PFAS Substitution Guide

FOR TEXTILE SUPPLY CHAINS

August 2022
Version 2

PFAS Substitution Guide for Textile Supply Chains

Introduction

This guide is a support for textile industry players, to improve commmunication about chemicals and raise the possibility for well-informed substitution work. It focuses on subsitution of highly fluorinated substances, also known as per- and poly-fluoroalkyl substances (PFAS), offering textile buyers a deeper understanding about water repellence and the associated chemistry. The guide can be used as a starting point for your chemicals management and substitution work, with many links to other information sources. We recommend using the Table of Contents below as a navigational tool, to start filling any knowledge gaps and expand your reading from there.

The Table of Contents and most cross-references in the text have clickable links highlighted in blue for direct access to further reading. There is a link back to Table of Contents at bottom of each page.

Contents

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For other referred sources, see References in the end.

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PART 1: STARTING PFAS SUBSTITUTION

1. PFAS, risk and substitution

Per- and polyfluoroalkyl substances (PFAS), sometimes referred to as highly fluorinated substances, fluorocarbons (FC), or per- and polyfluorinated compounds (PFC), is a multifunctional group of chemicals used in many consumer products for their ability to repel water, oil, dirt, and grease as well as to provide film forming properties, low friction, and to withstand other chemicals and high temperatures. In this report they will be called ***PFAS***, which is also the officially recommended acronym (Buck & al., 2011).

According to the official definition by OECD, a PFAS is any fluorinated substance that contains at least one perfluorinated methyl group (-CF_3) or a perfluorinated methylene group (-CF_2-) (OECD, 2021). PFAS are popularly described by the number of carbons in the molecule e.g., C4/C6/C8. For a very basic understanding of this class of chemistry, known as halogenated organic chemistry, all PFAS are man-made, containing carbon-fluorine bonds that are extremely stable and not known to exist naturally. PFAS are either extremely persistent themselves or degrade to other extremely persistent PFAS degradation products and are therefore often called "forever chemicals".

There are many thousands of different PFAS that all have persistency in common, but with a wide range of molecular structures and properties making them behave differently in the environment and in organisms. Only a few have been studied in detail in terms of human and environmental effects. The two most well studied PFAS - PFOS and PFOA - are now globally regulated together with any substances that can degrade to them, due to the adverse effects they have shown on human health (read more in Health, environment and brand reputation). They are highly mobile, bioaccumulate and magnify in the food chain, resulting in widespread environmental pollution and potential health risks far away from the emission sources. The annual health-related costs from PFAS exposure were in 2019 estimated to € 58-84 billion in Europe. (Goldenman & al., 2019) In addition, PFAS pollution affects ecosystems and generates high costs for cleaning up polluted land and water. It is important to not only consider the toxicity potential of included PFAS during use, but also the release of PFAS to the environment during production and end-of-life.

Phasing out PFAS is a major focus of the *EU's chemicals strategy*, published in October 2020. Beyond PFOS and PFOA, there are recent regulations of other PFAS (see PFAS regulation: EU and globally) and the number of yet unregulated PFAS are growing on the *Candidate List as substances of very high concern (SVHC)* within REACH. Since only a few PFAS have been studied in detail, currently unregulated PFAS cannot by default be considered safe and unproblematic. To overcome the challenge of evaluating and regulating PFAS substance by substance, and to avoid regrettable substitution, a proposal to regulate PFAS as a group will be submitted to ECHA by five member states in January 2023.

Whether the driving force is internal ambitions for increased sustainability, increased demand from customers or a reaction to future PFAS regulations, now is the time to substitute PFAS. However, alternatives to PFAS should not automatically be assumed as safe or free of hazards. Therefore, it is highly recommended to create a systematic chemicals management approach which addresses chemical risks regardless of the type of chemistry in question. There are several ways to do this, a few links are available in the section Tools for chemicals management.

2. DWR basics

Durable water repellents (DWR) are used for water-, oil- or dirt repellence with long-lasting performance. The water repellence of a textile is influenced by an intricate combination of macro- and microstructures in combination with material properties and DWR finishing properties. Often the chemistry applied needs to compensate for properties of a raw material, fibre form or textile construction which has hydrophilic or capillary effects – either by choice when prioritizing other properties, or unknowingly because the physics of water repellence were not known to the developer.

The key defining moment for DWR performance is the application process, when the DWR formulation is applied to the fabric and cured for bonding strength and optimal film thickness on the fibre. In this process, four main aspects will influence the result (see *Figure 1*):

- **Fabric chemistry** – The free surface energy resulting from the fibre polymer type, all additives including dyestuff and other finishing agents, and impurities such as oils from production or fingerprints etc.
- **Fabric structure** – From weave/knit density and type, through filament count of yarns and fibre constitution to surface structure of the fibres.
- **Formulation chemistry** – Bonding strength, film forming abilities, surface energy and structure.
- **Application process** – Tailored to combine the specific fabric chemistry and structure with formulation chemistry for optimal molecular bonding, film forming and curing process. Heat, time, concentrations and auxiliary chemicals are used to optimize the outcome.

To overcome the application process challenges, auxiliaries such as wetting agents and cross-linkers are important tools for the DWR finisher. From a chemicals management perspective, it is as important to keep track of these substances as the actual DWR formulation since they are handled by the finishers and will end up both on the fabric and in effluent water.

When testing textile water repellence (e.g. Spray test or Bundesmann), it is important to understand all of the above mentioned factors influencing performance and work closely together with DWR manufacturer, textile producer and finisher to find the best tailored solution for the intended use and fabric. The now prohibited C8 chemistry was more robust than both short-chain PFAS and PFAS-free solutions, meaning that this process tailoring work is even more important for alternative formulations (Schellenberger & al., 2018). With new less oil repellent chemistry, there are also risks for production contamination of fabrics after DWR application, why DWR performance should always be evaluated on both production-stage fabrics and finished garments before scaling up production.

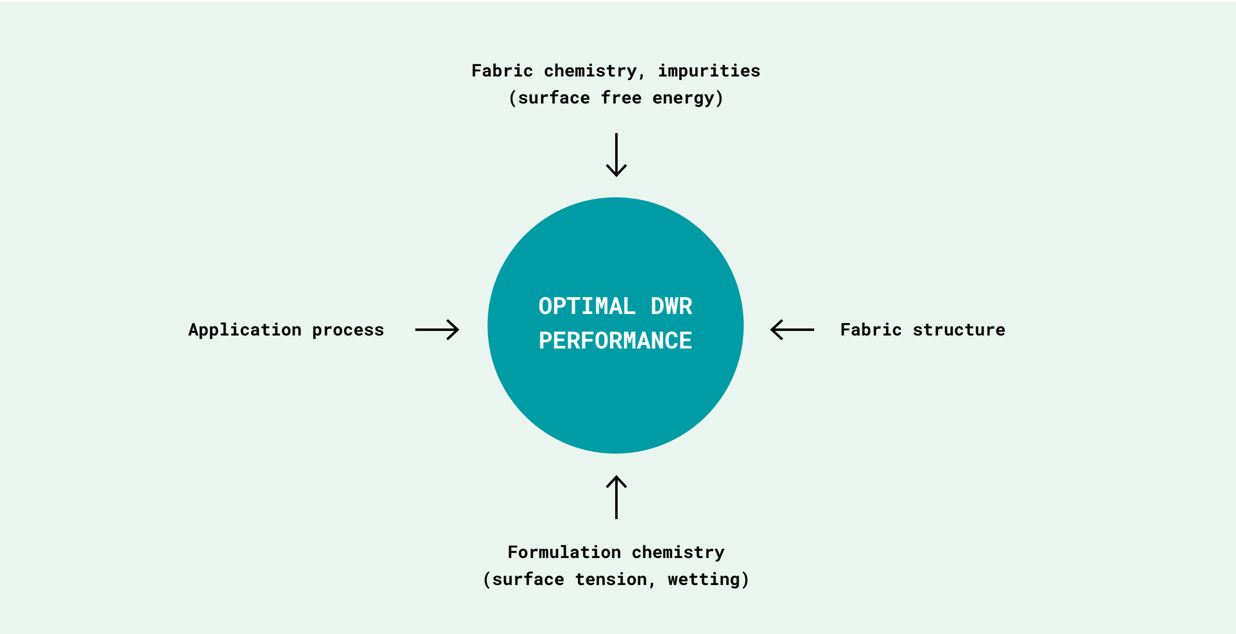


Figure 1. The complex interaction for an optimal DWR performance, based on learnings from POPFREE 2017-03730.

3. PFAS in textiles

In textiles and leather processing, the highly beneficial PFAS properties of repellence, chemical stability and lowering water surface tension are used in several ways. Functional uses of PFAS include waterproofing, oil resistance, stain release, and chemical splash protection in protective textiles to name a few. In textiles, PFAS may be found in the repellent DWR-finish, in trims and details, in membranes in waterproof breathable garments and as process auxiliaries for wetting and improving quality of coatings. In this document we will primarily focus on DWR finishes, but all other above-mentioned uses are relevant to investigate when mapping and substituting PFAS in the supply chain.

