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Tracking systems for hazardous chemicals in the textile industry supply chain

An interview study of Swedish clothing companies regarding PFAS

Master's thesis in Industrial Ecology

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Abstract

The textile industry includes many actors which has resulted in a problem with transparency regarding hazardous substances through the whole supply chain. It is also difficult to know if the information is correct since there is a lack of regulatory authorities. A tracking system is defined in this thesis as a system that is used by the whole industry and that controls the product from the first step in the supply chain. Per- and Polyfluoroalkyl Substances are a group of hazardous chemicals that are used as water- and soil repellents in the textile industry, which have been found to be harmful to both humans and nature. The aim of this thesis is to analyze how clothing companies work with tracking systems to ensure that their products do not contain any hazardous substances. The tracking systems included in the analysis are Digital Product Passport and Radio Frequency Identification. These two tracking systems were chosen based on a literature study where these systems theoretically showed good potential to be implemented in the textile industry. Digital Product Passport is also discussed on the EU level in the Sustainable Products Initiative. Per- and Polyfluoroalkyl Substances are included as examples of hazardous chemicals which should be covered by tracing systems. Semi-structured interviews were conducted with nine Swedish clothing companies and four organizations. The results indicate that there is a large variation in how companies track chemicals in their products. Most of the companies are using systems they have created themselves, such as regulated substances lists, and laboratory tests of the final product. Frequent communication with suppliers and manufacturers as well as certification systems were other important elements in companies' tracking systems. The main differences between these systems are that some are controlled by a third party while others are not. The advantage of the systems is that companies are mapping and testing materials and components in the products. However, one disadvantage is that companies are using different systems and that regulatory authorities are not involved. These systems can be effective for individual companies as they believe they have control. But there are still challenges related to the lack of standardization which makes it difficult to compare products and this results in decreased credibility. Based on the results, the recommendation is to implement regulation of all components in the product and not only the final product. The results indicate that it is theoretically possible to use Digital Product Passport as a tracking system to track the chemical content through the supply chain. However, there are still challenges related to the practical implementation of this tracking systems. Therefore, the recommendation based on this study is to implement a regulation on the EU level which would affect all companies within the EU as well as manufacturers outside the EU.

Keywords: Per- and Polyfluoroalkyl Substances, Digital Product Passport, Radio Frequency Identification, Textile industry

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Emma Andersson

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Abbreviations

DPP - Digital Product Passport

ECHA - European Chemical Agency

e-TAG - e-Textile Attached Gadgets

EPC - Electronic Product Code

PFAS - Per- and Polyfluoroalkyl Substances

POP - Persistent Organic Pollutant

RFID - Radio Frequency Identification

REACH - Registration, Evaluation, Authorisation, and restriction of Chemicals

SVHC - Substances of Very High Concern

SCIP - Substances of Concern In articles as such or in complex objectives (Products)

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1. Introduction

A product's life cycle consists of many different phases where different actors are responsible (Kogg 2009). Supply chain management is about coordinating and connecting different activities of different functions throughout the whole supply chain (Canel-Depitre, Taghipour & Vosooghidizaji 2019). However, the lack of transparency and information asymmetry have made supply chains untraceable through all suppliers and sub-suppliers (Agrawal 2019). Some examples of reasons why the information gap exists are because tracking chemicals is a voluntary measure for companies, there is no inexpensive technology for collecting information, lack of international tracking rules, and a lack of knowledge about the benefits of international standardized chemical tracking systems. It is important that all actors within the supply chain exchange information with each other regarding used chemicals (Brunklaus et al. 2013). Through better control throughout the whole supply chain, the environmental impact can be reduced (Kogg 2009). The environmental impact can also be reduced by reducing the number of actors in the supply chain, which leads to increased cooperation and insight into each phase. To improve the situation, communication among stakeholders needs to be improved (Dahlbo et al. 2020). The concern about lack of information and transparency has led to initiatives from both authorities and companies (Fransson 2012) such as the European Green Deal (European Commission 2021).

The textile industry is the second-largest industrial polluter (Dahlbo et al. 2020) and the major concerns regarding the textile industry are the complex supply chain and the high number of involved actors dealing with operations and raw materials (Agrawal et al. 2017). To create a more sustainable textile industry, all actors in the supply chain need to participate and together create a tracking system to create more sustainable processes. To be able to increase the opportunity of tracking, transparency is needed. It is also important to implement regulatory informational controls so that complete and correct information is used (Asford & Koch 2006). To achieve an international tracking system for chemicals, communication among stakeholders needs to be improved to decrease the asymmetric information (Dahlbo et al. 2020).

Over 15,000 different chemicals are used during the manufacturing process within the textile industry (Dahlbo et al. 2020) and the large use of different chemicals increases the importance of transparency and communication through the whole supply chain (Fransson & Molander 2012). Chemicals can be used to provide clothes with specific properties, such as water- and soil repellent (Brunklaus et al. 2013). Different synthetic chemicals are currently used due to their advantageous properties (Fransson 2012). The use of synthetic chemicals is increasing and therefore it is important to consider the negative effects that the usage entails. The risks that arise with the use of chemicals occur in different parts of the supply chain and since many supply chains have actors spread across different countries, the management of chemical risk is therefore more difficult. The problem of chemical risk management is partly due to the lack of information through the supply chain.

One group of hazardous chemicals that is used within the textile industry are *Per- and Polyfluoroalkyl substances* (PFAS)(Chemsec 2021a). PFAS is a group of substances that are used in many types of products, such as in outerwear due to its water- and soil-repellent properties. Common for all PFAS substances is that they are hazardous for both humans and nature and they cannot be broken down in nature, they are also synthetical chemicals (Kemikalieinspektionen n.d). The group of substances is therefore called `forever chemicals´. Some of the 4700 (Cousins et al. 2020) different PFAS substances are banned in the EU (The Swedish Chemical Society 2021) but this has not prevented companies from using other PFAS substances with similar properties instead (Cousins et al. 2021). PFAS has high mobility and is transported in water, and they are also bioaccumulative and cancerogenic. Even though the use of PFAS is known, it is not as clear what type of PFAS is used in different products and how much products contain. This type of insecurity affects the whole supply chain management.

1.1 Purpose and research questions

The thesis aims to analyze how clothing companies work with tracking systems in order to ensure that their products do not contain any hazardous substances. The following research questions will be answered:

- What tracking systems for hazardous chemicals are used by companies in the textile industry?
- What are the main elements and differences of these tracking systems?
- What are the perceived advantages/ disadvantages of using these systems?
- How effective are those systems in terms of reducing hazardous chemicals?

The thesis will hopefully inform how to use tracking systems to phase out and track hazardous chemicals. In the future, this may contribute to the industry avoiding hazardous chemicals throughout the supply chain to decrease the negative environmental- and health effects.

1.2 Disposition of the report

This thesis includes an introduction of the chemical used in the textile industry, methodology, background to the topic, interview results, discussion including methodology limitations, and further research and conclusions. In addition, there is also a reference list and appendix including interview questions.

The first section of the thesis includes an introduction of the problems with chemical use in the textile industry, the aim of the study is also presented. The next section presents methods and data used in the literature study including limitations for the study. The theoretical problem description presents three main chapters where the first one is related to the main problem regarding chemicals in the textile industry with a focus on PFAS, as well as the chemical information flow in the supply chain. Further regulation initiatives are presented which are used for enhanced information in the textile industry. Theoretical description of tracking systems is presented with a focus on Digital Product Passport and Radio Frequency Identification. The result is presented in two chapters, where results from companies are

presented in the first one, followed by results related to organizations. The results are presented through tables where all interviews are summarized as well as in text and complemented with relevant quotes. The discussion is based on the results to be able to get a broader perspective and to reach a conclusion. It also includes a critical discussion about the methodology that is used in the study and thoughts about further research. The report ends with conclusions including recommendations for the future, a reference list, and appendixes.

2. Method and data

This thesis is mainly based on qualitative research where the empirical data is supported by a literature study. The qualitative research is done by an interview study with nine clothing companies and four organizations. The interviewed companies can be seen in Appendix 1 and the interviewed organizations can be seen in Appendix 2.

2.1 Literature study

Initially, a literature study was done to gain more knowledge about different types of tracking systems and PFAS. Literature regarding the problematic situation with information flow, such as asymmetric information in the textile industry was also studied. Different initiatives and regulations were studied to gather information on what is currently done, related to PFAS, and what impact tracking systems could have in the transformation. One important part of studying existing literature early in the process is to gain better knowledge of the background topic, which can be used to set limitations (Bell, Bryman & Harley 2019). Interview methodology was studied to prepare for the interviews. Information and literature were mainly provided from reports related to the subject and institutes such as the European Chemical Agency. Articles were mainly found on the Chalmers Library database, Google Scholar, and from our supervisor and examiner.

2.2 Case study

From discussions with the supervisor and examiner, the collection of data was decided to be collected through interviews. A semi-structured interview methodology was chosen, which allows room for reflection (Essiasson et al. 2010). The methodology was also chosen to be able to have an open mind and see relations between data and theories (Bell, Bryman & Harley 2019). This could give a broader perspective on the market situation. The interview questions were discussed and rewritten several times to fit the different interviewees' situations. All companies in the study were overall asked the same questions to be able to compare the different answers. Some interview questions were not asked for everyone as it was not relevant for all interviews. Interview questions that were asked to companies can be seen in Appendix 3. Interview questions for the organizations can be found in Appendix 4- Appendix 7.

2.2.1 Interview study

Initially, the data was planned to be collected only from interviews with companies. During the process and inspiration from webinars, research, and by talking to organizations and persons with greater knowledge in the topic, it was decided to collect data from companies as well as organizations. The interviews with organizations provided a wider perspective. It has been challenging to contact companies and organizations to interview since some have not responded. To find relevant companies, research was done to gather information about companies who sell water- and soil-repellent clothes. These companies were contacted by email or LinkedIn and all companies that were willing to participate in the study were interviewed. To find organizations, research was done and those who were working with

relevant questions were asked to participate. To get as many interviews as possible, those who were available were selected to be a part of the study according to the convenience method (Trost 2010). However, only relevant companies were chosen to be contacted, but of those considered reasonable, all were asked to participate. This has been a successful method as it provided a wide range of different companies and thus different perspectives in the industry. Recommendations of persons to contact for interviews were received from a professor at the Chalmers University of Technology. Nine companies and four organizations have been interviewed.

The interviews were done by a digital meeting or by email. Due to the Covid-19 pandemic, no interviews were via physical meetings. It can be argued that email interviews do not generate the same amount and depth of data, and therefore digital meetings were preferred. Data received by email made it possible to collect data from a larger number of interviewees which was seen as an advantage in the study. The online interviews were done via Zoom and Microsoft Teams. All interviewees allowed the interview to be recorded, and the interviews were transcribed. All recorded meetings are saved until December 31st, 2021, and then deleted, according to the General Data Protection Regulation (GDPR). By recording the interview no information was missed and both interviewers could listen actively and ask questions as well as follow up questions. The interviewees had time to talk without any interruptions. The data received from the interviews were compiled and then sent to the interviewees for review and approval before it was used in the report. In the review the interviewee had the chance to comment, change, add or remove data. All participants have agreed to participate in the study and no personal data is obtained, which can be considered in line with the ethics of the research (Vetenskapsrådet 2002).

Overall, the data collected gave a good overview of the situation and the industry. More data should give a broader perspective of the whole industry. Similarities in data collected were noticed. Similarities in data where certain answers are frequently answered may indicate that these reflect the industry situation (Flick 2009).

