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**Use of Micro-Plastic Beads in Cosmetic Products
in Europe and Their Estimated Emissions
to the North Sea Environment**

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Use of Micro-Plastic Beads in Cosmetic Products in Europe and Their Estimated Emissions to the North Sea Environment

■ Introduction

Global plastic manufacture and consumption is estimated to be on the order of 280 million tonnes annually, with poor understanding of the fraction of

plastic that eventually becomes debris in the global marine environment (1). Other studies suggest that as much as 10 million tonnes are estimated to be present in the world's oceans, resulting in plastic debris being the single greatest

contributor to debris in the marine environment (2). An important factor influencing the potential for plastic debris to enter the environment has largely been attributed to relatively poor plastic waste recovery rates, combined with inappropriate disposal of plastic products (3). Unfortunately, there is a paucity of data quantitatively assessing the release rates of plastic to the terrestrial and aquatic environments, which makes it difficult to identify and manage the inappropriate release of plastic. Nevertheless, based on a number of semi-quantitative and/or qualitative assessments, the observation of plastic debris and its temporal and spatial accumulation, particularly in the marine environment, imply cause for concern.

Plastic debris is typically characterized based on its size. Consensus regarding the size classification of plastic debris, however, is currently lacking. A commonly used classification, based on a scheme proposed by Moore (4), is to assign all plastic debris >5 mm as being macro-plastic, with micro-plastic classified as being material <5 mm. More recently, *Costa et al.* (5) adopted a strategy whereby they defined all plastic >1 mm, but <20 mm as being termed »small«, and micro-plastic as material that was <1 mm. The classification of micro-plastic by *Costa et al.* (5) has also been adopted by *van Cauwenbergh et al.* (6), suggesting that this classification was more intuitive, i.e. the term »micro« should reflect particles in the micron size range. There is thus a need to resolve the confusion regarding the classification of plastic, since it has the potential to prove problematic when attempting to

Abstract

Plastic debris in the marine environment represents a growing environmental issue. The physical presence of macro- and micro-sized plastic debris in the marine environment may have the potential to negatively impact marine organisms as a consequence of entanglement, ghost fishing, and ingestion. The use and release of micro-plastic beads in scrub and exfoliating cosmetic products to the environment has received a substantial amount of attention recently, yet the relative importance and contribution of this source has not been quantified. In an attempt to address this data gap, the cosmetic products industry conducted a survey of its European membership regarding the use of micro-plastic beads used in cosmetic products, which provide a scrub or exfoliate function. The survey results report a total amount of 4360 tonnes of micro-plastic beads used across all European Union countries, plus Norway and Switzerland, for 2012. Polyethylene micro-plastic beads represented 93 % of the total amount. Polyethylene micro-plastic beads in the size range of 450-800 µm was the dominating material that was reported in the survey. The results of the Cosmetics Europe survey are used to help substantiate estimated use of micro-plastic beads based on sales data of liquid shower gels for Europe, with estimates regarding potential use and release of micro-plastic beads used in countries within the watershed of the North Sea being highlighted. It is estimated that micro-plastic beads originating from cosmetic products represent between 0.1 %–1.5 % of the total amount of plastic debris emitted to the North Sea marine environment.

review the levels of plastic debris in the marine environment in terms of micro- versus macro-plastic. For instance, using a micro-plastic classification scheme of <1 mm, *van Cauwenberghe et al.* (6) observed that levels of macro-plastic, on a weight basis, dominated the components of plastic debris found on beaches along the Belgian coast, but that the weight of micro-plastic in the water column and on the seafloor, was 100 to 400 times greater than the accompanying macro-plastic. Unfortunately, given the lack of consistency between studies regarding the classification of plastic debris, as well as with respect to how data are reported (i.e. mass/area; particles/area; particles/mass; particles/volume, etc.), and lack of clarity regarding the lower threshold of what is classified as micro-plastic, the ability to compare spatial and temporal trends to better understand sources and sinks of plastic debris can be difficult to assess.

Nevertheless, it is well understood that emissions of micro-plastic to the global marine environment include both primary sources (as derived from hand and facial cleansers, airblast cleaning media, and production waste from plastic processing plants, etc.) and secondary sources (derived from fragmentation of macro-plastic as a result of photodegradation and abrasion due to wind and wave action) (4,7,8), and can originate from either terrestrial or freshwater systems. Given recent observations regarding the relative abundance of micro-plastic in the marine environment, quantification of primary sources would provide greater awareness of their relative contribution to the problem of plastic debris, thus enabling efficient and effective risk management strategies to be implemented (9).