3.1 A life cycle perspective

When PFAS are used in DWR, the chemistry is present in most parts of the value chain. Therefore, all lifecycle steps need to be carefully considered from raw material extraction through manufacturing, the use phase, to product end-of-life. The exposure routes for a chemical includes solid waste, effluents, airborne emissions and direct workplace/user contact in each lifecycle step. To get an overview of the total impact, a value chain/lifecycle flowchart can be used to visualize the inputs, processes, outputs, effluents, emissions, and people involved in every step (See *Figure 2*).

While the DWR substances have their first contact with garment production in the textile finishing step, there are preceding processing steps of raw material extraction, chemical processing and mixing to DWR formulations which also need to be accounted for. Large-scale health effects from poor management practices in chemicals manufacturing was very clearly shown in the $671 million DuPont/Chemours settlements in 2017, which were related to health impacts from the PTFE production in Parkersburg, USA (Sisk, 2020).

In textile processing, DWR treatments are usually present in water emulsions during application to fabrics. Effluent water and air emissions from volatile substances are the main exposure routes in this phase. Besides DWR treatments, PFAS also have other uses in textile processing, e.g., as emulsifiers, surfactants, and lubricants in various production steps (Glüge & al., 2020). There may be more uses

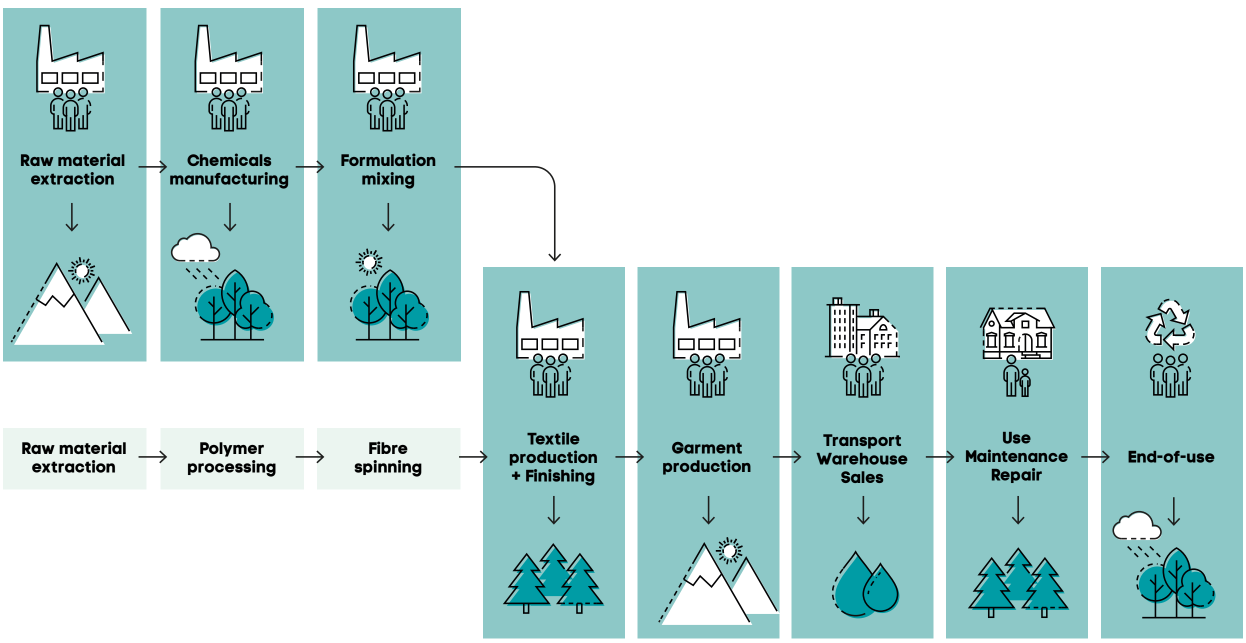


Figure 2. It is important to understand the impacts throughout the lifecycle of a chemical formulation. A simplified schematic of the value chain/lifecycle for textile DWR's can help indicating potential human exposure and diffuse spreading to surrounding ecosystems in each lifecycle step. (POPFREE 2017 - 03730)

that are still not fully understood and mapped. A way to investigate some of these are covered in the section Unknown uses of PFAS – a blind spot.

When the substances are on the fabric, many consider emissions negligable. However, residues of PFAS from production may be emitted through wear, off-gassing, or leach in contact with water. A study 2013 showed increased interior air concentrations of FTOH in sports/outdoor shops (Schlummer & al., 2013) indicating residues in the product which cause air emissions and human exposure by inhalation. Studies on exposed workers have shown that FTOH 8:2 can transform to PFOA in the body (Nilsson & al., 2013).

In the use phase, both wear of the DWR treatment itself and shedding of coated fibres are emission routes for PFAS. However, the largest PFAS emission source in this phase is most likely the re-proofing process, which can spread PFAS mainly in two ways:

- PFAS in the home environment from spray treatments of garments, home textiles and shoes.
- PFAS effluents in wastewater systems from wash-in treatments.

At end-of-use, any residual chemistry needs to be handled in the relevant material recovery method, regardless of if it is recycling, incineration, or landfilling. Because of the persistent properties of PFAS they are challenging in all types of end-of-use processes and a lot is still unknown about the fate and effects of PFAS after end-of-use.

4. Toolkit: Chemical investigations

A crucial part of gathering chemicals information is to identify whom to ask. While you may generally know who your Tier 1 suppliers (product assembly, cut and sew) are, it is likely they will only have very general information regarding the finishing treatments of your fabrics and trims. Fabric manufacturing and finishing typically starts at Tier 2, why developing direct relationships with your Tier 2 suppliers is essential. When digging deeper, you will also encounter the need to understand who your Tier 3 and 4 suppliers are. It is essential that you develop an understanding of the chemical and environmental management practices of your supply chain. This will provide better clarity on what comprises the materials, treatments, and finishes incorporated into your products as well as how they are managing it all at their facilities.

THE SUPPLY CHAIN TIERS

Tier 1 – Product assembly, cutting, sewing

Tier 2 – Fabric production, dyeing, finishing

Tier 3 – Textile fibre production

Tier 4 – Raw material extraction and processing

STEP 1 Identify relevant materials

First, make a broad scanning to identify all fabrics that potentially have a DWR treatment or a finish for water repellence and stain release. While it is easy to assume that this added functionality is always communicated, it is sometimes not mentioned if the water or stain repellence is a non-specified benefit rather than a strict requirement.

Next, look at textile trims, especially zippers, webbings and drawcords. These can be DWR treated for outdoor use, without that being communicated if the current use is different.

We recommend specifying explicitly whether or not you want DWR (or any other finish) applied to your materials and products in the Bill of Materials (BOM).

STEP 2 Investigate the chemicals used

When the question of functional finishes has been answered for all materials and parts in the product, you can continue to dig further, focusing on the materials with water repellence or stain release treatment. To start the investigations, it may be enough to ask for PFAS content (Yes/No), but down the line you will need the information on what type of chemistry is present regardless of PFAS content or not, to make an informed risk assessment.

To identify what chemicals are used in the DWR processing, these investigation steps can be taken for each DWR-treated material:

1. Ask questions about chemical content in the materials including all layers in bonded/laminated fabrics.
2. Ask about process auxiliaries: boosters, wetting agents, cross-linkers.
3. Ask about bonding films, glues, insulation materials, and trims.
4. Gather additional data by requesting SDS (plus TDS if available) for all chemical products found - and get expert help if needed for the interpretation. Use hazard classification and CAS numbers to search for more information, see Tools for chemicals management for search tools.
5. Get an overview of the production facilities for your materials, and what they produce besides your fabrics – to understand the risk for contamination from:
   a. Other production.
   b. Lubricants and surface treatments for machinery.
   c. Inbound water – How clean is it? Are there detectable PFAS levels? Is it treated before process?
   d. Wastewater – Is it recirculated and/or treated before release? Is there a wastewater facility or is untreated effluent being directly discharged to the ground or receiving body of water?

STEP 3 Responses and follow-ups

The responses to your questions may come in several forms, ranging from very general to specific.

When offered answers on a general level, **follow-up questions** can be adapted to move to a more detailed level. Follow-up questions can be modelled on the response to advance the supplier one level, or sometimes asking several of the follow-up questions at once to move to your desired level of disclosure. Typical responses and follow-up questions are listed in Table 1.

