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microplastics shedding from polyester fabrics

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MISTRA
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executive summary

This report describes an experimental evaluation of whether the shedding of microplastics from different types of polyester fabric is dependent on construction parameters. The project has been performed within the Mistra Future Fashion research program by joint work from three companies: H&M, Filippa K and Boob Design, and researchers from Swerea IVF.

Micro-sized particles of plastics, so called “microplastics” have turned out to be an environmental problem in marine and coastal waters. The oil-based microplastic particles attract contaminants that are normally not soluble in water. When the microplastics enter animals and plants in the aquatic environment, they bring contaminants with hazardous properties with them.

The literature search reveals studies pointing to that textile might be an important source of microplastics. For example, microplastics found in the ocean consisted of polyester and acrylic polymers – which are common textile material. Another observation was that the microplastics were found to have fibre shape.

Based on both literature and own experiments, the relation between polyester fabric properties and microplastics shedding was analysed. Fabrics samples were collected from the participating companies and tested at the research institute Swerea IVF. Since there is no standardised test method, the first part of the project consisted of developing a trustworthy method.

Preliminary findings are that the risk for microplastics shedding from garments is reduced if:

- Brushing is reduced
- Ultrasound cutting is applied in the cut & sew process
- Microparticles on fabrics are removed already at the production stage

There are different types of brushing equipment providing a range of surfaces, however, this study did not allow for comparison between different brushing techniques. Regarding cutting equipment, ultrasound and scissors were compared in this project, though cutting with laser technique is assumed to reduce the shedding in a comparable way to ultrasound cutting.

The study showed no support for the assumption that fabrics made of recycled polymers shed more than fabrics made of virgin polymers. It might instead be assumed that the concern that fleece material from recycled polyester is a main cause to the microplastics problem, is explained by the fact that fleece is a material that has traditionally been made from recycled polyester bottles.

The literature provides some additional advice on fabric construction for reduced microplastics shedding: two studies point to that the shedding is less when yarn size is above the microfibre range. There are also many findings in the literature related to the link between consumer behaviour and microplastics shedding. Though this is not treated in this report, some links to information on this topic are provided in the conclusions chapter.

The three most important recommendations based on the project finding are:

- Develop a standardised test method for microplastics shedding from fabrics. The experiences from method development in this project can be used for future work with development of a standardized method.
- Differentiate between fibres and other microparticles that shed from fabrics:
    - The test method need to be able to distinguish what type of micro-sized particle is included in the figures
    - Investigate whether fibres or other microparticles are most relevant for the environmental impact
- Remove microparticles, regardless of origin, from fabrics already at the production stage as point source emissions are easier to manage than diffuse emissions during the use phase. When microparticles are collected (preferably using dry methods), they should be disposed of in a safe way

More research needs to be carried out to corroborate the findings of this study.

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background

Microplastics pollution of marine and coastal waters is an environmental issue which is currently intensely discussed on a global level. There is a rising awareness of how microplastics in the ocean pose a threat to the marine environment.

It has been discovered that microplastics provide an additional vector for chemical pollutants, i.e. possibly providing a new entering mode into organisms of the pollutants (UNESCO-IOC 2010; UNEP 2016). The concentration of pollutants such as heavy metals, pesticides and flame retardants were found to be up to a million times higher in the hydrophobic microplastic particles compared to the surrounding water (Andrady 2011)[1]. The textile industry perceives its role as a contributor to this situation via shedding of microplastics from textiles as worrying and seeks for solutions (OIA 2016; Ecotextile News 2015). The cause behind the increasing amount of microplastics in marine water bodies is not fully known, though some of the few studies made so far point to household washing of textiles as a major contributor (Browne et al. 2011; Thompson et al. 2004). The alarming reports that microplastics shedding during use could be linked to recycled polyester fabric (fabric made from e.g. recycled PET-bottles) needs to be verified (e.g. Earth Island Journal 2014; Mother Jones 2011). If this is the major parameter behind microplastics shedding, it will be a game-changer for the industry where recycling of polyester is seen as an environmental asset (e.g. Ecotextile News, 2016a, 2016b, 2012). If not, such rumours can be met with facts.

Previous and on-going research activities on this topic focus of distribution of microplastics in the coastal and marine environments as well as environmental effects of microplastics on animals and plants (Nova 2015; Cole et al. 2011; Eerkes-Medrano et al. 2015). Several studies have found that textile fabrics do shed microplastics (Hartline et al. 2016; Napper & Thompson 2016; Pirc et al. 2016; Petersson & Roslund 2015). However, a research gap has been identified regarding the link between fabric construction properties and microplastics shedding, as well as studies on design solutions for fabric construction and washing machine filters (Bruce et al. 2015).

definition of microplastics

In the literature on microplastics contamination, the particles studied vary in size. The common definition of a microplastics particle is 5 mm (5000 µm) (Andrady 2011) and anything below that size would then be counted as microplastics. However, several studies limit their scope to particles to sizes below 1 mm (Browne et al. 2011), between 20-333 µm (Bruce et al. 2015) etc., depending on the equipment used – the size of the filters. As a general rule of thumb, the filter pore size should be five times smaller than the fibre.

