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Special Edition

Quantifying shedding of microplastic fibers from textile washing

Quantificação de fibras microplásticas provenientes da lavagem de tecidos

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ABSTRACT

Fiber fragments from synthetic textile materials are a subgroup of microplastics, and the presence of this debris in the environment may have its origin from some different sources. In order to investigate the formation of these residues during domestic washing, washings were simulated on samples of textile articles consisting of three different synthetic materials (polyamide, acrylic, and polyester). The effluent generated was collected and filtered, retaining the microplastic fibers shed. Through a gravimetric process, the mass of particles adhered to the filters was determined, and with the use of a fluorescent dye (Nile Red), these particles were quantified under a fluorescence microscope. This study concluded that the different textile compositions shed microplastic fibers during five washing cycles. Acrylic samples shed the highest mass value (40.9 mg) and polyamide samples shed the lowest value (7.5 mg). It has been estimated that an acrylic blouse can shed 726 mg of microplastic fibers in a single washing. Regarding the size of these particles, dimensions ranging from 11µm to 3mm were observed. Visualization in a 1.2µm filter also suggests the existence of particles in nano-dimensions. In general, it was possible to establish that the domestic washing of textile articles highly contributes to the insertion of these pollutants into the water environment. From a national perspective, approximately 13,800 tons of synthetic fibers can be released into water resources annually from washing clothes.

Keywords: Microplastics; Domestic Washing; Water Resources

RESUMO

Fragmentos de fibras provenientes de materiais têxteis sintéticos são um subgrupo dos microplásticos, e a presença destes detritos no ambiente pode ser dar de algumas fontes. Com o propósito de investigar a formação destes resíduos durante a lavagem doméstica, foram simuladas lavagens em amostras de artigos têxteis com três composições sintéticas distintas (poliamida, acrílico e poliéster). O efluente gerado foi coletado e filtrado, retendo as fibras microplásticas desprendidas. Por um processo de gravimetria, foi determinado a massa de partículas aderidas aos filtros, e com o uso de um corante fluorescente (*Nile Red*), estas partículas foram quantificadas em microscópio de fluorescência. Este estudo concluiu que as diferentes composições têxteis liberaram fibras microplásticas durante cinco ciclos de lavagem. Amostras de acrílico liberaram o maior valor de massa (40,9 mg), e poliamida o menor valor (7,5 mg). Estimou-se que uma blusa de acrílico possa desprender 726 mg de fibras microplásticas em uma única lavagem. Em relação ao tamanho destas partículas, foram observadas dimensões variando de 11 μm a 3 mm. A visualização em filtro de 1,2 μm sugere ainda a existência de partículas em dimensões nano. De maneira geral, foi possível estabelecer que a lavagem doméstica de artigos têxteis possui elevada contribuição na inserção destes poluentes em meio hídrico. Em uma perspectiva nacional, cerca de 13,8 mil toneladas de fibras sintéticas podem ser liberadas nos recursos hídricos anualmente, a partir da lavagem de roupas.

Palavras-chave: Microplásticos; Lavagem doméstica; Recursos Hídricos

1 INTRODUCTION

Microplastics are defined as synthetic polymers with dimensions generally not exceeding 5mm (CESA *et al*., 2017; COSTA *et al*., 2016; CLAESSENS *et al*., 2013; EERKES-MEDRANO *et al*. 2015; LI *et al*. 2018), which can be produced with the size aforementioned or fragmented from larger pieces. Costa *et al*. (2016) and Caixeta *et al*. (2018) evaluated the definition of different authors regarding the size of these particles, finding much divergence among researchers, especially regarding the so-called 'nanoplastics'. Besides dimension, according to previous studies by Carr (2017), Caixeta *et al*. (2018), Cesa *et al*. (2017), and Li *et al*. (2018), microplastics are divided into two groups according to their origin, namely: 1) Primary microplastics –particles industrially created with these dimensions to be used as raw materials or additives. 2) Secondary microplastics - particles formed in the environment by the fragmentation of larger pieces, caused by biotic and/or abiotic degradation processes.

The presence of these pollutants in the environment raises concerns on toxicity, as plastics are known to contain and/or adsorb high concentrations of organic contaminants (CLAESSENS *et al*., 2013), including possible carcinogens (HENRY *et al*., 2019; LI *et al*., 2018). As most of these additives are not chemically bound to the polymer (COSTA *et al*., 2016), they favor the leaching of chemicals from plastic products in aquatic systems (THOMPSON *et al*., 2009). Microplastics are ingested directly by small animals, introducing these compounds into the food chain, which are passed on via predation activities (ALLEN *et al*., 2017; MATTSSON *et al*., 2014). Regarding the human population, sources of plastic ingestion include drinking water (MASON *et al*., 2018; EERKES-MEDRANO *et al*., 2019), beer and salt (KOSUTH *et al*., 2018), and shellfish and fish (COLE *et al*., 2014), besides the inhalation of atmospheric air containing these particles (DRIS *et al*., 2017). Chronic exposure can result in a level of bioaccumulation (REVEL *et al*., 2018).