Type of statement	Example of response	Possible follow-up
1. General statements about certain properties	"Biobased content"	"How much biocontent? Is it PFAS-free?"
2. General statements about what is not there	"PFOA-free", "No isocyanates"	"Do you have a test report for X-free? Is it totally PFAS-free? What chemistry is used?"
3. Statements about structure rather than chemistry	"Nano technology", "Dendrimer shaped"	"Who is the supplier or what is the brand name?"
4. Referring to a supplier or brand	"It is Rudolf technology", "It is Ruco-Dry"	"Which Rudolf product is it? What type of chemistry?"
5. Generally stating material types or chemical families	"Wax based", "Hydrocarbon based"	"What are the functional ingredients?"
6. Specifying one or a couple of functional ingredients	"Siloxanes and polyurethanes."	"Can I get the CAS numbers for the functional ingredients?"
7. CAS numbers for a selected set of ingredients	"Main ingredients are..."	"Can I get the SDS for the whole formulation?"
8. Reference to the SDS as main source of information	"All information is in our SDS"	"Can you share the full ingredient list?"
9. A more comprehensive ingredient list	"Here is the content of the formulation"	"What auxiliaries do you use in the process?"

Table 1. Typical responses and suggested follow-up questions in chemical investigations.

STEP 4 Investigation tactics

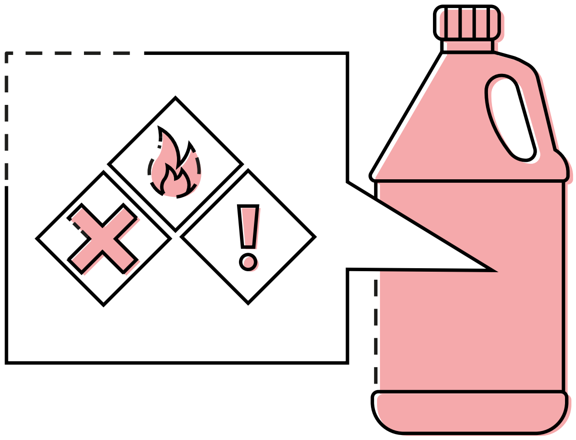
It is important, as mentioned above, to include auxiliaries and process aiding chemistry. Even if they are not present in the final product, some auxiliaries can provide higher risks for workers and environment at the production site than the actual DWR finishing agent.

As mentioned before, non-responses or signs of avoiding certain subjects should be an identifier for caution as your suppliers are supposed to have detailed knowledge of substances and processes. However, if it is the first time you venture into a chemicals investigation you will most likely find blind spots. A blind spot is a starting point for further investigation - ask your supplier to help you find the missing information!

One way to gain deep knowledge and data for analysing chemicals in your supply chain is the Chemical Inventory method. Collecting the chemical inventory data doesn't require chemistry knowledge and a basic assessment can be automated in the inventory file See Tools for chemicals management for more information.

4.1 Handling uncertainty

The lack of transparency and information from suppliers can be a challenge when investigating where PFAS are used and whether potential alternatives are better.



The Safety Data Sheet (SDS) is often the best source for chemicals information you can get from a supplier. There is a requirement to communicate known hazardous properties of ingredients in the SDS when they are classified as hazardous according to CLP, as persistent/bioaccumulative/toxic (PBT), or included in the Candidate List as substances of very high concern (SVHC). The thresholds for disclosure range between 0,1 and 1% and polymers are not required to be registered in REACH (this may be changed when the REACH process is updated).

WARNING:
PFAS ARE OFTEN MISSING IN THE SDS.

THERE ARE TWO MAIN REASONS:

- Many PFAS are not yet legally categorized as hazardous.
- The usable concentration of a highly effective PFAS ingredient can often be much lower than 1%.

Alternative approaches must often be used to identify these "hidden" PFAS.

Addressing the data gap

To manage this data gap, several measures can be taken, and a handful of tools are available. Knowledge building and effective communication are key to limit the risks of PFAS use. Suggested approaches for increasing knowledge and communication on PFAS:

- **Appoint at least one person** active in materials/production/purchasing/quality assurance to gain knowledge and lead investigations related to chemicals management, in which PFAS and other risk chemicals can be handled appropriately.
- **Build a relevant knowledge base**, by reading this and other similar guiding documents, taking seminars, joining chemicals management networks, and establishing direct access to an external textile chemicals expert.
- **Ask questions** to your suppliers. Complex investigations often start with general information requests, making it possible to learn and become more specific over time. **Where is it made, how is it made, what's in it, and where does it go** are all good basic questions to start with. A determined mindset may also be needed when starting your research, to establish a "minimum requirement" for their response time and disclosure level.
- **Document all responses**, even negative and imprecise replies, as they can provide useful insights when returning with more specific questions later.
- **Set targets** and communicate them with your suppliers. At first, they can be activity targets like having all materials reviewed for PFAS and other risk chemicals, to find blind spots and data gaps which in turn can be in focus for new targets. Once more is known, hard goals for substitution/elimination with public disclosure can be set and followed up.
- **Include PFAS in a wider Chemicals Management Program**. Find a suitable method for your company to structure your chemicals work to manage risks and spur innovation. See Tools for chemicals management for more details.

- **Seek assistance from the certification and service provider sector**. More on this below.
- **Request 3rd party analytical testing data**
  - **Against your RSL and MRSL**. This at least should minimize the risk of intentionally using chemistry that is regulated or otherwise unwanted.
  - **Total fluorine analysis** to get an indication whether materials, products, trims, or process chemicals contain PFAS.

A basic toolbox

There are a set of fundamental tools, which should always be at hand to support inquiries into the supply chain. As they are parts of a general good practice in supply chain management, there are many benefits in understanding their use regardless of your ambitions in PFAS substitution.

- **Supplier agreement/contract** can be used to regulate some of the information flow needed for your risk management. Make sure to include your chemical, environmental, and facility management approach in the agreement and specify how potentially sensitive information will be handled, for increased trust.
- **Code of Conduct** (CoC) can be part of or an appendix to a supplier agreement or exist as a parallel document. In the CoC general guidelines for governance and stakeholder interaction are communicated, as well as specific game rules for environmental and social sustainability. Chemical, environmental, and facility management approach should be expressed in the CoC.
- **Non-disclosure Agreement** (NDA) is sometimes needed to obtain information on suppliers, used chemical products, their ingredients and process parameters. If you consider openness and trust a way of supplier collaboration, it may not be the first thing to offer but is a good way to increase their will to share sensitive information. We recommend this method.
- **Safety Data Sheet (SDS)** is a mandatory documentation for chemical products with hazardous content. The standardized format is often used as a declaration for mixtures without hazard classifications too. Obtain all SDS's for the investigated chemical processes, including added cross-linkers, process boosters and other auxiliaries. Ask the textile finisher for substances used and the formulation supplier what they recommend and cross-check their information. From many suppliers, you can get relevant additional information in Technical Data Sheet (TDS) and additional process recommendations for the chemical product.
- **CAS number** is an international registration/identification for every chemical substance which is registered in a national or international register. They are the most common references when searching databases and should always be noted when investigating a substance.
- **Bill of materials** or a composition/ingredient list are fundamental for making deeper assessments of materials and formulations. They are not easy to come by from a supplier but may in some instances be shareable with neutral third assessment parties or in a tight partner relationship where NDAs govern the information exchange.
- **A Full Chemical Inventory** (or full chemical disclosure) including all your suppliers is highly recommended. This will give your brand a clear picture of what your suppliers use to make your materials and products. More about chemical inventory in Tools for chemicals management.

4.2 Regrettable substitution

When considering substituting a substance, chemistry, finish, material, etc., there is always the risk of replacing it with a new solution that has known or unknown negative effects on environment and health. This unwanted effect is called **regrettable substitution** and needs to be considered in all chemicals management work. The most important factor is to learn as much as possible about the replacement solutions. In the cases when little is known about the actual replacement, investigations can be made into chemical groups or types of solutions similar to the proposed substitute, to make a reasonable risk assessment.

If a new alternative has potential to introduce new risks to human health or the environment, a more elaborate environmental and health evaluation is highly recommended. The third-party solution providers listed in Tools for chemicals management are invaluable in helping with this important process. There are several types of tools to work in a structured way with substitution and chemicals risk management. One basic way to stay updated is to monitor or search the lists of chemicals that should be substituted or are proposed for future regulation, such as SIN List by ChemSec or the SVHC Candidate list for REACH by ECHA. Read more in PFAS regulation: EU and globally and Tools for chemicals management.

One example of potential regrettable substitution is replacing PFAS by formulations containing functional polysiloxane or silicone. The cyclic siloxanes D4, D5 and D6 are common building blocks for silicone-based substances, which can be emitted during manufacture or remain in the final silicone product as impurities. Since 2018, all three are listed on the SVHC Candidate list (ECHA, 2020) and are suggested to require REACH authorisation for use within EU. So, if considering a silicone based DWR, it is recommended to investigate contents, production processes and the regulation status for ingredients and impurities.

PART 2: DEEPER PFAS KNOWLEDGE

5. PFAS basics

The OECD definition of a PFAS is any fluorinated substance that contain at least one fully fluorinated methyl or methylene carbon atom, i.e., a substance containing at least one $-CF_2-$ or $-CF_3$ moiety in their structure (OECD, 2021). There are many thousands of structurally diverse substances matching this definition. In the past, PFAS were often referred to as "PFCs" (per- and polyfluorinated chemicals) or "fluorocarbons". They are often referred to by the number of the carbon atoms in the molecule, not mentioning fluorine in the description: e.g., C4, C6, C8 or C10. This has led some brands to call fluorine-free solutions C0 which is technically incorrect; they are generally organic substances with a carbon backbone, but without any fluorine.

