Polyester Textiles as a Source of Microplastics from Households: A Mechanistic Study to Understand Microfiber Release During Washing

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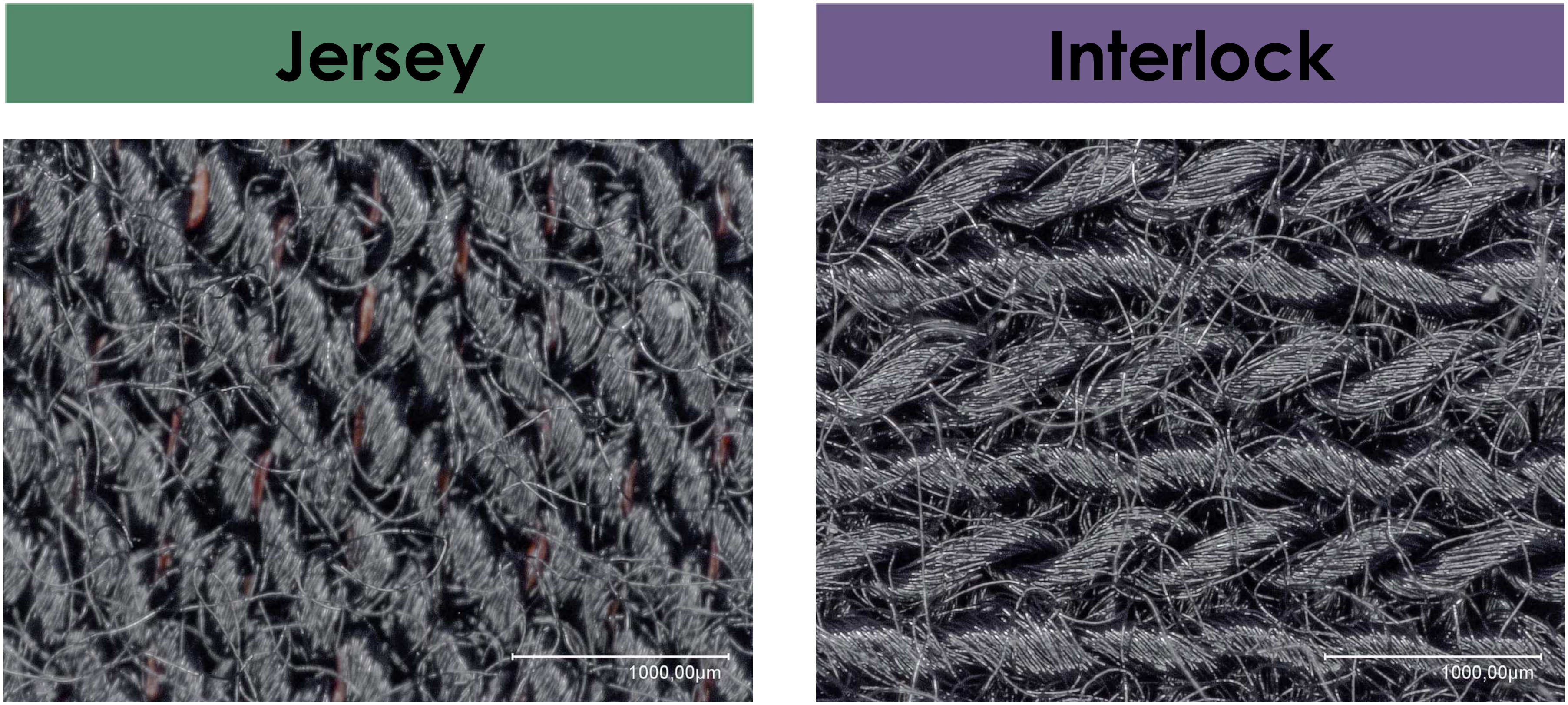

Figure S1: Close up images of the 100% PES interlock and jersey knit variants, where structural differences of the textile are clearl

