VINNOVA – UDI – S1
Fasa ut PFAS - POPFAS

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1. Executive summary

The general aim of the project POPFAS-Phasing out PFAS is to contribute with new PFAS free products to decreased environmental impact, secure pure drinking water and competitive Swedish industry by transdisciplinary collaborations.

The stage 1 project started with a kick-off meeting in November 2016 and it was then decided that the water purification area would be excluded from the continuation of the project due to the breadth of the challenge. It was instead decided to focus on actively replacing PFAS at the source to stop its release in the environment. Five different product categories were initially represented within the project, grease resistant paper, textile and leather treatment, cosmetics, film-forming products and firefighting foams. Individual interviews were organized with all partners to gain more insight in their specific challenges, their market and interests in the project. After an initial discussion about the general challenges within these categories, the consortium was extended to include further actors along the value chains. Ski wax was included as new product category due to the high visibility of the case and strong work-environment related challenge. Moreover, similar to the initial five applications ski wax is released to the environment quantitatively after its intended use. A number of alternative technical solutions or strategies to achieve alternatives to using PFAS were identified and further investigated. In parallel a pre-study was conducted on a natural surfactant that today is used in a non-related application. At a second workshop in May 2017, project organization for the second stage of the project was suggested, potential new technical solutions were presented to all partners together with the results from the pre-study, and partner roles were discussed in order to gain approval for the new application. Apart from the technical challenge of substitution, LCA, toxicity aspects, legislation and the challenges associated with communication were raised as essential parts of the project.

2. Identified and analysed solutions with high potential

PFAS have unique properties that render them appealing for a wide range of applications where properties as hydrophobicity, oleophobicity or rapid spreading are needed. However, PFAS have a strong environmental impact, as well as negative influence on health, and increased levels of PFAS can now be detected in 144 municipal water sources in Sweden. For definition of PFAS see Appendix 1.

To limit exposure to PFAS, the project was initially considering two approaches: limiting use of PFAS at the source during product manufacturing, and addressing the challenge of water purification. More than 3000 types of PFAS are commercially available on the world market. Just for one certain type of PFAS, PFOA-related substances, it is estimated that at least 100-

1000 tons are manufactured and marketed in the EU every year, based on data registered in REACH. Current discussions around the legal framework indicates that the use of PFAS might be restricted in the near future. Reducing emissions of potentially hazardous and persistent chemicals beforehand is in line with the prevailing precautionary principle. The project constellation decided early on to focus the second stage of the project on the replacement of PFAS at the source rather than on water purification. This decision was motivated by the breadth of the water purification and soil decontamination challenge, which would require a full project of its own. Moreover, several initiatives are already on-going in this area (see section 5).

Several technical solutions, based on chemistry or a combination of structure and chemistry, have been identified during the project and will be evaluated further in the second stage (see Appendix 2 for more detail). Apart from the relatively well-known silicones, natural surfactants, nanoparticles and plasma treatment will be studied. A specific type of naturally occurring surfactant system, currently used in another type of application, has been evaluated in a pre-study and shown promising results. Nanoparticles will be considered to impart a specific 3D-structure to the different substrates, but can also on their own or in combination with chemistry act as surfactants or surface active replacement of polymers, and thus, potentially replace PFAS. Plasma treatment is an efficient tool to activate the surface of materials and allows stronger bonding between, for example, the textile fabric and the finishing layer. A strategy to accelerate the substitution work is to capitalize on strong inter-branch collaborations and information exchange as technologies initially developed and tested in one branch could potentially be adapted to other sectors. For instance, Organoclicks DWOR (Durable Water and Oil Repellancy) or plasma treatment, currently designed for textile material, could be relevant for other sectors like paper treatment. Alternative technologies might not deliver the same level of performances as existing PFAS solutions and acceptable compromises will need to be discussed and identified for each product category.

In addition to technical solutions, improved communication within the value chain and towards end-users is required to phase-out PFAS. In the cosmetic industry for example, it is crucial that retailers or the manufacturer of the final consumer product ensures that no PFAS are introduced anywhere in the value chain. Thus communication with suppliers on different levels will be essential. At the other end of the value chain, it is important that producers and consumers are aware of the health and environmental risks associated with PFAS as well as of the availability of safe, technically feasible and environmentally benign PFAS-free products. It is important to keep the information intended for the consumer at an appropriate level that is comprehensible. With the vision of educated consumers, procurers and producers that make competent choices based on scientific facts, and thus drive the market towards a healthier living and environment, we aim to contribute to education.

One challenge with regulation is the global market and manufacturing of products. PFAS-free products may initially be more expensive than PFAS-containing products and exposed to tough competition at an international level as regulation may vary globally. Continuous monitoring of regulations at an international level rather than just Swedish level is therefore crucial for a shift to PFAS free products on the market, and thus constitutes an important part of this UDI-project.

3. Plan for how new solutions will be developed and exploited

When selecting non-fluorinated alternatives it is crucial to first identify criteria of importance resulting in certain functions of the product or in the manufacturing process. This is true for all levels in the value chain, but may be more difficult closer towards the end product. This task is heavily dependent on stakeholder engagement from the industry in order to reach high accuracy and level of detail. Selected alternatives will then be tested on lab-scale against functionality criteria mainly based on physicochemical properties. If the initial functional evaluation, the health and environmental assessment and the legal status of the alternative are satisfying, the performance of the alternative solution will be further evaluated in prototype or pilot scale according to industrial standards. To achieve a proper evaluation of the alternatives, updated or improved test methods that reflect the required functional performance in real life might be implemented. For some of the industrial cases (e.g. textile/leather and to some extent paper), several different material tretments may be required for full performance, and thus, effects of absence of PFAS on the compatibility between PFAS freeformulations and other material treatments may be studied including for instance dispersing properties on surfaces or chemical mixing properties within a chemical formulation.

As some PFAS and suggested alternatives have shown to be hazardous for the environment and/or human health, it is of high importance that both PFAS and their alternatives are evaluated in the project from an environmental and health perspective using mainly existing data, which in turn will generate important information concerning environmental impact. Therefore, part of the project will be devoted to Life Cycle Assessment and health evaluation of envisioned replacement technologies using used PFAS as benchmark. This assessment will initially be based on already available data which will be refined during the project as more information (type of exposure, exposure level etc.) is gained by the evaluation of the alternatives.

While some PFAS are already under regulation, others are targeted by a clear political agenda towards reducing their use in the market place. Since the political ambition in Europe and on a global level is quite high when it comes to PFAS phase out using legal instruments, it is crucial to work in dialogue with authorities. This work will provide the project with useful information about legal frameworks and upcoming regulations. The specific challenge concerning the global sourcing networks with different geographical regulations will also be addressed. Sharing of useful information about the ongoing work will increase the possibilities for industry partners to comply with new rules. Finally, several relevant authorities are tied to the project and results from the project will be shared to create valuable support to regulators.

It is important that the results generated in the project lead to utilization. Thus, all development towards new chemicals, technical solutions, new formulations and new products will have clear stakeholders within the project consortium. Ownership of results will be regulated by the consortium agreement, which will be signed by all partners at the start of the project. These results might have different added value for the partners depending on the position of the partners in the value chain (see Appendix 3). Producers of alternative solutions (chemically based or non-chemical) are expected to directly create value in terms of increased markets or market shares resulting in higher turnover and profitability. Also, business may be expanded to other sectors than previously targeted. For manufactureres of products using PFAS or alternatives (B2B) we foresee increased market shares when customers require PFAS free products due to increased awareness or imposed regulations. Regarding manufacturers of end products, we foresee shared value between actors in the value chain. The specific value has to be identified per partner company together with their specifically involved suppliers. The value creation is therefore of very high importance and may be direct (higher share of a certain market), or indirect due to legal compliance . This value will be discussed during meetings or workshops and used for business plans and preparation of a step 3 application.