5.1 The PFAS family

There are long chemical names and many abbreviations in the world of highly fluorinated substances making it hard to navigate in the jungle of all PFAS substances. A simplified summary of the different groups of PFAS are provided in Table 2, (OECD, 2021).

The non-polymeric PFAS comprise many subclasses including the well studied perfluoroalkyl carboxylic acids (PFCA) and perfluoroalkane sulfonic acids (PFSA). The PFCA and PFSA are divided into short-chain and long-chain depending on the lenght of the carbon backbone. C8 or longer is referred to as long-chain and C6 or shorter as short-chain. In the production, various carbon chain lengths are commonly obtained. Without sufficient purification, PFOA (C8) levels may exceed the restricted levels.

Polymeric PFAS: Fluorinated polymers are themselves considered PFAS and also often produced using non-polymeric PFAS. In the countries where PFOA is not yet regulated (e.g. China), it can still be used for production of PTFE/Teflon which is in turn imported to EU. PTFE produced in EU, US or Japan has not been processed with PFOA but other replacement PFAS. PTFE is by the fluoropolymer industry often described as inert and non-toxic during use. However, there are concerns that production and end-of-use processes for polymeric PFAS contribute to increased PFAS background levels in the environment (Lohmann & al., 2020).

Non-polymeric PFAS

Group	Example of use	Details
Perfluoroalkyl acids (PFAA)	Used in other PFAS production such as PTFE, PVDF and other fluoropolymers	Includes perfluoroalkyl carboxylic acids (PFCA, e.g., PFOA) and perfluoroalkane sulfonic acids (PFSA, e.g., PFOS)
Fluorotelomer (FT) substances	Common for making DWRs and as additives in other coatings	Can break down into PFCAs, e.g., FTOH 8:2 can transform into PFOA
Perfluoroalkane sulfonyl substances (PASF)	Common in DWRs as part of the side-chain polymers and as processing aids	
Per- and polyfluoroalkyl ether-based compounds (PFPE)	Used in high-performance lubricants and as alternative fluoropolymer processing aids	Carbon and oxygen backbone (ether-linkages) and are used as substitutes for PFOA such as ADONA and GenX

Polymeric PFAS

Group	Example of use	Details
Side-chain fluorinated polymers	Are often used as textile DWRs with extremely low surface energy.	Non-fluorinated polymer backbones with fluorinated side chains, e.g., PASF- or FT- based acrylate and -polyurethane polymers
Fluoropolymers	Are commonly used for microporous membranes in textiles and may be an ingredient in lubricants.	Carbon-only polymer backbone with fluorine directly attached, e.g., PTFE, PVDF, FEP, and PFA.
Perfluoropolyethers	Can be an ingredient of high-performance lubricants used in textile machinery, with contamination risks to textiles.	Carbon and oxygen polymer backbone with fluorine directly attached.

Table 2. Examples of non-polymeric and polymeric PFAS that are relevant in textile processing (ITRC, 2022).
For more information, see https://pfas-1.itrcweb.org/.

6. Health, environment, and brand reputation

There are several aspects of chemical risk management: cost, performance, process/material compatibility and hazard profiles of used chemistry, to name a few. From time to time, specific chemical risks turn up on the public agenda and companies are scrutinized on their practices. Unfortunately, when prioritizing chemical risks, media-driven warnings are not always a good indicator for the actual health and environment risks. There are many examples demonstrating how significant environmental risks have been neglected for long periods, due to debates about validity of scientific "proof" or chemical companies withholding known hazard data when introducing a product to the market. Or NGO's focusing elsewhere, resulting in a lack of media attention. Then, suddenly, the hidden risk emerges in the headlines due to for example a concrete pollution case, a research discovery or a new NGO campaign that targets a specific company, industry, or substance. Often, decades can pass between a chemical is introduced on the market and attention is focused on its negative impacts.

6.1 PFAS risks

The chemical risks of PFAS are present along the whole value chain, from production of raw materials to end-of-use scenarios including recycling. Since PFAS are persistent and can be mobile, even small emissions add to the global background exposure, affecting the environment and humans in every part of the world. *(see Figure 3)*. Continuous release of PFAS results in increasing levels and increasing probabilities of known and unknown effects. This also means that regardless of amount used and emitted, any brand using PFAS can be identified by NGO's or media as a polluter contributing to long-term negative health effects. In sports and outdoor industry, this risk is linked to core values of nature, activity, and health which stand in direct contrast to any polluting substances used for performance.

Direct PFAS exposure

In the textile finishing factories, high concentrations of PFAS are typically present. Emissions of volatile fluoroorganic vapours and contact with PFAS-containing process water are the most probable routes of direct exposure. Elevated PFAS levels have been found in textile workers (Heydebreck & al., 2016) (Lu & al., 2014), although there are very few studies done. This problem has also been identified in other professional uses of PFAS: 87 times elevated PFAS levels in blood and long-term health effects were observed among workers producing PTFE in the USA (Steenland & Woskie, S., 2012), and a study among ski waxing professionals at national team levels found 50 times higher levels of PFAS in blood compared to the general population (Nilsson & al., 2010) (Nilsson & al., 2013). Direct PFAS exposure of the upstream workers in chemical manufacturing should also be a concern to anyone buying DWR-finished fabrics.

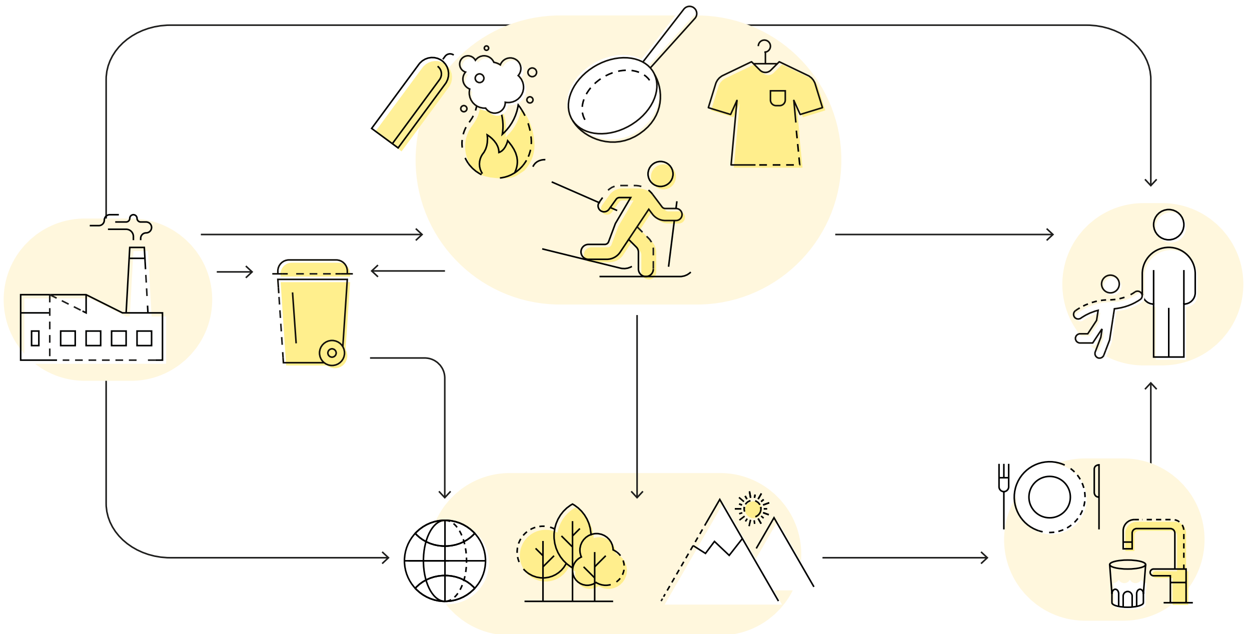


Figure 3. Routes for emissions and exposure of PFAS (POPFREE 2017 - 03730).

Diffuse PFAS spreading

The most likely dominating path for diffuse spreading of PFAS into the environment from the textile lifecycle is by process wastewater discharged into water bodies, sediment, and soil from facilities using PFAS in their processes. There are currently no effective wastewater treatment plant processes for large-scale handling of PFAS in effluents, why they will end up polluting sludge, soils, aquatic biota, ground water and drinking water supplies (Banzhaf & al., 2017). Volatile PFAS also spreads through the atmosphere and can be transported over very long distances. Today PFAS, like many other persistent organic substances, are now distributed in the environment on a global scale and bioaccumulated in biota, aquatic and terrestrial animals, where food together with drinking water and inhalation of indoor dust are the main sources of human PFAS exposure (EFSA, 2020) (Evich & al., 2022) (Sunderland & al., 2019). PFAS are detected in the blood of almost the entire human population, and have also been detected in placenta, breastmilk, and infants (Fenton & al., 2021) (Rappazzo & al., 2017).