Plastic products have become part of our clothing, as approximately two-thirds of all textile items are now synthetic, with the potential to become microplastic at any stage of their life cycle (HENRY *et al*., 2019). The issue of microplastics generated in this area is not discussed separately. Thus, the effects related to the presence of synthetic fibers in natural habitats are usually approached through the general context of microplastics. Still in the context of fibers as microplastics, Cesa *et al*. (2017) considered the use of the term 'microfiber' in environmental sciences to be ambiguous, as in the textile context, microfiber refers to the unit of measurement that is related to the mass per unit of length.

Synthetic fibers represent the most abundant type of microplastic found in the marine environment (approximately 85%, CARR 2017). As these are very small particles, they are capable of accumulating in aquatic systems through different dispersive pathways (LI *et al*., 2018). Due to the high volumes of discharge, wastewater treatment is cited as one of the main input sources of microplastics in water resources (LI *et al*., 2018; HENRY *et al*., 2019), although the processes commonly used for the treatment of domestic effluents is efficient in removing microplastics (CARR, 2017). However, this factor depends on the types of processes/technologies used in the treatment, as well as on the size of the particles. Furthermore, the removal of microplastics from sewage only transfers the contaminant from a liquid medium to a solid medium due to agricultural practices that use sewage sludge containing synthetic fibers and/or sedimented microplastics as fertilizer (CAIXETA *et al*. 2018; COSTA *et al*., 2016).

Studies related to microplastics are still incipient. The problem can be considered embryonic, requiring further research and scientific foundation to fill in the existing gaps. The present study evaluates how the domestic activity of washing textile articles made out of synthetic material contributes to the input of microplastics into water resources.

2 MATERIALS AND METHODS

The tests were carried out using textile samples with three different compositions, considering those with the greatest relevance in the world production of synthetic fibers, as well as the presence of fibers found in municipal wastewater treatment plant (WWTP) outfalls (BROWNE *et al*., 2011; ZIAJAHROMI *et al*., 2017; ALMROTH *et al*., 2017). The materials selected were, namely: Polyamide (PA), acrylic (PAC), and polyester (PES).

Textile articles made out of these compositions were purchased commercially. All compositions presented the same color, white. Information on the composition of the articles was obtained from the labels of the pieces, as they are mandatory for the labeling of manufactured textile articles (BRASIL, 2008).

The experiment simulated, in the laboratory, the activity of washing synthetic fabrics, which was performed by a domestic top load washing machine, with subsequent collection of the generated effluent and five washing steps being repeated per sample. In addition, detergents or softeners were not used, as they block the filter used for subsequent separation of particles (BROWNE *et al*., 2011).

Due to the reduced scale of the tests, entire pieces of clothing were not used. Thus, each sample was defined by a set of five pieces of fabric, with dimensions of 5 cm x 5 cm, totaling 125cm² for each synthetic composition.

Washings were performed for each set of samples in containers (600mL beaker) separated by composition using ultrapure water obtained from an Elga equipment, model UHQ, using deionized water. A volume in milliliters (mL) was used, considering a ratio of one hundred times the initial mass of the sample in grams (Table 1).

Table 1 – Water mass and volume ratio

Sample	Mass (g)	Volume (mL)
PA	1.7815	178.0
PAC	4.0722	407.0
PES	1.8563	186.0

Source: Authors' collection

Using three mechanical stirrers, each system was placed under stirring at 250RPM for 30 minutes. After washing, each sample was placed in an identified ceramic capsule and maintained in a forced air circulation oven for 24 hours. After drying, the samples were washed again until five washing cycles were obtained. The generated effluents were collected (n = 5 for each fabric type) and stored in a 500mL Duran Erlenmeyer flask.

2.1 Determination of the mass of microplastic fibers released in the effluent

According to Dias *et al*. (2016), gravimetric determination consists of a series of operations that involve the precipitation of a certain constituent and its separation from the solution in which it is found. Thus, the mass of synthetic fibers released in the effluent during each washing cycle was separated through filtration steps, with these particles being retained in the filter media. The filtration procedure was carried out in two steps, using filter media with different porosities.

The initial filtering of the effluents was carried out in order to remove coarser particles. Inside the flow chamber, a white quantitative filter paper (47mm diameter) was placed in a Büchner funnel coupled to a vacuum pump, under a kitasato glass flask. Each time, the effluent from one sample was poured through the filter. Using tweezers, the filter was removed to a glass Petri dish with a lid. The effluent remaining in the Kitasato flask was filtered again in a *Whatman GF/C* glass-fiber filter (47mm diameter) with typical retention of 1 .2μm (CYTIVA, 2019), with the filters being removed to a new Petri dish.

The flasks were slightly stirred before filtering and rinsed with ultrapure water after filtering as a measure to ensure that no fiber adhered to their sides. The Petri dishes were placed in an oven at 60°C until reaching constant weight. The filters were weighed using an *Ohaus* analytical balance, model AR2140. The values were determined using Equation 1. The initial mass (m_0) of each filter was previously obtained through drying until reaching constant weight.

$$m_{MFn} = \left(m_f - m_0\right) x\ 1000 \qquad (1)$$

Where:
m_{MFn} = Mass of microplastic fibers of *n* washing retained in the filter (mg)
m_f = Filter mass after effluent filtering (g)
m_0 = Initial filter mass (g)
For each *n* washing, the total mass of microplastic fibers was obtained by the sum of the mass retained on the paper filter with the mass retained on the glass-fiber filter.

