6: Ensure availability and sustainable management of water and sanitation for all
- SDG 12: Ensure sustainable consumption and production patterns

**Defence**

The US Department of Defence has released a National Defence Authorization Act (NDAA), which phases out the use of PFAS-containing firefighting foams by the US Defence Department by October 2024. The NDAA also immediately prohibits the uncontrolled release of fluorinated aqueous film-forming foam (AFFF) and the use of AFFF in training exercises at military installations. If this is copied into NATO, this will also result in a restriction in the Belgium Defense Department (Wood report, 2019).

**Plant protection Products Regulation (EC) No 1107/2009**

For the RMOA on the general restriction, there has been a search on ECHA's PACT tool, which yielded 37 hits for active substances in plant protection products for which the CLH process has been finished or is still ongoing. Of those 37, 3 are listed as being active substances in plant protection as well as biocidal products. A list of the 37 substances is provided in table 18 of Annex I.

**Biocidal Product Regulation (EU) No 528/2012 and amendments**

On ECHA's webpage for EU biocidal active substances, a total of 30 fluorine-containing substances can be found. 11 of these biocidal active substances fulfill the current working definition of PFAS (containing aliphatic $CF_2$- or $CF_3$-unit, see table 19 in Annex I). 9 of these 11 are currently approved as biocidal active substances and include product types PT18 (insecticides), PT08 (wood preservatives), PT (14) (rodenticides), PT07 (film preservatives), PT09 (fiber, leather, rubber, polymer preservatives) and PT10 (building material preservatives) and/or PT 21 (antifouling agents).

**EU Soil Strategy**

The EU Soil strategy[22] has been developed under the Biodiversity Strategy of the Green Deal and mentions the risks to soil and health related to PFAS. One of the actions under this soil strategy is the development of a Soil Health Law by 2023, which would envisage identifying contaminated sites and setting up an inventory of these sites, and starting the remediation of these sites that pose a risk to human health and the environment by 2050.

**Europe's Beating Cancer Plan**

https://ec.europa.eu/info/strategy/priorities-2019-2024/promoting-our-european-way-life/european-health-union/cancer-plan-europe_en#flagship-initiatives

→ includes action on reducing exposure to carcinogenic substances

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[22] https://ec.europa.eu/environment/strategy/soil-strategy_nl

*Table 13* EU Legislations other than REACH

| Relevant EU-legislation other than REACH | Community wide option for risk management |
|---|---|
| **Water Framework Directive,**<br><br>**Directive 2000/60/EC** | Releases of PFAS occur to the surface water and ground water. The aquatic compartment is an important media for PFAS in the environment and WWTPs are a main source of emissions into that compartment. Therefore, it is proposed to include PFAS as priority hazardous substances. However, WWTP is not the only source and the aqueous media is not the only environmental media of concern and therefore the use of the directive alone is insufficient. |
| **Drinking Water Directive,**<br><br>**Directive 98/83/EC** | Some PFAS have a low solubility in water, while others have a high solubility. High levels for some PFAS have been detected. For example, short chain polar PFAS are already widely detected in water.<br><br>Limit values for some PFAS are already included and for and for other PFAS limit values are proposed, including as a sum for several substances. The limit for total organofluorine (when method is available) is set in https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CONSIL:ST_6060_2020_REV_1&from=EN, Annex I part b and Annex III, part B, point 3. |
| **Sewage Sludge Directive,**<br><br>**Directive 86/278/EEC** | Limit values for PFAS in sludge should be established.<br><br>However, only levels in sludge would be regulated, not manufacture, use and emissions that ultimately result in contamination of sludge. |
| **Waste legislation (e.g. recollection, or classification as hazardous waste** | Waste management requirements can be considered as complementary to a restriction to manage risks related to derogations. |
| **Directive on industrial emissions (integrated pollution prevention and control),**<br><br>**Directive 2010/75/EU** | This Directive addresses pollution from large industrial installations, which can be considered as complementary to a restriction to manage risks related to derogations. |

