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Taking the sparkle off the sparkling time

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ABSTRACT

The awareness of impact of microplastics has led stakeholders to define strategies for the reduction of plastic emission and for their removal from aquatic environments. Glitter includes a wide range of shapes, chemical types of plastics covered by a metallic layer and color addition that confer them the typical 'sparkling' aspect. Here we focus on critical aspects that make glitter a product with a potential of significant environmental impact suggesting the need to take effective measures to limit emissions. Glitter is used here as a paradigm for all emergent plastic pollutants which calls for a deeper rethinking of our concept of sustainability. We are only at the beginning of the studies on glitter in the aquatic environment but on the basis of their potential impacts now is the time to take decisions taking the sparkle off the sparkling time.

1. Viewpoint

The information that in the last decade has filtered massively from the scientific community to the general public, through reports, awareness campaigns, events and information material of all kinds, have contributed to raising a critical conscience in consumers, who increasingly adopt behaviours aimed at the reuse of products and at a sustainable lifestyle (Heidbreder et al., 2019). There is by now a general awareness that we are living in the age of plastic (Vince and Hardesty, 2017).

The problem of plastics in the environment is currently only partially understood as regards its extent, its sources and the associated environmental risks. In this respect, legislators, producers and consumers are still adapting, although attempts to increase environmental sustainability of some products have been done. For example, primary microplastics from some categories of personal care and cosmetic products have been banned (Catarino et al., 2021). However, these measures are insufficient to stem the problem and, as has often happened following the ban of substances considered harmful to the environment and human health, the industrial process proposes alternatives that circumvent the prohibitions. In some cases, the substitutes, still not well known for their environmental behaviour and the risks they pose, can be equally harmful (Green et al., 2021) and, possibly even more, because the (erroneous) awareness of their harmlessness removes any qualms about their use.

In this paper, using 'glitters' as an example, we discussed potential risks for the marine environment from overlooked sources of microplastic pollutants and their environmental sustainability.

2. The pervasiveness of plastic pollution in the ocean

Nowadays, it is impossible even to try to imagine our world without plastics, given the extreme importance and the quantity of functions it has in a disproportionate range of aspects of industry and everyone's daily life. There are no other manufactured materials whose production has grown as plastic has over the last 70 years (Geyer et al., 2017). In 2019, the world production of plastics reached 368 million metric tons (PlasticsEurope, 2020), excluding polyethylene terephthalate (PET), polyamide (PA) and polyacrylic fibres. However, to understand the dimension of the problem from an environmental pollution perspective it is necessary to consider the cumulative production of plastics over the last decades. The lifetime of plastic items is, in fact, short or limited to a single use, while for more lasting products can vary from a few years to a few decades. In any case, plastic litter may persist in the marine environment even for centuries (Worm et al., 2017).

Since 1950 until 2015, 8300 million metric tons of plastics have been produced: 30% of products are in use, 10% has been incinerated, only 7% has been recycled and 55% has simply been discarded (Geyer et al., 2017). Therefore, also due to the insufficient effectiveness in waste management, billions of metric tons of plastics are constantly introduced in the marine environment, which is often their final destination and where they represent 60–95% of litter (Galgani et al., 2015; Hahladakis,

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2020), at a rate which was considered unsustainable already one decade ago (Thompson et al., 2009).

The bulk of stranded, floating or submerged macroplastics (items >5 mm; Fig. 1) is only the most evident outcome of plastic pollution in the ocean, with main direct effects limited to large, or relatively large, marine organisms through entanglement or ingestion (Baulch and Perry, 2014; Puskic et al., 2020). More elusive, and with largely unknown consequences on marine life, is the indirect pollution from microplastics (<5 mm) and nanoplastics (<0.1 μm) deriving from the degradation of larger plastic items (Piccardo et al., 2020). In a business-as-usual scenario, given the current rates of release, more than 200 million metric tons of plastic will have degraded into microplastic in the next few decades (Lebreton et al., 2019).