In this study we provide an assessment of the relative contribution of one primary source of micro-plastic, originating from use in cosmetic products, with an emphasis on the European market. For clarification, the technical definition of cosmetic products within Europe specifically refers to the definition outlined in the EU Cosmetics Regulation EC 1223/2009, Article 2 (a) (10), i.e. any substance or mixture intended to be placed in contact with the external parts of the

human body, or with the teeth and the mucous membranes of the oral cavity, with a view to cleaning them, perfuming them, changing their appearance, protecting them, keeping them in good condition or correcting body odours. To our knowledge there is a general lack of quantitative information characterizing the release of plastic to the environment from various sources, which only exacerbates our ability as a society to effectively manage an issue that is of general concern. The aim of this study is thus to report information regarding the use of micro-plastic beads used in cosmetic products that have been obtained from an industry use survey representing the majority of cosmetic companies operating within the European Union. The data compiled from the industry survey are then used to estimate per capita consumption use values of micro-plastic beads, and to derive an estimate of release associated with a primary source of micro-plastic to the North Sea environment. This study thus represents a first of its kind, and we hope that priority will be given towards the quantification of plastic debris being released from other sources in a manner that will enable the appropriate and effective introduction of actions aimed at reducing levels of plastic in the marine environment.

■ Methods

Estimation of European Use of Micro-Plastic Beads in Cosmetic Products

Micro-plastic beads used in cosmetic products in the European market are largely dominated by its use in niche consumer products, particularly in liquid soaps that make a claim of an exfoliate function (11). In estimating the usage of micro-plastic beads used in cosmetic products we have utilized two complementary approaches. The first approach is based on feedback to a user questionnaire received from companies that are members of Cosmetics Europe, the European Cosmetic Industry Association. The information obtained from the survey provides no geographic or company specific details, but rather provides an estimate of the relative use of micro-plastic beads used in cosmetic products

within the European market. The second approach attempts to assess usage spatially, utilizing data reported by Euroonitor International, which is a consumer products database that reports market data of various product types.

Consumer Products Manufacturer Survey

Cosmetics Europe is the European personal care association that represents the interests and needs of the companies and national associations that make up its membership. Its current membership represents all international cosmetic product companies, and includes the broad majority of small and medium-sized enterprises via its national sister associations. Thus the membership of Cosmetics Europe is comprised of the major consumer product manufacturers in Europe, and the information obtained adequately represents the European market. Cosmetics Europe requested all of its members to complete a survey regarding their individual use of micro-plastic beads in cosmetic products, with an emphasis on use in skin care products. The survey was focused on products marketed in the European Union, Norway, and Switzerland. Members were requested to provide the INCI Name of the micro-plastic beads used, the particle size, and particle shape (i.e. sphere, fragment, fiber) for the year 2012. For the purposes of the survey, participants were asked to provide information on petroleum-based micro-plastic beads in cosmetic products of any size <5mm, and used for any purpose in the cosmetic formulation. Additional information regarding the minimum and maximum inclusion levels, annual tonnage of micro-plastic beads, and product categorization were also requested.

Estimating Spatial Use of Micro-Plastic Beads Based on Marketing Data

In order to provide spatial information regarding the use of micro-plastic beads used as exfoliate or scrub agent and originating from cosmetic products, and to provide relevance regarding the potential release of this material to the marine environment, we have focused this assessment on countries that fall within the watershed of the North Sea, i.e. Nor-

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way, Denmark, Germany, Belgium, the Netherlands, France, Switzerland, Czech Republic, and the UK.

The use of micro-plastic beads in consumer products is dominated by its use in shower gels and liquid facial soaps (11). The total use of liquid facial soap and shower gels for all EU countries plus Norway and Switzerland, including each of the North Sea countries is obtained based on data reported by Euromonitor International (www.euromonitor.com), a consumer products database that reports market data of various types. Marketing data collected from Euro-

monitor for 2012, for which estimates of shower gels and liquid facial soaps use are reported, were thus used in estimating country specific amounts of micro-plastic beads (Table 1).