| | |
|---|---|
| **Volatile Organic Compounds (VOC) Directive,**<br><br>**Directive 1999/13/EC** | It has to be assessed if PFAS could fulfil the VOC criteria. |
| **Medicines and medical devices** | |
| **Workers protection** | To be noted: If no existing harmonized classification (under CLP regulation), then not in SDS (thus the majority of the PFAS) –> workers protection relies in those cases only on supply chain information |
| **EU legislation**<br><br>**Commission regulation (EU) No 10/2011 on plastic materials and articles intended to come into contact with food** | Recommendation for a controlled plan is given in COMMISSION RECOMMENDATION (EU) 2019/794[23].<br><br>A REACH restriction on articles can cover FCM if it is because of environmental issues. |

[23] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32019H0794&from=EN

# 7 Alternatives to PFAS

On the website from PFAS Central (PFAS-Free Products - PFAS Central), one can find an overview of brands that provide PFAS-free alternatives to products that traditionally contain PFAS. The website includes rain gear, apparel, shoes, car seats, strollers, furniture, personal care products (floss, waxes, etc.), cosmetics, food ware, carpets and rugs, textiles, and textile technologies. The website of PFAS free (Find PFAS free products & reduce environmental harm) provides information on consumer products from the UK.

The OECD has made a report looking into the alternatives for PFAS use in FCMs (Food Contact Materials). This report concluded that long-chain PFAS can easily be replaced by short-chain PFAS and non-fluorinated alternatives. The report also found that, in some cases, the non-fluorinated alternatives have a performance advantage over the short-chain PFAS (OECD, 2020). However, the market share of these non-fluorinated alternatives is 1% or less, which is mainly explained due to their present high production costs.

Furthermore, the OECD is working on a report on PFAS and Alternatives in Coatings, Paints, and Varnishes.
The OECD website also provides an overview of reports on alternatives from several member countries (https://www.oecd.org/chemicalsafety/portal-perfluorinated-chemicals/alternatives/). The following reports are listed

- ➔ Denmark
  - Mist suppression with non-PFOS (perfluorooctane sulfonate) surfactants for hard chrome plating (SubsPort), 2011
  - Substitution of PFOS for use in non-decorative hard chrome plating (Danish EPA), 2011
- ➔ European Commission
  - Alternatives to perfluoroalkyl and polyfluoro-alkyl substances (PFAS) in textiles (Danish EPA), 2015
  - Short-chain Polyfluoroalkyl Substances (PFAS) (Danish EPA), 2015
  - Moving Towards Safer Alternatives (SubsPort), 2006
  - Surface Treatment of Metals and Plastics (European Commission), 2006
  - Potentially environmentally sounder alternatives to PFOS compounds and PFOA (SubsPort), 2005
  - More environmentally friendly alternatives to PFOS-compounds and PFOA (Danish EPA), 2005
- ➔ Germany
  - Do without perfluorinated chemicals and prevent their discharge into the environment (German UBA), 2009
- ➔ Sweden
  - Occurrence and use of fluorinated substances and alternatives (KEMI, Swedish Chemicals Agency), 2015

The Stockholm Convention has reports on alternatives for PFOS (http://chm.pops.int/tabid/5219/Default.aspx).

The EU Commission and DG Environment have commissioned a study by Wood on fluorine-free alternatives in textiles, upholstery, carpets, leather, and apparel[24]. This report contains a summarized overview of the major categories of non-fluorine alternatives available on the market, being Hydrocarbons, Silicones, Dendrimers, Polyurethane, Nanomaterials, and alternative technologies (alternative weaving and fibre control).

Moreover, valuable information on alternatives was collected in the framework of the REACH restrictions.

