TEXTILE MICROPLASTICS: A CRITICAL OVERVIEW

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ABSTRACT

This paper presents an overview of the protocol developed by LEITAT for identification and quantification of released microfibres (microfibres shedding) from textiles in washing processes. Sampling, washing, filtering and quantification methods are described. Research has been carried out on the processing steps of the textile chain value that might affect microfibres release from textiles. Based on this, new strategies based on spinning processes, mechanical and chemical solutions have been pointed out as technological solutions for microfibre release.

Key Words: MICROPLASTICS, MICROFIBERS, TEXTILE SHEDDING, PROTOCOL.

1. INTRODUCTION

Concern about the presence of microplastic particles (MPs) and their effect on the environment and human health is increasing among scientists, policy makers and the society. It is generally accepted that a microplastic is a solid polymeric material with some of their dimensions being less than 5 millimeters that is: i) persistent in the environment (i.e. non-biodegradable) ; ii) bioaccumulative; iii) a vector of contaminants and microorganisms (i.e. biofouling); and iv) potentially trophic transferable. However, a more consistent and harmonized definition of microplastics was made and included by the European Chemicals Agency in their proposal for restriction of intentionally added microplastics. The definition states that *"a microplastic is a material consisting of a solid polymer-containing particles, to which additives or other substances may have been added and where approximately ≥ 1% w/w of particles have all dimensions between 1 nm and 5 mm, or in the case of fibres a length between 3 nm and 15 mm and a length to diameter ratio of > 3"* [1-2]. Within this definition, polymers that occur in nature that have not been chemically modified (other than by hydrolysis) are excluded, as are polymers that are (bio)degradable.
Microplastics can be classified according to their nature (e.g. synthetic polyester, polyamide, polyolefin), location (i.e. water such as wastewaters and ocean, soil and air), the product where they are released from (e.g. car tyres, textile washing processes, microbeads in cosmetics), or their origin (i.e. intentionally added or unintentionally added). In the context of the European Strategy for Plastics [3] as a part of the transition towards a more circular economy, the EC [4] together with the ECHA [5] are currently looking at scientific evidence for all intentionally-added microplastics. They are studying scientific-technical information and consulting stakeholders in order to define the scope of potential restriction on intentional uses of microplastics. Microplastics released from textiles (microplastics shedding) are considered unintentionally added microplastics. Therefore, they are not being considered in the scope of the next legislation in Europe. Synthetic textiles and clothing are a large source of microplastic pollution [6]. They are released due to textile abrasion during laundry and to their exposure to chemicals and detergents, causing the breakdown of synthetic fibers into smaller microfibers [7].
Although more knowledge and evidences of environmental in toxicological impact associated to textile microplastics are required [8-9], the interest from the textile industry in the evaluation

of microplastics released from textiles is increasing. Potential new microplastic-related ecolabels are also demanded. Similar trends have been observed worldwide, being particularly significant in the USA and in Japan.
In this scenario, LEITAT driven by its commitment to circular economy is being participating in different projects [10-13] and initiatives [14] focused on microplastics and microfibers. During the MERMAIDS project, a protocol in collaboration with Italian National Research Council (CNR) was developed firstly, for identifying and quantifying released microfibres from textiles (microfibers shedding) during industrial and domestic washing processes and secondly, for better understanding the parameters influencing microfiber shedding. Scientists across Europe and worldwide have also studied microfibers shedding from textiles using their own methods. However, since there is no standardized protocol, measurement parameters such as sampling, sample pre-treatment, washing conditions among others, vary from study to study and the amount of shed fibers do too. This scenario has led to the need for developing standardized protocol to be used for scientists and industry from the EU community in order to determine the magnitude of the problem, identify the main parameters affecting shedding, propose mitigation strategies and evaluate their effectiveness. As a result, the evaluation protocol derived from the MERMAIDS EU project [4], and others are currently under harmonization in Europe through several initiatives. In this regard, this article presents an overview of the protocol, effects of sampling, washing, filtering and quantification methods have been evaluated with the aim to set up a harmonized reproducible protocol that represents the effects of textile microplastics released into the environment. The potential generation of microplastics in different processing steps from the textile value chain (fibre, yarn, fabric, preparation, dyeing and finishing processing) is presented. Finally, the effect of several technological solutions based on textile structures, mechanical and chemical finishing are evaluated and discussed.

2. RESULTS AND DISCUSSION

2.1. Sampling, washing, filtering and quantification methods.

The following is a description of the protocol for identification and quantification of released microfibers from fabric pieces during the laundry process. This protocol was developed during the MERMAIDS project which has been used in other national and industrial projects as well as in other initiatives with some adaptations. Among the synthetic plastics, polyester, polyamide, polyacrylic and polypropylene, are known to be the main sources of microplastics.