2.2.2 Treatment of empirical data

All empirical data was collected from the interviews. The interviews that were done through a digital meeting were transcribed manually. From the transcription parts, data needs to be broken down and compared with the other interviews (Bell, Bryman & Harley 2019). This is done to see similarities and differences in the answers. Further, this will make the narrowed-down empirical data easier to manage and analyze (Trost 2010). The result was summarized into short answers in tables related to different topics, such as PFAS and tracking systems. This made it easier to analyze and see all answers from the companies related to the different questions. For further use of the empirical data, quotes from the interviewees were presented. The quotes were chosen to present the most important parts from all interviews as well as to give a better overview of the situation in the industry. The results from companies are presented in section 6 and the results from organizations are presented in section 7. In section 6, all results are presented in tables and complemented with quotes, where all quotes are presented

anonymously, and it is not presented which company stated each quote. In section 7 results are presented in text format and complemented with relevant quotes. It can be seen which organizations mentioned the quote and the organizations received different questions related to their work. Results from the study were discussed with the International Chemical Secretariat (Chemsec), to get a broader perspective of our results. The results and quotes were further discussed in section 8 where further reflections were made, related to the answers and the research questions.

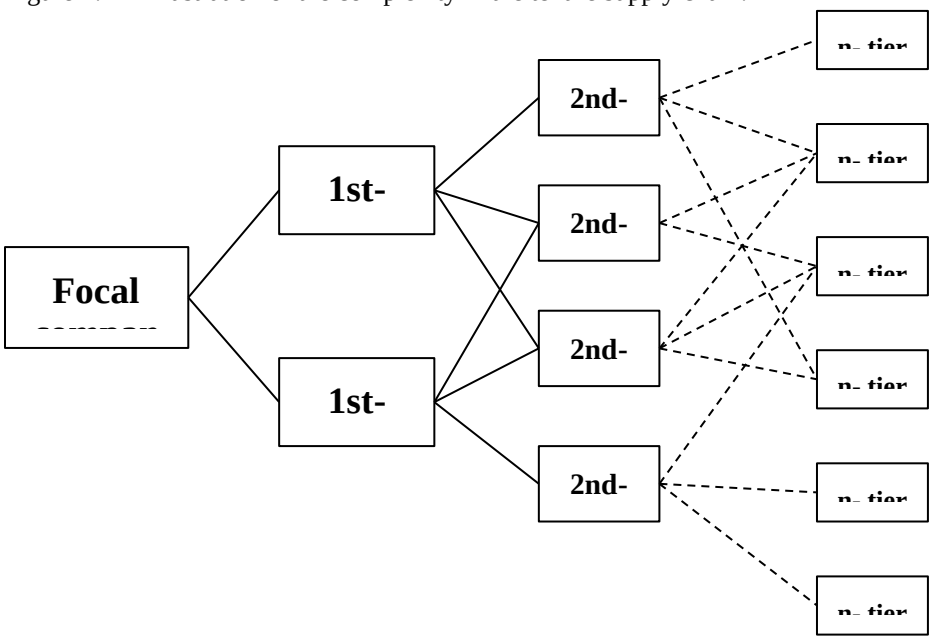
2.3 Limitations

The study only includes clothing companies that sell water- and soil-resistant clothes that are established on the Swedish market. The companies sell different types of clothes such as workwear, fast fashion, and outerwear. The study also includes relevant organizations that contribute with their thoughts about the situation in the industry. The report focuses on tracking systems that can be used to track hazardous chemicals, with an extra focus on PFAS, within the textile industry. The tracking systems that will be highlighted are electronic tags focusing on *Radio Frequency Identification* (RFID) and the use of *Digital Product Passports* (DPP). These tracking systems were chosen based on literature study. The literature study showed that DPP and RFID have good potential to be implemented in the textile industry, at least theoretically. DPP is also discussed on the EU level in the context of Sustainable Products Initiatives (Adisorn, Götz & Tholen 2021). Initially, the report is descriptive rather than prospective, where the situation in the industry will be presented. Then, from the results and related theory, a more prospective attribute will be presented. A proposal for how tracking systems could be implemented in the textile industry as well as the solutions for implementing it are presented.

3. Managing of chemicals in the textile supply chain

A supply chain is a system of all people, techniques, resources, organizations, and activities that are involved in producing a product (Brunklaus et al. 2013). The textile industry has a complex and extensive supply chain (Muthu 2017). A product goes through many different processes to achieve its final properties. Supply chain management can be described as the management of all actors through the supply chain. The complexity of the textile supply chain is illustrated in Figure 1. It can be seen in Figure 1 that the focal company has a relationship with many different suppliers. At the very end of the supply chain is the customers who have contact with the focal company. The focal company is the company that designs and manages all decisions regarding the final product. There are only some companies that are managing their manufacturing process. Instead, they are using suppliers and sub-suppliers (Boström & Börjeson 2018). The complexity in the textile industry arises due to a high number of suppliers and sub-suppliers that are scattered globally (Boström & Börjeson 2018) and because the textile production is in countries with less stringent environmental standards (Fransson & Molander 2012). By the sourcing strategy, focal companies are limiting their control over suppliers, and therefore also over the whole supply chain. It can be problematic for downstream manufacturers to know what the process exactly looks like. For example, it can be difficult to know where all the raw material comes from. The different steps in the process of the garment are often taking place in different countries, which makes the situation even more complex.

Figure 1: An illustration of the complexity in the textile supply chain.



Source: Inspired by Kogg (2009)

The textile industry is one of the oldest industries and clothes are representing a major part of the total consumer products (Fransson & Molander 2012). The environmental impact of the textile industry is critical, and it is continuously growing (Dahlbo et al. 2020). Since the industry is continuously growing, the textile industry is seen as one of the biggest threats to the environment (Ahamad et al. 2018). Textile production is seen as chemical-intensive since it

includes several environmentally unwanted chemicals (Ahmad et al. 2018) and chemicals are used within several manufacturing processes (Dahlbo et al. 2020). Chemicals used in textiles can cause negative effects for both the environment and the health of humans (Kemikalieinspektionen 2019). Many different chemicals are used to give clothes specific properties (Fransson & Molander 2012). The chemical risk cannot be solved within national borders and the risks are complex and disperse across both time and space (Boström & Börjeson 2018).

Today, different certifications are used within the textile supply chain to show and verify environmental efforts (Golden 2010). Certifications can have different focuses; some can have a focus on social aspects while others have a focus on the use of chemicals in the supply chain. But just because a product has a certain certification does not mean that the whole product is certified, the certification can apply to certain components in the product. One well-used and most successful consumer safety and health certification in the textile industry is the OEKO-TEX® Standard. The aim of the OEKO-TEX® Standard is to ensure that products do not contain hazardous chemicals that are unhealthy for consumers, and this is controlled by yearly laboratory tests on all components that are included in the product (OEKO-TEX® n.d). The test criteria that apply to OEKO-TEX® are standardized worldwide. OEKO-TEX® has stricter requirements than many laws and regulations to reduce the use of hazardous chemicals in textiles (Golden 2010). Another certification that is used in the textile industry is Bluesign® which focuses on the use of chemicals in products (Bach et al. 2021). Bluesign® includes a network of chemical suppliers, brands and manufacturers governed by the Bluesign® criteria. The certification is based on measures through the whole supply chain, and it tracks textiles through the manufacturing process. The final product can only be labeled as a Bluesign® product if a minimum of 30% of the used accessories and if a minimum of 90% of the used textile are Bluesign® approved. Bluesign® includes a substance list that indicates what chemicals can be used and cannot be used in products, the certification can approve both the whole product and specific components or chemicals in the product (Bluesign Technologies AG 2022).

3.1 PFAS in the textile industry

PFAS is a synthetic group of substances (European Environment Agency 2021) and has been used for a long time within the textile industry (Cousins et al. 2021). Its negative effects on the environment and the health of humans have led to the regulation of some PFAS substances, but this has not hindered the industry to use non-regulated PFAS substances instead. Therefore, PFAS can still be found in several products, such as clothes. Due to the problem of transparency, it is difficult to know what type of PFAS substances is used and how much PFAS specific products contain. The use and production of PFAS have resulted in contaminated water resources as it accumulates over time (European Environment Agency 2021). Today, there is pressure from the public to stop the use of hazardous chemicals and this has resulted in many companies have stopped using PFAS (Cousines et al. 2021) such as some clothing companies. As clothes are used close to the body, the negative effects of PFAS have been highlighted in the textile industry. PFAS substances can be used to give clothes specific properties, such as

being water- and soil repellent. (Blackburn et al. 2017). This is especially important when it comes to clothing with essential protection. The negative effects of PFAS have highlighted the importance of finding a substitute to be able to keep producing clothes with high functionality.

3.2 Chemical information flow through the supply chain

During the last decades, there has been rapid development in collecting and monitoring information in the textile industry (Benzie et al. 2019), but various factors affect future development. One factor is the size of the system and since many supply chains are spread all over the world, this is a major problem. Another factor is the division of responsibilities. To find a functioning system, that both collects information and controls the information, would require commitments from all actors in the supply chain and authorities that regulate them.

The textile industry supply chain is global and complex and therefore it is important to exchange information through the whole chain (Brunklaus et al. 2013). The flow of information is related to flows of money and products (Brunklaus et al. 2013) and information exchange is needed to connect different actors in the supply chain (Canel-Depitre, Taghipour & Vosooghidizaji 2019). The change of the global textile industry into lower-labor-cost countries has resulted in a substantial decrease in production in developed countries (Dahlbo et al. 2020) and this has led to more complexity and less transparency within the supply chain (Fransson & Molander 2012).

Traceability is defined as the ability to verify the history of the product (Agrawal et al. 2017). However, traceability is challenging to implement in a complex supply chain, since there is a great amount of information that is generated. Information sharing is an important role in tracking systems, and it needs to be shared in a secure way between the different actors (Agrawal 2019).

3.2.1 Asymmetric information

Asymmetric information is when one actor in the supply chain has additional- or more complete information about one part in the production than other actors (Canel-Depitre, Taghipour & Vosooghidizaji 2019). According to Akerlofs (1970), information can theoretically result in the shutdown of an entire market. When there is a lack of transparency and information, different actors in the market cannot trust each other and that may result in nobody consuming anything from the manufacturers. If customers demand that PFAS should not be in the clothes, but information gap is too large, and it is not possible to determine which supplier does not have PFAS.

Asymmetric information can also result in supply chain moral hazard (Han, Wang & Xing 2012). When a supply chain moral hazard occurs, the focal company will not have control over if the information reported from other actors is correct or complete. The supply chain moral hazard can be solved through the principal-agency model. The model consists of two different parts, (1) agents who are those who have private information and, (2) principals who are those who do not have private information. To decrease the asymmetric information regarding

chemical use in the supply chain, a standardized tracking system is needed. Authorities can implement different restrictions and regulations regarding what products can contain and not, but then it is also important that such regulations are followed up to ensure that actors follow said regulations (Fransson 2012). This is something the principal-agency model emphasizes as an important part to reduce asymmetric information (Zhang 2011). One major problem with supply chain management and information sharing is that a system needs to be implemented to ensure that the actor who shares information gains benefits from it and is not exposed to any risk (Fu 2011).

