Trends of microplastic abundance in personal care products in the United Arab Emirates over the period of 3 years (2018–2020)

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Abstract
Plastic microbeads in cosmetic products are considered one of the main contributors of primary microplastic pollution in aquatic environments. To assess the trends of microplastic usage in rinse-off cosmetic products over the last 3 years in the United Arab Emirates (UAE), 163 body scrub and face wash products were randomly selected and purchased from different UAE markets over a period of two (2019 and 2020) consecutive years as a continuation of our study of such products in 2018. Microbeads were extracted from the products and their composition was determined. The comparative analysis of the products revealed the presence of microplastic content in fewer products in 2019 and 2020 than to 2018. The results revealed that some of the products that contained microplastic in 2018 still have them in 2020. However, no new products were found on the market that contained microplastic. Overall, fewer products contained microbeads of any composition. Also, the consumer awareness, preferences, and behavior towards microplastic use in personal care products was assessed through a survey 2020 that complemented a survey carried out in 2018. An increasing awareness among the surveyed general public was noted regarding microplastic use in cosmetics and its adverse effects to the environment. The study indicates that an increasing global legislation is effective to curtail the use of microplastic containing microbeads in personal care products by replacing them with beads of alternative composition or avoiding the use of microbeads altogether. Nevertheless, products having microplastic content in the UAE were found to be imported or manufactured by companies based in countries where microplastic usage in personal care products has already been banned by law.

Keywords Microplastic · Microbeads · Cosmetic ingredients · Legislation · Consumer trend · Microparticles

Introduction
Microplastic, plastic particles of less than 5 mm in size, is seen as an emerging environmental pollutant and can be differentiated into primary and secondary microplastic (Habib and Thiemann 2022). While secondary microplastics form through the degradative fragmentation over time of meso- and macroplastic particles, primary microplastics are plastic particles formulated for a specific product application at that small size. Typically, microplastics can be used as abrasives in paint and rust removers and as drug delivery systems. While a large number of articles are being published every year on microplastic, their presence in the environment and their effect on different organisms, quite a few articles have looked at microplastic containing microbeads in cosmetic products in the last 5 years (Bashir et al. 2021; Sun et al. 2020). Nevertheless, the latest announcement by Greenpeace that their studies had found that roughly 25% of the analyzed 664 cosmetic products contained microplastic of some type reverberated around the world (Greenpeace 2021). This brings us back to our own investigation on the trend of solid microplastics in body scrubs and facial cleansers sold in UAE markets, which started in 2018 (Habib et al. 2020a) and now extended for a further 2 years (2019, 2020). Whereas there have been position and policy papers on the
effectiveness of legislation to ban single use plastic in general and microplastic in rinse-off cosmetics in particular, although few studies have discussed the trends of microplastic usage in cosmetics in the last years in order to evaluate the effectiveness of awareness campaigns and growing legislative efforts to ban microplastics in cosmetics (Anagnosti et al. 2021; Dauvergne, 2018), but these efforts were not sufficient because a significant percentage of products still contain microplastics.

Plastic containing microbeads in personal care products are used as exfoliants, viscosity enhancers, and as sorbents to deliver active ingredients (Boucher and Friot 2017). These microbeads can make up to 10% of the product’s weight and reach to several thousand particles per gram of the product (Lassen et al. 2015). A single use of product can release tens of thousands of microbeads (Napper et al. 2015) into the wastewater. Interestingly, products have been found that incorporated as much plastic in their formulation as plastic was used for their packaging (Leslie 2014). As plastic microbeads in cosmetics are intentionally added by manufacturers to personal care products, this has caused a call by the scientific community for policy intervention (Boucher and Friot 2017). In contrast, other microplastic particles often are unintentionally lost to the environment, either as secondary microplastics through the degradation of larger plastic pieces or through primary microplastic spills that make policy interventions harder and less straightforward (Boucher and Friot 2017).