2.1.1. Sampling. Polyester textiles with different constructions (i.e. continuous and staple fibers) were tested in the MERMAIDS project since it is the most abundant synthetic material [15] in the textile sector and its use has increased over the last year and is forecasted to be exponentially increased [16]. Additionally, LEITAT is working in other projects also evaluating other fibre types such as polypropylene and polyamide, among others.
Textile specimens are commonly used to study textile shedding at laboratory scale where domestic washing is mimicked with a simulator and following common standards used for wash fastness. Garments can be also used for studying domestic practices using washing machines. Sample preparation is an important parameter that might impact fiber loss in such a way that this might be underestimated or overestimated. Samples are prepared by cutting textile specimens with scissors and sealing the new edges with either a wielding machine (for 100% synthetic textiles) or sewing with a cotton thread (for 100% synthetic or blends, i.e. textile made of 50% cotton and 50% of polyester fibres). The shape of the samples can be square or

rectangular, being the rectangular shape the most useful for increasing the weight of the sample thus increasing the amount of microfibre loss since it has been proven that the higher the weight of the sample specimen the higher the fibre release. Higher fibre release will provide replicability and accuracy of the data obtained. Sample specimens are prepared and tested in triplicate.

2.1.2. Washing. Washing of fabric pieces is conducted using a Linitest or Gyrowash apparatus for simulating laundry conditions with mechanical stress and friction. Both can operate in domestic, following the standard "ISO 105-C06:2010" and industrial conditions following the "standard ISO 105-C12:2010", using different setting parameters. Sealed textile samples are placed into stainless steel vessels containing the liquor, meaning by liquor a specific amount of water plus a dose of detergent. For domestic washing, a liquor ratio 1:150 wt%/vol is commonly used which means that 150 mL of liquor is used per 1g of textile. Regarding detergent it has been proven that the presence of detergent lead to higher release of fibres compared to those trials performed without detergent (when only water is used) [17]. The release is even greater when using solid detergent compared to liquid detergent. The use of detergent is still a controversial parameter still to be determined since some authors claim its non-use due to its low solubility and therefore its tendency to remain on the filter as a thick layer embedding partially or completely the microfibres, thus being a source of error when conducting gravimetric analysis.
Stainless steel balls are also used and placed into the vessels for providing mechanical friction. The containers are then sealed and placed into whichever machine is used (Linitest or Gyrowash) and the chosen programme, domestic or industrial is conducted. The results obtained for the washed fabrics are then used for correlating fabric characteristics and/or washing conditions/laundry products with the extent of microfibres release.

2.1.3. Filtering. The liquor obtained from the domestic or industrial washings is then filtered using a common filtration set up which includes a funnel, a Buchner funnel, vacuum pump and a filter. Different filters with different chemical nature have being tested including cellulose, PVDF, polyamide and glass fiber filters as well as several pore sizes ranging between 20 and 1.6 µm. Due to the tendency of the filters to uptake moisture, a previous process of drying is followed prior to filtration. The filters are dried out in an oven at 105 °C for 22h and their weight before its use is recorded. Filtration step includes, filtering the liquor, rinsing the washed textile sample with 250 mL of distilled water for removal of the released fibres that might have been got adhered on the textile surface, and filtering two times the wastewaters. Finally, the filter with the collected and deposited fibres is dried out in an oven at 105 ºC for 22h for its evaluation afterwards.

2.1.4. Quantification methods. Gravimetric and optical analysis are the methods used for quantification. *Gravimetric analysis* involves weighting the filters with the deposited fibres and calculating by weight difference the weight of the fibres. The results are then expressed as grams of released textile fibres per grams of textile sample specimen. This method is very reproducible when using PVDF, polyamide or glass fiber filters with polyester textiles. However, when using cellulose filters due to its tendency to rapidly uptake water the weight results become altered. *Optical analysis* consists on taking images of already stablished specific areas of the filter and using a contrast image software for calculating the area of microfibres occupied by microfibres per total textile area. This method presents the disadvantage of taking 22 micrographies and and processing and modifying their contrast and color intensity characteristics for fibre evaluation which is done by area occupied of fibres per area of the image.

Harmonized protocol. LEITAT together with other experts are conducting work and sharing expertise on the identification and quantification of microfibres during the last year within two different frameworks, the Cross Industry Agreement lead by the EURATEX [10] and the TEXTRANET framework, both initiatives focused on developing a harmonized protocol for quantification and identification of microfibres shed from fabric pieces at laboratory scale and for garments at domestic scale, respectively.

2.2. Potential generation of microplastics in the different processing steps. Technological solutions based on textile structures and other approaches.

Fibre type (extruded filaments or wound staples), fabric structure (woven, knitted or non-woven), washing conditions (temperature, detergent/surfactant, length of washing, multiple washes) presence of finishing (acrylic, polyurethane, silicone finishing or coating) and specific size distributions and masses of fibres shed during the process are some of the factors influencing on fibre shedding. Studies conducted with washed garments point out that the characteristics of loose fibres, fabric composition, garment construction, presence of insulation in garments such as jackets are all likely to influence fibre shedding during washing.