There are several types of information that are needed to flow through the supply chain: scientific information, technological information, and legal information (Asford & Koch 2006). Scientific information focuses on information related to what the product contains, such as different materials and chemicals. This is information concerning the identity of hazardous chemicals. To produce risk information is both time-consuming and costly for companies. Information flows about chemical content are important to avoid harmful effects but currently, there is a lack of an international system for managing this (Fransson & Molander 2012). Communication that is related to chemical risk can be done in several ways, but the major problem is the lack of information and asymmetric information (Brunklaus et al. 2013). Since the supply chain includes many different actors, the logistics and structures become more complex and that increases the asymmetric information (Canel-Depitre, Taghipour & Vosooghidizaji 2019). Asymmetric information also affects the interaction between different actors, and these actors can experience different types of asymmetric information. One reason for the major problem of asymmetric information can be that tracking of chemicals is a voluntary measure and this results in a gap of information (Agrawal 2019). It is also difficult for supply chain actors to identify and track all the suppliers and sub-suppliers. Transparency within the supply chain has the potential to decrease the asymmetric information between different actors (Benzie et al. 2019).

4. Regulations and initiatives for enhanced information in the textile industry

It is known that the use of PFAS and other chemicals in the textile industry has a negative effect both on the environment as well as on human health (Cousins et al. 2021). There are organizations and authorities that work to improve the current situation. They work with areas regarding climate change as well as the use of hazardous chemicals by implementing different regulations and initiatives. One problem is that it is not regulated in any legislation how companies must work to ensure that the requirements have complied. However, it is important that companies can ensure that they meet the requirements (Asford & Koch 2006). This is important as approximately 80% of EU-consumed finished textiles are imported from outside the EU (Dahlbo et al. 2020) and involve many actors (Fransson & Molander 2012). All products that are consumed on the EU market have to follow EU requirements (European Chemicals Agency n.d.a). Therefore, all actors within the supply chain need to exchange information about chemicals that are being used (Fransson & Molander 2012).

The problematic situation with tracking of chemicals in the supply chain can be related to different initiatives. The initiatives and regulations that are mentioned in this report are used to ensure that different hazardous chemicals are not included in products. In the early 2000s, new laws, regulations, and policies were implemented to reduce the use of PFAS (Brennan et al. 2021). Initiatives and regulations which aim to reduce the use of PFAS put higher pressure on traceability in the supply chain, to be able to ensure that products do not contain PFAS.

4.1 European Chemical Agency

The European Chemical Agency (ECHA) works with implementing the EU´s chemical legislation (European Union n.d.). ECHA is working for the safe use of chemicals and aims to contribute to a better environment and human health as well as provide innovation and competitiveness within the EU. ECHA helps companies to fulfill the legislation with guidance and recommendations to make sure that hazardous chemicals are replaced with preferred substitutes and fulfill the requirements. Different segments help companies to fulfill the legislation in the EU (European Chemical Agency n.d.a). These segments collaborate with ECHA to contribute to the safe use of chemicals as well as information and identification of hazardous chemicals to stimulate innovations in the chemical industry to find better substitutes of chemicals.

The *Substances of Concern In articles as such or in complex objectives* (SCIP) database is a part of ECHA (European Chemical Agency n.d.b). It regulates the use of *Substances of Very High Concern* (SVHC) that are included in the Candidate List. The SCIP database ensures that all information is available through the whole life cycle for products that contain substances that are included in the Candidate List. It is therefore highly important to know the content of products on the EU market to ensure that it fulfills the requirements in the SCIP database and to be able to report the content to ECHA.

4.2 REACH

REACH stands for *Registration, Evaluation, Authorization of Chemicals*. The regulation aims to protect both the environment and human health through early identification of the intrinsic properties of chemical substances (European Commission n.d.f). The regulation puts all the burden of proof upon companies as it is their responsibility to prove whether their products contain the chemicals or not (European Chemicals Agency n.d.a). Manufacturers are required to register the content of their products to ECHA. Even if a company within the EU imports a product or material from a company established outside the EU, REACH only applies to the importing company established in the EU.

REACH is actively working to phase out hazardous chemicals from the market (European Commission n.d.f). Companies will be affected by REACH and the Candidate List since all companies use some types of chemicals in their manufacturing process. The authorization and regulations of substances are highly relevant related to the traceability of PFAS, but there are still challenges to knowing what the products contain and if the products fulfill the requirements. This means that traceability in the supply chain is important, and the use of a tracking system could be helpful to know if products contain PFAS or other regulated substances. It is also a good tool for companies to prove that products do not contain PFAS or other substances that are regulated by REACH, it will also make it easier for regulatory authorities to control that companies fulfill the requirements.

4.2.1 Candidate List

The *Candidate List* is a part of REACH where the SVHC list is included (European Environment Agency 2021). The list includes hazardous chemicals and substances. If the substance included in the Candidate List is used on the EU market in a product with a weight concentration above 0,1%, that must be reported to ECHA. This is done to ensure that the consumer will be able to use the product safely (Kemikalieinspektionen 2019). Some PFAS substances are on the SVHC list (European Environment Agency 2021). As mentioned in section 4.1, the Candidate List complements the SCIP database that is regulated by ECHA. The Candidate List, therefore, forces companies to inform and report the content of their products (RISE 2021). The Candidate List is currently regulating some PFAS substances (European Chemical Agency n.d.c) but there are still many PFAS substances that are not regulated or mentioned in the list.

4.2.2 Annex XIV

REACH Annex XIV, also called the REACH *Authorisation list* (ChemSafetyPRO 2021a). Substances included in the list require authorization from REACH regulations which are based on the Candidate List of SVHC substances. The substances mentioned in the list cannot be used on the market unless authorization is granted and therefore can be used in specific cases. Companies need to apply for authorization from ECHA to use the substance within the EU (Kemikalieinspektionen 2021b) (RISE 2021). Products that contain chemicals that received authorization need to be labeled before it enters the market (Kemikalieinspektionen 2021b).

The authorization includes both products produced in the EU as well as imported products outside the EU.

4.2.3 Annex XVII

Annex XVII is a part of REACH where substances are restricted (European Chemicals Agency 2021). The list is called the REACH *Restricted Substances list* (ChemSafetyPRO 2021b) and *Annex XVII* is based on the Candidate List. This means that SVHC substances with negative impacts on the health of humans or the environment are restricted (European Chemicals Agency 2021). This includes both substances in products as well as mixtures of listed substances. The list presents the consequent restriction conditions of the substance. By regulating different substances in different ways, some substances are banned, and others are regulated to use in specific situations (ChemSafetyPRO 2021). The regulations are established for all products within the EU and the responsibility to fulfill the requirements is on the producer or the company that imports the product (Kemikalieinspektionen 2021a). There are still specific exceptions where products are allowed to use substances mentioned in the Annex XVII list, but the requirements for labeling the product are in that case of importance.

4.3 Stockholm Convention - Persistent Organic Pollutants Regulations

Regulations of Persistent Organic Pollutants (POPs) are a part of the Stockholm Convention. POPs are a group of chemicals that are persistent in the environment (European Commission 2021). The POPS regulations include all EU- members (Kemikalieinspektionen 2021) and are used to regulate and prohibit the use of these types of chemicals (Kemikalieinspektionen 2019). PFAS is one example of a POPs chemical and is, therefore, one group of chemicals that is regulated in the convention (European Environment Agency 2021). By regulating PFAS under the Annex A of the Stockholm Convention for POPs, means that it is regulated in all EU countries (Environment Agency 2021). It is therefore important for companies in the EU to ensure that their products do not include PFAS. Today, there is a lack of traceability in the supply chain and therefore a tracking system could be used to make it easier to control the content and ensure that no POPs, such as PFAS, are included in products.

4.4 The European Green Deal

The European Green Deal is aiming to improve the environmental situation in the EU (European Commission 2021). The goal is to transform the EU into a modern society with a focus on resource efficiency and a competing economy. The European Commission's action plans are wide and are working with several aspects that are highly relevant for the phasing out of PFAS. The European Green Deal is working for improvements in the well-being and health of future generations, which is one part of the sustainable development goals (United Nations n.d). The European Green Deal works with these goals by providing for example fresh air, clean water, healthy- and affordable food, more public transport, longer-lasting products (can be repaired, recycled, and reused), a globally competitive and resilient industry as well as

cleaner energy. This is highly relevant in the phasing out of PFAS as PFAS has a negative effect on the goals regarding clean air and water which also includes healthy soil and biodiversity. This is because PFAS is a hazardous chemical that has high mobility and is easily transported both in water and air (Cousins et al. 2021). PFAS also affects the lifetime of products since the use of PFAS results in clothes that cannot be recycled and reused since no company wants to use a material that contains that hazardous chemical. The use of PFAS in the clothing industry will also affect global competitiveness as PFAS is only regulated in some parts of the world (The Swedish Chemical Society 2021). The European Commission's action plan also includes several areas, such as climate, industry, environment, and oceans as well as research and innovations. An important aspect to improve the situation in the textile industry, which today is an industry with large challenges, could be research and innovations which is one of the actions identified. One innovation that can have a great impact is the use of tracking systems to manage these problems and improve the textile industry.

One part of the European Green Deal is the Sustainable Product Policy which is a complement to the European Green Deal to decrease resource consumption as well as lessen the environmental impact (European Commission n.d.g). All products that are produced or sold in the EU should be in line with the technical standards for sustainability (European Commission n.d.a). It aims to improve the coherence to regulate products in the different phases of the life cycle. The use of a tracking system could be helpful to track the products in the whole supply chain, both within the EU as well as in products that are imported to the EU. This means that products should not include chemicals that are regulated in the EU in any part of the supply chain (European Commission n.d.f). PFAS is one compound that is regulated and is needed to be phased out. By working in accordance with the Sustainable Product Policy, regulated PFAS substances are not allowed to be produced or imported to the EU. Tracking systems can be used both to trace PFAS as well as other chemicals through the whole supply chain to ensure that the imported textiles do not include these types of chemicals.

5. Tracking systems

The large use of different chemicals in the textile industry raises the importance of communication throughout the whole supply chain. To identify the composition of a material, different types of tracking systems can be used (Chemsec 2021b). In this report, a tracking system is defined as a system that is used by the whole industry and that controls the product from the first step in the supply chain. From raw material to final product. It is important within the textile industry to use an international standardized tracking system due to the heterogeneous nature of the supply chain (Agrawal 2019). Even though tracking is a major problem within the textile industry, due to the size and complexity, there is no international standard that improves tracking possibilities (ElMEssiry & ElMessiry 2018).

5.1 Digital Product Passport

The European Commission has defined the product passport as *"a set of information about components and materials that a product contains, and how they can be disassembled and recycled at the end of the product's useful life"* (European Commission 2013). At the EU-level, Digital Product Passport (DPP) has mainly been discussed within the Sustainable Products initiative in combination with the development of the EU Ecodesign Directive (Adisron, Götz & Tholen 2021). The EU Ecodesign Directive aims to improve the environmental performance of products, which is done by a declaration of the energy consumption of each product (European Commission n.d.b). The EU wants to combine more products than just energy-related products and they want to introduce more product-specific minimums on sustainability and information requirements, which can be used in the textile industry. Digital solutions related to product information have proven to be successful in other industries, such as the automotive industry (Marinkovic, Steinbrecher & Walden 2021). As a DPP will follow a product throughout the value chain, it will enable more stakeholders to gain access to the same information.

With the help of digitization and technological development, the availability of data through the product life cycle can be improved (Ibits 2021). Access to more data increases transparency and should benefit all actors in the supply chain. A standard is needed to enable that all actors work in the same way. A DPP is a data set describing defined characteristics of the whole product (Holla 2021) and it aims to provide product-related information and information regarding track and trace to reduce the gap of information through the supply chain (Adisorn, Götz & Tholen 2021). The data gathered in the DPP include information from all phases through the whole life cycle of the product and from all actors in the supply chain (Ibitz 2021). Manufacturers have an important role in the supply chain since they are an important source of product information. A DPP should be designed so actors perceive them as an advantage to present information rather than control. The DPP ensures the possibilities of up-time updates and insights to all actors in the supply chain (De. et. al., 2019). The use of a product passport would increase the efficiency in resource management (Charnley & Portillo- Barco 2016).