Although Gregory and others sounded an alert early on (Gregory 1996) that microbeads could pose a serious threat to ecosystems, cosmetic, hygiene, and personal care product companies started to use them on a large scale in the mid 1990s. Follow-up studies (Derraik 2002; Fendall and Sewell 2009) added further warnings that there would be dire environmental consequences, if companies continued to add plastic microbeads to their personal care products. Because of their hydrophobic nature, their relatively low density and their small size, microbeads from personal care products, once released into the wastewater, are only partially retained by wastewater treatment plants with the remainder entering aquatic ecosystems via effluents. Although these microbeads contribute only 0.1 to 1.5% to the total amount of plastic waste released into the marine environment (Gouin et al. 2015), they have a significant impact on the food chain contamination within aquatic ecosystems. Microbeads found in cosmetic products can be ingested by marine and fresh water organisms found on the lower trophic level (Isobe 2016; Cheung and Fok 2017). They can be trapped in the digestive tracts, and bio-accumulate in the tissues of these organisms (EFSA Contam Panel (EFSA Panel on Contaminants in the Food Chain) 2016).

Furthermore, manufacturers use chemical additives such as phthalates and bisphenol A in their composition (Thiemann 2021), and microplastics can adsorb toxic contaminants such as polychlorinated biphenyls (PCB’s), pesticides, polyaromatic hydrocarbons (PAH’s), dioxins, perfluorinated alkylated compounds, and metals from the surrounding environment (Mato et al. 2001; Ogata et al. 2009; Fossi et al. 2014; Scopetani et al. 2018; Boucher and Friot 2017; Carbery et al. 2018) and thus serve as a medium of transport for such compounds. These additives and contaminants pose a serious food safety and human health concern and may cause changes in the normal functioning of the liver, pancreas, impair the normal development of fetus, and modify the reproductive process and neurological functions (Srivastava and Godara 2013).

Every year, trillions of plastics containing microbeads still continue to find their way into sewage treatment systems and from there to rivers, lakes, and oceans, ending up in zooplankton, coral, shellfish, fish, seabirds, and marine mammals (Browne et al. 2011; Eriksen et al. 2014; Desorges et al. 2015; Rochman et al. 2015). An implementation of a global legislation on microplastic in cosmetics was delayed (Maniates 2001; Dauvergne and Lister 2012; Borrelle et al. 2017; Raubenheimer and McIlgorm 2017; Simon 2016). Nevertheless, with the potential harms coming from microplastics, legislation has been put in place in some countries to partially or fully ban the primary production, sale, and use of plastic microbeads-containing products, with some levies raised, both nationally and regionally (Xanthos and Walker 2017). As of July 2018, eight (the USA, Canada, France, UK, New Zealand, China, South Korea, and Sweden) out of 192 countries worldwide had established bans on microbeads through national laws or regulations, with several countries yet to implement regional or national legislations (UNEP report 2018). From the time of our last review on microplastics in wastewater treatment in early 2020 (Habib et al. 2020b), two more countries (the Republic of Ireland, and China) have joined in legislating to ban plastic microbeads usage in cosmetics. In addition, organizations such as the European Chemical Agency (ECHA) have been tasked to examine the need for a restriction on the manufacture, sale, and use of intentionally added MPs in commercial products. In fact, in 2019, ECHA proposed a wide-ranging restriction of such MPs in the EC-market. This shows a slow and gradual trend in legislative development to ban plastic microbeads in cosmetics globally. It can be seen from Fig. 1 that legislative development to ban the use of microplastic in cosmetics has taken place only in a few countries, whereas cosmetic manufacturers can still sell microplastic-containing cosmetic products to the rest of the world with little or no restrictions.

Although plastic pollution has been categorized as one of the top 10 environmental global issues facing humanity (Klingelhöfer et al. 2019) and planning for plastic mitigation and reduction strategies started in the 1970s, an
assessment of the public attitude, awareness, and willingness to reduce plastic pollution from different products (Deng et al. 2020; Thomas et al. 2016; Ertz et al. 2017; Munirah et al. 2015) is still fragmentary. While microplastics have become an important research topic in academia, the public’s stance and awareness in regard to microplastics have not been explored. Nevertheless, a behavioral change of the consumer depends on a practical awareness of the issue (Nisbet and Gick 2008).

The United Arab Emirates (UAE) is one of the countries that has not yet announced legal restrictions on microplastic content in rinse-off cosmetics. On the other hand, UAE boasts a large expatriate population and can be seen as a cultural melting pot. It is ranked the 7th in the per capita use of cosmetics. Due to the diversity of its population, cosmetics are imported from all parts of the world. In addition, a significant local cosmetic industry has developed, and also international companies produce cosmetics under license in UAE. This combination seemed to make the UAE cosmetic market an attractive study object to gauge the recent trends on microplastic content in cosmetics. The current study will focus on solid microplastic content in rinse-off cosmetics bought in the UAE market in the years 2019 and 2020. It will use as a baseline a previously communicated study regarding the microplastic content in cosmetics from UAE markets of the year 2018 (Habib et al. 2020a). The main objective of the study was to explore the microplastics usage trends in personal care products for three consecutive years (2018–2020) in the United Arab Emirates. The study was supported by three surveys in years 2018, 2020, and 2021. The study revealed the consumer’s attitude, behavior, perceptions, and awareness level in regard to microplastic-containing products.

