EXPLORING THE OUTDOORS

MAPPING MICROPLASTICS IN THE TEXTILE DESIGN- AND PRODUCTION PROCESSES

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Abstract

Microplastics have been found in all aquatic environments and once they entered they cannot be removed. This has put new focus on the sources of microplastics where the textile industry has gained large attention. Much consideration has been given to the production of fleece fabric and the use of polyester but this report aims to explore the whole design- and production process and mapping those activities which has a large impact on microplastic release. Together with participants from five (5) Swedish Outdoor Brands and seven (7) field experts has this report mapped possible challenges and solutions. Main findings are 20 different challenging areas with 19 suggested solutions on how to prevent microplastic pollution. The result is the first in its kind doing a comprehensive study of the whole textile design- and production process and provides a broad foundation for further research. As there still is a considerable lack of knowledge about many of the issues that were brought up, both within the design- and production processes, has a shared responsibility among companies, organizations, universities and private persons been raised. Through common platforms are inspiration and awareness spread and this report aims to contribute to the gap in the current knowledge.

Keywords: microplastic, pollution, textile design- and production process, exploratory case study, mapping, outdoor

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1 Introduction

Plastic waste is one of the biggest threats to the world's ocean.
(UN Environment 2017)

The United Nations Environment Program (UNEP) states that in 2050 there will be more plastic than fish in the oceans (U.K Reuters 2017). Auta, Emenike and Fauziah (2017) reported that up to 85% of the marine litter said to be plastic. The plastic has accumulated into plastic islands and once white beaches are now covered in plastic litter. The raising awareness of plastic has resulted in a lot of media attention and become an increasing concern to researchers, industries, associations and the general public.

Figure 1: Plastic and microplastic in media

It is past time that we tackle the plastic problem that blights our oceans. Plastic pollution is surfing onto Indonesian beaches, settling onto the ocean floor at the North Pole, and rising through the food chain onto our dinner tables. We've stood by too long as the problem has gotten worse. It must stop.
Erik Solheim, Head of UN Environment (UN Environment 2017).

Although plastic litter has been the main focus, microplastics has become the new topic entering the black carpet as a key player of sustainable concerns (Auta et al. 2017). According to several scientific researchers, microplastics have shown to travel across the world and have been found in all types of salt- and freshwater (Chang 2015; Mauro et al. 2017; Auta et al. 2017) and even been found in the most remote areas such as the Arctic Ice and the Easter Islands (Kroon et al. 2018). With the possibility to travel across the globe the pollution has now become an international concern.

The textile industry has a long tradition of negative attention with rising issues of child labor, working conditions and toxicants. Most attention has been related to the fast fashion industry and according to the Earth-scientist Miriam Diamon at the University of Toronto could the fast fashion trend play a large role in the issue with microplastics (Messinger 2016). As many fast fashion brands offer low price products a larger tradeoff is made on quality and cheaper fabrics are more likely to shed. Therefore, is fast fashion, in comparison to the outdoor segment, a bigger threat as a microplastic polluter. Nevertheless, does all synthetic fabrics release microplastics and the outdoor segment (which will be discussed in this report) is still a valid starting point. Microplastics are plastic fragments; generally defined being smaller than 5 mm (De Falco et al. 2017; Auta et al. 2017) and in a large variation of shape, color and size (Cole et al. 2011). As the scientific community has not yet agreed on a common definition of microplastic they can be referred to either as microplastics, microbeads or microfibers. In relation to textiles, both microplastics and microfibers are commonly used, however microfibers could also include fibers from nature-based materials such as cotton or wool (Napper and Thompson 2016) so in order to minimize confusion in this report, the term microplastics will be used.

In July 2012, reported Bangor Daily News about microplastics found on the Blue Hill Bay, Maine, USA (BNG Hancock 2012). Maine is a popular area for outdoor activities and although it could not be directly linked where the microplastics came from, 80% of the microplastics found on the shore and in the water obtained of acrylic and polyester. The article inclined that the use of synthetic sportswear was the contributing factor to the pollution and a link to the commonly used outdoor garment fleece was drawn. Nate Simmons, the spokesman of Polartec (a big supplier of fleece), said they took the issue with microplastics “very seriously” and was willing to investigate their own production processes, however, he also said that fleece is just one part and that most of the pollution would to happen in the domestic washing machines (BNG Hancock 2012). Domestic washing machines has since then been the most researched area.

The outdoor industry has been held as the proxy of dealing with microplastics being active within several Nongovernmental Organizations (such as EOG and FESI) and participating in scientifically studies (Bruce et al. 2016; Mowbray 2017). Being dependent on customers engaging in outdoor-activities and having a large product assortment of synthetic origin,

outdoor brands has been driven to develop a strong sense of sustainability and let it being a part of their core value and business plan.

The many sources of microplastic release (established or not yet investigated) raise the concern of the level of accumulation. With the uncertainty of knowing what causes microplastics release and the waste management and infrastructure not yet developed to cope with the issue, makes it crucial to look elsewhere to solutions (Auta et al. 2017). Not managing microplastics in the end of the chain open up the question - What can we do in beforehand?

1.1 Problem statement

Even though microplastics have received much attention, previous research has mainly been focused on impacts on marine life and domestic washing methods established a large gap within the scientifically field. The relationship between microplastic and the textile value chain is mostly uncovered, only a few reports have been conducted covered this topic. As the textile value chain is a complex set of activities of design- and production processes there are many aspects to consider. One of the few reports considering some of the parameters from the design- and production processes is the report produced by the Swedish cross-disciplinary research program Mistra Future Fashion and the Swedish Institute Swerea (2018), who investigated the relationship between microplastic shedding, choice of material and fabric construction.

Furthermore, to fully understand the environmental impact from a product, a life cycle analysis of the whole value chain, from raw material all the way to waste management and recycling is needed (Dangelico et al. 2013; Boucher and Friot 2017). To help the textile industry with their environmental impact, several sustainable orientated tools has been developed but none has yet looked into the issue with microplastics. Dangelico et al. (2013) points out that the development of sustainable products is a challenge, but that the subject of sustainability has to be incorporated already in new product development. This strengthen the reason of investigate what possibilities there are for designers and production managers to change their design- and production processes to minimize microplastic pollution. The large gap of knowledge within this subject allows the possibility to declare if there are any alternatives available for the design- and production process or/ and where there is a need for further development.

1.2 Purpose and Research Questions

The purpose of this study is to explore the design- and production processes in the textile value chain to survey where there is a risk of microplastic release, and what actions could be set to minimize it. Five Swedish outdoor companies have been the outset and the starting point to establish status of knowledge and development.

Hence, the research questions constituting the thesis are as follows:

i. Where in the design- and production process does microplastic pollution occur?
ii. What alternatives are available in the design- and production process to minimize the microplastic pollution?

2 Microplastics: The Situation of Today

To better understand the extension of the issue with microplastics, as well as the relation to the textile industry, this part as follow will present previous research. The scientific research is limited but there are multiple initiatives admitted to this issue arisen from governments, NGOs, companies and individuals. The first subsection will guide the reader though the general idea of what microplastics are, where they come from, how they affect the marine life and be followed by related initiatives to minimize microplastic pollution. Then the succeeding subsection will explain the relationship between microplastics and the textile industry. Lastly, a description of the design- and production process will be presented.

2.1 A General Background

2.1.1 Sources and impacts

To better understand the many sources of microplastics they have been divided into primary and secondary sources, generated both from land-based (98%) and of sea-based (2%) activities.

- Primary sources are found in products such facial cleansers, toothpaste, shower and bath gels, scrubs and peelings but also in foundations, mascaras, shaving creams, nail polish, sunscreens and synthetic clothes (Chang 2015; Fendell and Sewell 2009; Napper et al. 2015; Lei et al. 2017), textile laundry, abrasion from tires, road marking and city dust (Boucher and Friot 2017) and from sewer overflows, tourism-related litter and illegal dumping (Piñol et al. 2015)
- Secondary sources come mainly from abrasion from tires or waste from artificial grass (Naturvårdsverket 2017), degradation from larger plastic items (Boucher and Friot 2017), fragmentation synthetic textile waste (Henry et al. 2018) and from sewer overflows, tourism-related litter and illegal dumping (Piñol et al. 2015)

Plastic is a strong, lightweight, flexible and inexpensive material and can be used in a diverse range of ways. The plastic industry was the fastest industry growing between 1950 and 2016, growing from 1,7 million tons to 335 million tons (Plastics Europe 2017; UNEP 2015). This numbers, however, does not include the manufacturing of synthetic textiles (37,2 million tons) being 65% of the total fiber production in the world (Boucher and Friot 2017).

Of the total plastic industry is almost 50% of all plastic produced for packaging and disposals and that over 90% of the total harm caused to marine life is due to such litter (Napper et al. 2015; PlasticSoupFoundation.org 2018). Nevertheless, has recent studies seen that it is not only big plastics causing harm but also microplastics. According to Boucher and Friot (2017) has microplastics now been seen as another big threat of the marine ecosystem with a release of 1,5 million tons per year. Microplastic comes from fragmentation of larger plastic objects, caused by physical and chemical exposure such as waves, UV light and other chemical substances (Auta et al. 2017). Such chemical process happens wherever litter is stored outside and where there is no waste management. It has been reported that storms and bad weather can transport large plastic object as well as smaller to new areas, scattering and impede any attempt to wield the debris (Auta et al. 2017). Furthermore does microplastics enter the environment through abrasion from tires and road marking. With no or very low possibility to enter any waste or wastewater treatment systems the fragments are either spread by the wind or washed of the road by rain and flushed into the soil or into runoffs. Depending on the regional connection of sewer and wastewater treatment plants (WWTP) the water could be filtered and purified but fact states no plant to this point captures all microplastics entered (Boucher and Friot 2017).

One of the identified sources of microplastic release, is according to Napper et al. (2015) and Lei et al. (2017) from cosmetic products. The particles are made of polyethylene in micro size and are used for their exfoliant properties (Chang 2015). The use of cosmetic products is estimated to release of up to 94,500 pieces in one single use (Chang 2015; Napper et al. 2015) reaching a contamination of 1,53 million tons yearly (Lei et al. 2017).

Based on scientific research have the large variety of size, shape and color of microplastics a direct relationship to how it will be encountered by the marine wildlife (Napper et al. 2015). There have been discoveries that microplastics has been ingested into filter feeding animals, fishes, marine mammals and birds (Rochman et al. 2013; Fendell and Sewell 2009; Auta et al. 2017; Napper et al. 2015; Mauro et al. 2017). As reported by Auta et al. (2017) has the consumption of microplastic shown to change the behavior of animals, causing physiological stress, internal blockage, cancer (result of toxins sorb on the particles) which could end in a fatal outcome (Chang 2015; Fendall and Sewell 2009; Felsing et al. 2017; Mauro et al. Benfield 2017).

Still, it is not only organisms and animals suffering of microplastics. Depending on size and weight does some microplastics float on the surface or near-surface as most studies have

presented. There are studies showing microplastics being ingested by plankton sinks to the marine sediments. The study of Auta et al. (2017) state that deep sea areas, submarine canyons and marine coastal are covered in microplastic. Furthermore does the study of Henry et al. (2018) state that 94% of the entered plastic ends up on the ocean floor, estimated that 70 kg plastic covers each square kilometer of the sea bed. The sunken microplastics mix with all things on the seafloor and the study made by Yang et al. (2015) found microplastics in 15 different sea salt brands, indicating a direct link between microplastic contamination and human consumption.

Finally, plastic can be generated from a diverse set of polymers. The polymers have different characteristics suitable various use. Plastic is durable and tough, so though that research state that the decomposing of plastics is low or even imperceptible. There are no ways, according to Napper et al. (2015), of removing microplastics from the oceans without harming also other microorganisms. This means that plastics entering aquatic areas will remain in there (Auta et al. 2017; Napper et al. 2015). The lack of decomposing and the unknown accumulation add to the complexity and uncertainty of how microplastic pollution will affect and are affecting our ecosystem (Kroon et al.2018). Such dilemma complicates the problem and increasing the severity to stop microplastics beforehand.

2.1.2 Initiatives for solutions

In 2015, the UN Environment Program (UNEP) released a report with a precautionary approach towards microplastics with the intention to phase-out and ban microplastics in personal care products and cosmetics (UN Environment 2015). The rising attention led to both U.S and Canada banned the production of cosmetic microplastics (Napper et al. 2015; Mauro et al. 2017; Chang 2015). The negative publicity led to several cosmetic brands excluded microparticles from their products (using sand and nut shells instead), added more information on labeling and packaging and spread more information through marketing campaigns (Chang 2015; Napper et al. 2015).

During the last year the interest of microplastics has culminated into multiple campaigns such as the *Clean Seas Campaign* launched by the UN Environment in 2017 with the aim to eliminate plastic waste and debris in marine areas and to enlighten consumers of their consumption and throwaway habits of disposables and cosmetics (UN Environment 2017). Also, *The Plastic Soup Foundation*, which by campaigns, media, educational programs pursuit to increasing attention to the marine debris (PlasticSoupFoundation.org 2018). Their campaign *Beat the*

Microbeads reach from picking up plastics in the near surrounding, to stop buying cosmetic products with microbeads and preventing people to release balloons. Further have they developed an app, *Beat the Microbead App*, for consumers to track their plastic footprint (Kirschbaum 2018). The Plastic Soup Foundation supports as well other projects such as the *Rozalia Projects*. Rachel Miller, Project co-founder and Executive Director of the project believe they can clean the oceans from the floating plastic debris (TEDx 2014). Through multiple development projects, scientific research, educations and cleanups the *Rozalia Project* attempt to find new ways of cleaning the oceans and to educate kids to value our marine environments (Rozalia Project 2013).

Disposables, being commonly used in the food industry have too received attention and The Guardian (Readfearn 2018) reported that plastic bottles contain twice as many microplastics than tap water. Such news has engendered several projects to minimize the use of plastic bottles. One such project is made by The Skipping Rocks Lab (2018). They created the *Ooho!*, which is a bottle made of 100% plants and could either be eaten after use or biodegrade within six weeks. Many bottles today are usually made of PET and according Piere-Yves Paslie, the co-founder of The Skipping Rocks Lab, does it take up to 700 years to decompose. Finally, he said in the interview with Innovation Forum (2017), "Just 0.03% of the brown seaweed in the world could replace all of the polyethylene terephthalate (PET) plastic bottles we get through every year".

Furthermore, did Robert Pocius, the founder of Tek Pak solutions say in an interview with Innovation Forum (2018), that they have developed a new solution for biodegradable plastics. The idea is that the plastic will fully degrade into CO_2, methane and inert material. The degradation would take 20 months if it would end up on landfill instead of being recycled. Nevertheless, he did not mention how the plastic would react if ended up in the ocean. The composition of the two environments are different and one could not say that the material would react in the same way irrespective of environmental conditions.

Vaughan (2016) said biodegradable plastics is a *'false solution'.* Vaughan reports in the magazine The Guardian that UN's top environmental scientist warns about the marketing of using biodegradable products as the solution of plastics in the oceans. The false assumption of biodegradable polymers being less harmful for the environment is also supported by the research conducted by Straube et al. (2017). They discovered in their study that the effects of petroleum-based and biodegradable microplastics does not differ in their effect on marine life.

In their study they tested a biodegradable bio-microplastic particle made of polyhydroxybutyrate (PHB) and petroleum-based microplastic particle made of polymethylmethacrylate (PMMA). Such result, according to the authors should be further discovered to understand the effect from the *environmentally friendly alternatives* (Straube et al. 2017, p. 15-16). The lack of knowledge of the real effect of changing to biodegradable polymers is it hard to see the benefits for the textile industry, being scared doing something that would be even worse than the first solution.

2.2 A Focus on Textiles

2.2.1 Sources and impacts

According to the Nonwovens Industry Magazine (2017) has the synthetic textile marked grown from 14 million tons to 71 million tons between 1980 and 2016. The flexibility and easy maintenance of synthetic fibers makes it a preferred choice for many consumers, wanting clothes which are adapted to their many activities, are easy to care for and comfortable to wear (Grandviewresearch.com 2018; Keiser and Garner 2012). The ability to modify synthetic fibers has generated a diversity of applications and they are commonly used by sport and outdoor brands. According to the research by De Falco et al. (2017) has some fabrics shown to release more microplastics than others, where polyester and acrylic top the scale. As reported by Grandviewresearch.com (2018), an U.S. market research and consulting company, has polyester the largest market share and account for almost 50% of China's total revenue and is expected to continually grow 7,3% until 2025.