Using the Euromonitor data, estimates of the volumes of micro-plastic beads contained in shower gels and liquid facial soaps are derived. Based on our analysis of the data, discussed below, we assume a conservative estimate that 6% of all liquid soaps contain micro-plastic beads in 2012. Given that the U.S. patent describing the use of micro-plastic beads in liquid soaps as an exfoliate

agent, describes a maximum inclusion level of 10% polyethylene beads (12), we estimate that the total amount of micro-plastic in skin cleansing products is 0.6% of the total volume of product sold. The above listed assumptions are four times greater than the assumptions adopted by *Gouin et al.* (13), who estimated a per capita use of micro-plastic polyethylene beads in cosmetic products of 2.4 mg·d⁻¹, for the U.S. market. Unlike *Gouin et al.*, however, we have based our analysis on the data obtained from the Cosmetics Europe survey, which we believe represents a more robust analysis of the usage

Country	Population (million)	Shower gel 000 litres	Face Wash (premium) 000 litres	Face wash (mass prod) 000 litres	Liquid hand soap 000 litres	Combined liquid soaps (litres)
Austria	8.2	8,881.0	51.0	1,097.1	1,922.2	1.20E+07
Belgium	10.6	7,864.8	20.4	1,151.1	1,661.8	1.07E+07
Bulgaria	7.3	1,307.6	0.5	226.3	n/a	1.53E+06
Croatia	4.3	958.0	1.4	212.7	340.3	1.51E+06
Cyprus	0.79	304.6	19.0	61.2	727.1	1.11E+06
Czech Republic	10.2	4,012.5	3.8	544.7	3,155.1	7.72E+06
Denmark	5.5	2,903.5	61.8	198.2	1,678.8	4.84E+06
Estonia	1.3	312.0	0.8	76.1	154.9	5.44E+05
Finland	5.2	3,617.3	9.2	424.4	2,004.9	6.06E+06
France	64	67,236.3	999.0	9,511.8	17,177.6	9.49E+07
Germany	82	78,551.4	391.7	14,500.8	18,443.8	1.12E+08
Greece	10.7	8,804.5	126.5	540.1	4,723.4	1.42E+07
Hungary	9.9	10,736.4	17.1	450.7	4,451.7	1.57E+07
Ireland	4.1	2,832.1	1.5	123.3	1,489.5	4.45E+06
Italy	58.1	24,750.2	740.4	2,466.4	28,067.9	5.60E+07
Latvia	2.2	229.6	1.5	47.8	261.7	5.41E+05
Lithuania	3.5	450.8	1.8	69.3	238.8	7.61E+05
Luxembourg	0.48	408.6	2.2	32.4	72.7	5.16E+05
Malta	0.40	133.4	0.7	11.5	94.3	2.40E+05
Netherlands	16.6	15,239.5	23.3	961.1	4,216.0	2.04E+07
Poland	38.5	13,835.1	52.6	3,564.0	6,357.2	2.38E+07
Portugal	10.7	13,416.8	19.1	146.6	989.8	1.46E+07
Romania	22.2	5,300.2	2.4	481.8	3,579.5	9.36E+06
Slovakia	5.4	3,109.2	0.7	280.6	827.9	4.22E+06
Slovenia	2	815.6	18.6	220.4	261.4	1.32E+06
Spain	40.5	110,683.4	367.6	2,854.2	11,007.2	1.25E+08
Sweden	9	5,361.4	11.6	433.3	5,223.8	1.10E+07
UK	61	63,204.3	407.0	7,426.5	42,114.7	1.13E+08
Norway	4.9	4,456.0	61.1	123.4	2,558.5	7.20E+06
Switzerland	8	9,356.0	18.6	435.1	2,967.8	1.28E+07
Total	516					6.88E+08

Table 1 Summary of output from Euromonitor International reporting total volume of cosmetic product types associated with micro-plastic beads used as an exfoliate in skin cleansing products, for each country included in the Cosmetics Europe survey for the year 2012. Values reported are estimated as averages and could vary by as much as a factor of 10.

of micro-plastic beads used as an exfoliate in skin cleansing products for a given country in the European Union.

■ Results and Discussion

Summary of Results Based on Cosmetics Europe Survey

Polyethylene micro-plastic beads are reported to be the dominant type of plastic material used as an exfoliating agent in skin cleansing products, with a total amount of 4073 tons used in European Countries, including Norway and Switzerland, reported. The total amount of micro-plastic beads other than polyethylene is 287 tons. Typical inclusion levels of polyethylene micro-plastic beads reported in the various products ranged between 0.05% and 12%, consistent with the patent describing optimal efficacy associated with exfoliation with respect to maximum inclusion levels.

