Journal of Environmental Protection, 2025, 16(4), 354-383
https://www.scirp.org/journal/jep
ISSN Online: 2152-2219
ISSN Print: 2152-2197

# Presence of Microplastic in Personal Care and Cosmetic Products from Markets in Punjab, Pakistan

**Sajjad Hussain[1], Nuzhat Sial[1*], Zarqa Nawaz[2], Muhammad Naeem[3], Rana Zeeshan Habib[4], Thies Thiemann[5*]**

[1]Department of Zoology, The Islamia University of Bahawalpur, Bahawalpur, Pakistan
[2]Department of Chemistry, The Women University Multan, Multan, Pakistan
[3]Department of Pharmacy, Shah Abdul Latif University, Khairpur, Pakistan
[4]Department of Biology, College of Science, United Arab Emirates University, Al Ain, United Arab Emirates
[5]Department of Chemistry, College of Science, United Arab Emirates University, Al Ain, United Arab Emirates
Email: *nztsial@gmail.com, *thiesthiemann@yahoo.de

**How to cite this paper:** Hussain, S., Sial, N., Nawaz, Z., Naeem, M., Habib, R.Z. and Thiemann, T. (2025) Presence of Microplastic in Personal Care and Cosmetic Products from Markets in Punjab, Pakistan. *Journal of Environmental Protection*, **16**, 354-383.
https://doi.org/10.4236/jep.2025.164018

**Received:** March 9, 2025
**Accepted:** April 19, 2025
**Published:** April 22, 2025



## Abstract

In order to assess microplastic content in personal care products in Pakistan, 103 body scrubs and face washes were randomly selected in August-October 2021 from different markets in Jhang, Multan, and Bahawalpur in Punjab, Pakistan. It was found that 47 (45.6%) products incorporated plastic microbeads, including 44 (42.7%) products that exhibited polythene microbeads. Overall, a higher proportion of imported products exhibited plastic microbead content than locally manufactured products.

## Keywords

Rinse-Off Cosmetics, Body Scrubs, Plastic Microbeads, Microbeads, Plastic Pollution

## 1. Introduction

Microplastics (MPs) have become a pervasive environmental concern globally due to their widespread presence in water bodies and their potential to enter the human food chain. In 2021, global plastic production amounted to 390.7 million tons [1] [2], an increase of 4% over the preceding year. A significant amount of the plastic reaches the environment, especially at the end of life or due to spillage during production and transport. It is estimated that 10% of the plastics produced worldwide enter the oceans, thereby contributing 80%~85% of the marine litter [3]-[5] and >90% of the floating debris [6], constituting between $2.1 \times 10^{23}$ and 1.7

× $10^{24}$ plastic particles [7] [8]. The fate of single-use plastics is especially worrisome. Its production, use and fate at end of life are governed by reglementary laws in a number of regions. Historically, there have been products whose plastic constituents would automatically be released into the environment upon use. Typical such products are plastic abrasives for blast cleaning surfaces and microplastic (MP) containing personal care products [9]-[12]. In both instances, the plastic particles are less than 5 mm in size, hence microplastics, and "soft" enough not to damage the surface to be cleaned, may it be the skin, tooth enamel, or the hull of a ship, and in both instances the particles belong to the class of primary MPs. Primary MPs as opposed to secondary MPs are plastic particles that are purposefully produced in their small size for certain applications. Secondary MPs, on the other hand, derive from the degradation of larger plastic pieces, such as meso- and macroplastics. In the last decade, a number of countries (**Figure 1**) started to severely reduce the use of MPs in rinse-off cosmetics that include toothpastes and body scrubs. These efforts range from outright banning MPs in rinse-off cosmetics to governmental recommendations [13]. The first culmination of this effort was the Microbead-Free Waters Act of 2015 [14] [15], which was passed by the 114th Congress of the United States and which prohibits the sale and distribution of rinse-off cosmetics containing plastic microbeads. Bans on microbeads in rinse-off cosmetics were also put in place in Swe-den (2018), UK (2018), Italy (2019), France (2017), the Netherlands (2014), India (2020), Thailand (2017), South Korea (2017), Taiwan Region (2018), Canada (2018) and New Zealand (2017). In addition, in September 2018, in an effort to restrict the manufacture and sales of products with intentionally added MPs, the European Parliament called on the Commission to implement a MP ban in cosmetics, personal care products, detergents and cleaning products in all European Community (EC) member states by 2020, with the idea that the manufacturers of cosmetics operating in the EC would have phased out MPs voluntarily at that time. The adoption of this ban has taken more time than expected but has been voted on positively by the EC member states and as amending Annex XVII to Regulation (EC) No 1907/2006 of the European Parliament and of the Council concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) as regards synthetic polymer microparticles is currently scrutinized by the Council and European Parliament [16] [17]. Many of the industrialized countries such as Australia focused on a voluntary industrial phase-out of plastic microbeads found in rinse-off personal care and cosmetic products [18]. In Australia, the voluntary phase-out was led by Accord Australasia (Accord), and a recent study has shown that of 8100 unique stock keeping units of rinse-off products scrutinized at different shops in the country, only 58 (0.7%) exhibited plastic microbeads [19], most of which were facial and body scrub products.