2.2 Quantification of microplastic fibers

In order to verify the occurrence and characterize the synthetic fibers retained in the filters, a method based on the methodology by Maes *et al* (2017) was adopted, which uses the *Nile Red* (NR) dye as a fluorescent marking tool for microplastics. The NR has good application in the detection of synthetic polymers, being adsorbed to the polymeric material, where it emits fluorescence at specific wavelengths of incident light. The NR solution consists of 0.5mg of the dye in 1mL of acetone (MAES *et al*., 2017).

In each Petri dish with the respective glass-fiber filter (*Whatman GF/C*) coming from the second filtration, 12mL of ultrapure water were added and 0.5mL of the NR solution was pipetted. After 60 minutes, each sample was filtered again (as described in section 2.1) with the supernatant from the Petri dish. Each filter was then placed on two slides simultaneously for microscopy (26mm x 76mm), placed in the Petri dish with a lid, and the set was maintained in a forced air circulation oven at 40°C for 24 hours.

The detection method was carried out using a fluorescence optical microscope, brand Zeiss, model *Scope A1*, with excitation and emission wavelengths in the ultraviolet (UV) range. In the optical equipment, the entire filter area was scanned and the number of particles found in the respective washing/synthetic composition was recorded. Control samples were also scanned.

2.3 Control sample

The use of a control sample contributed to verifying the adequacy of the applied method. In this context, possible contamination sources from external environments, such as ambient air, besides the water used, were considered. For this purpose, two filtrations were carried out in paper and glass-fiber filters with the ultrapure water used. These filters were subjected to the same characterization procedures adopted for the effluents.

During all activities, preventive measures were taken to mitigate possible contamination by microplastics from the environment. Equipment and recipients were washed with ultrapure water at each use and between steps. The workstations were previously washed and tests were conducted with researchers using a coat made of 100% cotton. Similarly, whenever used, the flow chamber was turned on 15 minutes before work started.

2.4 Quantification of the number of microplastic fibers per piece of fabric

In order to establish an estimate of the total microplastic fibers emitted by a textile article, the results were extended, considering the total masses and dimensions of the pieces that originated the samples. The area of each piece was obtained through the measurements performed (Table 2). Considering the adopted sampling area of 125cm², the area ratio factor (FAr) is equivalent to the division of the area of the piece by the sampled area. Regarding the mass, the pieces were weighed. Considering the mass of the sample of each composition, the mass ratio factor (FMr) is also equivalent to the division of the mass of the piece by the sampled mass.

Thus, the ratio factor (RF) of each composition corresponds to the weighting of the arithmetic mean between area and mass (Table 2), where: FAr – area ratio factor between piece/sample; FMr - mass ratio factor between piece/sample.

Table 2 – Piece/sample ratio factor

Composition	**Piece área (cm²)**	**FAr**	**Piece mass (g)**	**FMr**	**RF**
PA	8250	66.0	100.235	57.3	61.7
PAC	6846	54.8	207.173	51.9	53.4
PES	5644	45.2	115.432	63.2	54.2

Source: Authors' collection

Using the RF as a multiplier to the values found for mass and number of microplastic fibers, the results are extended to one garment unit, as proposed in Equation 2 and Equation 3.

$$M_{MF(piece)} = m_{tMF} \ x \ RF \qquad (2)$$

Where:
$M_{MF(piece)}$ = Estimated mass of microplastic fibers shed by a garment piece (g)
m_{tMF} = Total mass of microplastic fibers quantified per washing (g)

$$N_{MF(piece)} = n_{tMF} \ x \ RF \qquad (3)$$

Where:
$N_{MF(piece)}$ = Estimated number of microplastic fibers shed by a garment piece
n_{tMF} = Total number of microplastic fibers quantified per washing

2.5 Extrapolation of results

In a national estimation of the potential amount of microplastic fibers released annually by domestic washing effluents, the results of the mass of synthetic fibers emitted by a textile article were extrapolated. For this purpose, the number of Brazilian households with washing machines, washing frequency, and the number of items washed were considered.

The frequency corresponds to a national average of 3.5 washings per week (DUPONT, 2013). The number of pieces washed was arbitrated as 15 pieces per wash, 5 of each composition studied. The mass detached per piece was considered as the arithmetic mean of the results obtained from the five washings. In addition, the 52 weeks that comprise a year were considered.

The calculation presents the estimated mass of microplastic fibers emitted annually by a single washing machine (Equation 4). It was considered that in Brazil only 49.1% of sewage is treated (BRASIL, 2019), and WWTPs have a removal efficiency of 90% for particles larger than 10μm (LI *et al*., 2018). There is also total of 41,601,000 washing machines in the country, according to statistical data from the Brazilian Institute of Geography and Statistics (IBGE, 2015).

$$M_{MF(year)} = \frac{\left(\bar{M}_{MF(PA)} + \bar{M}_{MF(PAC)} + \bar{M}_{MF(PES)}\right) x\ 5\ x\ 3.5\ x\ 52\ x\ 0.558}{1000} \quad (4)$$

Where:
$M_{MF(year)}$ = Estimated mass of microplastic fibers shed by a washing machine in one year (kg/year);
$\bar{M}_{MF(x)}$ Average mass of microplastic fibers shed per article of a given composition (g).
Note: The term 0.558 refers to 50.9% of untreated sewage, plus 10% of particles that are not retained in the treated fraction.