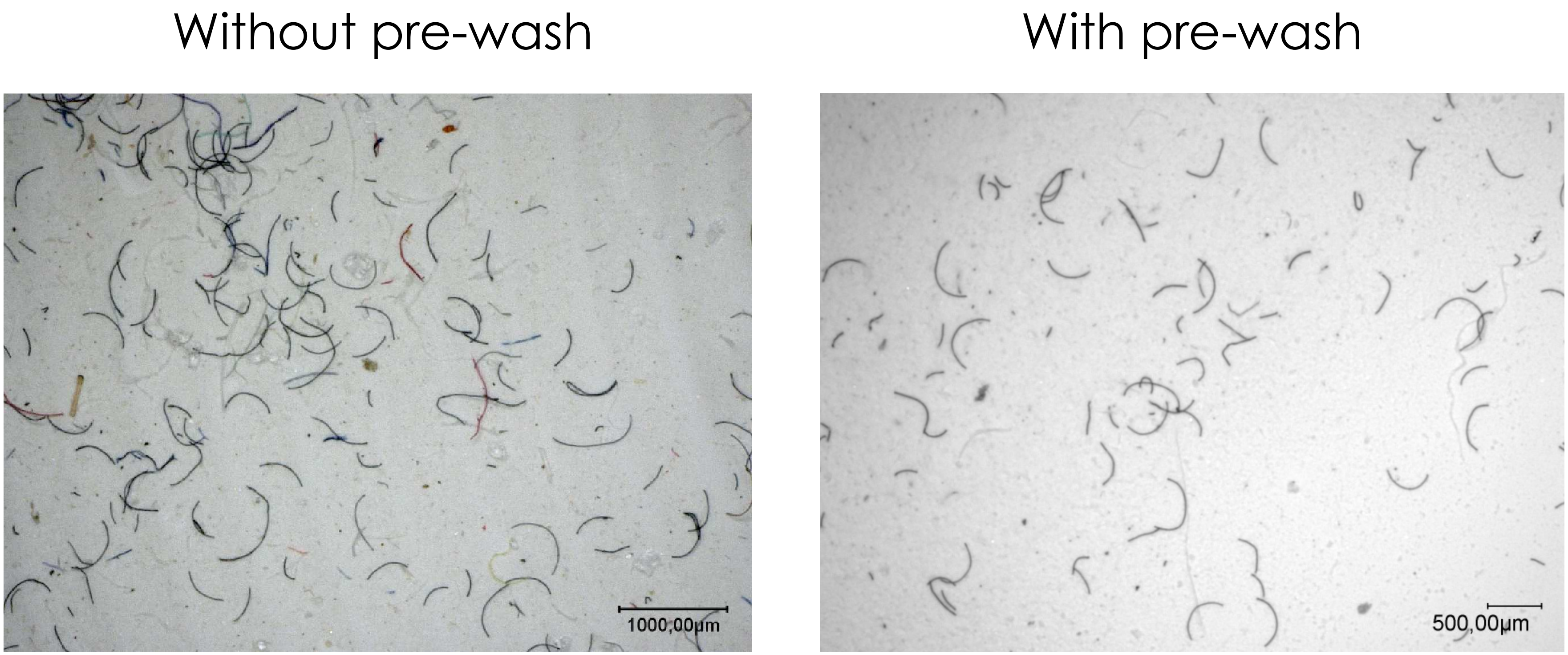

Figure S2: Snapshot of a typical filter image for textiles which have not undergone a pre-wash step (left figure) and which have had a prewash step before the experimental procedure (right figure). Without a pre-wash, it is evident that fibers and residues of different colors and morphologies have collected on the fabric during exposure to air and are subsequently released during the pre-wash cycle in DI water for 5 minutes. When fabrics undergo a pre-wash step before the experiment, only black fibers are present, which are consistent with the test textile at hand.

Figure S3: Close up image of the 100% PES fibers released from the textiles after washing.

