

PFAS Restriction process according to REACH
Fluorine-free solutions for personal protective equipment

B A C H E L O R T H E S I S

At the University of Applied Sciences Hof

Faculty of Engineering

Study Programme Innovative Textiles

Submitted to Prof. Dr. Anett Matthäi
Hof University, Department Münchberg
Kulmbacher Str. 76
95213 Münchberg

Submitted by Elisabeth Finger
Am Bergwald 3
83666 Waakirchen

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Preface

The following document was originally written and submitted in German under the title “PFAS-Restriktionsverfahren unter REACH- Fluorfreie Alternativen in Arbeitsschutzbekleidung”. I translated it after submission without altering its content, which means that information referring to the ongoing restriction process may be outdated as their latest update was on February 17th, 2023.

At this point I would like to take the chance to thank Sympatex for the opportunity to write my bachelors thesis there and for the support I was given. Special thanks to my mentor Nicole and our colleagues who provided me with much needed information without which I could not have completed my work.

E. Finger

I Abstract

Per- and polyfluoroalkyl substances (PFAS) are a large group of chemicals and subject of much controversy as they possess next to very useful properties also characteristics that are of high concern. In Europe there is a proposal ongoing to restrict all PFAS under the REACH-regulation. Some applications can receive an exemption if there are no suitable alternatives available. For clothing such exceptions are to be expected mainly for personal protective equipment (PPE). This study aims to discuss for which applications in PPE an exemption from the restrictions may be necessary and where PFAS can be replaced. The results will then be sent to ECHA during consultation phase of the restriction process, starting March 22nd, 2023, to provide decision-makers with much needed information.

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CMR: carcinogenic, mutagenic or toxic to reproduction.....	12
CSS: Chemicals Strategy for Sustainability	18
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ECHA: European Chemicals Agency.....	10
ePTFE: expanded polytetrafluoroethylene	5
FTOH: fluorotelomer alcohols	5
MS: Member State	10
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PBT: persistent, bioaccumulative and toxic	12
PFAS: Per- and polyfluoroalkyl substances	1
PFBS: perfluorobutanesulfonic acid.....	6
PFCA: perfluorinated carboxylic acids	5
PFHxA: perfluorohexanoic acid.....	6
PFOA: perfluorooctanoic acid.....	3
PFOS: perfluorooctanesulfonic acid.....	6
PFPs: Perfluorinated and polyfluorinated polymers	5
PFSA: perfluoroalkyl sulfonates	5
PFT: perfluorinated tensides	5
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PPE: personal protective equipment.....	1
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SVHC: substances of very high concern	12
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1 Introduction

Per- and polyfluoroalkyl substances (PFAS) are a group of chemicals consisting of several thousand man-made compounds. PFAS, also called fluorocarbons, have been controversial for years because they possess very questionable properties as well as useful ones. For example, they are valued for being extremely durable, as they can be utilized to make long-lasting products, but at the same time the durability causes problems too.

Since many PFAS are persistent and very mobile, they spread all over the globe via air and water and are detectable in the blood of the majority of the world's population.¹ Some PFAS can cause severe health problems, which is why individual substances have already been banned.² Checking each compound individually takes an exceptionally long time, which is why a process is currently underway in the EU to put the entire group of chemicals to the test and aim for a general PFAS-ban.³

For some applications, PFAS fulfil functions that cannot be dispensed with. For such cases, legislation allows for exemptions if no suitable substitute is available.⁴ With regard to clothing textiles, such exemptions are to be expected for personal protective equipment (PPE). If opinions from the PFAS industry are to be believed, the entire sector must be granted an exception, otherwise it will cause economic and societal collapse.⁵

The company Sympatex produces laminates for outdoor clothing, apparel, footwear, and protective workwear, which are characterized by the fact that thanks to a membrane they are completely waterproof and at the same time breathable, while being free of fluorine compounds. The company is committed to a sustainable textile industry and advocates the elimination of potentially hazardous substances such as PFAS. Based on the conviction that the use of PFAS can be completely phased out for clothing, including PPE, Sympatex wants to get involved in the ongoing process and provide decision-makers with needed expertise.

This thesis discusses the question for which PPE areas PFAS are dispensable or substitutable and where further research is necessary. The study serves as the basis for Sympatex's statement in the PFAS restriction procedure and questions the requirements placed on PPE. No comparable analysis is known

¹ (European Environment Agency (EEA), 2022)

² (European Parliament, Council of the European Union, 2019)

³ (European Chemicals Agency (ECHA), 2023)

⁴ Cf. Chapter 3.3.1

⁵ (textil + mode, 2022)

to date. Although many studies compare fluorine-free products with PFAS-based ones and observe differences in characteristics, the question of when these properties are actually required is unasked.

The research first highlights how PFAS are used in clothing textiles and outlines the legal framework. Although this is of secondary importance for the genuine question, an understanding of the processes is fundamental to the preparation of the position paper. The analysis is based on the requirements for PPE, which are defined via tenders and standards. At the beginning, the current state of specifications is determined and then it is examined which of the requirements can already be fulfilled by fluorine-free products. The position paper is then created from the results.

2 Overview of the chemical group PFAS

PFAS can be defined in various ways. For the EU restriction process,

"PFAS are defined as substances that contain at least one fully fluorinated methyl (CF₃-) or methylene (-CF₂-) carbon atom (without any H/Cl/Br/I atom attached to it)".⁶

They can be subdivided into various subgroups, where different classifications are possible. Some of the subgroups have very different properties, which is why it is difficult from a scientific perspective to produce general statements about PFAS.⁷

Some PFAS, such as perfluorooctanoic acid (PFOA), are known to have properties of concern. Persistence, bioaccumulation, and health effects like some types of cancer, deformities and lowered birth weight in new-borns, reduced immune response or increased cholesterol levels are part of the portfolio of these PFAS.⁸ Other substances, which do not have these properties, can decompose into the dangerous variants. For many PFAS very little is known about their toxicity, especially to humans, because of a lack of data. Furthermore, it is challenging to predict the effects of mixtures of substances because the composition is usually unknown.⁹

PFAS can be detected worldwide, as they are dispersed through the air and water over long distances including the polar regions. The substances also enter the blood of the population via drinking water, food or products containing PFAS (Figure 1). According to a study, even children and adolescents sometimes have higher concentrations of PFAS in their blood than is considered safe by statutory limits.¹⁰ Since the substances are not broken down in the body and continue to accumulate with prolonged exposure, health consequences in later years cannot be ruled out. A recently published study concludes that the PFAS content in rain is above the applicable statutory limits.¹¹ Thus, rainwater which is important for producing food must be classified not drinkable. In regions that depend on rainwater as a source of drinking water, this is particularly fatal. Many soils are also polluted, and the long-term consequences for the environment can hardly be assessed. Some PFAS have a greenhouse gas or ozone-depleting potential, so they contribute to exacerbate climate change.¹²

⁶ (European Chemicals Agency (ECHA), 2023)

⁷ (Anderson et al., 2022)

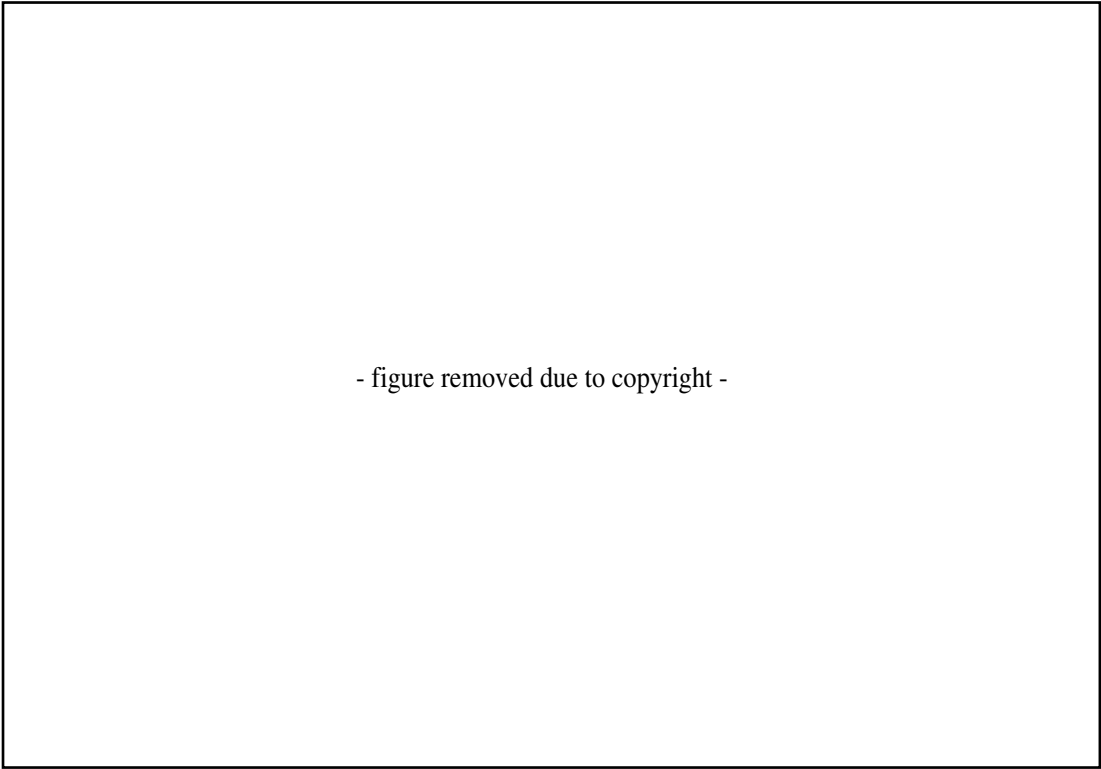
⁸ (European Environment Agency (EEA), 2022; Blum et al., 2015)

⁹ (Anderson et al., 2022)

¹⁰ (Duffek et al., 2020))

¹¹ (Cousins et al., 2022)

¹² (Wahlström and Pohjalainen, 2021)



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Figure 1: Distribution of PFAS in the environment;
source: Umweltbundesamt, (2020), <https://www.umweltbundesamt.de/en/press/pressinformation/pfas-excessively-high-in-blood-of-children>

2.1 PFAS in clothing

Not all known PFAS are used deliberately. For many areas only certain subgroups come into question (see Figure 2). Glüge et al (2020) provide an overview of which PFASs are utilized for various applications. Perfluorinated and polyfluorinated polymers (PFPs) are frequently used for clothing textiles. Expanded polytetrafluoroethylene (ePTFE) is used for membranes and PFPs with acrylic, methacrylic or polyurethane backbones and fluorinated side chains are common for durable water repellents (DWR). These side chains are predominantly produced with the help of perfluorinated tensides (PFT), which include perfluoroalkyl sulfonates (PFSA) and perfluorinated carboxylic acids (PFCA). Less common is the use of polyfluorinated tensides, especially fluorotelomer alcohols (FTOH). Furthermore, PFAS are used as auxiliary and processing agents to produce PFPs and in textile production, for example as wetting agents, defoamers or emulsifiers.¹³

By using PFPs, products can be made water and oil repellent, soil and stain resistant as well as chemical resistant, which is why they are utilized primarily, but not exclusively, for functional textiles like outdoor and workwear.

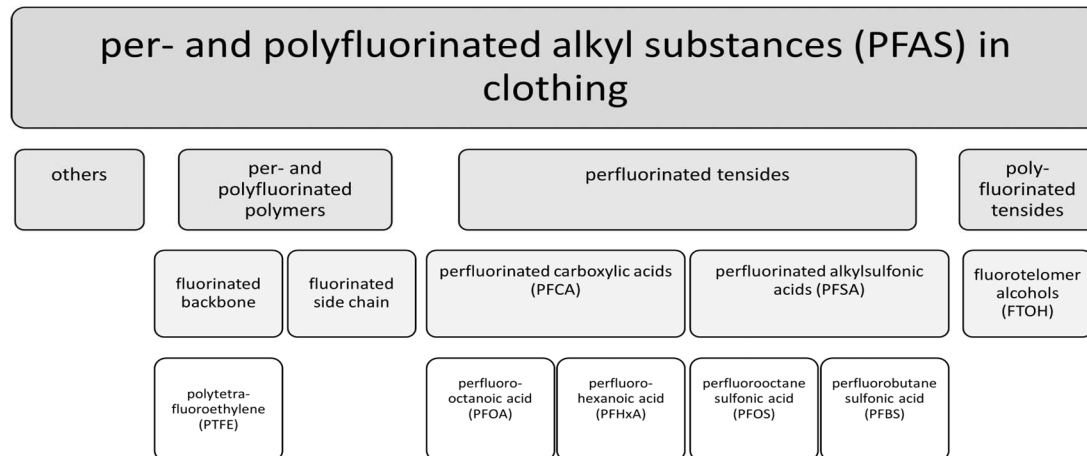


Figure 2: Overview PFAS in textiles; after (Glüge et al., 2020)

¹³ (Glüge et al., 2020)

2.2 Fluoropolymers

Most DWR work on the same principle and consist of a polymer linked to the fibre via a functional group with outward facing hydrophobic side chains (Figure 3). These must be tightly packed for good hydrophobicity and act as a barrier between fluid and textile.¹⁴

In the past, PFOA and perfluorooctanesulfonic acid (PFOS) have been the primary agents used to produce side-chain fluorinated PFPs for DWRs. These are frequently referred to as C8 chemistry because their chain consists of eight carbon atoms. Because of their toxic properties, both substances have been banned and short-chain PFTs are commonly used at present. The most common are the six-chain perfluorohexanoic acid (PFHxA) known as C6 chemistry or four-chain compounds like perfluorobutanesulfonic acid (PFBS).¹⁵