The European Food Safety Authority (EFSA) has set the tolerable weekly intake recommendation of 4 common PFAS (PFOA, PFNA, PFHxS and PFOS) to 4.4 ng/kg bodyweight per week. The recommendation is that only 20% of the total PFAS intake should come from the drinking water. The new EU drinking water directive has set a limit of 100 ng/litre for the sum of 20 PFAS (500 ng/litre for all PFAS), that will be implemented in all national legislation by 2023.

6.2 Health effects from PFAS

The main concerns about health effects from PFAS are more about long-term health effects than acute toxicity. A summary of human candidate health effects from specific PFAS are summarised in Figure 4 based on what is known today. It should be noted that it is extremely challenging to study risks of chemicals exposure, and when it comes to the large group of PFAS, only a few have been studied in detail such as PFOA and PFOS. The human health effects are also observed in animal studies (Fenton & al., 2021).

Although more studies on toxicity and health effects from exposure to various PFAS are needed, it is an extremely ineffective and too slow process to study one PFAS substance at a time. Combined with the persistence shown in all PFAS, the health effects shown are enough to promote voluntary precautionary substitution of PFAS throughout product value chains.

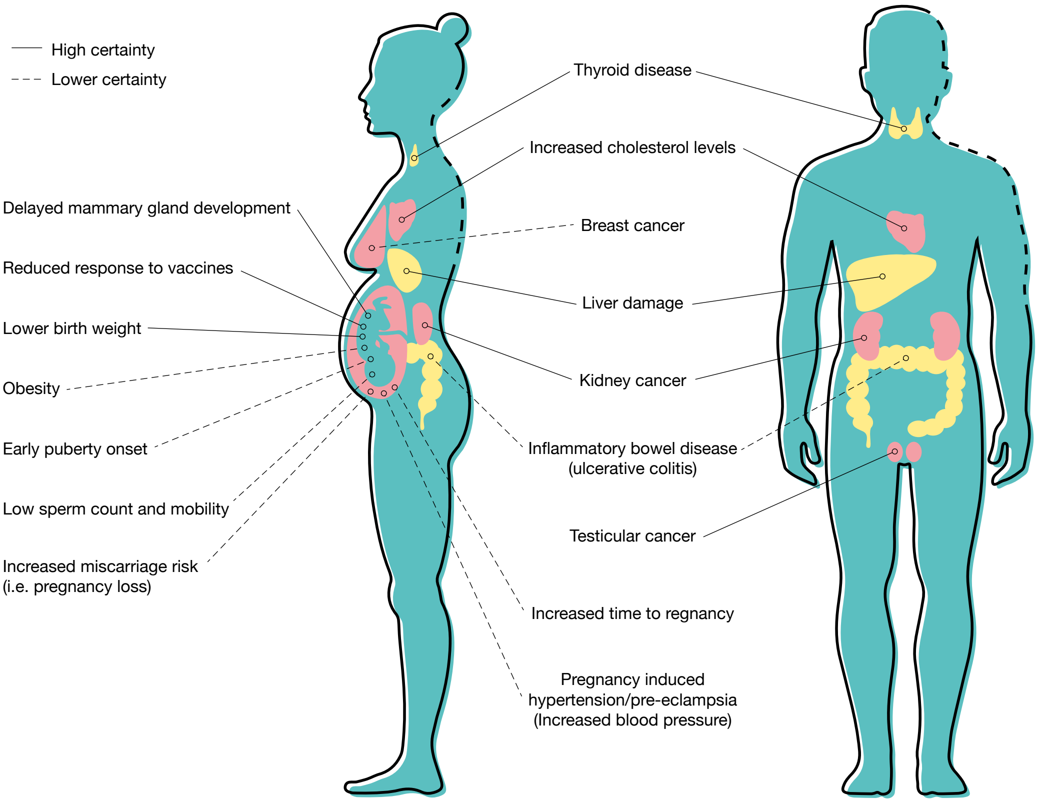


Figure 4. Effects of per- and polyfluoroalkyl substances on human health. Illustration inspired by (European Environment Agency, 2019).

6.3 C4 and C6 DWR - performance and risks

The PFAS used in DWR-finish are often side-chain fluoropolymers (SFP) and due to the PFOA-regulation, C8 has been replaced with C6 and C4 solutions. When it comes to performance, the short-chain PFAS generally show both lower performance levels and lower durability than the C8 chemistry, in many cases comparable to PFAS-free alternatives (Schellenberger & al., 2019) (Schellenberger & al., 2018). It is only for oil/grease repellence, especially important in protective clothing, that shorter-chain PFAS may be required. It should be noted that emerging PFAS that have been introduced as replacements for C8 are also extremely persistent and some have shown similar adverse effects in animal studies. As mentioned in Accelerating regulation, some shorter-chain PFAS are under investigation for further regulation.

7. PFAS-free alternatives

There are many alternatives to PFAS on the market today. They are often marketed by what they are not rather than what they contain. It is always recommended to research thoroughly what the PFAS have been substituted with, and if possible, get a certificate of chemical analysis for fluorine (see 7.2 PFAS analysis methods) to be certain.

7.1 What is PFAS-Free?

When the statements "fluorine-free", "PFC-free", "C0", are communicated, it is important to understand what that really means. In the strictest and most sensible of senses, it should mean the molecule, compound, formulation, and marketed tradename is totally "free" of organic fluorine. Any NGO testing a "fluorine-free" product will react if there are any traces of fluorine in their lab tests. However, it is important to understand that chemical manufacturers and textile production units may have historical/ unsolved contamination issues from equipment or inbound water which can result in measurable PFAS/ fluorine levels in testing.

WARNING: PFOS/PFOA-FREE

Products labelled "PFOS-free" or "PFOA-free" are not necessarily free from all PFAS. Mistakes in this communication have been discovered in various industries, why it is always recommended to investigate any "x-free" statements.

7.2 PFAS analysis methods

The best choice of PFAS analysis method depends on what is to be measured and for what purpose. Two common objectives in testing are compliance for specific substances (legal or RSL) and to investigate PFAS-free statements.

Compliance testing

A targeted analysis of specific PFAS is generally the method used to check compliance with the PFOS/ PFOA-regulation or a RSL requirement, but it is easy to miss PFAS content in such analysis (Swedish Chemicals Agency, 2022). It is a very sensitive technique where low concentrations can be detected of both original substances and potential breakdown products. The drawbacks with target analysis are that you only capture the specific PFAS that you include in the analysis, meaning that there is a big unknown.

Investigating PFAS-free statements

Total fluorine (TF), measured with for example Combustion Ion Chromatography (Liagkouridis & al., 2021), can be used as a first indication of PFAS content in liquids, solids and powders. It indicates a total concentration of fluorine, including both organic (fluorine bonded to carbon which is characteristic for PFAS) and inorganic (fluorine not bonded to carbon, e.g., sodium fluoride in toothpaste), but gives no further information about the included substances. Particle-induced gamma-ray emission spectroscopy (PIGE) is a non-destructive surface measurement that also measures total fluorine (Ritter & al., 2017).

For most solid materials and products, the content of non-PFAS fluorine should be neglectable, meaning that detectable concentrations suggest intentionally added PFAS and motivate further investigations in potential PFAS uses and contamination.

When receiving any PFAS or fluorine analysis report or certificate from a lab or a supplier, data for measured concentrations and stated minimum detection levels contain much more usable information than a pass/fail report which can have arbitrary limits. PFAS are effective already in low concentrations and when calling something PFAS-free, there should not be any intentionally added PFAS at all.

The targeted analysis methods have a much higher sensitivity than the TF methods, why targeted testing may be needed to investigate unintentional contamination.

7.3 PFAS-free technologies

When substituting PFAS in DWR's, there are four main families of substances that are generally used for water repellence (Holmquist & al., 2016). For oil and stain repellence, there seems to be no effective substitutes for PFAS so far - more research and innovation is needed in this area. Oil repellence may protect against contamination (e.g., from production processes, skin contact, greasy stains etc) which can affect appearance and the effectiveness of a DWR but is otherwise an added benefit that has no direct impact on water repellence. The water repellence is determined by several factors, one of them is the inherent surface tension values for chosen chemistry.

THE FOUR MAIN FAMILIES OF ALTERNATIVE SUBSTANCES

1. Paraffin waxes
2. Hydrocarbon chains/branched
3. Silicones
4. Nanomaterials

Get to know your alternatives
As a buyer of fabrics, you generally need to specifically request a PFAS-free treatment in the textile finishing process, since PFAS DWR's are still an industry standard in many production countries. The alternatives are today available from several DWR suppliers under a variety of brand names, often not describing DWR family or base chemistry. Some textile suppliers are even reluctant to share information on what PFAS-free solutions they use. For most DWR formulations, auxiliaries like wetting agents, cross-linkers and boosters are used for ideal results and should be included in an assessment of environmental and health impacts.