Finally, sharing relevant information to value chain actors, public, authorities, trade organizations and NGOs is of high importance. Therefore an external communication strategy with an external project website will be established. Workshops, conferences, seminars will be organized to improve industrial awareness and increase the societal value of the project. Consumers will be reached by information campaigns and surveys by partners and with the help of new and already existing networks within the consortium.

4. Mapping and reporting relevant needs of stakeholders

PFAS are present in a variety of consumer products. Each product sector, investigated in the project through individual interviews with relevant industrial actors and authorities, has its specific needs. The selected industry cases are described in more detail in appendix 4.

In general the industrial challenges reside in finding suitable alternatives that give acceptable performance. During the interviews, the technical challenge of identifying chemical alternatives to PFAS was broadened as to take into account manufacturing and processing parameters as well as costs. Moreover, the need to set up criteria on materials content towards suppliers was raised as an important issue as it is not always clear in which step the introduction of PFAS occurs in the manufacturing process. The global market calls for an international legislation that also targets imports to preserve the compliance and thus competiveness of the Swedish industry. An important aspect that was raised during discussions with partners was the risk associated with communication; although industries are aware of the necessity to be transparent in their communication, they cannot jeopardize their image and market. From a consumer perspective, clear information is required on product composition and the risks associated with a product. Products marked as PFAS-free can still have a negative impact on the environment or imply a toxicity risk depending on the formulation and remaining ingredients of the product. It is thus crucial that consumers get comprehensible and relevant information on for example health and environmental aspects of PFAS containing as well as PFAS free products.

5. Business intelligence reporting needs and conditions in a global market

Due to problematic health and environmental impact related to long chain PFAS, a voluntary phase out of the production of PFOS, its salts and PFOSF began in 2003 by the most important global producer resulting in a major decrease in global production and use. Since 2006, the major manufacturers of long-chain fluorotelomers (8:2 fluorotelomers) in EU, Japan, and US have been working towards the elimination of C_8-based and longer-chain-based PFASs by year-end 2015, in accordance with the United States Environmental Protection Agency's (US EPA) voluntary 2010/2015 PFOA Stewardship Program.[1] Currently, C_6-fluorotelomers increasingly dominate the trade.

From a regulatory perspective, several international agencies are currently working on facilitating the exchange of information on PFAS to support a global transition towards safer alternatives. In 2013, the Global Perfluorinated Chemicals (PFC) Group[2], by Organisation for Economic Co-operation and Development (OECD) and United Nations Environment Programme (UNEP), developed a non-exhaustive worldwide compilation of manufacturers of fluorinated substances as provided to the OECD Secretariat. While there is today extensive data on some short chain alternatives such as perfluorobutanoic acid (PFBA), perfluorobutane sulfonic acid (PFBS) and perfluorohexanoic acid (PFHxA), for which studies are peer reviewed and published in journals, publically available scientific data on other fluorinated or non fluorinated alternatives listed in the document is lacking. In addition, US EPA has been reviewing substitutes for PFOS, perfluorooctanoic acid (PFOA) and other long-chain perfluorinated substances since 2000, including over 150 alternatives of various types. Similarly, other government agencies have received and reviewed information on alternatives. (OECD) has established a web portal on perfluorinated chemicals to facilitate information exchange on perfluorinated chemicals.[3]

The Danish Veterinary and Food Administration has set up a recommended limit value for the total amount of organic fluor that is accepted in paper and board for food contact materials. This limit is currently set at 0.35 µg of organic fluorine per dm^2 paper (which is equivalent to 0.5 µg of PFOA per dm^2 paper). Studies are on-going to possibly adjust the limit after evaluation of the suggested analysis method and completion of more extensive studies on background level. The limit is set low to ensure that fluorinated compounds are not used in

[1] www.epa.gov/oppt/pfoa/pubs/stewardship/index.html.
[2] OECD portal on perfluorinated chemicals , http://www.oecd.org/ehs/pfc/
[3] http://www.oecd.org/ehs/pfc.

the treatment of paper. In Denmark, the total content of organic fluorine is taken into account while most of the other existing regulations only address PFOA or PFAA.

In Sweden, a broader initiative, which gathers research organizations and authorities, has been launched in 2017 to join efforts to address issues related to PFAS. So far 37 partners have joined the initiative which focuses on minimizing the risks and increasing general knowledge about PFAS. The partners will continue working on their specific expertise area, but a stronger communication between them will facilitate risk assessment, legislation work, environmental monitoring, research and development, and observation when coming to PFAS. The network will also work with mapping of the contaminated areas in Sweden and associated measurements of background level as well as mapping of human exposure. The network is actively contributing to the development of new sampling and analysis methods with focus on water cleaning and soil decontamination. The POPFAS and POPFREE initiative will have relevant contact and collaboration with the described networks, indirect via project partners or direct.

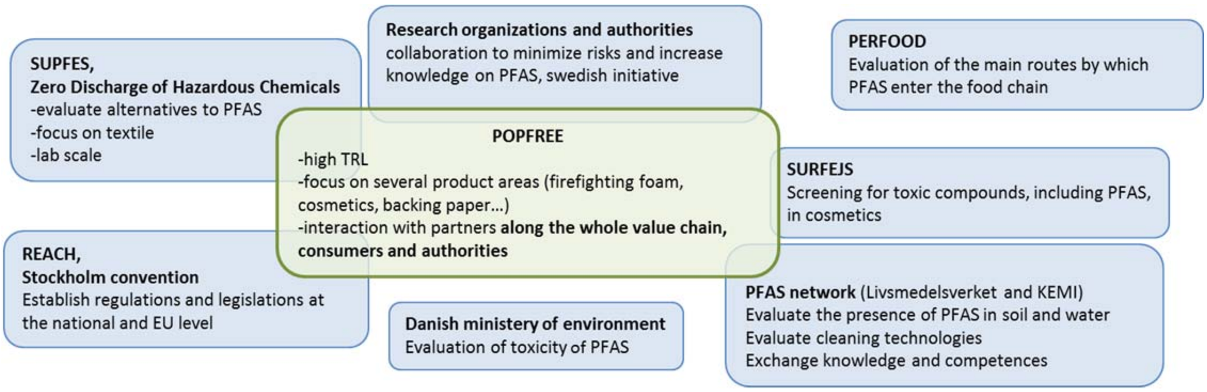

Figure1. Interaction of POPFREE with other initiatives.

Apart from these major initiatives, several research activities take place to map current use, search for alternatives, develop alternatives, to fill data gaps (especially regarding environmental and health aspects)[4] and standardize test methods.[5, 6] These research activities may be on product level or may study effects and occurrence of PFAS in the environment.[7] Some of these research activities take place in cooperation between scientist and authorities to

[4] www.supfes.eu
[5] Within EU standardization (CEN/TC248/WG26, EC restricted substances in textiles) there is an ongoing activity to develop a new EN analytical method for PFAS.
[6] http://icce2017.org/downloads/PFAS.pdf
https://www.bluetechresearch.com/reports/perfluoroalkyl-substances-pfas/
[7] http://www.tandfonline.com/doi/full/10.1080/10643389.2017.1326276 ; example on research coopertaion between Australia and the US regarding PFAS in for instance drinking water.

create scientific based decision support for governmental institutions.[8] For an overview of relevant activities in the close vicinity to POPFREE see Figure 1.