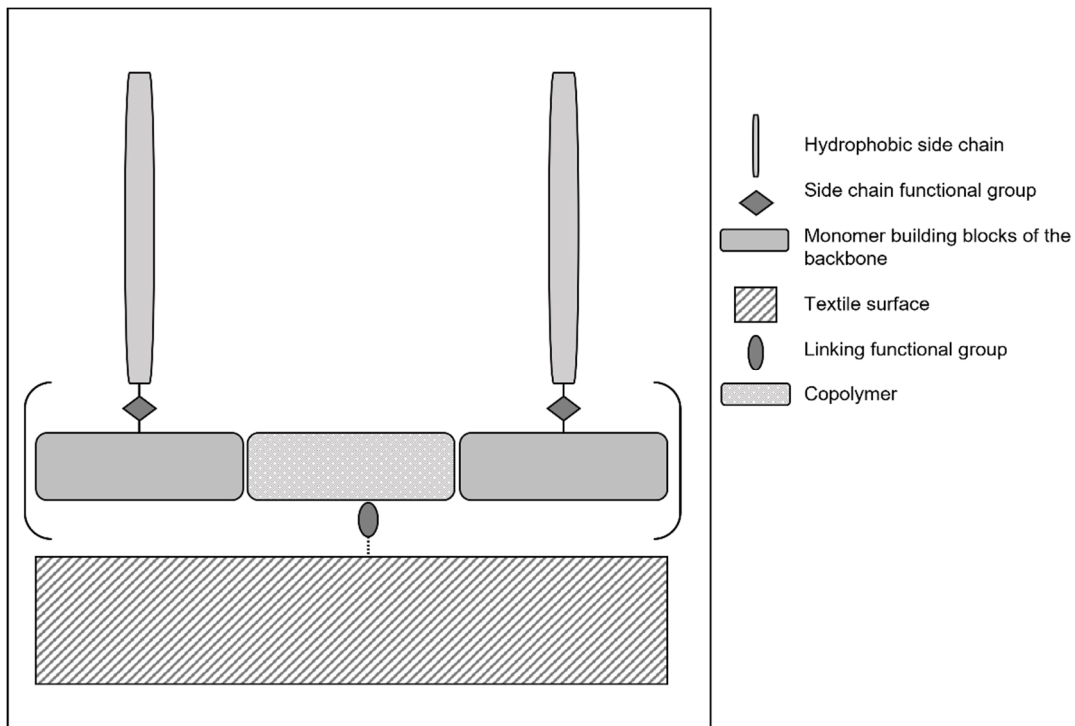


Figure 3: Working principle polymeric DWR; after (Holmquist et al., 2016: p. 255)

¹⁴ (Holmquist et al., 2016)

¹⁵ (Glüge et al., 2020)

The effectiveness of a DWR finish depends, among other things, on how densely the side chains are distributed on the textile and how strong their hydrophobic properties are. A surface is water repellent when its surface energy is significantly lower than that of water. On a chemical level, this effect is strongest with fluorocarbon compounds, although good hydrophobic properties can also be achieved with hydrocarbon compounds.¹⁶ More recent developments involve the textile structure and use nanotexturing, which produces air cushions. Similar to lotus leaves, this creates a barrier effect that also favours oleophobicity. This suggests the possibility that fluorine-free oil repellent DWR will be available in the future.

2.3 Problems with PFAS in textiles

PTFE itself is often described as harmless because it is inert and very durable. However, if one considers not only the finished product but also the production and disposal, this statement must be viewed very critically. The extraction of the raw materials already involves certain risks. Hazardous substances are used in production or arise as by-products, and even after use, questionable degradation products are released into the environment.¹⁷

The primarily used precursor substances PFOA and PFOS were replaced by short-chain compounds, which were initially considered harmless. In the meantime, there is growing evidence that the successor chemicals also have questionable properties.¹⁸ In addition, harmful by-products may be present as impurities in the finished textile or may be released during use. This occurs, for example, through ageing of the material and during laundering.¹⁹ Volatile components accumulate indoors in the air and dust, where they can be absorbed by humans and pose a risk especially to babies and children, as they have a lower tolerance limit.²⁰

Toxic gases are produced during combustion. For PTFE-coated cookware such as non-stick pans toxic vapours can already be measured from 200 °C, at low amounts which are dangerous for animals such as birds. At increased temperatures above 360 °C emissions that can also be dangerous or even lethal for humans.²¹ In some countries waste like textiles or electronics is often openly incinerated. Many municipal

¹⁶ (Holmquist et al., 2016)

¹⁷ (European Environment Agency (EEA), 2022)

¹⁸ (Gaballah et al., 2020; Wasel, Thompson and Freeman, 2022)

¹⁹ (Schellenberger et al., 2022)

²⁰ (Winkens et al., 2018)

²¹ (Sajid and Ilyas, 2017)

waste incineration plants also do not operate at sufficiently high temperatures to decompose all hazardous components. These gases are released into the environment.²²

In many areas, available data are insufficient. For example, it is perceived that compounds used on the outside of clothing can migrate to the skin over time. Whether dermal uptake is happening there is not known, but it cannot be ruled out. Since firefighters are more likely than average to develop cancers linked to certain PFAS, it is of considerable interest to understand whether firefighting equipment is a source of exposure to PFAS.²³

²² (European Environment Agency (EEA), 2022)

²³ (Muensterman et al., 2022)

3 Legal frameworks for chemicals in the European Union

The EU has established various mechanisms to regulate chemicals. The predominant goal is the protection of the population and the environment. Some of these mechanisms apply to all the used chemicals, others focus on particularly hazardous compounds.

Two significant regulations that are fundamental to all chemicals within the EU are Regulation (EC) No 1272/2008 on classification, labelling and packaging of substances and mixtures, commonly known as the CLP Regulation. The second is Regulation (EC) No 1907/2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH), commonly referred to as the REACH Regulation or REACH.

These are supplemented by other laws and regulations, such as Regulation (EU) 2019/1021 (2019) on persistent organic pollutants, which relate to specific chemicals.

3.1 Regulation (EU) 2019/1021: POP Regulation

Persistent organic pollutants (POP) are compounds that distribute in the environment over long distances and remain there because they are not degradable or degrade only very slowly. They can enter organisms, for example through food or water and accumulate in there. POP are often harmful to humans and the environment.²⁴

Various international treaties regulate the handling of POP, including the POP Protocol on Long-range Transboundary Air Pollution (CLTRAP)²⁵ and the UN Stockholm Convention on Persistent Organic Pollutants,²⁶ to which Regulation (EU) 2019/1021 has represented the European equivalent since 2019.

There are two restriction classes under the POP Regulation. Annex I includes substances that may not be manufactured, placed on the market, or used. Mixtures of substances and products that contain POP only as by-products are also included. Annex II lists substances whose manufacture, placing on the market

²⁴ (European Parliament, Council of the European Union, 2019: preamble, par. 2)

²⁵ (United Nations Economic Commission for Europe (UNECE), 1979)

²⁶ (United Nations (UN), 2001)

and use are restricted. It also deals with stockpiles, which must be recycled properly if no special authorisation for use is available.

Substances listed in the POP Ordinance are, for example, the insecticide dichlorodiphenyltrichloroethane (DDT) or the PFAS chemicals PFOA and PFOS, their derivatives, salts, and related substances.²⁷

3.2 Regulation (EC) 1907/2006: REACH Regulation

The REACH Regulation on the Registration, Evaluation, Authorisation and Restriction of Chemicals oversees the manufacture and distribution of substances, aims to reduce the need for animal testing, establishes the necessary procedures for that and installs an authority responsible for the execution and coordination of the processes.²⁸ This section aims to give an overview to the elements relevant to the topic of the thesis.

3.2.1 European Chemicals Agency (ECHA)

The European Chemicals Agency (ECHA) is the authority convened by the REACH Regulation. It is divided into several elements, including the Member States Committee (MSC), the Risk Assessment Committee (RAC) and the Socio-Economic Analysis Committee (SEAC).²⁹ These are significantly involved in the implementation of restriction procedures, other positions in ECHA are not considered here.

All Member States (MS) have a position in the MSC.³⁰ The MSC is involved in substance and dossier evaluations as well as in the authorization procedures and is supposed to mediate if there are disagreements in decision-making in this regard.³¹ Candidate lists are drawn up for RAC and SEAC, for which the MS nominate candidates. The ECHA Management Board subsequently elects one to two members per MS to the respective committee for three years. The Committees may decide to appoint up to five auxiliary members to broaden their expertise.³² If the committees are to prepare an opinion on a

²⁷ (European Parliament, Council of the European Union, 2019: Annex I)

²⁸ (European Parliament, Council of the European Union, 2006: preamble, Par. 15)

²⁹ Ibid. art. 75, par. 1c, d, e

³⁰ Ibid. art. 85, par. 3

³¹ Ibid. art. 76, par. 1e

³² Ibid. art. 85, par. 1, 2, 4

process under REACH, the RAC looks at the potential risks to the environment and the population, while the SEAC considers the socio-economic consequences of a decision.³³

ECHA is required to make information publicly available at various points. To achieve this, it maintains lists on its website. One of these is the Public Activity Coordination Tool (PACT), which provides an overview of all activities concerning a substance, regardless of which body is carrying them out or under which regulation.³⁴ Information concerning procedures under REACH is also recorded in the Registry of Intentions (RoI). The entries include information on the substance, its properties, ongoing and planned processes, and results of completed procedures.³⁵

3.2.2 Registration of substances

According to the principle of "*no data, no market*",³⁶ substances must be registered under REACH before they can be produced and put on the market. The registration obligation under REACH applies to substances, mixtures of substances and articles if an annual consumption volume of one tonne is exceeded for a certain substance and a release of the chemical cannot be ruled out. It is required that manufacturers and importers join forces and submit a joint registration dossier containing comprehensive information on the substance to be registered, its use and properties.³⁷ The submitted dossiers are reviewed by ECHA and missing information is requested.³⁸ Figure 4 shows a schematic overview of the described workflow.

³³ (European Parliament, Council of the European Union, 2006: art. 76, par. 1c, d)

³⁴ (European Chemicals Agency (ECHA), n.d.)

³⁵ (Bundesanstalt für Arbeitsschutz und Arbeitsmedizin (BAuA), n.d.)

³⁶ (European Parliament, Council of the European Union, 2006: art. 5)

³⁷ Ibid. art. 5-14

³⁸ Ibid. art. 20, 41

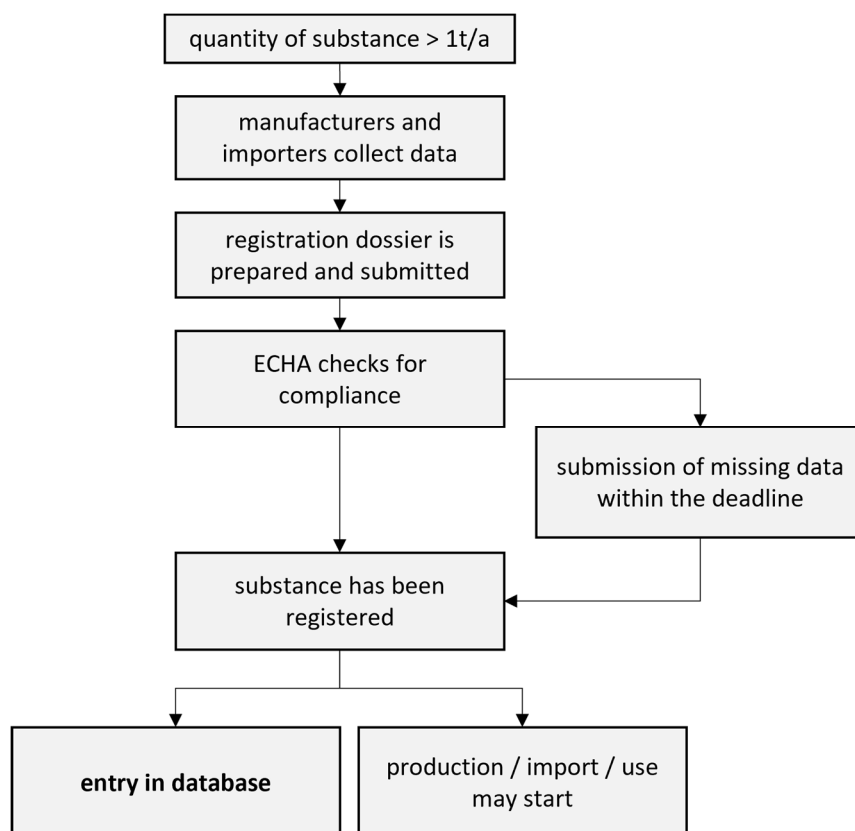


Figure 4: REACH registration process; source: E. Finger

3.2.3 Evaluation and identification of SVHC

The following stage after registration is substance evaluation, which assesses whether the use of the notified substances should be restricted or not (Figure 5). At the beginning, prioritisation is done according to certain criteria. The criteria are a substance is likely to possess properties of concern due to its structure, the probability of exposure is high or very large quantities of the substance are circulating within the EU.³⁹

Properties of concern are defined in Article 57 of the Regulation. According to that substances of very high concern (SVHC) are carcinogenic, mutagenic or toxic to reproduction (CMR), persistent, bio accumulative and toxic (PBT) or very persistent and very bio accumulative (vPvB). Further, substances that do not fall into these categories but represent a comparable risk, for example endocrine disruptors

³⁹ (European Parliament, Council of the European Union, 2006: art. 44, par. 1)

can be considered SVHC.⁴⁰ The search criteria are also explained in the Roadmap on Substances of Very High Concern.⁴¹ The roadmap is intended to make the process of identifying and assessing SVHC more efficient and transparent.