Synthetic textiles have been identified as one of the contributing source of microplastic pollution in our oceans were polyester, together with acrylic and polyamide has been the most recurrent synthetic fiber found in sediments and wastewater across the world (Naturvårdsverket 2017). Furthermore states the Mermaids report by Gavignano et al. (2015), an active NGO and important for this report, that polyester, acrylic, polypropylene, polyethylene and polyamide is supposed to be the largest contributors of microplastics in washing effluents from the textile industry. However, the scientifically research points out that the main entry of microplastics is from domestic washing machines (De Falco et al 2017; Auta et al. 2017; Napper and Thompson 2016). This highlights the contradictions between reports conducted by associations and scientific research, indicating there is a lack of coherency in the level of knowledge.

Microplastic release from textiles, also referred as *shedding*, have been scientifically related to the type and quality of fabric, age of the garment, type of washing machine (top-loading vs front-loading), the level of mechanical stress (centrifuge), temperature and chemical stress (type of detergent used) (Henry et al. 2018; De Falco et al. 2017). However, to this point there is no common way of measuring microplastic release from textiles. Although there has been presented new research of microplastic shedding from textiles, the issue with no standard test method makes the results incomparable, with evident effects of not knowing whom or what to believe.

One study, made by De Falco et al. (2017) investigated the difference in microplastic shedding from three types of textiles made with different yarn and fabric constructions together with parameters such as detergents, temperature, time, water hardness as well if washed in domestic or industrial machine. The study did also analyze warp and weft yarn and what impact staple or filament fibers have. The results showed that liquid detergents compared to powder caused less microplastic release (a decrease of 6,000,000 microfibers per 5 kg wash). The explanation being that powder detergent contains insoluble compounds as well as having a higher pH which increases friction and stress in the laundry, causing more microplastic release. When analyzing the impact of the yarn the study showed that staple fibers were more likely to release than filament fibers during washing. The reason said to be that shorter staple fibers were more likely to slip from the yarn. Nevertheless, as comparison to de Falco et al.'s report stands (among others) the research made by Napper and Thompson (2016) saying a 6 kg wash load could release between 137,951-728,789 microplastics which would make De Falco et al. result impossible. These differences have been widely acknowledged among the researchers who say this is an issue with current research.

To prevent release of microplastics, De Falco et al. (2017) said that the use of softener could decrease release up to 4,000,000 microfibers per 5 kg wash. However, the use of softeners has been proved otherwise in the research mad by Smith and Block (1982) as well as by Chiweshe and Crews (2000) saying softeners rather bolster microplastic release in domestic washing machines. Furthermore showed the study by De Falco et al. (2017) a correlation between microfibers release and higher temperature, longer washing time and mechanical action (centrifuge). The different sizes of the microplastics identified in the study could be further matched with those found in marine organisms and animals, strengthen the correlation between the potential negative environmental effects associated with synthetic textiles.

Even though the research of microplastics is scares in relation to the textile value chain, the interest of the more specific aspects causing microplastic release has been investigated, although in limited extent. Naturvårdsverket did a study in 2017 trying to identify what parameters could increase microplastic release, they found as well as Gavignano et al. (2015) from the Mermaids, that the choice of fibers (fiber type, fiber mix, fiber length) and fabric construction (weave/knitted, loose/tight) has an significant impact. The bachelor study made by Peterson and Roslund (2015) from the Textile University of Borås, confirmed in their report that yarn made by staple fibers generally precipitated more than filament yarn. They also found that a tighter fabric construction yielded fewer microplastics than those of a loose construction and finally that aged fabrics tend to shed more. The worst result was of those fabrics held with all three components giving a significantly greater amount of microplastic release than those fabrics with only two or fewer. De Wael et al. (2010) stated in their research that the weave of the fabric becomes important if the fabric consists of more than one fiber type, some fibers shed more and dependent whether it is exposed or not (warp or weft) to the surface. Considerable is that many garments can be composed by many different fibers and fabric constructions whether it is the outer shell, the lining or the cuffs, implying that one garment should be tested per different fabric construction.

A study founded by Mistra Future Fashion with researchers from Swerea delivered new research in 2017 on how the construction of fabrics affect the release of microplastics (Roos et al. 2017). Additionally findings of the study showed that using an ultrasonic cutting machine instead of regular scissors reduced shedding significantly. When testing the two methods a total of 1927 fibers where shed from scissor while only 890 fibers were shed from the ultrasonic cutting. Additional preliminary findings were that shedding could be reduced if mechanical processes such as brunching were reduced and if microplastics were removed already in production. Similar to Roos et al. (2017) states Nayak and Padhye (2016) that the use of laser helps to avoid the problem of fraying which occur whit conventional cutting. The locked edges would prevent microplastics as synthetic materials would melt in contact with the laser and therefore remove all loose edges.

As mentioned, did the Mermaids release a report in 2015 which described the influence of spinning, weaving a knitting, mechanical and chemical finishing. They found 5 components having the most effect on microplastic release;

i. fiber length
ii. yarns twist and re-twist
iii. yarn count
iv. fabric warp and weft densities
v. fabric's weight

According to the Mermaids report (Gavignano et al. 2015) are there three spinning processes most used for producing yarns; ring spinning, rotor spinning and compaction spinning. Of the two main alternatives (ring spinning and rotor spinning), the rotor spinning process is the most efficient to minimize hairiness and reduce pilling on the yarn. However, yarn twist, fiber length and yarn count could also affect the final quality of the yarn, saying that the best alternative (to minimize microplastic release) would be to have a high twist of low yarn count with filament fibers. Yet, if high speed is obtained during the yarn formation it is more likely for the fibers to break and therefore increase hairiness leading to pilling and release.

As the yarn is produces it will continue into the waving or knitted process, constructing the fabric. The characteristics the yarn received from previous process will be transmitted into the fabric. If a yarn is of a hairy character the mechanical stress from the waving or knitting machine will increase the risk of breakage and shedding. The released microplastics will then become loose parts in the fabric which will either fall into the machines, become dust in the air or on the floor end up in washing machines, and later in our aquatic environments.

In opposite to those mechanical processes associated with microplastic release gave the report two suggestions on how to use mechanical finishing's to prevent microplastic release; singeing and calendaring. By using a finishing, the appearance of pilling can be reduced. According to the report does synthetic fibers have a high tendency for pilling, it could however be reduced by applying any of the nine chemical finishing tested. All the products showed a reduced pilling behavior.

Not covered by the Mermaids report is the use, or non-use of biodegradable polymers. As discussed in previous chapter, plastics can degrade even though there is a discussion to what level (Auta et al. 2017; Napper et al. 2015; Kroon et al.2018). Biodegradable polymers have been much discussed from a medical perspective (Subtricia et al. 2018; Golding et al. 2006; Domb and Kumar 2011). In the research of Younes (2017) an in-depth analyzes have been

made about the diversity of biodegradable polymers applications in both the fiber and fabric industry. According to Younes can biopolymers be made either by natural, regenerated or synthetic origin with the potential to lower the environmental impact. However, the author also says that even though biodegradable fibers have the potential for several applications it is mostly making single or short-term items. Thus far, the relationship between biodegradable polymers and microplastic pollutions is still to be discovered.

2.2.2 Initiatives for solutions

As there are a limited amount of scientific research about microplastics in the textile value chain does much of the available information come from NGOs and professional organizations which feeling the pressure to find the cause and the solution. One such initiative comes from the organization Mermaids, which is additionally a part of EU's Life+ Project (Life-mermaids.eu, 2018), who has developed the *Handbook for zero microplastics from textiles and laundry* (2018). As a further development from the previous study made by Gavignano et al. 2015 this is one of the more extended reports found this far addressing such variety of parameters in the textile value chain. The handbook have provided a guideline for synthetic textile manufacturers to reduce microplastic release in the production process. They identified four main areas with higher risk for microplastic release; the fiber, the yarn, the fabric and the garment. Each area has further been analyzed into following processes: (i) fiber: fineness, irregularities and length, (ii) yarn: number of plies, twist value and yarn count, (iii) fabric: dyeing, knitting/weaving, sizing agent, fabric structure, fabric density and finishing; and (iv) garment: industry and domestic washing and stated with potential solutions (Mermaids 2018).

AREA	POTENTIAL SOLUTIONS
FIBER	- Lowering and graduate the melting temperature and increase fiber fineness: could preserve the fibers mechanical properties and reduce in yarn construction propensity to form protruding microfibers. - Larger fiber irregularity: due to increased friction between fibers the risk of release could be lowered, this could be adjusted through different hole shapes in the spinnery. - Keep caution of the processes of cutting, stretching, creasing and dyeing the fiber: which all affect the fiber and increase risk of breakage and microplastic release.
YARN	- Use filament fibers: longer fibers have fewer tendencies to release microplastics than shorter (staple) fibers. - Have plied yarns with higher twist: as it lowers the risk of breakage and pilling. - Have a low yarn count: because there would be less fibers per cross section.
FABRIC	- Lowering the pace in knitting and weaving: would lessen the damage when in contact with the yarn carrier and needle - Yarn dyeing: has less impact that garment dyeing. - Optimize sizing agents: could reduce microplastic release. - Collect waste from mechanical processes: brushing, napping and shearing creates loose microplastics which has to be collected and should be recycled. - Using softening and smoothening finishing's: can have a positive effect on protecting the surface of the fabric.
GARMENT	- Pre-wash: with a controlled and efficient water treatment system most of the microplastics could be washed off before sent to customer.

Table 1 Mermaids Solutions

According to the Mermaids report these changes mentioned in the table above could lead to a product more reluctant to microplastic release. Contemplate the changes addressed to the production of fibers the slower production and lower temperature could increase the quality of the fiber, however it could also lead to a longer production time and difference between customer expectation and the finished product (Gavignano et al. 2015).

Some of the Mermaids results are supported by the European Commission. The European Commission launched a report where Benton et al. (2014, p. 96) said that the quality of the yarn being dependent on the properties of the yarn itself, as these affect the "tensile strength, abrasion resistance, and elongation of yarn during weaving". They did also declare the importance of the sizing agent. As the sizing recipes contain molecules with high TOC (Total Organic Carbon) content can these, if not correctly processed, contribute to water contamination from the desizing process. Some of the most commonly used sizing agents are starch, gelatin, oil, wax and polymers. The authors concluded that the need of sizing agents is highly dependent on the

nature of the fiber, quality of the yarn and the weaving loomed used (Beton et al. 2014). Saying that need for of sizing varies between natural and synthetic fibers and quality of yarn was synthetic, according to the authors, are more resistant to stress and could be without sizing during the weaving process. As many of these changes affect the property of the fiber, yarn, fabric and garment or the way of the production, the design- and production managers has to evaluate what would be the best implementations and their tradeoffs.

It is common to use different chemical finishing's when producing fabrics as a finishing can change or give new properties to the final products. Gavignano et al. (2015) acknowledged in the importance of working with finishing's with good washing fastness. If the finishing is likely to be washed out there would be a high risk of contaminating the wastewater from washing machines (Gavignano et al. 2015). Furthermore, if a finishing is added it is important that it is compatible with also other chemicals so the properties or qualities does not change if added. As always, working with chemicals they must answer to current regulations and legislation. Legislations however can vary in large between countries and continents. The different circumstances add into the complexity of working with one or more supplier located around the word. Similar complexity stands for the control of efficient waste water treatment plants (WWTP), since the use of water in washing and other wet processes are a big part of the production process and likewise a main source for pollutions.

The impact of washing machines has thus far been most discussed in relation to domestic washing machines (De Falco et al. 2017, Napper and Thompson 2016). However, according to a dispatch from the Ecological Society of America (ESA) (2015), the Founder and Director of the Plastic Soup Foundation Maria Westerbos, said she thought that clothing companies out to do more, and that they should support the development of filters and redefine the term "greenwashing". Another solution stated by The Guardian was that waterless washing machines could be a solution, cleaning with pressurized carbon dioxide instead of water (Messinger 2016). Such waterless system could also lead to a lower use of WWTP, since then there would be no water effluent.

WWTP are a big issue within the textile industry. The industrial washing methods are more aggressive than domestic and the research from De Falco et al. (2017) showed a considerably larger microfiber release than been observed by domestic washing machines. The impact of washing from industry level has gained some attention. However, as Gavignano et al. (2015)

stated, does many manufactures not have an efficient water treatment system, and even fewer being able to collect such small particles and microplastics. This would imply investments. Bruce at al. (2016) confirm the hardship, saying WWTP would not necessary be the most effective way of reduce microplastic pollution and that the investments could become costly. This is supported by the research from Piñol et al. (2015) saying "Microplastics are particularly worrying because water treatment plants do not take them into account in their management processes and they are deposited in waterways and sewage sludge". As a reaction on the impact, did the EU Water Framework Directive (WFD) in 2000 to set up new goals to regulate the textile wastewater plants to govern the quality of effluent discharged from industry (European Commission, 2007). The directive implies that those companies and/or manufactures who has a discharge of wastewater are obligated to take responsibility that the treatment from their WWTP reach the desired water quality. If the water would not reach the desired quality, it would be the companies and/or manufactures liability to take the cost to implement a sufficient WWTP. According to Beton et al. (2014) they believe that the most likely reaction of the WFD will lead to more recycle and reuse of water.

The attention microplastics has gained and the connection to fabric constructions have made one supplier of fleece to developed a new fabric. the fabric, according to Pontetorto, does not release any microplastics and is called *Biopile* (PONTETORTO 2018). According to the brand lays the solution on Biopiles unique construction, as the brushed side does not consist of polyester but of 100% Tencel. They claim, as this is a biodegradable fiber, it will not harm the oceans but decompose within 90 days. The Biopile has been recognized by the environmental magazine ECOTEXTILE as being the "First fleece to 'not shed' microplastics" as it was awarded with the Eco Performance award by Performance day (Hinchcliffe 2017).

Except for initiatives directly addressing to the properties of design and production, the legislature of California, U.S, raised in 2018 a proposition saying that all clothing manufacturers must put a label on all textiles with more than 50% synthetic material (Leginfo.legislature.ca.gov, 2018). This proposition shall make the consumer aware that synthetic materials shed microplastics and recommend them to handwash. The proposition shall become active in the beginning of 2020. Alongside with California has Connecticut, U.S published a bill requiring clothing manufacturers to label their products (Styles 2018). However, it should be recognized that even though both states try to raise the customer awareness about the issue with microplastics the legislations do not change anything in the

design- and production process of the garments, neither giving the industry to take the responsibility.

3 Textile design- and production process

The textile sector is a fast-growing industry and during 2016 and 2017 it increased with 2,5 % worldwide (UNIDO.org 2017). It is an industry located all around the world and is recognized as being complex and with low level of control. The structure of the supply chain has, according to research, led to both environmental and social negative impacts (Pedersen and Gwozdz 2013; Doyal 2005). The production process is set of many mechanical and chemical processes which entails the risk of toxic pollutants to contaminate both air and water. As the awareness of these issues as been covered in media has many companies now recognized their responsibility and implemented sustainable initiatives and practices into their business model, although much remain (Gardetti et al. 2013; Stotz and Kane 2015; Turker and Atluntas 2014; Pedersen and Gwozdz 2013).

The design- and production process is the foundation to create a product. It enhance a unique collaboration between a large network of actors consisting of agricultural, chemical manufacturer, textile manufacturer, retail and waste management (Beton et al. 2014). Each product creates their own supply chain dependent on design, production specification, quantity and delivery date. The following of this chapter will therefore present the main activities within the design- and production process to give the reader an understanding of the complexity, as within every activity multiple decisions are to be determined.

The design- and production process are divided into several steps, many overlapping with previous and upcoming collections. A new product and collection takes traditionally 10-12 month (Keiser and Garner 2012) but there are brands working with cycles of 4 weeks and those working with 24 months.

