Microplastics from synthetic clothes: environmental impact and mitigation strategies

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Abstract Microplastics represent a new and very alarming source of pollution for marine environment. Classified as plastic fragments smaller than 5 mm, they mainly derive from the deterioration of scraps of large dimensions, from abrasives or from cosmetics. However, in 2011, another source was identified in the domestic and industrial washing processes of synthetic clothes. The real impact of this newly discovered source of microplastics is not clear yet, so quantitative investigations are highly necessary. For this purpose, the present work aims to assess the role of domestic and industrial washing processes of synthetic clothes, on the release of microfibres. Firstly, standard fabrics were washed simulating both industrial and domestic washing processes, using different detergents and washing conditions. The washing liquor was then filtered and the filters were observed by scanning electron microscopy (SEM). A specific counting method was set up to evaluate the amount of microfibres contained in each filter. Secondly, several finishing treatments were applied on the fabrics to prevent or reduce the amount of microplastics released during the washing process. The obtained results identified the best detergents, washing conditions and treatments to use in order to mitigate the impact of such source of pollutants.

Keywords: Microplastic, synthetic fabric, textile washing process, finishing treatment.

1. Introduction

The human impact on aquatic ecosystems represent a critical problem, deriving from the combination of multiple threats to marine life like overexploitation, pollution, global climate change and accumulation of plastic debris (Eriksen M., *et al*. 2017). In particular, the threat of plastics to the marine environment has been ignored for a long time, and its seriousness has been recognised only in the last decades. Following the increasing global production of plastics and an indiscriminate disposal, plastic litter has been extensively accumulating in marine habitats (Derraik J. G. B. *et al*. 2002). Its properties of buoyancy and durability, the sorption of toxicants, and entanglement of marine flora and fauna, have made plastic a really hazardous waste (Bakir A., *et al*. 2014; Bouwmeester H., *et al*. 2015).

As recently discovered, the environmental impact of plastic debris is not only present at a macroscale level, but also involves micro dimensions. The so-called "microplastics", fragments smaller than 5 mm, have been extensively found in marine salt, beaches, fish and other marine fauna. (Cole M., *et al*. 2011). Microplastics are classified as primary and secondary. The first have already micro dimensions in the production phase (i.e. the microbeads in the cosmentic industry), the latter reach the micro scale after deterioration of larger plastic items (i.e. bags, abrasives etc.) (Thompson R. C., *et al*. 2004). The issue of microplastics connects to several European water policies. The European Marine Strategy Framework Directive (MSFD, 2008/56/EC) addresses the issue of marine litter, including plastics. In particular, decision 2010/477/EU describes the "Criteria to be used by the Member States to assess the extent to which good environmental status is being achieved". Recently, an unexpected source of microplastic has been identified in the washing processes of synthetic clothes. The mechanical and chemical actions inside a washing machine, deteriorate the yarns of the fabric, which eventually releases microfibres in the water. Then, due to their dimensions, such microfibres are able to pass through wastewater treatment plants, reaching in this way marine ecosystems and shores. (Browne M. A., *et al*. 2011; Cole M., *et al*. 2013). Taking into account the lack of knowledge about the real environmental impact of this newly discovered source, the present work was focused on the quantitative evaluation of microplastic release during textile washing processes, and on the individuation of promising mitigation strategies. The setup of a counting method, based on scanning electron microscopy, allowed the quantification of microplastics released by three types of fabrics (woven and knitted polyester, woven polypropylene) during washing processes in domestic and industrial conditions, using different detergents and washing parameters. As mitigation actions, fabrics were treated with different textile auxiliaries as attempt to reduce the release of microplastics.