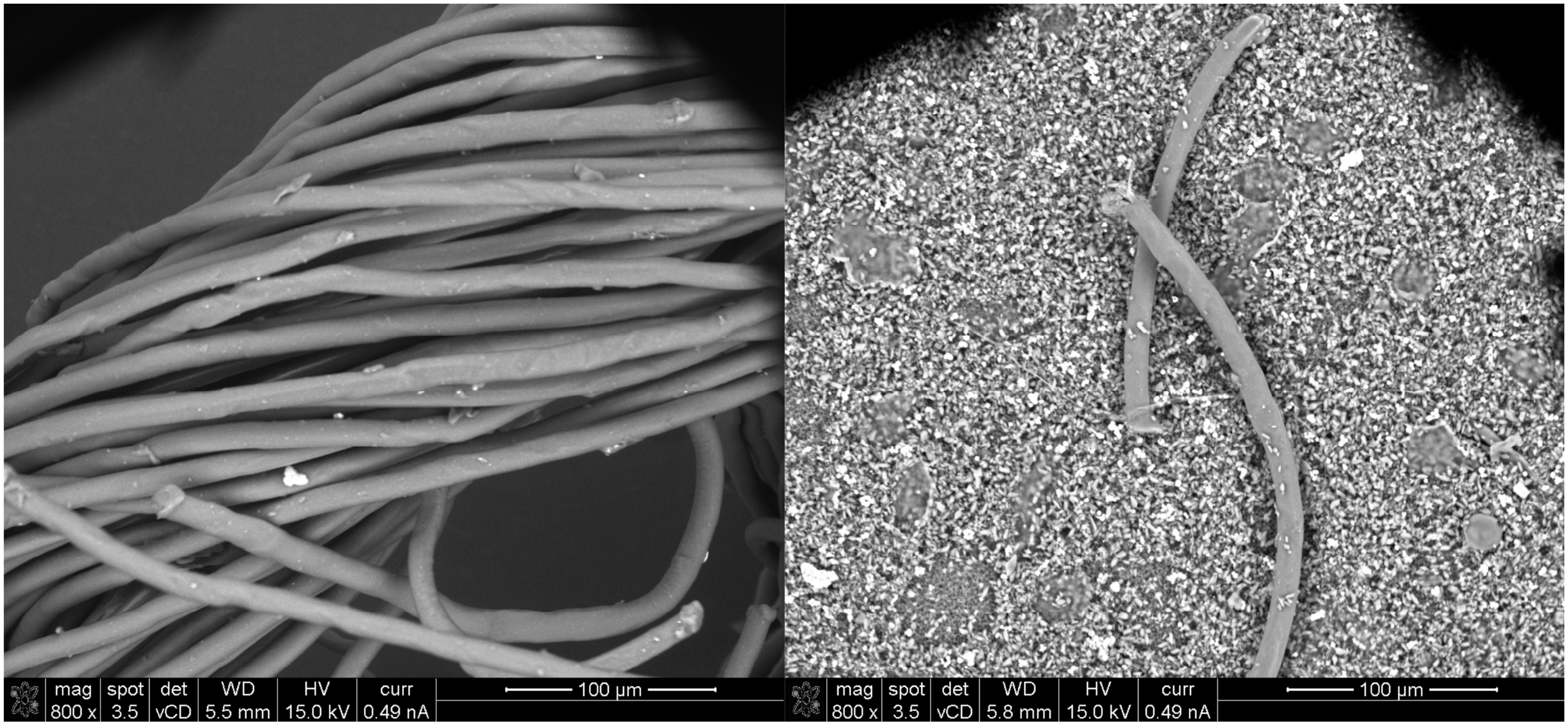

Figure S4: SEM images of textile yarn. Fibers were imaged using a SEM (NanoSEM 230, FEI). The SEM was operated at an acceleration voltage of 15 kV in immersion mode using the vCD (low voltage – high contrast) detector for image formation. For the yarn image (left image), a whole yarn was pulled/cut from the fabric and placed on a sticky SEM stub for analysis. For fibers released during washing (right image), the entire filter was placed in the SEM and images taken directly from the filter. Remnants of washing detergent solution can be seen in the image background.