Based on the literature from Keiser and Garner (2012) and the report of Beton et al. (2014) the below model of the design- and production process been developed:

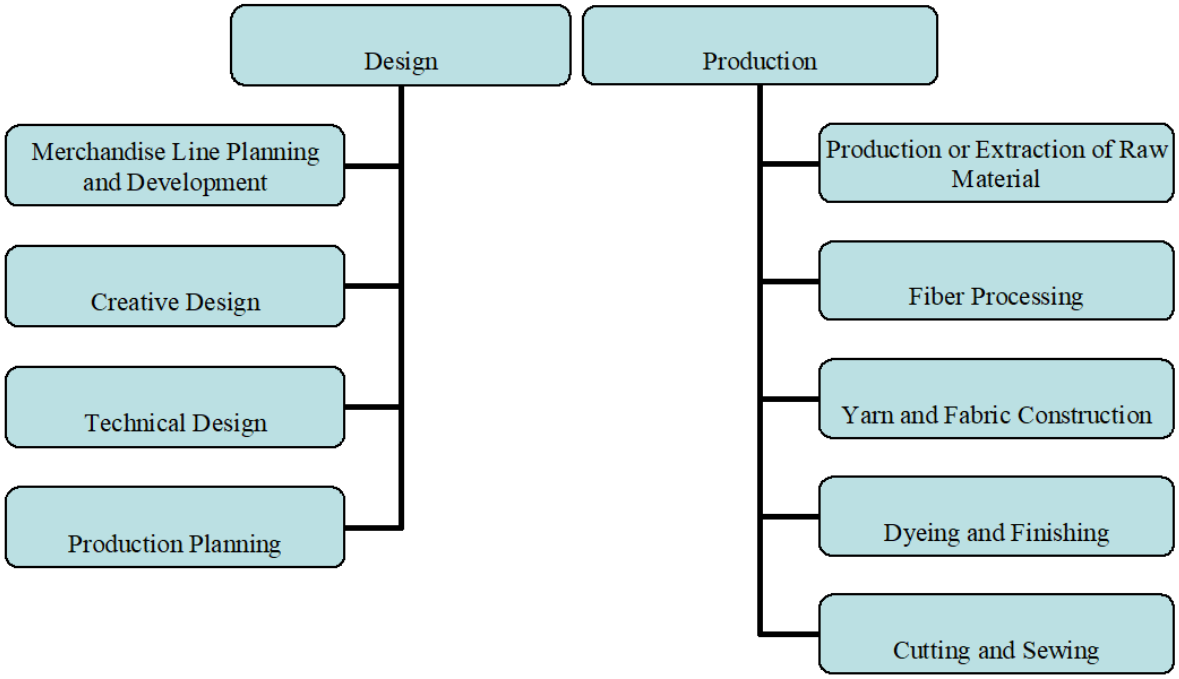

Figure 2: The Design- and Production Processes

3.1.1 Design

According to *The Guide for Sustainability* (own translation) developed by the Swedish Industrial Design Foundation (Svid.se 2018) does the design processes stands for 80 % on the total environmental impact, emphasis on all the decisions taken in this step will affect the all the production processes. Napper and Thompson (2016) urges the need of connecting sustainability and design, saying most designer focus on the style rather than the environmental impact and states this should become a natural part of the design educations being on the top of the hierarchy.

Product managers will also appreciate that product design is the stage where all the possible environmentally harmful materials can be designed out and sustainable materials can be designed that will largely determine the final product output in terms of creating differentiation value for customers or creating new opportunities.
(Dangelico et al. 2013, p. 654)

According to Keiser and Garner (2012) does the design process includes four areas and a short description will follow as to describe the main activities within each area.

- Merchandise line planning and development
- Creative design
- Technical design

- Production planning

Merchandise line planning and development

This process includes merchandise planning and line development, creating products, meeting customer demands and following brand identity. Merchandise planning sync the strategic and tactic plan, production planning, budget, sales and marketing. Through this process the overall sales plan is set, the product line and assortment plan are developed. (Keiser and Garner 2012).

Creative design

This process includes trend tracking, color and fabric decision (aesthetics, fashion, details and function) and style development (Keiser and Garner 2012). Fabrics can either be developed with the supplier or being sourced by the supplier based on specification. Both the creative and technical designer need to consider what raw material to be used and how the formation on the yarn shall be designed. This knowledge is essential to keep current with new developments (Keiser and Garner 2012).

Technical design

This process includes developing specification for fitting, materials and construction (Keiser and Garner 2012). Here is also when new styles combine with before fit in the assortment, technical sketches and prototypes are made as well as product and quality tests (construction, color, fabric etc.)

Production planning

This process links all previous processes into the real construction of the new collection (Keiser and Garner 2012). This include, as many manufacturers are located outside of the home country of the brand, a transit of information negotiating upon trims, fabrics, prototypes, quality assurance and production capacity.

How the above areas are structured or combined depend in large on the business model and the size of the company (Keiser and Garner 2012). The textile industry is in an ever-changing environment and the ability to be agile and find synergy between departments is responsible for the success or failure of the brand.

3.1.2 Production

Based on the report by Beton et al. (2014) has the production process been divided into five areas as listed below. A short description will follow as to describe the main activities within each area.

- Production or extraction of raw material
- Fiber processing
- Yarn and Fabric confection
- Dyeing and Finishing
- Cutting and Sewing

Production or extraction of raw material

This first process includes cultivation of fiber-producing crops or extraction of petroleum-based chemicals, plastics, and/or coal (Beton et al. 2014; Keiser and Garner 2012). The source of the fiber will affect the characteristics and properties of the finished garment as well as the final aesthetics and hand (Keiser and Garner 2012).

Fiber processing

The choice of fiber processing depend on the requirements of the final product and the formation impacts on luster, drapability, texture, durability, comfort and retention (Keiser and Garner 2012). For manufactured fibers this are either categorized as regenerated or synthetic fibers which through polymerization (a process of heat, chemicals and pressure) converted into long-chain synthetic polymers in the form of flakes or chips (Burns et al. 2011). For natural fibers this includes pre-treatment (Beton et al.2014).

Yarn and Fabric construction

This process includes sizing, spinning, desizing, warping sizing and fabric formation (Beton et al. 2014). During yarn confection the properties of the fiber can be enhanced, modified or transformed (Keiser and Garner 2012). A yarn is either produced as a staple fiber or as continuous filaments. All manufactured fibers are produced as filaments but can be cut into staple fibers. The appearance of the manufactured filament fibers can be changed by different shapes and sizes of the spinning holes (Burn et al. 2011). Generally, the filaments fibers are grouped or twisted together to create the formation of the yarn. For natural fibers or staple fibers, the fibers are spun together by twisting or bonding to create a continuous yarn.

The confection of the fabric has also a large impact on the properties of the final garment. There are several ways of constructing a fabric, some being weaving, knitting, nonwoven web-forming, and nonwoven-bonding (Younes 2009, p 678). Depending on fiber content, constructing technique and weight the use and functionality of the fabric can be decided (Keiser and Garner 2012).

Dyeing and Finishing

This process includes dyeing, printing and coating (Beton et al. 2014). Dyeing can either be done through fiber dyeing, yarn dyeing, piece dyeing, garment dyeing or by any print method (Keiser and Garner 2012). Prints are included in this process and could be applied with dyes or pigments. Dependent on the type of fabric and choice of colorants the printing could be applied on top on the fabric or penetrate the fibers. Most commonly stated is prints' which penetrates the fiber gives a better color fastness than those applied on the surface (Keiser and Garner 2012). The four most common printing techniques is screen printing, roller printing, heat-transfer printing and digital printing (Keiser and Garner 2012). A finishing could enhance the light or reflection of a fabric by applying glazing or waxing. Other finishing methods are embroidery, beading, felting, embossing, brushing, sueding, flocking to mention a few (Keiser and Garner 2012). Even after a garment is assembled it can require final wet processing such as color removal, color addition or application of a chemical finish to provide wrinkle or soil resistance (Keiser and Garner 2012, p. 442).

Cutting and Sewing

This process includes the garment manufacturing (Beton 2014). First step in the garment manufacturing is the development of the production marker. By fit the garment patterns as efficiently as possible companies minimize fallout (Keiser and Garner 2012). To further efficient the cutting process the fabric is layered before the marker is applied. In this way multiple pieces could be cut at once. Cutting can be accomplished in various ways; hand-guided, vibrating or ultrasonic, electric straight knife tools, electric rotary cutters with circular blades, die-cutting, water-jet cutting or computer-driver laser cutting (Keiser and Garner 2012, p. 439). When the pieces are cut they are assembled and stitched to full garments. There are different assembly methods such as the progressive bundle system, unit production system and modular manufacturing methods; each method with their own pros and cons in relation to cost, speed and quality (Keiser and Garner 2012).

Stitching is one critical activity during the sewing, it will build the garment and have a large effect on the total quality of the product; up to 50% of the end quality is determent on the quality of stitching (Keiser and Garner 2012). The most common used stitches are made by either a lockstitch machine or a chain-stich machine. There is a commonly used standard to describe what type of stich to use (ASTM and ISO) where the quality and complexity varies from single-thread chain stitches to multi-thread chain stitches and cover stitches (Keiser and Garner 2012). There is no thread that fit every application, so consideration has to include fiber type, thread construction and thread size. Last in the process is the application of labels, button and snaps before pressed, folded and packed.

Before the finished garments can be shipped to the distribution centers or stores they are packed. Packaging includes both folding or hung on hanging racks. The finished garments could either be separately placed in plastic bags or being grouped for protection from soil or dust during transport (Keiser and garner 2012).

4 Methodology

The following chapter outlines the methodology of the report and gives clarification upon the research design, the process of collecting and analyzing data and the delimitations of the study. The chapter will provide with guidelines how the research was executed as well as argue for its relevance.

To conduct this report an exploratory case study approach has been adopted. The report contains of three main compounds: a literature review (of academic and nonacademic origin), a qualitative empirical data collection and presentation of the result and findings. The method and the approach have been chosen due to its nature of conducting empirical data from contemporary events (Yin 2009). Microplastic pollution is a new phenomenon within the scientific literature which led to the amount of non-academic data collection through NGO's web pages, research institutions and industry experts to grasp the contemporary recognition of the subject. According to Yin (2009) does a researcher strengthen its report by using multiple sources, and this can clearly be said for this study. The collected data has been evaluated through its connection to the issue of microplastics in the environment and the textile value chain were the intent is, as Yin (2009) states, to enlighten the current state of knowledge within the scope of microplastic pollution in the textile value chain.

The process model of the case study method was inspired by the linear but repetitive model made by Yin (2009) but has been re-design to better show the flow of the study. However, as this study developed, the process has shaped the study in a heterogeneous way, although with a strong focus on the sharing of knowledge. The sharing of knowledge has become especially important during this work due to the many requests from participants of sharing the final product.

Figure 3 Method Model

The first step included the identification of the research gap. This was conducted through a scientific literature review as the findings should, according to Yin (2009) become the foundation for the construction of the research questions. The literature review included findings on the effects of microplastics in aquatic environments and marine animals, and the occurrence of microplastics released from domestic washing. A large gap was found in relation to the design- and production process of the textile value chain. Based on the gap the research questions was formulated to best understand how the design- and production process affect the release of microplastics and what alternatives are available to minimize the issue. In order to best present the result of the report the findings was analyzed and presented as list of critical areas and solutions for further research.

The empirical data was collected through interviews and e-mail correspondence. The sample for the empirical data was chosen due to the participant's relevance for the topic. Microplastics within the textile industry have the last year received extensive interest but are still yet to be widely discovered. The usage of synthetic fibers is expected to rise the coming years and is seen as a main source of microplastic pollution.

As the outdoor sector can be seen as the proxy for research and development within the area of microplastics, five Swedish outdoor brands have been chosen to participate (hereafter referred to as the Outdoor Brands). The outdoor industry is novel in the sense they work with more technical fabrics than fashion brands and are active to find solutions on the issue of environmental impact. As the textile value chain is a complex set of activities and involves a variety of actors has additional companies and organizations with in-depth knowledge within their field (hereafter referred to as the Expert Panel) been contacted to further extend the scope

of knowledge. Focus during interviews has been to receive a general view of the design- and production process within the outdoor industry, to better understand in what extent companies know and understand the issue with microplastic pollution and what alternatives they have seen in order to minimize microplastic release.

4.1 Resources

This study have been complied with the participation of employees from five Swedish outdoor brands (Elevenate, Fjällräven, Haglöfs, Houdini and Tierra), from two NGOs (European Outdoor Group and TEKO), one research institution (Swerea), one PhD student at the Institute for Polymers, Composites and Biomaterials of the National Council of Italy and also a member of the NGO Mermaids and participator in the Mermaids Life+ Project (and author to one research report used in this study) and three industry representatives (FOV Fabrics, Korallen AB and Environmental Enhancements). The results has been analyzed with published scientific research as well as with non-scientific information collected from websites and textbooks. See participants in Appendix 1.

4.2 Interviews

The interviews for this research have followed a qualitative semi-structured method, characterized by certain head questions to be covered during the interviews (Bryman 2012). By using head questions, the analyze of the answers could ensure a certain comparability between the interviewees. According to Wengraf (2001) does an in-depth interview allow one or more phenomena to be discussed in a greater way, allowing to interviewee to further explain the meaning behind their words. Another reason for doing interviews, instead of using other methods, is the need of establish the complex link between the pressing issue of microplastic pollution, scientific knowledge and company understanding. As Yin (2009) states, a survey does not capture the complexity in real-life interventions and would therefore not be the right method to discover such correlations.

The interviews were structured in such manner that questions were prepared beforehand with head questions to direct the conversation within the subject of microplastics (see Appendix 2). All interviews lasted approximately for one hour and were recorded either with the authors cell phone or computer program. As Bryman (2012) describes, the semi-structured interview

technique allows for unexpected topics to rise, and if relevant for the research further questions followed.

The recruitment of participants begun with the author contacting eight outdoor brands in Sweden, describing the purpose and the aim of the study interviews. For best relevance, the design- or production manager was requested, however the brands decided them self who would be the best informant. Of the eight brands five replied willing to participate. Since the brands were located in different places around Sweden it was decided to perform the interviews via Skype or phone. However, due to time limitation one interview was cancelled and instead replaced with a questionnaire through e-mail (Appendix 2). A clear difference could be seen in the answers between the interviews and the e-mail correspondence, indicating that this area of topic was best discussed though interviews. Nevertheless, the e-mail questionnaire have been analyzed in the same manner as the interviews as it still contributing with relevant information.

The selection of participants for the Expert Panel was based on two main factors, either they been highly promoted in the area of microplastic pollution or/and assigned in a snowball effect (recommended by other interviewees). The members of the Expert Panels were located around the globe and the interviews were therefore conducted through Skype or phone.

4.3 Data Analysis

The results of the interviews have firstly been transcribed in a word-by word manner to avoid missing any data. Secondly, the coding of the interviews was executed by reading and highlighting the thoughts and knowledge within the research field. As thirteen people participated some recurring subjects and phrases was acknowledged. From identifying what each participant said within challenges and solutions in the design- and production processes the subjects and phrases was later divided into thematic units.

As there is a risk for the author to interfere in the results, when working with qualitative data such as interviews, there has been a high focus during the thematic process to be as objective as possible in order not to influence the results. Such approach is of much importance according to Yin (2009) to strengthen the internal validity of the report.

4.4 Ethical Considerations

Doing a social research muster several ethical considerations as they are related with the integrity of the research and its content (Bryman 2012). As Bryman (2012) states, this cannot be ignored and has therefore also been a part of this report. As to not trespass moral dilemmas has this report been conducted based on Bryman's (2012, p. 129) four areas of considerations; whether harm comes to participants; informed consent; invasion of privacy; and deception.

The foundation of this report lays in the interviews with employees and students from different companies, organizations and institutions, everyone seen as an expert within their field and doing. However, this report does not focus on the single opinion of the participant but rather the overall knowledge level of the industry. To avoid causing harm, such as stress, has interviews been booked according to agreements and been held in private setting so not to be overheard. Further has the interviewee decided upon what questions to ask, if any intruded on either business or research secrets (as products has not yet been launched or research papers being under review) these were avoided. All documentation from the interviews and email correspondences are being kept as confidential records. Furthermore, by assuring the participants being the experts the author is convinced no harm was brought upon their self-esteem or could risk further development within their field, as should be avoided according to Bryman (2012). This more generally focus has motivated to make the participants and companies anonymous in the text in order not to be identified.

When this report was conducted a high emphasis was set to inform all participants on the background and meaning with the research, making sure each participant saw their contributing value. By reading the e-mail with information about the report, the participants gave their consent to be a part of this report. However, it could be argued, according to Bryman (2012), that a full understanding of the study could not be fully done without an explicit description (in writing) about the research intent. This however, did not occur as an issue during the e-mail correspondence before the interviews, during the interviews nor has been questioned after.

As the report did not focus on the participances private life, rather their professional view of the issue with microplastics, there was a low risk of invading their privacy. As personal reflections cannot be avoided during an interview, they were however limited as no question focused on their personal but rather professional opinion. As stated above, none of the recorded

or transcribed interviews/e-mail correspondence has been shared as they are confidential and the thoughts of the participants can therefore not be linked to a specific individual. Nevertheless as Bryman (2012) states, some recognition of themselves cannot (and maybe should not) be avoided.

Lastly, the aim of this report has been very clear from the beginning throughout the whole research and this is important as Bryman (2012) says in order to present the report for what is it, and not something else. The aim is to explore what challenges and solutions is known by the outdoor sector and those working within the industry, and the research questions as well as interview- and questioner questions has been devoted to this topic. Further will the results focus on the main critical areas addressed by the interviewees.

4.5 Delimitations

Focus of this study has been delimited to the design- and production process in Swedish outdoor brands. The purpose of this direction is due to Sweden is in the forefront researching the issue of microplastics and outdoor brands is the leading sector within the textile industry of new product development and environmental responsibility. Five outdoor brands have been participated; Elevenate, Haglöfs, Houdini, Fjällräven and Tierra. The chosen brands are relevant for this study due to their product assortment (many products being made of synthetic material) and their profound sustainability profile.

