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The influence of textile finishing agents on the biodegradability of shed fibres

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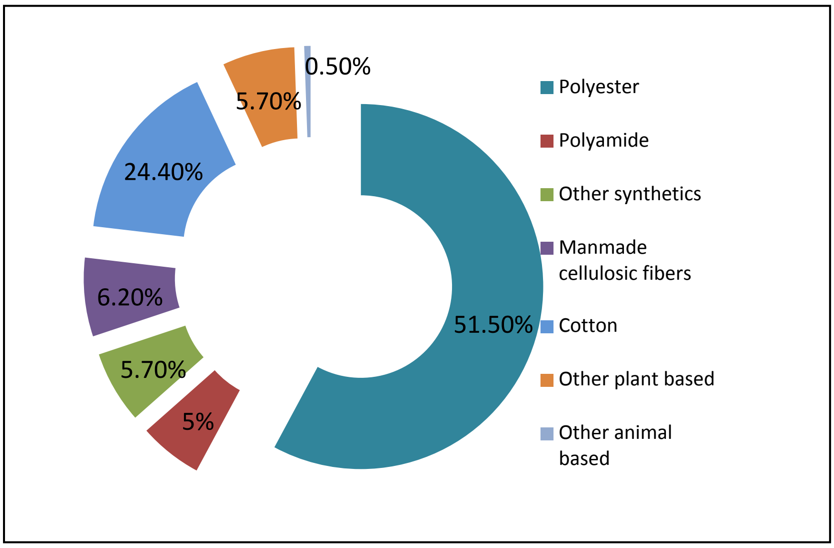

Figure S1. *Global fibre production in 2018 (partly adapted from Textile Exchange Market Report 2019).*

Dyes integration into textile substrate

For the most common fibres, i.e. polyester, man-made cellulosic fibres and cotton, there are different modes of binding and incorporation of the dyes into the textile matrix widely used in textile manufacturing processes. First category consists of the reactive dyes that are water soluble and used mainly for dyeing cellulose fibres. During the dyeing process a covalent chemical bond is formed between the dye anchors and the functional groups of the cellulose. A distinction is made between reactive dyes with one, two or three anchors per dye molecule. With increasing number of anchors, the degree of fixation to the fibre increases. The second category includes the disperse dyes that are mainly used for the dyeing of PET via solution of the hydrophobic dye in the hydrophobic PET polymer chain. Disperse dyes are insoluble in water therefore it is necessary to be dispersed in the aqueous dyebath, including dispersing agents, heating up to 130 °C, diffusion of the molecularly distributed dye particles into the fibre and dissolution. The procedure leads to the formation of solid compound fibre-dye stuff after the reduction of the temperature. Both dyeing processes lead to stable links between fibre and dyestuff, however which connection is more stable cannot be generalized. The disperse dye is physically bound to the polymer matrix within the fibre cross-section and is therefore less accessible to environmental factors, e.g. bacteria, after dyeing. While reactive dyes form a stable chemical bond which are, however, more accessible to environmental factors.

(*Responsible person for further information in case requested: Stefan Brandt)

Antimicrobial (AM) substances used in apparel industry

Different AM substances are used in textile industry; among others quaternary ammonium compounds (QACs), triclosan, metal salts, polyhexamethylene biguanides (PHMBs) and natural polymers such as chitosan[1–3]. The most common functions are explicitly described in two review studies of Morais et al.[1] and Windler et al.[2] Briefly, modes of action include permeation of bacterial cell wall and inhibition of cell membrane function, disruption of normal metabolic processes, damage or inhibition of cell wall synthesis, together with inhibition of protein and nucleic acid synthesis. Approaches to introduce the active ingredient into the textile involve either the incorporation of AM agent in the polymeric bulk during textile fibre synthesis, or by applying the chemical topically on the fibre's surface as coating during the final finishing stage[3]. The effectiveness of the application procedure depends on the type of fibre (synthetic, natural) and the physicochemical features of the finishing agent used[53].