- Current restrictions: https://echa.europa.eu/fr/substances-restricted-under-reach
- Restrictions under discussion: https://echa.europa.eu/fr/registry-of-restriction-intentions

It is also to be highlighted that non-chemical alternatives are also to be considered. Moreover, the essential uses principle being discussed implies that a ban can be done for some uses, even if only alternatives with a lower level of performance are available or even when there is no alternative.

[24] https://echa.europa.eu/documents/10162/13641/pfas_in_textiles_final_report_en.pdf/0a3b1c60-3427-5327-4a19-4d98ee06f041

# 8 Discussion and Perspectives

This report highlights the complexity of the PFAS topic due to the large number of substances this group encompasses, as well as the multitude of uses of these substances. It is clear there are still many uncertainties; especially regarding PFAS production, export, and use in Belgium and abroad, as well as knowledge on PFAS toxicology, emissions, and end of life. However, this report also highlights that many different projects are planned and ongoing to broaden the knowledge base regarding these substances. The same can be said for the regulatory landscape, on the one hand showing a lack of current regulation (only a few PFAS are regulated at this moment), while some major policy actions are underway (i.e. planned PFAS restrictions under REACH and the Stockholm convention, as well as limit values under several EU and regional legal initiatives).

To ensure that these planned regulatory actions will provide the best protection of human health and the environment it will remain important to generate the needed data to be able to conduct a realistic risk and socio-economic analysis. With the specific case of PFAS (with persistence in the environment as common adverse property), especially costs of clean-up and decontamination will be important to correctly take into account. Information should be generated and made available on unacceptable costs and effects that are likely if the use of PFAS continues. Water resources, soils, and human exposure are of particular concern. Even though this report shows that a lot is happening regarding PFAS research, it is clear that PFAS regulatory decisions (1) will involve decisions with irremediably incomplete scientific information due to the large amount substances (>6000) and uses, and (2) there are sufficient indications that the possible effects (without action) are inconsistent with the chosen level of protection of health and environment in the EU and Belgium.

PFAS policy in the EU is taking the direction of increased protection of health and the environment, within a circular economy with non-toxic material and product lifecycles. Synergies between regulations (e.g. REACH and water regulations, REACH and IED, REACH and environmental permits, etc.) are important. Upstream measures, grouping of substances when regulating, safe and sustainable by design and essential uses definition are being proposed because a substance-by-substance approach for risk assessment/management of PFAS is not feasible while regrettable substitutions are possible. Amongst the various measures being discussed, the following ones are likely to have the biggest effect on PFAS production, use, releases, exposure, and placing on the market:

- REACH restrictions;
- Socio-economic analysis and essential uses definitions;
- New CLP categories on persistence and mobility;
- Strict environmental permits;
- Enforcement (including developing new analytical methods);
- Innovation for substitution and safe and sustainable by design.

Particular attention is needed for PFAS in imported articles (i.e. development of analytical methods and enforcement activities) for ensuring a level playing field for the EU and BE industries. Building and sharing expertise, collaboration, and making investments in green chemistry (in the technical sense) and sustainable chemistry is a promising path for avoiding regrettable substitution of PFAS in many uses. It is helpful to use environmental, health, and sustainability criteria for orienting investments.

There is already a legacy of pollution to manage, for which monitoring will be needed for many years. Use conditions, best available techniques, and environmental permits have a role in emission reduction, and this is likely to be also the case for future accepted essential uses until substitutes are developed. Monitoring of the environmental compartments will also remain necessary for confirming that the upstream measures are working.

In the following paragraphs, we list some key topics that pose uncertainties and perspectives that might become important points of discussion in the PFAS regulatory landscape for the following months and years.