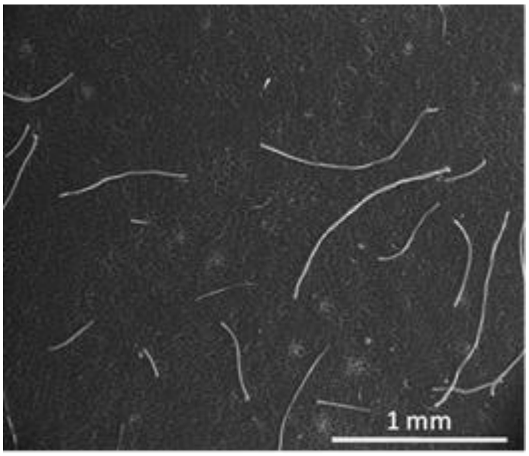
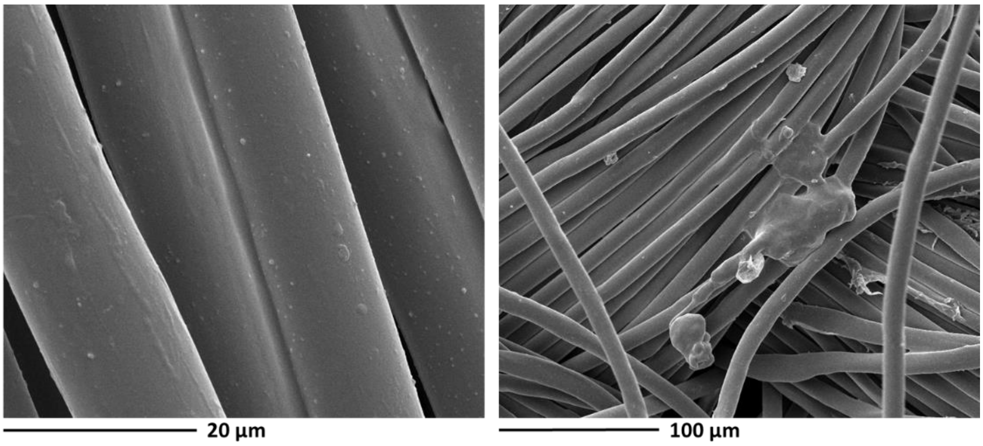


Figure 1. SEM micrograph of a filter containing woven polyester fibres



(a) **(b)**

Figure 2. SEM micrographs of WPE treated with (a) silicon emulsion and (b) acrylic resin

2. Materials and methods

Three standard textiles, woven polyester (WPE), knitted polyester (KPE) and woven polypropylene (WPP), were selected and tested through washing experiments.

Washing tests were simulated in a "Linitest" equipment in both domestic and industrial conditions. The detergents used during washings in domestic conditions were: liquid, powder, oxy-product, bleach and softener. Those used in industrial conditions were a reference standard alkaline detergent and two commercial ones. All the washing tests were also performed by using just distilled water as reference.

The washing effluents from the "Linitest" apparatus were collected and filtrated on PVDF (Polyvinylidene fluoride) membrane filters (pore width = 5 µm). Concerning the evaluation of the amount of microfibres released during a single washing test, a counting method was developed based on the acquisition of several micrographs of the surface of the filter by using a scanning electron microscope, SEM FEI Quanta 200 FEG. The number of fibres contained in each micrograph was obtained by visual observation.

The textile auxiliaries selected for the finishing treatments were: acrylic resins, a silicon emulsion and a polyurethane/acrylic resin. All auxiliaries were applied on fabrics by padding.

3. Results

Figure 1 represents an example of SEM micrograph used to determine the amount of microfibers released from WPE, KPE and WPP samples, washed in domestic conditions only with water and with liquid and powder detergents. The results indicated that the presence of the detergent induced an increase of the amount of microfibres released for all fabrics. In particular, the greatest numbers were recorded for the cases when powder detergent was used. A possible explanation for this trend is the friction between powder particles and fabric, which could induce a breakage of the fibres and consequent release in water. Concerning the type of fabric, WPE appeared to release the greatest amount of microfibres. For this reason, further investigations were carried out on WPE, firstly using different types of detergents (bleach, softener and oxidizing products), then changing the washing conditions (temperature, time, mechanical action and water hardness) and finally applying industrial washing conditions and detergents.

The results on the type of detergent pointed out that bleach and softner caused a minor release of microfibres, probably due to their ability to decrease the friction among the fibres. Instead, the outcomes of the analysis on the washing conditions highlighted that higher temperature, washing time and mechanical action produced an increase of microplastic release.

Finally, the washing simulations of WPE in industrial conditions induced a larger number of microfibers released compared to domestic one, since they were based on harder washings.

In order to find a strategy to mitigate the amount of microfibres released, WPE underwent different finishing treatments. The aim was to create a coating on the surface of the fabric, which could prevent the breakage of the fibres. The number of fibres per gram released by the treated fabrics during domestic washing tests, with and without detergent, indicated that the silicon emulsion assured the lowest amount of microfibres, even less than the washing with only water. In fact, in a SEM analysis, for such sample a homogeneous coating was observed on the surface of the fabric (**Figure 2a**), whereas for other auxiliaries irregularities and agglomerations were observed (Figure **2b**).

4. Conclusions

A successful evaluation of the amount of microplastics released during the washing processes of synthetic fabrics was achieved. The collected information clarified the influence of several parameters on the release. The use of liquid detergents, in particular softner and bleach agents, had a decreasing effect on the number of microplastics released in domestic tests. Instead, harder washing conditions such as higher temperature and mechanical action damaged more the fabric, resulting in a greater detachment of microfibres from the yarns. Industrial washing tests recorded high values of microplastics released. Regarding the mitigation strategies, the application of a silicon emulsion on the fabric resulted to be a possible solution to this environmental problem.

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