THE USE OF PTFE IN THE CLOTHING AND FOOTWEAR INDUSTRY IS HARMFUL TO THE ENVIRONMENT AND HEALTH - AND THANKS TO EXISTING ALTERNATIVES, NOT ESSENTIAL

A scientific opinion on the European Green Deal target "Transforming the EU's economy for a sustainable future: A zero pollution ambition for a toxic-free environment",

with a focus on the PFAS group of substances under the EU Chemical Strategy for Sustainability, the EU Sustainable Product Initiative as well as the climate goals of the Paris Agreement.

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EXECUTIVE SUMMARY

The importance of a functioning health, climate and environmental policy is currently being emphasised worldwide. The protection of people and the biosphere is becoming an increasingly important political priority. In the course of this, products and production processes harmful to health and the environment are also being brought more into focus and re-evaluated in legislation.

This report deals with the use of polytetrafluoroethylene (PTFE) membranes in the clothing and footwear industry, their harmful effects on health and the environment, as well as proven alternatives that have been in use for many years.

The garment and footwear industry has a great responsibility due to its very high environmental impact. Adapting textile production processes for around 100 billion garments produced each year is an immense lever for better health protection and environmental sustainability through optimised circular economy, reduced CO_2 emissions and pollutant reduction in the environment.

The production, use and waste disposal of PTFE membranes are under urgent suspicion of causing massive health damage such as cancer, miscarriages, malformations in newborns, reduced vaccination effectiveness and weakened immune systems. The substitutes now used for PTFE production (GenX, etc.) also have harmful effects: they are classified as substances of very high concern in the European Union.

Rivers and bodies of water near PTFE production sites are often heavily contaminated resulting in some cases blatantly increased cancer rates in the immediate vicinity. Proximity with production sites is not the only source. Due to the volatility of the substances, enriched amounts of fluorochemicals have already been detected in human blood even in distant regions.

The persistence of PTFE is a necessary criterion for other areas of application, such as cable sheathing or medical implants. For textile products, however, thanks to adequate alternatives, it represents an avoidable health hazard for the user and an unnecessary disposal problem. PTFE membranes, due to their unfavourable disposability in the textile sector, prevent the more environmentally friendly recycling and thus all efforts towards a circular economy.

Moreover, the CO_2 emissions from the production of PTFE membranes are more than 30 times higher than available alternatives. HFC-23 measurements in the atmosphere clearly show that the globally increasing PTFE production contributes comparatively strongly to climate change.

PTFE membranes can be made neither safe nor sustainable.

On the other hand, environmentally friendly polyester (PES) membranes, harmless to health, allow high-quality recycling and greatly reduced greenhouse gas emissions with the same technical performance. At the same time, PTFE alternatives will support the EU Chemicals Strategy for Sustainability and the upcoming EU Sustainable Product Initiative, aiming at accelerating closing the loop, reducing waste and chemicals impacts. They will also reduce environmental risks within the supply chain to be identified under future due diligence legislation.

PES membranes are both healthier and environmentally safer alternatives, as well as technically equivalent to PTFE membranes. Therefore this study urgently calls for legal restrictions on PTFE membranes for all non-essential applications in the textile, clothing and footwear industry.

CONTENT

1 BACKGROUND

> ***"Whenever possible, avoid products containing, or manufactured using, PFASs (in government procurement). These include many products that are stain-resistant, waterproof, or non-stick. "***
>
> *Extract from the Madrid Statement on PFASs, addressed to authorities, buyers, retailers and individual consumers etc., 2015* [1]

At the international PFAS (per- and polyfluoroalkyl substances) Conference 2020, numerous scientists gave presentations on legislation, future PFAS restriction procedures and diverse cases of contamination by per- and polyfluorinated chemicals, their effects and measures. The worldwide contamination of soils, groundwater and drinking water, and thus food, as well as the consequences for humans and animals where highlighted. [2] Many of the PFAS substances released into the environment since the 1960s are already classified as PBT substances. [3] They accumulate in the human body, sometimes causing cancer and malformations in newborns. Research is currently being conducted into the extent to which the immune system is influenced by PFAS and the effect of vaccines is reduced.

Among the many PFAS chemicals mentioned during the conference, the chemicals PFOS and PFOA, which are now banned in the EU, as well as their substitutes such as GenX, which have so far only been classified as SVHC, appear significantly. In numerous tests, such as in the USA, the Netherlands and Italy, the PFOA levels found in the blood, for example, massively exceeded the legally defined limits. The damage to health is immense. After large-scale tests with about 69,000 people in West Virginia, USA, 3,500 cases of illness and/or death resulting from these tests have already been recognised and convicted in court, and further proceedings are underway. [4]

A 2016 report reveals four of the biggest PFCA pollution hotspots in the world, all around PTFE manufacturers. [5] PFCAs (perfluorocarboxylic acids), including PFOA and their substitutes, sometimes serve as emulsifiers in PTFE production. The PTFE polymer, which is stable in itself, can still contain PFOA impurities as well as decompose to PFCAs, including PFOA, during combustion. [6, p. 37] These findings are particularly relevant to the textile industry as one of the largest users of PFASs, with predominant disposal routes and emissions to the environment being wastewater, incineration and landfill. [6, p. 125]

Due to the focus on fluorocarbon finishes of textiles, as in the latest large-scale EU study on PFAS, [6] fluorocarbon membranes are hardly looked at and their alternatives were not mentioned at all. As a result, the majority of the textile public procurement, apparel and footwear sectors are still unaware of the comprehensively devastating impacts of the unnecessary use of fluorine-based membranes.

In its analysis of the most relevant environmental risks of the textile industry, the Boston Consulting Group identified the issues of chemical use, water, CO_2 emissions and waste. [7] In contrast to technically equivalent membrane material alternatives tried and tested for years, such as polyester-based membranes, PTFE membranes massively counteract each of these environmental issues:

a) Water: In addition to the water and soil near PTFE production sites, which have been contaminated for decades, traces of PFOA can now be found worldwide, even in the most remote places in the world. [8, p. 15]

b) Chemicals: Detectable amounts are already found in the blood of humans, even foetuses, and contaminate the body. [8, p. 14]

c) Recycling: PTFE membranes, in contrast to technically equivalent alternatives in the laminate structures relevant to the textile industry, cannot yet be recycled in an ecologically and economically sensible way. As a result, they (and all materials permanently bonded to them, e.g. by lamination) represent barriers to the EU [9] and its Member States' future objectives regarding recycling, recycled content, recyclability for the textile and footwear industry. They also represent high hazards in recycling streams not controlled by high level environmental standards, or through individual burning of garments and shoes in the open air. Therefore the contact of innocent third parties with highly toxic hydrofluoric acid cannot be excluded. [10]

d) CO_2 emissions: The CO_2 emissions of PTFE membranes are more than 30 times higher compared to those of other alternatives available in the textile industry. [11], [12] The textile industry is already responsible for more than 8% of the world's greenhouse gas emissions, [13] a reduction to achieve the Science Based Targets and thus the goals of the Paris Climate Agreement is essential.

Back in 2015, 230 scientists from 40 different countries signed the Madrid Statement on Poly- and Perfluorinated Substances. They called on the international community to work together to limit the production and use of PFASs and to develop safer non-fluorinated alternatives. [1]

At the 2020 International PFAS Online Conference, renowned chemist Prof. Arlene Blum, who helped draft the statement, identified six classes of hazardous substances, of which she believes PFAS is by far the most serious. With a view to the use of PFAS and the introduction of "green chemistry", she also described the three most relevant issues from her point of view:

1. Is the use necessary?
2. Is it worth it?
3. Is there a safer alternative? [14]

The following report is dedicated to the consideration of the four most relevant environmental issues of the textile industry mentioned above, taking into account the above three questions of necessity, impact and alternatives. It summarises the evidence on environmental pollution and health hazards associated with PTFE production and use that has been known since the 1970s and gained worldwide in recent years. Moreover it uses best practice examples to show that the use of PTFE membranes in the textile industry is long overdue.

