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# Evaluation of microplastic release caused by textile washing processes of synthetic fabrics☆

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## ABSTRACT

A new and more alarming source of marine contamination has been recently identified in micro and nanosized plastic fragments. Microplastics are difficult to see with the naked eye and to biodegrade in marine environment, representing a problem since they can be ingested by plankton or other marine organisms, potentially entering the food web. An important source of microplastics appears to be through sewage contaminated by synthetic fibres from washing clothes. Since this phenomenon still lacks of a comprehensive analysis, the objective of this contribution was to investigate the role of washing processes of synthetic textiles on microplastic release. In particular, an analytical protocol was set up, based on the filtration of the washing water of synthetic fabrics and on the analysis of the filters by scanning electron microscopy. The quantification of the microfibre shedding from three different synthetic fabric types, woven polyester, knitted polyester, and woven polypropylene, during washing trials simulating domestic conditions, was achieved and statistically analysed. The highest release of microplastics was recorded for the wash of woven polyester and this phenomenon was correlated to the fabric characteristics. Moreover, the extent of microfibre release from woven polyester fabrics due to different detergents, washing parameters and industrial washes was evaluated. The number of microfibres released from a typical 5 kg wash load of polyester fabrics was estimated to be over 6,000,000 depending on the type of detergent used. The usage of a softener during washes reduces the number of microfibres released of more than 35%. The amount and size of the released microfibres confirm that they could not be totally retained by wastewater treatments plants, and potentially affect the aquatic environment.

## 1. Introduction

Marine contamination caused by plastics debris represents a global problem that has become particularly relevant in recent years, due to the direct impact these pollutants have on the environment (Gall and Thompson, 2015), or to their potential effects on human health (Bouwmeester et al., 2015). Several scientific studies have shown that plastics dominate the waste found in oceans and inland waters (Derraik, 2002; Barnes et al., 2009). The United Nations Environment Programme, UNEP, estimates that up to 18,000 pieces of plastic debris are floating on every square kilometre of ocean (Eriksen et al., 2014). Plastic fragments can be found across the Southwest Pacific in surprisingly high quantities, even in remote and non-industrialised places such as Tonga, Rarotonga and Fiji (Gross, 2015; Gregory, 2009). The durability and slow rate of degradation allow these fragments, constituted by synthetic polymers, to withstand the ocean environment for years to decades or longer (Sudhakar et al., 2007a,b; Shaw and Day, 1994). It is considered that (with the exception of materials that have been

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incinerated) all the conventional plastics that have ever been introduced into the environment do not degrade, becoming smaller in size as a result of abrasion, weathering, and fragmentation (Thompson et al., 2005). Moreover, many studies suggest that wind, wave action, and density of plastic influence the spread of these fragments (Thompson et al., 2004; Browne et al., 2010).

Microplastic has been defined as particles smaller than 5 mm (Arthur et al., 2009; Costa et al., 2010). Microplastics have been detected on beaches and in subtidal sediments worldwide (Browne et al., 2010, 2011; de Lucia et al., 2014; Song et al., 2014), and represent a threat for marine biota (Wright et al., 2013; Rochman et al., 2013) since they can be ingested by plankton (Cole et al., 2013) or other marine organisms (Rochman et al., 2015), eventually entering the human food web (Yang et al., 2015). Several studies report that plastics transfer contaminants such as plasticizers (Mathalon and Hill, 2014), dyes (Collard et al., 2015) and flame retardants (Schreder and La Guardia, 2014) to marine environment. Furthermore, these fragments can also adsorb and concentrate organic pollutants that, once ingested by marine fauna, could be transferred to the food chain and potentially reach humans (Rochman et al., 2012; Bakir et al., 2012, 2014). Several sources of microplastics have been identified. Microplastics derive from the deterioration of debris of large dimensions (bags, packaging), or are directly produced for a specific application such as abrasives (sandblasting) or additives for cosmetics (such as microbeads used for skin scrubs) (GESAMP, 2015; Napper et al., 2015). Another source of microplastics is the domestic and/or industrial washing process of synthetic clothes (Zubris and Richards, 2005; Habib et al., 1998; Thompson et al., 2004). In fact, microplastics found in marine sediments showed that the proportions of polyester and acrylic fibres used in clothing is similar to those found in habitats that receive sewage-discharges and sewage-effluents itself (Browne et al., 2011). The release of microplastics from synthetic clothes is caused by the mechanical and chemical stresses that fabrics undergo during a washing process in a laundry machine. Due to their dimensions, a majority of released microfibres cannot be blocked by wastewater treatment plants, reaching in this way seas and oceans (Magnusson and Wahlberg, 2014).

