

THE INFLUENCE OF WASHING PROCESS OF SOME SYNTHETIC KNITTED FABRICS FOR SPORTSWEAR ON MICROFIBERS SHEDDING

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The washing process is a primary contributor to microplastic pollution, with synthetic sport textiles releasing thousands of microfibers per garment in every wash cycle. The purpose of this paper is to detect the microfibers (MFs) released from some knitted fabrics in sportswear after subjected to washing process with a laboratory James Heal machine. The investigating the morphology and specific functional groups of textile samples before and after washing process was performed using an optic microscopy and ATR-FTIR analyses. The data show that the different knitted fabrics and the number of washing cycles influence the MFs shedding.

Keywords: knitted fabric, microfiber, washing, shedding, optical microscopy, FTIR, size dimension

1. Introduction

The use of plastics has defined 21st century society, generating a global plastics production of 413.8 million metric tons in 2023 [1]. The sports sector widely uses synthetic materials due to their durability, mechanical performance and low cost. Synthetic pitches, sports equipment, sportswear, and food and beverage packaging are potential sources of microplastics [2],[3]. Modern sportswear is largely made from synthetic fibers: polyester, polyamide (nylon), and elastane (spandex). In 2023, synthetic fibers accounted for approximately 67% of the global textile fiber production volume. Polyethylene terephthalate (PET) is among the most widely used thermoplastic polymers, being widely applied in packaging and textiles [4], [5]. Polyethylene terephthalate alone had a market share of 57%, while polyamide (PA) and other synthetic materials accounted for 5% each [6].

MFs are generally defined as fibers up to 15 mm long with a length-to-diameter ratio greater than 3 [7]. In the textile industry, however, the term

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"microfiber" usually refers to ultrafine synthetic fibers with a linear density of less than 1 denier, commonly used in clothing and household items, less than 5 mm in all dimensions, with a length/diameter ratio above 3 [8].

Microfibers (MFs) generation is strongly attributed to the washing of textiles in both in households and industrial laundries, the wear and tear of clothing during wear, as well as industrial textile manufacturing and finishing processes [9]. Physical activity intensifies the process of releasing MFs, especially in running, cycling or team sports [10]. Drying clothes, especially in electric dryers, also contributes to the release of microfibers into the air [11]. Global estimates show that households contribute up to 35% of microplastics released into the environment [12]. It was reported that the released MFs during automatically washing garments decreased with the washing load [13]. Thus, for a 150 g of garment load, the amount of generated MFs was estimated at 401 ± 17 mg/kg, whereas washing a 2.5 kg garment load resulted in 76 ± 5 mg MFs/kg [13]. This behavior can be attributed to the synergistic effect of the water-to-fabric ratio and the mechanical stress exerted on the fabric. Also, repeated friction between the textile and the skin or between textile layers causes the MFs to detach. These small particles can end up in the air, water or food and can be inhaled or ingested, raising concerns about their impact on human health and the environment. The problem is exacerbated by the inefficient management of textile waste: globally, 87% of textile waste ends up in landfills, where the degradation of synthetic materials favors the release of MFs into soil and water. In Europe, only 15-20% of textiles are collected separately, and about half of them are then exported to developing countries [14]. Consequently, investigating the shedding of MFs into the environment and identifying solutions to reduce this form of pollution are particularly important.

The objectives of this study are: (i) to establish the type of sportswear textile material (recycled polyester, non-recycled polyester or polyamide/elastane) that releases the highest amount of MFs during washing and (ii) to evaluate the influence of the number of washing cycles on the generation of MFs.

2. Experimental part

2.1. Materials

The sport knitted fabrics were coded according to the fiber composition, origin, and washing treatment. Thus, the investigated materials include virgin polyester (PET), recycled PET (rPET), recycled polyamide/elastane (rPA/EL), virgin polyamide/elastane (PA/EL), and aged polyamide/elastane and polyamide/elastane with perforations (PA/EL-A and PA/EL-P-A, respectively). The last two samples were previously washed for 50 cycles with a classical washing machine in order to simulate the aged material at the end of the life cycle. It was

considered that 50 washing cycles of a textile item correspond to 2 years of wearing of that item. In this study, these knitted fabrics were washed with James Heal machine for one washing cycle, which is equivalent to five washing cycles in a household automatic washing machine. These samples provided from the Romanian stores dedicated to synthetic sportswear.