**PFAS production and use in Belgium**

PFAS are (possibly) produced at several industrial locations in Belgium. The 3M site of Zwijndrecht is known to have produced long-chain PFAS substances in the past, which have now been replaced by short-chain alternatives. However, specific information on PFAS production at this site and by other companies is scarce, while emissions data indicate that many PFAS substances are being either produced or used on multiple industrial sites. On top of this emission data showing which companies emit these PFAS, this report also includes a list of Belgian companies that have registered PFAS substances under REACH, which indicates these companies either produce or market these substances in Belgium. Further action by inspection authorities could be an additional tool to broaden the knowledge base in this regard.
Knowing at which sites these chemicals are produced and used is important to properly follow up on potential emissions (and thus exposure to the local population) of these substances. This could then be followed up with risk reduction measures like emission reductions and proper waste management. As the recent case in Zwijndrecht and many others around the world have shown it is important to act on these production and use sites to prevent emissions and increased exposure of populations living nearby production sites.

PFAS are imported to Belgium in large quantities due to their presence in a multitude of products, mainly concerning substances in textiles, coatings, firefighting foams, and food contact materials. The report also includes a SCIP database search which demonstrates the presence of SVHC-identified PFAS in a wide variety of products, although this search highlighted that the SCIP database is lacking in clarity regarding the specific product type in which these are present, making it impossible to clearly identify which products contain PFAS.

The above discussion clearly shows that only fragmented information is available on the production, use, and import of PFAS and that it was challenging to collect. This highlights one of the bigger challenges regarding PFAS substances which is knowing and tracking where PFAS are produced and used in materials and products throughout their life cycle. Knowing the limitations of the SCIP database (i.e. only SVHC-identified PFAS are included and only limited product information is available), it is more than likely that downstream users are many times not aware that PFAS are present in their products, which might become important information once the general restriction enters into force. Furthermore, considering the rising public awareness of the challenges and risks regarding PFAS, it would be favourable to have a clear indication of whether PFAS are present in a consumer product. This shows that there is a need for clear and transparent communication throughout the supply chain to ensure that downstream users and consumers know that PFAS are present in their products and materials.

**Lesser known PFAS: F-gasses and Fluorinated polymers (i.e. fluoropolymers, side-chain fluorinated polymers, and fluorocarbons)**

A large class of PFAS for which many uncertainties remain is the fluoropolymers. This group will most likely be getting increasingly more attention in the coming years due to their many uses and the different toxicological profile they seem to have compared to other PFAS. The industry has indicated that they consider in many cases fluoropolymers irreplaceable in specific applications due to their unique properties and have indicated that these chemicals are vital for the move to more green and energy-efficient technologies[25]. Furthermore, the current research seems to indicate that the fluoropolymers themselves seem to be of low risk during the use phase due to the (currently known) absence of hazardous properties.

Nevertheless, as these substances also are built out of the persistent C-F bond, it will be inevitable that these will pose similar risks compared to other PFAS, meaning they will barely break down and concentrations could increase irreversibly in the environment, acting as a sink for exposure to humans and ecosystems[26]. Another important point of discussion regarding these lesser-known PFAS will be their exposure throughout their life-cycle. For example for the production of fluoropolymers, there is often a need for non-polymeric PFAS as processing aids, which are known to have hazardous properties and therefore can pose a risk when emitted to the environment[27]. Also at the end-of-life stage, PFAS-containing products must be properly disposed of, recycled, or reused, to prevent their emissions to the environment. Another example is the recurrent removal/re-coating of fluoropolymers in bakeries' forms, with unknown releases (Lohmann & Cousins, 2020).

The industry has acknowledged this life-cycle challenge and these processing aids proposed to have voluntary agreements for responsible manufacturing, which have been shown in some sites to reduce emissions by up to 99%[28]. The significance of the 1% remaining in terms of risks is not known presently to the CCIEP PFAS working group. Moreover, the drawback of only having voluntary agreements could be that there would be a lack of legal tools to enforce these emission reductions, risking that only frontrunners in the industry will follow these agreements. It would therefore be preferable to also have legal requirements on these emission reductions to ensure best practices and minimal emissions across the industry. These kinds of emissions reductions could either be enshrined under the coming REACH restriction or the reformed IED. Regarding the end-of-life of these products, there would be a need for proper waste management and ways to separately treat PFAS-containing waste to ensure that emissions to the environment are prevented via this route.