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***Table S1**. Dyeing Process of textile viscose fibres.*

	Avitera Red SE		**Remazol Red RB**	
Liquor ratio	1:10	1:10	1:10	1:10
Dyestuff	0.25%	4%	0.25%	4%
Soda	8 g/L	18 g/L	8 g/L	18 g/L
Sodium Sulfate	30 g/L	90 g/L	30 g/L	90 g/L
Start Temp.	30°C	30°C	30°C	30°C
Time at Temp.	10 min	10 min	10 min	10 min
Rate of Rise	2°C/min	2°C/min	2°C/min	2°C/min
Dyeing Temp.	60°C	60°C	60°C	60°C
Time at Temp.	60 min	60 min	60 min	60 min
Cooling Rate	8°C/min	8°C/min	8°C/min	8°C/min
End Temp.	25°C	25°C	25°C	25°C

Table S2. *Finishing Process of textile viscose fibres.*

	AM Finish	**Softener**
Liquor ratio	1:15	1:15
Ruco-Bac HAS conc.	0.2%	-
Tubingal RSK	-	2%
pH (with Acetic acid)	4.5	3.5
Start Temp.	30°C	30°C
Time at Temp.	5 min	5 min
Rate of Rise	2°C/min	1°C/min
Dyeing Temp.	60°C	40°C
Time at Temp.	20 min	20 min
Cooling Rate	1°C/min	1°C/min
End Temp.	40°C	30°C

Table S3. *Analytical data for the tested fibre samples used in this study (ThOD = Theoretical Oxygen Demand, COD = Chemical Oxygen Demand), as well as the calculated mass and the size of fibres added to the Oxitop® respirometric flasks.*

Sample	ThOD (mg O_2/g)	COD (mg O_2/g)	Calculated mass (mg/L)
PET	1667	1331 ± 93	112 ± 0.001
Oxo-degradable PET	n.a	766 ± 28	108 ± 0.00
Mixture PET/Cotton	n.a	646 ± 168	134 ± 0.01
Cotton	n.a	819 ± 14	184 ± 0.00
Viscose	n.a	812 ± 38	193 ± 0.00
Cellulose	1185	1016 ± 154	156 ± 0.007
PE	3400	270 ± 23	580 ± 0.016
Av – 4%	n.a	789 ± 109	260 ± 0.02
Av – 4% + S	n.a	712 ± 1	234 ± 0.01
Av – 4% + AM	n.a	722 ± 46	189 ± 0.001
R – 4%	n.a	742 ± 69	220 ± 0.003
R – 4% + S	n.a	717 ± 66	248 ± 0.007
R – 4% + AM	n.a	1063 ± 208	156 ± 0.006
Avitera (dye)	n.a	1062 ± 639	273 ± 0.00
Remazol (dye)	1226	534 ± 95	310 ± 0.01

Table S4. *Biochemical oxygen demand (BOD) for reference materials (cellulose, PE) and inoculum (blank).*

Time [days]	**BOD_{Blank} (mgO2/L)**	**$BOD_{Cellulose}$ (mgO2/L)**	**BOD_{PE} (mgO_2/L)**
0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
2	5.6 ± 1.2	5.5 ± 1.7	5.7 ± 3
5	6 ± 2.5	29.5 ± 9.7	6 ± 3.4
10	7 ± 2.1	71.3 ± 7.68	7.2 ± 3.3
15	7.8 ± 1.6	96.3 ± 16.5	8.4 ± 3.5
20	8.3 ± 1.9	109.8 ± 13.54	8.5 ± 3.7
25	9 ± 1.6	118.7 ± 10.7	9.3 ± 4.1
30	8.9 ± 1.7	125.7 ± 9.4	9.3 ± 3.8
35	9.2 ± 1.4	130.8 ± 7.9	9.8 ± 3.9
40	10.6 ± 1.8	135.3 ± 7.3	9.7 ± 4.1
45	10.4 ± 1.4	138.2 ± 5.5	10.1 ± 4.3
50	10 ± 1.1	140 ± 5.3	10.4 ± 4
55	10.5 ± 1.6	140.6 ± 5.2	10.5 ± 3.8
60	11.2 ± 1.2	142.4 ± 3.9	12.3 ± 2.2