5.1.1 Digital Product Passport in the Supply Chain

To be able to use DPP, data, and information from the product's life cycle are required (Charnley & Portillo- Barco 2016). An effective way to collect data and information about products is through sensor integration in the product. A DPP will only work effectively if all actors in the supply chain work in the same way (Ibits 2021). DPP will not only increase transparency in the supply chain but will also simplify the decision-making processes based on product information.

5.1.2 Challenges with Digital Product Passport

One challenge with DPP is how to keep the information in product passports updated throughout the life cycle (Marinkovic, Steinbrecher & Walden 2021). To use the DPP efficiently, all parts through the supply chain must use the DPP in the same way (Ibitz 2021). Another important aspect is how to optimize the flow of information through the supply chain (Adisorn, Götz & Tholen 2021). Since a DPP contains sensitive information from all actors, it is important to take the security aspect into account (Ibits 2021). To solve the security problem, companies need to create a unique digital identity for all products to make them identifiable.

5.2 Electronic tags and Radio Frequency Identification

Electronic tags or *e-Textile Attached Gadgets* (e-TAGs) can connect wires in e-textiles (Jones et al. n.d). E-textiles are textiles integrated with electronics such as communication storage or generation capabilities. The electronic devices are seamlessly embedded into clothes (Bakker, Hilly & Köhler 2011) and they can store information by using small integrated circuits (De et al. 2019). The digital information stored in the tag can be scanned to read the information. The most common is *Radio Frequency Identification* (RFID), and this technology can be used to track the chemical content of a product (Chemsec 2021b).

The RFID technology allows monitoring and control of a product due to the unique identifier (Călin et al. 2017). An RFID system includes an RFID tag with unique data. It also requires an RFID reader that is connected to a computer to scan the tag. The technology uses electromagnetic fields to transmit energy and the tag contains digital electronic devices where the reader uses radio frequencies of electronic waves. The use of RFID has enabled the possibility to store and retrieve information from an individual product (Fleisch et al. 2003). RFID typically consists of a $1mm^2$ silicon chip embedded into the textile (Glaser et al. n.d) and is efficiently used to track and monitor products (Călin et al. 2017). The development of the technology has achieved integration of circuits and software development. It has also enabled a reduction in the price which has made it more useful and preferred from the economic perspective.

A unique structure and code are needed to be able to track and identify. The identifier code is selected to ensure the uniqueness is supplemented by trackable resource units (Agrawal 2019). The use of a unique *Electronic Product Code* (EPC) identifier in the tag on the article can identify the company's information system (Azevedo 2014). EPC is the individual

identification description of a product where each product contains a code that can be identified by the RFID reader (Fleisch et al. 2003). To minimize the costs, the tag only retains the EPC but no other information. By using the EPC, every product has its unique ID. The use of EPC in the tag is used within the product through the whole supply chain (Mogre, Perego, & Tumino 2009) and can provide information such as production country but also chemical treatment. By scanning the EPC with an RFID, information is obtained, at the same time as new information is added. Contactless electronic tags instead store data by using an electronic microchip and an antenna (Agrawal 2019). The benefits of electronic tags are the possibilities of long-range readability, low-cost and high memory stored but they can easily be cloned and require a special device for readability.

5.2.1 RFID in the supply chain

The use of RFID technology can be important to enable communication in the supply chain (Călin et al. 2017). RFID increases the transparency through the supply chain and provides opportunities for a large amount of real-time data which can be used in the decision-making process (Azevedo 2014). RFID enables the monitoring of products in the supply chain and therefore results in better control of the process (Mogre, Perego, & Tumino 2009). The use of RFID in the supply chain is labor and timesaving, but it also contributes to an increase in the visibility of the products, which can reduce the inventories and transportation costs (Azevedo 2014).

5.2.2 Challenges with RFID

Historically, there have been challenges to attaching the RFID chip to textiles, where different patents have suggested different solutions (Cork 2018). The largest challenges today are to minimize the size of the tag. The possibility of using the tag in harsh environments is today a challenge. RFID is also facing challenges related to confidential data due to its long-range readability (Agrawal 2019). It is easy to duplicate the tags, and this poses security risks and privacy for companies (Nayak et al. 2015). As it is easy to provide wrong information and break through the security algorithm this provides challenges. There is also a lack of standardization using RFID. The radio frequencies need to be specified and established (Călin et al. 2017). Ultra-High Frequency (UHF) and Super High Frequency (SHF) can be used when a greater reading distance is needed or with high-speed communication.

6. Perspectives from companies

The following result is based on interviews with nine companies, and compiled data are summarized in tables as well as complimentary quotes. Section 6.1 is presenting how companies manage hazardous chemicals. Then successes and challenges related to the phasing out of PFAS are presented in section 6.2. Section 6.3 presents the chemical management in the supply chain and lastly, 6.4 presents challenges with information flows in the supply chain.

6.1 How companies manage hazardous chemicals

Table 1 presents how companies work with hazardous chemicals. Results from the reasons for why companies are managing hazardous chemicals, as well as how companies work to decrease the use of hazardous chemicals in their clothes can be seen in Table 1.

Table 1: How participating companies are managing the use of hazardous chemicals

Company	What are the reasons you work with managing hazardous chemicals?	How do you work to decrease the use of hazardous chemicals in your clothes?
PEAK Performance	Certain chemicals are used to provide clothes with specific properties	Member of Bluesign Dialogue with suppliers Internal knowledge for product development Member of the Swedish Chemical Group, RISE
H&M Group	Ambition to become circular A Long history of proactive chemical work	Chemical Restriction List Initiated brand collaboration with AFIRM Founding members to Zero Discharge of Hazardous Chemicals (ZDHC)
Henri Lloyd	Certain chemicals are used to enhance performance for performance functional outerwear clothes	Developing fabrics that structurally absorb less moisture Pursuing where possible C-Zero
RÖYK	Work with product development to understand and avoid hazardous chemicals	Transparent with suppliers Educating both suppliers and consumers Developing our fabrics and from an early stage deciding what fibers and treatments to use

Company	What are the reasons you work with managing hazardous chemicals?	How do you work to decrease the use of hazardous chemicals in your clothes?
Kappahl	Laws and regulations Do not want to make a negative effect on the environment or humans	Restricted Substance List Stricter requirements than the legal requirement in many cases
Outnorth	Laws and regulations Do not want to make a negative effect on the environment and consumers	Members of the Swedish Chemical Group, RISE Testing Dialogue with manufacturers
Alligo AB	Laws and regulations Requirements from customers Our desire to be a sustainable company	OEKO-TEX® certification Member of PFAS Movement, Chemsec
Stadium	Laws and regulations Stadium environmental goals	Restricted Substance List Members of the Swedish Chemical Group, RISE
Fristads	Laws and regulations Certifications	OEKO-TEX® certifications Restricted Substance List Members of the Swedish Chemical Group, RISE

As can be seen in Table 1 all companies have different reasons for managing hazardous chemicals. One company mentions that *"//...// all production requires some form of chemical".* This is further described by the same company as "//…// *when it comes to functional clothing, you put on certain chemicals to get a certain function".*

It can be seen in Table 1 that many companies are affected by laws and regulations regarding the use of hazardous chemicals. One company mentions "//…// *laws and regulations which we need to follow".* This is further described by a company that mentions that they "//…// *complies with the strict restrictions of EU chemicals legislation REACH"*. Related to regulations, one company mentions "//…//*all environmental requirements are getting stricter".* Another aspect that was mentioned by several companies was the environmental impact. One company mentions that "//…// *we do not want to have a negative impact on the environment".* Further results from the interviews are that several companies have stricter requirements than what laws and regulations regulate. One company mentions that "//…//*we have stricter requirements than the legal requirement in many cases".* Another company mentions that they are "//…// *aiming to be a pioneer in making sustainable clothing*". Three companies mention that they are

members of the Swedish Chemical Group and one of those companies mentions "//…// *together with the industry has the same message to suppliers regarding chemicals which is powerful when it comes to chemicals that are not regulated today but probably will be in the future"*.

Companies are also aiming to become a leading company "//…//*we collaborate with our industry to further develop and improve our industry's chemical management and have set ambitious goals towards 2030".* The reason why companies want to be in the front of the development can be described as "//…// *both for ourselves but also requirements from customers".*

As can be seen in Table 1, all companies work to decrease the use of hazardous chemicals. Some companies use different certifications, such as Bluesign and OEKO-TEX®. From the interviews, it was seen that several companies use restriction substance lists for chemicals to regulate what chemicals that can be included in their products. One company that uses a restricted substance list mentions that "//…//*from that list you can see which substances are banned or have restrictions".* The same company also mentions that "//…// *many of them are within legislation but also those that we use in other ways".* Another important thing that companies mentioned regarding the restriction substance lists is communication with suppliers. One company mentions that "//…// *our suppliers are committed to fulfilling our chemical requirement by our business agreement".* The same thing is also highlighted by another company "//…// *we try to have a dialogue with all our suppliers, so they know what applies"*. The same company also mentions that it was done to "//…// *have a high level of knowledge internally".* Another company mentions "*//...// the use of chemicals is driven by consumer preferences",* as an important part regarding the chemical use in their products.

Communication with suppliers was also mentioned by many companies and the importance of transparency throughout the supply chain to be able to manage hazardous chemicals. One company mentioned "//…// a *very important part of it is to be transparent".*

6.2 Success and challenges of phasing out PFAS

Table 2 presents how companies are working regarding PFAS. The first column presents if the companies use PFAS in their products. Depending on the answer in column two, yes or no, companies were asked to answer columns three and four or column five.

Table 2: How participating companies work regarding PFAS

Company	Do your products contain PFAS?	If yes, Are you working to find a substitute?	If not, what hinders?	If not, what are you using instead?
PEAK Performance	Yes	Yes	Consumer's acceptance Using Gore-Tex A larger amount of chemicals to achieve the same performance	A combination of silicone and paraffin
H&M Group	No	-	-	We use any PFAS-free alternative available on ZDHC Gateway
Henri Lloyd	Yes	Yes	Have yet to find an alternative The behavior of leading fabric mills is not always offering alternatives The science is progressing Consumer's acceptance	Trialing some alternative finishes Creating fabrics that do not pick up moisture
RÖYK	No	-	-	Making layers Jersey or flat knits Merino wool Rudolf Bionic Eco finish
Kappahl	No	-	-	Rudolf Bionic Eco finish
Outnorth	No	-	-	Rudolf Bionic Eco finish
Alligo AB	Yes	Decreasing the use of PFAS in in products where it is not necessary	No alternative for workwear with specific properties	-

Company	Do your products contain PFAS?	If yes, Are you working to find a substitute?	If not, what hinders?	If not, what are you using instead?
Stadium	No	-	-	Non-fluorinated, bio-based, durable water-repellent finish
Fristads	Yes	Decreasing the use of PFAS in in products where it is not necessary	No alternative for workwear with specific properties	-

It can be seen in Table 2 that five companies do not have PFAS in their products. One of those companies describes their work as "//…// *we have phased out PFAS "*, and another company mentions that "//…// *we have a ban on PFAS, so our products should not contain it"*. Both companies have been using PFAS before. One company that does not use PFAS mentioned that "//…//*new EU legal requirements are sometimes too slow".* One company that never has used PFAS in their products mentions that "//…// *as a young company we had the chance to be sustainable from the first beginning".* The same company also mentioned, "//…// *all our fabrics have always been PFAS free".* Today, different substitutes are used by the companies.