To support the outdoor brands and broaden the level of understanding seven other experts has been contacted. The experts are either employees, members, owners or students from NGOs, institutions, manufactures or universities. The relevance of the participants has been evaluated beforehand and their information is used as reconciliation and contrast to the literature and brand knowledge. It has been important for this study not to limit the empirical data only to outdoor brands but reach out and grasp developments in the whole value chain.

In the outset of this study the aim was not only to answer the questions of where in the design- and production process microplastics occurs and what, if any, alternatives are available to minimize microplastic pollution. The ambition was to create a learning tool for the textile industry to use during their design- and production process so they may reflect on their choices and lower the pollution. However, the field of microplastic and the relationship to the textile

industry is limited and the result of the study showed not enough reliable alternatives to create a helpful tool. This project has therefore been delimited to enlighten and give directions on where and to what areas the Outdoor Brands and the Expert Panel request more information and further research.

5 Results and Analyses

The following chapter will present the results from the interviews and the e-mail questioner, aiming to present the highlighted challenges and solutions within the design- and production processes discussed by the Outdoor Brands. The results from the interviews will be presented in a ranking based on the most common occurrences, related to how many of the participants brought the up the subjects in total. Each subject will first give a view of what the Outdoor Brands thought and then present the Expert Panels view.

As there are 6 interviews from the Outdoor Brands, but only five brands, the pseudonym will be based on the number of brands; C 1-5. Same applies to the Expert Panel; E 1-7.

5.1 Design process

The following subsection will present the identified challenges and solutions within the design process based on the Outdoor Brand and Expert Panel interviews.

5.1.1 Challenges

When asked what was the main factors for causing microplastic pollution in the design process the Outdoor Brands and the Expert Panel provided with eleven areas; (i) fabric construction, (ii) choice of fiber, (iii) total environmental impact, (iv) quality, (v) costs, (vi) yarn construction, (vii) product assortment, (viii) design elements, (ix) mass consumption, (x) filters and finally (xi) fillings. Each factor will firstly present the Outdoor Brands view; in so far as they mentioned it. Some areas, as will be discovered, was not mentioned by the Outdoor Brands but rather developed by the Expert Panel, this was also seen the other way around.

Fabric construction

The most recurrent topic discussed in the design process was the impact of fabric constructions. C2 describes their view of fabric construction as:

[...] we are investing more in natural fibers and wool for the future, and then we try to some extent set aside those products we think would release more. Then we are working a lot with our fabric manufacturers to find other types of constructions and other types of manufacturing which could release less than a classic fleece product.

C4 explains their thoughts about different fabric construction as:

One could say that a fluffy fleece and loose knitting could release more than a laminated outer layer, but one would never stand in front on a decision between those fabrics. Rather, if you stand in front of two fleeces it will be much harder to evaluate and it is here more research is needed, so one could know this construction and this yarn and these processes release less than these processes and these yarn and constructions.

The uncertainty on what are actually the worst choice and the best alternatives is much asked under the interviews, as can be seen by the statements above. C4 underline that, so far have research brought some premonitions on what could cause microplastic release and what to avoid, but not what to do instead.

From the Expert Panel point of view, E4 explained the complexity of the fabric construction by saying:

[…] during Mermaids project we analyzed woven polyester, knitted polyester and woven polypropylene and we found that woven polyester released the most fibers. We tried to understand the cause. so we analyzed the single yarn of the fabric and found that the yarn of the woven polyester was made of staple fibers. The yarns can be made of staple fibers or continuous filament fibers. The one of the woven polyester was made of synthetic staple fiber meanwhile the knitted polyester and the woven polypropylene was made of filaments, so we stated that yarn made of staple fibers would have it easier for fibers to slip in the mechanical action in the washing process and in the wastewater. Of course one component is the design of the material and even the type.

The statement made by E4 links the decisions in the design process and highlights the relationship between choices of fiber, the yarn construction and the fabric construction saying: one will affect the other. Such influence affects the construction of the fabric and so also the functionality of it (Beton et al. 2014). C1 makes a comment that despite wanting to make environmentally good choices, functionality is the priority. Making trade-offs has been commonly discussed among both the Outdoor Brands and the Expert Panel, as being a more technical focused segment they cannot neglect the value of functionality. However, C1 also say that working close with their suppliers who develop new fabric constructions for lowering microplastic release is to advantage.

The fabric construction is, according to Keiser and Gerner (2012), already decided in the creative- and technical design stages in the design process. Here it lays great importance according to Dangelico et al. (2013) that the designer considers upon the environmental effects. It can be seen among the Outdoor Brands than some have acknowledged the design process

being of much value in order to create sustainable products and to change the process. As Naturvårdsverket (2017) and De Wael et al. (2010) both discuss can the fabric can be constructed in such way that affects the microplastic release. The most common fabric constructions discussed by all interviewees was weaving and knitting and each technique has multiple ways of designing patterns, structures and surfaces. Presumably, according to E3 could loose fabric constructions be less resistant to wearing and tearing as the fibers within could conduce to more microplastic shedding. This is supported by Naturvårdsverket (2017) and by Peterson and Roslund (2015) which both say loose fabric constructions generate more microplastics. The thought about loose constructions and the reason behind could also be supported by the handbook by Mermaids (2018) saying loose constructions could lead to easier breakage and greater pilling of the fibers which could cause more microplastic release.

The construction of fabric is recognized as an difficult, but important part of the design process. With the uncertainty of knowing what will and will not cause microplastic release the designer stands in front of cross-road; to do something without actually knowing if it will benefit or cause even more harm or choose to do noting or wait for more research.

Choice of fiber

In relation to the choice of fiber the most significant discussion was whether to exchange synthetic fibers into natural fibers or biodegradable fibers.

There are signs that there are issues also for natural fibers and regenerated fibers too. The degradation time is dependent on the fibers in different nature. But would you also look to the short sighted and look upon what chemicals they carry could it still have harmful effects. (C4)

Both C3 and C4 discussed whether or not to use biodegradable fibers, non-believed it as a solution. C3 saying:

Then there are these ideas to use biological degradable polyester […] The problem, as I see it, is with this method that you just make it smaller, maybe you created nanoplastics instead. Then you did not make it into soil as you do with cotton or wool when that decompose, you still have the synthetic chain but in smaller pieces, I don't think that is the solution. You will not be able to see them but you can't hide from the fact they are a problem. It is tricky with microplastics.

And C4 states "internally we don't use biodegradable because we don't think it will help the microplastic problem" and C5 say that they wait for a standardized research method before

they would adopt any such changed as to use biodegradable fibers. The risk of being a contributor to the problem puts company off to invest. C3 declares, “We want to base our decision of facts but when there is none, it is really hard”.

The choice of fibers is according to E3 leveled with many aspects, saying there is not only one problem and one solution but rather a set of factors. Such factors is whether to use synthetic or natural fibers, or in combinations as well as be the decision whether to use staple or filament fibers. The choice of fiber is lines with many questions and uncertainties such expressed by E1:

> *All fabric whether it is natural or synthetic will shed fibers and because natural fibers are shorter they are thought they would shed more than synthetic fabrics because of the shorter stable length. And actually natural fibers could also do harm because they could carry chemicals, finishing chemicals or dyeing chemicals so we are being really open minded at the moment that we don’t want to tell everyone to use natural fiber as the solution. Because we feel that right now that we don’t know if they are the safer bet.*

Further said E4, the choice of fiber affect the final product (see statement in previous subsection). The characteristics of the fibers will not be changed if not altered during the process, or carefully extruded. If the fiber is produced fast and in high heat there is a greater risk of breakage during following processes (Mermaids 2018).

E1 says bio synthetics could be an option, but saying there is firstly to be a risk analyze. Scientific research need to find definite answers on how the fibers biodegrade since it as E1 says, depends a lot on the conditions of the environment as a material which decompose in a lab environment does not necessarily decompose in the sea. The ability to decompose is discussed by several researchers, but still there it is not known to what level synthetics degrades into (Auta et al. 2017; Napper et al. 2015; Kron et al. 2018). As the degradation is questioned so is the accumulation rate. The scientific researches for biodegradable fibers are still under development, seeing a larger progress within the food market producing disposable products such as the *Ooho!* bottle (Skippingrockslab.com 2018) or produced by Tek Pak (Innovation Forum 2018).

The choice of fibers comes back to the lack of knowledge of what would be the best decision. As natural fibers are linked with resource restrains and being a carrier for toxics it is not easy to set aside the use of synthetic fibers. Neither is the choice of using biodegradable fibers as these, are still not considered as a more environmentally friendly choice.

Total environmental impact

During the interviews all of the members of the Expert Panel expressed a concern about the issue with microplastics as it being a complex matter. However, none of the Outdoor Brands expressed it as explicit. According to the Expert Panel, the solution not isolated into one factor nor due to only one decision; it is a chain of activities. They recognized that changing the design- and production processes must inquire a larger view.

E3 said during the interview that due to the textile industry being so environmentally demanding there is great urgency to consider all the aspects of design and production; creating products lasting long is the most sustainable factor.

If you are to produce a sustainable product it is very important that it is a products with a long life due to the whole production process being so environmentally demanding- so that has a really high priority. […] and you need to think about how much tear resistance, tensile stress, colorfastness, or if it shall withstand water or sun or whatever you can imagen. Then you have to think about what fibers or fiber combinations are the most sustainable, what dye is the most sustainable or what mechanical and chemical processes are the most sustainable. (E3)

Working with sustainability is a complex matter according to E3, many decisions are to be made and within each several options lay before you. Much of what E3 said was brought up in the *Handbook for zero microplastics and laundry* by the Mermaids (2018). As the total environmental impact is connected to the whole process this should not come as a surprise. Designers, as Dangelico et al. (2013) said, bear the responsibility to incorporate sustainability already from the beginning and all the way to the finished product.

As the total environmental impact is a large subject, in fact related to all processes, this would be something to further discuss with the Outdoor Brands. Evaluating the total environmental impact could contribute to a new discussion, looking into even more areas.

Quality

C2 thought that working with quality was a constant challenge. As well as having specifications for tearing resistance and color fastness there could be, in the future a specification for microplastic release. The quality of the fabric and garment could then be of significance in order to lower the microplastic release. C2 has a wide assortment of fleece products and since fleece is a big discussion area the following was said:

[…] but we look at lot into what and how we do things, is there anything else which could fulfill what the fleece does without compromising the quality. Because, that is a really big thing, that it should not be lower in quality. Because, then you contribute with other environmentally problems. So it is a balance between developing something in the same quality but with less release.

Quality was said to be of great importance yet hard to grasp. In line with C2 who talked about how there are many decisions to consider in order to create good quality did E2 say that designing for good quality could result in a tradeoff between functionality and sustainability. Dependent on the choice of the material, the design, the look and the feel of the fabric the designer can make environmentally friendlier choices, such as using a lighter brushing and thus release less microplastics. E5 further discussed quality as a range of aspects. Producing products of high quality is producing product for the right purpose. This would incline, according to E5 a product that can withstand sun, wear and tear and multiple washings. The research by Henry et al. (2018) point out that the quality of garments has a significant impact on the amount of microplastics release, and should therefore be highly invested upon, reconnecting with durability and long life.

Quality affects all parameters of the design process, every step from the choice of fiber, to fabric construction and "precision in cutting and sewing" (C2). Quality should, as Henry et al. (2018) says be a read thread throughout the whole design process; something being both the challenge and the reward.

Costs

The issue with costs consists of several aspects but was considerably not mentioned by any of the Outdoor Brands. The Expert Panel however discussed several factors related with costs. E1 said related to the choice of fibers that bio synthetics could be an option to lower the release of microplastics, if not being so costly.

I know that bio synthetics are being held as the answer but I also know that bio synthetics are also very expensive. And I don't know if consumers are yet in the situation where they would pay the extra. I think, from a pollution side that bio synthetics has many many advantages over petrol-based synthetics but I know they are very expensive and I know there is a lot of consumer not wanting to pay 2 euros extra for a garment because it's biosynthetic and of course the consumers drives the consumption.
(E1)

The choice of fibers and the related costs was also brought up by E5 who said are unwillingly to change to better alternatives because they are more expensive;

E5: There most important reason is price. Staple fiber vs filament is rubbish. The knowledge you need to make filament vs staple and the equipment is miles away. If you would compare it would be between garbage and the real deal.

- So how do we create a way of making cheaper filament?

E5: That is a wrongly approach. I don't think it is the price that, you should increase the price on staple fibers. It is as with sugar products. Put a lot of tax so people learn how to eat properly and it is the same here so the consumer learns how to consume properly.

E5 continues saying that working with sustainability, no matter from which point of view, you counter costs but add that sustainability and costs must come hand in hand, and in the end in as something good.

The cost aspect has not been brought up in that extent by the scientifically literature, nor by the other sources used in this report. The aspect of costs may be unrevealed as there is still no clear direction on what is the most preferable alternatives.

Filters

Filters has been widely discussed in relation to the production process, being one way of collecting microplastics before they entering any effluents and WWTP. However, C4 explained that every supplier are working with water in different ways, some have systems for dyeing others has a station where they collect all the water inside or outside the factory. The many ways of systems challenge the design of the filter leading to the questions if anyone could create a filter that works for every supplier.

Also, E7 and E4 points out that designing filters may not be that easy, E4 said:

Even though there is a lot research of filter it is quite complicated because the engineering of the filter have to not clog but at the same time collect even the smallest fibers it is not easy to find a filter that works well.
(E4)

Filters for the textile industry are yet to be discussed. As the focus lay today, to my knowledge, mostly on the efficiency of the filters and that they, to this point, cannot capture microplastics (Boucher and Friot 2017) indicates a lack of research and applicable implementations.

Mass consumption

There is a growing interest among companies, organizations, industries and the general public for the issue with microplastics. However, C2 raise the concern of working in the outdoor sector and not being the largest companies or selling the greatest volumes.

I believe the hard thing is to get the whole textile industry to do a change, especially in the cheaper materials that does not last, which is one of the biggest issues because it is a great volume and quantity and low quality and it is hard to reach out to everyone. (C2)

Also C3 said:

The way to consume, that you buy things in lower quality more often is further a sign that it is not good. It is not possible to make that type of consumption sustainable, period!

There are, however, those who put more effort into finding solutions than others. E5, as an expert within the textile industry, said "the best thing would be if everyone did as us", but the big industries are dependent on mass consumption and does not support the transformation towards better quality and designing products lasting long. Promoting sustainable consumption does not lie in their business model.

Mass consumption and microplastics has, to my knowledge, mostly been discussed in relation to throwaway habits of disposables and cosmetics (UN Environment 2017) and not with textiles. Even though the outdoor industry is not generally associated with mass consumption, as quality, functionality and longevity is more imbedded in the core of the business model, they still want to sell their products. Many of the brands has also reach an international market and thus reach higher volumes and therefore cannot neglect this aspect.

Yarn construction

Yarn constructions were similarly discussed as fabric constructions. This was also an area which the Outdoor Brands did not put much emphasis on. It was rather the Expert Panel discussing how the construction of the yarn could affect microplastic release. E3 said, according to their knowledge does loose yarn constructions tent to release more since short fibers could more easily slip. Even though yarn construction and yarn texturizing (E1) was acknowledge, it was scares in comparison to how it has been discussed in literature. Yarns made of staple fibers were according to Peterson and Roslund (2015) much more likely to release microplastics. Also, the Mermaids report from 2015 states that hairy yarns will in

greater degree breaks and shed during mechanical processes. The loose parts from the yarn will then end up in the fabric until it someone removes it with intention, or not. Further research by the Mermaids (2018) points out that plies, twist and count could influence the yarn.

In comparison to the literature was yarn construction not discussed in that extent even though there are some clear directions on what could lower the microplastic release from yarns.

Fillings

One area potentially being a source for microplastics, but which was only mentioned by the Outdoor Brands, was fillings. According to C1 do they use fillings in jackets for isolating purposes. The filling is often made by synthetic materials for their lightweight and isolating purposes. Only two of the five brands mentioned fillings, neither had thought much of this being a potential polluter. However during the interview both considered it being a potential source. C1 said they had evaluated weather to use down or wool (but not directly as an act to minimize microplastic release) and C3 focused on the outer shell being resistant of migration (but more as a quality assurance). However, according to C1 does neither down nor wool have the same valued properties as the synthetic materials and both entails other ethical and environmental concerns.

C3 did also mention, thus briefly that they had seen suppliers of fillings reacted to the issue of microplastics but not heard on any solutions, neither in design or production.

Fillings have not, to my knowledge been a highlighted area within the literature, nor within the textile industry. Fillings, being small synthetic fibers, could both in the production process and use phase cause microplastic release and to this point does the designer not see any sufficient replacements in order to lower the use of synthetic fillings and thus lower the release of microplastics.