Non-fluorinated alternatives have made some gains in the marketplace, especially in textile treatments and firefighting foams. However, further gains for the non-fluorinated alternatives will be based on their ability to provide higher performance as well as on stricter regulatory policies that will not permit continued use of fluorinated chemicals in commerce.[9, 10, 11]

6. Associated relevant actors with the project

The constellation for the first stage of the project consisted of two research partners, RISE and Swerea IVF, and 7 industrial partners: Nordic Paper, Billerud Korsnäs, Organoclick, H&M, Paragon Nordic, Chemex and Dafo Fomtec (marked in bold in Appendix 3). All the partners have decided to continue in the second stage of the project, proposed POPFREE. The partners represented 5 different product cases: textile/leather, firefighting foam, paper/packaging for food contact, cosmetics and film-forming products. Therefore the focus during the first stage of the project was to extend the consortium with additional partners interested in these product cases. One additional case, ski wax, was also added to the project as this type of product has led to severe working environment issues for workers exposed to fluorinated waxes on a regular basis. Moreover, it is a typical example of a consumer product that directly leaks out in the environment during use and where a compromise on extreme performances could be acceptable for amateurs and, on the long term, elite skiers. For this specific case, new research partners have been involved in the project with expertise within ski wax and related evaluation methods.

Overall, the consortium was extended with partners along the whole value chain but interest varied in the different product categories depending on the current status of the substitution work and legislation as well as industrial and consumer awareness of the problem, as described in the different industry cases (Appendix 3 and 4). Suppliers used by a specific partner may provide knowledge, information, data and materials, and are thus important for the project. However, all these actors cannot be engaged as partners based on organisational reasons as they may be situated in remote places and because the number of partners would be too large as most of the end product manifacturers have many different suppliers. However,

[8] https://www.epa.gov/chemical-research/research-and-polyfluoroalkyl-substances-pfas
https://www.foedevarestyrelsen.dk/SiteCollectionDocuments/Kemi%20og%20foedevarekvalitet/FKM/Notat-graensevaerdiforslag-for-fluorstoffer-i-papir-og-pap-emballage-FINAL.pdf
EU/EES roadmap for PFAS towards EAP 2020
[9] www.epa.gov/oppt/pfoa/pubs/stewardship/index.html and www.epa.gov/oppt/existing chemicals/pubs/actionsplans/pfcs.html.
[10] http://www.ec.gc.ca/epe-epa/default.asp?lang=En&n=AE06B51E-1. http://www.ec.gc.ca/epe-epa/default.asp?lang=En&n=AE06B51E-1.
[11] http://www.ec.gc.ca/toxiques-toxics/Default.asp?lang=En&n=6B9B6B28-1&xml=F68CBFF1-B480-4348-903D-24DFF9D623DC.

the result of the project will result in the ability of these partners to set relevant requirements and have fruitful dialoges and collaborations with their suppliers.

Several authorities (KemI (Swedish Chemicals Agency), National Food Agency, UBA (Umweltbundesamt)) and organizations (Naturskyddsföreningen) have now been joining the project as partners or as part of the reference group. This will facilitate communication to consumers, but also the dialog about regulations.

Interactions between partners during the first stage of the project have been positive and many actors see a strong potential in interdisciplinary collaborations to identify new solutions or technologies to solve their substitution problems. This can lead to a faster development of PFAS free alternatives and products with a high level of innovation, and by a joint effort, a stronger impact can be made for implementation of feasible regulations.

7. Draft agreements that govern intellectual property rights and ensure exploitation

A draft of a consortium agreement based on previous agreements for this type of projects has been established by the legal department of RISE. The draft has been circulated within the consortium to get an initial feed-back from all partners before submission of the Step 2 application (end of August). An updated version will be presented to the consortium and final negotiations initiated as soon as next step of the project has been approved. The aim is to get the agreement in place within 2 months after the start of the project.

8. Learning and failure recovery

Overall the project has been successful and generated a very strong interest so far. A few changes have been made to the original project plan; for instance the second workshop planned to gather actors from branches that were not initially represented within the project was replaced by individual meetings with original and new partners. This change was made as it was decided that the scope of the project was already broad enough and thus there was no need to involve additional sectors. The identified important ski wax that was added at an early stage and successfully engaged via a webinar with clear focus rather then a general WS. Moreover, individual interviews were crucial to clearly identify needs and interests from the partners as well as potential collaborators or competitors.

One challenge within the project was – and will continue to be – communication, as several partners have clearly expressed a hesitance for publicly showing their participation of the project. For several of them who currently have a strong green environmental profile, being associated to PFAS could severely damage their image and potentially lead to loss in market shares. Several partners commented on the name of the project. “POPFAS-Phasing out PFAS” had a negative connotation and it was perceived as presumed that partners currently had PFAS in their products. Thus, a new title was discussed during the final workshop and it was decided to change the project name to “POPFREE - Promotion of PFAS free alternatives”. Thus communication will have to be handled with care, and a clear communication strategy need to be established early in the stage 2 project.

9. Measurable results and deliverables

- A kick-off meeting and another workshop have been held within the project.
- Individual meetings/interviews have been performed with the 7 initial industrial partners from the consortium as well as with in-coming partners resulting in mapping of industry challenges and understanding of positions.
- A webinar was held for newly included Ski wax actors to create common ground and understanding of the PFAS challenges to be addressed (environmental impact, legal staus and technical performance).
- A pre-study has been conducted on a natural surfactant currently used in other type of application. Results from this study were presented to the consortium at the workshop.
- The consortium has been extended from 9 partners to more than 30 for the second stage of the project and new actors added to the reference group.
- A draft of a consortium agreement has been established by the legal department of RISE distributed to the consortium.
- 682 hours (370 h by women and 312 h by men) have been spent on the project.
- 45% women (8 women and 10 men) has worked actively in the project.

10. Appendices

Appendix 1: Definition of PFAS
Appendix 2 : Potential technical solutions to PFAS for evaluation in POPFREE
Appendix 3 : Overview consortium
Appendix 4 : Industry Case descriptions

Definition of Poly and perfluorinated alkyl substances (PFAS)

The fluorochemistry includes a wide variety of substances and polymers that at least contain one or more fluorine atoms that provide specific performance properties for a wide range of industrial and consumer uses[1].

The carbon–fluorine bond is very strong and the perfluoroalkyl moiety, $–C_nF_{2n+1}$, is characteristic for linear and branched fluoro chemicals that are described as per- and polyfluorinated chemicals, abbreviated PFAS, with the exception of cyclic PFAS that are characterized by the perfluoroalkyl moiety, $–C_nF_{2n}$ and polyfluorinated chemicals that don't contain any one or several monofluorinated moieties (e.g –CHF-) in the PFAS chain.

The PFAS chemistry represents a vast number of substances on chemical structures and technical performance[2].

The long and short chain PFAS terminology[3]
The Organisation for Economic Co-operation and Development (OECD) currently defines non-polymeric PFASs "long chain" as follows;

Perfluoroalkyl carboxylic acids (PFCAs) with eight carbons and greater (i.e. with 7 or more perfluorinated carbons) and, perfluoroalkane sulfonates (PFSAs) with six carbons and greater (i.e. with 6 or more perfluorinated carbons).

The ''long-chain'' definitions for PFCAs and PFSAs are different in number of C atoms because a PFSA (e.g. PFHxS, $C_6F_{13}SO_3H$) with a given number of carbons (6 in the example given) has a greater tendency to bioconcentrate and/or bioaccumulate than a PFCA with the same number of C atoms.

Although the OECD definition does not include perfluoroalkyl substances other than carboxylates and sulfonates, one may consider that a perfluoroalkyl chain with 7 or more C atoms, e.g., C_7F_{15}–, is, in any case considered as ''long''[4].