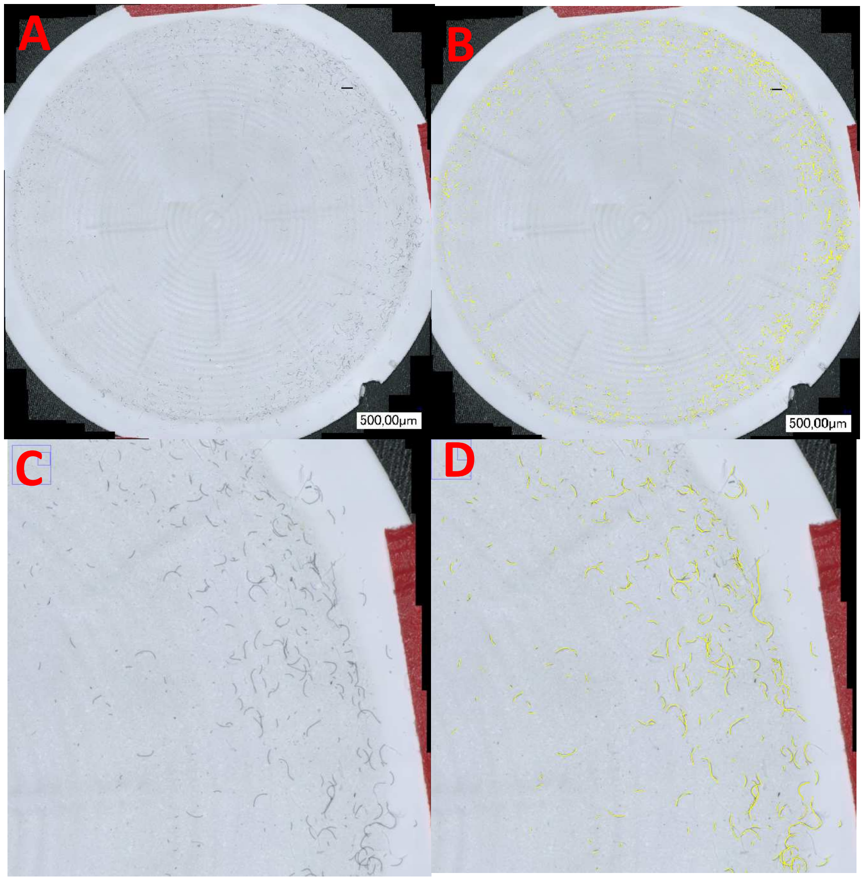

Figure S5: Examples of lines drawn onto images using ImageJ to measure individual fibers on the wash water filter. A) unaltered full filter image and B) full filter image with lines drawn over fibers. C) closer up of unaltered image of filter and D) measurements of fibers using ImageJ

Fiber Area Coverage Correlation Curve

The correlation showed that in the filter coverage range between 0 and 0.4% filter coverage, one slope represented the expected mass, whereas for filter coverage values above 0.4% a different slope more closely resembled the mass calculated from the fiber length distribution. This is because setting the image threshold to make the image binary was increasingly difficult for filters with more fibers, as shadows were created from fiber overlap which were incorrectly counted as fiber pixels instead of as filter pixels. In order to have just one function that could be applied to all filters regardless of fiber coverage, the data points were fit into one modified hyperbolic function in excel (equation 1),

$$mass = a * \frac{b * Coverage}{1 + b * Coverage}$$

where the filter coverage is in percent, a = 1.595 mg and b = 0.109.

It should be re-instated that the total volume of liquid passed through each filter varied as a function of how many fibers visibly appeared with each aliquot of 50 mL of wash water processed. Since an excessive amount of fibers would be increasingly difficult and time consuming to manually count and because additional fiber overlap had the potential to cause further underestimation of the total mass of fibers calculated, the total volume of wash water filtered varied depending on the sample. We aimed to have a maximum of 2% filter coverage by fibers for each replicate. The final mass of fibers was then scaled accordingly depending on the volume of filtrate, which is the figure reported in all examples hereafter, except in Figure 1 where the correlation values are presented as they were actually measured. This scaling approach was validated since we confirmed that, when the wash water was mixed constantly and analyzed soon after wash completion, the fibers were homogeneously dispersed in the wash solution both in terms of fiber size and number.

Table S1: Chemical composition of the washing detergents provided by the manufacturer.