2 FLUOROCHEMISTRY USE IN THE TEXTILE INDUSTRY

> ***"Reducing the use of PFASs is more important than climbing the world's highest mountains."***
>
> *Prof. Arlene Blum, leader of the first women's expedition to Annapurna (1977) and Executive Director of Green Science Policy Institute Berkley/ California, USA* [14]

The group of PFAS comprises about 4700 different substances, [15] many of which fall under the so-called PBT substances and are thus persistent, bioaccumulative and toxic. [8]

Their use in the clothing and footwear industry is of two kinds:

(a) the outer fabrics are in most cases water-repellent impregnated from the outside by means of a DWR (Durable Water Repellent) finish, as well as
(b) the material is protected against the penetration of water to the body by a waterproof intermediate layer (membrane or coating).

In the past years of environmental debate, the focus of the textile industry on the topic of PFAS has mostly been on legislation and the effects of DWR finishes containing fluorocarbons. Therefore, the following section is specifically dedicated to the interlayer containing fluorcarbon - the PTFE membrane.

2.1 PTFE membranes

While DWR finishes impregnate the fibres of the outer fabric, membranes serve as a waterproof barrier between the textile layers.

On 11 May 2020, ECHA launched a consultation on a restriction procedure covering a wide range of PFAS uses. This covers all PFASs and possible alternatives in textiles, upholstery, leather, clothing and carpets. [16], [17] It also includes PTFE membranes. The Netherlands and Germany, with the support of Norway, Denmark and Sweden, are planning to prepare a corresponding restriction dossier. [18]

The restriction proposal will be prepared by the national authority over the next two years. The ECHA Scientific Committees will give their opinion after the submission of the restriction dossier. The entry into force of this restriction is expected in 2025. [18]

The background is as follows: until the end of the 1990s, PTFE membranes were mostly manufactured with the process chemical PFOA. PFOA salts mainly serve as emulsifiers in the synthesis of the fluoropolymer PTFE. Due to the discussions about the eco- and human-toxicological properties of PFOA, the fluorochemical industry replaced PFOA with alternative perfluorocarboxylic acids (PFCAs), such as GenX or Adona. However, in the course of recent investigations, the substitute chemical GenX has been classified by ECHA as a SVHC substance (Substance of Very High Concern) [17] and the chemical Adona [...] has been assessed as undesirable substitutes, as they are most likely to be similar to chemicals such as GenX and other PFCAs in terms of persistence, mobility and possibly toxicity. [19]

In Europe and the USA, PFOA environmental concentrations are already slowly decreasing due to various measures. This is due to a 2006 agreement between the fluorochemical industry and the US Environmental Protection Agency (EPA), in which eight companies voluntarily committed to reduce PFOA by 95% by 2010 (compared to 2000) and to eliminate it completely by 2015. However, many companies, for example in the emerging Asian market, do not participate in the stewardship programme. This means that PFOA and its precursors enter the EU market through imported products [20] - and their volatile collateral damage via the diversions of waters and atmosphere. A 2016 Greenpeace report confirmed this, noting that "global production of PFOA for the manufacture of PTFE (Teflon) is shifting to China, where the same pattern of pollution is now being repeated." [5] In 2020, more than 75% of global PTFE production did not take place in the EU, but 41.5% in China, 15.5% in the US and 8.5% in Russia, for example. [21] Although the newly elected American President Biden has declared the issue of PFAS substances to be a priority, PFAS are not yet listed as harmful substances in the USA. [14] That means PFOA, GenX and other PFCAs are so far only listed as harmful substances or undesirable substitutes in the EU. But what exactly makes them so dangerous?

Effects of PFOA

PFOA is difficult to degrade, accumulates in the organism and is toxic. For this reason, PFOA is listed in the POP Regulation (Persistent Organic Pollutants) Annex 1 and is limited to 0.025 mg/kg in substances, mixtures or articles. [22] PFOA can enter the environment during production and use. In addition, there is evidence that PFOA can be formed in the environment during the degradation of fluorotelomers. It is highly persistent in all environmental media and is transported over long distances. PFOA has a high bioaccumulation potential. In animal studies it is carcinogenic, toxic and endocrine disrupting. PFOA is toxic to aquatic organisms and may cause long-term adverse effects in aquatic environments. [23]

Effects of PFOA substitutes

GenX, Adona and similar substances with comparable technical properties as PFOA substitutes are equally persistent, very mobile, have the potential for long-distance transport and the bioavailability for drinking water ingestion. They also have a very high potential for irreversible effects. [17] This assessment has recently been taken into account by the official classification of the chemical GenX (HFPO-DA and its salts and acyl halides) as SVHC. The ECHA agreed that the substances identified in the proposal as HFPO-DA are of equivalent concern in terms of carcinogens, mutagens and substances toxic to reproduction (CMRs), persistent, bioaccumulative and toxic substances (PBTs) and very persistent and very bioaccumulative substances (vPvBs). [24]

This means that although PTFE membranes are not made from PFCAs (e.g. PFOA, GenX, ADONA) or their precursors, variants of various PFCAs are used as process chemicals in their manufacture and the final product may contain residues of these substances.

There is no manufacturing process or application of PTFE membranes that is not harmful to health and the environment. However, there are alternative safe membrane materials.

2.2 BEST PRACTICE: Fluorocarbon-free membranes

Through years of education and legislation, fluorocarbon-free finishes have gained significant market share and increasingly displaced DWRs containing fluorocarbons from some applications. In contrast, knowledge about the manufacturing processes of PTFE membranes and their impact on the environment and health has not yet brought to consumers' minds.

Yet there are various alternative materials to PTFE that have been available on the market for a long time and achieve comparable performance characteristics. In view of the superior recyclability, i.e. necessary grade purity and the fibres mainly used in the textile industry, the following comparison is made with a hydrophilic PES membrane.[1]

Hydrophilic PES membranes are usually produced via extrusion processes from the corresponding polymer melt. The associated polyester-based copolymers, in turn, can be produced using processes that have been established in the plastics industry for many decades. Usually, the different building blocks of the polymer are linked together in a melt polycondensation and the desired molecular weight is then adjusted via a solid phase condensation.

Both the membranes and the polymers are usually produced without the use of solvents, so that their more or less complex separation and recovery is usually not necessary for hydrophilic polyester-based membrane systems.

[1] Besides PTFE and PES membranes, membranes and coatings made of polyurethane (PU) are used in the textile industry.

3 FLUOROCHEMISTRY IN WATER AND ENVIRONMENT

"People need to know that this stuff is now everywhere. In the environment, in drinking water and even in the blood of almost every living creature on this planet."

Robert Bilott, environmental lawyer, lead plaintiff against DuPont interviewed for the film 'Dark Waters', 2019 [25]

Whether '*The Devil We Know*' or '*Dark Waters*' – both movies have in common the exposure of the environmental and health damage caused by PTFE production.

PTFE production pollutes the local environment, including surface water, drinking water, groundwater, as well as air and dust. There is large evidence of pollution in places around the world where chemical companies produce PTFE, including those that still use PFOA or PFOA substitutes such as GenX. [5] Some examples will be discussed below, listing the concentrations in the water and blood of the surrounding population. But these dangerous substances do not only enter the human body through drinking water, and thus food. They can also be absorbed directly from the skin or inhaled through dusts. [26] Previous measuring methods also suggest that currently only the tip of the iceberg is discernible [27] and that the demand of politics and science for an overall consideration of the PFAS substance group is more than justified. [28] In the course of the current restriction proceedings, costs for environmental remediation and compensation payments amounting to millions are also in the offing.

3.1 Environmental and health impacts of PTFE production

A 2016 report listed four PFAS hotspots, which are summarised below. In three of the regions, PFASs are used significantly for PTFE production.