1. Synthetic polymers such as polyester, nylon and acrylics are hydrophobic (likes oil) and can thus act as accumulators and transporters of pollutants into organisms. Cellulosics and wool are hydrophilic (likes water) and do not share the same risk scenario.

method

The project included four activities: parameter selection, fabric sample collection, washing study and evaluation. The study was limited to polyester fabrics.
parameter selection

The parameter selection was made jointly by the representatives from the participating companies and the researchers, listed in Table 1.

Table 1. Project participant

Name	Affiliation
Mattias Bodin	H&M
Titti Larsen	H&M
Christina Muljadi	Filippa K
Therese Groth	Boob Design
Jenny Kaleinek	Boob Design
Anne-Charlotte Hanning	Swerea IVF
Oscar Levenstam Arturin	Swerea IVF
Sandra Roos	Swerea IVF

First, a small literature study was performed to see which parameters that had already been tested in previous research, which parameters were proposed for further testing and also if different studies differed in results. The Scopus database was searched and also the Swedish Diva portal for university publications and Google was used. Based on this background information, the researchers together with the industry representatives listed the different fabric properties that might influence fibre shedding. The parameters are listed in Table 2. A fabric sample collection was set up based on these parameters, and accessible materials. Six materials were finally tested, also shown in Table 2.

Table 2. Parameters that may influence fibre shedding and coverage in the tested material samples

No	Test parameter	Samples coverage
1	Virgin polyethylene terephthalate (PET)	Materials 6, 12, 39
2	Mechanically recycled PET	Materials 1, 3, 13
3	Chemically recycled PET	
4	Biobased polytrimethylene terephthalate (PTT)	
5	Fossil PTT	
6	Micro-sized filament yarn (e.g. 150 den/ f288)	Materials 1, 3, 6
7	Micro-sized spun yarn (e.g. 150 d/F, 288 mm)	
8	Medium-sized filament yarn (e.g. 110 den/f 96)	Material 12, 13, 39
9	Medium-sized spun yarn (e.g. 150 d/F , 38 mm)	
10	Bright yarn	
11	Semi-dull or dull yarn	
12	Highly twisted yarn (e.g. 120 tpm)	
13	Slightly twisted yarn (e.g. 40 tpm)	
14	Single jersey knit Materials 13, 39	
15	Interlock knit	
16	Rib knit	
17	Warp knit	
18	Plain weave	
19	Satin	
20	Twill	
21	No brush	Material 12
22	Mild brush on one side (peach/suede/fibrillated)	Materials 13, 39
23	Mild brush on two sides	
24	Hard brush on both sides	Materials 1, 3, 6

fabric sample collection

When the relevant parameters to test were selected, matching fabric samples were searched for by the participating companies. Swerea IVF collected and marked the samples.

washing study

Washing and measuring of shedding was performed at the Swerea IVF laboratory using standardised equipment. The study was carried out as a screening study to test the cause behind fibre shedding. Therefore the experiments were designed to test as many parameters as possible.

Today, there is no standardized test method for microplastics shedding from textiles. Therefore, a washing test method was iteratively developed during the first phase of the project. As a starting point, the development of the method used the descriptions in the literature from the few studies that were available so far: the Patagonia/Bren University B.Sc. study (Bruce et al. 2015), the Plymoth University study (Browne et al. 2011) and a B.Sc. thesis from the Swedish School of Textiles in Borås (Petersson & Roslund 2015). The method development was made using a worst case sample and a best case sample: a fleece fabric from recycled polyester (worst case) and a woven fabric for outer layer of jacket (best case).

The resulting test method consists of three steps: preparation of samples, washing and analysis. All tests were performed testing a pair of fabrics, each with four duplicates. The trial method table with all details of the method is found in Appendix 1.

preparation of samples

The samples were constructed as "bags" that withheld 25 small metal balls (for friction during washing). The preparation step turned out to have a large impact on the results, and the method development strived therefore to reduce the impact of the human factor interference. The samples can be either vacuumed (see Figure 1), rolled with a sticky garment roll (see Figure 2, left), pre-washed (in a standard washing machine) or a combination of the three. Further, the samples were either cut with scissors or with an ultrasonic cutting machine (see Figure 3). All bags were sewn with an ultrasonic welding machine (see Figure 2, right).

Figure 1. A frame was created to be able to vacuum the fabric samples in a controlled mode.