Similar discussions and challenges are ongoing for other fluorinated polymers like fluorocarbons and side-chain fluorinated polymers. Regarding fluorocarbons, the industry indicates these are very inert compounds that do not have adverse characteristics, and therefore do not pose a risk to human health and the environment; although again here

[25] https://setac.onlinelibrary.wiley.com/doi/full/10.1002/ieam.4646
[26] https://pubs-acs-org.vdicp.health.fgov.be/doi/10.1021/acs.est.2c02765
[27] https://pubs.acs.org/doi/pdf/10.1021/acs.est.0c03244
[28] Verbally stated by Chemours

concerns regarding their production and disposal could arise, and toxic characteristics cannot be excluded[29]. For side-chain fluorinated polymers, a recently declassified report by the OECD summarized that more and more evidence is indicating these are important precursors to non-polymeric PFAS and therefore also act as an important source of non-polymeric PFAS emissions during production and end-of-life.

Considering the above concerns regarding fluorinated polymers, an important step to decrease the uncertainty on the risks of these substances will be for the registration of polymers under REACH, which could increase the knowledge base on fluoropolymers and in turn facilitate science-based risk analysis, as well as indicate whether these substances indeed pose less risk compared to other PFASs.

The unique properties of polymeric-PFAS, together with the types of uses in combination with uncertainties regarding hazards and risks will most likely drive the essential use discussions under REACH (even though essential use will not be used under the PFAS restriction). Nevertheless, for PFAS uses that might be deemed essential in the future, it will remain important to have the best available practices and proper waste management to prevent unwanted emissions as much as possible. Research and innovation into the hazards, as well as safe and sustainable alternatives, will be vital for this subclass of PFAS.

A similar yet different case entails the F-gasses, which also have their unique properties in the PFAS group, with differing toxicological profiles and according to industry some essential applications. The same challenges and perspectives as with fluorinated polymers could apply in this case, with again a need to look at the complete life-cycle of these substances, in combination with more toxicological insights and continuing research for alternatives.

## Research on PFAS hazards, risks, and mixture effects

One large challenge that remains is defining the potential hazards of all PFAS substances. As this is a large and diverse group of substances it is difficult to do a traditional risk assessment by identifying the hazard of each substance. Initiatives like the PFAS-tox database and ongoing academic research ensure that the knowledge is increasing, but it is unlikely that all PFAS will have a complete toxicological profile in the near future.

Even though the current grouping under REACH for PFAS is focussing on the common characteristic of persistence, it remains vital to research other potential hazards of specific PFAS substances, as this will further strengthen the risk assessment of the oncoming restrictions. For many of the investigated PFAS, it has been shown they have endocrine disrupting properties[30,31,32]. Especially considering that for multiple PFAS it has been shown that they exhibit low-

[29] https://www.ecetoc.org/wp-content/uploads/2021/10/ECETOC-TR-103.pdf

[30] Hormoonverstoorders | Beswic

[31] NAPED

[32] See following papers for more detail:
Endocrine-disrupting activity of per- and polyfluoroalkyl substances: Exploring combined approaches of ligand and structure based modeling - PubMed (nih.gov)

dose effects[33] and their dose-response curves do not follow the typical linear line, but more towards non-monotonic dose-response curves[34].

The scientific literature and REACH-related dossiers show that the main hazards related to PFAS are persistence and long-range transport. In Belgium, several studies have been conducted on PFAS presence in the environment, bio-monitoring, and possible hazards, of which this report gives an overview. Furthermore, the proposed actions under the CSS to include new hazard classes focussing on persistence and mobility might prove to be a valuable legal asset to classify more PFAS substances as hazardous substances, enabling more regulatory action.

The focus of toxicological research should not only be on human endpoints but should include ecotoxicological research as well. Some studies from Belgium universities for example have already shown the effects of higher PFAS concentrations on certain species, although these studies are still rare compared to the human end-point studies.