DuPont (Chemours)/ West Virginia:
The world's most famous case of PFAS contamination is near the DuPont plant in Ohio, West Virginia, USA and is the subject of the movie *Dark Waters*. Since the 1950s and until the end of production in 2015, the chemical PFOA used for PTFE production found its way into people's drinking water. As early as the 1980s, PFOA was detected in public drinking water in the vicinity of the plant, although DuPont was already aware of the harmful effects on health at that time. Very high PFOA levels of up to 22.1 µg/l were found in private drinking water. Even though production was reduced by 99% in 2013, measurements in drinking water in the surrounding area still showed a value of 0.0631 µg/l. The PFOA concentrations in the blood of the population were listed as an explanation. [5, p. 4]

In the course of this, the blood of 69,000 residents who had lived in the district for at least over a year was tested for their PFOA concentrations. Very high PFOA concentrations were found in the blood - a median of 28.2 ng/ml, with a mean value of 83.0 ng/ml - compared to a median of 3.9 ng/ml in the general population. According to two studies, exposure to PFOA was associated with both kidney and testicular cancer. Associations with prostate and ovarian cancer and non-Hodgkin's lymphoma are also suspected. [5, p. 4]

Chemours/ Dordrecht:
Further investigations took place at one of the largest PFAS production facilities in Europe, in Dordrecht, NL. The plant, which opened in 1960, was spun off from DuPont in 2015 under the new company name Chemours. Until 2012, PFOA was used for the production of Teflon, after which the chemical GenX was used as a substitute. State tests of the drinking water in 2015 did not reveal any elevated PFOA concentrations (note in relation to the limits applicable at the time). According to the preparation of various emission scenarios, "in the worst case, the limit value was exceeded for 25 years. At such levels of chronic PFOA exposure, health effects, for example on the liver, cannot be ruled out". [5, p. 5]

PFOA blood tests of a DuPont employee published in April 2015 showed 28.3 ng/ml PFOA in the blood, and in his wife, who was also tested, even three times as high values were found, 83.6 ng/ml. Further measurements of PFOA concentrations in the residents' blood were not carried out. However, after residents indicated interest in further blood testing, selected participants received an invitation for blood tests at the end of August 2016, which took place in September and October 2016. [5, p. 5] The clearest evidence was found for an association between exposure to PFOA and higher blood concentrations of total cholesterol, higher blood concentrations of the liver enzyme ALT and lower birth weight. There is less clear evidence for an association with higher blood concentrations of other liver enzymes, LDL cholesterol and uric acid. Evidence was also found for an increased risk of chronic intestinal inflammation (ulcerative colitis), testicular and kidney cancer, as well as pregnancy-related hypertension and pre-eclampsia. In addition, associations were found between exposure to PFOA and reduced vaccination response, changes in concentrations of thyroid hormones in the blood and thyroid disease. [29] Another report from 2020 compared cancer rates of Chemours plant residents with the rest of the Netherlands, finding them 15.7% higher than in the rest of the country. [28]

Leather industry/ Veneto:
The PTFE hotspot in the Veneto region of Italy had even higher PFAS levels in surface and drinking water, with an estimated 350,000 to 400,000 people potentially directly exposed. Up to 1,886 ng/l PFOA were found in drinking water alone. The source of 97% of this PFAS contamination was identified in 2013 as a wastewater treatment plant into which mainly tanneries discharge. Despite the cessation of PFOA production in 2011, the levels in 2016 were still 140 times higher than in the non-contaminated environment. After testing 600 people, concentrations of up to 754 ng/g (median 74.21 ng/g) were found in blood serum, which is up to 20 times higher than the rest of the population. [5, p. 6]

Dongyuchem/ China:
The final hotspot of the report was the waters around the Dongyuchem chemical plant in China's Shandong province. As one of China's largest PTFE producers (37,000 tpa), it serves customers such as DuPont. Total concentrations of up to 1,860,000 ng/l were measured in the river into which the chemical plant's wastewater is discharged (one of the highest concentrations ever reported - with PFOA dominating) and which flows into the Yellow Sea between China and Korea. To meet domestic and international demand for PFOA, production continues to increase. [5, p. 7] Blood tests of people from the immediate vicinity have not been carried out.

3.2 Health effects of textile products containing fluorocarbons

In addition to the ingestion of PFOA or its substitutes through drinking water, transmission also occurs through dermal absorption and inhalation of dusts. The consequences for health are catastrophic. In the last 30 years, cancer has replaced heart disease as the main cause of death in the fire service. Cancer caused 70% of deaths among professional firefighters in 2016. [30] There are proven links between PFOA and testicular cancer, mesothelioma, non-Hodgkin's lymphoma and prostate cancer. These are four of the eight most common cancers that firefighters are more likely to develop than the general population. In addition, the demonstrated immunotoxicity of PFAS in the body suggests that populations with elevated levels of PFAS in their blood sera are susceptible to a wide range of diseases and cancers. [26]

While firefighting foams are primarily the reason for the high death and illness rates, firefighting clothing is also suspected of being harmful to health.

The first examination of firefighters' protective clothing using PIGE[2] revealed very high total fluorine levels in firefighters' protective clothing - both in the outer material and in the membrane.

The materials tested consisted of outer materials finished with fluorocarbon-containing DWR, PTFE membranes as moisture barriers and fluorine-free thermoliners around the membrane.

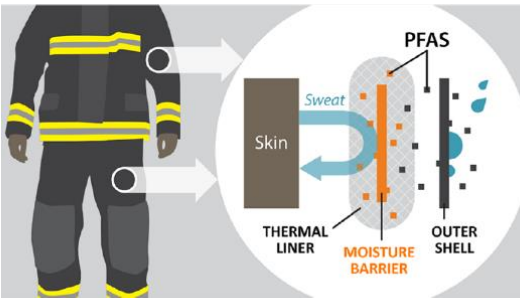


Figure 1: Over time, PFASs in a firefighter's gear can migrate from the moisture barrier (orange) into the thermal liner that comes into contact with the skin. PFASs can also be released from the outer shell (black) into the environment." [33]

PFAS migration to the layers worn on the skin

In the first step, it was found that significant amounts of fluorochemicals are excreted from firefighters' clothing during its service life. The thermal liners in this study were not treated with PFAS according to the manufacturers, yet significant amounts of fluorine were found in all sewn-in thermal liners of firefighters' clothing. The average total fluorine content found in eleven new material samples before they were processed into thermoliners was below the detection limit. This consistent observation of fluorine in the untreated layers is the first evidence that PFASs appear to migrate from the highly fluorinated layers and accumulate in the untreated layer - the clothing worn on the skin. [26]

PFOA substitutes also migrate from the PTFE membrane

Through further analytical procedures, additional evidence was found that the PFAS concentrations in the thermoliner also originate from the PTFE membrane. The majority of PFASs identified during extraction from textiles belong to the short and long chain fluoroalkyl acids, including PFOA. In addition, a PTFE membrane was examined that was produced using a PFOA substitute. This was the only sample examined that had no detectable PFOA, presumably due to the switch from long-chain PFAS solvent auxiliaries in the manufacture of PTFE in 2012. Instead, a very high level of PFBS was found in this material (>90 ppm), which may indicate a newly used solvent auxiliary." [26, p. C] Meanwhile, PFBS has also been classified as an SVHC substance by the ECHA. [31]

[2] PIGE – particle-induced gamma emission

It can therefore be deduced that the PFOA substitutes also migrate out of the membrane and can affect the body via dermal absorption.

PFAS uptake through dusts

However, there may also be more direct routes by which PFASs enter the body, for example through inhalation of PFAS-containing particles and fibres resuspended from protective clothing. Dust measurements from a textile warehouse also indicate a direct loss of PFASs from the fluoropolymers in the textiles. [26] The Greenpeace Hotspot study also reports that PFASs were detected in indoor and outdoor dust samples in the vicinity of a PTFE plant, with the concentration pattern decreasing with distance from the plant in both indoor and outdoor dust samples. For example, in indoor dust samples, the sum of PFASs in an area 2 km from the plant was up to 180 times higher than at sampling points 20 km away. [5, p. 7]

Meanwhile, the study on firefighters' clothing recommends that several important protective measures for firefighters should be considered immediately, such as wearing PFAS-free clothing under their turnout gear and washing regularly. This would help minimise skin exposure, and washing hands after touching the clothing would also be a precautionary measure. [26]

Since the migration of PFOA or PFOA substitutes from the PTFE membrane must be assumed, a non-porous, PTFE-free alternative PES membrane would be an immediate measure for firefighters' clothing that is as simple as it is health and environmentally friendly.