2.2. Methods

2.2.1 Standardized washing method

The sport knitted fabrics were washed using the James Heal washing machine (Gyro Wash), according to international standard ISO 6330 “Textiles — Domestic washing and drying procedures for textile testing”. In order to estimate the number of MFs that can be released from the washing process, the following steps were carried out: (i) the samples with dimensions of 40 mm × 100 mm were cut from the textile articles with a letcon, (ii) the samples were weighed using an analytical balance with accuracy (0.1 mg), (iii) a solution of 0.4% ECE Phosphate Detergent (B) was prepared in distilled, filtered water (0.7 μm). The washing parameters were: a temperature of 40 ± 2 °C, washing time of 45 minutes, and a washing solution volume of 150 mL. Ten stainless steel balls (with 6 mm diameter) were used in each stainless steel tank, total mass of 40 g ± 5%.

After the completion of the washing cycle, the washing and rinsing water was collected in order to estimate the number of MFs. The washed samples were subjected to two successive manual rinsing process by using of 100 mL of filtered distilled water. Two replicates were performed for the washing/rinsing process.

2.2.2 Optical microscopy analysis

Optical microscopy is a non-destructive method that allows morphological analysis in transmitted/reflected light. Examination of morphology of both initial and washed textile samples and the evidence of MFs released during washing process were performed with the optical microscope OLYMPUS BX 51 M (Olympus Corporation, Tokyo, Japan), Olympus Stream Essential 1.9.3 Software, resolution of 1 μm, which allowed image acquisitions at magnifications from 50× to 200×. MFs originated from laboratory and negative controls were detected in order to estimate plastic contamination [15]. They were subtracted from the final number of MFs.

2.2.3 Mass per unit area

The determination of the mass per unit area was carried out according to the standard EN 12127 – “Textiles — Fabrics — Determination of mass per unit area

using small samples”, at a temperature of 19.9 °C and relative humidity (RH) of 63%. The measurement uncertainty of the method was $\pm 1.36\%$. The conditioning of the textile samples was carried out according to the standard ISO 139:2005 – “Textiles. Standard atmospheres for conditioning and testing”. The initial and washed samples were weighed using an analytical balance. The specific gravity (g/m^2) was calculated by dividing the sample mass to the sample surface. The results are presented as mean \pm standard deviation for each type of material tested.

2.2.4 FTIR analysis

For the identification and characterization of the chemical composition of the investigated textile materials, the ATR-FTIR equipment (Interspec 200-X Spectrophotometer, Interspectrum, Estonia) was used, configured from the wavenumber 750 cm^{-1} to 3500 cm^{-1} , resolution 4 cm^{-1} , scanning speed 2 mm/s , number of scans 3, and a pyroelectric deuterated L-alanine doped triglycine sulfate (DLATGS) detector. Before analyzing the samples, a standard spectrum of a polystyrene (PS) film (reference material) with a thickness of $38\text{ }\mu\text{m}$ (PIKE TECHNOLOGIES Inc.) was scanned. The specific positions of the absorption bands of PS were observed at the 1028 cm^{-1} , 1154 cm^{-1} , 2850 cm^{-1} , 3060 cm^{-1} wavenumbers, with a tolerance of $\pm 1\text{ cm}^{-1}$.

2.2.5 Separation of MFs from the washing fleet

The washing fleet resulting from the first washing of the textile samples was vacuum filtered in the laboratory on a filter with a pore size of $1.2\text{ }\mu\text{m}$, then the filter was washed with plenty of distilled water, then, finally, 10 mL of ethyl alcohol (previously filtered through $0.7\text{ }\mu\text{m}$) was added. The filters with collected residue were placed in Petri dishes with a diameter of 9 cm and dried at room temperature. Three control samples consisting of the collecting of MFs from the laboratory during the textile washing process and the filtration operations were also analyzed.

3. Results

3.1. The morphology of the sport textile samples

Fig. 1 (a-f) shows the optical images of sport textile samples before and after washing/rinsing process. Microscopic examination of the virgin PET knitted fabrics revealed a regular and well-defined filaments, turquoise in color, with uniform filament thickness of $10\text{-}11\text{ }\mu\text{m}$, homogeneous distribution of the yarns in the structure, smooth yarn surface, without visible defects, as well as the absence of local deformations or structural degradation before and after washing process.