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[1] Handbook of Environmental Chemistry, Springer Verlag Vol 17, Editors: T.P. Knepper and F.T. Lange, Polyfluorinated Chemicals and Transformation Products, 2011, ISBN 978-3-642-21871-2.
[2] Buck et al. "Perfluoroalkyl and polyfluoroalkyl Substances in the Environment: Terminology, Classification and Origins", Integrated Environmental Assessment and Management, Vol 7, Number 4 – pp 513-541 (2011).
[3] http://www.oecd.org/chemicalsafety/portal-perfluorinated-chemicals/aboutpfass/
[4] Buck et al. "Perfluoroalkyl and polyfluoroalkyl Substances in the Environment: Terminology, Classification and Origins", Integrated Environmental Assessment and Management, Vol 7, Number 4 – pp 513-541 (2011).

Potential technical solutions to PFAS for evaluation in POPFREE

The role of flourinated compounds in products is often to provide a certain functionality, i.e. surface that is both water- and oil repellent and has a low surface energy, very level surface, rapid spreading of product, etc. Therefore we have focused and will continue in POPFREE on trying to find non-flourinated compounds or structures with the potential of fulfilling these criteria. We anticipate that one solution will not work for all applications or fulfil all functionality criteria, and therefore we need to have several alternatives and strategies ready. On the other hand, an existing alternative used in one sector may be applied as is, or after adaption, in other sectors. The main solutions we have identified and intend to investigate in this project are summarized below (confidential information). Both chemically and physically based solutions as well as formulation strategies are included. We will screen the physicochemical properties of the selected alternatives in order to find those fulfilling various functionality criteria and benchmark against relevant PFAS. Combinations of available alternatives may also increase performance, and can thus be part of the test matrix. In addition, to further scan the market and research society for potential solutions we will utilize the involved stakeholders' network, as well as a RISE innovation tool called Translucent Innovation.[1] This will allow us to search our network for available specific PFAS alternatives already tailored for a specific application, which may then be evaluated in the project.

a) Commercially available PFAS free alternatives with specific functionality

There are already on the market a number of PFAS free chemical alternatives, mainly based on hydrocarbons including waxes and dendritic/branched structures, silicons.[2] These are usually tailored for a specific function in different products and may not have been tested in other applications. An important role of the fluorinated tail of the PFAS is their oleofobicity. If the hydrophobic part of the surfactant could be selected so that it is not soluble in the oil of relevance for the product and, at the same time, not soluble in water, this might lead to acceptable product performance. We will search for commercially available surfactants of this kind in the project, using the concept of Hansens Solubility Parameters (HSP).

b) Tailored chemicals or chemical treatments for specific product performance

In the consortium we have a producer of PFAS free alternative textile and wood treatments, Organoclick, and Bim Kemi, producing chemicals for paper treatment. These actors will supply tailored solutions based on their current products for the project. These solutions can also be further adopted within the scope of the project.

c) Naturally occurring membrane proteins

We have identified a naturally occurring protein system that in combination with membrane lipids has exteremely interesting surface chemistry properties and has also established contact with a group at KI that has long experience and much knowledge about this protein. In a the pre-study conducted within POPFAS we obtained promising results and it is commercially

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[1] http://translucentinnovation.se/sv/translucent-innovation/
[2] UNEP/POPS/POPRC.12/INF/15

available today. Scale-up and production of a cheaper version will however be needed, and will be included up to small pilot scale in the stage 2 project.

d) Surface-modified particles

So-called Pickering-emulsions/foams can be formed using surface-treated nanoparticles instead of surfactants, and it is well known that such foams and emulsions are very stable. This route to fluorine free products will be investigated in the project together with AkzoNobel who will deliver a range of available particles. Furthermore, it is well known that structure in combination with chemistry give enhanced or suppressed wetting properties of a surface (e.g. superhydrophilic/superhydrophobic and in extreme case both), and thus, this strategy will be investigated for applications where this is needed.

e) Surfactants selected via the Surfactant Affinity Difference (SAD) concept for minimal emulsion stability

Another strategy that will be evaluated specifically where PFAS are included in the product for the formulation properties is selection of (normal, non-fluorinated) surfactants using the so-called Surfactant Affinity Difference (SAD) concept which RISE has many years' experience of using.

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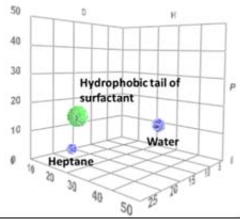
<td>
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f) Plasma

Plasma treatment is a method that can clean, activate or introduce chemicals in gas phase. Plasma is ionized gas and is sometimes called the fourth state of matter since it has unique chemical and physical properties that differ from solids, liquids and gases. It consists of a mixture of electrons, ions, radicals, excited neutral atoms and UV-radiation. When introduced to a surface, the surface itself will become activated for further chemical reaction (either via gas phase reaction or wet treatment).

There are two main processes for plasma, atmospheric plasma and vacuum plasma. It is easier to control the gas atmosphere in vacuum plasma than in atmospheric plasma equipment, which is open to the surrounding environment; on the other hand, atmospheric plasma is compatible with the continuous processing in for instance textile industry, which is an advantage. In the traditional wet chemical process the fabric is immersed in the chemical solution, thus the entire fabric is impregnated. By activating the surface with plasma treatment, the surface can be treated while the bulk remains unchanged. Plasma treatment modifies the surface chemically allowing stronger bonding (more prone to covalent bonding) between textile and finish, which enables reduction of chemicals.

Appendix 3

Actors in stage 1 in bold	Producers of chemicals and alternative solutions	Manufacturers of products using PFAS or alternatives, B2B	Manufacturers of consumer products	Consumers
Paper/packaging	**Organoclick** BIM Kemi AkzoNobel	**Nordic Paper** **Billerud Korsnäs**	COOP	
Textile/leather	**Organoclick** Deiner electronics	TPC **Paragon Nordic**	PEAK performance, Klättermusen, FMV, HH, Fristad, Mammut, Haglöfs, Starbucks, Icebug, Tesco, Sainsburys, **Paragon Nordic**	FIDRA
Cosmetics			**H&M**	**Naturskydds-föreningen**
Film forming products	AkzoNobel, KI, BIM Kemi	**Chemex**		
Ski wax	Deiner electronics **Organoclick**		RedCreek Swix	Vasaloppet, Peak Innovation
Fire foam	AkzoNobel, KI, BIM Kemi	**Dafo Fomtec**	**Dafo Fomtec**	
RTD performers	**RISE, Swerea IVF**, Mid Sweden University			
Reference group	**KemI**, National Food Agency, UBA, **Svenskt vatten, Stockholm University**			

Industry cases

The overall aim with POPFAS and the continuation in POPFREE is to create a transition in sectors using PFAS to feasible non-fluorinated alternatives. A number of industry sectors use PFAS, thus a number of different companies were involved in stage one. During stage one "POPFAS" challenges were identified related to the different selected sectors including the newly included sector ski wax. The challenges range from mismatch in function, criteria, and test methods, industry and/or consumer awareness of existing alternatives, to data gaps on for instance environmental and health impact. POPFREE aims at addressing these challenges. However, the approaches to addressing the challenges as well as the efforts required for transition from PFAS to non-PFAS use vary between the industrial sectors.

The POPFREE project workflow starts in a common position agreement, based in current research and industry knowledge. This is followed by mapping and selection of existing and emerging alternatives related to function. Adapting and optimizing the alternatives to match identified function criteria constitutes important parts. Also investigating and developing lab test methodologies for performance will take place. Finally environmental and health performance will be evaluated for fluorinated and predominantly for non-fluorinated alternatives.