3.3 Methods of analysis

Further research results also indicate that even modern analytical methods do not allow complete detection of PFAS despite high sensitivity. For example, in one study, the detection method LC-MS/MS, which is frequently used in trace analysis, only detected about 1% of the total fluorine quantities determined via another method (PIGE). This is consistent with previous measurements on textiles. "There are literally 100 times more PFASs present in the material, for example precursors, polymer-bound fluorine that remains in the finish, unidentified similar substances and oxidation intermediates that are neither identified nor detected in routine LC-MS/ MS analysis." says the addendum to the study on firefighters' textiles. [32]

Similar findings were made in another study. When comparing PFCA concentrations (e.g. PFOA) in wastewater before and after oxidation, an increase was found. This can be traced back to precursor substances that are only transformed into PFCAs by the action of sunlight, advanced oxidation processes or microbes on urban wastewater and can thus be measured. [27]

Effects also on military, police and everyday clothing

Based on the above studies on the migration of PFASs in firefighting textiles and the challenges of analytical methods, it can be assumed that this could also occur in other application areas such as military and police, but also in everyday clothing. Scientists fear this and state "The health consequences of such material loss are likely to extend far beyond firefighters' uniforms. Firefighters are out there risking their lives for us," says scientist Peaslee in an interview. "The least we can do is give them the safest equipment possible." [33]

3.4 PIONEER - The Netherlands draws consequences

With regard to the PFOA issue and its substitutes, which are now also classified as SVHCs, the entire PFAS group of substances is currently being reviewed by the EU to determine whether it is necessary. [17]

The Netherlands has already agreed to a declaration in parliament that excludes PFAS from public procurement, see chapter 4. Due to the investigated health effects of the Chemours plant in Dordrecht, the Dutch are sensitised. Meanwhile, even ministers are claiming millions in damages for PFOA and GenX contamination against Chemours and DuPont. In doing so, they are doing the same as the municipalities of Dordrecht, Sliedrecht, Papendrecht and Molenlanden, which have already announced that they will go to court to hold the company liable. While it is unlikely that the Dutch government will join the same court case, MP Suzanne Kroeger says the arguments will overlap. "We can strengthen each other," she says, adding that this is urgent: "In the film Dark Waters we saw DuPont pulling out all the stops." In her opinion, this is now very much the case in Dordrecht, as Chemours already announced that it does not want to comply with the stricter environmental requirements. The company, on the other hand, is asking the court in summary proceedings to draw a line under these requirements. The claim for damages would include the costs of finding out where the dangerous substances PFOA and GenX have all ended up. This is necessary because the company itself did not keep sufficient records of this. [34]

With the DuPont spin-off, Chemours assumed the chemical company's environmental liability in 2015. After the maximum estimated cost of the indemnities exceeded $945 million, Chemours sued the meanwhile merged DowDuPont in 2019 because no 'unlimited' liability had been agreed. At the beginning of 2021, both companies agreed on a cost-sharing of the lawsuits of 4 billion dollars as a precautionary measure, which gives an idea of the real extent of the damages. [35]

3.5 Water consumption membranes

Based on current calculations of recognised databases, the water consumption for PTFE membrane production is - independent of chemical water pollution - about three times higher than for PES membranes. If 26.4 litres of water are required for the production of 1 kg of PES membranes, the figure for 1 kg of PTFE membranes with a PU coating is 86.9 litres of water. [36]

In view of the environmental issues of water and health, the use of PTFE membranes is not necessary and certainly not recommended due to the availability of alternatives. Therefore, PTFE membranes should no longer be allowed to be used in these areas of application.

4 RECYCLING OF FUNCTIONAL TEXTILES

> ***„The Chamber, having heard the debate, considering that the government has an exemplary function with regard to sustainable procurement; noting that the government procures shoes and clothing for Defence and emergency services which contain GenX and pfoa in their membrane; noting that alternatives without substances of very high concern are possible noting that the procurement policy and technical specifications for clothing and footwear for Defence and the emergency services do not currently take into account the recyclability of the equipment; calls on the government to investigate whether the recyclability of clothing and footwear can be included in the procurement rules, and to proceed to the order of the day. "***
>
> *Statement by Suzanne Kröger MP, GroenLinks, Security in the supply of raw materials, House of Representatives of the States General, Netherlands, Motion of 30 June 2020.* [37]

The above motion by MP Suzanne Kröger to include recyclability of clothing and footwear in public procurement tendering rules was adopted by 92 votes out of 150 by the *Tweede Kamer*, the legislative body of the Netherlands.

However, recyclability is not only focused on in the Netherlands, also in Germany, the Circular Economy Act was amended. The background is the Circular Economy Action Plan (CEAP) of the European Commission. This action plan for the circular economy is one of the most important building blocks of the EU Green Deal, the new European agenda for sustainable growth. [38]

According to the CEAP, textiles are the fourth largest category for primary raw material consumption, with estimates that less than 1% of all textiles worldwide are recycled into new textiles. Given the complexity of the textile value chain, the Commission will propose a comprehensive EU strategy for textiles, based on input from industry and other stakeholders (see chapters 4.1 and 4.4) to boost, for example, the EU market for sustainable and recyclable textiles, including the market for textile reuse. This goes hand in hand with a strategic focus on sectors that consume the most resources and where the potential for circular economy is high, as in the case of textiles. [9, p. 13]

To close the loop, the European Commission has defined measures for the following areas: [39]

- Design and production
- Consumption and use
- Waste and recycling
- Global action

4.1 Sustainable design and production

The basis of all measures is the development of textile products by means of sustainable design to ensure that products are suitable for the circular economy, the use of secondary raw materials is guaranteed and hazardous chemicals are avoided. [9, p. 13]

The EU Policy Hub, the textile industry's stakeholder and voice to the EU, has set itself the goal of accelerating the circular economy in the clothing and footwear industry. The EU Policy Hub defined the most important points on sustainable design as:

- Design for duration of service
- **Design for cycylability**
- Design for repairability
- Design for more sustainable production

The definition in focus here is "design for recyclability":

"Design for cyclability means creating products that can be deconstructed and using materials that can be recycled or are industrially compostable at their end-of-life – with no risk emanating from their chemical inputs and a low carbon footprint. This can be achieved through further research and the development of new materials, where current ones do not provide the desired functionality and cyclability. Better cyclability supports among other things, a circular loop, where materials continue to be re-cycled and re-used at their end-of-life, optimising re-sources and minimising waste". [40]

Comparison of circulation capability of PES membrane and PTFE membrane
The membranes used in textiles are present in functional clothing as composite materials, so-called laminates. The figure below compares the recyclability of a laminate with a PES membrane and a PTFE membrane. Due to the PES fibres often used in functional textiles, the PES membrane can be incorporated into a 100% sorted composite. This allows for easy and high-quality recycling. This is not possible in the case of the PTFE membrane.

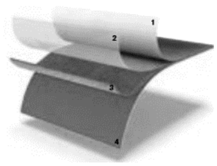
Design to recycle potential of membranes in laminate structures	
Recyclable 100% PES laminate - the PES, including the membrane, can be virgin, recycled or bio-based:	Fluorocarbon-based laminate - as PTFE is not used as a fibre, grade purity can never be achieved in combination with PTFE membranes:
 1. 100% PES Outer fabric 2. 100% PES Membrane 3. 100% PES Lining	 1. Outer fabric (e.g. PES, PA, CO) 2. + 3. Membran PTFE+PU[3] 4. Lining (e.g. PES, PA, CO)

Figure 2: Comparison of the grade purity of PES and PTFE laminates

[3] Due to the microporosity of PTFE membranes, a PU coating is needed to create the required water column, and thus waterproofness.

In addition to the CEAP requirements for sustainable design, the requirements for sustainable production are also described. The production of PTFE membranes is identified in detail in chapters 2.1 and 3.1 and is contrary to all aspects of sustainability: environmental, social and economic.

4.2 Consumption and use

Another CEAP target is to empower businesses and private consumers to make sustainable purchasing decisions and to have easy access to reuse and repair services. [9] Tools such as the Product Environmental Footprint (PEF) will be one way to inform consumers and incentivise sustainable consumption. [39] Currently, the PEFCRs (PEF Category Rules) are being developed together with a large number of textile and apparel companies. In addition to durability, the PEF also focuses on recyclability.

PTFE membranes and fluorocarbon-containing laminates are difficult to recycle, see section 4.1. PES membranes and laminates, on the other hand, enable recyclable materials and production processes.