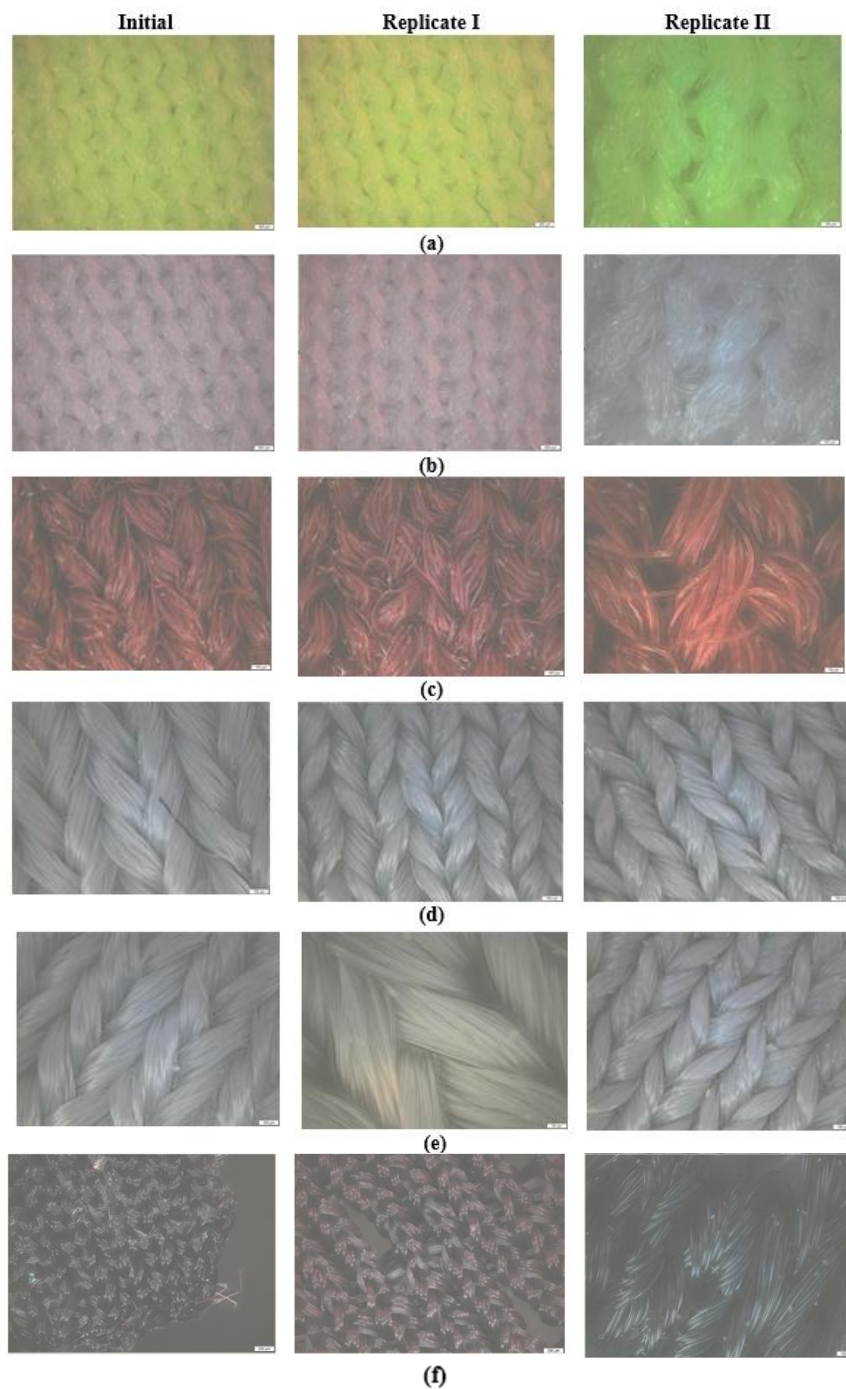


Fig. 1. Optical images of the knitted sport textile articles before and after washing/rinsing process: PET (a) rPET (b), rPA/EL (c) PA/EL (d), PA/EL-A (e), PA/EL-P-A (f)

These characteristics indicate a stable and technologically well-controlled knitted structure (Fig. 1a). In the case of the knitwear made from recycled PET (Fig. 1b), uniform white color of the yarns, variations in the diameter of the microfibers from 12 μm to 22 μm , and less compact structure compared to virgin PET were observed.

For the recycled PA/EL sample (Fig. 1c), the microscopic analysis revealed a mixed structure, with loops formed by yarns with different colors of brick and white, slightly deformed or elongated loops. Washing process led to the areas of uneven compaction. These observations indicate an uneven interaction between the components and transition zones amplified by the recycling of PA. The PA/EL and PA/EL-A samples washed presented grey color, well-defined and uniformly distributed loops, proper alignment of the MFs, compact and coherent structure, smooth surfaces, without obvious signs of degradation, with a diameter between 12 – 15 μm (Fig. 1d) and 23 μm (Fig. 1e), respectively. The PA/EL-P-A washed sample presented dark gray MFs, with a diameter of about 30 μm and empty spaces (perforations) between the two braids of the threads Fig. 1f). For all sport textile samples washed, no changes were observed as compared with initial samples.

3.2 Mass per unit area

Fig. 2 displays the mass per unit area of the investigated sport knitted samples, before and after each washing replication. Also, the average of the mass/surface area \pm standard deviation of the two washing replicates was plotted.