3 RESULTS AND DISCUSSION

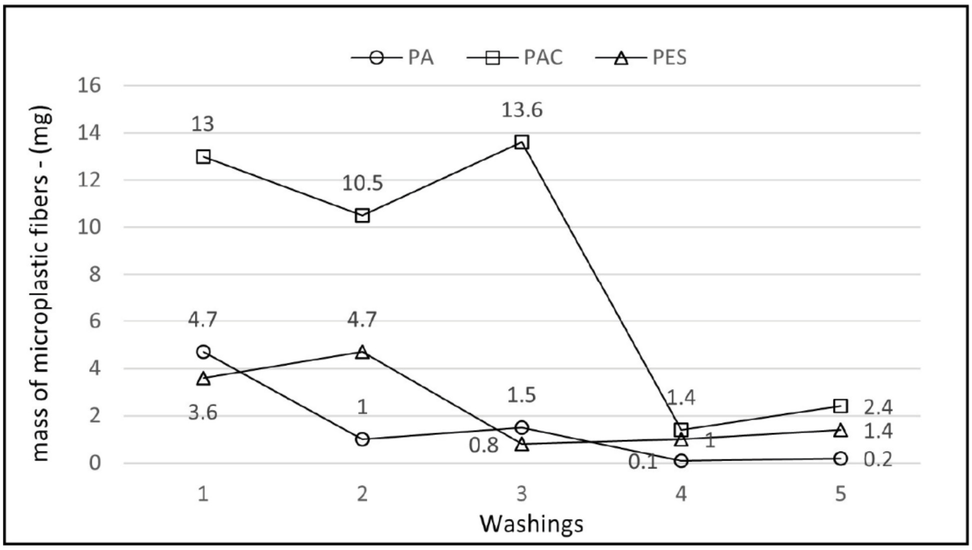
From the selection of the materials of the garments (PA, PAC, and PES), the five washing series were carried out, followed by one drying step each. The use of new samples, without having undergone domestic washing or previous use, allowed the evaluation of the mechanical action on the beginning of the useful life of the pieces and of their release of microplastic fibers.

3.1 Mass of microplastic fibers shed into the effluent

The fibers retained in the glass-fiber filters mostly presented dimensions smaller than 1mm, resulting in a very small mass and difficult to determine by the method used. Therefore, the sum of the masses retained in the two filter media in each washing was considered, making it impossible to present the data separately.

The values found for polyamide (PA), acrylic (PAC), and polyester (PES) samples are presented simultaneously per washing (Figure 1).

Figure 1 – Released mass of microplastic fibers for PA, PAC, and PES samples



Source: Authors' collection

In the washes that occurred with polyamide samples, a single process shed from 0.1mg to 4.7mg mass of microplastic fiber per washing. Considering the five successive cycles, the total detached was 7.5mg, representing 0.42% in relation to the initial mass of the sample (1.7815g).

For washings with acrylic samples, one single process shed from 1.4mg to 13.6mg mass of microplastic fiber per washing. Considering the five cycles, the total shed was 40.9mg, being categorically the highest value among the three compositions. This value represents 1.00% of the mass of the initial sample (4.0722g).

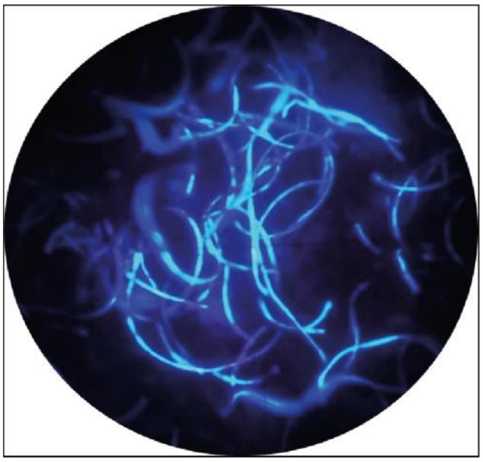
Considering the washings with polyester samples, microplastic fibers in the order of 0.8mg to 4.7mg were shed in one single process. For the five successive processes, the total mass shed was 11.5mg, representing 0.62% in relation to the initial mass (1.8563g).

In all three cases, there was the same tendency for a drop in the mass shed from the first to the fifth washing, with a noticeable tendency of higher values in the first three processes, decreasing after this period. However, PA samples clearly showed the highest value in the first washing.

3.2 Quantifying microplastic fibers released in the effluent

The observation of the filter media under a fluorescence microscope allowed the quantification of the number of particles released in the washing effluent. It is important to highlight that the values are absolute and refer to particles retained in the second filter (glass-fiber), not considering the fragments retained in the first filter (paper). One of these paper filters, observed at random (Figure 2), confirmed the existence of particles larger than the object of study (5mm), as well as the impossibility of applying the method of quantification. However, given the irregular shape of the particles and random orientation, the existence of smaller particles trapped between larger particles is not ruled out.