Microplastics have also a primary origin as components of several common use products such as, for instance, coatings, personal care products, plastic pellets, synthetic textiles, which reach seas and oceans. These particles are ubiquitous in the marine environment, from the interface between air and water, to water column, and to the sediment in the deep ocean (Thompson, 2015; Martellini et al., 2018; Renzi et al., 2018; Guerranti et al., 2020). Hence, they have been extensively found in living organisms and spread throughout the food webs, with unpredictable effects on marine ecosystems and human health (Andrady, 2011; Setälä et al., 2018; López-Martínez et al., 2021; Bulleri et al., 2021).

Plastic pollution in the global ocean is irreversible (Villarrubia-Gómez et al., 2018) and the only ways to mitigate its potential impact is to reduce emissions, to systematically remove macroplastic from the marine environment, and to improve wastewater treatments (Lebreton et al., 2019). This should be necessarily accompanied by a drastic resizing of primary microplastic production. In this respect, despite the use of some microplastic components having been banned in several countries, such as those from rinse off cosmetics, many other types of microplastics are still largely employed in several commercial products and industrial processes, requiring a careful revision of their environmental sustainability (Villarrubia-Gómez et al., 2018; Guerranti et al., 2019).

3. Unessential primary microplastics: an emblematic example

A particular class of these primary microplastics is composed by parcelled metallised plastics, whose main representatives are 'glitters'. Glitters (Fig. 2a) are microbeads or plated fragments, and sequins of any shape, with variable sizes and with different thickness, made mostly of

Fig. 1. Macroplastic litter photographed in a Elafonisos' beach (Greece), a Natura 2000 network site of Community importance (GR2540002). Image by C. Guerranti.

Mylar™, a film, biaxially oriented, of polyethylene terephthalate (BoPET), insoluble in water, having a melting point of 260 °C, and a density of 1.38 g/cm^3. Glitters can also be made of acrylic, polymethylmethacrylate (PMMA), polyvinyl chloride (PVC) or other resin mixtures, covered by a metallic layer of aluminium, titanium, iron or bismuth. Particles can have a variety of shapes (triangular, squared, or even more complex) and during the production process, holographic effects or colors, including gold and silver, can be added to give them the typical 'sparkling' aspect (Blackledge and Jones, 2007; Tagg and Ivar do Sul, 2019; Yurtsever, 2019a).

It might seem a kind of product used only in particular occasions, such as celebrating anniversaries, but fashion has brought this trend into everyday life, leading to an extensive use of glitters in cosmetics, for powdery or glossy make-up, body paints, nail polish, but also in bags, shoes, accessories, home decoration, greetings cards, clothing: the list is almost infinite (Fig. 2b, c). Larger particles can be sewn or fixed, but often glitters are applied with some kind of glue on clothing and objects, dermal oil on the body, or are simply contained in the product, so it is extremely easy for them to be released. Moreover, these products have often a single use, perhaps for example the make-up for a party or a show, that is washed off every day and redone the next day, or the application of nail polish, which may recur several times per week. The most impactful form is the use of glitters in cosmetic products that must be removed by washing and therefore end up in the household drains (with possibility of being retained by wastewater treatment plants still to be assessed) or, even worse, in the so-called glitters bombs, following the use of which large quantities of these microplastics are poured directly into the environment, without the possibility of being recovered.