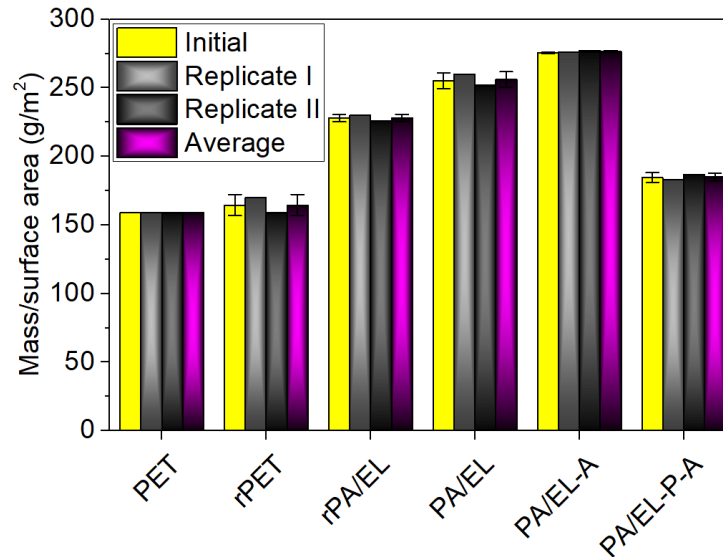
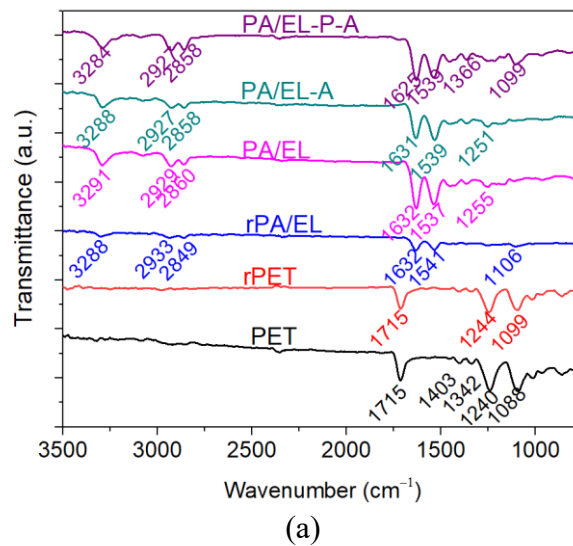


Fig. 2. Mass per unit area of sport knitted samples after washing/rinsing compared to the initial values

From Fig. 2 it can be seen that the values of the mass per unit area before and after washing for the PET and PA/EL-A samples are practically identical (the differences are within the 1.36% error limit allowed by the method), which means that the structure of these materials is dimensionally stable. The PA/EL-A sample, although it was previously subjected to the 50 washing cycles, did not cause relevant changes in the apparent density of the material. In the case of rPET, rPA/EL, PA/EL, and PA/EL-P-A samples, the differences between the initial mass per unit area and those after washing process are observed to be greater than the measurement uncertainty. PA/EL-P-A sample records a higher mass per unit area in the second washing repetition (187 g/m^2) compared to the first washing repetition (183 g/m^2), which can be explained by the shrinkage of the textile material (the area decreases, the mass remains almost constant) and the residual absorption of detergent. rPET, rPA/EL, and PA/EL samples record a greater variation in mass per unit area upon washing, $164.5 \pm 7.7\%$, $228 \pm 2.82\%$, and $256 \pm 5.65\%$, respectively, which can be explained by the loss of MFs and the relaxation of the textile structure.

3.3 ATR-FTIR analysis

Fig. 3 shows the ATR-FTIR spectra performed for the sport textile samples before and after washing experiment.



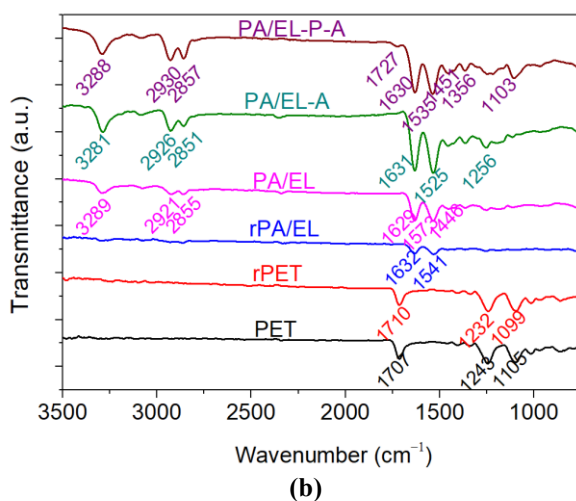


Fig. 3. ATR-FTIR spectra recorded for the sport textile samples: Initial (a), After washing (b)

The main absorption bands for the PET and rPET initial samples evidenced the stretching vibrations of the C=O ester (1715 cm^{-1}), C-O ester (1240 cm^{-1} , 1244 cm^{-1}), C-O-C ester (1088 cm^{-1} , 1099 cm^{-1}) and C=C aromatic (1403 cm^{-1}) groups [16]. No additional bands or differences in intensity of the bands associated to the virgin and recycled PET samples were observed.