It can also be seen in Table 2 that four companies are using PFAS in their products. Two of these companies sell workwear and it was seen that there are higher requirements on safety for the user regarding workwear. The reason for the use is described by one company that sells workwear as *"//...// we used the best chemical for our garments so that we get the best performance*". The same company also mentioned that it depends on the products *"//...// we have to use it, but we have PFAS substances in more clothes than that and that is because we have not had to think about it before as it has been okay before"*. One company mentions that *"//...// The clothes where we do not need PFAS, we will start replacing it" regarding if they are actively working to find a substitution for PFAS"*. There are also two companies that use PFAS in their products that do not sell workwear but instead sell outdoor and functional clothing. One of these companies mentions that *"//...// we are actively working towards c-zero"*. Another company mentions that *"//...// in 2016, we decided that we will phase out PFAS completely from our products"* and they explain one problem with phasing out PFAS as *"//...// you still have a promise to your customers and customers have expectations of the products they buy from us"*. They also mention that *"//...// PFAS which is a fantastic chemical from the perspective of what it can actually do"* is a problem to stop using PFAS and use other substitutes instead.

The performance of substitutes has been mentioned in the interview, where the opinions about the performance differ between companies. One company mentioned that "//…// *substances nowadays are in such high quality that you cannot see the difference".* But another company describes products without PFAS as "//…// *do not have the same performance".* The situation is described by one company "//…// *as an industry, we may have created a need that does not really exist. It's always difficult to get customers to go back to something that is actually a little worse".*

6.3 Chemical management in the supply chain

Table 3 presents questions and answers related to tracking systems and chemical content in products. This includes questions regarding how companies ensure the content of their products, manufacturing countries, and information systems between retailers and manufacturers. But also questions about how they ensure that EUs regulations are followed and how companies communicate with their manufacturers.

Table 3: How participating companies manage chemicals in their supply chain

Company	How do you ensure what your products contain?	Are you manufacturing your clothes?	How does the information system work with manufacturers?	How do you ensure that EU regulations are followed?	How do you communicate with your manufacturers regarding hazardous chemicals?
Peak Performance	Bluesign Regulation List Risk assessment Testing	No	All suppliers are aware of chemical legislation All suppliers have signed our regulation list	Same requirements and restrictions	Workshops with suppliers Bluesign®
H&M Group	Risk assessment Third-party chemical testing	No	Cooperation with our suppliers'	Requirements and chemical restrictions e.g AFIRM RSL	H&M Group Staff present in all production countries: they hold training and workshops, visit suppliers, etc.
Henri Lloyd	REACH	Makes approx. 50% of our styles ourselves and the balance in 3rd Party factories 80% are located in the EU.	Specification on components and fabrics High standard factories and mills	Supplier manual Factories agree to follow REACH	Agreement on which chemicals are being used
RÖYK	Long term relationship with suppliers Aiming for certificates	No	High demands Involved through the whole supply chain	Certified according to EU regulations	Communication through the whole supply chain

Company	How do you ensure what your products contain?	Are you manufacturing your clothes?	How does the information system work with manufacturers?	How do you ensure that EU regulations are followed?	How do you communicate with your manufacturers regarding hazardous chemicals?
Kappahl	Restriction Substance List Testings of products	No	Restriction Substance List and requirements	Manufacturers are well aware of EUs requirements Restriction Substance List	Restriction Substance List
Outnorth	Risk management Regular testing of products	Yes, our own brand	Clear agreements with suppliers	Manufactures are well aware of EUs requirements Communication	Guide for use of chemicals
Alligo AB	Communication with suppliers Mapping all materials that are used	Yes, our own brands	Communication with both material suppliers and product suppliers	OEKO-TEX® Amfori code of conduct External audits	Communication between product developers and suppliers
Stadium	High demands on suppliers Regular inspections in production	Approximately 50% of assortment in our store is our own brands	Communication each season to decide which products should be tested	Restricted Substance List	Information through a web portal called Stadium.biz
Fristads	OEKO-TEX® Regular testing of products High-quality suppliers	Yes, the production of products but not fabric production	OEKO-TEX® Nominates all components of the products	OEKO-TEX®	We nominate all components that are included in the products

It can be seen in Table 3 that companies work in different ways to ensure what their products contain. The companies use, among other things, different certifications, restricted substance list, testings of products and communication with suppliers and manufacturers. The certifications mentioned are Bluesign® and OEKO-TEX®. The importance of communication with suppliers are explained by a company as "//…// *a close and long-term relationship with our trusted suppliers"* as their way to work and ensure the chemical content of their products. This is in line with what another company mentions "//…// *the only thing we can do is ask, take in and test".* Testing is also mentioned by several companies, where one company mentions "//…// *we test all materials".* The testing is done in different ways where one company mentioned that "//…// *a third party does these tests for us"*. Testing are done both on specific materials and the final product. Companies are also working with risk assessments to ensure that hazardous chemicals are not included in their products. Many companies work with

restricted substance lists and the way of working with this list is described by a company as "//…// *Based on the things that we have banned or had some restrictions on, the suppliers themselves can choose how to produce".* Which also describes that companies are working with communication with their suppliers. Another company mentioned that "//…// *we have high demands on our suppliers and regular inspections in production"* which is something that several companies mentioned in the interviews.

It can also be seen in Table 3 that most of the companies do not manufacture their clothes. Five companies manufacture parts of their products, but they also buy from manufacturers. Four out of nine companies do not manufacture their clothes at all. However, all companies depend on their manufacturers in some way. Therefore, the manufacturers are an important aspect in all companies' sustainability work as well as to be able to trace the chemical content in products.

Table 3 is also presenting how the information systems work between the companies and their manufacturers. The companies have different experiences regarding communication with their manufacturers where one company mentions that "//…// *we have a close cooperation with our manufacturers",* while another company mentioned that "//…// *I think you can get even better at keeping track"* in order to improve the communication. The most common thing that was mentioned is the importance of communication and one company mentioned that "//…// *we have a very close communication with our manufacturers".* The importance of communication with suppliers was also described by another company as "//…// *also contact with various material suppliers so we have not only contact with the garment manufacturers but also with the material suppliers".* It is also mentioned that some companies are working with the same manufacturers and suppliers during a long time and one company mentioned that "//…// *we have a long-term relationship with all our suppliers"* and another company mentioned that "//…// *the suppliers we work with, have we worked with for many years".* The advantage with working in long-term with suppliers and manufacturers can result in higher trust, this is mentioned by a company as "//…// *we trust our supply chain and work with high standard factories".* Some companies use their restricted substance list to communicate with their manufacturers, where one company mentioned that "//…// *we probably feel that our restricted substance list and the way we work is quite established"*. Another company describes the use of their restricted substance list as "//…// *all suppliers have also signed our chemical list and it is stated in our contracts".* The same company also mentioned that "//…// *it is we who decide exactly which materials should be in the products"*. Another way of working to improve the communication with manufacturers was mentioned by one company as "//…// *certain security in that we have OEKO-TEX® and that they have written the amfori code of conduct".*

Table 3 is presenting how companies ensure that EU regulations are followed. One company mentioned "//…// *we apply the same requirements and chemical restrictions regardless of where the product is produced"*, this is applied to all companies in the study. It can be seen that all companies are regulated by laws and that is how companies ensure that their manufacturers follow EU's regulations. The overall reason for this is mentioned by a company as "//…// *important is what applies to laws where the clothes are to be sold".* Other companies mentioned "//…// *agree to follow REACH",* as well as "//…// *certified according to European*

regulations". Overall, the companies mentioned that manufacturers themselves are aware of the situation and laws related to textiles in the EU. This is described by one company as "//…// *they are very familiar with the requirements they must follow"* and a reason for this is mentioned by another company as "//…// *the products will not be legal if they do not meet the standards that we have said they should have".* Some companies mention that they use certifications, for example OEKO-TEX®, to ensure that their manufacturers follow all regulations.

Table 3 also presents how companies work and communicate with their manufacturers about hazardous chemicals. One company mentioned "//…// *communicate with every step in the supply chain"*, which is mentioned by other companies as well. Another company that had similar thoughts mentioned "//…// *through our product developers out to the suppliers and material suppliers"*. One problem that was mentioned by one company was "//…// *as a small company we do not have a perfect system".* Furthermore, workshops, restricted substance lists, and local teams are also mentioned as how some companies are working. One company mentioned that "//…// *many of our suppliers are also Bluesign® certified".*

Table 4 presents how companies use tracking systems to track chemicals. The table is complemented with the company's thoughts regarding possible disadvantages and advantages with tracking of chemicals. Table 4 is also presenting how companies would prefer to track chemicals in the supply chain.

Table 4: The use of tracking systems

Company	Do you use any types of tracking systems for chemicals?	Disadvantages to tracking chemicals	Advantages to tracking chemicals	How would you prefer to track chemicals through the supply chain?
Peak Performance	Not a formal one	Challenging to understand the complexity of chemicals	It is our duty to track chemicals	Certifications Increase knowledge An important part is the chemical suppliers
H&M Group	Yes	Information provided by the chemical industry is not enough to base decisions on regarding better alternatives	It is needed to secure legal compliance	More transparency from chemical suppliers
Henri Lloyd	Not a formal one	-	-	-
RÖYK	No	None, only advantages	Always advantages	Work with institutes, startup tools, and independent organizations

Company	Do you use any types of tracking systems for chemicals?	Disadvantages to tracking chemicals	Advantages to tracking chemicals	How would you prefer to track chemicals through the supply chain?
Kappahl	Not a formal one	None	Avoid costs that appear if products contain unwanted chemicals is one of many advantages	A tracking system that follows all steps in the supply chain, such as product passports
Outnorth	No	Difficult to get information from sub-suppliers	Always advantages	Regulate the use of chemicals in an earlier step
Alligo AB	No	Difficult to get the right information in the supply chain	Transparency against customers	Track chemicals by mapping material manufacturers
Stadium	No	System constraints Takes time to verify data	Easier to nominate better options Increased understanding	-
Fristads	OEKO-TEX®	Problems with different test methods and that everyone should test in the same way	More information is available	Through some kind of chip that is following the product the whole lifetime A standardized way of tracking chemicals

As can be seen in Table 4, some companies are using tracking systems but not a formal one. Some companies are using a system they themselves have created, one company mentions "//…// *we have built our work and history in excel"* and another company mentions "//…// *we do testings"*. Two companies are not using any type of tracking system. One company mentions that *"//...// we are trying to confirm that the suppliers continue to use the same sub-suppliers in production"*, to have better control through the supply chain.