Via a continuing action plan, the MSC is notified annually of those substances for which closer consideration is deemed necessary.⁴² The assessment does not have to be carried out by ECHA itself, which predominantly fulfils a mediating role, but can be taken over by the authorities of a member state.⁴³ The implementing authority of a substance evaluation can, if it deems it necessary, request further information and must publish an opinion within twelve months.⁴⁴ In many instances a so-called Risk Management Options Analysis (RMOA) is prepared, which suggests how to proceed.⁴⁵

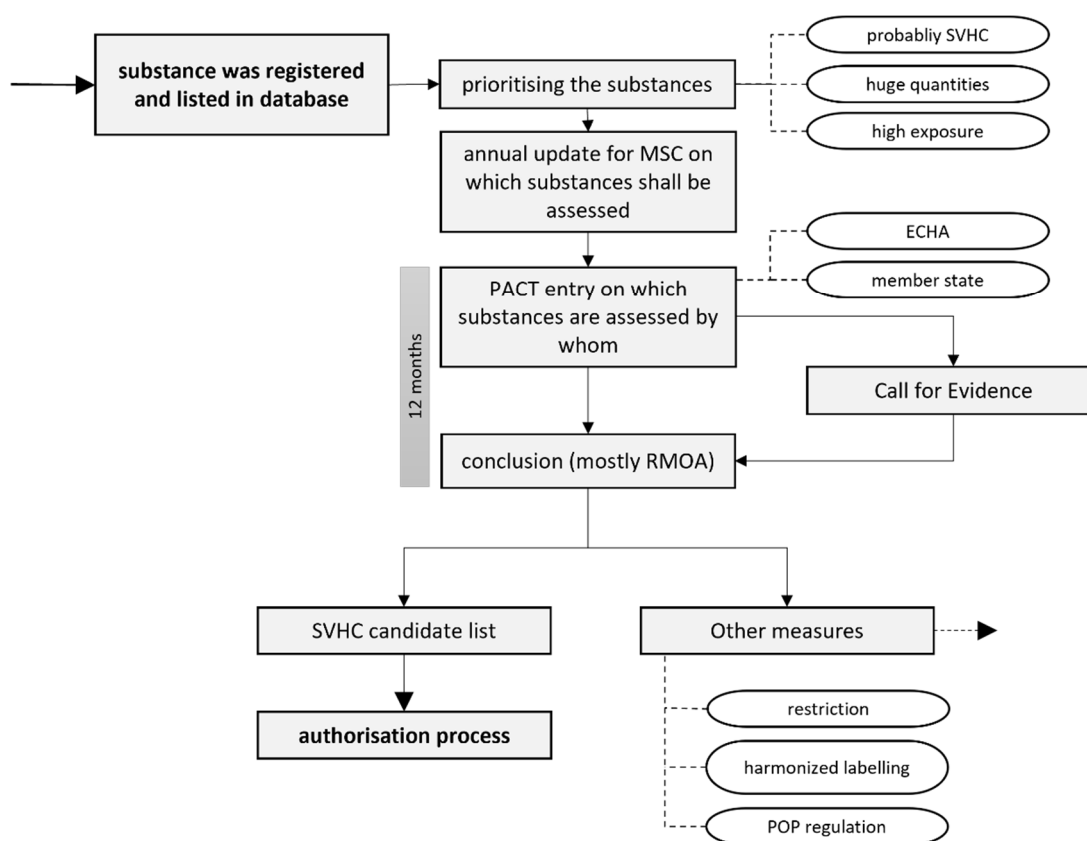


Figure 5: REACH evaluation process; source: E. Finger

⁴⁰ (Bunke et al., 2013: p. 8)

⁴¹ (European Commission, 2013)

⁴² (European Parliament, Council of the European Union, 2006: art. 44, par. 2)

⁴³ Ibid. art. 45, par. 1, 2

⁴⁴ Ibid. art. 46, par. 1

⁴⁵ (European Commission, 2013)

3.2.4 Authorization process: listing of SVHC

If a substance is confirmed as SVHC, it is included in the so-called candidate list and thus proposed for an authorization procedure. If a substance is subject to authorization, its use is generally not permitted unless there is a reason for an exemption.⁴⁶

„The aim [...] is to ensure the good functioning of the internal market while assuring that the risks from substances of very high concern are properly controlled and that these substances are progressively replaced by suitable alternative substances or technologies where these are economically and technically viable.“⁴⁷

Regulating substances in this manner is supposed to make their usage as unattractive as possible for companies without depriving them of their economic capacity to act. An authorization requirement is issued primarily, but not exclusively, for chemicals that have been classified as SVHC.⁴⁸ (Figure 6)

Article 59 defines the procedure and provides for the preparation of a document (so-called Annex XV dossier) according to the requirements of Annex XV of the REACH Regulation. The dossier is prepared by ECHA or an EU member state. Which substances are processed by whom is openly displayed on the ECHA website. Initially, a declaration of intent is issued, and a deadline is set for the period during which contributions can be made by the public. After completion and publication of the dossier, a two-month consultation phase follows, which offers the possibility to submit comments.

If no comments are received, the substance is directly included in Annex XIV, otherwise the case is submitted to the Member State Committee for voting. If the Committee does not reach a decision, the matter is forwarded to the EU Commission.⁴⁹ Once a decision has been developed to classify the substance as SVHC, Annex XIV will be amended accordingly. From then on, applications for authorization for the continued use of the substance can be submitted.

⁴⁶ (European Parliament, Council of the European Union, 2006: art. 56)

⁴⁷ Ibid. art. 55

⁴⁸ Ibid. art. 57

⁴⁹ Ibid. art. 59

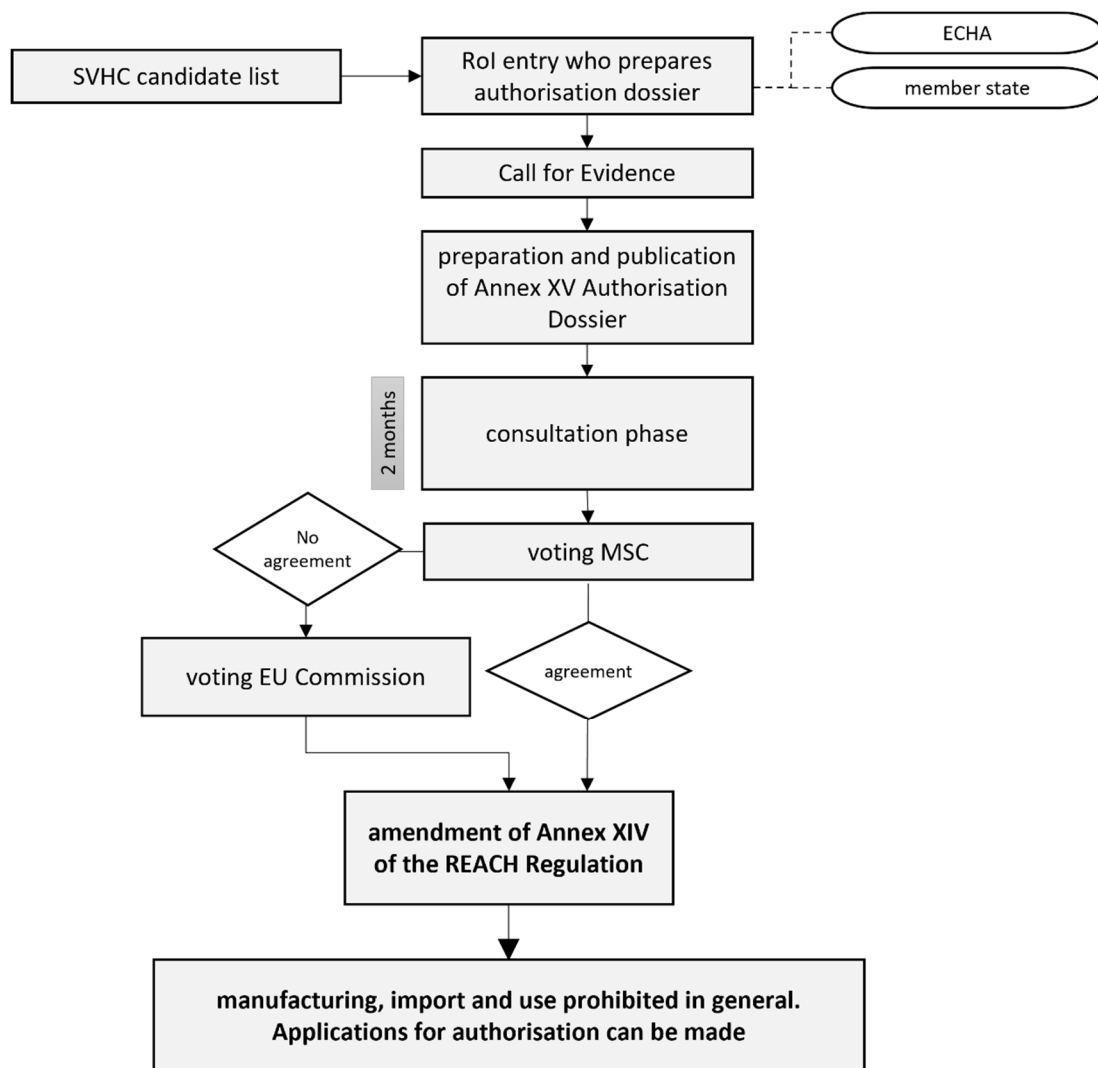


Figure 6: REACH authorisation process; source: E. Finger

3.2.5 Restriction process

Although the authorisation process already severely restricts the use of harmful chemicals, further measures may be deemed necessary. The REACH regulation states in this regard:

„When there is an unacceptable risk to human health or the environment, arising from the manufacture, use or placing on the market of substances, which needs to be addressed on a Community-wide basis, Annex XVII shall be amended [...] by adopting new restrictions, or amending current restrictions in Annex XVII[...]. Any such decision shall take into account the socio-economic impact of the restriction, including the availability of alternatives.“⁵⁰

There are different options for the process of listing a substance in Annex XVII (Figure 7) described in Article 69: ECHA assesses whether substances regulated by Annex XIV still pose a risk or are managed sufficiently safely. It can also be called upon by the EU Commission to write an Annex XV dossier. In addition, member states have the option of preparing such a document themselves.

From here on, the procedure is the same for all variants. The dossier is announced via ECHA and submitted within twelve months to be checked by the committees to decide if it fulfils the formal criteria. If the document is accepted, it must be published on ECHA's website with the advice that interested parties and companies affected by the restriction are encouraged to comment thereon within six months.⁵¹

The results of this consultation phase as well as the dossier itself are considered in the respective opinion-development of the committees. The RAC receives nine months from the announcement of the dossier, the SEAC twelve months. SEAC first releases a draft which can be commented on within 60 days before the final opinion is adopted.⁵² Both statements are published and submitted to the EU Commission for voting.⁵³

⁵⁰ (European Parliament, Council of the European Union, 2006: art. 68, par. 1)