Consequently, in the last years, a strong need has arisen of evaluating and quantifying the effects of the release of microfibres during washings of synthetic clothes. Several approaches have been developed to evaluate the amount of microfibres shed during washings. In particular, by using a gravimetric method, the microfibre release from polyester, acrylic and polyester-cotton jumpers was examined during domestic washing cycles carried out at two temperatures (30 °C and 40 °C) and in presence/absence of a detergent and a fabric conditioner (Napper and Thompson, 2016). A gravimetric method was also applied to evaluate the release of microfibres during washings of polyester jackets or sweaters, either new or mechanically aged. The release was discussed taking into consideration the type of washing machines (top-versus and front-load), the garment brand and age (Hartline et al., 2016). A similar approach was also used to determine the amount of microfibres released from polyester fleece blankets during washings in domestic conditions, in presence of a detergent and a fabric softener (Pirc et al., 2016). In most of the cited works, a conversion formula was used to transfer the gravimetric results into the number of microfibres released.

Therefore, there is still a lack of information on the direct quantification of the microfibres released from standard fabrics due to laundering, and on the correlation of the release with fabric properties. Moreover, the role of washing detergents, in liquid and powder forms, as well as softener, oxidizing and bleaching agents, and parameters such as temperature, time, water hardness and mechanical action, have not been examined yet. The investigation herein reported was performed to assess the influence of several washing parameters, such as those listed above, on microplastic release from different synthetic textiles. In order to reach this main objective, a new procedure was developed to evaluate the microfibre release during washings. Such procedure consists in the filtration of the washing solutions and the analysis of the filters by scanning electron microscopy (SEM). In this way, a direct quantification of the number and the dimension of the microfibres released was obtained. Compared to previous works (Hartline et al., 2016; Napper and Thompson, 2016; Pirc et al., 2016), in addition to the different adopted approach, the present study also differs because it analyses microfibres with very low dimensions. In fact, a filter with a small pore size (5 μm) was used, allowing the detection of microfibres that could escape through filters with a greater pore size (25 μm in Napper and Thompson, 2016; 20 and 330 μm in Hartline et al., 2016; 200 μm in Pirc et al., 2016). Three different synthetic fabrics, woven polyester, knitted polyester and woven polypropylene, were investigated and quantitative information was collected about the amount and dimension of microplastics released during washings simulating domestic conditions. In addition to the results related to fabric type, the effect on microfibre release of different detergents, washing parameters (i.e. temperature, time, water hardness, etc.) and washing conditions (domestic and industrial), was evaluated.

## 2. Materials and methods

**Materials.** Three different commercial standard fabrics (Testfabrics Inc. USA) were selected for the washing experiments: plain weave polyester, double knit jersey polyester and plain weave polypropylene. The fabric type, code and the weight (g/m$^2$) provided by the manufacturer, along with the fibre length, are reported in Table 1.

The identity of each fabric type was confirmed by Fourier Transform Infrared (FTIR) spectroscopy. The spectra are reported in Figs. S1–S3 of the Supporting Information (SI). Untwisted yarns (both warp and weft for woven fabrics), removed from the selected fabrics, were analysed by optical microscopy using a Stereo microscope Lynx S115 (Vision Engineering, UK).

The detergents used in domestic and industrial washing experiments, are listed in Table 2.

**Washing Process**. Washing tests of synthetic standard fabrics were conducted in Linitest apparatus (URAI S.p.A., Assago, Italy), as laboratory simulator of a real washing machine, operating in both domestic and industrial conditions, in order to correlate fabric characteristics and/or washing conditions/laundry products with the extent of microfibres released. A detailed description of the Linitest apparatus is reported in the SI.

In particular, simulations of domestic washing tests were performed according to the ISO 105-C06:2010 standard method used for testing the colour fastness of textiles to domestic and commercial laundering, using the liquor ratio (liquor:specimen) 150:1 vol/wt, corresponding to 150 mL of liquor per gram of fabric, where liquor means the solution constituted by water plus the dose of detergent. One cycle of the employed washing process simulates

**Table 1**
Fabric type, code, weight and fibre length.

| Type of Fabric | Code | Weight (g/m$^2$) | Fibre length (mm) |
|---|---|---|---|
| Plain weave polyester | PEC | 126 | 35 |
| Double knit jersey polyester | PEP | 200 | -[a] |
| Plain weave polypropylene | PP | 170 | 50 |

[a] PEP yarns are made of continuous fibres.

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