Methodology

Surveys

To assess the impact of raising awareness on the participant’s stance towards microplastic use in cosmetics, two surveys were conducted in two consecutive years, 2020 and 2021. The results of these surveys were compared to each other and to a survey that had been conducted in 2018, published in a previous study (Habib et al. 2020a). For the purpose of following up potential changes in consumers’ behavior, the survey of 2021 was given only to those students, faculty, and staff of the United Arab Emirates University and their families that had already participated in the 2018 survey. The participants reflected well the age distribution of the Emirati population (UAE Population Statistics 2022: Infographics). There were 319 participants for the 2018 survey, 107 participants for the survey of 2020 and 104 participants for 2021 (2020–2021 was still within the time period of COVID restrictions). Within the accessible pool of people, the candidates were randomly selected. Females tended to be more eager to take the questionnaire as were persons of the ages 20–40, less than 10% of the inhabitants of the UAE in rural areas, so that there was no bias in the selection process in that regard. In regard to age, excluding the age brackets 0–18 and over 65 years of age, 92.5% of the population of the UAE falls in the age bracket 18–54 years, while in our surveys 92% (2017), 84% (2020), and 83% (2021) of the respondents are 20–40 years old, with the latter two surveys having 8% and 14% of the respondents older than 40 years. Here, the objective was to assess the existing awareness level and knowledge in regard to microplastic
and cosmetics and to evaluate any changes in the participants caused by the survey in 2018. A sample of the answers to pertinent questions from all three surveys (2018, 2020, and 2021) is shown in the supplementary data (Suppl. Figure 7).

**Assessment of microplastic content in commercially available body scrubs and facewashes**

The trend in microplastic content in rinse-off cosmetic products in UAE was evaluated by analyzing cosmetic products collected randomly over the last 3 years from UAE markets for their potential microplastic content. Thirty-seven products were collected in 2018, extracted, and analyzed as to their solid microbead content. This data has been published previously (Habib et al. 2020a) and is taken as the baseline data for this study. In 2019, 89 products were collected, and their contents were evaluated according to the product appearance and the product label. In 2020, 74 products were obtained commercially and analyzed. For the latter analysis, a previously published procedure was used (Habib et al. 2020a).

Solid contents were extracted from the products by dissolving the cosmetic product (5 g) in warm water (100 mL, 45°C). Three replicates for each product were obtained. The solid content was initially filtered through a cotton cloth (Suppl. Figure 3). The obtained filtrate was filtered subsequently through a Whatman millipore filter paper (ashless, grade 42, 2.5-μm pore size) to ensure that all the microbeads were captured from the sample. After filtration, the microbeads were dried in an Ecocell oven (MMM-group) at 37 °C for 14 h. In cases, where more than one type of microbeads was present in the product, the particles were separated manually by hand under the stereomicroscope (stereoscope model SZ2-ILST).

A few products having organic-rich contents were treated with Fenton reagent to dissolve the organic matter to ease the filtration process. For the treatment with the Fenton reagent, the product sample (1 g) was treated with H2O2 (30% v/v, 1 mL) mixed with catalyst (0.5 mL). This resulted in a solution of pH 5. The catalyst solution contains iron (II) sulfate heptahydrate (FeSO4·7H2O, 20 g) in distilled water (1 L) (Tagg et al. 2017). Then, the sample was left at room temperature approximately for 10 min to complete the reaction. Thereafter, water (100 mL) was added to the solution, and the solution was filtered through a Whatman filter paper (ashless, grade 42, 2.5-μm pore size) for microbead separation. To remove impurities from the filter paper surface, it was rinsed three times with distilled water (10 mL). Then, the filter paper and the extracted microbeads were dried in an Ecocell oven (MMM-group) at 37 °C (14 h).