⁵¹ Ibid. art. 69, par. 1, 2, 4, 6

⁵² Ibid. art. 70, 71

⁵³ Ibid. art. 72, 73

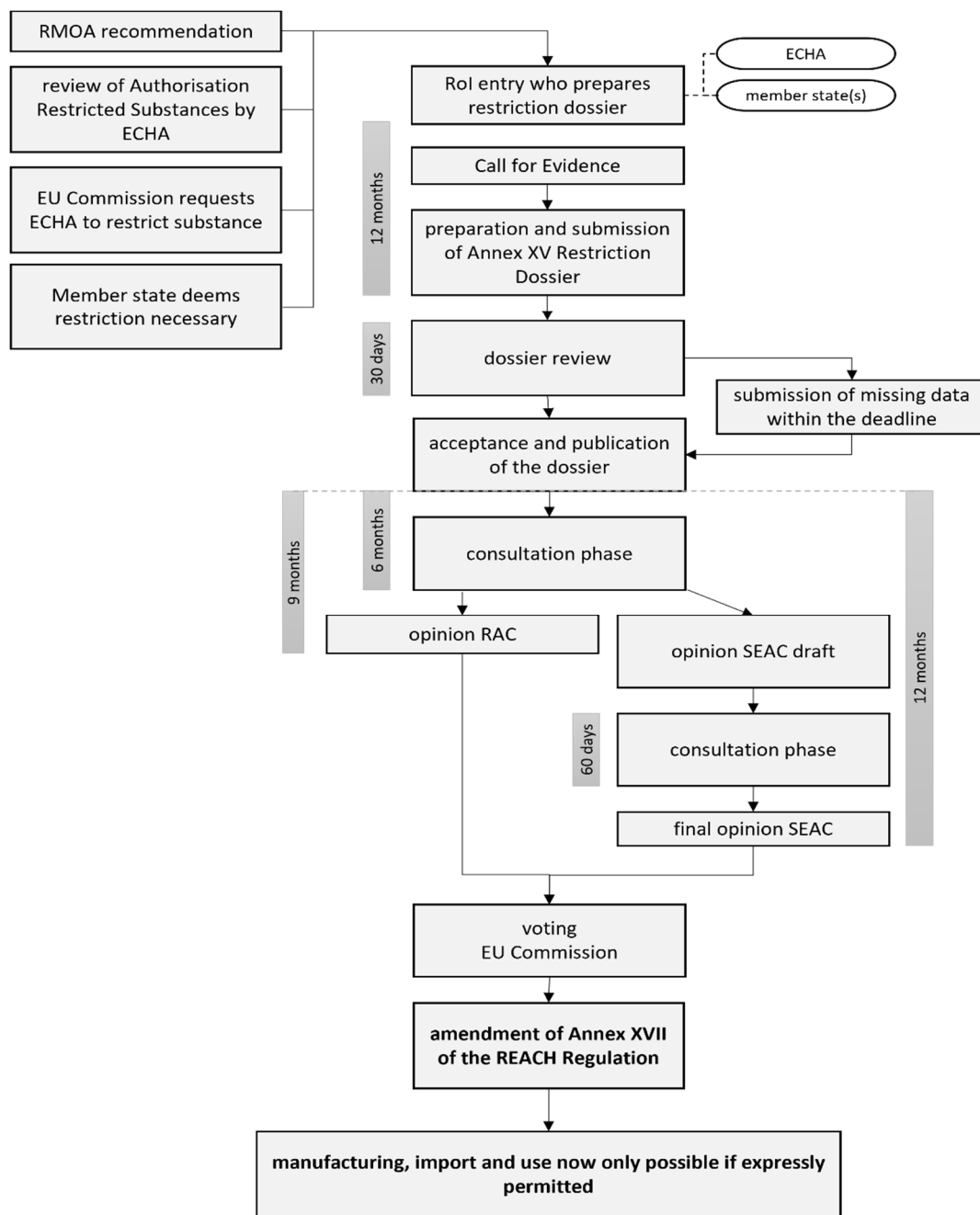


Figure 7: REACH restriction process; source: E. Finger

3.3 EU Chemicals Strategy

The Chemicals Strategy for Sustainability (CSS) is a communication of the EU Parliament published in October 2020. In the context of the European Green Deal, according to which the EU wants to have zero emissions by 2050, it is intended to reform the chemical legislation within the EU. To this end, a whole series of measures have been laid down. For instance, material cycles are to become non-toxic, especially those that are intended for vulnerable groups or that have high potential for recycling such as textiles. Chemicals shall be assessed in groups, as it takes a long time to analyse each individual substance.

The chemical group PFAS is explicitly mentioned and should be banned in its entirety where no exemption is justified. The elimination of existing damage caused by PFAS should be promoted, as well as the development of sustainable and safe alternatives.⁵⁴

3.3.1 Essential Use Concept

The Essential Use concept focuses on the fact that there are sometimes applications that cannot be dispensed with and for which there is no alternative to the use of certain chemicals. The CSS specifies that such an exemption exists for a chemical,

*“if their use is necessary for health, safety or is critical for the functioning of society and if there are no alternatives that are acceptable from the standpoint of environment and health.”*⁵⁵

The basis for this has already been laid down in the Montreal Protocol on ozone-depleting substances and has been effectively implemented there.⁵⁶

Within the framework of the REACH revision, criteria are currently being developed to determine when an essential use exists. A legally binding definition is not expected before completion of the ongoing PFAS restriction process. Based on the Montreal Protocol, Cousins et al. (2019) propose a preliminary classification of uses into the three categories non-essential, substitutable, and essential.⁵⁷ This is

⁵⁴ (European Commission, 2020)

⁵⁵ Ibid. p. 10

⁵⁶ (United Nations (UN), 1987)

⁵⁷ (Cousins et al., 2019)

intended to speed up the search for alternatives in REACH procedures, as only those classified as essential need to be looked at rather than all applications.

The Swedish non-profit organization ChemSec proposes the following approach to the question of how to distinguish essential and non-essential uses:

*"Which products are so essential that they need to be used even if they contain chemicals that may harm human health or the environment?"*⁵⁸

Under the current regulation, exemptions for substances subject to authorisation can also be granted if the applicant is able to demonstrate that the emerging risk is controlled.⁵⁹ In practice, this means that dangerous chemicals that could be replaced will remain in use. This is critical from a moral point of view and against the background of climate change, which is why the Essential Use concept is intended to lay down clearer rules.

⁵⁸ (ChemSec, 2022)

⁵⁹ (European Parliament, Council of the European Union, 2006: art. 60, par. 2)

4 PFAS restriction process

In the current procedure, the focus is on the entire PFAS group of chemicals. In the past, some representatives of the group have already been restricted. For example, PFOS and PFOA are regulated by the POP Regulation (cf. Chapter 3.1 on the POP Regulation). A restriction procedure is advanced for PFHxA, which is used as a substitute. The RAC and SEAC committees generally support a ban, but a binding decision is still to be made.⁶⁰ Also ongoing is a restriction procedure for PFAS in aqueous firefighting foams, at the moment the committees are working on their opinions.⁶¹

The usage of PFAS is not only being questioned in Europe. For example, in California a law was passed that bans the use of PFAS in textiles from January 1st, 2025. The only exception is outdoor clothing for extreme weather conditions, where there is an extended transition period until 2028.⁶² This law is the most comprehensive to date regarding PFASs, as it deals with the entire group of chemicals, similar to the ongoing process at EU level.

4.1 Schedule and content, as of 17 February 2023

In July 2021, it was announced in ECHA's RoI that an Annex XV dossier on the restriction of PFAS as a whole group would be prepared. This was worked out by Germany, Denmark, the Netherlands, Norway and Sweden, with a submission date of January 13, 2023.⁶³ The start of the consultation phase is planned for March 22, 2023.⁶⁴

The procedure is intended to ensure that all PFAS are withdrawn from the market and may no longer be manufactured or imported. Exemptions can be defined if no suitable substitute is available for an application. Small quantities for research purposes are usually also exempted from restrictions.⁶⁵ Each of the countries involved in the procedure deals with a different industry in which PFASs are used. For textiles, the Swedish authority is responsible.

⁶⁰ (European Chemicals Agency (ECHA), 2022 b)

⁶¹ (European Chemicals Agency (ECHA), 2022 a)

⁶² (State of California Legislative Council, 2022)

⁶³ (European Chemicals Agency (ECHA), 2023)

⁶⁴ (Umweltbundesamt, 2023)

⁶⁵ (European Parliament, Council of the European Union, 2006)

4.2 ECHA consultation phase

Sympatex is in favour of a general ban on PFASs and has already submitted a statement to ECHA regarding ePTFE membranes in the textile and clothing industry during the second Call for Evidence prior to the preparation of the application dossier. For the upcoming consultation phase, an important aspect will be to define which areas of application qualify for an exemption from the general restriction. Research mostly focuses on DWRs, membranes are often not considered. Explicitly around PPE, discussions about the necessity of exceptions are to be expected. This is where Sympatex can contribute needed expertise. The company is also in contact with ChemSec, which is advising SEAC and confirms the information provided can be helpful.

4.3 Restriction application: Annex XV dossier

The application dossier is still being reviewed, but was pre-published on 7 February 2023, so the following summary is conditional.

An RMOA was carried out and concluded a restriction procedure is the most appropriate option for PFAS. Active substances for biocides, pesticides and pharmaceuticals for humans and animals are not included in the ban, as these are considered sufficiently controlled through their respective regulations. It was noted that for some uses exemptions may be necessary. Limited exemptions for five or 12 years are proposed. Only two applications are proposed to be permanently exempted. These are refrigerants for air conditioning in houses, where building regulations do not allow alternatives and for calibration of measuring equipment and as reference material.⁶⁶

Regarding clothing textiles, the proposal foresees a general ban on PFAS, to apply 18 months after the entry into force of the restriction. Exemptions are only foreseen in PPE. These are protective clothing against hazardous chemicals and biological hazards, PPE for professional firefighting and agents for reimpregnation of both groups, each for 13.5 years after entry into force.⁶⁷ According to the application dossier, the conclusion that PFAS are in principle not required for PPE was reached on the assumption that some of the alternatives known for everyday and outdoor clothing are applicable to PPE. It follows

⁶⁶ (BAuA Federal Institute for Occupational Safety and Health et al, 2023: pp. 5, 6)

⁶⁷ Ibid. p. 5

that information submitted during the upcoming consultation phase concerning the existence of alternatives for PPE will influence whether further exemptions are considered or whether the application is confirmed in this form.

5 Alternatives for PFAS in Personal Protective Equipment

This chapter addresses the question for which PPE areas PFAS are dispensable or substitutable and where further research is necessary. The consideration is limited to apparel, sports and outdoor clothes, home textiles and PPE, whereby only clothing is taken into account for PPE. Other equipment like head and facial protection is not considered. Since the essential use concept is not yet implemented, all applications must be considered.

5.1 Methodology

The evaluation is based on expert knowledge from the company and literature research. In some cases, information from research was only accessible to a limited extent, so it is possible solutions exist, that could not be taken into account. An essential component in connection with PPE is public procurement. The majority of protective clothing for many occupational groups is requisitioned through tenders and thus the standard is set for which requirements the textiles must fulfil.

The requirements are laid down in the Technical Terms of Delivery or Technical Requirements (TR) of a tender. The inspection of TRs was an essential part of the research work. As these are not normally publicly accessible, but only made available to applicants, research was limited to TRs that were already accessible to Sympatex. This limits the investigation to certain areas in which Sympatex is or has been involved in tenders, but in return it is possible to refer to practical experience.

Foremost, a list was generated of which requirements are demanded in the TRs and the standards mentioned were noted (see VI Appendix). Next the requirements found were sorted according to relevance and divided into groups. Specifications that were identified as particularly critical with regard to the replaceability of PFASs were examined in more detail. The next step was to assign in which occupational fields the critical requirements are needed. Based on the previous study, it was assessed for which areas PFAS are dispensable or replaceable, where they are not replaceable, or where more research is needed.

5.2 Defining critical areas according to the Essential Use Principle

For the assessment of where an exemption is justified under REACH, although it has not yet entered into force, the principle of Essential Use as described in 3.3.1 is used. Based on Cousins et al. (2019), a division is made into non-'essential', 'essential and replaceable' and 'essential and non-replaceable'.⁶⁸ The classification is based on whether a function is so indispensable that even the use of hazardous chemicals must be accepted. This does not necessarily refer to an entire product, but to certain characteristics of a product achieved through PFAS. Apparel, outdoor and home textiles are classified as non-essential here, PPE needs to be studied more closely.

In case of apparel, the properties made possible by PFAS are dispensable and fall into the 'non-essential' category. PFAS are frequently used to achieve an anti-stain effect or make jackets and coats water-repellent. The California Assembly Bill 1817/762 states in this regard:

„For addressing stains, soap and water work well for most situations, and alternative materials and cleaning solutions offer additional options.“⁶⁹

Although it is convenient if clothes do not stain easily and stubborn stains can make a garment visually unusable, that does not justify the use of hazardous chemicals. Furthermore, there are fluorine-free products that achieve comparable results. Some manufacturers already offer products that are supposed to provide resistance to water-based stains such as red wine.⁷⁰ Some even achieve oil repellent properties.⁷¹ Fluorine-free variants do not always achieve the same properties as PFAS-based products but are sufficiently effective in many cases.

Regarding outdoor clothing fluorine-free alternatives are already established on the market and do not bring any disadvantage in terms of functionality. Sympatex customers frequently confirm this, and there are other providers as well. It is contradictory when products for such a nature loving clientele are manufactured with hazardous chemicals. Furthermore, oil and dirt repellent properties are not seen as necessary by consumers.⁷²

Regarding home textiles, PFAS are primarily used to protect against stains. This is a non-essential application as stains on for example seat covers represent mainly a visual problem and not a safety risk. The risk here is rather from the PFAS containing products themselves when volatile components of the

⁶⁸ (Cousins et al., 2019)

⁶⁹ (State of California Legislative Council, 2022: Sect. 1a, par. 4)

⁷⁰ (Remington, 2021)

⁷¹ (Fleischmann, 2017; Shabanian et al., 2020)

⁷² (Schellenberger et al., 2019)

finish are released into the air and deposit in the living area. Impregnation sprays also contribute to this. The contamination of indoor spaces poses a risk especially for babies and children.⁷³

Lists of manufacturers of fluorine-free products for various applications can be found among others at Ri.Se (Research Institutes of Sweden),⁷⁴ Greenscreen,⁷⁵ or ChemSec.⁷⁶

Protective workwear is intended to protect the wearer from hazards. Therefore, it must provide specific properties adapted to the situation. The demands here are usually higher than for everyday products and in many cases cannot be dispensed with. For this reason, PPE will be examined in detail.

5.3 Criteria for the suitability of alternatives

When searching for alternatives, criteria need to be established as to when a product is acceptable and when it is not. The question of whether PFAS can be substituted in textiles has often been asked and repeatedly answered with a no, as fluorine-free technologies do not achieve identical results. One of the leading factors here is oleophobicity, which is not or only partially achieved by fluorine-free DWRs. A zero-tolerance approach while searching for alternatives is not useful as it misses the target and prevents novel innovative solutions. Preferably, the application itself must be looked at instead of the substance in question.

A good example of this is outdoor clothing: If only fluorine-based and fluorine-free products are compared, it becomes apparent that the fluorine-free variants do not achieve the same performance and are classified as unsuitable. However, if instead the application itself is looked at and questioned which properties outdoor clothing actually has to fulfil, it turns out that there are many suitable substitutes.⁷⁷ A study conducted by students of the University of California in cooperation with W.L. Gore & Associates on the suitability of fluorine-free DWR, concludes that there would have been more approaches suitable for the application, but that they did not meet the requirements set by Gore because it would have been an alternative technique.⁷⁸ For in-house sourcing this can be legitimate, but for a procedure under REACH such an approach is not useful.