The wide spread in branches enables cross sector innovation. Specific descriptions on proposed work in POPFREE are to be found below.

1 Paper

Background
The industrial need concerning grease resistant paper is to start phasing out PFAS as repellent agent. PFAS are used to impart fat and oil repellency to the paper and maintain a certain level of permeability to water vapor. In an effort to phase out PFAS, compromises might be needed on the performance of the paper. One strategy to achieve fat and oil repellency is by using physical barriers while compromising on water vapor permeability. Alternatively, PFAS could be substituted by other chemicals such as silicones or silanes; in that case water vapor permeability might be maintained but at the expense of performances on oil and fat repellency.

There are specific requirements entering the legal frameworks starting out with a recommendation for limit values by the Danish Food and Veterinary Administration (DK Food). These requirements are discussed and most likely to be applied on a European level in the near future. The Danish regulation may affect the market in the sense that not only PFAS will have to be substituted in finishing processes of papers, but also that the raw material and consumed water will have to be thoroughly analyzed for impurities from earlier treatments. This is in parity to the experiences from the initial Norwegian regulation of PFOA in textiles. In practice, both intentional and unintentional presence of PFAS may cause paper fail a test in relation to the requirements.

Challenges
- Impurity levels of upstream processes from these sources.

- Data gaps in information to both upstream actors and regulators on relevant levels for upcoming legislation.
- Data gaps in technical and environmental/health performance on non-fluorinated alternatives.
- Identification and evaluation of relevant alternatives to substitute PFAS, on lab scale and, if relevant, prototype.
- Public awareness of PFAS free options; for instance labeling options, education material for users.

Suggested scope

Within POPFREE, alternatives in use will be assessed in depth for health and environmental as well as technical performance. Within the scope, critical criteria will be discussed, but also communication towards end customer. In addition, mapping actions up-stream involving measure of potential impurities will be important input on cause-effect chains to regulating bodies for regulating unintentional addition of PFAS.

Partners

Within POPFREE, actors aiming for phase out and actors with PFAS already substituted are engaged. Manufacturers of chemical alternatives to PFAS will collaborate with paper producers that have already phased out, or are in the process of phasing out PFAS.

2 Textiles and leather

Background

The level of performance required in textiles and leather is highly dependent on the type of product and its intended end use and is built on different layers applied on the materials as well as on post- and re-impregnation, the latter often used by the end-consumer. Durable water repellence (DWR) is used for many garments provided currently by non fluorinated alternatives. In textiles and leather, PFAS (fluorotelomer acrylates and/or methacrylates or fluoro sulphonamidoacrylates and/or methacrylates) are today mainly used to provide oil, dirt and water repellency, so called DWOR (durable water and oil repellence). Today, long chain poly- and perfluorinated alkyl substances (PFAS) have primarily been phased out for most products on the market, though there are exemptions for high performing products such as extreme outdoor and protective equipment. Several short chain PFAS are, however, still applied to textile and leather products as replacements to “long chain” PFAS.

A range of specific and parallel requirements and consequently technical performances need to be fulfilled for many products like military equipment, personal protective equipment (PPE), upholstery and high-performance outdoor apparel and rainwear. For example a simultaneous requirement of durable DWOR and flame retardant properties, has proven to be challenging in the ambition to phase out PFAS. The technical performances must be met in substitution cases together with increased health and environment performance for chosen replacement chemicals. Moreover, the challenge is that such information regarding health and environmental aspects or even technical aspects may be missing or not publically available. Thus, retrieving, identifying or developing publically available technical performance data in combination with substance environmental and hazard information are critical to fill current data gaps and for creating valuable decision support in the substitution process.

Challenges

- Data gaps in technical and environmental/health performance on non-fluorinated alternatives.
- Compatibility between different specific and parallel requirements/material layers/chemical treatments.
- Public and industry awareness of fluorine free alternatives or how to choose a level of performance.
- Non-fluorinated alternatives do not provide high enough performance or fulfill security requirements (flame retardant/high visibility).

Suggested scope
In the project, one main goal is to identify and test relevant substitutes to PFAS containing products and treatments currently in use by appointed sectors. Novel technical solutions will be evaluated in impregnation products. The suggested treatments/products will be tested and evaluated for technical performance and environmental & health characteristics, using PFAS as benchmark. The technical performance will focus on targeting or developing relevant and specific technical criteria (water column, surface tension) and functionality testing (spray test, oil repellency, abrasion test and ageing tests) associated with the different product categories and their specific needs. The textile case will also include compatibility studies for different chemical treatments through studying underlying physical and chemical phenomena necessary for high level of performance, for example oil repellency and flame retardance). Environmental and health assessment will be performed using green screen methodology and LCA. To increase awareness and to further understand customer needs, surveys will be performed using the UK market via FIDRA. Communication with industrial and private end customers will be important to help consumers choose PFAS-free products when appropriate. Partners producing or using high performance textiles will continue to work with substitution of PFAS in their products, together with the project researchers, on the basis of existing and gained knowledge of performance and hazard characteristics of the identified alternatives. The outcome of the project will serve as a basis to set up relevant requirements and technical performance tests in communication with their suppliers.

Partners
In the case of textiles and leather, the project consists of partners representing public sector (military, PPE), retailer (high performing outdoor, work wear, footwear, hardware (for instance sleeping bags and backpacks)), material and fabric suppliers and suppliers of chemical products. The market is global, therefore partners and engaged suppliers will be Swedish and international.

3 Cosmetics

Background
The awareness of the presence of PFAS in cosmetics has recently increased and several brands and suppliers have started to phase out these chemicals. Studying content of a number of consumer products, have revealed that PFAS can be present in, for example, lip liner, eye shadow, concealer or foundation. The content screening was also made based on the European cosmetic ingredient database CosIng, which lists about a hundred PFAS.

Where PFAS such as perfluorodecalin or perfluorooctyl triethoxysilane have been intentionally added as ingredients, this occurred in small quantities. In some cases, PFAS come from ingredients purchased from suppliers higher up in the value chain. The intentions of adding PFAS in those cases are still unknown and as of today, it is not clear whether PFAS actually have a defined function in the final formulation of the product or if they are just a contamination from an earlier part of the manufacturing process. This question is even more relevant as several brands have in their range of products both PFAS-free and PFAS-containing alternatives within the same product category. When PFAS have been added intentionally, the reason has been to get a formulation with properties as for example improved adhesion to skin, silky feeling and better fastness to perspiration. Several organizations and distributors still claim that PFAS are not used in cosmetics.

Challenges

- Identification and evaluation of relevant alternatives to PFAS based on dialog with industrial actors from other branches.
- Establishment of a list of requirements for the suppliers of base formulation and ingredients based on current and upcoming legislation as well as health and environmental assessment.
- Communication towards consumers to help them select PFAS-free products.

Suggested scope

In the project, focus will be placed on communication with customers as well as with suppliers. Communication with customers will be important to help them choose PFAS-free products. On the supplier's side, it is important to educate and set up relevant requirements on the base formulation to ensure that no PFAS are used. Partners will also work with substitution work on their products and identification of relevant alternatives. For that purpose, a transdisciplinary dialog with other branches can be highly valuable.

Partners

In the case of cosmetics, the project consists of partners representing retailers as well as environmental organization.

4 Film forming products

Background

Film-forming products can be e g paints or protective coatings (e g anti-graffiti coatings or car care) and in these products fluorinated compounds can be present for two reasons. Either as so-called leveling agents, where their role is to assure that an absolutely flat surface is formed when the applied formulation dries on its substrate, or as an additive to make the film water-, oil- and dirt-repellent. Fluorinated surfactants and polymers (PFBS derivatives or fluortelomer derivatives) are currently used in these applications due to the low surface energy and oleophobicity of the fluorinated groups.