Some of us pursued a study on MP content of body scrubs sold in the United Arab Emirates in 2018 - 2020 [20] [21], and it was shown that gratifyingly only a small percentage of products contained MPs, the share of which even declined during the time of the study, and this in a country that had not signed off on legislation banning or restricting plastic microbeads in rinse-off cosmetics. These studies were augmented by a survey on MPs in toothpastes available in UAE [22], in addition to toothpastes bought in Syria. None of them showed any MPs. The results seemed to indicate that MPs were being phased out in cosmetics, including in toothpastes, generally, even in regions where no ban on microplastics had been announced. Similarly, O'Farell and Harvey [19] reported that none of the toothpastes analyzed in Australia showed MPs, and Lei *et al*. found no plastic microbeads in the 135 toothpastes from 23 brands they studied in China [23]. Disparagingly, however, from some parts of Asia such as India and China came other reports of continuing significant use and release of MP into the environment of MPs from cosmetic products [24] [25], including from toothpastes [26] which seemed to indicate a more complicated situation worldwide. Therefore, when the opportunity presented itself to undertake a study on MP content of cosmetic products in Pakistan, the authors were happy to seize it.

In recent times, a number of studies have appeared that analyzed for MP concentrations in different environmental compartments in Pakistan, predominately in aquatic environments such as in nearshore waters [27], and along the coastline of the Arabian Sea [27]-[29], but also in relatively secluded lakes such as the Mahodand Lake, Swat, Khyber Pakhtunkhwa District [30] and Rawal Lake, Margalla Hills, Islamabad Capital territory [31] [32]. MP concentrations were found to be significant. Also, the studies made clear that MPs are taken up by marine organisms including fish such as the Indian mackerel (*Rastrelliger kanagurta*) [28] and the Crescent grunter (*Terapon jarbua*) [29] that are used for local consumption, giving the chance for MPs to penetrate the human foodweb [33] [34]. However, little is yet known about the contribution of different sources to MPs in the Pakistani environment. As plastic microbeads from personal care products have always been seen as contributors of primary MPs to the environment, this study has also been undertaken to understand to what degree cosmetic products contribute to the overall MP contamination in the environment. For this reason, 103 different rinse-off cosmetics were bought from markets in Punjab, Pakistan and analyzed for microplastic beads. The following is the account of this study.

## 2. Materials and Methods

103 cosmetic products, including scrubs and personal care and cosmetic products (PCCPs), were selected randomly from various local markets located in Jhang, Multan, and Bahawalpur in Punjab, Pakistan. The products were purchased during the months of August, September, and October 2021. The products were purchased without any attention to cost or to the country of manufacture of the products. 30 facial scrubs were purchased from Jhang, 42 were purchased from Multan and 31 scrub samples were bought from Bahawalpur. The products were of different brands, made by diverse manufacturing companies and had diverse countries of origin.

Solid content from the cosmetic products was obtained by addition of 10 g of the selected cleanser to 200 mL of water at 50˚C. The resulting mixture was stirred for 10 min. Thereafter, the mixture was filtered through a cotton cloth. This procedure was performed in triplicate for each product. Then, the acquired filtrate was put through an additional round of filtration using a Whatman filter paper (ashless, grade 1001-070, pore size 11 μm) to ensure that all potential microparticles had been removed. The particulates were dried in a Vacuum Oven DZF-6090 drying cabinet at a temperature of 40˚C for 10h. Before filtration, the seven products SH3, SH11, SH16, SH20, SH29, and SH96 were discovered to have a significant of non-soluble organic components. These samples were subjected to treatment with Fenton reagent ($FeSO_4$ + $H_2O_2$) in order to decompose the organic matter. There were also organic solids in the samples SH36, SH48, SH85 and SH92, which could be removed with the organic solvents ethyl acetate and chloroform.