Figure 2 – Fiber entanglement in the first filter medium (paper filter)

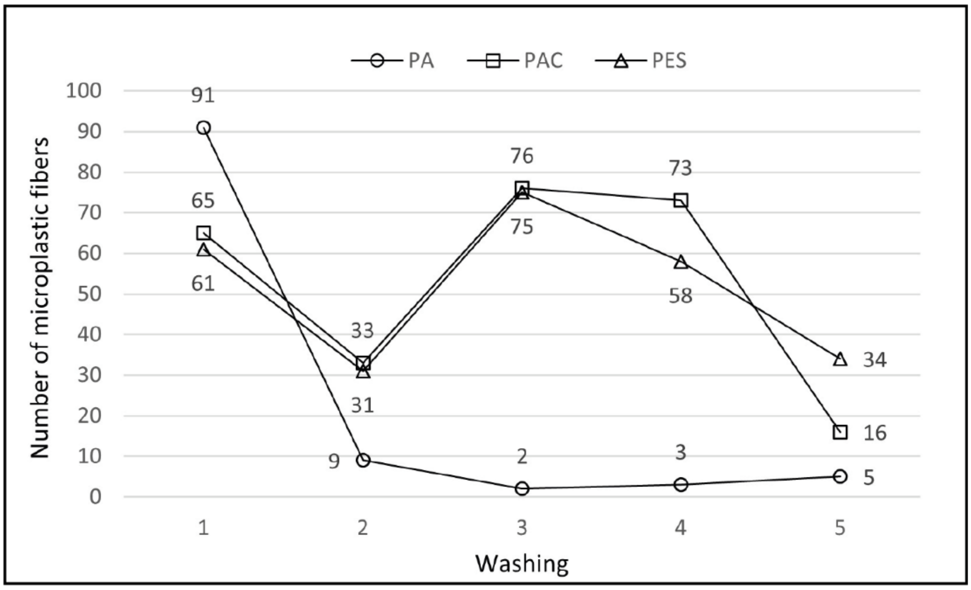


Source: Authors' collection

The amounts of microplastic fibers found in glass-fiber filters are shown in Figure 3.

One washing with polyamide samples shed from 2 to 91 microplastic fibers. In five washings, the total detached was 110 fibers, the smallest amount among the analyzed samples. Regarding lengths, fragments from 21.3µm to 1.56mm were found. When observed with light in the UV range after dyeing with NR, the fragments showed a pinkish color (Figure 4 - A).

Figure 3 – Number of microplastic fiber particles for PA, PAC, and PES samples



Source: Authors' collection

With acrylic samples, one single process shed 16 to 76 microplastic fibers. In five washes, the total shed was 263 fibers, the largest amount among the analyzed compositions. Regarding the length, fragments from 11.0μm to 3.04mm were found. Under UV light, the microplastic fibers of this composition showed an intense blue color after dyeing with NR (Figure 4 - B).

Finally, considering the washings with polyester samples, one single process shed from 31 to 75 microplastic fibers. In five washings, the total shed was 259 fibers. Under UV light, these fibers showed an intense blue color (Figure 4 - C).

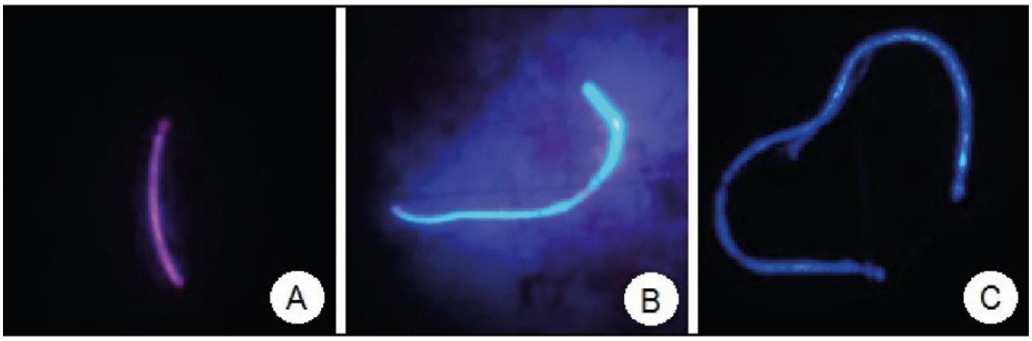
As with the gravimetric method, a decreasing trend of fragments from the first to the fifth washing was also observed in the method of quantification, with a well-defined behavior for PA samples, although presenting a more random behavior until the third cycle for PAC and PES samples.

Regarding the variations in colorimetry between materials, according to Maes *et al*. (2017), these differences are related to the ‘polarity’ of the polymer surface and the solvatochromic properties of NR. The fluorescence emission spectrum changes as the polarity of the solvent increases. The authors investigated the potential of this solvatochromic response in plastic particles known, dyed, and photographed. From the values obtained, a ‘fluorescence index’ was created, represented by the ‘polarity’ of the polymer surface. These values were then plotted against values found in the literature for the static contact angle in these polymers, showing a clear trend of a relationship between polymer surface polarity and the fluorescent color of the NR.