Challenges

- Find alternatives providing low surface energy and oleophobicity.

Suggested scope

Replacing fluorinated compounds in these types of products is a great challenge in itself, due to the very special chemistry of fluorine. In the project we will apply the different strategies aimed for in the project, based on both screening and evaluation of commercial PFAS-free chemical solutions, but also evaluate a new natural surfactant systems, as well as structure/chemistry combinations for e.g. oil- and dirt-repellence. Specific challenges will be to adapt the different strategies to the different products, e g incorporating a new (partly protein based) surfactant system or particles into a coating formulation (storage stability, denaturation of the protein, sedimentation or agglomeration of particles etc. may be complications), which will require a large amount formulation work as each solution/product will need a specific, tailor-made, formulation effort.

Partners
Manufacturers of potential alternatives to PFAS and producers of film forming products.

5 Firefighting foams

Background
One important use for PFAS is related to firefighting foams and involves different users, e.g. the municipal Fire and Rescue Services (FRS), the petroleum and chemical industry, airports, the military, and by the maritime and offshore sector. The most efficient foams used today are based on the use of various fluorochemicals, and are normally designated AFFF (Aqueous Film Forming Foam) or FFFP (Film Forming Fluoro Protein foams).

As a result of the environmental concern related to these foams, the foam industry have developed foam concentrates without fluorochemicals (PFAS) which are normally referred to as 3F (Fluorine Free Foam). However, there is currently a great concern about the efficiency compared to existing AFFF and FFFP and there are also practical problems for the users due to very high viscosities of the foam concentrates.

Challenges
- Performance level of fluorine free alternatives, for instance stability, surface tension and oleophobicity
- Practical issue in use phase, i.e. high viscosity of some fluorine free alternatives.
- Establishment of a list of requirements as a complement to existing standards identifying critical properties that is of importance for PFAS free foams.

Suggested scope
In the project, focus will on trying to develop a PFAS-free foam that provides similar firefighting efficiency as existing AFFF and FFFP foam, but with significantly reduced viscosity of the concentrate compared to 3F formulations. New strategies described as solutions to reduce surface tension and obtain oleophobic characteristics (lower fuel pick-up in the foam/lower risk of re-ignition of the foam after extinguishing the fire/longer burn-back times of the foam) will be evaluated. Most relevant for the firefighting foams will be the natural surfactant that have been identified, the particle-stabilized foams approach and formulating foams with a deliberate, built-in, low stability towards formation of fuel-in-water emulsions (using the SAD concept and/or any commercially available surfactants with "fuelophobic", but still hydrophobic, headgroups).

Evaluation of the new foam characteristics will be made using both non-fire-based in-house methods (present at Dafo Fomtec), small scale standardized test methods. First of all small scale standardized test methods, and (for the most promising candidates) large scale standardized fire tests will be performed.

Partners
Manufacturers of potential alternatives to PFAS and producers of firefighting foam.

6 Ski glider wax

Background
According to current research, friction between skis and snow consist of four components: Dry and wet sliding friction, snow compacting and impact resistance. Ski glider waxes are said to, alongside ski mechanics and ski base properties, play an important role in providing the optimal gliding properties for a ski in specific snow/weather conditions and type of use.

Ski bases are generally made of Ultra High Molecular Weight Polyethylene, UHMWPE. Additives and fillers are added to the base, and together with surface structure modification and well-chosen glider waxes as lubrication claimed to give situation-optimized gliding properties. Heat applied (”Iron-on”) glider waxes are widely used for both recreational skiing and competitive ski racing, available in various forms and formulations for different conditions and uses. Glider waxes are generally based on hydrocarbon paraffins (alkanes), with mixed-in additives giving additional properties. Important ingredients in many high-performance waxes are fluorine based chemicals (PFAS), applied in various amounts (0-100%). The fluorocarbons can improve water repellence, dry friction, dirt release and finishing properties for the waxed surface. Waxes are generally harder with longer chain hydrocarbons for cold weather, and softer/shorter chain for warm weather.

Challenges

- Definitions of glider performance in relation to other parameters, to allow effective comparison between different technologies.
- Development of glider testing methodology which offers results in line with practical use.
- Wet friction and water contact angle for non-fluorinated alternatives, hardness and dry friction against snow/ice crystals.
- Application process and surface bonding to the ski base
- Test methods that emulate skiing conditions well enough to give repeatable test results in real-life testing.
- Industrial and public awareness of non-fluorinated alternatives

Suggested scope
Main goal is to find appropriate gliding properties using alternative solutions to the fluorinated waxes or components therein, and make these available for further testing and development by industry partners. The main focus for the project is cross-country skiing (classic and skate), but results can also offer a good foundation for future development of alpine skiing glider waxes. One important aspect of the work is to suggest a definition of performance and a testing methodology that makes evaluation of different ski glider wax solutions more effective and repeatable than they are at present. Environmental and health properties of both PFAS-based and alternative solutions will be assessed according to the general project methodology. In the project is also included a communication effort to raise awareness of the risks and possibilities regarding ski glider wax choices among cross-country skiers and the wider public.

Partners
Two consumer-facing ski wax industry brands. A university with sports science specialization is involved for performance testing, together with a sports industry innovation actor (Vinnova VinnVäxt initiative) for coordination and industry communication. A big cross-country skiing event organizer is involved as public/consumer communication partner.

Definition of Poly and perfluorinated alkyl substances (PFAS)

The fluorochemistry includes a wide variety of substances and polymers that at least contain one or more fluorine atoms that provide specific performance properties for a wide range of industrial and consumer uses[1].

The carbon–fluorine bond is very strong and the perfluoroalkyl moiety, $–C_nF_{2n+1}$, is characteristic for linear and branched fluoro chemicals that are described as per- and polyfluorinated chemicals, abbreviated PFAS, with the exception of cyclic PFAS that are characterized by the perfluoroalkyl moiety, $–C_nF_{2n}$ and polyfluorinated chemicals that don't contain any one or several monofluorinated moieties (e.g –CHF-) in the PFAS chain.

The PFAS chemistry represents a vast number of substances on chemical structures and technical performance[2].

The long and short chain PFAS terminology[3]
The Organisation for Economic Co-operation and Development (OECD) currently defines non-polymeric PFASs "long chain" as follows;

Perfluoroalkyl carboxylic acids (PFCAs) with eight carbons and greater (i.e. with 7 or more perfluorinated carbons) and, perfluoroalkane sulfonates (PFSAs) with six carbons and greater (i.e. with 6 or more perfluorinated carbons).

The ''long-chain'' definitions for PFCAs and PFSAs are different in number of C atoms because a PFSA (e.g. PFHxS, $C_6F_{13}SO_3H$) with a given number of carbons (6 in the example given) has a greater tendency to bioconcentrate and/or bioaccumulate than a PFCA with the same number of C atoms.

Although the OECD definition does not include perfluoroalkyl substances other than carboxylates and sulfonates, one may consider that a perfluoroalkyl chain with 7 or more C atoms, e.g., C_7F_{15}–, is, in any case considered as ''long''[4].