It was necessary to use a microscope (Olympus microscope BX51M) in order to manually separate the particulates in some of the tested products due to the existence of more than one kind of microplastic. In SH36, SH48, and SH85, there were microbeads present that had a variety of colors, including blue, pink, yellow, and white. These microbeads were separated through the process of floatation using a variety of differently dense organic solvents, such as chloroform ($CHCl_3$, d = 1.40 g/mL) and ethanol ($C_2H_5OH$, d = 0.789 g/mL).

In the case of digesting products with Fenton's reagent, 5 g of the product sample was treated with a mixture of 5 mL of a solution containing hydrogen peroxide ($H_2O_2$) and 2.5 mL of a solution containing Fenton's catalyst. The solution was pH 5. To prepare Fenton's catalyst, 20 g of iron (II) sulphate heptahydrate ($FeSO_4 \cdot 7H_2O$) were dissolved in 1L distilled water [35]. A reaction between the sample and the solution was allowed to proceed at 25˚C for approximately 15 min. After this, 10 mL of water were added to the solution, and the resulting suspension was filtered using a Whatman filter paper (ash less, grade 1001-070, 11 μm pore size). A final washing of the filtrate was carried out with 315 mL distilled water. The filter paper with the filtered solid was then dried in an oven (Vacuum Oven DZF-6090) at 40˚C.

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, whereas microphotos of the beads were taken with an Olympus microscope BX51M. Three replicates from each product were used for the photos and quantification procedures. For characterization and Feret's diameter of the microbeads, the photos were analyzed by Fiji Image J software [36] [37]. The Feret's diameter represent the size of microbeads. The Feret's diameter corresponds to the longest distance between two points along the microbeads boundary [38].

Fourier Transform Infrared (FT-IR) spectroscopy (model Bruker ALPHA platinum) was used to determine the composition of extracted microbeads for each product. The obtained spectra were matched with OMNIC 9 software to identify the type of polymer.

To obtain an insight in the inorganic constituents, the filtered solids of the cosmetic products were subjected to ashing, where samples were weighed in crucibles of 40 ml volume and were heated in a Vacuum Oven DZF-6090n for 1.5 h at 550˚C. The amount of ash that was left behind and which constitutes the inorganic content of the microbeads is shown in the text as w%.

During isolation and analysis of the product samples, suitable contamination control measures took place to prevent microplastic and fiber contamination. White cotton laboratory coats were worn, and single-use latex gloves were used throughout the study. The number of persons in the laboratory was kept to a minimum, and the laboratory door was closed at all times. Surfaces were cleaned carefully prior to use. Randomly, filter paper was scrutinized under the microscope for any contamination before use.

## 3. Results

Of the products sampled for this study, 26 products had been manufactured locally by Pakistani companies, 34 samples had been produced in India, 8 products in the United Arab Emirates, 12 products in Thailand, 11 products in China, 2 products in South Korea, 5 products in the United States of America, and 5 products were made by companies in France (**Figure 1**).

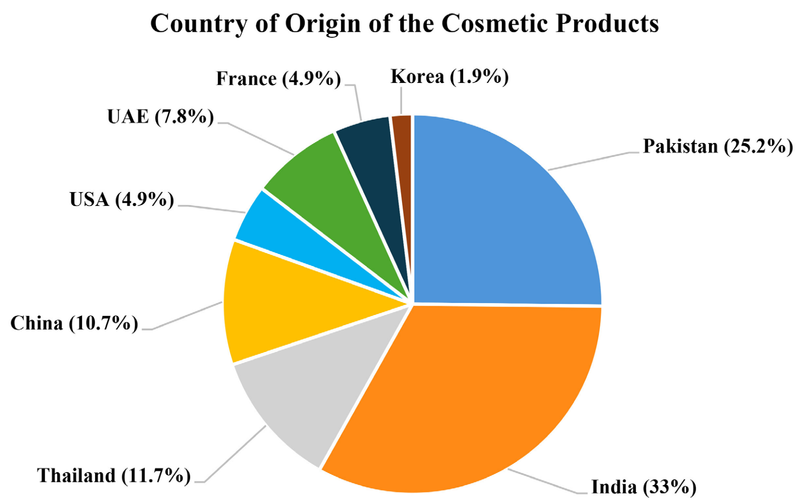



**Figure 1.** Country of origin of the cosmetic products investigated in this study.

From the evaluation of the solid content of the cosmetic products under study, it could be seen that out of 103 products, 27 products (26.2%) did not contain any microbeads at all, 20 products (19.4%) contained walnut shells as abrasive, 3 products (2.9%) contained hydrated silica as the only solid abrasive, and 6 products (5.9%) exhibited microcrystalline cellulose as the sole solid abrasive (**Table 1**, **Figure 2**). 10 other products (9.7%) incorporated microcrystalline cellulose in their formulation, but then invariably in combination with polythene microbeads. It was found that 47 (45.6%) products incorporated plastic microbeads, including