As can be seen in Table 4, the majority of the companies did not think of any disadvantages with tracking chemicals. Three companies experience disadvantages with tracking chemicals due to the complexity of chemicals, but also that it can be difficult to get the right information from suppliers and sub-suppliers. One company mentioned "//…// *as a young and small business we don't have the resources to tracking systems more than demanding certificates and transparency".*

Table 4 is also presenting the advantages with tracking chemicals. All companies experience advantages related to tracking chemicals. Some companies mentioned that they have to do it due to legal compliance as well as transparency to their customers. One company mentions that "//…// *get a completely different transparency towards the customers which is very important".*

The same company also mentions "//…// *It is important for our customers and if we cannot answer them, they do not want to buy from us".* Consumer satisfaction is also described by one company as one advantage to have control of what the products contain. One company mentions "//…// *would hurt us very much if it turned out that we put a product on the market that contains a chemical that should not be there*". This is further described by another company as "//…// *it costs a lot if we get a product that does not live up to the legislation for us".* The same company also mentions "//…// *it is better that we have more control.* Several companies also mention that environmental responsibility is important regarding tracking chemicals, one company mentions "//…// *our duty to do right".*

In Table 4, it can be seen how the companies would prefer to track chemicals through the supply chain. Transparency is mentioned by some companies, where one company mentioned "//…// *what is important on the whole is transparency".* Some companies mention that chemical suppliers are an important part of tracking chemicals. One company mentioned that they "//…// *would prefer and need more transparency from chemical suppliers"*, while another company mentions "//…// *our focus right now is on being able to track our materials even more and gain increased transparency in the supply chain".* The transparency through the whole supply chain is further described by another company as "//…// *it would have been good to have a tracking system that leads back to all steps in the supply chain, such as product passport"*. Another company is also highlighting the importance of tracking chemicals through the whole supply chain and that it should be standardized, they mention that *"//.../ Data chip that shows a complete content declaration".* The same company is also highlighting the importance of confidential data that must be taken into account *"//.../ the information does not have to be open to everyone as it is about what the suppliers are likely to provide".* One reason why companies prefer to include the whole supply chain is described by one company as "//…// *an important part is the one that actually puts chemicals on the market and sells chemicals"* and is then referring to chemical suppliers.

6.4 Challenges with information flow in the supply chain

Table 5 presents how companies experience problems regarding information flow in their supply chain.

Table 5: Flow of information in the supply chain

Company	Do you have problems with the information flow in your supply chain?	If yes, is that a problem regarding the tracking of chemicals?	If not, how have you solved this problem?
PEAK Performance	Yes, it is hard to have full control	We test twice a year to be able to find chemicals that should not be included. So it's our security system.	-
H&M Group	-	-	-
Henri Lloyd	Yes	Occasionally it can be a problem in the sense that we have to enquire	-
RÖYK	No	-	Communication through the whole supply chain
Kappahl	No	-	Restricted Substance List
Outnorth	Yes	Communication and avoiding misunderstandings are a big part of the work	-
Alligo AB	No	-	Transparency through the whole supply chain
Stadium	Yes and no	Sometimes difficult to reach through to sub-suppliers	-
Fristads	No	-	Restricted Substance List

As can be seen in Table 5, three companies mention they experience problems with the information in their supply chain. Four companies do not mention any gaps in the information as a problem in their supply chain. The companies have solved that problem through communication and transparency throughout the whole supply chain and that can be used to increase the possibilities to map materials and components in the products. The use of restriction substance lists is also mentioned by two companies, which are used to make the requirements clear for manufacturers.

To quote one of the companies "//…// *better manufacturing partners want to give this information and as we work in factories that have much larger customers with much larger development teams, the factories and mills have to have this information"*. It is possible to receive the right information but sometimes companies have to ask for it. Some companies

described the size of the companies as an important aspect where one company mentioned "//…// *we as a company are very large and our suppliers have good control over what they do".* Another aspect that is described by a company is the requirements concerning EU regulations and other companies' requirements on suppliers, which is described as "//…// *had become a greater risk than it would have been questionable if we had had a list that was very different from everyone else".* Therefore, standardization is seen to be important. The different substance lists that are used make it more difficult to work more effectively. Some companies are also using different certifications, but there are no requirements for this from the EU level. However, these certifications are not used by all companies, and therefore no standard for how certifications can be used to increase the information flow in the supply chain.

7. Perspectives from organizations

The following sections present results from the interviews with four organizations. Section 7.1 presents results from the Swedish Chemical Agency and section 7.2 presents results from three organizations. Interviewed organizations are Smart Textiles by Science Park Borås, Swedish Textile and Clothing Industries' Association and The Good Environmental Choice-The Swedish Society for Nature Conservation. Results are summarized in tables as well as presented in text and complemented by quotes.

7.1 The Swedish Chemical Agency

Table 6 presents the result from the Swedish Chemical Agency. The results present the current situation regarding tracking systems as well as problems with the systems used today. It is also presented how to follow up regulations as well as advantages and disadvantages with the implementation of tracking systems.

Table 6: Results from the Swedish Chemical Agency

The current situation regarding the tracking of chemicals"	**Problems with the tracking system used today**	**What is the best way to follow up regulations?**	**Advantages and disadvantages with the implementation of tracking systems**
Many companies have higher ambitions than today's laws and regulations	High complexity	Regulatory authorities	More and better information

In table 6, it can be seen that the Swedish Chemical Agency states that today many companies are ambitious and have higher ambitions than current legislation. A problem with the systems used today is that it is highly complex. Regulatory authorities are stated to be the most suitable way to follow up regulations. The Swedish Chemical Agency also stated that an advantage of implementing a standardized tracking system is that it allows more and better information as

an advantage and no disadvantages. They mentioned "//…// *requirements for information and that it must accompany the product through the whole life"*, when discussing advantages.

The Swedish Chemical Agency states that regulations by authorities are seen as the most effective way to ban hazardous chemicals such as PFAS to put the responsibility on companies to fulfill the requirements. It is also stated that regulations can make it easier to deal with suppliers and one reason for this is mentioned "//…// *it can be more difficult for small actors to get a hearing from their suppliers".* The largest problems with PFAS in the textile industry are stated to be the manufacturing and environmental problems where the manufacturing in other parts of the world is presented as a part of the problem. They also mentioned that "//…// *an important part is the one who actually puts chemicals on the market and sells chemicals".*

7.2 Three organizations

Table 7 presents the result from the three organizations that participated in the study. The table presents the problems with both information in the textile industry as well as problems with tracking chemicals in clothes. It is also presented how companies should work with a standardized tracing system as well as how that system should be like. Lastly, the disadvantages and advantages of tracking systems are presented.

Table 7: Results from three organizations

Organizations	Problems with information flow in the textile industry	Problems with tracking of chemicals in clothes	How a tracking system should work	Disadvantages with tracking systems	Advantages with tracking systems"
Smart Textiles by Science Park Borås	Difficult with control in the supply chain	Differences between countries All information needs to be visible	Standardized information flow A credible technology	Monetary cost	Transparency and information
Swedish Textile and Clothing Industries' Association	-	-	Efficient system for gathering information Digital tools	The complexity	Increased possibilities in the future Equal for all companies
The Good Environmental Choice - The Swedish Society for Nature Conservation	Complex supply chain	Knowledge of chemicals used	-	Currently low knowledge	Traceability and transparency

It can be seen in Table 7 that two organizations present the complexity and difficulties with the control in the supply chain as the largest problems regarding the information flow in the textile industry. It is also stated that currently, many companies do not have control over their supply chain. It is also presented that many companies use different types of certifications, but it is not an optimal tool. The largest problems with the tracking of chemicals in clothing are presented to be that certifications are sometimes used but do not work in all countries. The interviewee also mentions *"//... // all transactions in and out of systems must be visible"*. It is also presented that companies need to gain more knowledge about the chemical content of their products and one way to achieve this is stated to be the introduction of tracking systems.

In Table 7, it can also be seen what a tracking system would be like and how companies should work. It is stated that there is a need to build efficient systems for the gathering of chemical information in the supply chain and a digital tool is suggested. The importance of a standardized information flow was also highlighted as well as the importance of credibility, where one organization mentioned "//… // *Some form of locked output, that you cannot change what is entered*".

Lastly, disadvantages and advantages can be seen in Table 7. As disadvantages monetary costs are presented, as well as the price of the products, will become more expensive. The low knowledge that currently exists from companies, as well as the complexity of tracking systems, are also stated as a disadvantage. One organization stated that *"//... // these kinds of systems cannot be too complex for small and medium-sized companies to use".* An advantage that is presented by two organizations is the transparency as well as the traceability and information possibilities. *"//... // a product passport can make relevant environmental information available, such as chemical and material content"*. Increased possibilities in the future are also presented as an advantage and that will be equal for all companies with a standardized tracking system.

8. Discussion

The discussion is based on interviews with nine companies and four organizations to analyze how companies track chemicals in their supply chain and how a standardized tracking system can be used in the textile industry.

8.1 How companies manage hazardous chemicals

The results indicate that all interviewed companies work with managing hazardous chemicals but in different ways. Many companies work with managing chemicals due to laws and regulations, but they also believe it is important to not make a negative effect on either the environment or human health. To decrease the use of chemicals, companies use different kinds of chemical restricted substance lists, and it aims to gain better control of product content. Companies mention that they are working together with different groups and organizations to have the same requirements for suppliers. Companies believe that it is easier to put higher demands on suppliers by collaborating and having the same requirements. It will be easier for suppliers to work continuously with the use of chemicals if companies have the same demands.

But to find an effective way of managing chemicals, the interviewed organizations believe that requirements from the EU need to be implemented to make it more powerful. This is because if requirements come from the EU, requirements will automatically apply to everyone in the industry compared to if individual companies have their requirements. It can be difficult for small companies to achieve changes at the manufacturing level if they are not seen as a major actor in the industry. If there are initiatives from companies that are not supported by laws and regulations, no regulatory authority can ensure that all information is correct and complete. If there is no regulatory authority in production countries, it can result in manufacturers and suppliers not following the company's requirements. Then problems can arise in the supply chain and products can contain unwanted chemicals. This analysis is supported by the theory that a regulatory authority can be implemented to control what the products contain and not. The regulatory authority will also make it possible to control that companies are following restrictions. This is especially important as the global textile industry has production in lower-labor-cost countries outside the EU. The textile industry supply chain can be related to suppliers and sub-suppliers and by the sourcing strategy, that most of the companies in this study are using, and that limits the focal companies' control over suppliers. Some companies have solved this issue by nominating sub-suppliers and some components in the product.

Many companies mention that they have stricter requirements than today's laws and regulations and that demonstrates that companies are willing to make a change to decrease the use of hazardous chemicals. The organizations have the same experience: that companies want to make a change and that companies have stricter requirements than what is required. However, companies are not only affected by laws and regulations, but they are also affected by the customers' requirements. Higher demands are placed on the market from consumers and for consumers to choose a company's products, it is important that companies can show what they contain. As consumers cannot ensure what the products contain, or information is not

available about it, asymmetric information arises. As mentioned in Section 3.2, this can lead to a negatively affected market. What happens is that consumers can not choose what to buy because they do not know what the products contain.

To be able to decrease the use of chemicals in products, communication with manufacturers and suppliers is an important part as they possess a large part of the information. That is something that companies highlight as a major part of their work to track chemicals through the supply chain. Manufacturers and suppliers are an important part of the information flow through the supply chain since they possess a large part of the information.-Transparency and control in the supply chain can reduce the environmental impact which many companies also are highlighting. If a standardized tracking system is implemented in the textile industry, all companies will manage chemicals in the same way.

8.2 Success and challenges with phasing out PFAS

There are many different ways of controlling the use of PFAS, this study focuses on tracking systems and it can be seen that no standardized tracking system is used to control the use of PFAS. As the result indicates, there are companies that still use PFAS and need to use it in the future until substitutes that fulfill the same requirements are available. The companies that currently need to use PFAS are those with stricter requirements, such as companies that sell workwear. Both the companies that sell workwear, and the organizations, agree that some workwear that is used to protect the user in specific situations needs to use PFAS since there is no substitute that fulfills the high requirements. However, since PFAS has a negative effect on both the environment and human health, it should only be used for essential use. Today, there is only a ban for certain PFAS substances, but soon there might be a total ban for using it when it is not for essential use. If all PFAS substances should be included at the REACH Candidate List, it should be taken into account that some exceptions can be needed for these products. In the beginning, while focusing on developing new substitutes, exceptions may be required. But by implementing stricter requirements on all PFAS substances, products that have the possibility to use substitutes will need to change. This study shows that PFAS is currently needed in workwear but not in other types of clothing where the requirements are not high.