The survey results also found that approximately 70% of micro-plastic beads used is > 450 μm , which is based on the size distribution of polyethylene micro-plastic beads for which size data were reported (660 tonnes) in the Cosmetics Europe survey. These results are also found to be generally consistent with the U.S. patent on the use of micro-plastic beads as scrubbers in cosmetic products, which suggests that beads <60 μm are generally ineffective as a scrubber, with the ideal size being in the region of 420 μm (12). Consequently, given the documented evidence that the efficacy of micro-plastic beads as an exfoliating agent is significantly reduced with decreasing size, we would expect limited use of micro-plastic beads <450 μm . We believe that this information should be helpful in developing improved sampling and identification techniques targeting the collection of micro-plastic beads associated with their primary release from cosmetic products.

Additionally, the data can also be used to obtain a preliminary assessment regarding the relative contribution that the use of micro-plastic beads in cosmetic products represents when compared to the amount of plastic debris estimated to be present in the global marine environment. While deriving an estimate quan-

tifying the relative contribution is challenging, as there are no recent and robust quantitative data reporting the amounts of marine litter worldwide (14), a 1975 estimate derived by the National Academy of Sciences (USA) suggested that 6.4 million tons of litter were discharged to the marine environment each year (15). Using 6.4 million tons as a first estimate, relative to the 4073 tons reported in the Cosmetic Europe survey, suggests that the contribution of micro-plastic beads used in cosmetic products in Europe represents <0.1% of the annual emissions of litter worldwide. This assumes direct discharge to the marine environment. Recent reports, however, suggest that removal efficiencies within waste water treatment plants can be as high as 90% (16), consequently if we were to include removal the relative contribution would be estimated as being <0.01%.

Estimates of Daily per Capita Use of Micro-Plastic Beads in Cosmetic Products

Whereas the data obtained from the Cosmetics Europe survey represent our best quantification regarding the use of micro-plastic beads in cosmetic products across the European market, they do not contain the necessary spatially resolved use patterns to enable geographically explicit estimates of emissions to the environment. In an effort to obtain an improved estimate regarding the release of micro-plastic beads used in cosmetic products to the marine environment we have thus utilized data obtained from Euromonitor International to derive an estimate of per country usage (Table 1). The data obtained from Euromonitor International report the total volume of a product type for a specific country on an annual basis. It does this by utilizing information regarding the total number of units sold of a particular product type, and converting the units sold to a volume based on the average unit size. For instance, in 2012, in Austria, 29.4 million units of shower gel were sold, with the average unit of shower gel assumed to be 0.3L, which gives an estimate of approximately 8 880 000 L of shower gel sold in Austria during that year.

The total volume of liquid soaps reported for each of the countries listed in Ta-

ble 1 and included in the Cosmetic Europe survey is 6.88×10^8 L. Assuming that liquid soap has a density approximately equal to water (based on knowledge that liquid soaps are water based formulations), the total volume can be reported as being approximately 6.88×10^5 metric tons. The results from the Cosmetics Europe survey report the total amount of micro-plastic to be 4360 tons for the European market. Assuming that both the Euromonitor International data and the amount reported in the Cosmetics Europe survey are representative of use within the European market, in 2012 the total amount of liquid soap will contain approximately 0.6% micro plastic beads.

Summary of Results Based on Market Data

Combined with the assumptions described above, which are based on results from the Cosmetics Europe survey and the Euromonitor International data reported in Table 1, the estimated use of micro-plastic beads associated with use in skin cleansing products for each of the countries that fall within the watershed of the North Sea can be estimated, and are reported in Table 2.

Results reported in Table 2 for countries within the European Union plus Norway and Switzerland imply a total use of micro-plastic beads of 4130 tons. This number is consistent with the data reported in the Cosmetics Europe survey of 4360 tons. Table 2 also reports the estimate associated with per capita usage of micro-plastic beads, with an average value of 17.5 mg/day estimated for individuals across the EU plus Norway and Switzerland (standard deviation of 10). Note that the variability in per capita use scenarios results from the variability associated with volume of liquid soap sold in a specific country relative to the total population of that country. Consequently, the variability in per capita consumption estimates are an artifact of the semi-quantitative approach used in deriving use estimates for each country, and do not necessarily represent real differences between countries regarding the use of micro-plastic beads in skin cleansing products. Nonetheless, the variability represented in Table 2 provides an indication of the likely range of

probabilities associated with per-capita use across the European Market.