⁷³ (Winkens et al., 2018)

⁷⁴ (Ri.Se Research Institutes of Sweden, 2022)

⁷⁵ (Greenscreen for Safer Chemicals, 2022)

⁷⁶ (ChemSec, 2023)

⁷⁷ (Schellenberger et al., 2019)

⁷⁸ (Augustine et al., 2017)

In quality management, good quality is not achieved when the maximal possible has been reached. Instead, it is about balancing effort and demands. The principle is not 'as good as possible' but instead 'as good as necessary'. This approach should also be used as a basis when seeking alternatives.

The European Court of Justice derived a similar conclusion in the context of an application for authorisation under REACH. The applicant had concluded that there was no suitable substitute product. This was successfully objected to because a zero-tolerance threshold, which means substitution without reduction in performance, was applied in the evaluation of products. According to the court ruling, this does not correspond to the intention of the REACH Regulation:

„However, to decide, as a matter of principle, that replacement must not entail any reduction in performance not only amounts to adding a condition not provided for in that regulation, but is likely to prevent that replacement and, consequently, to deprive that regulation of much of its effectiveness.“⁷⁹

If the required function is fulfilled, other technologies can also be considered as alternatives.

5.4 Exclusion of alternatives in public procurement

The requirements that a textile for protective workwear must fulfil are regulated via standards on the one hand and tenders on the other. Comparing different tenders, it is noticeable that the criteria for the same field of application can be very inconsistent and sometimes contradictory. Especially in the case of membranes, this repeatedly excludes or favours certain product categories. In Table 1, the description of the membrane or laminate from various tenders in the period 2006 - 2022 is quoted. For reasons of confidentiality, the tendering body is not named. All examples are rain or weather protection jackets according to DIN EN 343 or with comparable requirements for protection against the wind and weather and to ensure visibility. Protection against other hazards such as fire and heat are not included in any of the examples.

⁷⁹ (Court of Justice of the European Union , 2021: par. 56)

Table 1: Comparison of material specifications for the membrane in tenders for jackets for protection against rain according to EN 343 or comparable

No.	Quote of description in tender	Year	Allowed materials
1	2-layer laminate, GoreTex®	2006	GoreTex
2	Water vapour permeable, waterproof and windproof membrane	2012	All
3	Membrane 100% polyester water vapour permeable hydrophilic – compact	2014	PES
4	Laminate as protective clothing against rain, which fulfils EN 340 (or new DIN EN ISO 13688) and EN 343, class 3/3 with increased requirements according to this performance specification	2015	All
5	water vapour permeable wind- and waterproof membrane	2017	All
6	Water vapour permeable, waterproof and windproof bicomponent membrane based on multidirectional ePTFE or a material at least equivalent in functionality and quality	2017	All
7	2-layer direct laminate with PU or PTFE membrane	2018	PU, ePTFE
8	Bicomponent membrane based on ePTFE, PES or equivalent	2018	All
9	Bicomponent membrane based on ePTFE	2019	ePTFE
10	Waterproof, water vapour permeable bicomponent membrane based on multidirectional ePTFE or a material at least equivalent in function and quality	2020	All
11	Permanently waterproof, windproof and water vapour permeable membrane Note: The use of a membrane based on ePTFE is not permitted!	2022	All, except ePTFE

Often ePTFE is set as the standard, even if other materials are also permitted. In examples 1, 3, 7, 9 and 11, precise material specifications are made. No. 3 also specifies PES for the upper fabric of the laminate, here the decision can be explained with an emphasis on sustainability and that the textile should be recyclable. Example 11 can likewise be justified with sustainability. From a technical point of view, there is no obvious reason why only the explicitly named materials are permitted for 1, 7 and 9.

It is similar for DWRs. Some tenders specify a certain performance level that must be met, others specify which chemistry the DWR should be based on. Usually this is then fluorocarbon-based, as oil repellent properties are desired. In some cases, no testing of oleophobicity is required, only fluorine-based DWR.

Given these circumstances, it seems advisable to question which typical requirements are actually necessary. As shown by the example of outdoor clothing, there are often more options on the market if it is recognised that not everything that is possible is indeed necessary. Conversations between Sympatex employees and those responsible for tenders confirm specifications are frequently adopted out of habit without questioning. Under the Green Deal, the EU has set itself the goal of becoming climate-neutral, which includes making public procurement sustainable. If the Textile Strategy⁸⁰ is to be implemented effectively, responsible personnel must be trained accordingly and established habits have to be rethought.

⁸⁰ (European Commission, 2022)

5.5 Identifying and grouping requirements for PPE

For clothing PFAS are used in form of membranes or as DWRs. However, PFAS have also been detected in other components, for example in used firefighters' protective clothing.⁸¹ In these cases, migration due to ageing can be assumed, which is why only the membrane and DWR are taken into account. Only a portion of the specified requirements are directly or indirectly influenced by them, which is why first it must be defined which properties are relevant for the research.

Requirements related to tailoring, such as size and dimension specifications, information on haberdashery and others, are excluded. In the case of multilayer textiles, linings, insulation materials and other layers are generally not included, unless required for a specific scenario. Mechanical properties, including tensile and tear strength, abrasion resistance, delamination and common fastness properties such as friction and wet fastness, are only examined where necessary.

The properties listed below are a collection from various tenders from different sectors that Sympatex has in its possession (for details see VI Appendix). Standards referred to were also taken from the TRs and supplemented by information from overriding protective standards, for example the so-called weather protection standard EN 343. Other specifications, such as guidelines for specific areas, are also included in the research. Unless stated otherwise, the current version of a standard valid at the time of tendering applies in each case.

The list does not claim to be complete, but it can be assumed that the most common requirements and tests are included. In addition, the tests in the tenders are not always strictly according to the standard but are in reference to a specific standard. Occasionally, TRs also mention own test specifications for individual properties without reference to a test standard. The requirements have been divided into several groups. Foremost, a distinction must be made between those that are related to PFAS and those that have no relation to it or only a negligible one (Table 2). For example, the membrane also has a part in the insulation performance, as this is tested on the total layer structure of the finished garment. However, the influence here is so small that it can be regarded negligible, which is why the test is classified as not relevant in relation to PFAS.

For the properties directly related to PFAS, a distinction is made between whether alternatives are already available (see Table 3) or whether substitution is not possible or only very difficult (see Table 4). This

⁸¹ (Peaslee et al., 2020)

last group of PFAS-relevant critical properties is subject to detailed consideration. In addition, a distinction must be made as to which component the property refers to, which is also noted in the table.

Table 2: Overview of non-PFAS-relevant requirements for protective clothing

Requirement	Standard	Applies to	PFAS-relevance
Tensile strength	ISO 1421	Membrane/ Laminate	Minor influence
		DWR	Differences are solvable
Tear strength	ISO 4674-1	Membrane/ Laminate	Minor influence
		DWR	Differences are solvable
Abrasion resistance	ISO 12947	Upper fabric	Possible, depending on thickness of DWR
Delamination	ISO 6330	Laminate	No significant difference but other requirements for the adhesive in the laminate
Heat transfer (radiation)	ISO 6942	Overall structure/ insulation layer	No connection
Heat transfer (flame)	ISO 9151 EN 367	Overall structure/ insulation layer	No connection
Insulation value	ISO 15831 EN 342	Insulation layer	No connection
Antistatic (conductive fibres)	EN 1149	Laminate/ overall structure	No connection
Antistatic (finish)	EN 1149	Upper fabric/ finish	DWR may interfere with finish
Protection against electric arcs (conductive fibres)	IEC/CD 61482-2	Laminate/ overall structure	No connection
Protection against electric arcs (finish)	IEC/CD 61482-2	Upper fabric/ finish	DWR may interfere with finish

For some tests, a different assignment would also be possible. For example, the tensile strength or tear resistance of the laminate is not directly relevant with regard to PFAS, but the membrane is part of the fabric compound and thus also has an influence on the result. In addition, microporous membranes react more sensitively to stretching than compact membranes. The DWR can also have an influence on the tensile strength or abrasion resistance, but here it may be assumed that this can occur with both fluorine-containing and fluorine-free DWRs, whereby a thicker application is usually necessary with fluorine-free variants.

There are other types of finishes for textiles, meant to give a softer handle, for flame retardant or anti-static effects. When different finishes are combined, they can affect each other. These effects can occur with both fluorocarbon-based and fluorine-free variants.

Delamination presents different challenges for the adhesive, with ePTFE membranes being more demanding. Since this primarily plays a role in production and there is no significant difference in the finished laminate, the property is not classified as relevant in this context.

Table 3: Overview of replaceable PFAS-relevant requirements for protective clothing

Requirement	Standard	Applies to	PFAS-relevance
UV-resistance	ISO 105 – B02 EN 20105 -B01	Upper fabric, DWR	No significant difference
UV-resistance	ISO 105-B02 EN 20105-B01	Membrane	Differences are solvable
Water repellence	ISO 4920 EN 24920	DWR	No significant difference
waterproof (rain tower test)	EN 14360	Overall structure	No significant difference
Waterproof (new)	ISO 811 EN 20811	Membrane	No significant difference
Waterproof after 10x washing	ISO 6330 ISO 15797 EN 26330	Membrane	No significant difference except for ISO 15797
Waterproof after cleaning	ISO 3175-2	Membrane	No significant difference
Waterproof after abrasion	EN 530	Membrane	No significant difference
Waterproof after bending	DIN 53359 EN 7854	Membrane	No significant difference
Waterproof after contact to oil and fuel	ISO 1817 EN ISO 7854	Membrane	No significant difference
Waterproof after hydrolysis	DIN 53896	Membrane	Minor differences
Windproof	ISO 9237	Membrane	No significant difference
Fastness properties*	ISO 105	Upper fabric	No significant difference
Waterproof after weathering	ISO 4892-2 EN 12280-3	Membrane	Differences are solvable
Water vapour transmission resistance	ISO 11092 EN 31092	Membrane/ Overall structure	Differences are solvable

* Collective term for several tests

PTFE has the better inherent resistance to UV radiation, but other materials can also achieve good UV resistance through stabilisers. For waterproofness after pre-treatment by washing, there is basically no significant difference, unless the washing procedure is specified according to ISO 15797. Industrial washing at high temperatures stresses all membrane systems, but for PES the washing conditions are particularly tough because the specified detergent damages the material.

For waterproofness after pre-treatment with oil and fuel, there are initially no significant differences. In the long term, PES is more chemically damaged than PTFE. On the other hand, the pores of an ePTFE membrane can become clogged or impurities in the fuel can cling to the textile, noticeably reducing its hydrophobic properties. There are also no significant short-term differences in the waterproof after hydrolysis test. Delamination can occur under prolonged test conditions. As especially the adhesive is affected, laminates with PES membrane tend to fail earlier. Whether the durability is sufficient must be tested for the respective application.

In the case of water vapour transfer resistance according to the so-called skin model, microporous membranes usually achieve better results in the laboratory than compact membranes. Under operating conditions however, the results can differ greatly, as the environmental circumstances are different. It is therefore questionable how well the test method is suited to represent the required material property.

Table 4: Overview of critical PFAS-relevant requirements for protective clothing

Requirement	Standard	Applies to
Oil repellence	EN ISO 14419	DWR
Chemical repellence/resistance*	ISO 6530	DWR/Membrane
Waterproof after contact to seawater	following ISO 1817	Membrane
Cold bending resistance	DIN 53359	Membrane
Thermal resistance	EN 469 ISO 17493	Membrane/ overall structure
Limited flame spread	ISO 15025 EN 13274 EN 14325	Membrane/ overall structure
Tensile strength after exposure to heat	EN 469	Upper fabric
Waterproof after exposure to heat	ISO 17493	Membrane
Protection against heat and flames	ISO 11612	overall structure, since several tests

*i.e. for firefighting as medical textiles use different standards

6 Description of requirements and discussion of their necessity

The following section describes some of the requirements, especially those that have been identified as critical or appear to be confused frequently. This is intended to assist people without in-depth textile expertise to better understand the requirements, while at the same time discussing when the specifications are advisable or not. A concluding statement cannot always be produced, instead it is intended to provide impulses for further research. In addition, it should help to limit TRs to the essentials to reduce unnecessary logistical and financial effort that textile testing according to the standard entails. When asking for essentiality, two key questions arise. Firstly, whether the characteristic itself is necessary, and secondly, whether there are alternatives to PFAS if the characteristic is not dispensable.

6.1 Impermeability and related requirements

Membranes and DWR are mostly used to make a textile waterproof or otherwise protect it against liquids. Depending on the application scenario, this can be more demanding or less.

6.1.1 Water repellent and waterproof

Both terms are often used and repeatedly confused, or the difference is not clear. Water repellent means that the material is hydrophobic, instead of being absorbed by the textile, the water rolls off. This effect, achieved with DWR, can already be sufficient against splash water or light rain, but it does not make the textile waterproof. Waterproof means that no water penetrates the fabric even under pressure, for example in pouring rain or when sitting down or kneeling on wet ground. This can only be effectively achieved with a membrane if the material is to be breathable at the same time. The value of how much pressure a material can withstand before water gets through is given in Pascal [Pa] or as a water column [mH₂O or mWS].⁸² Testing is usually done after predefined pre-treatment such as washing or cleaning. In this way, use is simulated, and the durability of the textile is estimated.