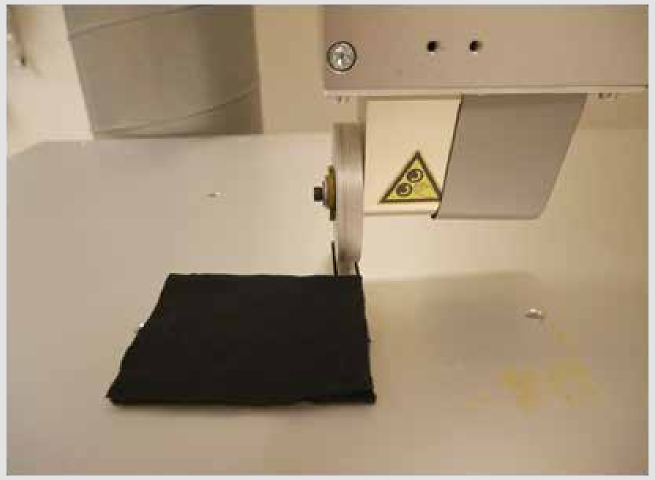


Figure 2. To the left the sticky garment roll for cleaning the fabric and to the right ultrasonic welding of the edges.

Figure 3. The ultrasonic cutting machine.

washing and collection of fibres in the waste water

Washing of samples was made in Gyrowash for 60 minutes at 40°C. Washing was made both with and without the use of detergents. The Gyrowash equipment (see Figure 4, left) is in itself standardized and this part did not need extensive method development. The original water amount of 150 ml was however reduced to 75 ml to optimize the bath ratio. The filters used to catch fibres in the washing machine's waste water (see Figure 4, right) were of three different sizes: 100 μm, 5 μm and 0.65 μm.

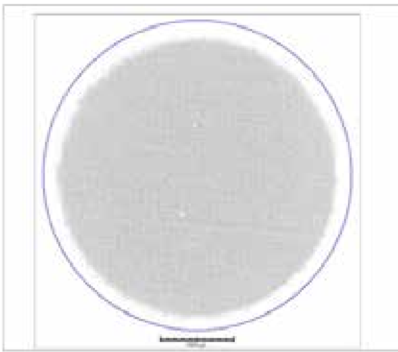
Figure 4. To the left the Gyrowash and to the right the filter equipment set-up for collecting the fibres in the waste water.

analysis of shed fibres

The fibres from the waste water collected in the filters were analysed both using optical microscopy technique and scanning electron microscope (SEM). In order to be able to distinguish the filter from the fibres in the SEM, filters made of fluoropolymer materials were used. However, this did not provide the necessary distinction. Another drawback with the SEM technique is that only a small part of the filter (approximately 1 x 1 cm) is analysed at the time, and the track with using SEM for analysis was abandoned.

The optical microscopy technique (see Figure 5) was instead used and connected to an automatic fibre identification software quantifying the number and describing material properties and size distribution of the particles. This turned out to be an effective method to count different types of particles and for example distinguish between fibres and other types of contamination.

Figure 5. To the left the optical microscope and to the left the filter.



evaluation

Based on the literature and empirical results, the relation between polyester fabric properties and microplastics shedding was analysed and recommendations for fabric construction were created.

results and discussion

This chapter presents and discusses the results from the experimental studies. All values given are averages from the four duplicate test samples. In addition, a comparison with literature data is made.

experimental results

Figure 6 shows the results for the outer layer fabric (best case) and the fleece fabric (worst case). It is striking how much "dirt" that is brought along with the brushed microfleece fabric, and not all of the particles are of textile origin. It is clear that it is needed to distinguish between fibres that shed from the fabric and particles that are contaminants that the fabric brings along, both in the analysis of particles and in order to find design solutions.

Sample 12: DWR Jacket Fabric — Sample 3: Microfleece Fabric

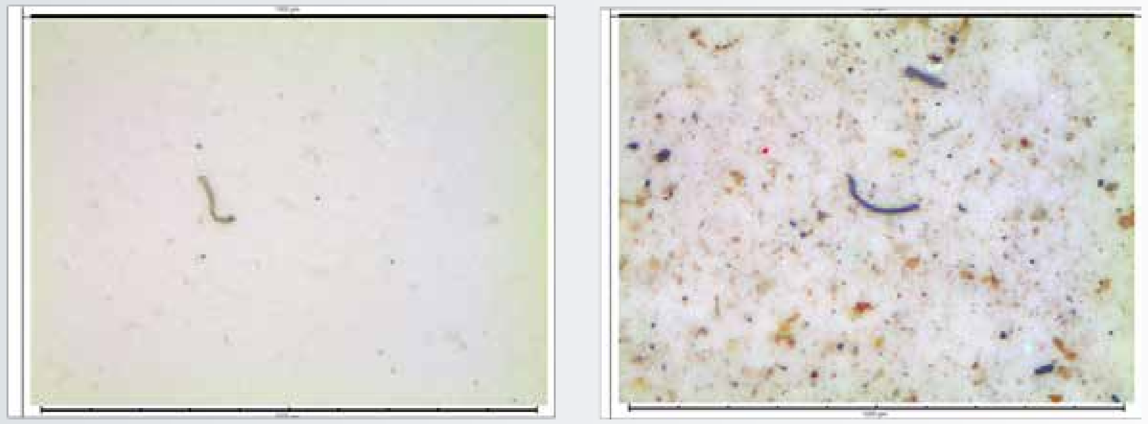


Figure 6. Optical microscopy pictures showing the difference in particle shedding from best case (sample 12) and worst case (sample 3) fabrics.