Due to their characteristics and their wide diffusion, these kinds of microplastics have an enormous potential for contamination of marine environments, which could have been largely underestimated considering the spread of other microplastic components especially in coastal areas (So et al., 2018). As for microbeads, microfibers, and other microplastics, potential effects on marine organisms related to leaching of chemicals and physical damage at tissues and cellular level could be envisaged also for glitters (Auta et al., 2017; Botterell et al., 2019), which could be further increased by the presence of heavy metals and sharp edges on these plastic particles (Yurtsever, 2019b). The diffusion and impact of glitters is beginning to be understood from the very few studies that have been published, while the possibility of penetration into food webs and potential disturbances on the metabolism of individual organisms or at ecosystem level are still to be widely clarified. Glitter has been found in 5 out of 10 sludges from Norwegian domestic wastewater treatment plants, where they represented 2% of microplastics (Lusher et al., 2017), and in riverbeds in Northwest England (Hurley et al., 2018). However, these two crucial works which have found glitter in their analysis for the first time, are the only two studies reporting timely information on the occurrence of these microplastics in marine environmental matrices to date, highlighting the gap in our knowledge on their abundance and distribution. On their occurrence in the environment, a study of 2019 (Yurtsever, 2019b), describes a methodological underestimation of glitter, that can remain undetected during Fenton oxidation at low pH (2–5) or become transparent, because the addition of acidic solution, or heating, dissolves the coating. This means that after eventual ingestion they can be less or simply not visible. Moreover, a substantial quantity of high-density glitters is probably settled as sediment at the bottom of the aquatic environment, while low-density plastics would float for some time. However, to date, there are no studies in the scientific literature, from observation in the field or experimental (exposure of target organisms, for example), on the possible effects of glitters, at different levels of the biological/ecological hierarchy.

Considering that the problems related to the use of glitters have reached a part of consumers, it is not difficult to find websites that recommend the use of natural alternatives. These range from completely different products in nature and aesthetic result (for example, salt, sand

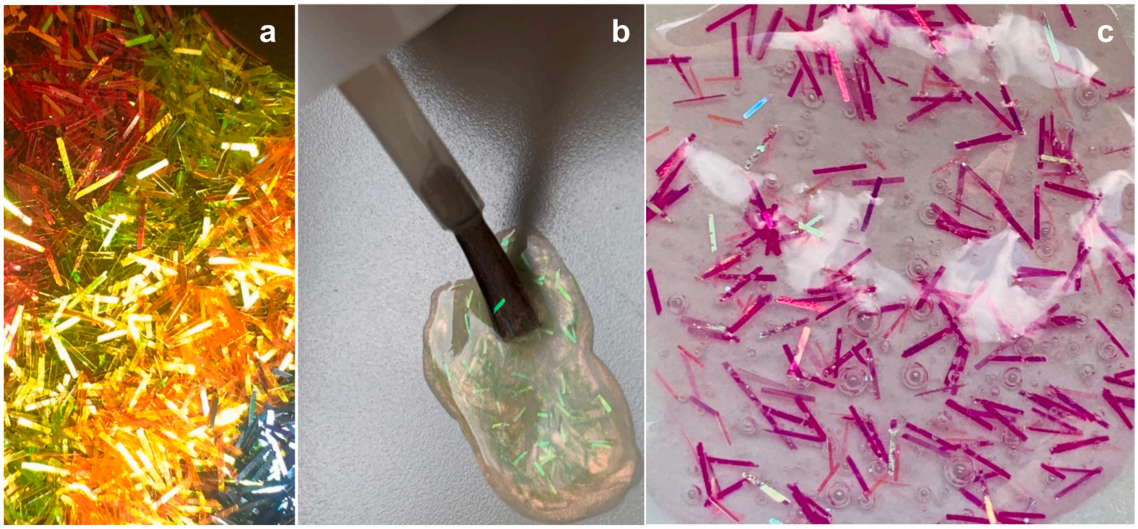

Fig. 2. Glitters of different colors (a). Glitters contained in cosmetic products: hair gel (b), and nail polish (c).

or coloured rice) which however are not conceivable as real alternatives in the cosmetic field. Same is true for "ecological glitters": cellulose-based products, biodegradable, very similar in appearance to conventional glitters, but incompatible with the use of solvents and, due to their rapid biodegradability, with a very limited possibility of use in cosmetics. A study comparing the impact in a semi-natural mesocosm of fresh water of conventional glitter, made of non-biodegradable PET, and biodegradable eco-glitter of recent production, made of Modified Regenerated Cellulose (MRC), mica or synthetic mica, showed counterintuitive results. The analysis highlighted not only an ecological impact of the exposure to both types of glitter, such as root length and phytoplankton biomass reduction, but also found that the alternative biodegradable glitter produced stronger effects than the conventional one (Green et al., 2021). Given the great interest and rapid spread of bioglitters and considering the increasing awareness of consumers towards the problem of microplastics, the outcomes of this study are very worrying and worthy of being further investigated.