The filtered, washed, and dried microbeads were analyzed for size, shape, and total count. An electric balance type ABT 220-5DM (detection limit: 0.01 mg) was used for weighing. Microphotos of the beads (Suppl. Figure 4) were taken with a stereo microscope (Model SZ2-ILST). Three replicates from each product were used for the photos and quantification. For characterization and determination, the Feret’s diameter of the microbeads, the microphotos were analyzed by Fiji Image J software (Suppl. Figure 4) (Schneider et al. 2012; Schindelin et al. 2012). The Feret’s diameter represents the size of microbeads. The Feret’s diameter corresponds to the longest distance between two points along the microbeads boundary (Santagapita et al. 2012).

Fourier Transform Infrared (FT-IR) spectroscopy was performed on Thermo Nicolet Nexus 670 and Perkin Elmer Spectrum 2 FT-IR spectrometers and was used to determine the composition of extracted microbeads for each product. The obtained spectra were matched with OMNIC 9 software to identify the composition of the microparticles.

Ashing of the microbeads was carried out in a Carbolite electric oven heating the samples at 600 °C for 2 h (Suppl. Figure 5), with a weighed sample of each product placed in a crucible (79C-00, Waldenwanger, Berlin). The ash contents are expressed in w% within the text. In cases, where appreciable ash content was found, the remnant ash was analyzed by FT-IR spectroscopy to identify the composition of the residue. This helped identify the colorants used for the microparticles as well as the inorganic constituents of the microparticles and the products as a whole.

In those cases, when the product did not exhibit any microparticles ≥ 5 μm (e.g., products A37-A43), the product (5 g) was diluted with water (100 mL), and any resulting solids were filtered through a filter paper (Schleicher & Schuell 589/3). The filter cake was dried in an Ecocell oven (MMM-group) at 37 °C (14 h). The solid was weighed, submitted to IR spectroscopy, and ashed at 600 °C (2 h) in a Carbolite electric oven. The resulting ash was weighed and submitted to IR spectroscopy.

**Results and discussion**

**Surveys**

Raising awareness and monitoring the existing knowledge in consumers regarding microplastic containing microbeads in personal care products can be a key contributor to a shift in the consumers’ behavior away from microplastic-containing products (Sandu et al. 2020). Communicating the problems associated with microplastic-containing products to the general public can complement legislative developments and can mobilize manufacturers to produce plastic-free cosmetics. To have
an idea about the general public’s stance on microplastic in rinse-off cosmetics, the authors have conducted two surveys, directed to university students, faculty, staff, and their families, one in 2019 and one in 2021. In addition, the survey of 2021 was given to 103 persons who had already taken the survey in 2018, i.e., around 2 years before, to understand, if there was any change in the participants’ attitude to microplastic in cosmetics.

The results of the first survey, conducted in 2018, were published in 2020 (Habib et al. 2020a). Looking at the results of the survey of 2020 (Suppl. Figure 7) and comparing them to the results of 2018, participants were more decisive in their choice as to what ingredient they would not like to see in their cosmetic products. While more participants disliked to have polyethylene microbeads in their product in 2020 (33%) than in 2018 (21%), interestingly, also more participants did not like to have walnut shells in their product. In 2020, only 25% of the participants said that environmental concerns were a priority for them when buying products. In regard to persons retaking the survey of 2018 after 2 years, the participants generally opted for microbead-less products. The dislike of beads or particles of any sort (polyethylene, ground walnut shell, microcrystalline cellulose, and synthetic wax) increased across the board, which can also be recognized by the fact that only 3% of the participants said that they did not mind any of the microbead compositions, down from 25% for the same question answered by participants not having taken the first survey. Interestingly, also, while more participants in 2020 than in 2018 thought that microplastics should be banned in cosmetics, the trend in 2020 was less pronounced with participants having taken the first survey in 2018 than with participants taking the survey for the very first time. In all, there seems to be a slowly increasing awareness of environmental issues related to microplastic-containing cosmetics. One-off surveys, however, do not necessarily strengthen the awareness of participants over a longer period of time.

Remarkably, although in 2019, the overall number of microplastic-containing products dropped by 17% in the UAE markets as compared to 2018, the microplastic-containing products user rate (approximated through the surveys) has shown a smaller drop of only 6% from 2018 to 2020. This factor can be attributed to the consumers’ preference of a number of brands stemming from South Asia and also imported from Europe, which still carry microplastic (Suppl. Figure 1).