Washing Solution Chemistries			
Liquid Detergent		**Powder Detergent**	
	Wt %		Wt %
Water	70.00	Sodium sulfate	25-30
n-Alkyl(C10-13)benzolsufonic acid	5.28	Sodium carbonate	10-15
Alkyl(C12-14) diglykoletherfulfate, Na-salt	5.80	Sodium carbonate peroxide	6
Alkyl(C12-18) carbonic acid	4.49	Sodium-alluminim silicate (Zeolite A)	10-15
Oxoalcohol(C13-15) polyetheylenglycolether (7EO)	3.40	Sodium silicate	5-10
Sodium hydroxide	1.40	Sodium methyl 2-sulphooctadecanoate and soldium 1-methoxy-1-oxohexadecane-2-sulphonate	8
1,2-Propyleneglycol	3.99	Tetraacethylethylenediamine	7-8
Cumene sulphonate, K-Na-salt	0.00	Oxoalcohol (C13-15) polyethyleneglycolthether (7EO)	2-3
Trisodiumsulfate dihydrate	1.74	Alkyl (C10-16) sulfate, sodium salt	0.5-1
Polycarboxylate, Na-salt	0.05	Fatty acids and oils	0.5-1.5
Protease	< 0.01	Benzosulfonic acid, C10-13Alkylderivative, sodium salt	0.5-1.5
Alpha-Amaylase	< 0.01	Carboxymethyl cellulase, sodium salt	0.5-1
Enzymes	< 0.01	Sodium carbonate, colorant	0.7
Cellulase	< 0.01	Scent	0.55
Sodium borohydrate	0.00	Disodium-4,4-bis((4-anilino-6-morpholin-1,3,5-triazine-2-yl)amino) stilbene-2,2-disulfonate	0
5-Chloro-2-methyl-4-isothiazolin-3-on +2-Methyl-4-isothiazonlin-3-on	< 0.01	Sodium hydroxide	0.25
Modified Polystyrol-Dispersion	0.02	Phthalimidoperoxyhexane acid	0
Scents	0.60	Hydroxythan-1,1-diphosphonic acid, sodium salt	0.2
Colorants	< 0.01	Polydimethylsiloxane	0.1
		Copolymer wth 1-Vinylmidazol and 1-Vinyl-2-pyrrolidine	0.76
		Enzyme Mix (Protease, Amylase, Cellulase)	< 0.1