For the countries that fall within the watershed of the North Sea an amount of approximately 2300 tons is estimated to be used, which also assumes that the total population for each of the North Sea countries resides entirely within the watershed of the North Sea, which we note is only the case for Belgium and the Netherlands. Consequently, the amount reported in Table 2 for release to the North Sea represents an overly conservative estimate.

Estimating Impact to the North Sea Environment

Building on our earlier estimates, that suggest that micro-plastic beads used in cosmetic products in Europe represent <0.1% of litter that is emitted each year to the global marine environment, we provide here an assessment of the contribution emitted to the North Sea. Supported by the European Union Interreg Programme for the North Sea, and operated by KIMO International, the Save the North Sea project estimates that approximately 20000 t·y⁻¹ of marine litter enters the North Sea (17), with suggestions that this number could be much higher. Nonetheless, using the approximate estimate of litter annually emitted to the North Sea (20000 t·y⁻¹), and assuming that all of the mass of micro-plastic beads originating from cosmetic products is directly emitted to the North Sea

environment it is possible to estimate the relative contribution from cosmetic products. Based on the values reported in Table 2, a conservative estimate of the relative contribution of micro-plastic beads from cosmetic products would be approximately 11% (i.e. 2300/20 000), which represents the worst-case scenario where direct discharge dominates the emission of effluent to the marine environment. Note that the above calculation is based on qualitative assumptions that have been derived using what is believed to be an underestimate of the annual emission of plastic debris to the North Sea environment, and that there is likely to be considerable uncertainty with respect to the estimate provided. Consequently, the values reported here should be considered as representing a worse-case scenario, and that the actual percent contribution is most likely less than reported.

It is notable that waste water treatment plants in member states of the European Commission must meet strict operating requirements regarding the release of suspended solids in their effluent. According to Council Directive 91/271/EEC (18), the removal of total suspended solids (TSS) must be >90%, measured by a 0.45 micron filter membrane. It is notable, that 70% of micro-plastic beads used in cosmetic products identified in the Cosmetics Europe survey would be captured on the 0.45 micron filter. Additionally, the removal of TSS is further

regulated, in that removal efficiencies of at least 50% must be achieved following primary treatment, whereby removal is facilitated by physical and chemical processes, such as the use of chemical flocculants. In many areas, final polishing of the effluent is conducted utilizing sand filtration and other membrane filtration systems, to ensure efficient removal of TSS. Thus it would be anticipated that significant removal of micro-plastic beads can potentially be achieved. Indeed, in a report investigating the removal efficiency of a Dutch waste water treatment facility, with respect to micro-plastic, *Leslie et al.* (16) report that 90% of micro-plastic was efficiently removed. Consequently, a more realistic scenario regarding a conservative estimate of release of micro-plastic beads via cosmetic products to the North Sea environment suggests that the total contribution to the overall litter emitted would generally be <1.5% (relative to the estimate of 20000 t/y).

It should be obvious that the accuracy of deriving a percent contribution associated with the use of micro-plastic beads used in cosmetic products depends on obtaining accurate use data relative to accurate information regarding the amount of plastic debris emitted to the marine environment each year. While the main objective of this study was to provide micro-plastic bead use data from the member companies of Cosmetics Europe, which we

Country	Population (million)	Euromonitor estimates of liquid soaps for 2012 (litres)	Euromonitor-based estimated annual use of micro-plastic beads (tons)	Per capita use (mg/day)
Norway	4.9	7.2x10 ⁶	43	24
Denmark	5.5	4.84x10 ⁶	29	14
Germany	82	1.12x10 ⁸	671	22
Belgium	10.6	1.07x10 ⁷	64	16
France	64	9.49x10 ⁷	570	24
Netherlands	16.6	2.04x10 ⁷	122	20
UK	61	1.13x10 ⁸	680	30
Switzerland	8	1.28x10 ⁷	75	26
Czech Republic	10.2	7.72x10 ⁶	46	12
North Sea Countries (Total)	263	3.84x10 ⁸	2300	21.3±6
European Union plus Norway and Switzerland	516	6.88x10 ⁸	4130	17.5±10

Table 2 Estimated mass of micro-plastic beads used by countries within the watershed of the North Sea.