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[1] Handbook of Environmental Chemistry, Springer Verlag Vol 17, Editors: T.P. Knepper and F.T. Lange, Polyfluorinated Chemicals and Transformation Products, 2011, ISBN 978-3-642-21871-2.
[2] Buck et al. "Perfluoroalkyl and polyfluoroalkyl Substances in the Environment: Terminology, Classification and Origins", Integrated Environmental Assessment and Management, Vol 7, Number 4 – pp 513-541 (2011).
[3] http://www.oecd.org/chemicalsafety/portal-perfluorinated-chemicals/aboutpfass/
[4] Buck et al. "Perfluoroalkyl and polyfluoroalkyl Substances in the Environment: Terminology, Classification and Origins", Integrated Environmental Assessment and Management, Vol 7, Number 4 – pp 513-541 (2011).

Potential technical solutions to PFAS for evaluation in POPFREE

The role of flourinated compounds in products is often to provide a certain functionality, i.e. surface that is both water- and oil repellent and has a low surface energy, very level surface, rapid spreading of product, etc. Therefore we have focused and will continue in POPFREE on trying to find non-flourinated compounds or structures with the potential of fulfilling these criteria. We anticipate that one solution will not work for all applications or fulfil all functionality criteria, and therefore we need to have several alternatives and strategies ready. On the other hand, an existing alternative used in one sector may be applied as is, or after adaption, in other sectors. The main solutions we have identified and intend to investigate in this project are summarized below (confidential information). Both chemically and physically based solutions as well as formulation strategies are included. We will screen the physicochemical properties of the selected alternatives in order to find those fulfilling various functionality criteria and benchmark against relevant PFAS. Combinations of available alternatives may also increase performance, and can thus be part of the test matrix. In addition, to further scan the market and research society for potential solutions we will utilize the involved stakeholders' network, as well as a RISE innovation tool called Translucent Innovation.[1] This will allow us to search our network for available specific PFAS alternatives already tailored for a specific application, which may then be evaluated in the project.

a) Commercially available PFAS free alternatives with specific functionality

There are already on the market a number of PFAS free chemical alternatives, mainly based on hydrocarbons including waxes and dendritic/branched structures, silicons.[2] These are usually tailored for a specific function in different products and may not have been tested in other applications. An important role of the fluorinated tail of the PFAS is their oleofobicity. If the hydrophobic part of the surfactant could be selected so that it is not soluble in the oil of relevance for the product and, at the same time, not soluble in water, this might lead to acceptable product performance. We will search for commercially available surfactants of this kind in the project, using the concept of Hansens Solubility Parameters (HSP).

b) Tailored chemicals or chemical treatments for specific product performance

In the consortium we have a producer of PFAS free alternative textile and wood treatments, Organoclick, and Bim Kemi, producing chemicals for paper treatment. These actors will supply tailored solutions based on their current products for the project. These solutions can also be further adopted within the scope of the project.

c) Naturally occurring membrane proteins

We have identified a naturally occurring protein system that in combination with membrane lipids has exteremely interesting surface chemistry properties and has also established contact with a group at KI that has long experience and much knowledge about this protein. In a the pre-study conducted within POPFAS we obtained promising results and it is commercially

[1] http://translucentinnovation.se/sv/translucent-innovation/
[2] UNEP/POPS/POPRC.12/INF/15

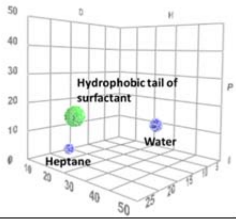
available today. Scale-up and production of a cheaper version will however be needed, and will be included up to small pilot scale in the stage 2 project.

d) Surface-modified particles

So-called Pickering-emulsions/foams can be formed using surface-treated nanoparticles instead of surfactants, and it is well known that such foams and emulsions are very stable. This route to fluorine free products will be investigated in the project together with AkzoNobel who will deliver a range of available particles. Furthermore, it is well known that structure in combination with chemistry give enhanced or suppressed wetting properties of a surface (e.g. superhydrophilic/superhydrophobic and in extreme case both), and thus, this strategy will be investigated for applications where this is needed.

e) Surfactants selected via the Surfactant Affinity Difference (SAD) concept for minimal emulsion stability

Another strategy that will be evaluated specifically where PFAS are included in the product for the formulation properties is selection of (normal, non-fluorinated) surfactants using the so-called Surfactant Affinity Difference (SAD) concept which RISE has many years' experience of using.




a)	**b)**	**d)**	**e)**

f) Plasma

Plasma treatment is a method that can clean, activate or introduce chemicals in gas phase. Plasma is ionized gas and is sometimes called the fourth state of matter since it has unique chemical and physical properties that differ from solids, liquids and gases. It consists of a mixture of electrons, ions, radicals, excited neutral atoms and UV-radiation. When introduced to a surface, the surface itself will become activated for further chemical reaction (either via gas phase reaction or wet treatment).

There are two main processes for plasma, atmospheric plasma and vacuum plasma. It is easier to control the gas atmosphere in vacuum plasma than in atmospheric plasma equipment, which is open to the surrounding environment; on the other hand, atmospheric plasma is compatible with the continuous processing in for instance textile industry, which is an advantage. In the traditional wet chemical process the fabric is immersed in the chemical solution, thus the entire fabric is impregnated. By activating the surface with plasma treatment, the surface can be treated while the bulk remains unchanged. Plasma treatment modifies the surface chemically allowing stronger bonding (more prone to covalent bonding) between textile and finish, which enables reduction of chemicals.

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Appendix 3

Actors in stage 1 in bold	Producers of chemicals and alternative solutions	Manufacturers of products using PFAS or alternatives, B2B	Manufacturers of consumer products	Consumers
Paper/packaging	**Organoclick** BIM Kemi AkzoNobel	**Nordic Paper** **Billerud Korsnäs**	COOP	
Textile/leather	**Organoclick** Deiner electronics	TPC **Paragon Nordic**	PEAK performance, Klättermusen, FMV, HH, Fristad, Mammut, Haglöfs, Starbucks, Icebug, Tesco, Sainsburys, **Paragon Nordic**	FIDRA
Cosmetics			**H&M**	**Naturskydds-föreningen**
Film forming products	AkzoNobel, KI, BIM Kemi	**Chemex**		
Ski wax	Deiner electronics **Organoclick**		RedCreek Swix	Vasaloppet, Peak Innovation
Fire foam	AkzoNobel, KI, BIM Kemi	**Dafo Fomtec**	**Dafo Fomtec**	
RTD performers	**RISE, Swerea IVF**, Mid Sweden University			
Reference group	**KemI**, National Food Agency, UBA, **Svenskt vatten, Stockholm University**			

Industry cases

The overall aim with POPFAS and the continuation in POPFREE is to create a transition in sectors using PFAS to feasible non-fluorinated alternatives. A number of industry sectors use PFAS, thus a number of different companies were involved in stage one. During stage one "POPFAS" challenges were identified related to the different selected sectors including the newly included sector ski wax. The challenges range from mismatch in function, criteria, and test methods, industry and/or consumer awareness of existing alternatives, to data gaps on for instance environmental and health impact. POPFREE aims at addressing these challenges. However, the approaches to addressing the challenges as well as the efforts required for transition from PFAS to non-PFAS use vary between the industrial sectors.

The POPFREE project workflow starts in a common position agreement, based in current research and industry knowledge. This is followed by mapping and selection of existing and emerging alternatives related to function. Adapting and optimizing the alternatives to match identified function criteria constitutes important parts. Also investigating and developing lab test methodologies for performance will take place. Finally environmental and health performance will be evaluated for fluorinated and predominantly for non-fluorinated alternatives.

The wide spread in branches enables cross sector innovation. Specific descriptions on proposed work in POPFREE are to be found below.