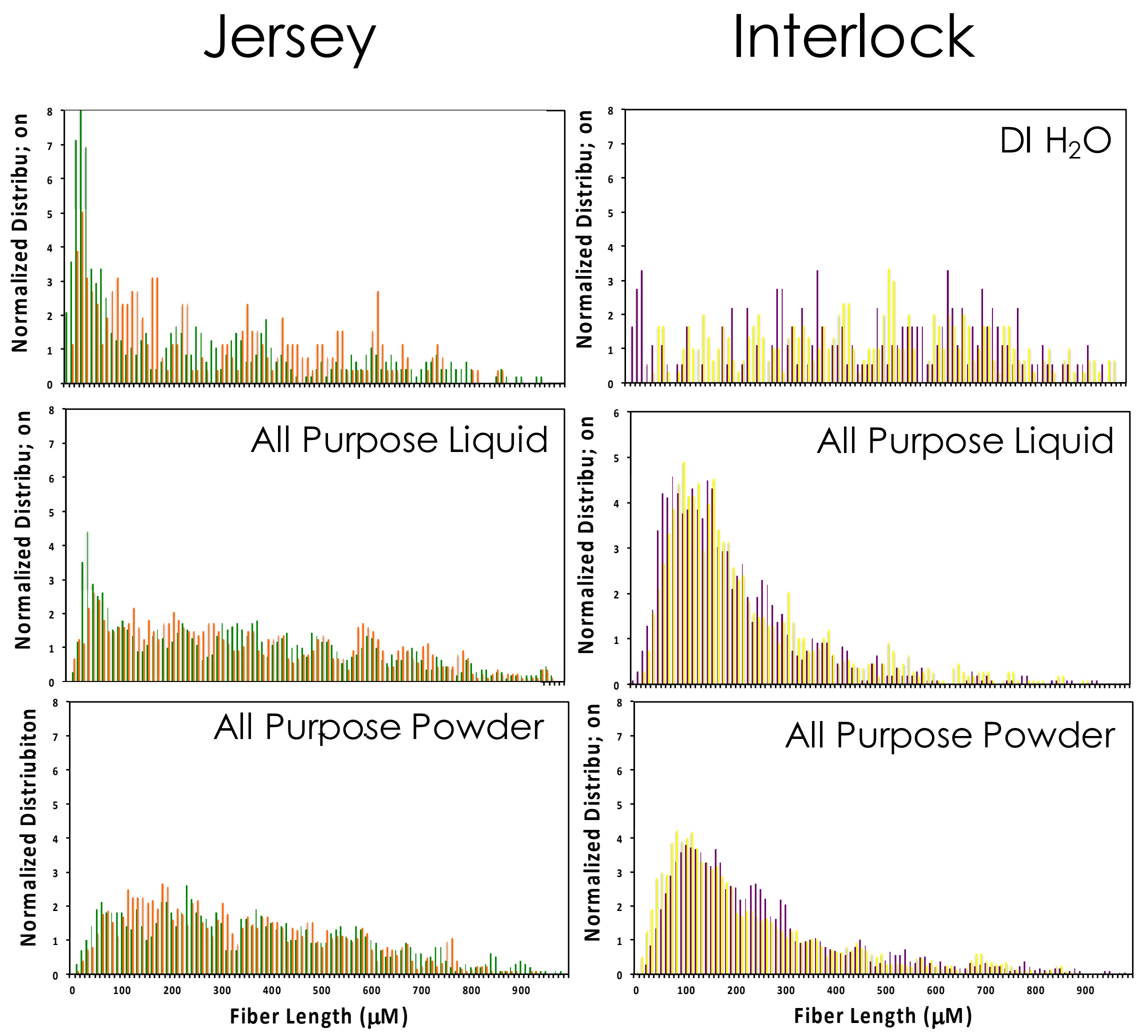

Figure S6: QA/QC of triplicate filters from a subset of wash water. Analysis of the fiber length distribution for jersey fabric (left graphs) and interlock fabric (right graphs) in DI H_2O, liquid detergent and powder detergent. Fibers measured on different filters are shown in different colors. Since these are aliquots of the same wash water, this data does not represent the variability of the washing procedure between different fabric swatches but rather the variability associated with sample processing, filter preparation and filter analysis.

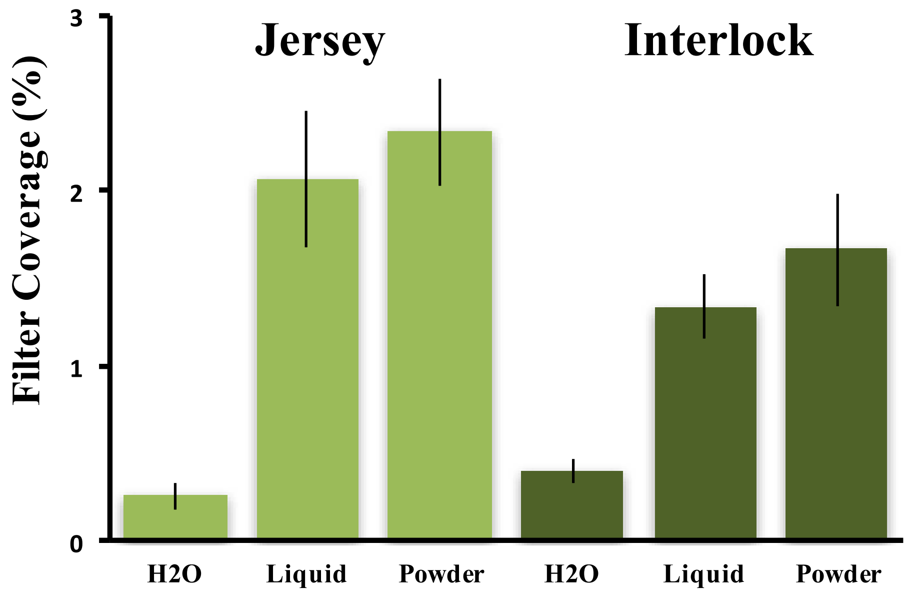

Figure S7: QA/QC of triplicate filters from a subset of wash water. Analysis of the percent filter coverage after binary image analysis for jersey fabrics (light green) and interlock fabrics (dark green) in DI H_2O, liquid detergent and powder detergent. Since these are aliquots of the same wash water, this data does not represent the variability of the washing procedure between different fabric swatches but rather the variability associated with sample processing, filter preparation and filter analysis.

Table S2: Values of underestimation from filter coverage mass estimates (binary pixel area) compared to total values from counting individual fibers (manual pixel area). Samples were randomly selected and compared. For the manual pixel quantification, a fiber width had to be used to calculate the pixel area covered and this number varied between 2 to 5 pixels depending on the image but was determined by the program ImageJ.