Product assortment

The product assortment, the collection and the styles of the garments could, according to E3, be a challenge where the designer needs to prioritize. The outline of the product assortment defines the following activities; such as choice of fibers and mechanical processes which could be an issue if the designer does not have knowledge about the processes

[…] and this cannot the designer, he or she cannot know exactly how everything works but they have to build up competence around their product assortment. That is why you have such impact in the beginning.
(E3)

The creation of the product assortment lays in the first step of Keiser and Garners (2012) design model. Here the designer decides what products should be produced and how they should look like and what they should be made of. The product assortment is a part of the business model as well as being the competitive means. The Outdoor Brands did not mention the product assortment as a challenge, but rather as the solution (which will be further presented in the next subsection).

Design elements

The last challenge in the design process was brought up by one member of the Expert Panel. Design elements are all the details the designer puts onto or into the garment. One such detail is the inside fabric label with the description of production country and fiber composition. In many cases, is the label long, of poor quality and made of polyester. So when the label tears, or "as many with me cut it off" the label fringe and ruffles and the small fibers ends up in the washing machine (E3). A detail could be both the initial inspiration for a collection or as the final touches of the garment (Keiser and Garner 2012) and have a great impact on the finished garment. It would be up to the designer to determine how and by what details such as labels should be made of as this could affect the release of microplastics.

It is easy to forget the small parts but one should try to remember, notes E5. To this point does the literature not discuss the value of design elements in relation to microplastic release. However it cannot be forgotten that, to this point, is no standardized way of measuring microplastic release, not even the definition of microplastics is uniform. Consequently has design elements not yet been discussed.

5.1.2 Solutions

When asked how to prevent microplastic release during the design process it was clear that both the Outdoor Brands was very supportive within the initiatives they themselves worked with, also being where they had the greatest knowledge. However, many of those areas that as seen as challenges were also seen as the potential solution. In the design process the following

suggestions was identified (i) choice of fiber, (ii) fabric construction, (iii) design elements, (iv) garment construction, (v) quality, (vi) product assortment, (vii) yarn construction, (viii) mass customization and finally (ix) packaging. .

Choice of fiber

As the most common discussed solution for lowering the release of microplastics among the Outdoor Brands was the choice of fibers. C2 said they tried to use more natural fibers instead of synthetics yet highlighted that it was important to remember that all choices have consequences, the solution could not solemnly be dependent on everyone change to natural fibers because there is not enough resources nor is it really stated they are the better alternative. Nevertheless C2 continued saying that the use of biodegradable fibers could be a part of the solution, as those would dissolve more quickly than normal polymers.

C3 said:

I could also influence in how, we are trying to switch to more nature fibers in the garments, and that is one way of use wool, even if they release they decompose and they are proteins. If a fish eats it will not be to harmful, even if plankton withhold more nutrition. So small amounts of wool could a fish handle.

C4 did also discuss in a variety of ways how they tended to work with fibers in order to minimize microplastic release.

We actually talking about natural fiber, […] we assume nature fiber is better because it could be dissolved naturally and quick and if we need to use the fluffy like fleece we try to use wool instead of polyester. It is what we assume but we don't know. […] But we feel that maybe wool compared to polyester is much easier, would to disappear by itself, dissolve. (C4)

C4 continued to explain about their decision to look into alternative fibers with "our biggest project for 2018 is using cotton/polyester blends". The interest of finding natural fibers that could replace synthetic fibers was also said to involve the usage of "recycled wool as the mid layer" and Tencel instead of polyester.

In accordance to the Outdoor Brands did the Expert Panel discuss the choice of fibers as possible solution. E6 brought up how they had seen the development of cellulose fibers become more prominent and suggested that as an alternative. However, E3, E4 and E5 focused on the length of the fiber.

Let's take this with synthetic fibers and polyester, since we have focus on microfibers. When you spin the polyester it is a filament fiber, if you then make a jacket out of it, it will be a less risk of microfiber release than if you would have done it in staple fibers.
(E3)

E4, being a part of much research said based on their discoveries they could state that staple fiber was more likely to release and therefor would filaments be the better choice. E5 declares simply that filament is superior staple fibers. E5 continued saying that choosing fibers was however not solemnly about the fiber length, but choosing a fiber that could be a part of the circular economy. In that way there should be no need for the garment to end up on landfill.

Lastly did E3 say they were very positive for the development of degradable fibers and to "change from fossil-based to bio-based" materials.

Both the Outdoor Brands and the Expert Panels acknowledge the impact the choice of fiber has on the environment. Moreover does this imply that both group has understood the signification of early decision which is line with Dangelico et al. (2013) theory being that it is in the design process the first step of eliminate harmful materials happens, and thus in the choice of fibers. As the choice of fibers is imbedded in the creative design process according to Keiser and Gerner's (2012) model, the designers has the ability to think outside the box and be proactive in their sustainable design already from the start.

Fabric construction

Both C2, C3 and C5 mentioned 3D constructions being a part of their development of making fabrics that would prevent or lessen the release of microplastics. C2 said they currently have some constructions under development using different knitting and weaving techniques. C3 described in more detail one of their products they developed:

Then we made this X sweater which is knitted with wool and polyester but is not brushed and not cut. It is knitted with a technique which make it pull together when it comes out from the knitting machine and creates a bubbly structure which creates a sort of air-layer which is exactly what you want from a fleece sweater. Without us brushing and cutting we get a really nice sweater which sales really well and for sure release less microplastics.
(C3).

Creating new fabric constructions could be one solution according to C3, but said also that "without any standardized test methods we cannot know if our very nice sweater is better compared to a traditional fleece". However, C3 was not alone in waiting for a standardized method, both C2 and C4 begun their interviews stating that without any common way of

measuring the level of microplastic release the problem will remain, but they hope that with a set method microplastic release could one day become a part of the specification list for fabrics. C3 is not alone in trying to develop alternatives to fleece fabric, C4 said their main focus during 2018 is their de-fleece project.

We have a main focus which is called the De-fleece Project because we assume fleece may be the main issue for microplastics. So we have a De-fleece Project, what we will try to do is either a t-shirt or a mid-jacket to not do a brush or peach. Any process which destroy the fabric surface in production we try to avoid.
(C4)

As a contradiction to the Outdoor Brands focus on fleece, seen as the worst fabric, E2 found in their study that the microplastic release did not vary between fleece and jersey, saying it be more dependent on other factors such as the weaving or knitting method or the brushing. However, fleece is still mentioned by E2 who said:

I am convinced there is a way to construct a fleece that does not release so much, but exactly how that process looks like which does it, if it is the material construction or if it is the brushing technique or if it is the combination […] is still a question mark for me.

Further did E5 say that the fabric construction could be used in such way of making the finished product in less need of washing, by simple wipe it off. If such construction would become common in the apparel manufacturing there would be a lesser need to wash the garment and thus led to less microplastic release.

The thought of E5 is very much in line with what Keiser and Garner (2012) said, the fabric construction is one part in the creative design step were the designer could modify and enhance properties of the fabric. The request for new constructions could be done by change the shape and size in the spinning process (Burns et al. 2011). If the designer where to discuss they could according to Keiser and Garner (2012) develop new construction together with their suppliers and look into both new materials and manufacturing possibilities.

Design elements

When talking about solutions C2 said they tried to work a lot with the details on the garment, trying to eliminate all unnecessary things which could cause extra stress.

[…] put more focus on design which eliminate as much things that could tear and stress, maybe try to minimize the amount of zippers and things which cause stress in washing. It is still an important thing to consider in the beginning, during the development of a garment and

bring that in mind and keep that in mind all the way from the start in order lower microplastics. It must go all the way, it does not work if one group works with it and the next don't.
(C2)

E5 did also discuss the benefits of developing simpler designs, since that would help also with recycling of garments.

As with the challenges with design elements have the literature, according to my knowledge, not discussed the topic. There is a gap of research exploring design elements as a solution for minimizing microplastic release. Nevertheless, both the Outdoor Brands and the Expert Panel acknowledge the relation.

Garment construction

Many of the brands focused on fabric construction as being the solution for minimizing microplastic release, C4 however is also currently working on a project developing a new garment construction in the attempt to lower microplastic release.

[…] we can use different construction of garment. So to be honest we will come out with a new solution in the Fall 2019 season. so we will already come out with something from the designer point of view that would solve the problem instead of using the fluffy fleece we can use something to keep our body worm. It is a mid-layer. It is a part of our collection. It is not a new fabric, it is a new design. New construction of the garment and we keep the air trapped into the system without the fluffy part on the inside. But it is not on the market yet.
(C4)

E5 did also discuss how future garments could be design in order create more sustainable and environmentally friendly clothing.

I told you before that it takes 30 years for new technology to become commercial and then I know for an example that today on lab-level there is a development of material which by electricity you can change color and patterns. This would imply that if I made you a pair of trousers in an extremely durably material, let say Graphene which you could never wear out, and then you make it in one slim-fit, regular and one over-.size and they you just change patterns a colors as you like.
(E5)

E5 continue by explaining that such material and technology clearly could be the future. E5 could see a future were the designer would focus more on colors and patterns which the customer could download and then upload into their trousers. Creating technological garments would not only mean the customers would not be in need of so many products, if they also were

designed in such way of lower the need of being washed (without any hygiene consequences) it could really be the way of making sustainable apparel.

De Wael et al. (2010) discuss the complexity of microplastic release in relation to garment construction saying garments, and especially outdoor wear, are many times constructed by many types of fabric constructions. Each fabric in return has a different level of microplastic release making it hard to control the release from the whole garment. One way to lower the microplastic release, according to the Mermaids (2018), would be to pre-wash the garments before the customer. By doing this at supplier level they could, with efficient WWTP, collect the biggest part of loose microplastic from production. However, this does not change the construction of the fabric nor does it consider the lack of efficient WWTP plants (Boucher and Friot 2017). Cutting and sewing is also connected to the garment construction, this will however be further discussed under *Production Challenges* and *Solutions.*

Garment construction has shown to be recognized by both the Outdoor Brands and the Expert Panel as an area the designer could change the design in order to lower the microplastic release. The literature however is still undeveloped within the area and connected to the design process but rather focused on the production processes.

Quality

When asked how to minimize the release of microplastics many of the brands were said high quality and longevity would need to be a key factor to reduced shedding. C3 said that based on the studies they seen it is the low-price garments with short life that shed the most, supporting the idea of good quality could reduce the release. C2 strengthen this reason by saying they have also has seen the difference between high- and low-quality garments, the large volumes of low quality products being one of the prominent risks within microplastics. C2 hopes that by taking responsibility to produce products that will last long will be the direction of lowering the microplastic pollution.

Quality have been an underlying topic in many areas in the literature, however not been explicit disused as a parameter to minimize microplastic release. Instead has quality been referred as a part of the choice of fibers, to the construction of the yarn and fabric and garment (Keiser and Garner 2012; Mermaids 2018; Roos et al. 2017).

Quality is an umbrella perspective consisting of many parameters. Such broad term has been discussed by the Outdoor Brands but clearly hard to distinguish the explicit meaning of it. This could also be seen in the literature where quality *is a part* of each step of the design process.

Product assortment

Designing for minimize microplastic release was according to C2 about changing their product assortment. By evaluating new designs and reevaluating old designs they looked into their assortment and removing products that they thought would cause microplastics and either replace with new production or not at all.

[…] we have also excluded some materials vi previous had that we don't see fit anymore but which was also in the risk zone of to release more than others. So we are trying for the future, at development and assortment, to have the microplastic topic as a big part forward and not develop products which contribute as much, or at least what we think release less. Because we still think some fabrics release more than other and we are working from there. (C2)

C2 worked a lot with changing the product assortment and a big part of their business model is to design for recyclability and the range of products should suit well into that, more recycling would lead no less landfill.

The development of the product assortment is done in the first step of the design process according to Keiser and Garners (2012) design process model. Here the designer look at previous models and new collections to create an assortment best suited for the brands purposes and image. As the *Merchandise line planning and development* step is closely linked to both the strategic and tactic planning of the business, core values such as sustainability and environmentally conscious products gain a natural place in development of the product assortment.

Only one brand did explicitly state they evaluated their whole product assortment in their current design process, C1 mentioned they would look into it from now on and C4 said they have something coming up for coming seasons. With a clear strategy, according to Keiser and Garner (2012), can the development of the product assortment feature the core value of the business and becoming a great way for the Outdoor Brands to express their responsibility.

Yarn construction

Yarn constructions was mention only briefly by C2 when also speaking about fabric construction. C2 said they worked with different yarn constructions to find a yarn more reluctant to pill and break.

The literature has in contrary to both the Outdoor Brand and the Expert Panel discussed the yarn construction with greater emphasis. De Falco et al. (2017) found in their research that yarns made of staple fibers was much more likely to shed microplastics and the solution could therefore be to change to filament fibers. Peterson and Roslund (2015) did also found the same result in their study. Gavignano et al. (2015) did a more detail explanation in the Mermaids report saying that the construction of yarn could be altered in a various way for lower the risk of microplastic release.

The many factors described by Gavignano et al. (2015) and then later developed in the Mermaids report 2018 was neither brought up by the Outdoor Brands nor the Expert Panel. The reason why cannot be determent in this study but one likely reason could be a lack of knowledge of the impact different yarn twist and yarn count have on the final yarn.

Mass customization

Discussing the issues of mass consumption E5 suggested mass customization would be the solution.

[…]so you go from mass consumption to mass customization because then it is made for you and it will be more expensive and you cannot buy as much, and it creates more respect. (E5)

As a reaction to the wear and tear behavior related to cheap clothing E5 believes that making product more personal would not only make the customer willing buy more expensive products but also creates a stronger bond towards the product. As customization is not that common among the outdoor industry this could be the explanation that none of the Outdoor Brand discussed this possibility. C3 did however, discuss one issue being an outdoor brands and already offering pricy products saying there are brands which products are expensive due to status more that due to quality.

[…] so that's the tricky part being a premium brand, how do we get the consumer to understand that it is even cheaper to buy expensive? (C3)

C2 continue to ask “so how do we make our customer to care about their products and repair them, how do we create a sentimental value?”. According to E5 could customization be a solution.

Henry et al. (2018) did particularly discussed the relation between mass customization and microplastics but did in contrast discuss the issue with mass consumption and fast fashion being a great contributor to the enormous waste ending up on landfill. As synthetic textiles have the highest proportion of the textile industry landfill from such secondary sources contributes to microplastic pollution. Therefor could a greater focus on customization and creation for stronger bond between customer and product lower the risk of the product ending up on landfill. Nevertheless much such relation be further analyzed.

From the interviews there is a gap of discourse how and if . Nor has the Outdoor Brands not the literature analyzed the possibilities of customization in order to minimize microplastic release.

Packaging

The last subject to be presented as a potential solution for lowering microplastic pollution from a design process perspective is the design of packaging. As not being directly connected to the garment itself it is still used in great extent. The textile industry being located around the globe comes with long distance transportation and with a growing e-commerce garments are sent back and forth more then ever. This cares for protection of the garment and E6 said they have experiences a change among textile brands going more and more from plastic packaging to carbon boxes.

As Keiser and Garner (2012) describes it are all garments firstly packed in plastic bags before put in a larger carbon box. E6 has seen new ways of bundling and folding the garments which could lower the use of plastic bags in each box. Packaging has mostly been discussed related to disposable products (Napper et al. 2015) such as food contaminators or bottles. As there has been developments on producing new packaging materials that would decompose one solution could be to use the same technology for packaging for textiles. This is however something needed for further research.

The relation between textiles, packaging and microplastics was only discussed by one company among the Expert Panel. It may be due to the lack of acknowledgment being a part of the design process when most emphasis has been put on the textiles itself. It could however be one of the many solution for the textile industry to lower its microplastic release.

5.2 Production process

The following subsection will present the identified challenges and solutions within the production process based on the Outdoor Brand and Expert Panel interviews.

5.2.1 Challenges

When asked what was the main factors for causing microplastic pollution in the production process the Outdoor Brands and the Expert Panel provided with nine areas; (i) wet processes, (ii) cutting and sewing, (iii) mechanical processes, (iv) WWTP, (v) weaving and knitting, (vi) chemical processes, (vii) costs, (viii) waste management and (ix) packaging. Each factor will firstly present the Outdoor Brands view; in so far as they mentioned it. Some areas, as will be discovered, was not mentioned by the Outdoor Brands but rather developed by the Expert Panel, this was also seen the other way around.

Wet processes

According to the Outdoor Brands was wet processes was mostly related to washing and dyeing. Both C1, C2 and C3 said wet processes being of high risk for microplastic release since they are in direct contact with water effluent systems and the uncertain efficiency level of WWTP.