test No 1: comparison of virgin and recycled polyester jersey

The fabrics that were used to compare whether virgin or recycled polymers shed most were two jersey tricots (no brushing). They had identical construction parameters except that material 13 is made of mechanically recycled polyester (PET) and material 39 contains polyester (PET) from a virgin origin.

The virgin polyester was found to shed more than the recycled, see Figure 7. A total number of 843 fibres were shed from the recycled polyester and 1890 fibres were shed from the virgin polyester.

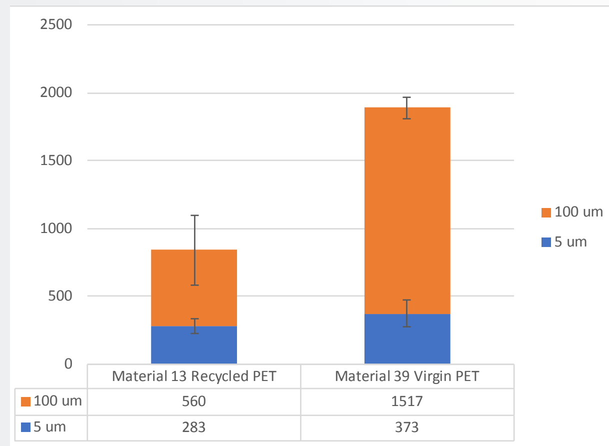


Figure 7. Fibre shedding from virgin respective recycled polyester jersey divided after particle size (orange bars show amount of fibre collected in the 100 μm filter and blue bars amount of fibres collected in the 5 μm filter).

test No 2: comparison of ultrasonic cutting and scissors

Whether shedding from the edges created during cutting dominated over shedding from the fabric surface was analysed by testing different cutting techniques on the same fabric, a jersey tricot from mechanically recycled polyester (material 13). One sample was cut with a fabric scissor and the other was cut with an ultrasonic cutting machine.

Although both samples do shed, the sample cut with scissors show to shed a considerable higher amount of fibres. A total number of 890 fibres were shed from the ultrasonic cut fabric and 1927 fibres were shed from the scissor cut fabric.

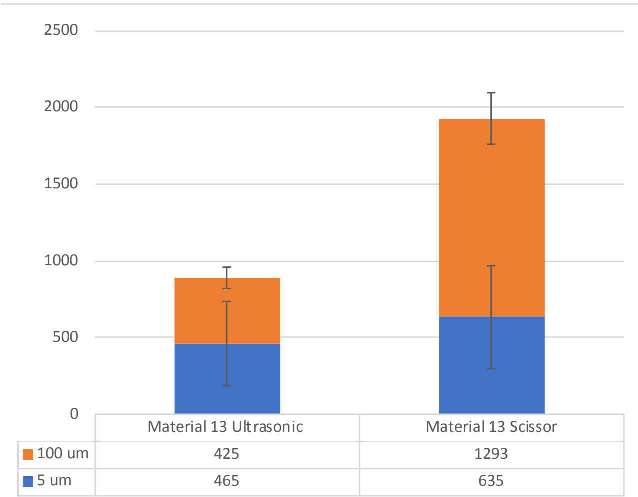


Figure 8. Fibre shedding from ultrasonic cut fabric respective scissor cut fabric divided after particle size (orange bars show amount of fibre collected in the 100 µm filter and blue bars amount of fibres collected in the 5 µm filter).

test No 3: comparison of virgin and recycled polyester microfleece

In this test setup of microfleeces, the fabrics differed in more parameters than their polymer origin, for example weight. Material 6 was 100% virgin polyester with a fabric weight of 139 g/sqm while Material 1 was 94% mechanically recycled polyester and 6% elastane with a fabric weight of 245 g/sqm.

In this trial, only the 100 um filter was used. 1855 fibres were shed from the recycled fleece nr 1 and 2559 were shed from the virgin fleece nr 6, see figure 9.