In relation to other studies with results referring to experiments in laboratory equipment, Almroth *et al*. (2017) used pieces of fabric with an area of 100cm², finding from 9 to 1210 units of microplastic fibers, depending on the type of textile composition and the use of detergents. On the other hand, this study used an area of 125cm² and found from 2 to 91 units. Thus, with a ratio of 0.8 (100/125), the total shed is equivalent to 2 to 73 units of microplastic fibers, respectively. These values are conservative when compared. However, it should be noted that Almroth *et al*.

(2017) did not use commercial pieces of clothing to extract the samples and the washings were conducted in a Gyrowash machine in their research, which according to the authors adds mechanical impact to the washing.

Figure 4 – Microplastic fibers observed with light in the UV range after dyeing with Nile Red



Source: Authors' collection

Regarding the evaluation of the two control samples, when the gravimetric method was applied, the variation in mass was null (zero). When the scanning using the fluorescence microscope was performed, only one particle (approximately 50μm) was detected in the glass-fiber filter, showing a satisfactory result with perceptions that are not capable of compromising the results.

Finally, the visualization of the glass-fiber filters (1.2 μm) indicated the presence of fragments smaller than 10 μm, also suggesting that the liquid that has passed through this filtration may contain particles smaller than those recorded, including nanometric particles.

3.4 Quantification of the number of microplastic fibers per piece of fabric

We established an estimate of the mass and number of microplastic fibers emitted by an entire garment based on the total masses and measurements of the articles that originated the samples. Applying the reference factor (RF) in each case, Table 3 shows the estimated values for mass and number of microplastic fibers from each composition, besides the average values for mass and number of microplastic fibers considering five washings.

Table 3 – Calculation of microplastic fibers per piece of fabric

Washing	PA (RF = 61.7)		PAC (RF = 53.4)		PES (RF = 54.2)	
	Mass (mg)	Number	Mass (mg)	Number	Mass (mg)	Number
1	290	5615	694	3471	195	3306
2	62	555	561	1762	255	1680
3	93	123	726	4058	43	4065
4	6	185	75	3898	54	3144
5	12	309	128	854	76	1843
Total	463	6787	2184	14043	623	14038
Average	92.6	1357.4	436.8	2808.6	124.6	2807.6

Source: Authors' collection

Thus, the quantifications indicate the prevalence of values in the hundreds to thousands of microplastic fibers for one single garment. If the five washings are added, acrylic was the article that presented the greatest polluting potential in units (14043) and in mass (2184mg). This fact can be associated with the type of weaving and not only with the material, since Almroth *et al*. (2017) found that knitted fabrics tend to release more fibers compared to woven fabrics in general. However, the value found is lower than that obtained by the authors, who estimated more than 110,000 fragments in just one single washing, although being a higher value than the 1900 microplastic fibers determined by Browne *et al*. (2011).

A polyamide article can emit more than 5600 synthetic particles in the first washing. The fact that they are mostly concentrated in the first process (66%) presents an interesting possibility of mitigating the contribution of microplastics to the environment, regarding proposing the implementation of control measures and adequate pre-treatment of these particles still in the industry, potentially reducing the amount of fibers released into the environment during the use phase. The polyester article, despite not appearing in both extremes, also demonstrates emissions in significant quantities.

3.5 Extrapolation of results

Considering washings only with the articles in question, we established a perspective on the mass of microplastic fibers emitted annually on a national scale. Using the average values per article shown in Table 3 (PA = 92.6×10^{-3}g, PAC = 436.8×10^{-3}g, and PES = 124.6×10^{-3}g) applied in Equation 4, a domestic washing machine is capable of shedding microplastic fibers in the order of 0.332 kg/year. Considering the 41,601,000 washing machines in the country (IBGE, 2015), approximately 13,800 ton/year of microplastic fibers can be released into waterways.

In any case, these numbers must be observed in a conservative manner, as a regular washing can contain well over 15 pieces, besides articles with varied compositions, consisting of two or more synthetic fibers or even mixed with natural fibers. On the other hand, Equation 4 takes into account the fact that 49.1% of the country's sewage is treated with a 90% capacity to remove these particles, and this efficiency was not verified in practice. Moreover, as the samples originated from larger pieces, the effects of fabric edges should be evaluated as vectors in the propagation of fibers.

Regarding washing parameters, Henry *et al*. (2019) stated that the shedding of fibers is greater in top load (vertical axis) washing machines than in front load (horizontal axis) washing machines. In addition, according to Cesa *et al*. (2017), mechanical and chemical factors are important principles of the washing dynamics. Regarding the use of detergents, Browne *et al*. (2011) suggested the exploration of this issue, as the effect of detergents on fiber shedding needs further investigation.

It is important to highlight the importance of continuing research to evaluate the behavior of these articles during washing regarding the shedding of microplastic fibers.

4 CONCLUSIONS

This study investigated the shedding of microplastics during the domestic activity of washing synthetic fabrics. Therefore, the washing effluent of the three following different compositions was analyzed: PA, PAC, and PES. The main conclusions are:

- The fabrics studied proved to be potentially responsible for the contribution of microplastics to the environment;

- The different synthetic textiles shed unequal amounts of fibers, as well as decreasing the shedding amount along the washings;

- Acrylic was the composition that showed the greatest polluting potential;

- Polyamide shed 66% of the microplastic fibers in the first washing, inferring the possibility of controlling these fragments even in the industry;

- There was high intermittence related to the length of microplastic fibers, ranging from 11.0μm to 3.04mm;

- The extrapolated results (limited number of factors explored) estimate approximately 13.8 thousand tons of synthetic debris dumped annually in water resources only in Brazil;

- Some particles presented a very small area at the type of magnification used (10X), suggesting the existence of nanoparticles (< 1 μm).