I believe in the washing, or in the dyeing because it is a water process were the fabrics enters a bath with color and then continue into a heat, it is fixated with heat. That is the first time the fabric is being wet. Often with fleece, which you know release more in the beginning, then there should be pretty much microplastics in that bath.
(C3)

The majority of the Expert Panel did also acknowledge the wet processes as being a big source of microplastic pollution. E3 said:

This is where it happens. Partly in the factory due to washing and dyeing and having wet processes and there will those loose parts slip away and those parts which had not been removed after, for an example, in cutting and sewing will end up in the consumers

washing machine and draining system.

E2 and E4 and E7 all spoke about issues related to wet processes, all of them being in line with E3 statement. E2 did also say that it is not only the connection to water making the wet processes a contributor, the washing machine add also stress to the fabric increasing the microplastic release. E7 said that even though they thought most of the microplastic pollution comes from domestic washing machines, as then it is divided into every individual, the industry processes could still have a big part of it dependent on the suppliers WWTP.

Even though E6 did not talk about dyeing as an issue for microplastics saying "we don't have any microplastics in any effluents from garment dyeing, if there is not any residues from the clothes" the question remained about what plastic is.

The origin of the paint is made of oil, but it is not really plastics. But I don't really know what it looks like, and it hasn't really been up on display. So I'm very unsure if it's possible to call it plastic.
(E6)

From a literature perspective, has wet processes mostly been related washing and WWTP (which will be discussed later in this subsection). Dyeing is discussed in terms of different dyeing techniques. According to Keiser and Garner (2012) can dyeing appear either on fiber-, yarn-, fabric-, or garment level. Each level has their own process which also could change dependent on the material and colorants. Those results where the pigment penetrates the fibers are those, according Keiser and Garner (2012), which gives the best result.

Seen from the Outdoor Brands and the Expert Panel there is a common understanding this could be a potential source, however not really knowing what is the cause. The literature does neither bring up explicit characteristics of wet processes more than it is where microplastics from earlier processes ends up and flushes down with the effluent.

Cutting and sewing

Precision in cutting and sewing was recognized as having an effect of the release of microplastics. C2 thought cutting could be a source of dust and waste, but that most suppliers trying to have clean working environments. However, that which has not been collecting during dry processes would end up in the wet processes (as mentioned in previous section).

After cutting the fabric is assemblies into garment and sewn together, C4 said they seen research saying different flatlock and overlock seams could affect the microplastic release. In order to locate where in C4's processes there is a risk for microplastic release they have conducted a review of their own processes.

We actually defined every process from fiber stage, weaving stage, fabric stage and it also comes to cutting and sewing. In every cutting all these fluffy goes somewhere else, also in the sewing process. Actually every process have little tiny fibers that goes somewhere else.
(C4)

Three of the members of the Expert Panel acknowledged cutting and sewing being a source for microplastic release due to dust.

There are different ways of trying to eliminate waste from cutting, according to Keiser and Garner (2012) could this be done by fitting the garment patterns as efficiently as possible in the production marker. The cutting can then be done in various ways and according to Roos et al. (2017) is regular cutting with scissors a source of microplastic release. Further does Keiser and Garner (2012) describe stitching as 50% of the total quality of the garment. Together with stitching and the choice of thread can the total quality of the garments significantly increase.

Both the Outdoor Brands and the Expert Panel raised their concern about shedding from the cutting and sewing processes. The literature has, to some limit, described the challenges of cutting and sewing, however this is still an unexplored area.

Mechanical processes

The most frequent factor, causing microplastic pollution, was according to the Outdoor Brands the mechanical processes. The process of lifting and cutting fibers to receive a fluffy surface (such as on fleece) was seen as the biggest source of microplastic release. The mechanical processes, in its nature, to cut small pieces from the fabric has made the Outdoor Brands to question their use of mechanical processes. C4 said much would be dependent on what fabric was used and the type of brushing technique and machinery.

For instance one of our suppliers are doing a lot of fleece, the knitted fleece is probably where the pollution comes from because it is very easy, it is very fluffy and when you brush the shedding is everywhere.
(C4)

Even though many of the brands suppliers have implemented solutions such as vacuums into their production there is still an uncertainty if all microplastics are collected and what happens with those that are not.

The Expert Panel did also discuss mechanical processes in a great extent, in more detail describe how the brushing is connected to shedding.

> *When you mechanically process something, let say fleece, you cut it, rug it which makes it much easier for loose fibers to slip. It is the same if you make plush or terry, or think about a plush robe, that is a terry with loops which you cut up open and then brush or rug. And then you wash. […] it is dry mechanical processes, and when you do them it is important there is a good extraction so that you suck away, or shake away [the loose fibers].*
> *(E3)*

E2 said *"from all mechanical processes we get fiber release"* . The challenge with brushing is though you want to create the functionality and the feeling a brushed surface gives and the potential environmental impact it brings along. E2 continued to discuss the different brushing techniques and thought it would be interesting to further understand if there is really better or worse alternatives.

To this point brushing has been acknowledge in literature as a contributing factor to microplastic release (Roos et al. 2017). As the mechanical processes breaks the fibers and is responsible for microplastic formation (Gavignano et al. 2015). The challenges however remains if there is any alternatives between use a brushing method and not doing so. According to Mermaids (2018) could there be difficulties to adjust the machinal parameters in the napping machines to both lower the negative environmental impacts such methods have and still fulfill customer requirements.

Mechanical processes such as brushing, peaching, sueding, filtering etc. is used for their desirable effects on the fabric surface and is highly appreciated in the outdoor segment. The result of such process is however one of the most argued areas and the Outdoor Brands has recognized the dilemma. Also the Expert Panel has grasp the challenge with mechanical processes and urges for more research. To this point have the literature only begun exploring the impact of brushing, something that will hopefully be developed in the future.

Wastewater treatment plants

Much have been said about WWTP during the interviews with the Outdoor Brands. Although as WWTP could have the possibility to collect a clear majority of the microplastics at one single point the standard of the WWT systems are of great variation and none, to this point, includes a process for microplastics. However, it is not only *how* to collect the microplastics which has caused concern, it is also what to *do* with them once collected. C4 raised the question about what would happen with the collected microplastics, saying sludge from today's WWTP ends up on fields for corps, and if not separated the microplastics would still end up in the nature.

C3 described how they been briefly was taught by a WWTP-certifier what to look for when out visiting suppliers, although on a very simple level. None of the brands had thought of making any tests on the water collected from the WWTP at their suppliers, C3 thought it might could become a part of the bluesign system for the future as for today there is no way of testing for microplastics.

The uncertainty of the efficiency level of WWTP was also discussed among the Expert Panel. According to E1 and E3 there is also an uncertainty knowing if they even are on as some suppliers turned them off to save cost.

[…]everyone is talking about washing, everyone is talking about what the consumers wants and do. But what's probably what's really really miniscule is when you look at manufacturing and is effluent being treated, how is microfibers being eliminated in the wastewater treatment plant, if the waste water treatment plant is even running.
(E1)

E4 said that accessibility and purification efficiency was the most challenging factors since some of the microplastics are so small they can easily slip through. E4 also said that some countries does not even have treatment plants and could therefore not do anything to stop the pollution, while some countries even try to deny it.

We have a lot of contact with the textile association in Germany were they actually denies the problem, saying that the wastewater treatment plan they retain all of the microplastics. So no microplastics end up in the ocean.
(E4)

E4 continuing saying that some have efficient WWTP that can collect microplastics to some level, but that it is very dependent on the country, regulations and levels of purifications.

Wastewater treatment plants is one topic received a greater space in the literature although not always related to the textile industry. According to both Boucher and Friot (2017) and Gavignano et al. (2015) there are no WWTP that could capture all levels of microplastics and even more so according to Piñol et al. (2015) that this is many times not even considered by the management. Even though WWTP has been highlighted by the European Commission in their WFD none of the Outdoor Brands nor the Expert Panel seems to acknowledge any signs of the implications.

The challenges laid with WWTP is one of the areas which has been discussed by both interview groups as well in literature. Nevertheless is the current state of knowledge limited to the lack of measurements. Without a legitimate way of collecting and counting microplastics the severity of WWTP will remain unknown.

Weaving and knitting

Much in line with cutting and sewing C4 associated knitting and weaving as a source of dust. E2 was of much the same opination saying weaving and knitting with yarn made of staple fiber was a source for microplastic release as the mechanical processes can create a very dusty environments since there is a greater risk that the staple fibers breaks or slip away.

According to Gavignano et al. (2015) have both the weaving and knitting process and impact on the microplastic release. The authors say in their report that hairiness is the main cause for microplastic release and that weaving and knitting is a contributing factor for such behavior. The friction that appear in the loom when the thread is fed into the machine through a coming and going movement could cause the fiber to break and make the yarn hairy. High-speed processes could increase breakage of the protruding fibers and fibers loops as they could be "caught into machine elements and needles causing breakage in the fabric structure" (Gavignano et al. 2015, p. 11).

Based on the available literature there is still room for further development about how the weaving and knitting affect microplastic release. The Outdoor Brands could however already look closer to their own processes for evaluation of hairy tendencies.

Chemical processes

One area which did not gain large attention among the Outdoor Brands was the challenge with chemical processes. Chemical processes includes those processes by which chemicals are used to change the appearance, touch, look or function of the product. Chemical processes are mostly managed by the suppliers and the brands mostly only knowledge weather they followed regulations or not, rather than knowing the content of them. C4 said; as they were "not being the supplier of chemicals" it is hard for them knowing what chemicals the most sustainable and what options are the best as well as understand the whole degradation process and the effect of such.

Chemical processes was well discussed among the Expert Panel as many of the members of the group has expert knowledge within the field. E3 had several suggestions on chemical processes that could increase the release of microplastics; weight reduction, finishing, choice of chemicals, and printing pigments. According to E3 are the most common pigments for dyeing and printing laminate-based, which is basically plastic. E3 did also describe the chemical process of weight reduction, not being sure this was a source for microplastics release E3 thought it might.

Then there are another thing, maybe it will not create microfibers but there will be microplastics. It is, if you have a polyester product which is initially a bit stiff, and to make it silk-like as a silk dress or top, you could chemically peel the polyester. It is like this, it is a weight reduction. And this created very small particles. But I have not seen anyone highlight this peeling process, but information tells me this is quite common, I have myself been a part of the process […]
(E3)

According to E4 are the textile auxiliaries available today of synthetic nature such silicon and acrylic and the tricky thing is the resistance when washing, because you need to produce a coating that stays on the surface.

[if you add] a finishing treatment that is made of synthetic material, if the finishing detach from the fabric surface during washing of course you introducing another polluting agent that is made if synthetic material […]
(E4)

E4 points out one of most challenging parts of finishing treatments being that none of the treatments available today are designed to prevent microplastic release. The treatments available today have other purposes such as to be fire protection, to have hydrophobic properties

or to improve dyeing. Synthetics being quite resistant to dyeing can sometimes need extra finishing to improve the dyeing process.

Even more these finishing's use chemicals that as are suspected to pollute. When microfibers are release the main threat is not only the fibers itself but also the release of additives or some chemicals that are on the fiber. They all use chemicals of synthetic nature so none of the materials is eco-friendly.
(E4)

As there is a risk for chemical treatments such as finishing and coatings to wear off from use and washing the substances of the chemical composition have a great effect on the environment (Henry et al. 2018). A critical factor for all auxiliaries is the ability to remain on the surface, if released from the fabric and entered to aquatic surroundings the shape of microplastics form textiles have a relative high surface area which increase the risk of facilitate additional chemicals from surrounding water ingested in both marine organisms and animals but also in human food sources (Henry et al. 2018). Beton et al. (2014) drew attention to sizing and desizing processes saying due to high TOC these chemical recipes could contribute to water contamination.

The consequences of chemicals used in the textile industry together with microplastics are still not well understood. The scientific research of chemical processes related to textiles and microplastic release has to this point been focused on detergents and softeners (De Falco et al. 2017; Napper and Thompson 2016; Chiweshe and Crews 2000). To the degree of previous research, powder detergents has been stated to trigger microplastic release while liquid detergents are said to be a better alternative (De Falco et al. 2017; Napper and Thompson 2016). De Falco et al. (2017) also found softeners being a potential solution for lower microplastic release while both Smith and Block (1982) and Chiweshe and Crews (2000) found the opposite result. However, C4 said that even if softeners would be a solution for microplastics it would not be functional for outdoor wear since it would clog the surface of the fabric and damage the functionality of the garment.

Chemical processes is located at several steps in the production process; sizing agents are used in the weaving step, auxiliaries are used during dyeing, detergents are used in washing and finishing are used for coating. As many of the Outdoor Brands seem not to have chemical expertise, the issue of knowing what chemicals lead to microplastic release and how they affect the environment remains a challenge. Even though there are many regulations for

chemical use, none has yet been developed to lower microplastic release which makes it hard to know what would be the better alternative.

Costs

Channing production processes could be a costly activity, despite that did only one of the Outdoor Brand mention cost as a challenge. Working closely with their suppliers C1 said that their they needed first to know what the alternatives would be, and then look at the costs.

One have simply to ask the question, what are the alternatives and what can you do, and is it a fair price. That's the next question.
(C1)

The Expert Panel put more concern into the cost aspect. The textile production process includes several steps and each step is laden with decisions and costs. E5 discussed the possibility to use chitosan in the dyeing process instead of synthetic based recipes, saying that the good quality of chitosan is very expensive and the cheap one is not applicate to function as required. So even if there is a willingness to make more sustainable and environmentally friendly choices it is not always so easy.

Sustainability and economy goes hand in hand. If you can see it in the long term, and this has been a huge problem for us to make or customer not only looking at the price tag but see things over a longer horizon. Then it will be widely superior also economically and the same goes for manufacturing, sustainability and economy goes hand in hand […] that we need to invest a lot to achieve this is another thing but if you can see it from a longer perspective it will become cost efficient.
(E5)

Introducing new alternatives or update current status on machines could according to E3 be a challenge. Many suppliers have older machinery which may not necessary was in the best shape, but at the same time they are expensive indicating that replacing one is not always an option. E6 said they previously had an filter installed in their production processes but when it broke it was too expensive to buy a new one.

[We are] quite small so at the moment does it not pay off, but we use to be much bigger and had a relay good fiber strainer, but it cost about 100 – 1500 thousand [Swedish kroners] one such strainer and when it broke we had to remove it.
(E6)

E5 said it is not always known what costs really are, some production sites offers very cheap clothing and E5 ask how that could be.

[…] because cheap does only mean hidden costs, and one can wonder what is hiding. Who has to pay for it, maybe some that is not that fortunate. But maybe it is many, maybe everyone is paying the price for the cheap.
(E6)

E6 question about whom is really paying the price has also been discussed by Naturvårdsverket (2017). As the environmental impact of microplastics is not yet stated the textile industry cannot add this costs into their products. Further did Naturvårdsverket say that potential solutions should be considered based on costs, as it is still unknown what is the preventions. The WFD directive developed by the European Commission (2007) indicated that production facilities may be charged if their WWTP does not reach required purification, but according to Bruce et al. (2016) is the capital costs for WWTP very high making many supplier reluctant to change or update their systems.

Napper and Thompson (2016) does also discuss in their report that synthetic fibers are in many cases a cost efficient choice, being added into cotton fabrics in order to lower the costs. This indicated, together with synthetic textiles being diverse in use the challenge of stop or lower the use of synthetic textiles in apparel.

Waste management

Waste management is related to WWTP and other cleaning and collecting activities installed in the production facilities. C4 points out the challenge many of the textile manufactures face, being lack waste management system. Without a system there is no way to secure what the suppliers do with the collected microplastics, with the risk of them ending up in the nature.

E7 did also reflect on what would happen with the collected microplastics. Those collected in dry environments could easier re-enter the manufacturing process but what to do with those ending up in the water.

There is some companies discussing what to do with the collected microplastics. My goal is to collect it and set aside with your regular waste collection or make into new products, clothing, ropes or mats that is what I ultimately want to do with it.
(E7)

Natrurvårdsverket (2017) state that one of the main global sources for marine litter is due to insufficient waste management systems. Waste includes also sludge collected from WWTP, and there is a misunderstanding about the efficiency of microplastic collection if not waste

management of sludge is considered. The efficiency rate of collected microplastic may be high (up to 97% according to Naturvårdsverket 2017) but relocating the sludge to other environments would still lead to microplastics contaminating the environment. Mermaids (2018) indicate in their report it is important to set a policy for waste management, however no directions on how or what to do with the collected microplastics. Auta et al. (2016) summarize their report that the issue with microplastic waste cannot be reduces if not the general public, socio-economic sectors, tourism and companies specialize in waste management.

Waste management was not a topic generally discussed among the Outdoor Brands, not the Expert Panel. Most focus has been laid on WWTP (when waste has been the subject). However, even if new efficient WWTP would be developed capturing microplastics, the issue remains on what to do with it.