Apart from hazard assessment of individual substances, it will be important to also research the mixture effects of PFAS. This includes the combination effects of different PFAS, as well as effects of PFAS in combination with other substances. Research under the HBM4EU already indicated that co-exposure to higher levels of both Cd and certain PFAS was associated with a decrease in kidney function in adults, which suggests a combined mixture effect[35].

Even though there are still a lot of unknowns on these substances, it is positive to see a lot of projects in the pipeline to fill in the knowledge gaps. The work being done by the regional authorities on (bio)monitoring with projects like the PFAS-action plan, CARIBOUH, BIODIEN, and others, as well as the extensive mapping exercises of contaminated sites shows that Belgian is playing a pioneering role in regards to PFAS research. Federal projects like FLUOREX, NAPED, and PERFOOD add to this body of knowledge being generated by Belgium. It will be vital in the future to follow up on these projects and share their results with the bodies working on the banning of PFAS.

**Innovation across the life-cycle**

Belgian authorities are taking initiatives at various levels: in the Walloon and Brussels regions, environmental monitoring has been conducted for several years. The Flemish region has adopted a PFAS action plan, which encompasses bio-monitoring, environmental monitoring, and the development of new methods to detect and analyse lesser-

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Vagi et al. 2014
Zota et al., 2018
[33] See following references:
Dixon et al. 2012 - Tucker et al. 2015 - White et al. 2011
[34] Relatie tussen dosis en effect | Beswic - Meng et al., 2018 - Kim et al. 2018
[35] Synergistic impact of co-exposures to toxic metals cadmium, lead, and mercury along with perfluoroalkyl substances on the healthy kidney function - ScienceDirect
Preston 2020 -- Prenatal exposure to per- and polyfluoroalkyl substances and maternal and neonatal thyroid function in the Project Viva Cohort: a mixtures approach - Environ. Int., 139
The role of maternal high fat diet on mouse pup metabolic endpoints following perinatal PFAS and PFAS mixture exposure, Marques, 2021
Combined effects and toxicological interactions of perfluoroalkyl and polyfluoroalkyl substances mixtures in human liver cells (HepG2, Ojo 2020)

known PFAS substances. This work has been expanded following the Zwijndrecht case, now including several new studies, the construction of a PFAS map, and a report being prepared for giving policy advice regarding these substances.

Taking into account this available information, the most important variables that will drive possible evolutions in the future are research on the potential human and environmental hazards of the lesser known PFAS substances, to determine which substances require the most stringent regulatory action. Furthermore, new analytical methods to analyse the wide variety of PFAS substances, as well as methods to analyse PFAS more efficiently in different matrices (i.e. water, air, and soil) are essential to indicate the scale at which these substances are present in the environment. Lastly, as the emissions of these substances will most likely continue for several years, and due to their persistent nature, the development of remediation techniques from different environmental compartments will be vital as well.

Research and innovation initiatives focussing on methods to remediate and destroy PFAS remain important to reduce the environmental presence of these substances, but it is at least equally important to look more upstream and prevent further emissions by redesigning products and services and substituting PFAS uses as much as possible. Concepts like Safe and Sustainable by Design (SSbD) and substitution projects like Belgium Builds Back Circular (BBBC) are vital to helping the industry in moving to alternatives that are safe and sustainable. For specific uses that might need to continue due to essentiality considerations, it could be interesting to look into concepts like the Extended Producer Responsibility (EPR), where a producer of a substance stays responsible for that product throughout the life-cycle.

**REACH revision and other regulatory actions**

The recent developments at the 3M Zwijndrecht site have demonstrated that it is important to ensure that industrial production processes generate minimal emissions and exposure to the local population and workers. By having mandatory best practices it can be ensured that emissions are minimised and risks are limited. Concepts like responsible manufacturing are an important first step in this, however, they should be legally implemented and not limited to voluntary agreements, as not only frontrunners should by applying these principles. Actions under the IED and the REACH restrictions could ensure that site management is legally required for PFAS-producing industries.