4.3 Waste and recycling

EU Member States must ensure the conditions for separate collection of textile waste by 2025. CEAP therefore calls for the provision of guidelines to achieve a high level of separate collection. This goes hand in hand with the promotion of sorting, reuse and recycling of textiles.

Fundamentally, the European Union's approach to waste management is based on the waste hierarchy (see Figure 3). This waste hierarchy defines the design of waste policy and the order of priority: prevention, (preparation for) re-use, recycling, recovery and - as the least preferred option - disposal by landfill or incineration without energy recovery. [41]

In line with the waste hierarchy, the 7th Environment Action Programme sets targets for waste policy in the EU:

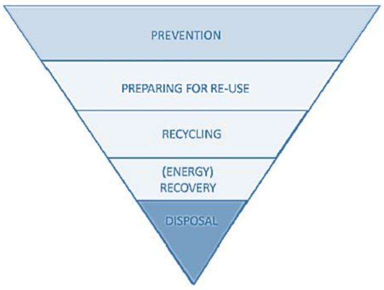


Figure 3: EU waste hierarchy [41]

Table 1: Comparison of the implementation potentials of the EU waste policy targets when using PES and PTFE membranes

Priority objectives of EU waste policy [42]	**Implementation potential PES membrane**	**Implementation potential PTFE-membrane**
1. Reduction of waste	✓	x
2. Maximising recycling and reuse	✓	x
3. Limiting incineration to non-recyclable materials recyclable materials	✓	x
4. Limiting landfilling of non-recyclable and non-recyclable waste	✓	x
5. Ensure the full implementation of the waste policy objectives in all Member States	✓	x

It is clearly listed in the table that due to the lack of grade purity PTFE membranes cannot contribute to the fulfilment of the objectives of the European waste policy.

The renewed German Circular Economy Act, amended on 29 October 2020, has even noted in §45 Obligations of the public sector, paragraph 2, that **preference is to be given** to products that:

- "have been manufactured in production processes that conserve raw materials, energy, water, pollutants or waste,
- have been produced by preparing them for re-use or by recycling waste, in particular by using recycled materials, or from renewable raw materials
- are characterised by durability, ease of repair, reusability and recyclability, or
- compared to other products, result in less or less polluting waste or are more suitable for environmentally sound waste management." [43]

The European Commission formulates it similarly in the document "Green Public Procurement" and points out, in the sense of sustainable and conscious public procurement, that the authorities include criteria with a view to lower environmental impacts when purchasing goods, services and works. The criteria for textiles focus on the main environmental impacts along the life cycle of the products, including fibre sourcing, chemical restrictions according to the POPs Regulation (e.g. PFOA), durability and life extension, energy saving during use and design for reuse and recycling. [44]

However, it is not only the difficult recyclability of PTFE membranes that is against legislation, PTFE membranes are also problematic as waste, especially when incinerated.

Combustion tests of common membrane types

In a test of smoke density and smoke toxicity according to EN ISO 5659-2 (NBS-Box), the Frankfurt-based institute Warringtonfire determined the concentration of the most common toxic combustion gases in functional textiles, i.e. all three commercially available membrane types PTFE, polyurethane (PU) as well as polyester. Not surprisingly, CO_2 (carbon dioxide), CO (carbon monoxide) and NOx (nitrogen oxides) are typical gases that are also released during the combustion of other organic materials such as wood, coal or diesel. [10]

Furthermore, all materials released small amounts of prussic acid, which were well below human-toxic levels, but roughly equivalent to what one might expect in a small smokers' pub after visiting 15-25 guests and smoking 10 cigarettes each. The values for polyester were about 1/3 lower than for the other two materials.

Only in the case of PTFE membrane material were additional high values of highly toxic hydrofluoric acid, the aqueous solution of hydrogen fluoride (HF), of 63 ppm and hydrochloric acid (HCl) of 36 ppm measured. [10]

The main absorption route for HF is via the respiratory tract and the skin. According to EU Directive 2000/39/EC, the EU workplace limit value is a maximum of 1.8 ppm as an 8h average value and 3 ppm as a short-term limit value; the IDLH value (Immediately dangerous to life or health) is set at 30 ppm. In principle, it is assumed that 50 ppm HF can be fatal for humans at an exposure of 30 to 60 minutes. [10]

Based on the values determined on a laboratory scale, it must be assumed that in the case of uncontrolled combustion of a commercially available functional jacket in which a PTFE membrane has been processed, the quantity of hydrofluoric acid (HF) produced in the process alone can lead to death for people directly exposed to the smoke for 30 to 60 minutes. The hydrochloric acid (HCl) also released during the combustion of PTFE additionally leads to severe burns in the lungs when inhaled; irritation and burns of the mucous membranes and respiratory tract can occur. These findings are particularly problematic because around 50% of the textiles collected worldwide are sold via used clothing collections to lower-income third countries for further use - a globally growing billion-dollar business. [45, p. 88] In these countries, the most common waste disposal route is (often uncontrolled) landfill or open fire. According to one study, 40 % of global waste burns uncontrolled in open fires. [46] It must be assumed that, purely statistically, about 15-20% of clothing ends up in open fires in the immediate vicinity of settlements.

Due to these facts, the combination of difficult recyclability and lack of circular economy of PTFE membranes and laminates is all the more fatal and additionally unacceptable due to existing alternatives.

4.4 Global action

CEAP also calls for the introduction of regulatory measures such as extended producer responsibility (EPR) as a further step. [9, p. 13]

EPR is an approach that ensures that producers contribute financially to the costs of waste management. That is, EPR obliges producers to take operational or financial responsibility for the end-of-life phase of their products, creating incentives for better design to reduce these costs. Monetary contributions are then incurred, for example, for the separate collection and treatment of waste, with the costs of individual products or product groups being assessed taking into account durability, reparability, reusability and recyclability, as well as the presence of hazardous substances. [47]

Euratex also points out in its position paper that the EPR of textiles should enable a circular economy through cooperation and shared responsibility. The circular economy requires partnerships in which the existing barriers to closing the loop are jointly solved instead of shifting responsibilities. To achieve this, the EPR should support collaborations that aim to: e.g. enable the flow of information and data, establish a mutual understanding of circular design, support material pooling, eliminate conflicting rules, link demand and supply of recycled materials. [48]

Garment companies using PTFE laminates will not be able to comply with circular economy requirements on producer responsibility.

4.5 BEST PRACTICE - wear2wear™ Cooperation

In compliance with all four aspects of the CEAP - 1. sustainable design and production, 2. sustainable use and application, 3. from the point of view of recyclability and waste reduction and 4. including producer responsibility and cooperation promotion, the European cooperation wear2wear® was set up.

Behind wear2wear™ are well-known European companies that have set themselves the task of producing new textiles exclusively from recyclable and unmixed materials. New functional textiles are produced from textile fibres of used clothing on state-of-the-art production facilities. Depending on the area of use, these meet high requirements such as waterproofness, breathability, protection and comfort. In order to close the raw material cycle, these textiles can be fully recycled again at the end of their life cycle.

In January 2020, the world's first upcycled functional jacket "rEvolution Hybrid" made from 30% recycled used textiles and 70% recycled PET bottles was presented - a 3-layer high-performance jacket.

It offers certified rain protection according to EN 343, is environmentally and skin friendly and tested according to the strict environmental standards STANDARD 100 by OEKO-TEX® and bluesign®.

The manufacturing process of the rEvolution Hybrid works as follows: Largely unmixed waste polyester (PES) textiles are mechanically dissolved, processed into granules by mechanical or chemical recycling processes and spun out into new PES filament yarns. These yarns are processed into textile polyester fabrics and laminated with a 100% recyclable PES membrane to create a single-grade, recyclable, highly functional and 100% waterproof functional textile. The percentage of recycled old textiles in the rEvolution Hybrid products already amounts to 30%, the remaining 70% is supplemented by PET bottle polymer yarns and can be diluted to a spinnable concentration in the future by equivalent upcycling processes and thus gradually disappear from the recycled textiles. The aim is to increase the proportion of recycled old textiles to 100% in the medium term.