Packaging

Plastics in textiles is not only related to synthetic materials but also to packaging. Although it is a part of the production process, packaging was not mentioned by neither of the Outdoor Brands, and only by one of the members of the Expert Panel. As packaging is a part of E6's supply chain they have recognized the high volume of plastic bags wrapped around the clothes, estimating that around 20 ton plastic pass through every year. Even though E6 tries to reuse packaging as much as possible much of the plastic goes directly to waste.

According to Keiser and Garner (2012) is packaging the last step in the production process, wrapping plastic bags around the clothes before they are put into carbon boxes and shipped to the customer (Keiser and Garner 2012). As larger plastic items are seen as a big secondary source for microplastics (Boucher and Friot 2017) it is important to have sufficient waste management systems in place (for more detail see previous section).

Packaging did not seem to be considered by many of the interviewees. Even though it is a part of every supply chain, protecting the products from soil and dust during transport, it did not give the appearance of being anything of consideration.

5.2.2 Solutions

In the production process the following solutions was suggested (i) filters, (ii) chemical processes, (iii) vacuums, (iv) recycling, (v) print and dyeing techniques, (vi) wastewater treatment plants, (vii) cutting and sewing, (viii) encapsulate machines, (ix) mechanical processes and finally (x) production systems.

Filters

The most spoken of solution for the production process what the use of filters. Among the Outdoor Brands did C2, C3 and C4 discuss the possibility of implementing filters. C4 thought that filters in wet processes and WWTP would be much preferred by suppliers since it would be fewer collection points and easier than having vacuums in each stage (as they have, more or less, today). C2 said they also thought this would be a good solution, although it would not solve the problem with microplastic release from the products.

C4 said they thought that filters would be much more efficient since the supplier would be able to work in a bigger scale by using pressure and pumps to push water through a fine mesh. The biggest problem would be to convince suppliers making the investment. “Here I believe in legislations” C4 said, as it is a natural development when encounter new problems.

The filter discussion was the predominate subject among the Expert Panel as a solution for preventing microplastics entering aquatic environments. E2 said they have seen a rising discussion among suppliers evaluating the implementation of filters to lower the microplastic emission. E2 did although not think this would be the whole solution. Actions are needed already in the earlier stages.

E4 said that the only way to really increase the purification rate of WWTP would be to implement better filters. E6 had previously a filter installed in their production process where they saw good collecting results. E6 described their previous filter as:

It was a rotating drum which the water passed through and then pumped out which made the fiber stay on the outside on a really fine metal wire and then there were a brush brushing it off, so it was self-cleaning so to say.

E7 thought filters on industrial washing machines would be a possible solution, implemented as a two-stage process. Firstly one filter with coarser mesh would be placed upstream and

then a combination of a coarser and finer mesh would be placed downstream. E7 saw no problem upscaling washing machine filters to commercial levels, it would just be a matter of engineering.

It could be scaled up, but I think, when you go to industrial which has more volume of wastewater you have to design different types of filters, this one is a contained design, but it has its limitations. It has to be a case to case thing, what do they filter, in the facility [and] what do they have already. […] You would need an engineer company to do larger scale. (E7)

Much literature has focused on the capacity of collecting microplastics from domestic washing machines (De Falco 2017; Napper and Thompson 2016). The possibility to implement filters also on industry level has not, to my knowledge, yet been discussed more than a recommendation for further development as by Maria Westerbos (ESA 2015). Nevertheless did many of the participants think this would be good idea, collecting waste from one big source instead of trying to collect on a domestic level.

Filters could be a good way of preventing microplastics contaminating the water from the suppliers production sites, nevertheless, both the Outdoor Brands and the Expert Panel does not think this would the whole solution. Preventions and changes are needed already from the start.

Chemical processes

Among the Outdoor Brands only C4 brought up chemical processes as a part of the solution for lowering the release of microplastics. Without working on any special solution designed for microplastic release, C4 said they used with wax for their jackets and coats. As the wax acts as a lubrication it could have binding properties and therefore lowering the risk for fiber breakage in the fabric. The use of wax could potentially lessen the shedding and prolong the life length of the garment and thus lower the risk of microplastic release.

We have our wax. If you think it would increase the life length and resilience. It could be a way, if you would to wax your garment they won't dry out and lessen the friction between the fiber threads and the yarn. This is only a guess but it should release less fibers if you would to have a well-waxed fabric than an un-waxed fabric. (C4)

However, C4 continues with saying once you wash the garment the wax would wear off and the customer would have to re-wax.

In comparison to the Outdoor Brands, chemical processes were more thoroughly discussed among the Expert Panel. E3 said they thought bio-based finishing's could be an option instead of synthetic ones. Not only would a bio-based treatment go from using fossil materials but it would also lower the non-biodegradable particles entering the environment. E4 agreed saying that the textile auxiliaries available today are of synthetic nature (such as silicon and acrylics) and wants therefore to develop new auxiliaries of natural, or at least, biodegradable polymers. If the auxilians in the same time obtain a good covering of the surface and being resistant to washing treatment it could also prevent the risk of microplastic release.

I am working on a natural polymer which is Pectin, it is an natural polymers from the plant cells which can be obtain from the food waste and is used in the food industry because it has some jellying properties […]. In this stage I have got some really good results, with a decrease of almost 90 % of the microfibers release. I also did other studies with biodegradable polymers, biocompatible and biodegradable so even if they end up in the ocean they will compose after a period. All these treatments gave really good minimizing results.
(E4)

E5 said they have re-designed their production process and with that lower their chemical use with 20%. By going towards dry processes they have been able to change from synthetic to biological auxiliaries as well as using biological glue in weaving. E5 said they constantly looking into biological alternatives, chitosan being one of them. Chitosan made of the shell from shellfish (Bhuiyan et al. 2014) is a possibility in the coloring process, however, the use of chitosan is limited due to the high expense of quality chitosan. If they were to use less expensive alternative they would instead have issues with the quality of the finished product. E5 continues saying as they are not a chemical producer they can only follow what is available on the market, but could still, as a provider for the society make the best choices available.

The production process includes several chemical processes were recently new focus has included biological and bio-degradable alternatives. The Outdoor Brands and the Expert Panel has in variated scale discussed and implemented new processes in order to lower their chemical use. Only E4 hade mad special focus on microplastic release, supported by Gavignano et al. (2015) saying finishing's with good washing fastness could be a solution. Nevertheless, most focus has not yet been to the most point to lower microplastic release.

Vacuums

The Outdoor Brands had seen a growing instillation of vacuums among their suppliers, mostly fleece manufactures. Vacuums has mostly been seen in the cutting and sewing processes as the mechanical actions increases the fabric to break and shed.

Many fleece manufacturers has begun to vacuum, to clean after each cutting like a giant vacuum which suck up everything loose.
(C3)

E3 said they also seen suppliers use different types of vacuums and blowing techniques in order to remove loose microplastics. This is mostly, as was also described by the Outdoor Brands, common in relation to mechanical processes.

The literature only touched the use of vacuums in relation to microplastics, saying that pollution could be reduces if they was removed already in production (Roos et al. 2017).

Recycling

Recycling was only briefly mentioned by the Outdoor Brands, C3 saying that a recycling process should be connected to the collections process (vacuums, filters) in order to reuse the microplastics into new textile.

The Expert Panel had a couple of different ways of interpret recycling, discussing different staged in the production process where recycling could be implemented. E2 said that some processes (such as pulverization) could be a good process for microplastic as you break down the molecule and then rebuild the polymer chain. In that was impurities could be removed and new fibers could be created.

E5 said as much of their products are made of polyester and polyamide, these products could be included in a recycling and circular process. As E5 does not believe that the solution is to prohibit all plastics material they rather believe in new ways of working with existing products.

Off course we could go out and say "Hey, let's forbid all plastics and plastics materials", but I am not sure this would be the best. It is much about to see the circularity in order to use it again.
(E5)

E5 said they have, as an example one product which is 100% circular. The customer return the old products which then breaks down to monomers for reusing. This is off course, as E5 said, hard to implement for all products (since many are shipped all over the world) but, if every country could implement a recycling station a lot of synthetic apparel and textiles could be included in a closed loop.

However, the textile industry does not work only with synthetic textiles, E6 associated the recycling process to the plastic packaging which apparel manufacturers pack and ship the finished garment in. according to E6 does plastic packaging reach up to 20 ton yearly in their warehouse. Most of the larger plastics found in the ocean comes from larger packaging plastic materials and E6 highlights the importance to have a functional recycling program installed.

E6 linkage between larger plastics in the ocean and the microplastics pollution is strongly supported by science (Boucher and Friot 2017; Napper at al. 2015; PlasticSoupFoundation.org 2018). Also synthetic textiles end up in ocean (Henry et al. 2018) causing microplastic pollution. According to Auta et al. (2017) does a lack of recycling systems contribute to microplastic pollution in marine environments and according to Boucher and Friot (2017) could better waste management systems be a solution.

Wastewater treatment plants

Among the Outdoor Brands, only C3 said WWTP could be a part of the solution. C3 developed the common way of sedimentation into a process adding chemicals which to attract the microplastic particles. The clusters of microplastics would then sink to the bottom and become sludge. When a part of the sludge the microplastics could in an easier way be managed. C3 also say they could see a change in the future where environmental standards such as bluesign could involve microplastic tests into their forms.

The Expert Panel say more potential of using the WWTP as a collector of microplastics. E4 said that many WWTP already has different levels of purification and does already today collect some level of microplastics (however the scale is not yet know). Furthermore E4 said "*it is more likely to block all the microfibers if you increase the purification system"*, this however is still to be discovered.

E5 said they worked with their own system, giving them increased control over the system and any potential water effluents. Other than that E5 believe that much of the microplastics are collected in the systems and ends up in the sludge.

WWTP are to certain level discussed in the literature as a solution for microplastic pollution, the filtration of the water could be a way of collecting the microplastic but as Boucher and Friot (2017) said no plants today has yet reached that level. As a reaction on the lack of filtration in the WWTP has WFD set up new regulation aiming to increase the quality level of textile waste water. This being one way of increasing awareness of the importance of WWTP.

Print and Dyeing techniques

Many of the Outdoor Brands acknowledge wet processes such as printing and dyeing some a contributing part of microplastic release, however few looked at is as a solution. Only C1 said they saw solution-dye or spin-dye techniques being a way of lowering microplastic release. By color the yarn already before fabric manufacturing, C1 thought it would not only reduce microplastics but also be a great way of preserving water and reduce the amount of chemicals used.

Among the Expert Panel both E3 and E5 both printing and dyeing techniques as a part of the solution. E3 said by using screen print you can create much thinner layers of color. As many printing techniques applies layers of plastic coating a thinner layer would lower the quantity of microplastics that could be released. E5 said they was very open to look into new alternative dyeing and printing techniques as it would not only be a potential way of minimizing microplastic but would also use less water and chemicals.

[we have] begun looking at new technology and new ways of doing thing and something we have looked really much at is the ink-jet technology, which we can use already today to print and there is no problem, it uses very little water and especially less chemicals and everything. (E5)

As written in the *Handbook for zero microplastics from textiles and laundry* (Mermaids 2018) is yarn-dyeing a potential solution for lowering microplastic release in the production process. Adding color already in an early process does, as C1 said but also Keiser and Garner (2012), improves color fastness. However, Keiser and Garner do not consider color fastness in relation to microplastics.

Cutting and sewing

Although cutting and sewing is a big part of the textile production process did only C4 mention it as a part of the solution for lowering microplastic release. C4 said they thought different way of seams, such as flatlock and overlock, could impact the release.

[…] There are some studies that show much fibers comes from cutting, so one can think that different types of seams could affect a great deal, if you use a flatlock or overlock or what other else is used […]
(C4)

C4 did also mentioned they knew new cutting solutions to come out this year how to better cut your fabric and also that they themselves worked with different cutting solutions in order to prevent microplastic release, which however, could they not reveal.

Working with cutting and sewing as a part of the solution for prevent microplastic release. Roos et al. (2017) said in their report that using ultra cutting machines would reduce shedding significantly. However, the connection between cutting and sewing has, to my knowledge, not yet been well discovered which open up to new research on how to prevent microplastic release in the production process.

Encapsulate machines

One of the Outdoor Brands suggested also encapsulating machines in order to control the amount of dust and dirt spreading and hinder it from being flushed out. C4 thought by encapsulating the machines the factories could in an easier way manage the shedding from mechanical processes.

None of the members in the Expert Panel thought of such solution. Neither has the literature developed the discussions about concrete suggestion on how to manage microplastic waste. Although the earlier Mermaids report by Gavignano et al. (2015) said shedding from mechanical processes are in need of careful managing has only the later report by Mermaids (2018) highlighted this area. Mermaids (2018) highlight that the collecting of waste from brushing and other mechanical processes is a potential solution for reduce microplastic pollution as it lower the risk of microplastics entering air and water.

Mechanical processes

Mechanical process was seen among the Outdoor Brands have a direct link to microplastic release, however none thought of this also being a part of the solution.

E2 however thought machinal processes such a lighter brushing could partly be a solution to the more heavy brushing which is common today. Yet, a lighter brushing does not give the same finish as a rougher brushing does, it is as E2 a "trade-off".

According to Gavignano et al. (2015) can mechanical processes such as singeing and calendaring lower the risk of microplastic release. Both processes are said to lower the risk of pilling and thus release. The risk of air and water polluting from mechanical processes has been given some attention from both scientific literature as well as among many companies implementing sustainable initiatives in order to take greater responsibility (Gardetti et al. 2013; Stotz and Kane 2015; Turker and Atuntas 2014; Pedsersen and Gwozdz 2013).

Production systems

The last solution area to be brought up as a solution was mentioned E5. As a producer of textiles they thought to re-design their production process in order to lower the environmental impact. By going towards dry processes and working with closed system E5 thought, in the future, would have very low risk of release microplastics.

Production systems has not yet, to my knowledge, been discussed in the relation to microplastic pollution.

Result overview

The overall view brought up by the Outdoor Group and the Expert Panel is the common view of the issue with microplastics as a fast-growing subject with many questions still be answered. The results displayed above is a collection of the knowledge and thoughts brought up by the participant during the interviews. The results display both the similarities and the differences between the Outdoor Brands and the Expert Panel and the below tables specify the groups individual focus areas within each topic. What has not been a subject to this report but highly important for all participants is the importance of collaboration. Only by working together with suppliers, other brands, organizations, universities and researchers can a solution be found.

The Outdoor Brands

	DESIGN	PRODUCTION
CHALLENGE	choice of fiber fabric construction quality fillings	mechanical processes cutting and sewing and wet processes finishing's and coatings cost
SOLUTION	fabric construction choice of fibers quality product assortment design elements yarn construction garment construction	filters vacuums encapsulate machines dyeing techniques wastewater treatment plants cutting and sewing chemical process

Table 2: Outdoor Brands: Design- and production challenges and solution

The Expert Panel

	DESIGN	PRODUCTION
CHALLANGE	total environmental impact costs quality choice of fibers fabric construction yarn construction product assortment design elements mass consumption filters	wet processes wastewater treatment plants cutting and sewing costs mechanical processes chemical processes weaving and knitting waste management packaging
SOLUTION	choice of fibers fabric construction garment construction design elements mass customization packaging	filter recycling print and dyeing techniques chemical processes wastewater treatment plants cutting and sewing mechanical processes vacuums production systems

Table 3: Expert Panel: Design- and production challenges and solution

6 Discussion

This report has exanimated the existing research and initiatives available today regarding the issue with microplastics in marine environments. The environmental effects have been highly recognized by many researchers (Rochman et al. 2013; Fendell and Sewell 2009; Auta et al. 2017; Napper et al. 2015; Mauro et al. 2017) however many of the sources and solutions are still to be defined. The textile industry is identified by Henry et al. (2018) as a source of microplastics polluter, however, where and how are not yet exhaustively investigated. Together with participants from the outdoor segment and field experts has this report explored where in the design- and production process microplastics are released and what could be potential solutions.

The following chapter will give the reader an overview and discussion about the central aspects of previous presented result. As should be understood from the discussion is that the challenges and solutions are based on the belief and understanding of the interviewer and company knowledge. As stated throughout this research is the lack of scientific knowledge how the processes from the design- and production process affects microplastic pollution and the areas presented should be seen as a starting point for further research.

6.1 Design process

The design process is the initial stage of new product development (Kaiser and Garner 2012). As 80% of a products environmental impact is a result of the decisions made in the design process (Svid.se 2018) it is in the design process the first step of eliminate harmful materials should be achieved (Dangelico et al. 2013). The first challenges for the designer become therefore to consider the choice of fibers, yarn-, fabric- and garment construction, design elements and product assortment. Above this, to understand where and how microplastics occurs and how to prevent microplastics to enter the environment.