REFERENCES

ALLEN, AUSTIN S.; SEYMOUR, ALEXANDER C.; RITTSCHOF, DANIEL. Chemoreception drives plastic consumption in a hard coral. **Marine Pollution Bulletin**, [s.l.], v. 124, n. 1, p.198-205, nov. 2017. Elsevier BV. http://dx.doi.org/10.1016/j.marpolbul.2017.07.030.

ALMROTH, BETHANIE M. CARNEY; ÅSTRÖM, LINN; ROSLUND, SOFIA; PETERSSON, HANNA; JOHANSSON, MATS; PERSSON, NILS-KRISTER. Quantifying shedding of synthetic fibers from textiles; a source of microplastics released into the environment. **Environmental Science And Pollution Research**, [S.L.], v. 25, n. 2, p. 1191-1199, 28 out. 2017. Springer Science and Business Media LLC. http://dx.doi.org/10.1007/s11356-017-0528-7.

BRASIL. Ministério do Desenvolvimento, Indústria e Comércio Exterior. Conselho Nacional de Metrologia, Normalização e Qualidade Industrial – CONMETRO. Resolução nº02, de 6 de maio de 2008. Dispõe sobre a aprovação do Regulamento Técnico Mercosul sobre etiquetagem de produtos têxteis. Diário Oficial da República Federativa do Brasil, Brasília, DF, 09 maio 2008, Seção 1, p.77-79.

BRASIL. Ministério do Desenvolvimento Regional. Sistema Nacional de Informações sobre Saneamento– SNIS: Diagnóstico dos Serviços de Água e Esgotos – 2019 Brasília, 2019, p. 62. Disponível em: http://www.snis.gov.br/downloads/diagnosticos/ae/2019/Diagn%c3%b3stico%20SNIS%20AE_2019_Republicacao_04022021.pdf. Acesso em: 4 de ago. 2021.

BROWNE, MARK .A., CRUMP, P., NIVEN, S.J., TEUTEN, E., TONKIN, A., GALLOWAY, T., THOMPSON, R.,. Accumulation of microplastic on shorelines worldwide: Sources and sinks. **Environmental Science & Technology**, [s.l.], v. 45, n. 21, p.9175-9179, nov. 2011. American Chemical Society (ACS). http://dx.doi.org/10.1021/es201811s.

CAIXETA, DANIELA; CAIXETA, FREDERICO; MENEZES FILHO, FREDERICO. Nano e microplásticos nos ecossistemas: impactos ambientais e efeitos sobre os organismos. **Enciclopédia Biosfera**, [s.l.], v. 15, n. 27, p.19-34, 20 jun. 2018. Centro Cientifico Conhecer. http://dx.doi.org/10.18677/encibio_2018a92.

CARR, STEVE A. Sources and dispersive modes of micro-fibers in the environment. **Integrated Environmental Assessment And Management**, [s.l.], v. 13, n. 3, p.466-469, 25 abr. 2017. Wiley. http://dx.doi.org/10.1002/ieam.1916.

CESA, FLAVIA SALVADOR; TURRA, ALEXANDER; BARUQUE-RAMOS, JULIA. Synthetic fibers as microplastics in the marine environment: A review from textile perspective with a focus on domestic washings. **Science Of The Total Environment**, [s.l.], v. 598, p.1116-1129, nov. 2017. Elsevier BV. http://dx.doi.org/10.1016/j.scitotenv.2017.04.172.

CLAESSENS, MICHIEL *et al*. New techniques for the detection of microplastics in sediments and field collected organisms. **Marine Pollution Bulletin**, [s.l.], v. 70, n. 1-2, p.227-233, maio 2013. Elsevier BV. http://dx.doi.org/10.1016/j.marpolbul.2013.03.009.

COLE, MATTHEW *et al*. Isolation of microplastics in biota-rich seawater samples and marine organisms. **Scientific Reports**, [s.l.], v. 4, n. 4528, 31 mar. 2014. Springer Science and Business Media LLC. http://dx.doi.org/10.1038/srep04528.

COSTA, J. P., SANTO, P. S. M., DUARTE, A. C., ROCHA-SANTOS, T. (Nano)plastics in the environment – Sources, fates and effects. **Science Of The Total Environment**, [s.l.], v. 566-567, p.15-26, out. 2016. Elsevier BV. http://dx.doi.org/10.1016/j.scitotenv.2016.05.041.

CYTIVA, LIFE SCIENCES. Whatman filter paper grade GF/C. Disponívelem: https://www.cytivalifesciences.com/en/br/shop/whatman-laboratory-filtration/glass-and-quartz-microfiber-filter/binderless-glass-microfiber-filter/whatman-filter-paper-grade-gf-c-microfiber-glass-filter-binder-free-p-09618#tech-spec-table. Acesso em: 19 out. de 2020.