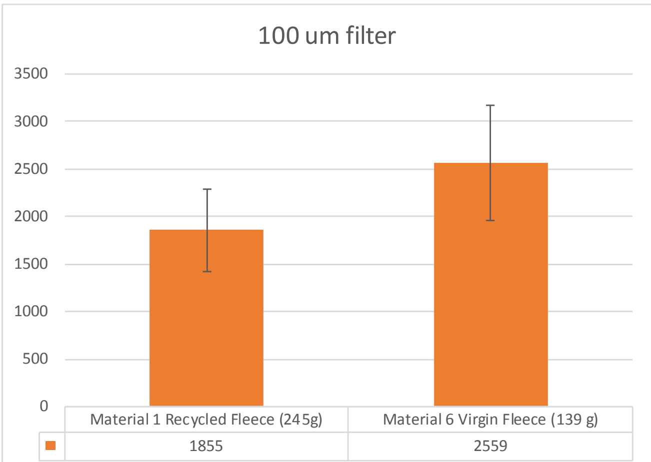


Figure 9. Fibre shedding from virgin respective recycled polyester microfleece.

discussion on challenges and recommendations on test method

A number of challenges for the test method were found that should be highlighted in future work with testing microplastics shedding both for research on fabric construction and for following-up supply chain requirements:

1. Software fibre identification
When two or more fibres were crossed over each other, the software counted them as one. This is a problem in particular for high-shedding fabrics, where many fibres crossed over each others could lead to underestimation. Increase number of cascaded filters could be a solution.

2. Surrounding environment gives contamination error
There are always a certain amount of fibres in the laboratory environment (except in cleanrooms) which results in a challenge of deducing the source of the fibres.

3. Pre-cleaning
How much pre-cleaning should be applied is essential for the results.

4. Isolation of parameters
In order to get comparable results when comparing two construction parameters, material sampling is crucial to get samples that only differ in the desired parameter. However, in our sample library only two fabrics were identical except one parameter.

5. Detergent foaming
When the washing liquid contained detergent, this caused foaming during filtering through the 5 um membrane filter, which slowed down the filter process.

6. Human input error
Due to the many steps of the test method done by hand, and not by a machine or tool, there may be differences in results between analysts.

the experiences lead to the following recommendations:

1. Production environment vs fabric construction vs supply chain requirements
Different test method setups are recommended depending on if the goal is to measure the shedding of the fabric in the context of exploring production environment, fabric construction or confirming supply chain requirements.

2. Software fibre identification development
More research about the fibre identification software and its possibilities is needed.

3. Measuring covered area
Instead of counting the amount of fibres, another possibility is to measure the covered area of the filter. It would then be recommendable to use a 20 um filter or bigger to let smaller contamination such as dust pass through.

4. Filter setup
The biggest difference in amount of fibres between the fabrics could be seen on the 100 um filter. Therefore, it could be possible to only use one filter instead of two (for example 100 um and 20 um), in the cases where the main point is to compare the amount of shedding between fabrics.

5. Net filter to prevent foaming
It is recommended to use net filter in combination with washing liquid containing detergent due to foam issues.

6. Fabric sample preparation
More method development around the sample preparation would be beneficial since the making of the bags used in this method is a time demanding process and not logistically the most efficient.

overview of the research area

This section summarizes and compares the conclusions drawn from the experimental results with results found in other studies.

In the literature, six studies provide data on fibre shedding during washing of garments (Browne et al. 2011; Bruce et al. 2015; Pirc et al. 2016; Napper & Thompson 2016; Petersson & Roslund 2015; Åström 2016). The experimental set-up differs between the studies and the interpretation of results must therefore be made carefully.

Four of the studies do not include any details about fabric construction parameters but aim to clarify for example whether fabrics do shed micro-sized particles and how much (Browne et al. 2011), and also if it differs between different washing conditions such as front load/top load machine (Bruce et al. 2015)[2] and use of detergent and conditioners (Napper & Thompson 2016; Pirc et al. 2016). The results are either reported as number of fibres or percentage of the sample weight, see Table 3. The Browne et al. (2011) study counted fibres manually while the Napper & Thompson (2016) study counted fibres based on average weight, which accounts for the difference in results. In the first case only optically visible fibres were counted and in the latter case all micro-sized particles were included. The Pirc et al. (2016) study reported the weight of the "fibres" collected on the filter, which probably included all sorts of microparticles, which would explain why their figure is much higher in comparison to the other studies.

Table 3.Reported results from studies not including construction parameters.