The COVID-19 pandemic has made online shopping more important and plays a significant role in the availability of desired products and the decline on the reliance on locally available products. The survey of 2020 also showed the product preference of the participants in regard to online available rinse-off cosmetics. The result indicated that about 15% of the preferred products had microplastic content. This is close to the value (12%) that we had found for the products available in the UAE markets in 2019–2020.

To assess the influence of our first survey of 2018 on participants, the participants were asked to take a second survey in 2021 to understand, if there had been any changes in their consumer habits. In that survey, they were asked whether they had changed their cosmetic product after taking the first survey. About half of the participants who answered had changed their product. Interestingly, 24 participants (6% of the total) who had taken the first survey were still using products that had plastic containing microbeads. Brands play a significant role for 80% of the participants. Also, products’ qualities such as “texture of the product” (38%) and “fragrance of the product” (32%) are more important than “environmental sustainability of the product” (25%).

In regard to the question “should microplastics be banned in cosmetics?”, in 2021, 80% of the participants who had already taken the first survey (in 2019) said “yes” and 20% answered with “no.” This is only slightly more than with first-time participants in 2020, 73% of whom said “yes.” Both results are slightly up compared to the results of the survey of 2019, where 71% said “yes, microplastics should be banned in cosmetics.”

**Microparticles—trends in the compositions of UAE rinse-off cosmetics (2018)**

From our previous study (Habib et al. 2020a), it was noted that in 2018, there were still polyethylene-based microplastic-containing rinse-off cosmetics sold in UAE markets. At the time, it was found that 11 (30%) out of the 37 randomly selected face and body scrubs had such microplastics (Fig. 2). Microcrystalline was the second most common ingredient found in face/wash and body scrubs bought in 2018. Next in line, were walnuts shell powder (19%) and hydrated silica (5%). Twenty-four percent of products were found to have no solid microbeads.

**Microparticles—compositions of UAE rinse-off cosmetics (2019)**

In 2019, 89 (Fig. 3) products were screened to identify the possible presence and composition of microbeads. Only 11 (12%) products were found to have microbeads composed of microplastic. This indicates an 18% decrease in plastic microbead-containing cosmetics products since 2018. Similarly, fewer products with microcrystalline microbeads were found in 2019 than in 2018. In 2019, more products were seen to carry walnut shell powder as abrasive or no microbeads at all. This change seems to indicate a slow phase-out of polyethylene in cosmetics and a shift to no microbeads products or to products with biodegradable microbeads in the UAE market. It must be noted that most rinse-off cosmetics
produced in the UAE have either walnut shell powder in their formulation or no microbeads at all. The category “others” includes products with charcoal powder and clay minerals.

**Microparticles—compositions of UAE rinse-off cosmetics (2020)**

The analysis of the data obtained for year 2020 revealed a similar percentage of products with microplastic content as in 2019. In 2020, 74 randomly selected cosmetic products were analyzed. Only 9 (12%) products were found to have plastic microbeads. The share of products containing microcrystalline cellulose was also reduced in 2020 as compared to 2019, from 17 to 12%. A slight increase was noted for products carrying silica and shell powder contents. In 2020, more products were found with no microbeads at all as compared to the previous 2 years. These results confirm the impact of voluntarily phasing out microbeads from cosmetic products by many cosmetic manufacturers (Gouin et al. 2015; Cosmetics Europe 2018; Department of the Environment and Energy 2018). Also, more products had to be grouped under “others,” especially as more products could be found that incorporated clay and/or charcoal powder in their composition (Suppl. Table 1). Out of the nine microplastic-containing products, two products were found to stem from two European countries, in which microplastic usage in cosmetics has already been banned. Interestingly, the current study shows that with 12% of products carrying solid plastic microbeads, the UAE market carries...
less microplastic-containing products than what has been found for the Polish market (55%, Piotrowska et al. 2020), the Spanish market (43%, Godoy et al. 2019), and the Greek market (39.8%, Anagnosti et al. 2021). It must be stressed that most of the products manufactured in the UAE use ground nut shells as solid exfoliant particles, which may lead to this difference (Fig. 4).