2.2.1. Shedding occurring at several different parts in the value chain. Microfibre release from textiles can occur at different parts in the textile value chain which includes raw material extraction, materials processing, yarn preparation and fibre production (spinning, twisting), fabric production (weaving, knitting, dyeing and finishing, printing, washing and drying, tumble drying, ironing), apparel production (cutting, sewing), make-up and retailing, transport (logistics and distribution) and use (retail and sales). The steps concerning yarn preparation, fibre, fabric and apparel production with all the involved stages seems to be the most influencing ones which include dyeing and finishing as well as drying. During these mentioned processes mechanical stresses produced on yarn/filament and even fabrics might lead afterwards to microfiber shedding. Fibre breakage capacity of textile products depends on various factors, their spinning and weaving/knitting process and the different mechanical treatments that have been applied on the fabric during and after its production.

2.2.2. Fibre type and textile structures.
Fibre type such as continuous and staple fibres have been found to present different shedding effect. In the MERMAIDS project it was studied the impact of having continuous or staple fibres in a textile, and it was found that continuous fibres of polyester with low hairiness characteristics resulted in a lower release of microfibres than those polyester textiles but also polypropylene textiles presenting staple fibres having high hairiness. So that shorter staple fibres cannot be easily wrapped into the yarn and could easily slip away from the yarn during the wash, leading to a higher microfibre release. Hairiness was also obtained when low twist fibres produced during weaving and knitting processes were studied [18-19], but it is also formed after conducting finishing processes and when handling. On one hand, it should be taken into account that fibres providing resistance and elasticity will promote higher twist values and this will be in benefit of less wrinkle formation. On the other hand, high twist values cannot be desired due to the decrease of the softness of the fabric. A high yarn count (fibres per yarn) means more fibres into the yarn cross section and more probability for them to protrude to its surface.

Pilling phenomenon. The main factor of loss of fibres from a textile is pilling, phenomenon that happens particularly for knitted fabrics, which consists on entangled fibres on the textile surface and thus the formation of fibre balls or pills during the processes like washing and wearing.

2.2.3. Washing conditions.

Softening and Bleaching agents were found to confer a mitigating effect on the number of microfibres released by the fabrics probably due to the reduction of the friction between fibres.

2.2.4. Mechanical Finishing

There are mechanical processes that are carried out as finishing processes that are responsible for microfibres shedding. For example, raising is a process that gives special insulating effect by mechanically lifting the fibres up to the surface and forming a dense layer on the textile. Due to the lifting of the fibers up to the surface propensity to pilling is promoted and therefore microfibre shedding after washing and overtime with wear occurs.

2.3. Solutions.

2.3.1. Spinning processes. Synthetic fibres such as polyester, polyamide or polypropylene are continuous fibres obtained from extrusion process which can be cut or not into smaller fibres. From these process, monofilament, short fibres multifilament or continuous filament yarns can be produced. In this regard, mitigation practices will include selecting continuous fibres, or short fibres with adequate length that allow reducing the propensity to form hairiness and pilling and therefore decreasing the probability to shed from the textile.

2.3.2. Mechanical processes. There are also mechanical processes such as *singeing* and *calendaring* that act in such a way that eliminate the protruding fibres of the fabric by burning the surface of the fabric or by applying pressure on the fabric between two hot rolls, respectively.

2.3.3. Chemical finishing.

Finishing and/or coatings such as silicones, polyurethane, acrylic polymers, among others, are commonly applied on textiles for conferring functional or aesthetic properties but they can also be employed for reducing microfibre shedding from textiles. Chemical finishing will easily cover the surface and act as protective layer. On one hand, research for evaluating the mitigating effect of several common finishing formulations on the microfibre shedding from textiles has been carried out successfully[10]. On the other hand, adaptation of chemical finishing formulations for minimizing the release of microfibres in washing processes is still under research[13]. The capability of the treatment to fix the protruding fibres and avoiding shedding will depend on the chemical agent applied and its linkage with the textile surface.

3. CONCLUSIONS

In this paper, an overview of the protocol used in MERMAIDS and used in other projects and initiatives with some adaptations has been described. This protocol and the expertise from LEITAT have been shared in the EURATEX and TEXTRANET initiatives for developing a harmonized protocol, a future standard for textile fibre loss, which will allow the identification and quantification of fibres loss from textiles, but most importantly for better understanding the characteristics that most influence microfibre shedding from textiles. Microfibres shedding from textile is an issue that textile industry should manage through the whole supply chain of textile industry, including fabric design and processes. In this regard, the protocol will also help to identify all and the most important processes of the textile value chain contributing the most to microfiber shedding with the aim to propose strategic solution for mitigating and reducing microfiber release from textiles. In last instance, an ecolabel could be created in order to raise awareness, so clothes could be labelled depending on their fiber loss.

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