Within each alternative DWR family there are competing products which may have different properties, tailored for different uses, processes and fabric types. PFAS-free chemistry is generally more sensitive to the process conditions and suppliers are less experienced with them, why it is crucial to control the auxiliaries and process parameters rigorously and make repeated factory trials to get the desired performance results. It can often be small details in the application process that determine if you get good or bad performance when testing a new PFAS-free fabric/DWR combination.

Family 1 The paraffin waxes come in many forms, from simple solid melt-on waxes to cross-linked high-performance DWR treatments used in breathable shell garments. The waxes can come from both fossil and renewable sources, and range from fully biocompatible to toxic, legally regulated waxes (e.g., chloroparaffins). There may be additives such as for example diisocyanate cross-linkers with an environmental risk profile. Many alternative solutions exist and can be tried to find the desired performance and environmental profile. Generally, it is not possible to reach the highest levels of hydrophobicity with paraffin waxes without molecular modification such as in Family 2.

Family 2 Hyperbranched (or dendritic) hydrophobic polymers and comb polymers are described as active components in this family of DWR formulations. The "base chemistry" in this family can be a multitude of different hydrocarbon substances mixed for optimal functionality. Some manufacturers claim to reach superhydrophobic properties, meaning water contact angles larger than 150°, when applied in coatings, textile, and leather. Some hydrocarbon substances also have environmental hazard profiles in themselves and can be mixed with solvents and additives such as cross-linkers with hazard profiles, so to know more about your chosen DWR formulation you will need detailed supplier information (e.g., SDS, TDS).

Family 3 Notable from risk management perspective is that some of the silicone based DWRs may face a phase-out process within a couple of years, as risks with siloxane precursors D4, D5 and D6 have been identified. Read more about this in Regrettable substitution.

Family 4 The nanomaterials DWR family are not a chemical group of their own - they can be a mixture of substances, even potentially containing PFAS, with the addition that at least one of the ingredients either have nanoparticles or create nanostructures which add functionality. From a chemicals risk perspective, formulations from this family must be thoroughly investigated regarding their ingredients. There is an added risk with nanoparticles which due to their scale are suspected to penetrate cell membranes and interfere with functions in organisms. It is still too early to say what the risks are and if there are specific nanoparticles to avoid. As a minimum precaution, it is wise to get to know which substances both the overall formulation and the nanoparticles are made of and avoid those with a high-risk profile, since nanoscale increases bioavailability. The nanomaterials area will be monitored from legislators the coming years and we can expect regulation development in this area.

7.4 Searching for PFAS-free alternatives

The development in the PFAS-free alternatives has accelerated since 2010 and it is not always easy to find all the solutions out there to evaluate performance and environmental profile. Below are a few sources that may help you in your search.

- The POPFREE list of DWR alternatives - a list of PFAS-free DWR formulations compiled by RISE in collaboration with an international textile brand.
- ChemSec Marketplace – an open database of green chemistry and safer solutions for many uses. It is connected to SIN list, making it possible to first search for a PFAS chemical and then finding an alternative.
- The ZDHC Gateway Chemical Module – a search engine for ZDHC members which claims being the world's first of safer chemistry for the entire value chain.
- A Danish EPA report about PFAS alternatives in textiles from 2015.
- A University of California research report about alternatives from 2017, in collaboration with W.L. Gore and Associates.
- Greenscreen Certified™ Products - A list of PFAS-free products (mainly textiles and firefighting foams) that are certified to different levels under Greenscreen.
- Green Science Policy Institute PFAS-Free Page - A non-exhaustive list of products and product lines that do not contain PFAS. A spreadsheet of the list is available *here*.

7.5 Minimizing the risks of alternative chemistry

There are great uncertainties when implementing new chemistries with little research data on hazard profile, potential long-term health effects and performance. A brand faces goodwill risks when switching to less proven chemistries, with less data on process parameters for optimal performance. This uncertainty is one of the biggest hurdles among brands and suppliers to switch to PFAS-free solutions.

Collaboration between chemical suppliers, textile manufacturers, finishers, brands, and third-party service providers for screening and systematic testing of new formulations is key to enable implementation of new solutions on a larger scale. More open communication regarding chemical content, toxicological profiles and process parameters are needed to avoid regrettable substitution. Sound chemical and environmental management practices at each facility in the value chain are necessary to successfully introduce alternative DWR products and ensure their integrity.

DWR, isocyanates and chemical risks

Diisocyanates are very common in both PFAS-based and PFAS-free DWR's, either as building blocks for polyurethane, which is a common DWR chemistry base, or as auxiliaries (e.g., boosters, cross-linkers) in the application process for many types of DWR finishes. Since 2020, diisocyanates have restrictions in REACH and handling is only allowed by trained personnel. There are also related solvents (e.g., NMP and DMFa which are SVHCs) that can cause chemical risks. To avoid the solvent issue in textile finishing, there are water based DWRs using polyurethane suspensions, which may still include traces of solvents from the polymerization process. It is very common to use boosters (blocked isocyanates) for additional cross-linking, where the blocking agents can cause carcinogenic end products during curing and drying. There are alternative cross-linkers (e.g., carbodiimides) with less hazardous properties, but they must often be requested specifically and need thorough testing from case to case to ensure proper functionality.

No-DWR alternatives

There is a possibility for innovative "No-DWR" solutions where water repellence in fabrics is based on textile inherent fibre properties combined with yarn and fabric construction – without adding a DWR finishing. A few products with high hydrophobicity level are already on the market, currently based on synthetic Polypropylene fibres or natural fibres like wool. This area is under development and whether the performance is suitable to your intended use must be assessed from case to case. All new alternatives must also be assessed from an environmental and health perspective to identify both benefits and potential challenges.

Biodegradability in DWR

While PFAS are established as persistent, many of the other polymer alternatives in DWR are also long-lived in natural environments. Since DWR easily enters effluents both during textile production and washing by the end-user, biodegradability of the DWR is an important aspect. If there is a toxicity profile in the material or ingredients, this is especially important, but even without a known toxicity profile there is an accumulation of materials and substances that do not break down – microplastics and nanoplastics that may affect water- and soil-living organisms. The actual biodegradability definition for a DWR depends on the proposed spreading route and conditions for degradability there. Read more in the OECD guideline for the testing of chemicals. Section three in the guideline covers environmental fate and behaviour, including screening tests of biodegradability.

8. Unknown uses of PFAS – a blind spot

In the quest for totally PFAS-free coatings and fabrics, you may also need to investigate "hidden" PFAS uses, primarily in process auxiliaries and trims. The properties of PFAS make them usable in a wide range of industrial applications beyond water repellence in textiles. In NGO testing campaigns, even products claiming to be PFAS-free have been found to have significant PFAS content. Contamination of process water and machinery from previous production have been mentioned as possible sources, but results from other tests indicate that there can be other more direct contamination sources as well. One theory is that some of the PFAS uses are not known even to the DWR producer and textile finisher because they may be related to other parts of textile processing.

Using the list of properties, functions, and potential industrial applications below, you can backtrack hotspots where PFAS may be used, to concentrate further investigations into what specific chemicals are used there.

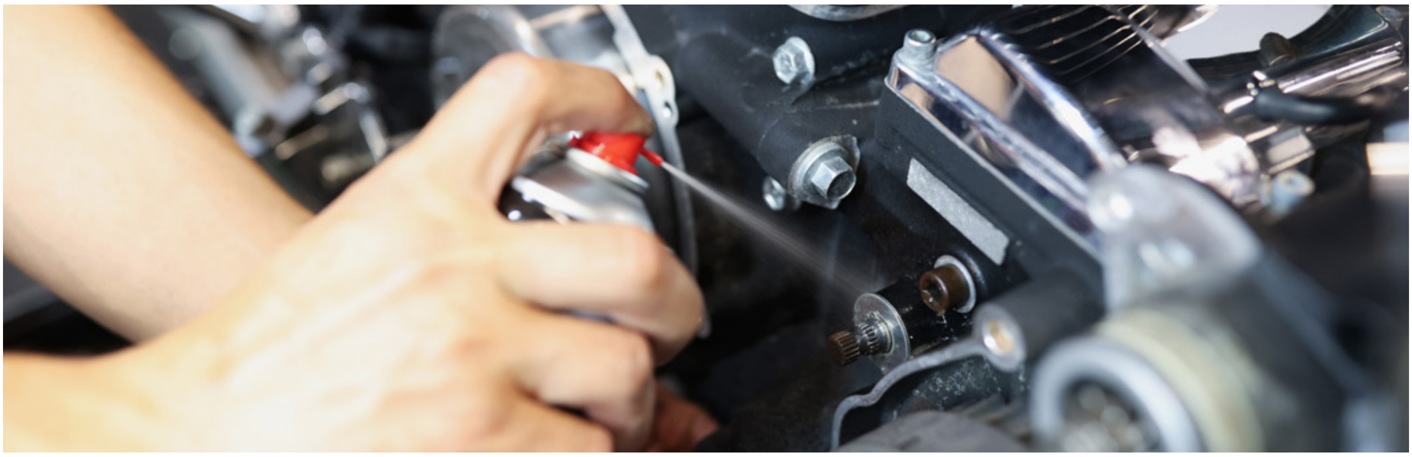
PFAS - Key properties in use
PFAS have three key properties that make them useful in many industrial applications: They are **surface tension lowering** in water-based systems, **repel both hydrophilic and hydrophobic substances** and have **high chemical and thermal stability** when used at low concentrations.