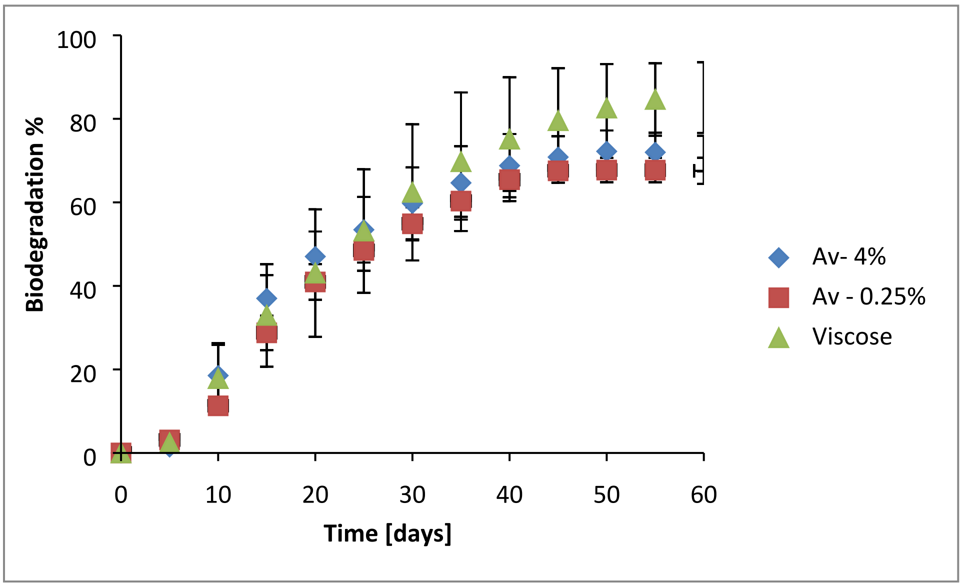

Figure S2*. Influence of different dye (Avitera) concentrations on the biodegradability of viscose fibres. Error bars represent the standard deviation (n=3).*

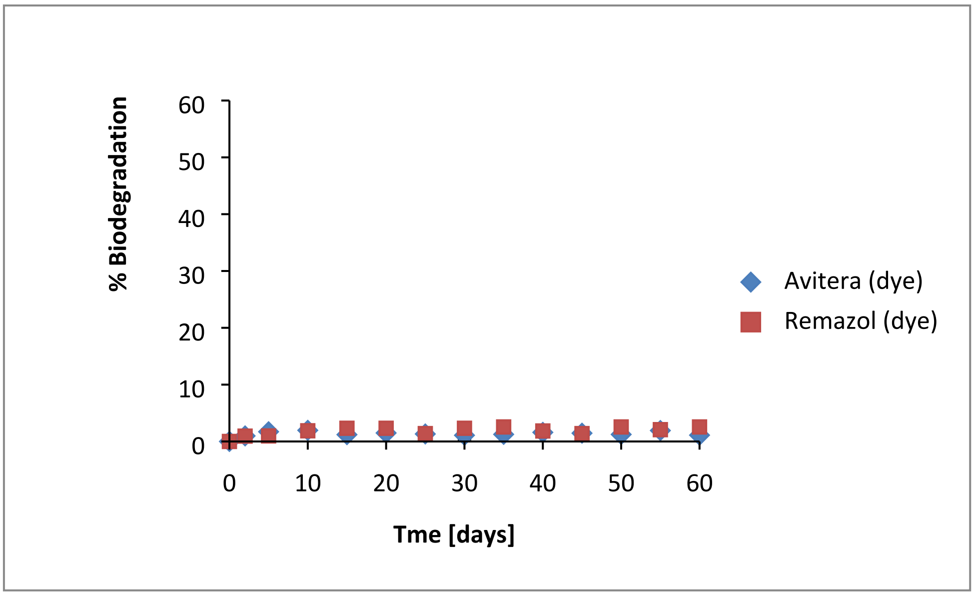

Figure S3. *Biodegradability potentials of chemical dyes used in this study. Error bars represent standard deviation (n=3).*

References

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