1 Paper

Background
The industrial need concerning grease resistant paper is to start phasing out PFAS as repellent agent. PFAS are used to impart fat and oil repellency to the paper and maintain a certain level of permeability to water vapor. In an effort to phase out PFAS, compromises might be needed on the performance of the paper. One strategy to achieve fat and oil repellency is by using physical barriers while compromising on water vapor permeability. Alternatively, PFAS could be substituted by other chemicals such as silicones or silanes; in that case water vapor permeability might be maintained but at the expense of performances on oil and fat repellency.

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Challenges

- Impurity levels of upstream processes from these sources.

- Data gaps in information to both upstream actors and regulators on relevant levels for upcoming legislation.
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- Identification and evaluation of relevant alternatives to substitute PFAS, on lab scale and, if relevant, prototype.
- Public awareness of PFAS free options; for instance labeling options, education material for users.

Suggested scope

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Partners

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Challenges

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- Public and industry awareness of fluorine free alternatives or how to choose a level of performance.
- Non-fluorinated alternatives do not provide high enough performance or fulfill security requirements (flame retardant/high visibility).

Suggested scope
In the project, one main goal is to identify and test relevant substitutes to PFAS containing products and treatments currently in use by appointed sectors. Novel technical solutions will be evaluated in impregnation products. The suggested treatments/products will be tested and evaluated for technical performance and environmental & health characteristics, using PFAS as benchmark. The technical performance will focus on targeting or developing relevant and specific technical criteria (water column, surface tension) and functionality testing (spray test, oil repellency, abrasion test and ageing tests) associated with the different product categories and their specific needs. The textile case will also include compatibility studies for different chemical treatments through studying underlying physical and chemical phenomena necessary for high level of performance, for example oil repellency and flame retardance). Environmental and health assessment will be performed using green screen methodology and LCA. To increase awareness and to further understand customer needs, surveys will be performed using the UK market via FIDRA. Communication with industrial and private end customers will be important to help consumers choose PFAS-free products when appropriate. Partners producing or using high performance textiles will continue to work with substitution of PFAS in their products, together with the project researchers, on the basis of existing and gained knowledge of performance and hazard characteristics of the identified alternatives. The outcome of the project will serve as a basis to set up relevant requirements and technical performance tests in communication with their suppliers.

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Challenges

- Identification and evaluation of relevant alternatives to PFAS based on dialog with industrial actors from other branches.
- Establishment of a list of requirements for the suppliers of base formulation and ingredients based on current and upcoming legislation as well as health and environmental assessment.
- Communication towards consumers to help them select PFAS-free products.

Suggested scope

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Challenges

- Find alternatives providing low surface energy and oleophobicity.

Suggested scope

Replacing fluorinated compounds in these types of products is a great challenge in itself, due to the very special chemistry of fluorine. In the project we will apply the different strategies aimed for in the project, based on both screening and evaluation of commercial PFAS-free chemical solutions, but also evaluate a new natural surfactant systems, as well as structure/chemistry combinations for e.g. oil- and dirt-repellence. Specific challenges will be to adapt the different strategies to the different products, e g incorporating a new (partly protein based) surfactant system or particles into a coating formulation (storage stability, denaturation of the protein, sedimentation or agglomeration of particles etc. may be complications), which will require a large amount formulation work as each solution/product will need a specific, tailor-made, formulation effort.

Partners
Manufacturers of potential alternatives to PFAS and producers of film forming products.

5 Firefighting foams

Background
One important use for PFAS is related to firefighting foams and involves different users, e.g. the municipal Fire and Rescue Services (FRS), the petroleum and chemical industry, airports, the military, and by the maritime and offshore sector. The most efficient foams used today are based on the use of various fluorochemicals, and are normally designated AFFF (Aqueous Film Forming Foam) or FFFP (Film Forming Fluoro Protein foams).

As a result of the environmental concern related to these foams, the foam industry have developed foam concentrates without fluorochemicals (PFAS) which are normally referred to as 3F (Fluorine Free Foam). However, there is currently a great concern about the efficiency compared to existing AFFF and FFFP and there are also practical problems for the users due to very high viscosities of the foam concentrates.

Challenges
- Performance level of fluorine free alternatives, for instance stability, surface tension and oleophobicity
- Practical issue in use phase, i.e. high viscosity of some fluorine free alternatives.
- Establishment of a list of requirements as a complement to existing standards identifying critical properties that is of importance for PFAS free foams.

Suggested scope
In the project, focus will on trying to develop a PFAS-free foam that provides similar firefighting efficiency as existing AFFF and FFFP foam, but with significantly reduced viscosity of the concentrate compared to 3F formulations. New strategies described as solutions to reduce surface tension and obtain oleophobic characteristics (lower fuel pick-up in the foam/lower risk of re-ignition of the foam after extinguishing the fire/longer burn-back times of the foam) will be evaluated. Most relevant for the firefighting foams will be the natural surfactant that have been identified, the particle-stabilized foams approach and formulating foams with a deliberate, built-in, low stability towards formation of fuel-in-water emulsions (using the SAD concept and/or any commercially available surfactants with "fuelophobic", but still hydrophobic, headgroups).

Evaluation of the new foam characteristics will be made using both non-fire-based in-house methods (present at Dafo Fomtec), small scale standardized test methods. First of all small scale standardized test methods, and (for the most promising candidates) large scale standardized fire tests will be performed.

Partners
Manufacturers of potential alternatives to PFAS and producers of firefighting foam.

6 Ski glider wax

Background

According to current research, friction between skis and snow consist of four components: Dry and wet sliding friction, snow compacting and impact resistance. Ski glider waxes are said to, alongside ski mechanics and ski base properties, play an important role in providing the optimal gliding properties for a ski in specific snow/weather conditions and type of use.

Ski bases are generally made of Ultra High Molecular Weight Polyethylene, UHMWPE. Additives and fillers are added to the base, and together with surface structure modification and well-chosen glider waxes as lubrication claimed to give situation-optimized gliding properties. Heat applied (”Iron-on”) glider waxes are widely used for both recreational skiing and competitive ski racing, available in various forms and formulations for different conditions and uses. Glider waxes are generally based on hydrocarbon paraffins (alkanes), with mixed-in additives giving additional properties. Important ingredients in many high-performance waxes are fluorine based chemicals (PFAS), applied in various amounts (0-100%). The fluorocarbons can improve water repellence, dry friction, dirt release and finishing properties for the waxed surface. Waxes are generally harder with longer chain hydrocarbons for cold weather, and softer/shorter chain for warm weather.

Challenges

- Definitions of glider performance in relation to other parameters, to allow effective comparison between different technologies.
- Development of glider testing methodology which offers results in line with practical use.
- Wet friction and water contact angle for non-fluorinated alternatives, hardness and dry friction against snow/ice crystals.
- Application process and surface bonding to the ski base
- Test methods that emulate skiing conditions well enough to give repeatable test results in real-life testing.
- Industrial and public awareness of non-fluorinated alternatives

Suggested scope

Main goal is to find appropriate gliding properties using alternative solutions to the fluorinated waxes or components therein, and make these available for further testing and development by industry partners. The main focus for the project is cross-country skiing (classic and skate), but results can also offer a good foundation for future development of alpine skiing glider waxes. One important aspect of the work is to suggest a definition of performance and a testing methodology that makes evaluation of different ski glider wax solutions more effective and repeatable than they are at present. Environmental and health properties of both PFAS-based and alternative solutions will be assessed according to the general project methodology. In the project is also included a communication effort to raise awareness of the risks and possibilities regarding ski glider wax choices among cross-country skiers and the wider public.

Partners

Two consumer-facing ski wax industry brands. A university with sports science specialization is involved for performance testing, together with a sports industry innovation actor (Vinnova VinnVäxt initiative) for coordination and industry communication. A big cross-country skiing event organizer is involved as public/consumer communication partner.