PFAS Functions (Buck & al., 2012)
From the above key properties, four main industrial uses can be found:

- Surfactant - Extremely low surface tension.
- Emulsifier
- Low friction
- Water, oil, grease, solvent repellent

Potential industrial applications for PFAS (Buck & al., 2012)

- **Surfactant in liquids** – Alkaline cleaning agents, hard surface cleaning agents, etching fluids, foaming stabilizers, film forming agents.
- **Surfactant** for high wetting properties in pesticides, coatings, digital printing, high-bond glues.
- **Emulsifier in liquid suspensions** – dyestuff, textile finishing agents.
- **Mist suppressant** – in metal plating.
- **Low-friction (non-stick) treatments** – polishes, lubricants, waxes, greases for industrial uses.
- **Easy-clean surfaces –** Coatings, polishes for hard and porous surfaces to assist easy cleaning.



Investigating unknown uses
Some uses, like lubricants and greases, may be easily detectable while others like glue, etching, or coating ingredients may take longer to uncover.

The first check should be in the product BOM list, to see if any materials or trims have been overlooked. DWR or stain release treatments are common standard applications in modern synthetic fabrics and trims. They can be applied without your knowledge if the specification lacks a "no DWR" requirement. When making water repellent zippers, the side tapes are often treated for water repellence. Until 2018 it was almost impossible to get a water-resistant zipper without PFAS content, and it still is something needing specific request on your product BOM to be sure. Webbings, strings and drawcords are also relevant to check, as well as backing fabrics, liner fabrics for bags, thin pocket fabrics etc.

When the basic materials/trims check is done, there are several levels of deeper investigations that can be done. These PFAS uses are often unknown and unintentional, even to people in the textile processing. Successful questioning may in this case be by backtracking a set of specific functional properties in the processes and trying to pin-point potential hotspots.

To aid a deeper PFAS investigation, you may consider the Chemical Inventory method. It will uncover your supplier's full list of chemical products with ingredient CAS numbers and give a good starting point for analysis.

To ensure that the items you are purchasing from a supplier do not contain PFAS or any other restricted substance (specified by you), we recommend that you ask for 3rd party analytical test reports as proof.

9. PFAS regulation: EU and globally

Chemical regulation is generally controlled by national legislations, with two wider-reaching exceptions: The United Nations (UN) Stockholm Convention which has global reach to harmonize the most hazardous chemicals, and the EU REACH legislation which aligns chemical regulation within the EU. Among national legislations that have great influence internationally is the US Toxic Substances Control Act (TSCA). Where legal status of specific substances is mentioned, it refers to the status at this guide's publishing date. For updated status, use the referred sources in this section.

UN Stockholm Convention
To stop global use of the most hazardous substances, a **convention for elimination of Persistent Organic Pollutants (POP)** was signed 2001 in Stockholm in a process initiated by the UN Environmental Programme, UNEP. With 184 ratifying parties, it is the chemical legislation agreement with widest global spread. PFOS was registered for restriction in 2009 and PFOA was 2020 registered for elimination. Salts and substances that can break down to PFOA or PFOS are also included in the regulation, resulting in a regulation covering over 800 PFAS. The C6-PFSA substance Perfluorohexanesulfonic acid (PFHxS), its salts and related substances are also under evaluation for inclusion in the Stockholm Convention in 2022. The Stockholm Convention is binding for national execution in the ratifying states but the time to implement new restrictions may vary to some extent. Among the few countries not ratifying the convention are USA, Israel, Malaysia, and Italy. Typical production countries like China and Vietnam have signed the convention, as well as the European Union.

EU REACH
Within the European Union (EU), a harmonized chemicals legislation called Registration Evaluation, Authorization and Restriction of Chemicals (REACH) sets the standard since 2007. It sets the mark as the most ambitious and influential chemical regulation globally yet is nowhere near to regulate all potential risk substances on the market. In 2021 approximately 23 500 substances were registered within REACH. There are estimates from both European Chemicals Agency (ECHA) and earlier registration efforts indicating this is only a small part of the available chemical substances on the market. The hazard and risk assessments are slow, scientific processes and all substances already on the market are considered legal until proven hazardous with suitable regulations.

PFOA and PFOS are implemented in the EU legislation through the POPs-convention. The long-chain

PFCAs (C9-C14) and their salts and related substances are included for restrictions in REACH, with implementation entering into force in February 2023. Work with restricting PFHxA in REACH is in progress. See ECHA website for regulation status of specific PFAS substances (ECHA, 2020). Several PFAS are listed in the Public Activities Coordination Tool (PACT) as they are under evaluation.

Classification, Labelling and Packaging (CLP) Regulation

The CLP Regulation is based on the United Nations' Globally Harmonised System (GHS). At present (May 2022), PFOS, PFOA, PFNA, PFDA) and APFO have harmonised classifications and a proposal for the addition of PFHpA and 6:2 fluorotelomer alcohol (FTOH) is in progress.

Within the ECHA work, the Candidate List of Substances of Very High Concern (SVHC) is a list of substances that will be investigated for authorization measures. The SVHC list is regularly updated as new substances are reviewed and is a good tool to stay slightly ahead of the legislation work for company substitution efforts. Among the approximately 200 SVHC substances, ten PFAS can be found (May 2022) Articles containing more than 0.1% of an SVHC require registration in the EU SCIP database, and anyone marketing a chemical formulation containing a SVHC is required to have a SDS stating the SVHC content. Upon consumer request, there is also an obligation to inform about any SVHC content above 0,1% in a product and offer instructions for safe use of the product. Tools for more progressive substitution approaches are available in Tools for chemicals management.

Accelerating regulation

Phasing out PFAS is a major focus of the EU chemicals strategy, published in October 2020. The strategy is part of the EU vision of a toxic free environment and The Green Deal. The national authorities for REACH of the Netherlands, Germany, Denmark, Norway, and Sweden are in 2022 preparing a REACH proposal for the group of PFAS that will be submitted to ECHA in January 2023. The reason for considering regulation of PFAS as a group is that it takes too long time to evaluate and regulate one substance at time, many PFAS show similar properties that are worrying and to avoid "regrettable substitution" by switching from one regulated PFAS to another not-yet regulated PFAS. All PFAS may not be bioaccumulating or toxic, but all PFAS are extremely persistent.

In the Chemicals Strategy for Sustainability it is mentioned that "the use of PFAS is phased out in the EU, unless it is proven essential for society" as well as that "the Commission will address PFAS with a group approach". The work to define criteria for what constitutes an essential use is ongoing, and therefore the final criteria are not available for inclusion in the initiative for a universal PFAS restriction currently being developed by five member states.

Reference to regulations	
The Classification, Labelling and Packaging (CLP) Regulation	*(EC) No 1272/2008*
Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH)	*(EC) No 1907/2006*
POPs regulation	*(EU) 2019/1021*

10. Tools for chemicals management

Below you can find examples of tools to use in your chemicals management work. These tools are not PFAS specific but most of them can be used in the PFAS phase-out. There is no one-tool-fits-all approach – as you build your chemicals management approach you will likely use different tools in different stages, and some of them in parallel to cover all bases. It also depends on company structure, type of products and supplier network, which approach is most effective and what tools will work best for you. Take some time to go through your options, and if it is overwhelming seek advice from an expert in the field to get started.

The Chemical Inventory method

An inventory of all chemicals used in the production of your product is a solid starting point for any chemicals management work. The method comes from industries with strict chemical reporting legislation, such as chemicals and electronics industries, where inventory lists are mandatory in many countries. Creating the inventory is often in itself a good way into a deeper supplier dialogue. It demands less work than may be anticipated and the finished list can then be updated with regular intervals. Each facility reports chemical inventory in two lists:

- **A list of all chemical products** the facility has in their inventory, highlighting those used for your production. For each product, the Safety Data Sheet (SDS) must be linked.
- **A list of ingredients** collected from the SDS data, including CAS numbers to categorize and identify any substances of potential concern.

The inventory itself can readily be built with internal resources and suppliers, but for deeper assessments of your inventory findings and suggestions for further work you may need external expert support. A **chemicals inventory template** with automatic hazard assessment functionality is available from the POPFREE website (*www.ri.se/popfree*). If the supplier is reluctant to open their inventory to you, you can use a non-disclosure agreement (NDA) to ensure confidentiality.