Sample	No of washes	No of shed fibres	Mass shed (w%)
Browne 2011 blanket	1	120	
Browne 2011 fleece	1	290	
Browne 2011 shirt	1	160	
Bruce Patagonia A Technical non-fleece synthetic jacket	1		0.493
Bruce Patagonia B Synthetic fleece pullover	1		0.282
Bruce Patagonia C Synthetic fleece midlayer jacket	1		0.361
Bruce Patagonia D Synthetic sweater fleece jacket	1		0.275
Bruce Budget Budget synthetic sweater fleece jacket	1		0.404
Napper 2016 PET-cotton jumper	5	137951	7.5E-06
Napper 2016 polyester jumper	5	496030	4.65E-05
Napper 2016 acrylic jumper	5	728289	4.38E-05
Pirc 2016 fleece blanket	10		0.0012

2. Also reported in (Hartline et al. 2016).

Two M.Sc. theses performed at the Swedish School of Textiles respective Gothenburg University have studied the link between microparticle shedding and construction of the fabrics. Figure 6 below shows the results for different material constructions from the studies by Petersson & Roslund (2015), Åström (2016) in comparison with Browne et al. (2011), all of which counted optically visible fibres manually. In Figure 10 can be seen that fleece materials (18-23 + 25) shed generally much more than the other materials though some fleeces (21, 23, 25) shed considerably less than the others.

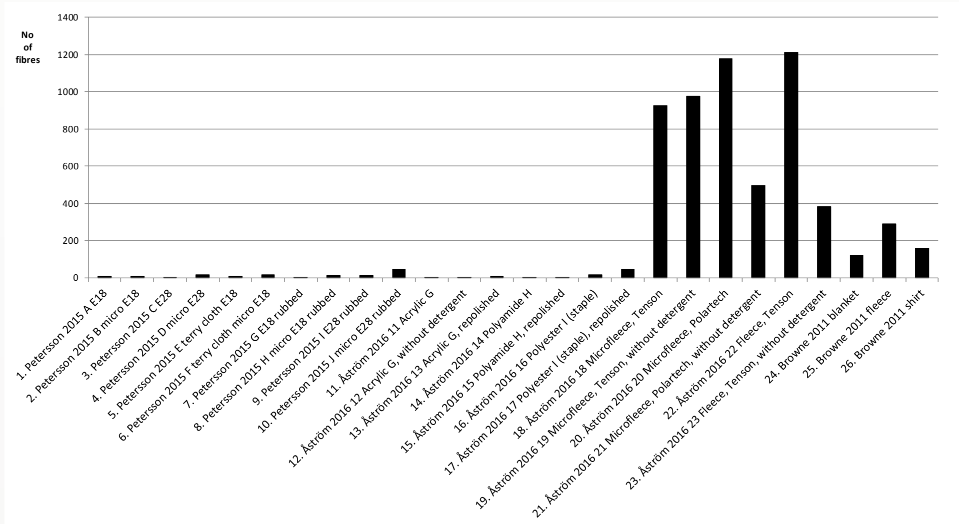


Figure 10. Number of shed fibres from three studies.

Figure 7 shows in detail the shedding from non-fleece materials, manufactured at the Swedish School of Textiles (Petersson & Roslund 2015). The materials that were rubbed/repolished to simulate ageing shed more than the original materials. The materials made of microfibre yarn could also be seen to shed more, though this was not confirmed by the tests of fleece in the Åström (2016) study. Also the more tightly knitted fabrics (E28) shed more fibres than the more loosely knitted (E18). Thus several other construction parameters have impact in addition to the brushing.

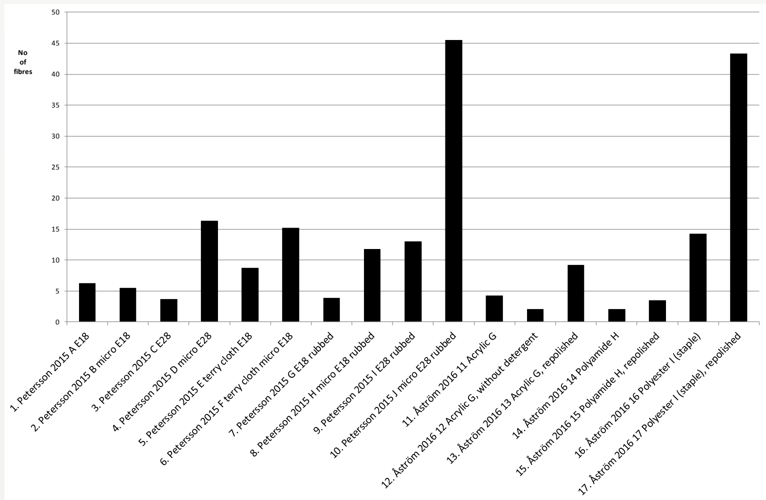


Figure 11. Number of shed fibres for non-fleece materials.

Other relevant information that can be drawn from the literature is that release of fibres during tumble drying was approximately 3.5 times higher than during washing in the Pirc et al. (2016) study. Regarding number of washes and it relation to fibre shedding, Pirc et al. (2016) as well as Napper & Thompson (2016) states that shedding is reduced with the number of washes, while Petersson & Roslund (2015) report an increase of shedding during the first washes.