Samples based on PA and EL, both virgin and recycled PA, show absorption bands specific to the stretching vibrations of the N-H groups (3284 cm^{-1} – 3291 cm^{-1}), CH_2 (2849 cm^{-1} – 2929 cm^{-1}), C=O (amide I) (1625 cm^{-1} – 1631 cm^{-1}), the deformation vibration of the N-H group (amide II) (1537 cm^{-1} – 1541 cm^{-1}) and the stretching/deformation vibration of the C-N/C-C group (amide III) (1251 cm^{-1} – 1366 cm^{-1}) [17, 18]. The absorption bands present at frequencies of 1100 cm^{-1} – 1300 cm^{-1} are due to the vibration of the C-O-C bond in the elastane structure [19]. Unlike the PA/EL, PA/EL-A, and PA/EL-P-A samples, the rPA/EL shows lower intensities of these characteristic chemical groups. Also, the PA/EL-A and PA/EL-P-A samples, show shifts of the characteristic bands of N-H (3288 cm^{-1} , 3284 cm^{-1}), CH_2 (2927 cm^{-1} , 2858 cm^{-1}), amide I (1625 cm^{-1}), amide II (1539 cm^{-1}), and amide III (1251 cm^{-1}) compared to PA/EL, attributed to the reorganization of hydrogen bonds, conformational changes of the polymer chains, and possible superficial hydrolysis of the amide groups (Fig. 3a).

After washing (Fig. 3b), the phenomena highlighted by ATR-FTIR analysis refer to the decrease in the intensity of the band at 1715 cm^{-1} of the PET textile material and its shift to 1707 cm^{-1} (PET sample). Also, the shifts of the bands specific to the C-O ester groups (1232 cm^{-1} , 1243 cm^{-1}) and C-O-C ester (1082 cm^{-1} , 1105 cm^{-1}) were observed. This behavior is attributed to the superficial hydrolysis of the ester bonds, the surface structural changes and the removal of

textile finish as a result of the interaction of the textile samples and the detergent solution. Similarly, for rPET sample, the decrease in intensity and the shift of the specific band to the C=O group to lower wavenumbers (1710 cm^{-1} and 1232 cm^{-1}) are observed. rPA/EL sample after washing shows an increase in the intensity of the amide I-specific band (1630 cm^{-1} and 1632 cm^{-1}) compared to the initial sample, which indicates an increased exposure of the C=O group at the fiber surface, intensification of hydrogen bonds, and reorganization of the polymer chains. PA/EL-A after washing shows a decrease in the intensity of the main bands compared to the initial sample and a shift of these bands to lower wavenumbers (for example: 3286 cm^{-1} , 2851 cm^{-1} , 1629 cm^{-1}). The absorption peak shifted from 1537 cm^{-1} (initial sample) to 1573 cm^{-1} (washed sample) can be explained by the weakening of the C=O bond. The PA/EL-A and PA/EL-P-A samples show shifts of the characteristic absorption bands to lower (3281 cm^{-1} , 2926 cm^{-1} , 2847 cm^{-1} , 1627 cm^{-1} , 1525 cm^{-1}) or higher (3289 cm^{-1} , 2938 cm^{-1} , 1633 cm^{-1} , 1256 cm^{-1}) wavenumbers, as a result of the mobility, ordering, and relaxation of the polymer chains.