believe represents an accurate estimate relative to use within the European market, estimates regarding the amount of plastic debris emitted and present in the marine environment are highly uncertain. This is illustrated in the various calculations present in this report. We have, for instance, used a value derived in 1975, which suggested 6.4 million tons of litter enter the marine environment each year (which includes natural litter debris in addition to plastics), but note that a more recent publication suggests that the amount of plastic present in the marine environment is estimated to be about 250000 tons (19), which is 25 times less than the earlier estimate of 6.4 million tons. Given the limited information available regarding the amount of litter in the marine environment, combined with significant variability regarding these estimates, suggests that the associated uncertainty could possibly be several orders of magnitude. In this study we have provided estimates regarding the relative contribution of micro-plastic beads used in cosmetic products ranging between 0.01–11%, representing extremes regarding conservative use and release estimates. In the absence of more robust data regarding estimates of global marine litter, we believe that the value of between 0.1–1.5%, representing use and release estimates for the North Sea environment, be utilized as a reference point from which to perform future assessments. Given that a number of major cosmetic product companies have taken voluntary action to eliminate micro-plastic beads from their products (20), it is anticipated that the continuing contribution of micro-plastic beads used in cosmetic products will dramatically decline to negligible amounts.

Definition of Micro-Plastic Beads in Cosmetic Products

Recently there has been a substantial amount of attention directed towards the use of micro-plastic beads in cosmetic products, with a number of regulatory jurisdictions targeting the implementation of measures to restrict the use of this material in the near future. For instance, at the

time of preparing this summary and analysis of the Cosmetics Europe survey results, the U.S. state of Illinois enacted legislation that would ban the use of micro-plastic beads in cosmetic products (20). In their definition of micro-plastic beads, which they refer to as »synthetic plastic microbeads«, they clearly target any intentionally added non-biodegradable solid plastic particle measured less than 5 mm in size, and is used to exfoliate or cleanse in a rinse-off product (20). Plastic, in this context, refers to a synthetic material made from linking monomers through a chemical reaction to create an organic polymer chain that can be molded or extruded at high heat into various solid forms, retaining their defined shapes during life cycle and after disposal (20). Similar bans have been proposed in New York and in California, adopting the Illinois definition. In this study we summarize data obtained from a recent Cosmetics Europe survey, which aimed to quantify the use of micro-plastic beads, which is reportedly dominated by polyethylene in a solid (particle) form, used in cosmetic products for use as scrubbing or exfoliating agents. Based on the results obtained from the Cosmetics Europe survey we believe that the material investigated in this study is consistent with the definition of plastic microbeads proposed by each of the U.S. states, and suggest that the data reported here help to strengthen regulatory action aimed at reducing the release of these materials to the environment. Consequently, we believe that the results reported in this study will benefit regulatory bodies currently assessing the relative impact of micro-plastic beads used in cosmetic products.

Perspective and Implications

Given the current debate regarding the environmental fate of micro-plastic in the marine environment, it is important to quantify and identify key sources that are contributing to the issue. The data presented in this study imply that the relative contribution of micro-plastic beads originating from cosmetic products to the North Sea environment in 2012 is likely to be between 0.1–1.5%,

particularly where removal via waste water treatment facilities dominates the release scenario, which is prevalent in the majority of European countries included in this study. This observation is consistent with an earlier study, which also concluded that the contribution of micro-plastic beads used in cosmetic products is representative of a minor source of plastic debris to the marine environment (8). Consequently, while there is general agreement that appropriate actions should be taken to reduce the release of plastic debris to the marine environment, it appears that reductions in the use of micro-plastic beads in cosmetic products are likely to have only a limited impact on reductions of plastic debris to the marine environment. We thus believe it to be imperative that additional work be performed towards an improved quantification and identification of important sources of plastic debris, particularly since it is well understood that the major source of micro-plastic to the marine environment is largely influenced by the degradation of macro-plastic (19,21). The approaches adopted in this study should thus provide useful insight towards the development of complementary methods aimed at quantifying the release of plastic debris to the marine environment, and identifying appropriate and effective prioritization actions towards reducing the relative influence of key primary sources. The results of this study are helpful in this context, in that they provide perspective regarding the relative contribution that micro-plastic beads originating from cosmetic products represents. Finally, we note that at the time of finalizing this study, a number of major cosmetic product companies have taken voluntary action to eliminate micro-plastic beads from their skin cleansing products (20), and we would anticipate that the future source of this material originating from cosmetic products will be significantly reduced as a consequence of these actions. It is thus suggested that the data presented here demonstrate that the release of micro-plastic beads to the aquatic environment, associated with use in cosmetic products, has been representative of a minor source of plastic debris to the marine environment, the

relevance of which will continue to diminish as a consequence of voluntary initiatives aimed at reducing their use in cosmetic products.

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