Table 4 shows a summary of the fibres shed in the experimental part of the study. All results are shedding after only one wash per sample. All tests were performed testing two pairs of fabrics. The test conditions were different between pairs, which makes comparison not valid between pairs. The results illustrate well the results' dependence on test conditions. It should be noted that in tests 1 and 2, the edges we welded thin at 5 mm width. In test 3, the edges were welded thick at 12 mm width after cutting to be able to focus on the difference in shedding from the fleece surfaces, though the absolute values on shedding were then reduced. All test conditions are specified in Appendix 1.

Table 4. Summary of experimental results. Please note that testing techniques differ between tests, and comparison is only valid between pairs.

Test No	Material and cutting technique	No of shed fibres
1	13. Mechanically recycled polyester Jersey, soft brush Ultrasonic cut Welded edges 5 mm Detergent	843
	39. Virgin polyester Jersey, soft brush Ultrasonic cut Welded edges 5 mm Detergent	1890
2	13. Mechanically recycled polyester Jersey, soft brush Ultrasonic cut Welded edges 5 mm Detergent	890
	13. Mechanically recycled polyester Jersey, soft brush Scissor cut Welded edges 5 mm Detergent	1927
3	1. Mechanically recycled polyester Microfleece Scissor cut Welded edges 12 mm No detergent	1855
	6. Virgin polyester Microfleece Scissor cut Welded edges 12 mm No detergent	2559

conclusions and recommendations

The literature survey showed that very little is known about how the fabric construction is linked to the shedding of microplastics. In addition, the few studies made give non-consistent results. This is partly due to the fact that there is at present no standardized test method. The development of such a method would improve the possibilities to compare fabrics' shedding properties. The experiences from method development in this project can be used for future work with development of a standardized method. One important conclusion drawn during the method development is that there is an obvious risk for contamination of samples from the surrounding environment. As long as the test method does not require cleanroom, handling of cross-contamination is needed for trustworthiness.

One construction parameter stands out as a parameter that leads to increased shedding: brushing to fleece, though not only of fibres but also of other types of micro-sized particles, clearly illustrated by Figure 6. The environmental impact of these particles in comparison to shed fibres is unknown and should be investigated.

Preliminary findings are that the risk for microplastics shedding from garments is reduced if:

- Brushing is reduced
- Ultrasound cutting is applied in the cut & sew process
- Microparticles on fabrics are removed already at the production stage

There are different types of brushing equipment providing a range of surfaces, however, this study did not allow for comparison between different brushing techniques. Regarding cutting equipment, ultrasound and scissors were compared in this project, though cutting with laser technique is assumed to reduce the shedding in a comparable way to ultrasound cutting. Both laser and ultrasound cutting has the additional benefit of improved working conditions, reducing the staff's exposure to fibres.

The study showed no support for the assumption that fabrics made of recycled polymers shed more than fabrics made of virgin polymers. It might instead be assumed that the concern that fleece material from recycled polyester is a main cause to the microplastics problem, is explained by the fact that fleece is a material that has traditionally been made from recycled polyester bottles.

Finally, it can be concluded that more research is needed in order to understand the differences in results between different studies and to complement the findings of this study regarding possible construction solutions.

The literature provides some additional advice on fabric construction for reduced microplastics shedding: the shedding is less when yarn size is above the microfibre range. There are also many findings in the literature related to the link between consumer behaviour and microplastics shedding. Though this is not treated in this report, some links to information on this topic are provided.

- Wash at the most mild washing programme to prevent fibre breakage (short time and high temperature is preferable over long time and low temperature)

- Consumer exposure (mainly inhalation of microparticles) is reduced if the garments are washed before use

- More recommendations are found at http://life-mermaids.eu/en/

The following recommendations based on the project finding are:

- Develop a standardised test method for microplastics shedding from fabrics

- Differentiate between fibres and other microparticles that shed from fabrics

- Investigate whether fibres or other microparticles are most relevant for the environmental impact

- Remove microparticles from fabrics already at the production stage

- If microparticles are collected (preferably using dry methods), they should be disposed of in a safe way

Several of the construction parameters that may influence shedding are still to be investigated: yarn twist, weave binding and different brushing techniques among others.

Finally, it can be concluded that more research is needed in order to understand the differences in results between different studies and to complement the findings of this study regarding possible construction solutions.