3.4 Microfiber (MFs) evaluation

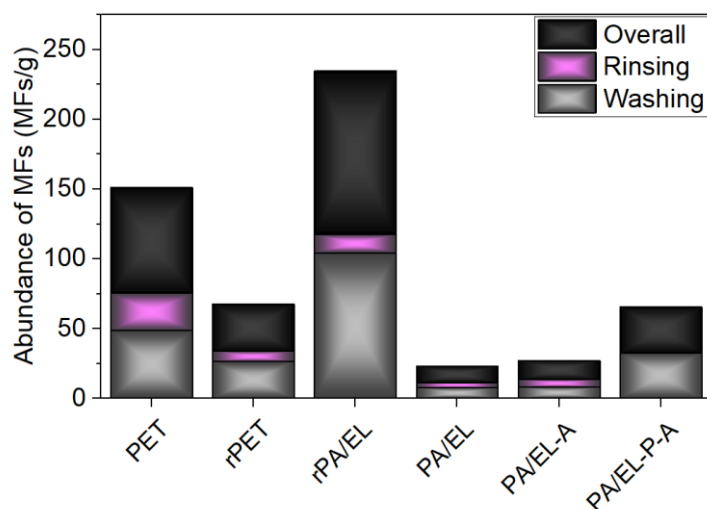


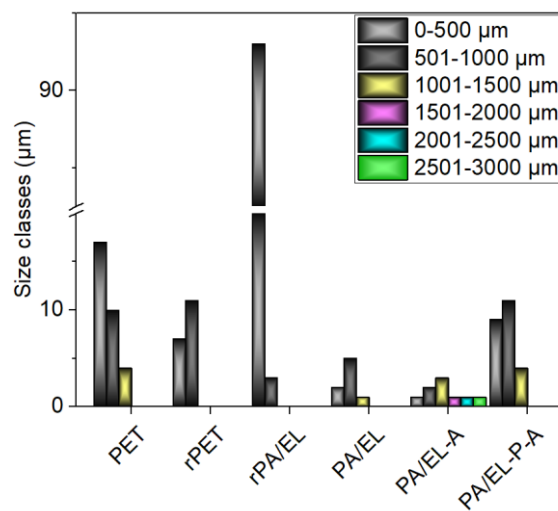
Fig. 4. Estimation of the number of MFs per gram of sport textile sample shedded during washing and rinsing

From Fig. 4 it is observed that the rPA/EL sample shows the most MFs/g collected from washing and rinsing (117 MFs/g), followed by washed PET sample (75 MFs/g). rPET sample totals 33 MFs/g, a smaller number of MFs released compared to PET sample. Gao et al. [20] studied the release of MFs from polyester men's sportswear clothes, both virgin and recycled PET and concluded that it no

significant difference between these structures exist. Contrary to this study, another paper [9] reported that the washing of textile from recycled polyester led to release of higher number of MFs compared with the virgin polyester sample (1193 MFs versus 908 MFs).

Comparing the textile samples based on PA/EL, it is observed the release of a smaller number of MFs compared with the samples based on PET. The textile samples subjected to repeated washing cycles show an increasing in the generation of MFs/g as compared with PA/EL. Thus, the PA/EL-P-A sample generates 32 MFs/g, the highest abundance of MFs compared with PA/EL sample, probably due to the less dense structure ($185 \pm 2.82 \text{ g/m}^2$). Literature reported a release of MFs during washing in the range of 1,600 to 56,000 MFs/g, depending of the processed textile surfaces [20]. In real household conditions, using a reference load of 6 kg of synthetic fibers, an average rate of 18,000,000 synthetic MFs were reported [18]. Another study reported that the most MFs are released in the first few washes, and after the third wash, the number of MFs is stabilized at a very low level [9, 13].

The order of MFs released as resulting from the washing and rinsing of textile samples intended for active sports is as follows: rPA/EL > PET > PA/EL-P-A > rPET > PA/EL-A > PA/EL. These results are correlated with those reported in the literature, which show that the most MFs were released in the first washing cycles [14, 21, 22]. In Fig. 5 (a, b) the size classes for MFs released from washing and rinsing of sport textile articles examined by optical microscopy, are shown.



(a)

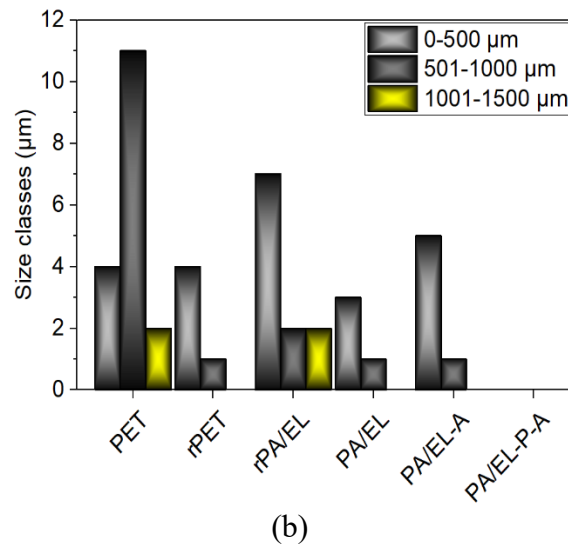


Fig. 5. Distribution of MFs shed from washing textile samples by size classes (μm): Washing (a), Rinsing (b)

From Fig. 5a) it is observed that the majority of MFs detected during washing process (54.7% for PET and 96.7% rPA/EL samples) fall within the size range of 0 – 500 μm . rPET, PA/EL, and PA/EL-P-A samples present the majority of MFs in the size class of 501 – 1000 μm , with values of 61%, 62.5%, and 45.7%, respectively. Also, the analysis of the water resulting from the rinsing stage of washed sport textile samples revealed MFs that are found both in the 0-500 μm size distribution class in the case of rPET (80%), rPA/EL (58.3%), PA/EL (75%), and PA/EL-A (83.3%), and 501–1000 μm size class for PET sample (64.7%) (Fig. 5b).