To be able to implement such a ban, there has to be a system to control that it is only used for essential use. To ensure and reduce the use of PFAS, a standardized tracking system is needed. To be able to implement such a ban, there has to be a system to control that it is only used for essential use. To ensure and reduce the use of PFAS, a standardized tracking system can be used. A standardized tracking system can improve the possibility to know the chemical content of the product. If there is no way to make sure what the products contain, there is no way to control that the substances are not used on the market. By implementing a ban for all PFAS substances in combination with a standardized tracking system, it is possible to have good insight into what chemicals are used. This will also increase the possibilities to phase out PFAS since the companies have to present the chemical content. Another important reason for tracking and phasing out PFAS is because consumers place higher demands that PFAS should not be included in the products. To be able to ensure that products do not include PFAS, there

has to be some way of controlling that. It is also of high importance that this is controlled in the same way by all companies so consumers can be sure that the information is correct. Consumer demand is important for all companies, and some companies mentioned the quality of the products as an important aspect. It was seen that PFAS often gives the products good quality, whereas substitutes often have difficulty living up to the same quality. This does not mean that the substitutes are not working well. Both organizations and some companies agreed and mentioned that substitutes work well. It was seen that the companies may have created a need that does not exist, but now consumers have high requirements for the products it can sometimes be difficult for companies to stop using PFAS.

However, all companies work to reduce the use or completely stop using PFAS, but even though the companies themselves want to stop using PFAS, there is a problem with those who produce and deliver the products. Suppliers and manufacturers are therefore an important part of the information flow since they possess very important information. To be able to have control throughout the entire supply chain, a tracking system is needed that follows the product throughout the whole life cycle.

8.3 Chemical management in the supply chain

The study shows that the interviewed companies use a variety of systems for tracking chemicals in their products. Only one company uses a certified system while others use systems they themselves have created. The main elements of the used tracking systems are laboratory tests of both the product and components in the final product, regulated substances list and communication with suppliers and manufacturers. There are only some companies that are using certifications to ensure what their products contain. However, these systems are lacking in control of sub-suppliers and problems regarding getting in contact with sub-suppliers are something that companies mention. The companies also believe that communication with suppliers and sup-suppliers is important as they possess a large part of the information. They also see tracking the history of a product is very important.

One major problem with today's way of tracking chemicals is that it is very complex since all companies are using their system. The companies that use certifications are controlled by a third party while the companies that only use systems they have created are not controlled by a third party related to product information. Another problem regarding certifications is that they are only a document and easy to change and it is not possible to use that in all countries since some countries are running a higher risk of corruption. Corruption can increase the risk that the certifications will not be credible as they may be influenced by external factors. To reduce that risk, one interviewed organization believes that the system should be digital and that everything that is put into the system can be tracked. There must be a system that is credible in all countries since the textile supply chain is spread all over the world. The companies also mention that there is a big problem with monitoring and control of the information. It is also difficult to compare certifications with each other since they regulate different things. The results indicate that OEKO-TEX® and Bluesign® are used by the companies and a product can be certified with Bluesign® even though all components in the product are not certified. It

reduces credibility with certifications, and it becomes especially difficult to compare them with each other.

Many companies believe they have full control of their supply chain and that might affect their opinion on the need for a standardized tracking system. But companies have another idea of what the reality looks like compared to interviewed organizations. If the companies had full control, the current situation with a lack of information regarding chemical use would not be a problem. Many companies report that they try to work long-term with their suppliers and this may be to create the opportunity to build trust and thus be able to control that they have received the correct and complete information. In the past, companies may have changed sub-suppliers more often, however, in today's sustainability-focused world this is no longer feasible because to achieve sustainability we need a more controlled and consistent long-term relationship with suppliers. To increase the possibility of having better control over sub-suppliers, some companies are working to nominate sub-suppliers so they ensure that they use the same sub-suppliers during a longer time period. It is hard to compare companies since they are tracking chemicals in different ways, which is also increasing the complexity of controlling if all information that is reported by companies is correct. As companies do not have the same view of the problem without themselves believing that they have good control over their supply chain, this may affect their view of the need for a standardized tracking system in the industry. But they also mention that it is a big challenge in the industry and companies want to track chemicals in a different way than how it is done today.

One reason why companies think they have control may be because companies do not know how to have control and the lack of knowledge about what information is available. As there are currently no clear regulations on how to track chemicals and report that information, there is also nothing to compare with to ensure whether the companies have control or not. As it is currently not possible to check whether a company has full control, it is also not possible to punish the company if this is lacking. The fact that it is not possible to be punished can cause companies to down-prioritize this problem, as nothing happens if they do not have full control. The cost can also be a reason why companies do not have control. If the companies do not have complete control, they themselves do not know what information is missing.

One way to overcome these problems can be to implement a standardized tracking system. For this to work, data needs to be collected from the first step and all the way to the consumer. This is in line with how RFID works since it can be attached into a product. To have a standardized tracking system, some type of monitoring is also required. Although the human factor may come into play and errors may occur, it is important to be able to track all data entered to minimize the risk of cheating.

A problem regarding a standardized tracking system that is mentioned in the results is to be able to create a transparent supply chain. That requires a monitored and processed system to be able to present data in securely. Interviewed organizations mention that better and more information can be collected by using tracking systems. But the problem with increasing transparency is that there is a lot of confidential data. This is also something that the one

interview organization considers important to know what goes in and out of a system to reduce the risk of corruption or fraud. Companies must see transparency as an advantage to open their systems, which is an important part of the design of a DPP. This is because there is very sensitive information that companies should not have to share to compete in the market. Companies gain a better insight into their supply chain through tracking systems, but companies may not be willing to disclose all types of information to the public. Advantage of how companies today track and document chemicals is that they choose what they want to share. This is good for companies as they can see an advantage in not having to share sensitive information. But there is a big disadvantage with the companies themselves choosing which information to share, as this can lead to an even greater gap in the flow of information.

Information management throughout the supply chain works in other industries, an example that is discussed together with the implementation of DPP is the EU Ecodesign Directive. It is part of the Sustainable Product Policy where energy use is declared for each product. This directive shows that it is possible to collect the information needed to gain full control of products. The EU wants to develop this directive to include more products and here the chemical handling of textiles should be included. Having an already implemented directive as a basis should make it easier to implement a standardized tracking system in the textile industry.

8.4 Challenges with information flow in the supply chain

The result indicates that the companies themselves believe that it is not a big problem regarding information flow through the supply chain, but they do mention that there is a problem to have control through the whole supply chain due to many actors. The companies also believe that more responsibility should be placed on the suppliers that put chemicals on the market and that this is how chemicals should be traced. There are currently only requirements for the final product. To decrease the gap of information between the focal company and suppliers and sub-suppliers, requirements and restrictions are needed through the whole supply chain and not only on the final product. One thing that companies mentioned as a problem regarding the information is the possibility to gain control from the beginning of the product's lifetime. Many companies state that they ask suppliers about information that is needed, but since there is no information obligation, there is a high risk that information is omitted. Communication is used to map all materials and components, and both the organizations and the companies highlighted the importance of communication and transparency throughout the supply chain. However, even if communication is an important part, it cannot be seen as a tracking system. By implementing a standardized system, all actors need to report the same type of information in a controlled way. This also makes it possible to track the chemical content through the whole supply chain, from the beginning, through the production, to the final product. A standardized tracking system can improve the credibility of the information and all information is visible.

The companies believe they have solved the problem with good communication with all suppliers and manufacturers. But at the same time, the results from the interviewed organizations show that it is a big problem. If the information cannot be ensured that it is correct and complete information throughout the supply chain, it is difficult to check whether

companies today have complete control as there is no way to control this. Some companies use restriction substances lists to ensure that the manufacturer does not use any unwanted chemicals. The advantage of using these is that it gives the manufacturer clear directives of what chemical content is okay to use. But today, there are no regulatory authorities that control these lists that are used. Another problem is that it has been seen that there is still a risk that manufacturers do not follow these lists, for example by accidentally using the wrong chemical. The companies have tried to solve this problem with laboratory tests. The tests are seen to be a good way to get information on the chemical content of that product. But one problem is that the companies do not test all products that are placed on the market and therefore important information may be missed. It can also be costly to do testing and in many cases. Besides this, companies do different types of testing, which means that not all information is presented in all testing methods. An advantage of using testing is that many companies use a third party, which means that it is not possible to affect the result.

It has also been seen that some companies use certifications and that some companies think that this is one type of tracking system while others do not see this as a tracking system. In this thesis, certifications do not fulfill the requirements for being a tracking system since it does not include tracking of the product throughout the whole life cycle. One advantage of using certifications is that they are reviewed by a third party, which increases credibility. However, it has been seen that different types of certifications are used on the market and two of the certifications that have been mentioned by the companies in this thesis are Bluesign® and OEKO-TEX®. It has been seen that these are to ensure the content of the products. Since companies use different types of certifications, it becomes difficult for the consumer to compare different products. One disadvantage of using these certifications is that a part of a product can be certificated, but still not the whole product, which also increases the complexity of the system. This can lead to certifications can lose credibility as it is not possible to compare them with each other.

Overall, the way that companies today work with communication with suppliers, restricted substance lists, testing, and certifications can be seen as better than not doing anything. All systems have advantages and disadvantages, but none of them fulfill the requirements for what this thesis defines as a tracking system. The major problem with these is that there are no standards that are used by all companies and therefore it is difficult to compare between different companies and products. The organizations believe this is a problem because it results in difficulty to control if the information is correct since there is no standardization where a regulatory authority or third party controls the information. OEKO-TEX® is an international certification system, which can be seen as effective with high credibility. But since all companies are not using it, it is difficult to compare with other products, and therefore it cannot affect the entire industry that is desirable. This thesis, based on interviews with companies and organizations, believes a standardized tracking system is needed to be implemented on the market and used by all companies to be able to have control of the chemical content in products. To be able to use it in all products and all companies it needs to be easy to use. It is also important that it is used from the first step in the production to the final product. This would result in high credibility and fairness in the market where all companies are working in the

same way. The consumers can be ensured that they know what type of product they buy and use. By implementing a standardized system, it is possible to control what the company says and the market becomes more credible as well as it minimize the problem with asymmetric information.

8.5 Methodology limitations

This study includes nine companies and four organizations, so this is not a study that covers the complete industry. The number of interviews can affect the validity of data, even though different types of clothing companies have been interviewed. There are only the focal companies that have been interviewed and not suppliers, which also limits the perspective on the study. Interviews with suppliers should provide a broader perspective on the problem. Many companies mention similar things related to the problem of tracking chemicals, so this shows the validity of the data. The study covers both larger and smaller actors on the market, so it includes aspects from different perspectives. Since there is no standardized way of tracking chemicals today, such type of information can be confidential. That is something that can affect the answers in the interviews, for example on how companies practically track chemicals. That is also something that some companies have raised as a problem regarding talking about how they are working with specific things. There is also a risk that companies want to give a beautified picture of how their work on sustainability and that these are not completely transparent answers. The study would have been deeper and more valid if more authorities were included.

A lot of companies mentioned that they had no time to have an oral interview and that they preferred to answer by email, or that they did not have time at all to participate, due to the Covid-19 pandemic. There is then a risk that persons that are not as knowledgeable about the subject have answered our questions and that can have affected the depth of the answers. To minimize that risk, we sent our questions before the interviews, so they had time to be well prepared. But it was noticed that some people have not been able to answer all of our questions.