Both Naturvårdsverket (2017) and Gavignano et al. (2015) has explicitly stated that the choice of fiber is of great importance, the fiber type, mix and lengths affect the microplastic release. A simplified view of the challenge with microplastics is held to the choice of fiber. Synthetic fibers are to be believed being the main issue, however, changing to natural fibers has been recognized with its own restrictions and effects. If every brand were to exchange synthetic fibers to natural fibers, would it not only stress the corps production but a lot of functionally

would be lost. Another facile solution would be to only use filament fibers. According to one of the interviewees from the Expert Panel does price have a large impact on the choice of staple fiber, being less expensive. The solution could be a raised price for staple fibers, functioning as a tax for less environmentally option. In such way would more companies choose to use filaments. However, the touch and feel of a filament fiber are different than of staple fibers and there could be reasons why brands using staple fibers.

Other alternatives on a fiber level is the use of degradable fibers. If degradable fibers were to become an option companies should not need to choose between fiber length or mix, however, this solution is still in future prospect. Several of the participants expressed their concern about degradable fibers, they saw it as a great way of handling microplastics but worried about the process. Important, they said, is that when the particle degrade it does not break down to an even worse particle and to this point of knowledge is the lack of knowledge considerable. The challenge becomes instead of increasing the quality of raw material, secure quality processes and design for longevity. the technical design step, according to Keiser and Garner's model (2012) put emphasis on this action. By increasing quality throughout the whole design process considerable improvements can be achieved. The challenge becomes a question of product assortment and product variability. Only one brand did explicitly state they evaluated their product assortment in their current design process. With a clear strategy, according to Keiser and Garner (2012), can the development of the product assortment feature the core value of the business and becoming a great way for the Outdoor Brands to express their responsibility.

Looking into the next steps in the product development process, there are three main constructional stages; yarn construction, fabric construction and garment construction. Each constructional stage comprises of multiple compositions and the Outdoor Brands expressed their uncertainty what would be the best design. The impact of yarn construction has been described by Peterson and Roslund (2015), Gavignano et al. (2015) and later developed in the Mermaids report 2018. The construction of the yarn was said to lower the risk of microplastic release if it was made of filament fibers, had a high twist and made with low yarn count. The constructions could be done by change the shape and size in the spinning process (Burns et al. 2011) yet, neither the Outdoor Brands nor the Expert Panel brought this up. The reason why this was not acknowledged cannot be determent in this study, but, one reason could be the lack of knowledge of the impact different yarn twist and yarn count have on microplastic release. Further has fabric construction retain greater focus among the participants. One of the members

of the Expert Panel thought, in line with Keiser and Garner (2012), that the fabric construction as a part in the creative design step, is where the designer could modify and enhance properties of the fabric. If the designer where to discuss with their suppliers they could develop new weaving and knitting designs, fining a fabric which fulfills both aesthetics and environmental demands. brought up during the interviews was that some members of the Expert Panel are currently doing research of the effects of fabric constructional impact. Nevertheless, the results from these researches are among the firsts so each conclusion is to be the foundation for further research. Lastly is the garment construction, being the assembly process of the product. This design process has been recognized by both the Outdoor Brands and the Expert Panel as an area where the designer could change the design in order to lower the microplastic release. Without the possibility to share constructional information, informed one members of the Outdoor Brands, that they would launch products with new garment constructions in order to lower the microplastic release. What that involves will be for further research to investigate. The literature regarding garment construction and the relation to microplastic release is still undeveloped. Only the report by the Mermaids (2018) gave an example of pre-wash, yet this is more connected to the production process.

The design processes in this report has shown not only to include the textile products itself but also engineering design. Filters, being widely discussed, has also design challenges. The many ways of working with wet processes and with/without waste management put a large pressure on engineering, creating filters fit for different machines. Yet, it is not only the fit of the filter but the efficiency of the filtering. To this point, of my knowledge, has only one from the Expert Panel explained a potential filter capable for microplastics. They had previously had a self-cleaning filter which pushed water through a rotating drum where the fibers stuck to the outside on a fine metal mesh. The collected fibers were then brushed off by a brush. However, they did also say that once it broke it was too expensive to replace. The implementation cost for such system is therefore not only a concern for suppliers in low cost countries, but should be as Maria Westerbos from the Plastic Soup Foundation (ESA 2015) a common responsibility. Many of the Outdoor Brands explained their close collaboration and long-term relation with their suppliers and how also worked together in shared platforms with other brands. If efficient filters could be developed a shared responsibility of implementation could be of prosperity.

Making changes is rarely without costs, but without knowing the cause and the solution it is hard for the companies to make changes or investments. Therefore, it comes down to the total

environmental effect. The focus of today among the Outdoor Brands is on quality, making products that can withstand wear and tear and have a long life. Products that last long are believed to release less microplastics. Many brands have already shown initiatives to eliminate products that could have a high microplastic release. The industry is able to change; however, the change shall not affect the environment in other ways or are worse ways so to cause more harm to the environment that what it currently does, it has to be seen from a holistic point of view (Henry et al. 2018). Quality is an umbrella perspective consisting of many parameters. Such broad term has been discussed by the Outdoor Brands but clearly hard to distinguish the explicit meaning of it. This could also be seen in the literature where quality *is a part* of each step of the design process.

The relation between textiles, packaging and microplastics was only discussed by one company among the Expert Panel. It may be due to the lack of acknowledgment being a part of the design process when most emphasis has been put on the textiles itself. It could however be one of the many solutions for the textile industry to lower its microplastic release.

6.2 Production process

The production process is the physical development of a new product and it includes several mechanical and chemical processes. One such processes are wet processes and these were seen as the most challenging processes as its effluent has a direct link to aquatic areas. Even though both the Outdoor Brands and the Expert Panel had acknowledged this as a critical area, has this not been reflected in the scientific literature. Instead have WWTP received immense interest. WWTP are discussed in the literature as a solution for microplastic pollution, the filtration of the water could be a way of collecting microplastics, but, as Boucher and Friot (2017) said, no WWTP has yet reached that level of filtration. If efficient WWTP could be installed at the supplier's production sites a may it prevent water contamination. There are multiple challenges around WWTP, not only are they still not develop for capture microplastics, they would most likely be costly investments and many suppliers are located in low cost countries. Many of these countries does not have regulations supporting such implementation nor pressure from buyers. One of the Outdoor Brands thought suppliers would only to implement new WWTP if the law told them to. Nevertheless, neither the Outdoor Brands nor the Expert Panel thought this should be the only solution. Preventions and changes are needed already from the start and throughout the whole process.

To this point is the current state of knowledge limited to the lack of measurements. Without a legitimate way of collecting and quantifying microplastics from effluents there will be no indication on how efficient or non-efficient WWTP are. The question remains what to do. WFD (2000) instituted a new regulation aiming to increase the quality-level of textile wastewater. However, Boucher et al. (2017) did not think this would result in filtration but suppliers implementing recycling systems. Such instillation would need to be further researched and a comprehensive comparison between WWTP and recycling systems should be done. Yet none of these studies can be done before legitimate measurements are determined. The risk of trying to regulate processes were the severity is still not understood, is the possibility to take actions either require large investments or does not do anything good. Nevertheless, if new efficient WWTP would be developed capturing microplastics, the issue remains on what to do with it.

Closely linked to WWTP, are waste management. It was neither a topic generally discussed among the Outdoor Brands, nor by the Expert Panel but cannot be denied as equally important. According to Auta et al. (2017) does a lack of recycling systems contribute to microplastic pollution in marine environments and Boucher and Friot (2017) pointed out that waste management systems could be a part of the solution, yet, have the literature not developed any concrete suggestion on how to manage microplastic waste. The solution is therefore not solemnly to filter and collect microplastics but about scrutinizing every step and implementing preventions already from the start.

Wet processes, together with other mechanical processes such as cutting and sewing, brushing and sueding are all processes increasing stress to the fibers and fabrics which enlarge the risk of breakage and thus microplastic release. Mechanical processes are used for their desirable effects on the fabric surface. Only Gavignano et al. (2015) mentioned mechanical processes as a possibility to lower the risk of microplastic release. By singeing or calendaring can the risk of pilling be prevented, other than that is careful managing of fabric shedding the way of lower the risk of microplastic pollution (Mermaids 2018). As been described are the alternatives not in excess and the suggestions presented can only in limited extent be implemented. Mechanical finishing's within the outdoor segment are often related to fleece production and changing the process would also change the quality of the product. What has been seen is instead the use of vacuums. Vacuums are, according to several of the Brands, already implemented at some of their suppliers. To this point have the literature only begun

exploring the impact of brushing, something the Expert Panel urges for more research and the literature only touched the use of vacuums (Roos et al. 2017). Both the Outdoor Brands and the Expert Panel raised their concern about shedding from the cutting and sewing processes. The literature has, to some limit, described the challenges of cutting and sewing, suggesting ultra-cutting machines (ibid.), however this is still an unexplored area.

Although solutions are scares some have been displayed. Two of the most innovative solutions so far, is the potential of biological- and degradable fibers and a biobased coating preventing microplastic release. Chemical processes are located at several steps in the production process; sizing agents are used in the weaving step, auxiliaries are used during dyeing, detergents are used in washing and finishing's are used for coating. As many of the Outdoor Brands does not have chemical expertise, the issue of knowing what chemicals lead to microplastic release and how they affect the environment remains a challenge. Even though there are many regulations for chemical use, none has yet been set for microplastics. The Outdoor Brands and the Expert Panel has in variated scale discussed and implemented new processes in order to lower their chemical use, yet they stated they are not the chemical producers and can only use what is available. Among the Expert Panel was only one working with a chemical solution for microplastic release. The development consist of a natural polysaccharide coating preventing microplastic made of organic carbohydrate which has shown great testing result. The result showed a 90% reduce of microplastic when applied on polyamide fabric which withstand both washing fastness and even improved tear strength without losing the hand of the fabric. If such coating could be applied to industry level it could be a key player in the battle with microplastics. Other chemical processes that potentially could lower microplastic release was, according to the Mermaids report (2018) yarn dyeing. By coloring in an early stage could improve color fastness and there would be less risk for otiose color to release during further processing. Such techniques were supported by Keiser and Garner (2012) saying such techniques penetrate the fiber in a higher level and would therefore be the better alternative. However, the authors did not consider it in relation to microplastics.

6.3 Further considerations

Lastly there where some subjects considered in this report that may not receive the most attention but which still should be considered:

- Packaging; packaging is not directly linked to the textile design- and production process but it is a big part of the plastic usage. If companies where to evaluate their packaging materials and procedures they could find ways of reducing plastic material.
- Legislations; during this report has the discussion about implementing legislations or regulations of microplastic release. We have already seen initiatives from the U.S and WFD but still they are in limited scale. Even though there was a wish from both the Outdoor Brands and the Expert Panel was the realistically view of it doubtful.
- Collaboration; this was not a subject to this report but highly important for all participants. Only by working together with suppliers, other brands, organizations, universities and researchers can a solution be found.

7 Conclusion

This report has provided with a comprehensive description of challenges and solutions in the textile design- and production process related to microplastics. Such compilation has not been done before in this extent. Being the first of its kind this report shall be seen as a foundation for further research with emphasis on the participants expert knowledge of the outdoor industry and microplastic pollution.

The level of knowledge in regard to microplastics among the participants is of different degree and sometimes a clear lack of knowledge. However, as there are a great spirit of common responsibility has many projects and platforms developed. Though these shared platforms can knowledge and inspiration be spread and solutions be created.

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Appendix 1 - Participants

Outdoor Brands

Sofia Åberg, Production Manager - Elevenate
Elevenate is an outdoor brand with special focus on ski garments. Their target is making garments with sustainable design were they strive for longevity, high quality, good durability (Elevenate 2018).

Malin Wetterborg, Material Development - Houdini Sportswear
Houdini Sportswear is an outdoor brand offering a wide range of functional clothing. Houdini's vision is that their clothes shall make zero impact on the environment (Houdinisportswear 2018).

Erik Blomberg, Head of Product Development - Tierra
Tierra is an outdoor brand aiming to produce sportswear for innovation and sustainability. They want to develop technical clothes for longevity by fining sustainable materials and solutions for both people and planet (Tierra 2018).

Felix Aejmelaeus-Lindström, Material Responsible and Elva Chen, Material Technician, Research and Development - Fjällräven
Fjällräven is an outdoor brand who offers a wide range of hiking and ski-wear. They want to develop timeless, functional and sustainable outdoor gear (Fjallraven.se 2018).

Eva Mullins, Sustainability Manager - Haglöfs
Haglöfs is an outdoor brand with a great variety of hiking, skiing and climbing products. With a passion for innovation they want to offer products that are both sustainable and functional (Haglofs.com 2018).

Expert Panel

Katy Stevens, Sustainability Project Manager - European Outdoor Group (EOG)
The European Outdoor Group is an association representing the common interests of the European outdoor industry and want to encourage a life outdoors. With the common strength of the collaboration between brands and outdoor associations EOG undertakes a number of projects for the benefit of the whole European outdoor industry (EOG 2018).

Francesca De Falco, PhD student at the Institute for Polymers, Composites and Biomaterials of the National Council of Italy (IPCB-CNR)
Francesca has worked with the Mermaids Life+ project but are doing her PhD on the microplastic topic where she develops finishing treatments that could mitigate the release of microfibres from synthetic clothes during washing (De Falco 2018).

Weronika Rehnby, Textile and environmental expert - TEKO
TEKO is the industry and employers organization for Swedish textile and fashion companies. They represent the industry both nationally and internationally in all matters of common interest to the Swedish textile industry, its companies and products. The main task is to support and provide service to member companies in matters such as employer, logistics, intellectual property, environment and sustainability, research and development, business law and trade issues (TEKO.se 2018)

Christina Jönsson, Senior researcher - Swerea IVF
Swerea is a Swedish research group for industrial renewal and sustainable growth. Their mission is to create, process and convey research results in the areas of Material Development, Production Development and Product Development (Swerea.se 2018)

Fredrik Johansson, Business Developer - FOV Fabrics
FOV Fabrics is a textile manufacturer of woven fabric who join advanced textile functionality with circular sustainability. They work with a fully vertical process, including creative design and cutting-edge Research and Development. They manufacturing 10 million square meters of woven high-tech fabrics annually iand export to various industries across the world (FOV Fabric 2018).

Tage Andersson, - Korallen AB
Korallen AB is partly a third-party logistic supplier but has also one part of inhouse dye-house. The dye-house offers garment coloring, finishings and washing (Korallen 2018).

Blair Jollimore, Owner - Environmental Enchantments
Environmental Enchantments is a Canada located company owned and run by Blair Jollimore. Started in 2001 Blair developed a filter for domestic washing machines in order to prevent fibers and dust to clog the septic systems. The business has grown a lot since then and is now a worldwide supplier of domestic filter systems (Jollimore 2018).

Appendix 2 - Interview Guide

Outdoor Brands – Skype/Phone interview

- How does you design- and production processes look like?
- What do you know about microplastics?
- Where in you design- and production processes do you think most microplastics are released?
- What are the alternatives today, as you see it, to minimize microplastic release?
- Have you made any changes in your design- and production processes?
- How do you see, based on recent research, that fleece is the most polluting material?
- How aware do you see the industry is about the issue with microplastics?
- How much do you think your suppliers knows about microplastics?
- Has they taken any initiative to minimize microplastics in their production processes?

Outdoor Brands – E-mail Questioner

- When did you first came in contact with the issue of microplastics?
- What do you know about microplastic pollution?
- How does you design- and production process look like?
- Where in the design- and production process do you think microplastics are released?
- I what processes/activities do you think your brand can make the biggest difference?
- What available alternatives do you see today to lower microplastic release?
- Have your brand made any changes to minimize microplastic release?
- Do you think biodegradable materials are an option?
- How do you think this would affect your design- and production processes additional to your products?
- What do you say about that most of the research of today focus on domestic washing more than companies and the industry?
- What do you say about that most research of today is focus on fleece and acrylic as the worst material for microplastic release?
- Does this affect your chaise of fabric?
- How do you work with your suppliers?
- Have you talked with your suppliers about microplastics?
- How aware would you say your suppliers are about the issue with microplastics?
- Have your suppliers made any changes to lower microplastic release?

Expert Panel – Skype/Phone interview

- Tell me about your organization/company?
- What do you know about microplastics?
- When did you first hear about microplastics?
- Are you working on any project now related to microplastics?
- Where in the design- and production process do you think it is most risk for microplastic pollution?
- What do you think of using bio-degradable materials in textile production?
- How aware do you think the textile industry is about microplastics?
- How likely do you think the textile industry is to change to minimize microplastic pollution?
- What do you say about the literature connected to fleece fabric?

- Where in the design- and production process do you think you and/or other companies can make the greatest difference?
- What are the alternatives today?
- What would you need in order to work more with the issue of microplastics?

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Effort Agreement

Indicate your individual contribution to the project in the table below and attach this as an appendix in your report.

Name	Contribution (%)	Signature
Johanna Adner	100	

In case of different contribution, indicate here who has contributed with what. For example: Who has written the text, who did the presentations, who did the interviews etc: