



Characterisation, quantity and sorptive properties of microplastics extracted from cosmetics



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ABSTRACT

Cosmetic products, such as facial scrubs, have been identified as potentially important primary sources of microplastics to the marine environment. This study characterises, quantifies and then investigates the sorptive properties of plastic microbeads that are used as exfoliants in cosmetics. Polyethylene microbeads were extracted from several products, and shown to have a wide size range (mean diameters between 164 and 327 μm). We estimated that between 4594 and 94,500 microbeads could be released in a single use. To examine the potential for microbeads to accumulate and transport chemicals they were exposed to a binary mixture of ³H-phenanthrene and ¹⁴C-DDT in seawater. The potential for transport of sorbed chemicals by microbeads was broadly similar to that of polythene (PE) particles used in previous sorption studies. In conclusion, cosmetic exfoliants are a potentially important, yet preventable source of microplastic contamination in the marine environment.

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1. Introduction

Plastics provide a diverse range of inexpensive, lightweight, strong, durable and corrosion-resistant products (Thompson et al., 2009b). The success of plastics as materials has been substantial and they are used in a wide range of applications. This versatility, together with their low cost, has resulted in the annual worldwide production of around 300 million tonnes (Plastics Europe, 2014). Approximately 50% of production is used to make packaging, much of which is used in disposable applications. This creates a major waste management problem, with plastics accounting for approximately 8–10% of all the waste generated in the UK (Barnes et al., 2009; Hopewell et al., 2009).

Around 700 species of marine organism have been reported to encounter marine debris in the natural environment, with plastic debris accounting for over 90% of these encounters (Gall and Thompson, 2015). Large plastic items, such as discarded fishing rope and nets, can cause entanglement of invertebrates, birds, mammals, and turtles (Carr, 1987; Eerkes-Medrano et al., 2015; Fowler, 1987; Laist, 1997) but the marine environment is also contaminated with much smaller microplastics particles (defined by NOAA as <5 mm). These have been reported at the sea surface

(Law and Thompson, 2014), on shorelines (Claessens et al., 2011), and on the sea bed (Van Cauwenberghe et al., 2013). The sources of microplastics include fragmentation of larger items (secondary sources), and direct inputs of microplastic sized particles, such as microbeads used in cosmetics and pre-production pellets (primary sources). It is important to understand the relative importance of these sources as well as the size and abundance of microplastic particles released, since this will influence encounter rate and availability to biota (Teuten et al., 2007; Thompson et al., 2009a; Cole et al., 2011).

There is growing evidence that the amount of microplastics in marine waters is increasing, with unknown ecotoxicological consequences (Goldstein et al., 2012). Fendall and Sewell (2009) reported on microbeads used as “scrubbers” in cosmetics products, which they described as being up to 500 μm in diameter, being released into the natural environment and potentially available to organisms. Ingestion of microplastics, has been reported for a wide range of marine organisms including deposit and suspension feeders (Browne et al., 2008; Graham and Thompson, 2009), crustaceans (Murray and Cowie, 2011), fish (Boerger et al., 2010), marine mammals (Denuncio et al., 2011), and seabirds (Avery-Gomm et al., 2012; Van Franeker et al., 2011). However, the extent, if any, to which chemicals sorbed onto, or incorporated into plastics can desorb from plastic particles, and transfer to the tissues of marine organisms is less clear. Recent experimental trials provide evidence for the role of plastics in the transfer of chemicals with

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subsequent adverse physiological effects (Besseling et al., 2013; Rochman et al., 2013), but studies based on bioaccumulation models concluded that the transfer of contaminants from plastics to marine organisms upon ingestion is of limited importance compared to other pathways (Gouin et al., 2011; Koelmans et al., 2013).

Microplastics have been used to replace natural exfoliating materials (for example, pumice, oatmeal, apricot or walnut husks) in cosmetics and have been reported in a variety of products such as hand-cleansers, soaps, toothpaste, shaving foam, bubble bath, sunscreen, shampoo and facial scrubs (Fendall and Sewell, 2009; Gregory, 1996; Zitko and Hanlon, 1991; UNEP, 2015).

Industry uses the terms ‘microbeads’ to describe microplastic particles present as ingredients in personal care and cosmetic products; they may also be called microspheres, nanospheres, plastic particulates (UNEP, 2015). Around 93% of the ‘microbeads’ used in cosmetics are polyethylene (PE), but they can also be made of polypropylene (PP), PE terephthalate (PET), polymethyl methacrylate (PMMA) and nylon (Gouin et al., 2015; Eriksen et al., 2013; UNEP, 2015). Microbeads are likely to be transported to wastewater treatment plants, where some will be captured in oxidation ponds or sewage sludge. However, due to their small size, it is anticipated that a substantial proportion will pass through filtration systems and enter aquatic environments (Fendall and Sewell, 2009).

Leslie et al. (2013), examined wastewater treatment plants that discharge into the North Sea, the Oude Maas River or the North Sea Canal and reported that the treated effluent contained on average 52 pieces of microplastics/L. Eriksen et al. (2013) also reported substantial amounts of multi-coloured microplastic spheres in surface waters of the Laurentian Great Lakes of the United States which were suspected to originate from consumer products. This provides evidence that microplastics are not all captured in sewage sludge of wastewater treatment plants and is of broad concern, since treated effluent from sewage disposal sites is discharged into a range of water bodies, including into inland waters, estuaries and the sea (DEFRA, 2002).

Gouin et al. (2011) estimated that the per capita consumption of microplastic used in personal care products for the U.S. population, based on the usage of PE microplastic beads used in personal care products, was approximately 2.4 mg per person⁻¹ per d⁻¹, indicating that the U.S. population may be emitting an estimated 263 tonnes per yr⁻¹ of PE microplastic (Gouin et al., 2011). To set this into perspective, in terms of its contribution to marine litter, this annual quantity is approximately equivalent to 25% of the total mass of plastic that is estimated to have accumulated in the North Atlantic Subtropical Gyre (Law et al., 2010; Gouin et al., 2011).

Facial scrubs are one type of cosmetic which contains microplastics as exfoliating agents. Due to this, such products could contribute microplastics contamination to the marine environment. Despite concerns about the potential for products containing microbeads to represent a major source of microplastics to the environment, only one study has measured microplastics in facial scrubs (Fendall and Sewell, 2009), and there are no peer reviewed publications confirming the type or quantity of microplastic polymers used in facial scrubs. Here we examined six brands of facial scrubs manufactured by three companies and describe the microplastics (plastic microbeads) present, in terms of polymer type, colour, size, weight and abundance. We also investigated the sorptive properties of the microplastics in relation to the potential for transport of the POPs phenanthrene (Phe) and dichlorodiphenyltrichloroethane (DDT) and compared them with commercially available PE particles previously used in adsorption/desorption studies of persistent organic pollutants (POPs) (Bakir et al., 2012, 2014a,b; Teuten et al., 2007).

2. Methods

2.1. Sample preparation

Six major brands of facial scrubs were chosen, based on their prevalence in major supermarkets close to Plymouth UK. All of the products listed in their ingredients that they contained PE. Four replicates of each product were purchased, with each replicate sourced from a different supermarket to provide a representative sample.

Since the specific brand names of the products are not of particular relevance, they were labelled A–F.

Each facial scrub was a viscous liquid (A–D contained 150 mL of product, E contained 125 mL). The contents were subjected to vacuum filtration to obtain the plastic particles. The procedure required mixing each product in approximately 1 L of boiling water, followed by vacuum filtration over Whatman N°4 filter paper, then drying at 30 °C to constant weight. Once dry, the particles were weighed by Precisa 2200C weighing scales and the residues were transferred into separate glass vials. A Kruskal–Wallis test was performed on the data, using R studio, to test whether the amount of microplastics per unit volume extracted differed between products ($p < 0.05$). This was followed by a *post-hoc* Nemenyi-Test to find which specific products significantly differed.

2.2. Visualisation and identification

Microplastics from each product were identified using Fourier transform infra-red spectroscopy (FTIR), using a Hyperion 1000 microscope (Bruker) coupled to an IFS 66 spectrometer (Bruker). The spectra obtained were compared to a spectral database of synthetic polymers (Bruker I26933 Synthetic fibres ATR library).

Some non-plastic residues were extracted and separated from the plastic particles using Endecotts woven wire sieves of varying mesh size. The mass of plastic particles was recorded.

A Malvern Mastersizer 2000 laser particle sizer (MM2) was used to measure the size-frequency distributions (SFDs) of the extracted plastic into sixty-eight different sized bands with logarithmic spacing (range 0.015–2000 μm; Woolfe and Michibayashi, 1995). The resultant particle size distributions were expressed as a volume weighted mean from an average of twenty five measurements per product. The mean for each product was then calculated.

The number of plastic particles in each product, N , was estimated, assuming the particles were of spherical shape, using the following equations:

$$V_t = \frac{M_t}{D} \quad (\text{i})$$

$$V(\text{avg particle}) = \frac{4}{3}\pi r^3 \quad (\text{ii})$$

$$N = \frac{V_t}{V(\text{avg particle})} \quad (\text{iii})$$

where V_t is the total volume of plastic extracted, M_t is the total mass of plastic extracted, D is the density, $V(\text{avg.p})$ is the mean volume of one particle, N is number of particles, and r is the radius.

For each product: Eq. (i) allowed calculation of the total volume of microplastic extracted; Eq. (ii) allowed calculation of the average volume of a microplastic particle from each product; by dividing the total volume of microplastic by the average volume of a microplastic particle, Eq. (iii) allowed calculation of the approximate number of particles in each product. Particles were then

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