4. Conclusions

The types of sport textile materials and the characteristics of each sample significantly influenced the level of microfiber release (MFs) after the washing process with a James Heal laboratory machine. The rPA/EL sample followed by the PET sample presented the highest MFs/g among the investigated textile sample (117 MFs/g and 75 MFs/g, respectively).

The majority of MFs released from the washing of the textile samples are situated in the first two size classes of dimensions of 0 – 500 μm and 501 – 1000 μm , which indicates that these small particles can easily reach the sewage system and, then, the wastewater treatment plants.

Regarding the stability of the textile materials, the mass per unit area determined after washing for PET and PA/EL-A samples does not show significant variations compared to the initial values, indicating a good resistance of the material

to the washing process. In contrast, rPET, rPA/EL, and PA/EL samples recorded differences in the mass per unit area value that exceed the uncertainty of the method, suggesting real changes in the textile structure as a result of washing. These changes were also highlighted by ATR-FTIR analysis.

Also, the number of washing cycles influence both the shedding of microfibers and the structural degradation during washing, aspects essential for understanding how sports textiles contribute to microfiber pollution.

Future investigations such as the effect of washing time and temperature are needed to evaluate the generation of MFs from knitted fabrics for sportswear.

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REFERENCES

- [1] *Annual production of plastics worldwide from 1950 to 2023*. Available: <https://www.statista.com/statistics/282732/global-production-of-plastics-since-1950/>. Accessed on 25.12.2025.
- [2] X. Jiao, Q. Cao, Z. Deng, Microplastics and exercise: impacts on performance and physiological health, *Frontiers in sports and active living*, Vol. 7, 2025-08-19, 2025, Art no. 1611255, doi: 10.3389/fspor.2025.1611255.
- [3] A. Harusato, M. Kato, Mechanisms of Generation and Ecological Impacts of Nano- and Microplastics from Artificial Turf Systems in Sports Facilities, *Environments*, Vol. 12, Iss. 4, 2025-04-02, 2025, Art no. 109, doi: 10.3390/environments12040109.
- [4] S. Bentoufa, The dynamic of cooling heat flow of simple jersey polyester fabric, *Industria Textila*, Vol. 75, Iss. 5, 2024, 584–590, doi:10.35530/IT.075.05.202484.
- [5] P. Narakaew, S. Thungprasert, S. Narakaew, W. Baison, T. Promanan, P. Santakij, S. Sukdee, C. Chanogkun, K. Ruttanateerawichien, A. Chaisena, P. Krachodnok, The durable hydrophobic and antibacterial polyester textile coating with ZnO/Zn(OH)₂/starch/stearic acid composite, *Industria Textila*, Vol. 75, Iss. 6, 2024, 722–728, doi:10.35530/IT.075.06.2023129.
- [6] Distribution of textile fibers production worldwide in 2023, by type. Available: <https://www.statista.com/statistics/1250812/global-fiber-production-share-type/>. Accessed on 25.12.2025.
- [7] *Commission Regulation (EU) 2023/2055 of 25 September 2023. Amending Annex XVII to Regulation (EC) No 1907/2006 of the European Parliament and of the Council Concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) as Regards Synthetic Polymer Microparticles*. Available: <https://eur-lex.europa.eu/legal->