⁸² (DIN Deutsches Institut für Normung e.V., 1992)

There are different types of membranes available. Microporous membranes, for example made of ePTFE, transport water vapour through pores that are large enough for vapour but too small for water droplets. To remain waterproof under pressure, ePTFE membranes are coated with a thin PU film. Compact membranes such as the PES membrane from Sympatex are completely closed and thus inherently waterproof. Water vapour is transported by chemical-physical mechanisms along hydrophilic molecular chains. The greater the difference in temperature and humidity between the inside and outside of the textile, the more efficient the membrane.⁸³

6.1.2 Waterproof after exposure to seawater

Seawater is corrosive, which is why material must be chosen very carefully if continuous contact with salt water is to be expected. Among common membrane systems, ePTFE possesses the best resistance to salt water, but it should not be overlooked that even here, damage occurs after a certain period. The resulting degradation products pose a risk to humans and nature, which is why it should be carefully weighed up whether a prolonged usage period of clothing truly outweighs the risk posed by PFAS. There are already seawater-resistant fibres available on the market that are not based on PFAS, so it can be assumed that for membranes it could also be possible to achieve better resistance.

6.1.3 Waterproof after bending below freezing point: cold bending test

Clothing is flexed a lot when worn, which can cause the layers in the laminate to separate, or the membrane may leak if the material breaks. Most polymers become brittle in cold conditions, although the temperature range, when this effect occurs, varies between materials. However, it often seems unclear when this test should be carried out.

If different tenders for protective clothing that is to be worn in winter or all year round are compared, there are some that require the test, while many others do not. Comparing tenders from the same authority over several years, there seem to be no problems in application if the test is not required, as it is still not specified in later tenders. An explanation for this is that the body radiates heat. The heat radiates outwards even when the clothing is insulated and prevents the fabric from cooling down to the outside temperature,

⁸³ (Sympatex, 2022)

as can be seen in thermal images taken in a cold chamber.⁸⁴ For most applications, it can be considered unnecessary to carry out the test. The protection standard for protective clothing against coldness (EN 342) also does not list cold bending resistance.⁸⁵

Another crucial aspect besides the material properties themselves is the human factor. There is a high probability for most garments that the wearer will feel cold before the material has been cooled down to critical temperatures. This is supported by internal tests on shoes, which were carried out in a cold chamber at -21 °C. At the time when the test was stopped because the temperature became unbearable for the participant, the outside temperature on the shoe was -6 °C. It can be assumed that most people try to get out of the coldness at an earlier stage if they have the opportunity to do so. For protective clothing against severe cold, for example for use in polar regions, testing needs to be done to see how cold the material gets there and whether it makes sense to have a corresponding material specification.

6.1.4 Oil Repellence

Oleophobic materials repel oil, preventing a textile from getting soiled easily. These materials are often hydrophilic, meaning they attract water and vice versa. Achieving water and oil repellence at the same time is challenging. At present, this can only be reliably achieved by using PFAS with alternative technologies under development. Until these can achieve the technical requirements, the use of PFAS should be avoided as much as possible.

Many tenders call for oil repellent properties, but for most it is questionable if this is a necessity, as very few areas come into much contact with oil and fuel. For fire brigades, for example, this is the case when oil or fuel has leaked during accidents and must be removed. For police officers, it is already less likely they will come into direct contact with it. An oil repellent DWR is likewise not necessary for many service providers like the postal service, parcel delivery services or railway personnel.

When it comes to high-visibility clothing for road construction and other areas, the argument can be made that soiling of the clothing reduces visibility and thus the protection afforded. However, the degree of soiling must be very high for this effect to lead to a significantly increased risk to the wearer, and it is questionable whether this occurs in such a short time that there is no possibility of washing or changing the clothing between uses. Here it would also be possible to ensure that the garments can be cleaned

⁸⁴ (Ahmad, Rashid and Khawaja, 2017)

⁸⁵ (DIN Deutsches Institut für Normung e.V., 2018)

easily, for example through self-cleaning finishing, if harmful substances can be avoided thereby.⁸⁶ It must also be taken into account that a textile equipped with PFAS is much more difficult to clean if it should become soiled.

In general, the question must be asked why oil repellent properties are required. It is also possible to check whether the oil repellence has to reach grade 4 or 5 in the test according to EN ISO 14419 or whether a lower grade, which could already be achieved with fluorine-free DWR, would be sufficient instead of the top grade. For protection against hazardous substances, an oil repellent DWR is certainly justified, so it must be weighed up which goal is to be achieved.

6.1.5 Chemical repellence and chemical resistance

Chemical repellent means that not only water but also liquids like acids, bases and other chemicals will roll off the garment, but does not indicate whether the textile will be damaged in the process. Depending on the application, the list of chemicals, the textile is supposed to protect against can vary. Chemical resistant means that the textile will not be damaged from contact with certain chemicals but does not reveal whether the chemicals will be absorbed or repelled. In general, the chemical repellence of fluorine-free DWR is worse than that of fluorocarbon-based ones.

6.1.6 Water Vapour Transmission Resistance: Breathability

The human body sweats, especially when active. If sweat builds up beneath clothing, the wearer quickly feels uncomfortable, and the body can overheat. Breathability describes a material property that allows water vapour to be transported away from the body to the outside. Basically, breathability and waterproofness are contradictory properties. If both qualities shall be achieved, specialised materials are needed. There are different test methods, one of them measuring the so-called RET value (Resistance to Evaporation Heat Transfer), which measures the resistance of a textile against the penetration of water vapour. This test according to ISO 11092 or EN 31092 is also called the skin model and a value as low as possible is desirable. Other tests measure the MVTR value (Moisture Vapor Transmission Rate),

⁸⁶ (Saad et al., 2016)

which describes how much vapour is transmitted through the material over a certain period. In this case, a high value is an indicator of good breathability.

Generally, the tests can only provide guide values, as under real-life conditions there are other influencing factors such as movement and the wind that are not reflected in the laboratory. For example, the breathability of the Sympatex membrane is significantly better at a higher temperature difference than under laboratory conditions. Microporous membranes typically deliver great results in the laboratory, but during use the pores can be blocked for example by detergent residues and therefore lose their permeability. Also, in clothing systems consisting of several layers, all layers must have good permeability to ensure breathability.

6.2 Thermal resistance

Many substances are not suitable for use under high temperatures, as they would melt or decompose. The point at which the temperature is too high varies between materials. If high operating temperatures are to be expected, it therefore makes sense to set specifications for the thermal resistance of the material. Depending on the scenario, different tests are available, some of which are presented below.

6.2.1 Limited flame spread

Materials with limited flame spread are also referred to as flame-retardant, fire-resistant, or low flammability. Many areas specify this requirement to ensure a textile does not burn easily when it encounters flames. For buildings, this prolongs the escaping time and for clothing, it ensures no additional hazard is caused by the fabric. This means, for example, that in the event of brief contact with a flame, no hole is burnt into the textile, and no molten material drips onto the skin causing burns that might not have been created by the flame itself at that moment. The use of flame-retardant textiles alone does not provide sufficient protection against heat and flames, but it is still adequate for many applications. The property is tested by exposing the material to a flame for a predetermined time. After removing the flame, the sample should not burn or at least extinguish quickly. Depending on the requirement level, no hole may be created, and no molten material may drop off.⁸⁷

⁸⁷ (DIN Deutsches Institut für Normung e.V., 2002)

6.2.2 Heat transfer radiation/flame

This test is particularly relevant for firefighting. It is measured on the entire layer structure and measures the time it takes for the side facing the body to heat up by a certain temperature difference when the garment is exposed to heat radiation or flames. There are two values, the first measures a temperature increase of 12 K. At this point the body feels the temperature change as painful, the second value is measured at 24 K temperature difference, at which limit second degree burns occur. A sufficiently long-time interval between the two values should ensure that the emergency personnel have enough time to move away from the heat source or flame before burns appear.⁸⁸

6.2.3 Heat resistance and contact heat

To test heat resistance, the material is heated in an oven and should not change its properties significantly. This test is useful when the materials are to be used under very high temperatures, such as firefighting.

The test for contact heat is required, for example, for firefighters' clothing for special firefighting. Here, the material is brought into direct contact with the temperature source instead of just being exposed to thermal radiation. According to the principles of thermodynamics, the transfer of energy by heat radiation is different from the direct contact of solids (heat conduction), which is the reason for the different test methods. However, the test via contact heat is only necessary if physical contact with hot objects is to be expected, for example during firefighting in buildings when confined spaces must be passed.

⁸⁸ (Deutsche Gesetzliche Unfallversicherung e.V. (DGUV), 2013)

7 Analysis of individual PPE sectors

Theory and practice do not always coincide. Standards and TRs try to predict what conditions are to be expected and ensure that the material can withstand the influences. When assessing whether a property is essential, these real-life conditions must also be taken into account, as there may be differences between various areas of application.

To improve readability, an attempt has been made to group different PPE sectors where the required properties are comparable. In some cases, this grouping can be achieved by means of protective standards. These are not limited to individual tests, but list various tests required for a particular type of clothing. Other areas, such as firefighting equipment, are highly specialised so that they are considered individually.

Table 5 gives an overview of the focused sectors and their specific properties. Requirements such as tensile and tear strength, abrasion resistance or fastness are assumed for all areas and are not listed. Some PPE divisions such as chemical protective clothing, medical textiles or protective clothing against extreme heat cannot be considered because of limited resources. For some areas, a subdivision must be made, as different gear is used in different operational scenarios.

Table 5: Overview of PPE areas and their specific requirements

application	Specific requirements		PFAS
	Non-critical	PFAS-critical	
Corporate Fashion			replaceable
Casual workwear			replaceable
High visibility EN 20471	Visibility		replaceable
Weather protection EN 343	Waterproof and windproof, water repellent, breathable, thermal insulation if required		replaceable
EN 342 protection against cold EN 14058 cool environments	Waterproof and windproof, breathable, thermal insulation		replaceable
Power supply (protective clothing)	Heat resistant, flame retardant, antistatic, protection against electric arcs,		replaceable
Rescue services (DRK, water rescue, air rescue, etc.)	Visibility, wind and waterproof, water repellent, breathable, insulation against cold	Flame retardant	replaceable
German Federal Agency for Technical Relief THW	Visibility, waterproof, water repellent, breathable, insulation against cold	flame retardant, heat resistant, chemical and oil repellent/resistant	More data needed
Fire brigade (HUPF, EN 469)	Visibility, waterproof, water-repellent, breathable, insulating against heat and cold, antistatic	flame retardant, heat resistant, chemical and oil repellent/resistant	Partially replaceable
Fire brigade, EN 1486 special fire fighting	Insulating against heat	flame retardant, resistant to high temperatures and contact heat	More data needed

7.1 Corporate Fashion and Casual Workwear

Corporate fashion refers to uniform workwear for employees of a company. This field is very diverse, but in principle it can be assumed that PFASs are non-essential or substitutable here. The same applies to casual workwear, which includes workwear for private users, craftsmen, and others. This can but does not have to be tested and certified according to the standards for PPE, in some cases it is only individual components.

Strictly speaking, corporate fashion and casual work wear do not belong to PPE, but are nevertheless mentioned for the sake of completeness, as they are often part of workwear. For example, the ensemble for employees of a company may consist of a combination of corporate fashion and PPE. An example of this is train personnel. The uniform worn inside serves representative purposes and does not have to fulfil a protective function in the sense of the PPE regulation, while an associated outdoor jacket can be a weather protection jacket according to EN 343 and counts as PPE.

7.2 EN ISO 20471 High visibility clothing

EN 343 Protective clothing - protection against rain

According to DGUV Information 212-016 High visibility clothing, EN ISO 20471 is primarily used for work in the area surrounding vehicles and rail traffic, except for

„Behörden und Organisationen mit Sicherheits- bzw. Rettungsaufgaben [...] insbesondere Polizei, Feuerwehr, Technisches Hilfswerk und Rettungsdienst.“⁸⁹

[Authorities and organisations with security or rescue tasks [...] in particular police, fire brigade, technical relief organisation and rescue service.]

Therefore, it concerns areas such as waste management, construction sites, surveying office, building yard, railway network technology, towing services, port facilities, airports, maintenance, whereby additional requirements may be imposed for individual areas. (For details see VI Appendix; excerpt from DGUV).

EN 343 applies to rainwear designed to protect the wearer against the wind and rain and, if necessary, cold. It is used for the areas just mentioned, but not exclusively, because both standards are often required in combination. In addition, EN 343 is also applied by the police,⁹⁰ customs, judiciary, mountain rescue, postal services, parcel services, railways, workwear for energy supply, forestry, water and shipping authorities and others that do not have to fulfil the criteria of EN 20471. Sympatex has been working successfully with some of the above-mentioned sectors for many years, and both standards can be met without any severe difficulties without using PFAS.

⁸⁹ (Deutsche Gesetzliche Unfallversicherung (DGUV), 2021: p. 7)

⁹⁰ Referring to standard tasks; special forces can require equipment with different characteristics.

7.3 EN 14058 Protective clothing for cool environments

EN 342 Protective clothing for protection against the cold

Cool environments are defined as „*mögliche Kombination aus Luftfeuchte und Wind bei Temperaturen von -5 °C und darüber*“⁹¹ [possible combination of humidity and wind at temperatures of -5 °C and above] and can be outdoors or indoors. EN 342 applies to temperatures below -5 °C, thus primarily for outdoor use. Again, the use of PFAS is basically unnecessary, as the requirements can be met with fluorine-free products.

7.4 Protection during work on electrical installations

This includes protective clothing for employees in power supply, railway network technology and the like, where work in the area of high electrical voltage is to be expected. The core element here is protection against electrical voltage and heat caused by electrical arcing. The use of PFAS can be dispensed with here.

7.5 Rescue services

The GUV-Rettungsdienst⁹² specifies criteria that protective clothing for rescue services should fulfil. These are mainly based on EN ISO 20471 and EN 343, with flame retardancy as a supplementary specification. For this the use of PFAS in both the membrane and the DWR can be dispensed with. Experience from the company with tenders in the rescue sector can be referred to here.