For the products analyzed in 2020, the size of the microbeads (Suppl. Table 2 and Suppl. Figure 2) was found to range between 6 and 548.6 µm. The average microbead size in all microbead-carrying products was found to be 80.26 µm. The size range of microbeads in 2020 was found to be larger than that in 2018 (12.3 µm and 273.4 µm). However, the difference here was due solely to one product found in 2020, which exhibited microparticles of a larger size. The mean average microbead mass in products with microbeads was found to be 0.03 g per g of the product. On the average, 2866 microbeads were found per gram of product in microbead-carrying products analyzed in 2020. The microbead size has some importance as it affects the ability of wastewater treatment plants to retain the microbeads. Wastewater treatment plants (WWTPs) possess certain sizes of filtering screens that act as a barrier for the microparticles. Also, the size influences the settling behavior of microparticles in settling tanks, e.g., before and after activated sludge treatment (Habib et al. 2020b, 2021). Usually, smaller-size particles have a higher chance to pass through WWTPs and enter the effluents.

Interestingly, also in 2019–2020, products with microplastic content have been seen to be imported from Europe, the USA, South Asia, and South East Asia, where in part the products stem from countries in which microplastic content in rinse-off cosmetics has already been banned (Suppl. Figure 1 and Fig. 5).

### Smaller-sized solid constituents

Although the focus of this work was on the identification of microparticles in the cosmetic products, there are other solid constituents (< 5 µm) that are worth mentioning. On the one hand, often organic components such as glyceryl esters and glycol esters are added to the cosmetics. They include glyceryl mono- and distearates and glycol distearate, which are not soluble in water, and stearic acid, which is only sparingly soluble. The authors looked at the contribution of such esters in some of the cosmetic products, which otherwise carried ground walnut shells as microparticles. Here, the walnut shell can be separated easily from the remaining organic solid constituents as ground walnut shells have a density of more than 1.0 g/cm³. After filtering off the walnut shell, the remaining suspension was filtered through a Whatman filter paper. Here, it was noted that the stearates, including stearic acid, can make up as much as 18.5 w% of the product (such as in product A 41, see legend of Table 2 Supp.). Stearates are not particularly toxic—they are used as an emulsifier food additive (E-471)—but they contribute a heavy organic load to the wastewater.

Inorganic additives that were found but not included in the section on microparticles are small-sized clay particles and titanium dioxide (TiO₂). Where these additives were found in association with microparticles in the product, the microparticles were filtered off first with a cloth, which clays and smaller TiO₂ particles passed through. The suspended smaller particles were subsequently filtered off with
Fig. 5 Microplastic-containing products found in UAE markets from 2018 (A), 2019 (B), and 2020 (C), manufactured in different countries.

(A) Microplastic found in analyzed cosmetic products from different countries in 2018

(B) Microplastic found in cosmetic products from different countries in 2019

(C) Microplastic found in analyzed cosmetic products from different countries in 2020
a Whatman filter paper. Products were found to carry as much as 1.07 w% TiO₂. Again, TiO₂ is not very toxic. It can even be used as a food additive (E-171), although efforts are underway to withdraw approval in EU as a carcinogenic effect at least of TiO₂ nanoparticles (TiO₂-NPs) cannot be ruled out (Bampidis et al. 2021). Studies with TiO₂-NPs have shown that their presence in wastewater (Zeumer et al. 2020; Galhano et al. 2020) or their addition to fish feed (Tabassum et al. 2020) can have adverse effects on the health and growth of freshwater invertebrates (Galhano et al. 2020) and fish (Zeumer et al. 2020).