The Design2Recycle concept is based on a selection of materials that is as pure as possible in combination with pure, recyclable ingredients as well as environmentally friendly finishing and dyeing agents. By using special sewing threads, non-recyclable ingredients can be removed in a cost- and material-saving way to ensure an optimised recycling result.

Through adequate marking, wear2wear™ products can be made traceable and transparent for the consumer as well as for process partners. These are to be optimised by expanding existing collection systems with forward-looking sorting technology. The collection of worn clothing in the leasing business or occupational safety sector can also be guaranteed via a wear2wear® partner.

After collection by existing clothing collectors, sorting and separation, these are sent to the wear2wear™ upcycling network, which enables reuse again through a combined upcycling process. After raw material reprocessing, PES filament yarn is thus produced again, which is processed into new upcycled polyester fabrics. The wear2wear™ cycle is closed - a new, sustainable functional textile is created. [49]

5 CO_2 EMISSIONS OF TEXTILE MEMBRANES

„Act before you have to.“

Patricia Espinosa Cantellano, Head of the Secretariat of the United Nations Framework Convention on Climate Change (UNFCCC), Speech KeyNote at the Global Member Meeting FICCA, October 2020.

The textile industry is the second dirtiest industry in the world - it is already responsible for over 8% of all CO_2 emitted worldwide, about as much as the entire EU. Of this, 83% CO_2 is emitted by the clothing industry and 17% by the footwear industry. If left unchanged, this figure will rise by over 60% by 2030. [13]

The United Nations has already become aware of these abuses. On 10 December 2018, the Fashion Industry Charter for Climate Action (FICCA) for the apparel industry was officially launched at the COP24 global climate conference in Poland. It includes a list of targets agreed by representatives of major apparel brands, led by the UNFCCC, to mitigate the climate impacts caused by this industry. This includes reducing CO_2 emissions by at least 30% by 2030, and has since been tightened to 45% by 2030 to meet the 1.5°C climate target. [50]

While some companies are beginning to record and reduce emissions in the wake of the FICCA, there are also pioneers who have already been accounting for their emissions for several years, reducing them in line with the Science Based Targets (SBT) and even offsetting them.

Emission databases form the basis for recording emissions. The emission values of the databases differ greatly in some cases, depending on the system boundaries, the type (primary data, generic data) and method of data collection (e.g. GHG Protocol) and the timeliness of the data. The textile companies and platforms work with a wide variety of agencies and tools to determine emissions. In the textile industry, the Ecoinvent and GaBi databases often form the basis for this.

With regard to PTFE, the emission factors of Ecoinvent and GaBi are strikingly different. While Ecoinvent calculates 127 kg CO_2/kg PTFE (2016), GaBi calculates 11.6 kg CO_2/kg PTFE (2018). PES-based membranes cause a comparatively low 3.5 kg CO_2/kg of material.

The conversion of the PTFE value from Ecoinvent to GaBi within the SAC material database Higg MSI (Material Sustainability Index) in 2020, in whose core group a well-known PTFE manufacturer is located, therefore aroused particular interest. To clarify the large difference between the two values, both databases were contacted by third parties, although GaBi was unable to provide any information. The only information provided was that the data came from the fluorine manufacturers themselves and was subject to confidentiality. [51]

This step is remarkable against the background of the goals of FICCA and its now more than 100 signatory clothing companies, since low-emission materials are to be given preference. [52, pp. 3, point 6] The comparability and transparency of emission factors of different textile materials thus becomes of central importance. Sometimes, because materials account for an average of 85% of the emissions caused in the garment. [4]

[4] For transport via ship, truck; as soon as products are transported by air, the logistics share increases

5.1 PTFE data collection and global emission factor

The traceability and credibility of database values plays an increasingly important role in the context of companies' own and legal obligations to reduce CO_2 emissions.

As described in the introduction, the PTFE emission factors of the Econinvent and GaBi (Sphera) databases used in the textile sector differ greatly. Due to this, an expert opinion was prepared to assess the Ecoinvent and GaBi values (see Appendix, chapter 7).

This expert opinion by the environmental consultancy Öko-Recherche[5] shows that the country-specific emissions of PTFE production plants and their precursors vary greatly.

The table below clearly shows that emission factors range from 1.26 kg CO_2/ kg PTFE in Japan to 294.1 kg CO_2/kg PTFE in China. The value of 11.6 kgCO_2/kg PTFE given by GaBi (Sphera) refers to the European value, whereby the processing from raw material to ePTFE membrane is also reflected.

Table 2: Overview of country-specific PTFE emission factors [11]

HFC-23 emitted / PTFE produced (kg CO_{2eq} /kg) mit Faktor 1,73		
	Average 2012-2017	Emission factor 2017
Europe (without Russia)	6.3	7.73
USA	81.31	93.97
Europa (without Russia) + USA	47.77	55.86
Japan	0.8477	1.26
Industrial countries without Russia	37.02	42.95
Comparison China 2013-2015	394.44	294.1

This explanation is also provided by the SAC for the Higg MSI PTFE value, writing: " Sphera has worked with Europe's main producers of PTFE more recently (reference data of 2018), so we have more confidence in this data overall. However, since the dataset was produced using production data from Europe there could be differences amongst global production that are not reflected in this dataset. As with all Higg MSI process data, we will continue to review feedback and data sources to make sure that best available and most appropriate information is being reflected in the Higg MSI." [53]

However, there is no basis for such confidence in the Sphera data, and thus the MSI value, as scientific studies apparently refute the possibility of such a low global PTFE value.

Short explanation: The high emission values of PTFE depend almost exclusively on the by-product emission HFC-23 (R23), which is produced during the manufacture of chlorodifluoromethane HCFC (R22), which is a precursor in PTFE production. The by-product R23 has a comparatively very high emission value of 14800 kg CO_2/kg material. [11]

[5] Öko-Recherche - independent and internationally active office for environmental research and consulting; specialists for fluorinated and fluorochlorinated substances in various applications, their substitution and emission reduction and the preparation of material flow analyses and scenarios on these topics

HFC-23 emissions rise significantly

According to an article in the "Nature" journal, global HFC-23 emissions, derived from atmospheric concentration measurements, are currently increasing significantly. This is explained by the HCFC-22-related emissions. [54]

As the figure below clearly shows, the values for developed countries are decreasing; however, in developing countries, the values for HFC-23 emissions are increasing massively, at the same rate as HCFC-22 production.