⁹¹ (DIN Deutsches Institut für Normung e.V., 2004: p. 4, par. 3.1)

⁹² (Deutsche Gesetzliche Unfallversicherung (DGUV), 2016)

7.6 German Federal Agency for Technical Relief (THW)

Based on the tenders Sympatex has received, the requirements that THW clothing must meet appear to be comparable to those of firefighters or armed personnel (see VI Appendix). However, some requirements, such as resistance to cold bending at -20 °C, seem unnecessarily high from a technical point of view. Without a more precise examination of which requirements are necessary, it is not possible to say whether PFASs are dispensable or not. Discussions between Sympatex employees and representatives of the THW during the tendering process did not provide any justification for the high requirements.

7.7 Fire brigade

Fire brigades use different equipment with sometimes very different characteristics depending on the operational scenario. The area must therefore be subdivided into subclasses and considered in detail. For most operations, turnout gear functions according to the criteria of the Manufacturing and Testing Specification for Firefighters (HUPF), which is mainly based on EN 469 Protective Clothing for Firefighters and supplemented where necessary. Some of the requirements, including oil and chemical repellence and high resistance to heat, cannot be satisfactorily met with fluorine-free products according to current knowledge and at the present time.

The International Association of Fire Fighters (IAFF) and the Metropolitan Fire Chiefs Association (Metro Chiefs) have issued a joint statement on codes of practice for firefighters to handle their equipment safely to minimise exposure to PFAS.⁹³ The organisations also call for and are working on developing PFAS-free equipment.

In a roundtable discussion between IAFF representatives and researchers, it is stated that fluorine-free solutions already exist for DWRs, but that ePTFE cannot be dispensed with for membranes at present. The background to the position paper is also discussed.⁹⁴ According to the statement, firefighters are exposed to significantly higher amounts of PFAS caused by firefighting foams and equipment and the associated long-term health effects. It is criticised that manufacturers of PPE repeatedly argue that the short-chain PFAS used are harmless. However, increasing numbers of studies show that the short-chain

⁹³ (The International Association of Fire Fighters (IAFF) and Metropolitan Fire Chiefs Association (Metro Chiefs), 2022)

⁹⁴ (McMillan et al., 2022)

variants also have negative effects on health, only with a different potency than the legacy substances. For example, little is known about the dermal absorption of PFAS, but there are indications that short-chain variants are more easily absorbed because of their smaller size. Also, too little is currently known about how much PFAS contaminated dust detected in the stations is absorbed.

8 Conclusion

Regarding textiles for private use, such as home textiles, apparel, outdoor clothing, there are enough PFAS-free products on the market and thus no need to continue using PFAS, especially since the applications are non-essential. For PPE, a differentiation must be made.

A central cornerstone for PPE is the so-called PPE Regulation, which defines basic requirements that all PPE must fulfil. An important section with regard to PFAS is the principle of innocuousness. This requires the

“Absence of inherent risks and other nuisance factors[.] PPE must be designed and manufactured so as not to create risks or other nuisance factors under foreseeable conditions of use. [...] The materials of which the PPE is made, including any of their possible decomposition products, must not adversely affect the health or safety of users.”⁹⁵

The use of PFAS contradicts this, as they pose an inherent health risk.

For some areas PFAS can already be substituted, in others they cannot or need to be examined in more detail. PFAS are not needed in areas where protective clothing according to EN ISO 20471, EN 343, EN 342, EN 14058 or with comparable requirements is used. Here, there are alternatives available that are already being used, provided they are permitted. Only in scenarios with very specific requirements, such as firefighters' clothing or for the military, can the use of PFAS be justified by the fact that the immediate protective effect outweighs the intrinsic risk.

The example of the fire brigade clearly shows that no permanent exemptions should be imposed. Instead, an extended transition period during which safer technologies can be developed is a reasonable solution. The apparent lack of alternatives is in some areas due to the requirements of tenders, in which the demands are unnecessarily high. In these cases, it would make sense to review the requirements and adjust them accordingly. This would also be in line with the goals of the European Green Deal.

⁹⁵ (European Parliament, Council of the European Union, 2016: Annex II, par. 1.2.1, 1.2.2)

Table 6: PPE areas where PFAS can be phased out

Domain	Essential Use	PFAS replacable
Apparel	Not essential	Replacable
Outdoor clothing	Not essential	Replacable
Home Textiles	Not essential	Replacable
Corporate Fashion	Not essential	Replacable
Casual Workwear	Not essential	Replacable
Waste Management	Essential	Replacable
Surveying Works	Essential	Replacable
Work on construction sites	Essential	Replacable
Maintenance of Sewerage Systems	Essential	Replacable
Bridge Maintenance	Essential	Replacable
Street Cleansing	Essential	Replacable
Greenery and woodland maintenance	Essential	Replacable
Winter Road Maintenance	Essential	Replacable
Work in the area of railway tracks	Essential	Replacable
Towing and recovery work	Essential	Replacable
Port facilities (e.g. loading activities)	Essential	Replacable
Airports	Essential	Replacable
Hydraulic engineering and management	Essential	Replacable
Warehouse logistics	Essential	Replacable
Energy supply services	Essential	Replacable
Lake and river navigation	Essential	Replacable
Postal services	Essential	Replacable
Parcel delivery services	Essential	Replacable
Mountain Rescue	Essential	Replacable
Emergency Services	Essential	Replacable
Water Rescue	Essential	Replacable
Air Rescue	Essential	Replacable
federal civil protection organisations	Essential	Presumably replacable, further data needed
law enforcement	Essential	Replacable
Customs	Essential	Replacable
Firefighting	Essential	Not replacable
Military clothing	Essential	Not part of research
Special forces	Essential	Not part of research
Ocean Shipping	Essential	Not part of research
Offshore Work	Essential	Not part of research
Chemical protective clothing	Essential	Not part of research
Heat protective clothing	Essential	Not part of research
Medical textiles	Essential	Not part of research

VI Annex

i. Overview over tenders used for research

Table 7: Tenders used for research by country and authority

Authority	State	Number
Police	Germany	6
	Belgium	2
	Netherlands	1
	Canada	1
	Poland	1
	Sweden	1
	Switzerland	1
	Norway	1
Railway	Austria	1
Power supply	Germany	1
Postal service	Italy	1
	Germany	1
	Austria	1
Rescue service	Germany	1
Road construction	Germany	1
THW	Germany	1
Water and Shipping Office	Germany	1
Surveyor's Office	Germany	1
Customs	Germany	2
		total: 26

ii. List of referenced Standards

- DIN 53359:2006** Testing of artificial leather and similar fabrics - Fatigue buckling test
- DIN 53896:1985** Testing of textiles; artificial ageing by elevated temperature in air or oxygen
- DIN EN 1149 Series** Protective clothing - Electrostatic properties
- DIN EN 12280-3:2002** Rubber- or plastic-coated fabrics - Accelerated ageing tests - Part 3: Environmental ageing; German version EN 12280-3:2002
- DIN EN 13274-4:2020** Respiratory protective devices - Methods of test - Part 4: Flame test; German version EN 13274-4:2020
- DIN EN 14058:2004** Protective clothing - Garments for protection against cool environments; German version EN 14058:2017
- DIN EN 14325:2004** Protective clothing against chemicals - Test methods and performance classification of chemical protective clothing materials, seams, joins and assemblages; German version EN 14325:2018
- DIN EN 14360:2004** Protective clothing against rain - Test method for ready made garments - Impact from above with high energy droplets; German version EN 14360:2004
- DIN EN 1486:2008** Protective clothing for fire-fighters - Test methods and requirements for reflective clothing for specialised fire-fighting; German version EN 1486:2007
- DIN EN 20811:1992** Textiles; Determination of resistance to water penetration; Hydrostatic pressure test
- DIN EN 24920:1992** Textile fabrics - Determination of resistance to surface wetting (spray test) (ISO 4920:2012); German version EN ISO 4920:2012
- DIN EN 26330:1994** Textiles - Non-commercial washing and drying methods for testing textiles
- DIN EN 31092:2013** Textiles - Physiological effects - Measurement of thermal and water vapour transmission resistance under steady-state conditions (sweating guarded-hotplate test)
- DIN EN 342:2017** Protective clothing - Ensembles and garments for protection against cold; German version EN 342:2017
- DIN EN 343:2019** Protective clothing - Protection against rain; German version EN 343:2019
- DIN EN 469:2020** Protective clothing for firefighters - Performance requirements for protective clothing for firefighting activities; German version EN 469:2020
- DIN EN 530:2010** Abrasion resistance of protective clothing material - Test methods; German version EN 530:2010

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- DIN EN ISO 105-B02:2014** Textiles - Tests for colour fastness - Part B02: Colour fastness to artificial light: Xenon arc fading lamp test (ISO 105-B02:2014); German version EN ISO 105-B02:2014
- DIN EN ISO 11092:2014** Textiles - Physiological effects - Measurement of thermal and water-vapour resistance under steady-state conditions (sweating guarded-hotplate test) (ISO 11092:2014); German version EN ISO 11092:2014
- DIN EN ISO 11612:2015** Protective clothing - Clothing to protect against heat and flame - Minimum performance requirements (ISO 11612:2015); German version EN ISO 11612:2015
- DIN EN ISO 12947-1:2007** Textiles - Determination of the abrasion resistance of fabrics by the Martindale method - Part 1: Martindale abrasion testing apparatus (ISO 12947-1:1998+Cor. 1:2002); German version EN ISO 12947-1:1998+AC:2006
- DIN EN ISO 1421:2017** Rubber- or plastics-coated fabrics - Determination of tensile strength and elongation at break (ISO 1421:2016); German version EN ISO 1421:2016
- DIN EN ISO 14419:2010** Textiles - Oil repellency - Hydrocarbon resistance test (ISO 14419:2010); German version EN ISO 14419:2010
- DIN EN ISO 15025:2017** Protective clothing - Protection against flame - Method of test for limited flame spread (ISO 15025:2016); German version EN ISO 15025:2016
- DIN EN ISO 15797:2018** Textiles - Industrial washing and finishing procedures for testing of workwear (ISO 15797:2017); German version EN ISO 15797:2018
- DIN EN ISO 20471:2013** High visibility clothing - Test methods and requirements (ISO 20471:2013, Corrected version 2013-06-01 + Amd 1:2016); German version EN ISO 20471:2013 + A1:2016
- DIN EN ISO 3175-2:2020** Textiles - Professional care, drycleaning and wetcleaning of fabrics and garments - Part 2: Procedure for testing performance when cleaning and finishing using tetrachloroethene (ISO 3175-2:2017, Corrected version 2019-12); German version EN ISO 3175-2:2018
- DIN EN ISO 4674-1:2017** Rubber- or plastics-coated fabrics - Determination of tear resistance - Part 1: Constant rate of tear methods (ISO 4674-1:2016); German version EN ISO 4674-1:2016
- DIN EN ISO 4892-2:2021** Plastics - Methods of exposure to laboratory light sources - Part 2: Xenon-arc lamps (ISO 4892-2:2013 + Amd 1:2021); German version EN ISO 4892-2:2013 + A1:2021
- DIN EN ISO 4920:2012** Textile fabrics - Determination of resistance to surface wetting (spray test) (ISO 4920:2012); German version EN ISO 4920:2012
- DIN EN ISO 6330:2022** Textiles - Domestic washing and drying procedures for textile testing (ISO 6330:2021); German version EN ISO 6330:2021
- DIN EN ISO 6530:2005** Protective clothing - Protection against liquid chemicals - Test method for resistance of materials to penetration by liquids (ISO 6530:2005); German version EN ISO 6530:2005
- DIN EN ISO 6942:2022** Protective clothing - Protection against heat and fire - Method of test: Evaluation of materials and material assemblies when exposed to a source of radiant heat (ISO 6942:2022); German version EN ISO 6942:2022
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DIN EN ISO 7854:1997 Rubber- or plastics-coated fabrics - Determination of resistance to damage by flexing (ISO 7854:1995); German version EN ISO 7854:1997

DIN EN ISO 811:2018 Textiles - Determination of resistance to water penetration - Hydrostatic pressure test (ISO 811:2018); German version EN ISO 811:2018

DIN EN ISO 9151:2017 Protective clothing against heat and flame - Determination of heat transmission on exposure to flame (ISO 9151:2016, Corrected version 2017-04-01); German version EN ISO 9151:2016

DIN EN ISO 9237:1995 Textiles - Determination of permeability of fabrics to air (ISO 9237:1995); German version EN ISO 9237:1995

DIN ISO 1817:2016 Rubber, vulcanized or thermoplastic - Determination of the effect of liquids (ISO 1817:2015)

EN 20105-B02:1993 Textiles. Colour fastness test. Light fastness with artificial light (xenon arc light).