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appendix 1 Trial Method Table

	Material	Cutting	Welding	Pre-cleaning	Washing	Rinsing	Filter Analysis
1	**PE Microfleece nr: 3 x4** **PE DWR Jacket fabric nr: 12 x4**	18,4*10,4 cm (fabric scissor)	Fold into 9,2*10,4 cm Weld sides 12 mm Cut sides 6 mm (fabric scissor) Invert bag, 25 steel balls inside Weld top 12 mm Cut top 6 mm (fabric scissor)	Sticky Roller 8*16 cm x3	Gyrowash 40°C 60 min 150 ml distilled water No detergent	Fabric bag each side 5 ml x5 Squeeze fabric bag Metal cylinder 5 ml x5 Metal lid 5 ml x2	0,65 um PTFE Membrane filter 10x >5 um 100 um Nylon net filter 5x >15 um
2	**PE Microfleece nr: 3 x4** **PE DWR Jacket fabric nr: 12 x4**	18,4*10,4 cm (fabric scissor)	Fold into 9,2*10,4 cm Weld sides 12 mm Cut sides 6 mm (fabric scissor) Invert bag, 25 steel balls inside Weld top 12 mm Cut top 6 mm (fabric scissor)	Sticky Roller 8*16 cm x3 Vacuum Clean 8*16 cm x3 + Between welding x1	Gyrowash 40°C 60 min 75 ml distilled water No detergent	Fabric bag each side 10 ml x2 Squeeze fabric bag Metal cylinder 10 ml x2 Metal lid 10 ml x1	0,65 um PTFE Membrane filter 10x >5 um 100 um Nylon net filter 5x >15 um
3	**PE Microfleece nr: 3 x4**	18,4*10,4 cm (fabric scissor)	Fold into 9,2*10,4 cm Weld sides 12 mm Cut sides 6 mm (fabric scissor) Invert bag, 25 steel balls inside Weld top 12 mm Cut top 6 mm (fabric scissor)	Vacuum Clean 8*16 cm x3 + Between welding x1	Gyrowash 40°C 60 min 75 ml distilled water No detergent	Fabric bag each side 10 ml x2 Squeeze fabric bag Metal cylinder 10 ml x2 Metal lid 10 ml x1	0,65 um PTFE Membrane filter 10x >5 um 100 um Nylon net filter 5x >15 um
4	**PE Microfleece nr: 3 x4**	18,4*10,4 cm (fabric scissor)	Fold into 9,2*10,4 cm Weld sides 12 mm Cut sides 6 mm (fabric scissor) Invert bag, 25 steel balls inside Weld top 12 mm Cut top 6 mm (fabric scissor)	Vacuum Clean 8*16 cm x3 + Between welding x1	Gyrowash 40°C 60 min 75 ml distilled water No detergent	Fabric bag each side 10 ml x2 Squeeze fabric bag Metal cylinder 10 ml x2 Metal lid 10 ml x1	5 um PTFE Membrane filter 5x >5 um 20 um Nylon net filter 5x >15 um
5	**PE Jersey: nr 13 x4** **PE Jersey nr 39: x4**	17*9 cm (ultra sonic)	Fold into 8,5*9 cm Weld sides 5 mm (open end) 25 steel balls inside Weld top 5 mm (open end)	Vacuum clean fabric roll x3	Gyrowash 40°C 60 min 75 ml distilled water 5 g/l detergent	Fabric bag each side 10 ml x2 Squeeze fabric bag Metal cylinder 10 ml x2 Metal lid 10 ml x1	5 um PTFE Membrane filter 5x >20 um 100 um Nylon net filter 5x >20 um
6	**PE Jersey: nr 13 x4** **PE Jersey nr 13: x4**	17*9 cm (ultra sonic) + (fabric scissor)	Fold into 8,5*9 cm Weld sides 5 mm (open end) 25 steel balls inside Weld top 5 mm (open end)	Vacuum clean fabric roll x3	Gyrowash 40°C 60 min 75 ml distilled water 5 g/l detergent	Fabric bag each side 10 ml x2 Squeeze fabric bag Metal cylinder 10 ml x2 Metal lid 10 ml x1	5 um PTFE Membrane filter 5x >20 um 100 um Nylon net filter 5x >20 um
7	**PE Microfleece nr: 1 x4** **PE Microfleece nr: 6 x4**	18,4*10,4 cm (fabric scissor)	Fold into 9,2*10,4 cm Weld sides 12 mm Cut sides 6 mm (fabric scissor) Invert bag, 25 steel balls inside Weld top 12 mm Cut top 6 mm (fabric scissor)	Vacuum Clean 8*16 cm x3 + Between welding x1	Gyrowash 40°C 60 min 75 ml distilled water No detergent	Fabric bag each side 10 ml x2 Squeeze fabric bag Metal cylinder 10 ml x2 Metal lid 10 ml x1	5 um PTFE Membrane filter 5x >20 um 100 um Nylon net filter 5x >20 um

Mistra Future Fashion is a research program that focuses on how to turn today's fashion industry and consumer habits toward sustainable fashion and behavior. Guided by the principles of the circular economy model, the program operates cross disciplinary and involves 50+ partners from the fashion ecosystem. Its unique system perspective combines new methods for design, production, use and recycling with relevant aspects such as new business models, policies, consumer science, life-cycle-assessments, system analysis, chemistry, engineering etc.

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