The inorganic contents of the microbeads themselves can also be found by “ashing” them at 600 °C (2 h). For ground nut shells, the remaining ash majorly consists of calcium carbonate, calcium oxide, and calcium hydroxide. In those cases where clays or hydrated silica have been used as microparticles, their content can be found by “ashing” them at 600 °C (2 h). For example, 1 product (CI 77,491 [Fe₂O₃, ferric oxide, red]), 3 products (CI 77,492 [FeO(OH),H₂O, iron oxide-hydroxide, yellow]), and 2 products (CI 77,288 [Cr₂O₃, chromium (III) oxide], 1 product CI 77,289 [Cr₂O₃, chromium (III) oxide hydrate]) were found to contain chromium (III) salts, usually chromium (III) oxide hydrate. Cobalt aluminate blue spinel, a blue pigment thermally resistant dye, is not stable at 600 °C under oxidative conditions. The complex copper phthalocyanine (CI 74,160), while advertised as a thermally resistant dye, is not stable at 600 °C under oxidative conditions. Cobalt aluminate blue spinel, a blue pigment often used in cosmetics, we have not come across in this study. Finally, having concluded the analysis of the different ingredients and not CI 77,289. Nevertheless, of the 50 products chosen, 3 products listed CI 77,491 [Fe₂O₃, ferric oxide, red], 5 products CI 77,492 [FeO(OH),H₂O, iron oxide-hydroxide, yellow], 3 products CI 77,499 [FeO(OH),H₂O, ferric-ferrous oxide, black], 2 products CI 77,288 [Cr₂O₃, chromium (III) oxide], 1 product CI 77,289 [Cr₂O₃, chromium (III) oxide hydrate], and 2 products CI 74,160 [copper phthalocyanine] as heavy metal salt pigments or complexes. In addition, lazurite (ultramarine, CI 77,007) was used in one product. The remainder of the products used organic dyes as colorants (Suppl. Figure 6A and 6B). Apart from indigo disulfonate (CI 73,015, violet) for 1 product, a hydroxyanthraquinone (CI 60,725) for 2 products, a triphenylmethane (CI 42,090, blue) for 14 products, and a bis(3-oxobenzothien-2(3H)-ylidine) (CI 73,360, red) for 4 products, azo aryl sulfonate sodium salts were used exclusively: CI 10,316 (yellow) for 1 product, CI 14,700 (red) for 2 products, CI 14,720 (red) for 4 products, CI 15,510 (orange) for 1 product, CI 15,985 (yellow) for 2 products, CI 16,035 for 3 products, CI 16,255 (red) for 1 product, CI 17,200 (dark red) for 7 products, CI 19,140 (yellow) for 12 products, and CI 47,005 (yellow) for 2 products.

**Water-soluble polymers**

While our study focused on insoluble, solid microparticles, going through the ingredient lists of the randomly chosen 50 products of the pool of commercially acquired cosmetics, it can be noted that many of them contained water-soluble polymers (Suppl. Figure 6c): 12 products contained polyacrylic acid (carbomer), 13 products contained acrylate co- or cross-polymers, 6 products contained polyquaternium-7, and 1 product each contained polyquaternium-30 or polyquaternium-39.

**Conclusions**

From our study of rinse-off cosmetics available in UAE markets, it can be concluded that the proportion of microplastic-containing products has decreased from 2018 (30%) to 2020 (12%), although the UAE does not yet have binding legislation that forbids microplastic in rinse-off cosmetics. Mainly, products have hydrated silica or microcrystalline cellulose as microparticles. Products manufactured in the UAE overwhelmingly contain ground walnut/almond shell. Also, many products have no microbeads at all. This points to a gradual phase-out of microplastic-containing products in the UAE. Interestingly, however, products with microplastic content have been seen to be imported from Europe, the USA, South Asia, and South East Asia, where in part the products stem from countries in which microplastic content in rinse-off cosmetics has already been banned. Consumer surveys centered at the United Arab Emirates University do not give a clear picture that consumers’ preferences are based on environmental concerns. Product brands play a major role in the consumers’ choice of product. “Environmental safety and sustainability” only comes third, with the products’ properties “texture” and “fragrance” having more importance. Nevertheless, 80% of the participants of our last survey (2021) want microplastic content banned from rinse-off cosmetics.

While this study shows that at least in the UAE microplastic-containing rinse-off cosmetics are on the decline, it will be important to continue to assess the situation, not
only here but worldwide, especially in regions that are not party to legislation that has banned microplastic in rinse-off cosmetics.

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**Data availability** Not applicable.

**Declarations**

**Ethics approval** The surveys were conducted under the UAEU ethical approval number ERS 2019 5991.

**Consent to participate** An informed consent has been provided to all participants of the surveys.

**Consent for publication** Not applicable.

**Competing interests** The authors declare no competing interests.

**References**

Anagnosti L, Varvaresou A, Pavlou P, Protopepa E, Carayannis V (2021) Worldwide actions against plastic pollution from microbeads and microplastics in cosmetics focusing on European policies. Has the issue been handled effectively? Mar Pollut Bull 162:111883

Bampidis V, Azimonti G, Bastos ML, Christensen H, Dusemund B, Durjava MF, Koubia M, López-Alonso M, Puente SL, Marcon F, Mayo B, Pechová A, Petkova M, Ramos F, Sanz Y, Villa RE, Woutersen R, Aquilina G, Bories G, Gropp J, Galobart J, Vettori MV, European Food Safety Authority (2021) Safety and efficacy of a feed additive consisting of titanium dioxide for all animal species (Kronos International, Inc.). EFSA Journal 19(6):6630