DIAS, SILVIO LUIS PEREIRA *et al*. Química analítica: teoria e prática essenciais. Porto Alegre: Bookman, 2016.

DRIS, RACHID; GASPERI, JOHNNY; MIRANDE, CÉCILE; MANDIN, CORINNE; GUERROUACHE, MOHAMED; LANGLOIS, VALÉRIE; TASSIN, BRUNO. A first overview of textile fibers, including microplastics, in indoor and outdoor environments. **Environmental Pollution**, [S.L.], v. 221, p. 453-458, fev. 2017. Elsevier BV. http://dx.doi.org/10.1016/j.envpol.2016.12.013.

DUPONT©. Brazil laundry habits & attitudes, TNS, January 2013. Disponível em : http://fhc.biosciences.dupont.com/fileadmin/user_upload/live/fhc/FHC_DuPontBrazilLaundryinfographic.pdf. Acesso em: 17 ago. 2019.

EERKES-MEDRANO, DAFNE; LESLIE, HEATHER A.; QUINN, BRIAN. Microplastics in drinking water: a review and assessment. **Current Opinion In Environmental Science & Health**, [S.L.], v. 7, p. 69-75, fev. 2019. Elsevier BV. http://dx.doi.org/10.1016/j.coesh.2018.12.001.

EERKES-MEDRANO, DAFNE; THOMPSON, RICHARD C.; ALDRIDGE, DAVID C.. Microplastics in freshwater systems: a review of the emerging threats, identification of knowledge gaps and prioritization of research needs. **Water Research**, [S.L.], v. 75, p. 63-82, maio 2015. Elsevier BV. http://dx.doi.org/10.1016/j.watres.2015.02.012

HENRY, BEVERLEY; LAITALA, KIRSI; KLEPP, INGUN GRIMSTAD. Microfibres from apparel and home textiles: Prospects for including microplastics in environmental sustainability assessment. **Science Of The Total Environment**, [s.l.], v. 652, p.483-494, fev. 2019. Elsevier BV. http://dx.doi.org/10.1016/j.scitotenv.2018.10.166.

INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA. Séries históricas e estatísticas, 2015. Disponível em: https://seriesestatisticas.ibge.gov.br/series.aspx?no=6&op=0&vcodigo=PD280&t=domicilios-particulares-permanentes-posse-maquina-lavar. Acesso em: 24 de out. de 2019.

KOSUTH, MARY; MASON, SHERRI A.; WATTENBERG, ELIZABETH V.. Anthropogenic contamination of tap water, beer, and sea salt. **Plos One**, [s.l.], v. 13, n. 4, 11 abr. 2018. Public Library of Science (PLoS). http://dx.doi.org/10.1371/journal.pone.0194970.

LI, JINGYI; LIU, HUIHUI; CHEN, J. PAUL. Microplastics in freshwater systems: A review on occurrence, environmental effects, and methods for microplastics detection. **Water Research**, [s.l.], v. 137, p.362-374, jun. 2018. Elsevier BV. http://dx.doi.org/10.1016/j.watres.2017.12.056.

MAES, THOMAS; JESSOP, REBECA; WELLNER, NIKOLAUS; HAUPT, KARSTEN; MAYES, ANDREW G. A rapid-screening approach to detect and quantify microplastics based on fluorescent tagging with Nile Red. **Scientific Reports**, [s.l.], v. 7, n. 1, 16 mar. 2017. Springer Nature. http://dx.doi.org/10.1038/srep44501.

MASON, SHERRI A.; WELCH, VICTORIA G.; NERATKO, JOSEPH. Synthetic Polymer Contamination in Bottled Water. **Frontiers In Chemistry**, [s.l.], v. 6, p.2-17, 11 set. 2018. Frontiers Media SA. http://dx.doi.org/10.3389/fchem.2018.00407.

MATTSSON, KARIN *et al*. Altered Behavior, Physiology, and Metabolism in Fish Exposed to Polystyrene Nanoparticles. Environmental Science & Technology, [s.l.], v. 49, n. 1, p.553-561, 9 dez. 2014. American Chemical Society (ACS). http://dx.doi.org/10.1021/es5053655.

REVEL, MESSIKA; CHÂTEL, AMÉLIE; MOUNEYRAC, CATHERINE. Micro(nano)plastics: a threat to human health?.**Current Opinion In Environmental Science & Health**, [S.L.], v. 1, p. 17-23, fev. 2018. Elsevier BV. http://dx.doi.org/10.1016/j.coesh.2017.10.003.

THOMPSON, RICHARD C. *et al*. Plastics, the environment and human health: current consensus and future trends. **Philosophical Transactions Of The Royal Society B**: Biological Sciences, [s.l.], v. 364, n. 1526, p.2153-2166, 27 jul. 2009. The Royal Society. http://dx.doi.org/10.1098/rstb.2009.0053.

ZIAJAHROMI, SHIMA *et al*. Wastewater treatment plants as a pathway for microplastics: Development of a new approach to sample wastewater-based microplastics. **Water Research**, [s.l.], v. 112, p.93-99, abr. 2017. Elsevier BV. http://dx.doi.org/10.1016/j.watres.2017.01.042.

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