Some interviews were answered by email, approximately 50%, which causes a risk that some answers might have been shorter and not as detailed compared to answers in a video interview. The downside of written interviews is that it does not allow for natural and fluent follow-up questions which might lead to less nuanced answers. The upside is that the rigidity of the questionnaire prohibits the interviewer from asking potentially leading follow-up questions, which would bias the respondent's answers. Almost all interviews were answered in Swedish and that can have affected the word choice and wording during the translation. To minimize that risk, all interviews were transcribed in English and sent back to the interviewee for review.

8.6 Further research

One topic for further research is to study whether tracking systems can improve the recycling of clothes and increase the use of recycled materials. Recycled materials are currently representing a small share of the total material use in the textile industry. One problem related

to the use of recycled materials is that companies cannot ensure what recycled materials contain. That is something companies mention as a problem regarding chemical use. By implementing a standardized tracking system for the whole industry, there will be better control of what the materials contain.

Another topic for further research is to look at how tracking systems can increase the phasing out of other unwanted chemicals. Many companies have stricter regulations than today's laws and restrictions, which shows that companies and the textile industry want to make a change when it comes to the use of chemicals. With the help of the implementation of a standardized tracking system, you can get a better overall picture of how much chemicals are on the market and whether it is an environmental problem.

9. Conclusions and Recommendations

Based on the interviews, we found that there is a lot of variation in how companies work with tracking chemicals in their products. Most of the companies use system they themselves have created, there is only one company that mentions that they use a certified system. The systems mainly consist of regulated substance lists, good communication with suppliers and manufacturers and laboratory tests of the final product and specific components. Some companies are also nominating components in their products to ensure that already tested components are used in all products. Companies are also using different kinds of certifications depending on what type of clothing they are selling. The main differences of these systems are that some companies are controlled by a third party while others are not. Those companies who are using certifications are controlled to get their products certified. The advantages of systems that currently are used in the textile industry are that the companies are trying to have good control by making a lot of laboratory tests on their products and they are trying to work in the long-term with their suppliers. They are also trying to map all materials and components that are used to gain better control. Even though companies are not using certified tracking systems, this way of working still increases the tracking of chemicals compared to if companies had not tried. The companies' way of working has also resulted in higher requirements than current laws and regulations in many cases. However, the major problem with today's way of tracking chemicals is that companies are using different systems. Another major problem is that even though companies are using restricted substance lists, there is no regulatory authority that checks if companies are following this or not. It is also hard to punish companies that are not following regulations. Since the main element of today's systems is to communicate with suppliers, there is a risk that companies are communicating regarding different things. That will make it harder to make a change in the whole industry. Currently, the systems can be considered effective for individual companies as they believe that they have good control of their supply chain. But there are still challenges, mainly related to the lack of standardization, which makes it difficult to compare different companies and products. The credibility is also affected since there is no way to compare these systems and to know that all information is correct. To be able to have a more efficient system in this complex supply chain, a standardized system is required.

9.1 Recommendations

The study shows that different systems to track chemicals are used on the market. However, these systems do not have control of the chemical content of the product and it is problems regarding the information flow through the supply chain. The study indicates that one major problem is the lack of standardization, which reduces the credibility as different systems cannot be compared with each other. A standardized tracking system can improve the possibilities of tracking the chemical content through the whole supply chain, it will also improve the credibility if all companies are working in the same way.

Today there is no standardized tracking system on the market. For a future tracking system, this thesis has seen that properties that are desirable are especially that it is easy to use for

everyone. This thesis has been studying DPP and RFID which can be used to present and track information through the supply chain. Theoretically, these systems are seen to have many possibilities, but there are still challenges to implementing them practically. To enable the use of DPP, there needs to be a way to register all information about the product from the product's first steps in the life cycle, i.e., from raw materials. It requires a regulation of all components in the product and not just the final product as the current situation looks like. In order to be able to register all information from the beginning, some form of a chip that comes with the product needs to be implemented, for example, RFID.

One problem with implementing a tracking system is how it in practice will work since the whole industry is complex and spread all over the world. Therefore, the recommendation based on this study is to implement a regulation on the EU level. Within the EU, there is today a similar initiative related to electrical products, the EU Ecodesign directive. Then the energy usage of the products is declared and in a similar way, it should be possible to declare the chemical content. By regulation of all components in the EU will not affect the whole world, but it will affect all the suppliers outside the EU who export textiles to the EU. In the long run, this can hopefully also affect the textile industry globally.

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Appendix 1

Appendix 1 shows an overview of the interviewed companies in the study. It presents the role of the interviewee as well as the contact form and date for the interview. The types of clothes that the companies sell are presented and the companies operating market.

Table 8: Introduction and general information about interviewed companies

Company	Role of interview person	Contact form & date	Type of clothes	Operating market
Peak Performance	Sustainability manager	Video 2021-11-18	Outdoor clothing and casual clothing	Globally
H&M Group	Sustainability Business Expert	Email 2021-11-12	Fashion and lifestyle	Globally
Henri Lloyd	CEO with a focus on Product and Sustainability	Email 2021-11-12	Functional Performance clothing	Globally
RÖYK	CEO and Head of Design and Product	Email 2021-11-18	Outdoor clothing	Globally
Kappahl	Quality assurance manager	Video 2021-11-25	Fashion and lifestyle	EU
Outnorth	Sustainability manager	Video 2021-12-02	Outdoor clothing and sportswear for outdoor activities	The Nordics and Germany
Alligo AB (Björnkläder, Univern and Gesto)	Product development manager	Video 2021-11-29	Workwear	Sweden, Norway and Finland
Stadium	Sustainability Manager Purchase & Category	Email 2021-12-01	Sportswears and outdoor clothing	Sweden, Norway and Finland
Fristads	Head of R&D raw material	Video 2021-12-01	Workwear	EU

Appendix 2

Appendix 2 shows an overview of the four organizations that participated in the study. The role of the interviewee is presented, together with the contact form and date for the interview. It is also presented which markets that they are operating on.

Table 9: Introduction and general fact about the four organizations

Organizations	Role of interview person	Contact form & date	Operating market
Swedish Chemicals Agency	Strategic advisor	Video 2021-11-24	EU
Smart Textiles by Science Park Borås	Strategic advisor	Video 2021-24-11	EU
Swedish Textile and Clothing Industries' Association	Sustainability Manager	Email 2021-06-12	Sweden
The good environmental choice - The Swedish Society for Nature Conservation	Method developer	Email 2021-12-08	Globally

Appendix 3

Appendix 3 presents the interview questions used in the interviews with companies.

Opening questions:

Please present yourself shortly.
Please describe your role in the company.
What type of clothes does your company sell?
Do you operate solely in Sweden or other countries as well?
In what way is your company affected by hazardous chemicals in clothes?
How do you work to decrease the use of hazardous chemicals in your clothes?

Questions related to PFAS:

Do your products contain PFAS?

- If yes, do you actively work with finding a substitution for PFAS? → if not, what hinders substitution?
- If not, what are you using instead to ensure that your clothes are water and soil-repellent?
- How do substitutes for PFAS work, are there any disadvantages and advantages?

Questions related to tracking system:

How do you ensure what your products contain, related to chemicals?
Are you manufacturing your own clothes or do you buy from a manufacturer?

- How does the information system work between you as a retailer and the manufacturer so you know what the products contain?
- If the production is outside the EU, how do you ensure that EU's regulations are followed?
- How do you work and communicate together with your manufacturers related to hazardous chemicals through the supply chain?

Do you experience asymmetric information flowing through your supply chain?

- If yes: Is that a problem regarding the tracking of chemicals?
- If not: how have you solved this problem?

Do you use any types of tracking systems for chemicals?
Are there any disadvantages to tracking chemicals through the supply chain?
Are there any advantages to tracking chemicals through the supply chain?
How would you prefer to track chemicals through the supply chain?

Final questions:

Would it be okay to contact you again?
Is it okay to mention in our report that we have been in contact with you and your company?

Appendix 4

Appendix 4 presents the interview questions used in the interview with the organization Smart Textiles by Science Park Borås.

Opening questions:

Please present yourself shortly
Please present your organization
Please describe your role in the organization
How do you see that smart tags can help the tracking of chemicals in clothing?
What problem do you want to solve with smart tags?

Questions related to tracking system:

What do you see as the biggest problems with asymmetric information?
How do you think a tracking system can contribute to the phasing out of hazardous chemicals?
What do you think are the disadvantages and advantages of using tracking systems?
What are the key features of a tracking system?
What do you see as the biggest problem with PFAS in the textile industry?

Final questions:

Would it be okay to contact you again?
Is it okay to mention in our report that we have been in contact with you and your company?

Appendix 5

Appendix 5 presents the interview questions used in the interview with the organization The good environmental choice - The Swedish Society for Nature Conservation.

Opening questions:

Please present yourself shortly
Please describe your role in the organization.
Are you engaged in environmental issues outside Sweden as well?

Questions related to PFAS:

How do you actively work with banning PFAS?
What do you see as the biggest problem with PFAS in the textile industry?
How do you want clothing companies to work with phasing out PFAS?
Do you think the textile industry is working actively with this?
Do you recommend any substitutes for PFAS? It is a chemical that contributes a unique property to clothing.

Questions related to tracking system:

How do you think a tracking system can contribute to the phasing out of hazardous chemicals, such as PFAS?
What do you believe are the benefits and drawbacks of tracking systems?
Are there any specific tracking systems that you think are the best to use in the textile industry?

Appendix 6

Appendix 6 presents the interview questions used in the interview with the organization Swedish Textile and Clothing Industries' Association.

Opening questions:
Please present yourself shortly.
Please describe your role in the organization.
What type of environmental questions do you work with?
Do you solely work with Swedish textiles companies?

Questions related to PFAS:
What is your experience regarding the use of PFAS within textile companies?
What do you think are the advantages and disadvantages of using PFAS?
How do you support and advise companies related to the phasing out of hazardous chemicals, such as PFAS?

Questions related to tracking system:
How do you prefer that companies should work to be able to ensure what their product contains, related to chemicals?
How do you think companies should work to be able to track chemicals throughout the supply chain?
Do you experience that companies think it is a problem to be able to track chemicals in the supply chain?
What are the advantages and disadvantages of being able to track chemicals in the supply chain?
Do you have any suggestions on tracking systems that can be used to track chemical textiles?
What do you think would be the advantages and disadvantages of implementing a standardized tracking system?

Final questions:
Would it be okay to contact you again?
Is it okay to mention in our report that we have been in contact with you and your company?

Appendix 7

Appendix 7 presents the interview questions used in the interviews with the Swedish Chemicals Agency.

Opening questions:

Please present yourself shortly
Please describe your role at the Swedish Chemicals Agency
Are you engaged in environmental issues outside Sweden as well?

Questions related to tracking system:

How is the tracking of chemicals handled today in the textile industry?
Are there any problems with the system used today?
How is the current work regarding tracking systems?
Why should companies use tracking systems?
Are there any tracking systems to be implemented on the market due to the new regulations?
What do you believe are the benefits and drawbacks of implementing standardized tracking systems?
Which tracking systems do you think are most beneficial for companies to use in the textile industry?
Which tracking systems do you think are least beneficial for companies to use in the textile industry and why?

Questions related to PFAS:

How do you actively work with banning PFAS?
What do you see as the biggest problem with PFAS in the textile industry?
How do you want clothing companies to work with phasing out PFAS?
Do you think the textile industry is working actively with this?
Do you recommend any substitutes for PFAS? It is a chemical that contributes a unique property to clothing.
How do you think a tracking system can contribute to the phasing out of hazardous chemicals, such as PFAS?

Final questions:

Would it be okay to contact you again?
Is it okay to mention in our report that we have been in contact with you and your company?

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