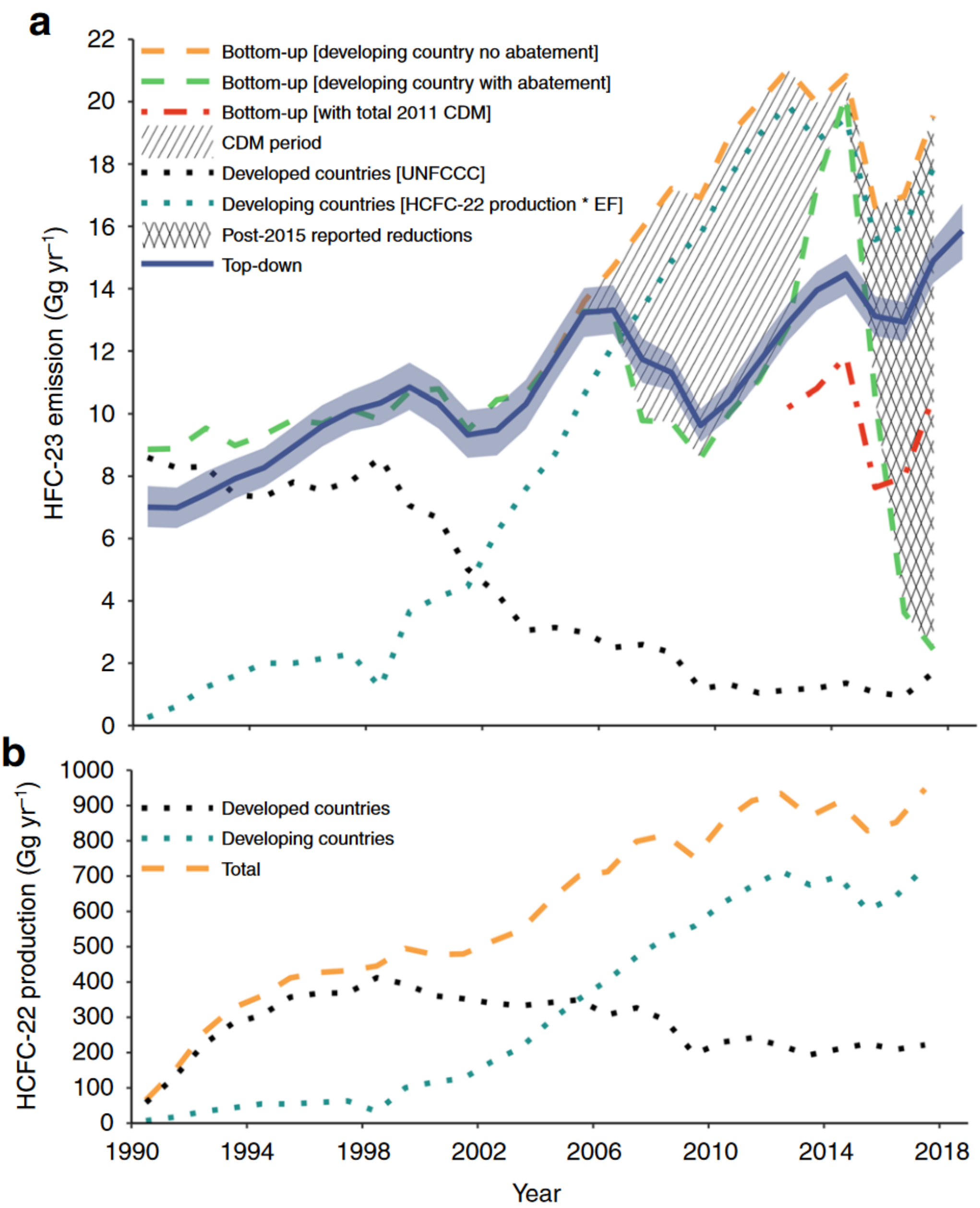


Figure 4: Global HFC-23 emissions and HCFC-22 production [54]

One explanation for this is the relocation of production to developing countries. For even if high-temperature incinerators for HCF-23 were added to HCFC-22 plants there by companies from the industrialised countries (for which those companies were issued enormous CO_2 certificates, i.e. earned a lot of money), it can be assumed on the basis of the concentrations measured in the atmosphere that the additionally high energy expenditure of these incinerators may have led to them not being put into operation. [55] This can be seen in the figure under CDM period (Climate Developing Measurements).

PTFE production capacities in China, India and Russia over 50%

This goes hand in hand with the country-specific PTFE production volumes. In 2020, over 41% of global PTFE production took place in China, over 8% in Russia, 4% in India and 15% in the USA. [21] Assuming that the production sites of the PTFE precursors and the resulting PTFE are manufactured in one location, the country-specific EFs determined by Öko-Recherche were calculated with the country-specific production volumes to form a global average value.[6] The table below thus shows the global PTFE value of 176.6 kg CO_2/kg PTFE, which is similar to the order of magnitude of the Ecoinvent emission factor.

Table 3: Global average PTFE value based on PTFE capacities, percentage share and country-specific emission factors

Calculation: PTFE locations and capacities worldwide according to Polyglobe			
	capacity (tpa)	% share	% share*EF 2017/100
China	61.9	41.57	122.26
Europe	35	23.51	1.82
USA	23	15.45	14.52
Japan	9.8	6.58	0.08
Russia[7]	12.7	8.53	25.08
India[8]	6.5	4.37	12.84
PTFE value global			**176.60**

As can be seen from the expert opinion of the environmental office Öko-Recherche, a more precise data situation is desirable in all countries except Europe and Japan. However, against the background of massively increasing R23 emissions and the shift of production to developing countries, it is presumptuous to calculate PTFE membranes with European emission values (see GaBi/Sphera as well as MSI/ SAC) and compare them with other membrane materials.

Based on the similar values from Ecoinvent and Öko-Recherche, it can be assumed that PTFE membranes have on average 30x higher CO_2 emissions compared to technically equivalent functional materials. Calculated on a single functional jacket, this causes twice as much CO_2 by choosing a PTFE membrane than alternative membrane materials such as PES.

[6] Note: The assumption of this data is that PTFE production sites and precursor production sites are equated, which is not certain at this stage and could not be found out by GaBi/Sphera or via available databases. It is known that large R22 plants in the USA and Europe produce both PTFE precursors and PTFE. For process-technical reasons, this makes sense and is therefore also conceivable for other countries such as China, etc.

[7] EF Europe + USA (based on assessment of Öko-Recherche, Dr. Winfried Schwarz)

[8] EF China (based on assessment Öko-Recherche, Dr. Winfried Schwarz)

5.2 BEST PRACTICE: biomassed-based PES membrane

PES membranes have a low emission factor of 3.5 kg CO_2/ kg material across all databases. Furthermore, the use of bio-based plastics from waste streams is already available on the market. Biomass-based plastics even have the advantage of generating new plastics from waste and thus saving CO_2 emissions in PES membrane production at the same time.

6 CONCLUSION

This report proves on the basis of numerous studies and sources that the production, use and disposal of PTFE membranes have harmful effects on health and the environment.

Research results from recent years show massive increased cancer rates and other adverse health effects in the vicinity of PTFE production sites worldwide, not taking into account that the worldwide spread of this "eternal chemical" also causes reference values to rise. The Western fluorochemical industry has shifted the problem around PFOA to Asia. At the same time, it is apparent that the PFOA substitutes in use in the EU, such as GenX and Adona, are also substances of very high concern. Thus, none of the current manufacturing processes for PTFE membranes are safe for health and the environment. Further studies also indicate that PFOA, but also PFOA substitutes, migrate from the PTFE membrane and can affect the body via dermal absorption, as can dusts containing PFAS. Research results also indicate that even modern analytical methods do not allow for a complete detection of PFAS despite high sensitivity. One study, for example, showed that only 1% of the total fluorine quantity could be detected. Precursors and oxidation intermediates are difficult to detect in trace analysis. These can also be transformed into hazardous substances such as PFOA by external influences such as exposure to sunlight, advanced oxidation processes or microbes.

In addition to their hazardous and environmentally harmful aspects, PTFE membranes and fluorocarbon-containing laminates are difficult to recycle. The report stated that due to the lack of purity of PTFE membranes, they cannot contribute to the fulfilment of the objectives of the European waste policy. Another study shows that in contrast to other textile membranes, high levels of highly toxic hydrofluoric acid and hydrochloric acid were measured exclusively when PTFE membrane material was incinerated. It can be assumed that clothing companies using PTFE laminates cannot comply with the circular economy requirements for producer responsibility.

Greenhouse gas emissions from the production of PTFE membranes are also relatively high. PTFE membranes have 30x higher CO_2 emissions compared to technically equivalent functional materials. The use of PTFE membranes thus contradicts the aspirations of the Montreal Protocol 2016, which aims for a global reduction of 85% in hydrofluorocarbon emissions.

For more than five years, scientists worldwide have been calling for PFAS substances to be replaced wherever possible. The report conclusions, as well as environmentally friendly and health safe alternative materials such as PES membranes proven for decades, call for PTFE membranes in the apparel and footwear industry to be classified as non-essential use. The Netherlands has already accepted a corresponding motion to use alternatives for clothing and footwear for public procurement in which there is no GenX and PFOA used for the membrane.

In the course of the EU Chemicals Strategy for Sustainability and as a forerunner to the envisaged American PFAS legislation, the EU Member States and the EU Commission should lead by example, classify PTFE membranes as non-essential for the general textile and clothing industry, and ban their use. The cat-and-mouse game between legislators - to ban a specific PFAS substance and the fluorochemical industry - to circumvent the ban with a harmful substitute - could thus be ended, at least for these areas of application.

It would be a simple yet immense lever for better health protection and environmental sustainability through optimised circular economy, reduced CO_2 emissions and pollutant reduction.