IEC/CD 61482-2 Live working - Protective clothing against the thermal hazards of an electric arc - Part 2: Requirements

ISO 17493:2016 Clothing and equipment for protection against heat - Test method for convective heat resistance using a hot air circulating oven

iii. Table of specifications from tenders

Table 8: Specifications from tenders

Tender (part 1)	EN 343	EN 20471	Others	Water repellence	Oil repellence	Chemical repellence/ resistance	Waterproof	Pre-treatment washing	Pre-treatment cleaning	Pre-tr. abrasion	Pre-tr. Oil and fuel	Pre-tr. Bending	Other pre-treatments for testing waterproofness	Breathability	Windproof
Fire brigade according to HuPF	X	X	EN 469	EN 469: acc. ISO 4920	HuPF: AATCC 118-1989	EN 469: EN ISO 6530	EN 343: test EN 20811	5 wash cycles; >20 kPa	5x cleaning, >20 kPa	343: test acc. EN 530	343: test acc. ISO 1817	HuPF: acc. DIN 53359 -5 °C >20 kPa		343/469 -> ISO 11092	
Fire brigade according to EN 1486				EN 24920, Grade ≥ 4											
Rescue service according to DGVU-105 003	X	X					EN 343 >13 kPa (GUV)	343	343	343	343	343: EN 7854 >20 kPa		EN 343: test acc. EN ISO 11092	
Police 01 - high-visibility jacket	Only size measurements	X		EN 24920	EN ISO 14419		EN ISO 20811	5 wash cycles; >10 kPa, 2min EN ISO 6330			EN ISO 7854	Room temp. > 10 kPa		EN ISO 11092	
Police 02 - Rain jacket				ISO 4920	DWR (C-6); no test specified		EN ISO 20811 100 kPa	ISO 6330 20 wash cycles; >100kPa	ISO 3175-2 10x cleaning; >100 kPa			-10 °C x 40.000; >100 kPa DIN 53359	Based on Bw -TL 8305-0287, f), h): Weathering and hydrolysis: hydrolysis (own), weathering ISO 4892-2	EN ISO 11092	
Police 03 - winter jacket				ISO 4920			EN ISO 811 > 50 kPa	3 wash cycles						No test specified	ISO 9237 < 0,5 l/m2/s
Police 04 - softshell jacket				EN ISO 4920 Grade 5			EN ISO 811 > 50 kPa							EN ISO 11092, < 8	No test specified
Police 05 – Rain jacket				ISO 4920			ISO 811	5 wash cycles, 100 kPa, 2 min						ISO 11092	
THW - Task jacket				ISO 4920	EN ISO 14419	EN ISO 6530	EN ISO 811 100 kPa, 2 min	ISO 15797 20 wash cycles	ISO 3175-2 10x cleaning	EN 530 M2, 1000 cycles	EN 343	DIN 53359 -20 °C	Heat 1x and 5x to 180°C for 5min. ISO 17493, weathering EN 12280-3	ISO 11092	
Customs 01 - Weather jacket	Class 3/3			X	Oil + dirt EN 14419 No 4		EN 343 + EN 20811; 10 kPa	X	X	X	X	X	EN 343 + rain tower test after 20 washing cycles	343 therefore EN ISO 11092	ISO 9237 < 5 l/m2/s
Customs 02 - Anorak				ISO 4920	FC DWR; no testing required		EN ISO 811 60 kPa, 2 min	ISO 6330/3A 10 wash cycles	ISO 3175; 10x cleaning			DIN 53359 -10 °C	weathering ISO 4892; 50 kPa 2min	ISO 11092 < 6	No test specified
Railway - Parka: Outer jacket				EN 24920 X	C6, oil repellence, no testing req.		A: > 100 kPa -	10 wash cycles -		X -	X -			EN 31092 x	ISO 9237 < 0,5 l/m2/s

Continuation 1; Table 8: specifications from tenders

Tender (part 2)	UV resistance	Heat protection	Limited flame spread	heat transfer (flame)	Heat transfer (radiation)	Thermal resistance	Other thermal specifications	Protection against electricity	Antistatic	Protection against infection	Other specifications
Fire brigade according to HuPF		X	469: test ISO 15025; compare Index 3 ISO 14116	Test ISO 9151; HTI24 $\geq$ 13 HTI24-12 $\geq$ 4	Test ISO 6942; RHTI24 $\geq$ 18 RHTI24-12 $\geq$ 4	469: 180 °C, 5 min	Tear strength after heat radiation 469: 10 kW/m2; >450 N		EN 1149		
Fire brigade according to EN 1486		X	ISO 15025; No hole formation, no dripping, no afterburning <2s	EN 367; HTI24 > 21	ISO 6942; RHTI24 > 120 bei 40 kW/m2	ISO 17493, 255°C	Contact heat: EN 702, 300 °C for minimum 15 s				
Rescue service according to DGUV-105 003		X	EN 13274 V3 + 14325; no dripping, no continued burning								
Police 01 - high-visibility jacket											
Police 02 - Rain jacket	EN ISO 20105 B										
Police 03 - winter jacket											
Police 04 - softshell jacket											
Police 05 – Rain jacket											
THW - Task jacket	ISO 105 B02	X	ISO 15025; no holes, no dripping, afterburning <2s			ISO 17493, 185 °C, 5 min.	Protection against heat and flames (protective standard) ISO 11612		EN 1149		Seawater fastness EN ISO 105 E02 solvent fastness
Customs 01 - Weather jacket											Seawater fastness
Customs 02 - Anorak	Cf. waterproof										
Railway - Parka: Outer jacket											

Continuation 2; Table 8: specifications from tenders

Tender (part 1)	EN 343	EN 20471	Others	Water repellence	Oil repellence	Chemical repellence/ resistance	Waterproof	Pre-treatment washing	Pre-treatment cleaning	Pre-tr. abrasion	Pre-tr. Oil and fuel	Pre-tr. Bending	Other pre-treatments for testing waterproofness	Breathability	Windproof
Mail service 01 Anorak				EN 24920	Oil + dirt, no test specified		EN 20811 > 20 kPa	EN 26330; 5 wash cycles	ISO 3175; 2x cleaning	EN 530			Hydrolysis ageing DIN 53896 + sprinkling test on finished garment	EN 31092	
Mail service 02 Parka				EN 24920 / ISO 4920	EN ISO 14419		EN 20811/ ISO 811 >100 kPa	ISO 6330/6N; 50 wash cycles	EN ISO 3175-2; 5x cleaning					EN 31092/ ISO 11092	
Mail service 03				EN 24920			EN 20811, 100 kPa 2min	20 wash cycles; 26330, test 20811	ISO 3175 10x dry cleaning 20 kPa	EN 530 15 kPa		EN 343; 15 kPa		ISO 11092 < 6	
Mail service 04				EN 24920			EN 20811 50 kPa	ISO 6330; 5 wash cycles 40 kPa						EN 31092	
Energy supply - protective clothing				EN 24920, Grade ≥ 4 after washing	EN ISO 14419 Grade ≥ 4 after 3x washing		Not specified								
Energy supply – standard clothing				X	X		EN 343 KI 1	X	X	X	X	X		X	< 5l/m2/s
Surveyor's office	class 3	class 3					343, KI 3/3 at 100 kPa							ISO 11092 < 8	
Road construction	class 3	class 3													
Nature conservation - Softshell jacket				X										X	X
Warning clothing general (GUV warning clothing)	X	X	Others if needed												
Military				EN 29865	EN ISO 14419	DIN 1310, ISO 80000-9 (9-12)	> 1500 kPa 15 bar WIWeb	10 wash cycles	EN ISO 105-D01	X	DIN ISO 1817	DIN 53359 -10 °C	Hydrolysis, weathering ISO 4892-2, seawater treatment according to ISO 1817	EN 31092	
Ballistic protective clothing (TR Polizei)				?	X		X		X		X		Ballistic protection waterproof packed; resistant to sweat, oil and fuel, dry cleaning, min 10 years shelf life		
Medicine - protective clothing against infectious agents			EN 14126			EN 14325 if required									
Medicine - OP coats and drapes			EN 13795-1	?			ISO 811								
Chemical protective clothing			EN 14325, EN 943, EN 13034, EN 14605			X						X			

Continuation 3; Table 8: specifications from tenders

Tender (part 2)	UV resistance	Heat protection	Limited flame spread	heat transfer (flame)	Heat transfer (radiation)	Thermal resistance	Other thermal specifications	Protection against electricity	Antistatic	Protection against infection	Other specifications
Mail service 01 Anorak											
Mail service 02 Parka											
Mail service 03											
Mail service 04											
Energy supply - protective clothing	Tensile test ISO 4674 Weathering: ISO 105 - B02	EN 531	X			X		electric arc: IEC/CD 61482-2	EN 1149-5 + EN 11495-3 or -1		
Energy supply – standard clothing		X	X					x	X		
Surveyor's office											Explicitly PU or PTFE requested
Road construction											
Nature conservation - Softshell jacket											
Warning clothing general (GUV warning clothing)											
Military	Cf. waterproof										Seawater resistance, solvent resistance,
Ballistic protective clothing (TR Polizei)	X	X	X			Up to 80 °C					
Medicine - protective clothing against infectious agents										EN 14126	
Medicine - OP coats and drapes										X	
Chemical protective clothing		X	X								

iv. Excerpt from DGUV Information 212-016 Warnkleidung, p.6 f.⁹⁶

Hazards to persons from road and rail vehicle traffic can occur in companies where, for example, the following activities are carried out:

- Work outside barriers or adjacent to the traffic area, such work includes, but is not limited to.
 - waste collection
 - Surveying work
 - Securing work and construction sites in road areas
 - Maintenance of sewage systems
 - Bridge maintenance
- Road operation and maintenance, e.g.:
 - Road cleaning
 - Greenery and woodland maintenance
 - Winter maintenance
- Activities of operational service staff and non-operational staff in track areas, e.g. railways, tramways, underground railways and material railways,
- Work in the track area during the construction, maintenance, alteration and removal of railway and other installations or work connected therewith,
- repair, towing and recovery work on vehicles on public roads in the danger zone of moving traffic,
- repair work on vehicles on company premises in the danger zone of moving traffic,
- work in container terminals in the area of traffic of vehicles, industrial trucks and lifting equipment,
- Port work, e.g. on ships and in the area of packing halls,
- work in designated areas of the airport,
- marshalling of vehicles,
- Hydraulic engineering and water management work.

The application of this DGUV Information is also recommended for work where an unintentional entry into the danger zone of flowing traffic or into the track area or internal plant traffic cannot be ruled out. This DGUV Information does not deal with special warning clothing that is used, for example, by authorities and organisations with safety or rescue tasks. This includes in particular the police, fire brigade, technical relief organisation and rescue service. Information on this can be found, for example, in DGUV Regulation 105-003 "Use of personal protective equipment in rescue services" and in DGUV Information 205-014 "Selection of personal protective equipment for fire brigade operations - Based on a risk assessment".

⁹⁶ Document only available in German, therefore I translated the paragraph myself [authors note]

v. Sympatex position paper for submission to ECHA:

Sympatex supports an ambitious PFAS restriction under REACH Regulation **January 2023**

Sympatex welcomes the initiative of five EU Member States to restrict per- and polyfluorinated alkyl substances (PFAS) under REACH Regulation and urges the European authorities to adopt an ambitious restriction of PFAS in textile products.

Mounting evidence is showing that PFAS have irreversible effects on humans and the environment. The widespread use of PFAS has led to global contamination of water, air, soils, wildlife, and human populations. Human exposure has been linked with serious health effects, including diabetes, infertility, and cancer^[1,2,3].

Sympatex is very concerned by the fact that outdoor clothing contributes to the PFAS pollution. Functional garments can typically be made of two different PFAS-containing components. The core membrane is made of PTFE, while the outer surface is treated with sidechain fluorinated polymers - a so-called Durable Water Repellent (DWR) finishing. Whereas PFAS release from DWR-surfaces can happen during product's use phase, release from PTFE-containing membranes takes place during production and landfilling. As reported by the European Environment Agency (EEA) in 2021, collecting, incinerating, or recycling PTFE-containing products presents significant technical challenges. EEA states that using PTFE might hamper circular potential and is not line with the toxic-free ambitions of the EU Commission^[4].

Given the alarming hazards, **Sympatex urges the European authorities to adopt an ambitious restriction of any kind of PFAS in textile products, with as few exemptions as possible, and a short transition period.** We would like to emphasize that PTFE-free membranes already exist on the market which retain an excellent level of functional performance. Consequently, the phase out of PTFE applications can happen within a period of 1-2 seasons (1-2 years). Regarding exemptions, we would like to point out that according to a judgement of the European Court of Justice from February 2021, alternatives do not require the identical performance level (threshold of zero), but the one necessary for the application^[5]. The exemptions based on insufficient studies must be critically reviewed. We are currently leading an in-house study on PFAS alternatives for professional equipment (PPE) whose results we will deliver to ECHA and all other interested stakeholders by the end of Q1 2023. In this study Sympatex is analysing numerous European tenders and their required standards. The study will provide a detailed overview of the applications for which PFAS alternatives are readily available, for which they should be further tested, or which are currently excluded.

Sympatex regrets that the upcoming PFAS restriction will be considered without a systemic application of the essential use concept. The urgent need to ban the non-essential uses of PFAS has been expressed, for several years, by the scientific community^[6], the European Parliament^[7], and the EU Council^[8]. Although the formal implementation of the essential use concept in REACH is impossible now due to independent timelines of the PFAS restriction and the REACH revision, Sympatex calls for a consideration of essentiality in another way. ECHA and the EU Commission should consider essentiality as a principal factor guiding the exemptions in the PFAS restriction. The SEAC Committee has already used essentiality as an additional factor, for example, in its discussions on the proportionality and the need for derogations for specific uses in the microplastics restriction^[9].

Kind regards,

Dr. Rüdiger Fox,
CEO Sympatex Technologies GmbH

sympatex®

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VIII Statutory declaration

I hereby declare that I have written this thesis independently and without the use of any auxiliary materials other than those indicated; any ideas taken directly or indirectly from outside sources are identified as such.

To the best of my knowledge, this thesis has not been submitted to any other examination authority in the same or a similar form and has not yet been published.

Hof, 17th February 2023

E. Finger