This bright and microscopic glitter sparkles at the top of an iceberg, made of old and emergent pollutants, including pharmaceuticals, endocrine disruptors, all sized plastics, long and short-term pollutants, heavy metals, which add to a number of human threats connected to climate change, overexploitation of marine resources and to an emerging rhetoric on a sustainable "blue economy" for what is going to be the Anthropocene Ocean. In the current situation, where the predicted increase of plastic waste risks rendering the efforts to reduce plastic pollution ineffective (Borrelle et al., 2020), the use of these unessential microplastics is emblematic of how far we are from sustainability.

4. It is a long way to the top, if we want sustainability

Sustainability is a complex concept integrating social, economic, and ecological aspects (Jamieson, 1998; Shrivastava et al., 2020). We can try to synthetize it as the property of a socio-ecological system to develop and persist ensuring present and future human welfare and environment health, social equity, and a low risk of catastrophic transitions towards adverse conditions (Folke et al., 2020; UNEP, 2021). Therefore, human activities may be sustainable only if their development is subject to a careful, science-based, consideration of potential negative effects on the environment and human health (Claudet et al., 2020). Instead, initiatives to reduce associated environmental consequences are delayed to when and if evidence of undesirable effects for the environment (and humankind) becomes undeniable. Then, solutions to environmental issues are often incorporated in market-based management actions which can be considered, at the least, controversial (Sovacool, 2011; Richardson, 2015; Spash, 2015).

An environmentally sustainable way to think about products' development presumes accounting for possible ecological and societal consequences *before* the productive cycles have implemented and the products are merchandised. However, production processes are still too often guided by cost-effectiveness of materials and manufacturing, leading to satisfy market requests while maximizing incomes, and largely neglecting external environmental costs (UNEP, 2021). Moreover, changes in producers' policy to increase environmental sustainability rarely occur as a spontaneous decision driven by ethical concerns. If not imposed by regulations, they are generally stimulated by the need to meet an increased awareness of public on environmental problems, which polarizes the demand of consumers around more eco-friendly products (Mitrano and Wohlleben, 2020). In practice, also sustainability obeys market laws.

Efforts to improve cleanup technologies for macro- and microplastic have proliferated in the last two decades (Schmaltz et al., 2020), international regulations on plastic materials have become more stringent and people have increased their consciousness of environmental issues related to plastic pollution (Mitrano and Wohlleben, 2020), indicating that we are on the right path for sustainability. But it is a long road. For plastic, other emergent marine pollutants and, more generally, for all ocean-based human activities, the strategy to achieve sustainability is too oriented towards mitigation and compensation rather than the prevention of environmental consequences. This probably stems from the dualism intrinsic to the concept of sustainability (Vucetich and Nelson, 2010): satisfying our present and future desires as much as possible while trying to maintain the integrity of the ocean or limiting them to the essential ones and preserving as much as possible the health of the ocean. It is a matter of fact that our view on sustainability of plastic materials currently falls within the former perspective, unfortunately with questionable results (Roachman, 2020). Perhaps, a better approach to sustainability requires overturning our way of thinking about our uses of plastics, from industrial processes to socio-cultural aspects, to attain more balanced trade-offs between our needs and the consequences for the marine environment. Letting the sunshine being the only thing sparkling on the ocean can be a first step in this direction.

Author contribution

SB, MR and MP conceived the idea. SB, CG, MR, MP contributed to the writing of the manuscript. SB and MR critically reviewed the manuscript.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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