7 ANNEX – Öko-Recherche expert opinion

Öko-Recherche, Frankfurt (Main), Germany

Research: On the climate-relevant HFC-23 emissions in the industrialized countries in relation to the production of HCFC-22 and PTFE

Requirements for the search

It is assumed that the PTFE production relevant for the application in question is located in industrialised countries and that the raw material HCFC-22 is also sourced from industrialised countries (excluding Russia). Therefore, we have determined the emission factor "HFC-23 emitted / HCFC-22 produced" for the industrially developed world region. This means specific figures for 1) Europe (excluding Russia), 2) USA, 3) Europe + USA, 4) Japan, 5) Europe + USA + Japan.

It is assumed that the USA plays an important role for the competition of PTFE users.

Data procurement

Unlike for the technically optimal emission factor already reported (a single plant in the EU with corresponding operator data), we have now calculated the values not on a plant-specific basis. This was not only impossible, but also unnecessary for the purpose at hand. This is because the governments of industrialised countries are obliged under international agreements to determine and report HFC-23 emissions. Since they have to report, but the companies themselves are not subject to any obligation to provide information, but rather report more or less voluntarily, the quality of the data can certainly be criticised, especially since there are different technical procedures for waste gas treatment with different degrees of efficiency (e.g. onsite or offsite destruction). On the other hand, the data on which our research is based are all quasi "governmental", which means that, firstly, they are certainly not too high[1] and, secondly, they are reliable in the discussion.

Data sources for HFC-23 and HCFC-22

For the emission factor "HFC-23 emitted / HCFC-22 produced" information on HFC-23 and information on HCFC-22 is required.

HFC-23

Under the UNFCCC (United Nations Climate Change Convention), industrialised countries are required to submit annual national greenhouse gas (GHG) inventories to the Climate Change Secretariat, including emissions of HFC-23, which are climate-relevant, and which consist of the National Inventory Report (NIR) and the Common Reporting Format (CRF) for each country. The latest reports all date from April/May 2019 and contain data until 2017, while the reports for 2018 are currently being prepared and will be submitted to the Climate Secretariat in spring 2020. Data for 2018 and 2019 are not yet available. However, no significant changes are expected at that time.

[1] However, we have completely excluded a certain plant from the calculation (i.e. also with the HCFC-22 production volume) because the operator (Öko-Recherche is, as you already know, directly involved in the emission reporting of the EU and Germany) has reported "zero emissions" for years and persistently refuses to provide reasonably credible measurements or estimates.

We have evaluated the National Inventory Submissions for 2010 to 2017 for all industrialized countries in question, namely France, Germany. European Union, Netherlands, Italy, Japan, Spain, United Kingdom, United States. These are the industrialized countries in which HCFC-22 plants were/are still existing after 2010. At present, there are only four manufacturers in Europe excluding Russia and only two in the USA. We have not collected any information for Japan. The number of companies (two of which produce both in the USA and in the EU) has decreased drastically since 2009, when it became apparent that R-22 could no longer be marketed as a refrigerant for a long time, but would only be permitted as "feedstock", i.e. further processing into PTFE. (Incidentally, some companies that closed down plants in the industrialized countries have rebuilt such plants in China).

HCFC-22

All countries report in CRF (table 2 (II), B.9) their "HFC-23 by-product emissions" from "fluorochemical production", partly also in the corresponding NIR. The latter sometimes also contain information on the production of HCFC-22, for example in Japan. The USA only reported HCFC-22 production until 2012 because there are only two companies since 2103 and the minimum number of companies required to report is three. The six EU countries in question (only four since 2016) do not publish their HCFC-22 production. HCFC-22 is an ozone-depleting substance that falls under the jurisdiction of the Montreal Protocol, not the Climate Protocol. Although the relevant company data must be reported to the European Commission, they remain unpublished.

However, we do have access to a list that was presented to the Multilateral Fund under the Montreal Protocol at the 27th Meeting in Bangkok on July 27, 2017[2] - with the HCFC-22 production figures for the industrialized countries (=non-Article 5 parties) as a whole and by individual developing countries (=article 5 parties) with HCFC-22 production, namely China, India, Argentina, Mexico, Venezuela and the two Koreas. In 2014 and 2015 the industrialized countries produced 225,000 t each, the developing countries 700,000 t, with China alone accounting for 600,000 t. HFC-23 emissions are estimated in this proposal only for developing countries, although it is noted for China that only 45% of the HCFC-23 generated was "destroyed" in 2015.

As far as the industrialized country groups are concerned, we can determine their HCFC-22 relatively well. The (according to NIR) produced quantities for Japan are, as mentioned, accessible. The production of the EU countries is known to us in confidence and has been rounded to their size. By subtracting the Japanese and EU quantities from the Bangkok estimate for the industrialised countries (non-article 5 parties) as a whole, we were able to deduce the missing US quantities, which have not been reported since 2013 but confirmed our own estimate.

GWP 14,800

Regarding the calculation method of the GWP used: All national submissions use the HFC-23 GWP of 14,800, which is taken from the 4th IPCC Assessment Report (AR) of 2007 (formerly

[2] UNEP Umweltprogramm der Vereinten Nationen): AUSSCHUSS FÜR DEN MULTILATERALEN FONDS ZUR UMSETZUNG DES MONTREALPROTOKOLLS, Neunundsiebzigste Sitzung, Bangkok, 3.-7. Juli 2017: SCHLÜSSELASPEKTE IM ZUSAMMENHANG MIT HFC-23 NEBENPRODUKTKONTROLLTECHNOLOGIEN (BESCHLUSS 78/5)

GWP of 11,700 from AR2). GWP values change over time for reasons not discussed here. There is a new value of 12,400 since 2014 (AR5), but we will stick to the general UNFCCC assessment report value of 14,800.

The results in detail

Reference value kg HCFC-22

Table 1: HFC-23 emitted / HCFC-22 produced (kg CO2eq /kg)		
	Average 2012-2017	Emission factor 2017
Europe (excluding Russia)	3,64	4,47
USA	47,00	54,32
Europe (excluding Russia) + USA	27,61	32,29
Japan	0,49	0,73
Industrial countries excl. Russia	21,40	24,83
For comparison China 2013-2015	228	170

The difference between the EU and the USA is striking. The data are robust, however. The high US value is due, among other things, to one of the two manufacturers, which does not operate an onsite-waste-gas treatment plant itself, but has the collected HFC-23 destroyed offsite, thus requiring refilling and transport.

Another interesting aspect for all industry groups is the comparison of the average value for 2012-2017 with the 2017 value. It shows that since 2012 there is no reduction in emission factors at all, but on the contrary an increase. Nevertheless, with regard to the years before 2009, emissions have fallen sharply.

By the way, for industrialized countries in general, the KEY ASPECTS RELATED TO HFC-23 BY-PRODUCT CONTROL TECHNOLOGIES mentioned above no longer expect a 3% formation rate of HFC-23 in HCFC-22 production, but only 2% thanks to improved process control. This question had arisen in connection with the "preliminary study".

Optimal efficiencies of the exhaust gas treatment are reported from Japan with 99.8%.

Reference value PTFE

The emission factors related to 1 kg PTFE are higher than the emission factors "HFC-23 emitted / HCFC-22 produced (kg CO2eq /kg)". If one assumes the double value (= 2), the values in Table 1 double.

Table 2: HFC-23 emitted / PTFE produced (kg CO2eq /kg)		
	Average 2012-2017	Emission factor 2017
Europe (excluding Russia)	7,28	8,94
USA	94,00	108,64
Europe (excluding Russia) + USA	55,22	64,58
Japan	0,98	1,46
Industrial countries excl. Russia	42,80	49,66
For comparison China 2013-2015	456	340

A chemically exact calculation of the relation HCFC-22 / PTFE (kg / kg) may be different from 2 / 1, probably with a slightly lower value than 2.

Theoretically, the value is not 2, but 1.73. For a 1-PTFE molecule (a member of the PTFE chain, -CF2-) you need one HCFC-22 molecule. If the molar mass of HCFC-22 (86.47 g/mol) and 1-PTFE (50.01 g/mol, 1/2*TFE) is taken into account, it follows that 1.73 kg of HCFC-22 is required per kg of 1-PTFE (1 kg 1-PTFE * 86.47 / 50.01).

In this case, the values in Table 1 would only have to be multiplied by 1.73 instead of 2.

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