Chemical Restriction Lists

There are many chemical lists available, some open and others linked to memberships or services. Not all lists are alike, you need to decide on your own ambition level to find a suitable list approach. The list is a passive tool – you need to set up a process for it to activate substitution work, and auditing is necessary for full compliance. There are two main types of lists – **restriction lists** decide what cannot be used, and **positive lists** decide what can only be used. Restriction lists are mostly used today, but within a few services (e.g., Bluesign®, Cradle to Cradle®) there are positive lists governing their approval of materials. The lists below are restriction lists.

- **Restricted Substance Lists (RSL)**: A restriction list determining what is prohibited or needs threshold values in the textile product. An example of a publicly available RSL is the AFIRM RSL.
- **Manufacturing Restricted Substance Lists (MRSL)**: A restriction list determining what is prohibited or restricted in the manufacturing processes. It extends further than the RSL since it also looks at process chemicals in production. Example of a widely spread MRSL is the ZDHC MRSL. Another is the **BSSL**, used by Bluesign® members.
- **ChemSec** has an informative article about setting up an RSL/MRSL *linked here*.
- SinList from ChemSec is one of the most referenced lists globally when using a precautionary approach, containing approx. 1000 substances (April 2020) which have shown health and environmental concerns in scientific studies.

Regulatory lists

The three following lists are often used for reference when checking for chemicals that need extra caution from a legal perspective.

- ECHA Chemicals search contains all registered chemicals within the REACH regulation, currently approx. 23 000 CAS numbers, with data on hazard classes and regulatory information.
- SVHC Candidate list of very high concern for authorisation is a list of approx. 200 substances (April 2022) that will be evaluated for REACH regulation, and hence a good monitoring tool to be ahead of legislation.
- California Prop65 List: Contains chemicals known to cause cancer or birth defects or other reproductive harm. These substances must also be clearly declared on any product sold in California.

Tools, Service Providers, and Certification Bodies
A few service providers have packaged tools and additional assessment work into external chemicals management services. Depending on your needs and scope for your chemical work, you may choose from the ones below.

- Bluesign®: Provides services and tools for vetting chemistry and materials in the textile industry. Their approach is called "input stream management" and they audit the supply chain all the way from chemicals manufacturers to brands.
- ChemSec: A non-profit international chemistry watchdog, offering a set of tools for chemicals management and substitution. They manage SIN List, SIN Producers and SINimilarity for identification of hazardous chemicals, and Marketplace for finding alternatives and Textile Guide for a simplified chemicals management approach.
- Greenscreen®: A software tool that reviews chemicals by CAS number providing an assessment of the health of the chemical by a grading system. It includes chemistry for textile and many other industry sectors. There is a "light" version of the tool called Greenscreen® List Translator.
- Higg MSI: A materials impact database, part of the Higg index suite. Chemical load is intended to be part of the material evaluation, but as of April 2020 the chemistry part is still under development and has limited information/scoring impact.
- OECD Toolbox is an extensive list of tools for chemical substitution supporting the Alternatives Assessment methodology.
- OEKO-TEX®: Provides services and tools for vetting chemistry and materials. Offers a multitude of tools like Standard 100, Eco passport, STeP, and Made in Green. The different tools cover chemical products, articles and production processes.
- Pharos is a tool that summarises known hazards where CAS# are used to search for information – used extensively for built environments in the US, using the Greenscreen® hazard assessments.
- PRIO database by Swedish Chemicals Agency is a web-based tool that can help you to preventively reduce health and environmental risks from chemical substances.
- Swedish Chemicals Group is run by RISE Swedish Research Institutes, supporting textile, footwear and electronics industry with knowledge building, chemicals database and news distribution in the chemicals area.
- Swedish Centre for Chemical Substitution is a government-funded support centre for substitution of hazardous chemicals and identification of better alternatives for products and processes. They have several useful tools and links on their website and offer education and guidance.
- Swedish Textile Importers have a Chemicals Guide in Swedish available at low cost with updated legal status, test methods and alternatives where available, including PFAS legal status and testing methods.
- ToxServices: International consultant specializing in services for vetting chemistry, from compliance to progressive circular chemistry.

CERTIFICATIONS WITH PFAS RESTRICTIONS

Ecolabels and certifications provide a three-way possibility. They can be used to: a) certify your products; b) use certified materials; or c) use their criteria and chemicals lists as a recommendation for better environmental performance. Since many of them have their criteria documents publicly available online, it is an easily accessible resource for your reference to good practices.

- GOTS: for functional outerwear from organic natural fibres – in GOTS all PFAS are prohibited.
- **National/Regional ecolabels:** Certifications like e.g., Nordic Swan provide criteria for PFAS elimination along with a set of other restricted chemicals and process requirements.
- Cradle to Cradle Certified™ has the toughest chemical restrictions among currently active certifications/ecolabels, including a total ban on PFAS.

3RD PARTY ANALYTICAL TESTING

Testing labs are available globally. Make sure you find an accredited lab with experience of your requested type of testing. Test reports are very effective for communication of what is actually in the chemical product or article you are buying. It is however a snapshot and recurring testing may be needed to track progress. Examples of Swedish and international providers are listed below.

- *Eurofins*
- *Intertek*
- *RISE*
- *SGS*

11. Mini glossary for non-chemists

Common expressions used in this guide and in dialogues concerning textile chemistry and impacts on environment and health.

- **Auxiliary**: A substance that is used in a chemical process but is not incorporated as an ingredient in the chemical product itself. Auxiliaries include but are not limited to solvents, separation agents, dispersing agents, wetting agents, boosters, crosslinkers and extenders.
- **Biodegradability:** A measure of the ability of a material to get decomposed by micro-organisms such as bacteria or fungi while getting assimilated into the natural environment.
- **Carbon backbone:** The "spine" of a hydrocarbon or PFAS molecule, consisting of X carbon atoms where hydrogen, fluorine or other atoms or groups of atoms are attached. The carbon backbone chain length is referred to as C(X).
- **Dendritic**: A molecular shape which is "branched", creating a structure which can be used to repel e.g. water.
- **Effluent**: An outflow of wastewater or contaminated water to a natural body of water, from e.g. wastewater treatment plant, sewer pipe, or industrial outfall.
- **Emission**: A release of e.g., substances, particles, gas or radiation into the surrounding environment.
- **Emulsion**: A mixture of insoluble liquids, often water and oily/fatty liquids, where one of the liquids is evenly distributed as micro droplets in the other.
- **Bioaccumulation**: The gradual accumulation of substances, such as pesticides or other chemicals, in an organism.
- **Chemical Hazard Classification:** The Globally Harmonized System of Classification and Labelling of Chemicals (GHS) was developed by UN for describing chemical hazards to health and environment, used in SDS (see below) and labelling of chemicals internationally.
- **Halogenated organic chemistry**: Organic substances where hydrogen atoms have been replaced by halogen atoms, e.g., fluorine or chlorine. PFAS are fluorinated organic substances.
- **Hydrophilic**: A substance or material which attracts water.
- **Hydrophobic**: A substance or material which repels water.
- **Moiety**: A specific group of atoms within a molecule which describes characteristics or function.
- **Oleophobic**: A substance or material which repels oils.
- **Organic substance**: A chemical substance in which one or more atoms of carbon are bonded to atoms of other elements, most commonly hydrogen, oxygen, or nitrogen. PFAS contain carbon-fluorine bonds.
- **Persistent**: Substances resistant to environmental degradation through chemical, biological, or photolytic processes. They can take years, decades or even centuries to degrade.
- **Persistent Organic Pollutant (POP):** Chemicals that persist in the environment, bioaccumulate through the food web, and pose a risk of causing adverse effects to human health and the environment.
- **Precursor**: A substance that participates in a chemical reaction and is transformed into another substance.
- **Safety Data Sheet (SDS):** A standardised document, which in 16 sections lists information about occupational health and safety for the various uses of a substance or product. A SDS should conform to the GHS (See "Chemical Hazard Classification" above). There is an older, non-standardised version called Material Safety Data Sheet (MSDS) which had less strict specifications of content.
- **Surfactant**: A substance that lowers the surface tension between two liquids, between a gas and a liquid, or between a liquid and a solid. Surfactants have one hydrophilic part and one hydrophobic part and may act as detergents, wetting agents, emulsifiers, foaming agents, and dispersants.
- **Technical Data Sheet (TDS):** A commercial/technical document describing a product (here focused on chemical formulations). The TDS can specify various data like performance, application process data and other aspects that are both within and outside the scope of a SDS (see above). Also sometimes called Product Data Sheet (PDS).
- **Volatile**: A substance that evaporates or sublimates at room temperature or below. Volatile substances can pose a problem to air quality and are easily inhaled. The European Union defines a volatile organic substance (VOC) as "any organic compound having an initial boiling point less than or equal to 250 °C measured at a standard atmospheric pressure of 101.3 kPa.
- **Wetting**: The ability of a liquid to maintain contact with a solid surface. Wetting is a crucial factor in the application of DWR to a fabric, influencing spread, evenness, and film formation.

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