- content/EN/TXT/?uri=OJ:JOL_2023_238_R_0003&qid=1695804976302. Accessed on 29.12.2025.
- [8] *S. Cabigliera, C. Scopetani, B. Muzzi, M. Albino, D. Chelazzi, D. Cantagalli, A. Cincinelli, T. Martellini*, Assessing the Efficacy of Magnetic Micro-Nanoparticles in Water Treatment as a Potential Solution for Textile Microplastic Pollution, *Microplastics*, Vol. **4**, ISS. 4, 2025-12-10, 2025, Art no. 104, doi: 10.3390/microplastics4040104.
- [9] *S. Akyildiz, S. Fiore, M. Bruno, H. Sezgin, I. Yalcin-Enis, B. Yalcin, R. Bellopede*, Release of microplastic fibers from synthetic textiles during household washing, *Environmental Pollution*, Vol. **357**, 2024, doi:10.1016/j.envpol.2024.124455.
- [10] *X. Zhang, W. Jiao, Y. Wang, Y. Gu, S. Zhang, J. Liu, Z. Zhang, C. Tan*, Occurrence, ecological risk of microplastics in campus athletic fields runoff and their adsorption behavior towards heavy metals, *Environmental geochemistry and health*, Vol. **47**, ISS. 3, 2025-03-01, 2025, Art no. 86, doi: 10.1007/s10653-025-02395-y.
- [11] *E. Visileanu, K. Altmann, R. Stepa, M. Haiducu, P. T. Miclea, A. Vladu, F. Dondea, M.C. Grosu, R. Scarlat*, Comparative Analysis of Airborne Particle Concentrations in Textile Industry Environments Throughout the Workday, *Microplastics*, Vol. **4**, Iss. 2, 34, 2025, doi:10.3390/microplastics4020034
- [12] *E. Vassilenko, M. Watkins, S. Chastain, J. Mertens, A.P. Posacka, S. Patankar, P.S. Ross*, Domestic laundry and microfiber pollution: Exploring fiber shedding from consumer apparel textiles, *Plos One*, Vol. **16**, Iss. 7, 2021-07-09, 2021, Art no. e0250346, doi: 10.1371/journal.pone.0250346.
- [13] *M. Volgare, F. De Falco, R. Avolio, R. Castaldo, M.E. Errico, G. Gentile, V. Ambrogi, M. Cocca*, Washing load influences the microplastic release from polyester fabrics by affecting wettability and mechanical stress, *Scientific Reports*, Vol. **11**, ISS. 1, 2021-09-30, 2021, Art no. 19479, doi: 10.1038/s41598-021-98836-6.
- [14] *B. Pinlova, B. Nowack*, Characterization of fiber fragments released from polyester textiles during UV weathering, *Environmental pollution*, Vol. **322**, 2023-02-03 2023, Art no. 121012, doi: 10.1016/j.envpol.2023.121012.
- [15] *A. Stancu, M. Rapa, E. Matei, A. Predescu, C. Predescu*, Recovery of microplastics from a synthetic water, *U.P.B. Sci. Bull., Series B*, Vol. **87**, ISS. 1, pp. 81-92, 2025-01-01 2025.
- [16] *S. Ducoli, S. Federici, M. Cocca, G. Gentile, A. Zandrini, P. Bergese, L.E. Depero*, Characterization of polyethylene terephthalate (PET) and polyamide (PA) true-to-life and their interactions, *Environmental Pollution*, Vol. **343**, 2023-12-17, 2024, Art no. 123150, doi: 10.1016/j.envpol.2023.123150.
- [17] *P. Peets, I. Leito, J. Pelt, and S. Vahur*, Identification and classification of textile fibres using ATR-FT-IR spectroscopy with chemometric methods, *Spectrochimica Acta Part A-Molecular and Biomolecular Spectroscopy*, Vol. **173**, 2017-02-15, 2017, pp. 175-181, doi: 10.1016/j.saa.2016.09.007.
- [18] *C. Marjo, S. Gatenby, A. Rich, B. Gong, S. Chee*, ATR-FTIR as a tool for assessing potential for chemical ageing in Spandex/Lycra®/elastane-based fabric collections, *Studies in Conservation*, Vol. **62**, ISS. 6, 2017-01-01, 2017, pp. 343-353, doi: 10.1080/00393630.2016.1198868.

- [19] *M. Gao, T. Yang, C. Som, B. Nowack*, Differences in the release of microplastic fibers and fibrils from virgin and recycled polyester textiles, *Resources Conservation and Recycling* 2024, Vol. **207**, doi:10.1016/j.resconrec.2024.107659.
- [20] *A. Galvao, M. Aleixo, H. De Pablo, C. Lopes, J. Raimundo*, Microplastics in wastewater: microfiber emissions from common household laundry, *Environmental Science and Pollution Research*, Vol. **27**, 26643-26649, 2020, doi:10.1007/s11356-020-08765-6.
- [21] *K. Klinkhammer, S. Kolbe, S. Brandt, J. Meyer, K. Ratovo, E. Bendt, M. Rabe*, Release of fibrous microplastics from functional polyester garments through household washing, *Frontiers in environmental science*, Vol. **12**, 2024-04-26, 2024, Art no. 1330922, doi: 10.3389/fenvs.2024.1330922.
- [22] *J. Novotna, M. Tunak, J. Militky, D. Kremenakova, J. Wiener, J. Novakova, A. Sevcu*, Release of Microplastic Fibers from Polyester Knit Fleece during Abrasion, Washing, and Drying, *ACS Omega*, Vol. **10**, ISS. 14, pp. 14241-14249, 2025-03-31, 2025, doi: 10.1021/acsomega.5c00258.