Bashir SM, Kimiko S, Mak C-W, Fang JKH, Gonçalves D (2021) Per-sonal and cosmetic products as a potential source of envi-ronmental contamination by microplastics in a densely populated Asian city. Front Mar Sci 8:683482. https://doi.org/10.3389/fmars.2021.683482

Borrêle SB, Rochman CM, Liboiron M, Bond AL, Lusher A, Brad-shaw H, Provencher JF (2017) Opinion: why we need an interna-tional agreement on marine plastic pollution. Proc Natl Acad Sci 114(38):9994–9997

Boucher J, Friot D (2017) Primary microplastics in the oceans: a global evaluation of sources. IUCN, Gland, Switzerland. https://doi.org/10.2305/IUCN.CH.2017.01.en

Browne MA, Crump P, Niven SJ, Teuten E, Tonkin A, Gal-loway T, Thompson R (2011) Accumulation of microplastic on shorelines worldwide: sources and sinks. Environ Sci Technol 45(21):9175–9179

Carbery M, O’Connor W, Palanisami T (2018) Trophic transfer of microplastics and mixed contaminants in the marine food web and implications for human health. Environ Int 115:400–409

Cheung PK, Fok L (2017) Characterisation of plastic microbeads in facial scrubs and their estimated emissions in Mainland China. Water Res 122:53–61

Cosmetics Europe (2018) ECHA workshop 30–31st May 2018 intentionally added microplastics to products break-out session: cosmetics ECHA Workshop Plenary Session 30th and 31st May 2018 Helsinki

Dauvergne P (2018) Why is the global governance of plastic failing the oceans? Glob Environ Chang 51:22–31

Dauvergne P, Lister J (2012) Big brand sustainability: governance prospect and environmental limits. Glob Environ Chang 22:36–45

Deng L, Cai L, Sun F, Li G, Che Y (2020) Public attitudes towards microplastics: perceptions, behaviors and policy implications. Resources, Conserv Recycl 163:105096

Derraik JGB (2002) The pollution of the marine environment by plastic debris: a review. Mar Pollut Bull 44(9):842–852

Desforges J, Galbraith M, Ross PS (2015) Ingestion of micro-plastics by zooplankton in the Northeast Pacific Ocean. Arch Environ Contam Toxicol 69:320–330

Department of the Environment and Energy (2018) An assessment of the sale of microbeads and other non soluble plastic polymers in personal care and cosmetic products currently available within the Australian retail (in store) market Department of the Environ-ment and Energy, Canberra

EFSAM Contam Panel (EFSAM Panel on Contaminants in the Food Chain) (2016) Statement on the presence of microplastics and nanoplastics in food, with particular focus on seafood. EFSA J 14:4501–4531

Eriksen M, Lebreton LCM, Carson HS, Thiel M, Moore CJ, Borre-ro JC, Galgani F, Ryan PG, Reisser J (2014) Plastic pollution in the world’s oceans: more than 5 trillion plastic pieces weighing over 250,000 tons afloat at sea. PLoS ONE 9(12):e111913

Ertz M, Huang R, Jo M-S, Karakas F, Sarigöllü E (2017) From single-use to multi-use: study of consumers’ behavior towards consump-tion of reusable containers. J Environ Manage 193:334–344

Fendall LS, Sewell MA (2009) Contributing to marine pollution by washing your face: microplastics in facial cleansers. Mar Pollut Bull 58(8):1225–1228

Fossi MC, Coppola D, Baini M, Giannetti C, Guerranti L, Marsili C, de Panti E, Sabata SC (2014) Large filter feeding marine organ-isms as indicators of microplastic in the pelagic environment: the case studies of the Mediterranean basking shark (Cetorhinus maxima) and fin whale (Balaenopterarophalus). Mar Environ Res 100:17–24

Galvan C, Hartmann S, Monteiro MS, Zeumer R, Mozhayeva D, Steinhoff B, Müller K, Prenzel K, Kunze J, Kuhnert KD, Schön-herr H, Engelhard C, Schlechtriem C, Loureiro S, Soares AMVM, Witte K, Lopes I (2020) Impact of wastewater-borne nanoparticles of silver and titanium dioxide on the swimming behaviour and biochemical markers of Daphnia magna: an integrated approach. Aquat Toxicol 220:105404

Goudry V, Martín-Lara MA, Calero M, Blázquez G (2019) Physical-chemical characterization of microplastics present in some exfoli-ating products from Spain. Mar Pollut Bull 139:91e99