	Binary	Manual *	Underestimation	Average
Name	**Pixel area**	**Pixel area**	**(percent)**	**(percent)**
Sample 1	281849	333444.3	15	**9.8**
Sample 2	162856	170225.8	4	
Sample 3	323995	380252.4	15	
Sample 4	228862	247619.8	8	
Sample 5	268189	288513.9	7	

Table S3: Number of individual fibers measured by hand on each filter analyzed. Since a different wash water volume was filtered depending on the samples, this raw data cannot be directly interpreted as to which fabric or wash condition ultimately released a higher number of particles (the number of measured particles here would need to be scaled accordingly to make such a comparison). This table is therefore simply indicative of the sample sizes which were measured for all of the standard wash conditions.

	Jersey Fabric, Fibers Counted			Interlock Fabric, Fibers Counted		
	Water	Liquid	Powder	Water	Liquid	Powder
Wash 1, Replicate 1	246	2091	654	304	1593	1250
Wash 1, Replicate 2	397	952	3234	655	975	1595
Wash 1, Replicate 3	465	1315	1329	409	2782	
Wash 2, Replicate 1	899	1693	1060	472	2551	1321
Wash 2, Replicate 2	530	3423	582	1029	1185	1145
Wash 2, Replicate 3		3405	605	1505	2533	
Wash 3, Replicate 1	1053	1908	857	1139	3328	851
Wash 3, Replicate 2	407	3431	630	632	1359	540
Wash 3, Replicate 3		574	645	342	2170	
Wash 4, Replicate 1	359	1188	335	358	2045	
Wash 4, Replicate 2	312	309	1228	286	2054	641
Wash 4, Replicate 3	528	1147	630	334	1782	729
Wash 5, Replicate 1	291	696	347	374	3107	
Wash 5, Replicate 2	256	700	624	159	615	462
Wash 5, Replicate 3	138	958	731	218	1833	990

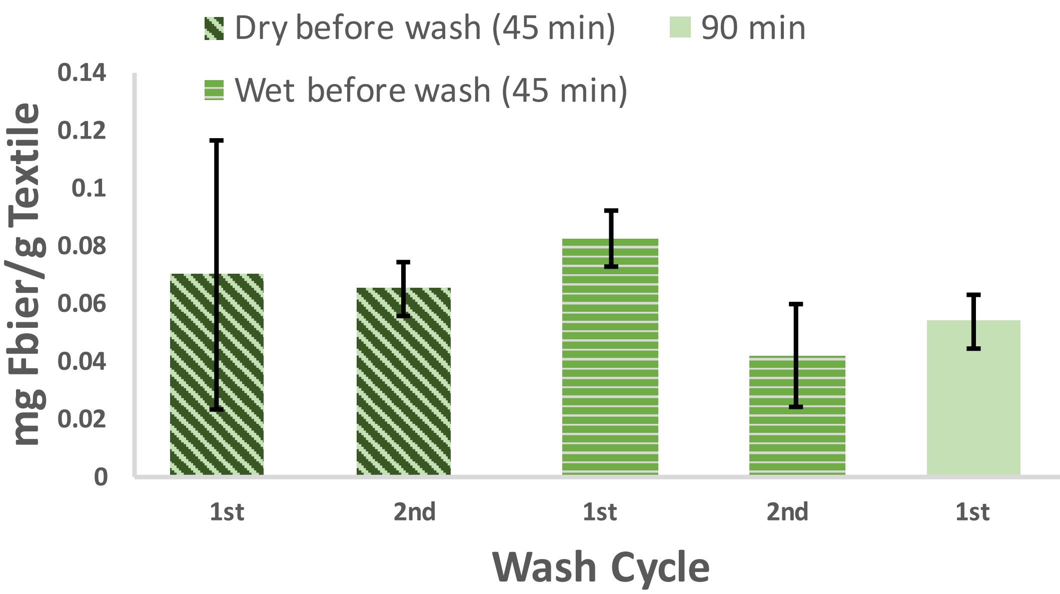

Figure S8: Effect of sequential washing and drying on the mass of microplastic fibers released during equivalent wash times in liquid detergent. When fabrics were air dried between 45 min standard wash conditions (dark green diagonal stipes), the same mass of fibers was released in the first and second wash cycles. Similar concentrations of microplastic fibers were found in the wash water of swatches which did not undergo drying between the was cycles (green horizontal stripes). Finally, when fabrics were not removed from the wash water and underwent a longer treatment corresponding to two wash cycles, the same amount of fibers were measured in the wash water as any individual single wash treatment, regardless of fabric drying. Error bars represent triplicate experiments.