Adding PMT and vPvM to CLP classification will be an important step to enlarge the range of research under CLP, which will aid in expanding the hazard profiles of PFAS substances, which in turn will ensure that other regulatory actions will be well founded in scientific information.

One of the most important and effective tools to prevent further exposure of humans and emissions of PFAS to the environment will be the restrictions underway under REACH. By banning these substances it can be ensured that further emissions are stopped and consequently levels will stop rising in the environment. However, it is also important to recognize that some uses are at the moment irreplaceable and essential for the functioning of society. Therefore it will be important to have a very thorough socio-economic analysis of these substances to identify the uses which might be needed to continue until alternatives are available. Therefore the concept of essential use could be a strong tool to ensure that this selection is made correctly. Even though the essential use concept will not be cemented in EU law yet when the restriction proposal will be published, it should be possible to already do a similar analysis of the different uses and correctly identify the costs and benefits, and essentiality of the different uses. This analysis should not be limited to monetary costs of stopping the production, but should certainly also include benefits like prevented disease burden, prevented effects on ecosystems, and prevented remediation costs, of which monetary estimations have already been made in several studies[36,37,38]. The extent of genuine systemic societal risks generated by a restriction should be considered as the marker of the essentiality of a substance for the functioning of society.

As PFAS are persistent and many have long-range transport potential, it will be important that these actions are not limited to the EU as emissions from outside of the EU could reach the EU (either via planetary processes, or the import of PFAS containing articles or waste). By including additional PFAS in the Stockholm Convention, or having international certification and labeling schemes, it can be ensured that this problem is tackled at a more international level, ensuring that the global emissions are minimized. Without actions on PFAS at the international level, we will partly delocalize PFAS industrial uses and receive the PFAS back through the environment even if the final products do not contain the restricted PFAS.

# 9 Conclusion

Despite the scarcity of information on production and import, the data collected on emissions indicate the wide use of many PFAS substances in Belgium, indicating there is more import and production than what we could find when collecting data for this report. Monitoring studies of water, soil, and biota in Belgium show that PFAS are widely present in the Belgium environment. The wide use of these substances in consumer articles also indicates exposure to many of these substances, which is reflected in biomonitoring studies, showing that several PFAS substances are found in the Belgium population.
Research on these substances will remain vital, as many uncertainties remain on lesser studied groups of PFAS substances. Especially in light of the oncoming regulatory actions on the whole of the PFAS group, it will remain essential to collect as much data as possible on the Belgium situation regarding these PFAS substances. (Bio)monitoring, (eco)toxicity research and the development of new analytical techniques and remediation techniques will remain vital to assure the right regulatory actions are taken to assure maximal efficient risk management of these substances. Due to a large amount of expertise, pioneering research, and extensive (bio)monitoring projects, Belgium can play an important role in providing data for these future regulatory actions.

Given the great number of substances and different uses under the PFAS group, it will be impossible to have a full-scale idea of the hazards and risks of these substances. Therefore, it will be vital to tackle these substances in a group approach. This unavoidably leads to a decision-making process based on limited data and information. Concepts like the precautionary principle, costs of inaction, and essential use will be important tools to use in order to ensure that

[36] https://pubs.acs.org/doi/10.1021/acs.est.2c02765
[37] Leveraging Systematic Reviews to Explore Disease Burden and Costs of Per- and Polyfluoroalkyl Substance Exposures in the United States | SpringerLink
[38] Ontwikkeling van gezondheidsindicatoren voor blootstelling aan hormoonverstorende stoffen in Vlaanderen en doorrekening van de maatschappelijke gezondheidskost | FRIS onderzoeksportaal (researchportal.be)

all PFAS will be banned unless they prove to be essential for the functioning of society. And even then efforts should be continued to be made to find safe and sustainable alternatives to phase out these substances as much as possible.

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