44 (42.7%) products that exhibited polythene microbeads. 10 (9.7%) of the products which revealed polythene had microcrystalline cellulose as a co-constituent.

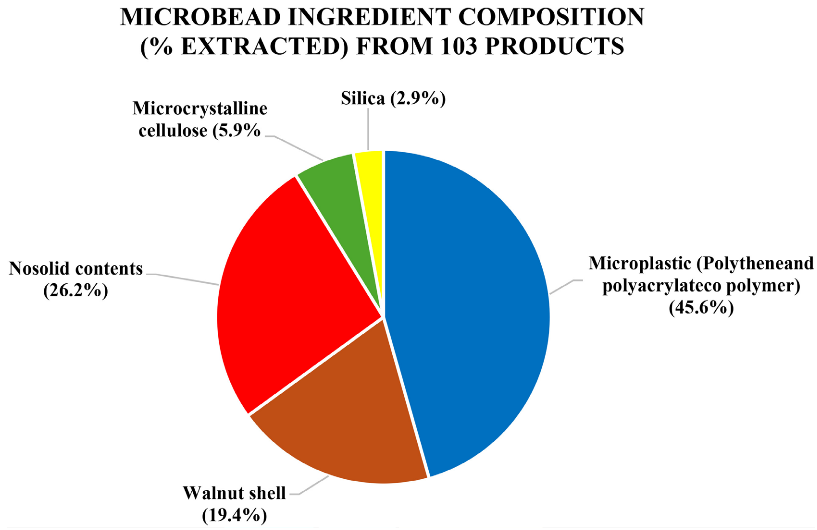



**Figure 2.** Composition of solids of the 103 cosmetic products sampled for the study.

**Table 1.** Country of origin, color, shape and polymer compositions collected from 103 facial scrubs purchased from different markets of Punjab, Pakistan.

| Sample | Country | Color | Shape | Polymer (MBs) composition by FTIR |
|---|---|---|---|---|
| SH1 | Pakistan | - | - | no solid particles were present |
| SH2 | Pakistan | golden | irregular | walnut shells |
| SH3 | United Arab Emirates | brown | irregular | walnut shells |
| SH4 | India | - | - | no solid particles were present |
| SH5 | USA | colorless | irregular | polyethylene |
| SH6 | India | red | irregular | polyethylene |
| SH7 | India | white | spherical | microcrystalline cellulose |
| SH8 | Pakistan | - | - | no solid particles were present |
| SH9 | Pakistan | brown | irregular | walnut shells |
| SH10 | Pakistan | yellow, green | spherical, granular | polyethylene |
| SH11 | India | white, red | irregular | polyethylene |
| SH12 | Thailand | white | granular | polyethylene |
| SH13 | India | - | - | no solid particles were present |
| SH14 | India | - | - | no solid particles were present |
| SH15 | India | - | - | no solid particles were present |
| SH16 | Korea | blue | irregular | polyethylene, microcrystalline cellulose |
| SH17 | USA | - | - | no solid particles were present |
| SH18 | Pakistan | - | _ | no solid particles were present |
| SH19 | Korea | - | _ | no solid particles were present |

**Continued**

| | | | | |
|---|---|---|---|---|
| SH20 | India | red | spherical | ethylene acrylate co-polymer |
| SH21 | UAE | - | - | no solid particles were present |
| SH22 | India | - | - | no solid particles were present |
| SH23 | Pakistan | - | - | no solid particles were present |
| SH24 | UAE | - | - | no solid particles were present |
| SH25 | China | - | - | no solid particles were present |
| SH26 | India | - | - | no solid particles were present |
| SH27 | India | - | - | no solid particles were present |
| SH28 | Pakistan | - | - | no solid particles were present |
| SH29 | India | colorless | spherical | walnut shells |
| SH30 | India | - | - | no solid particles were present |
| SH31 | India | - | - | no solid particles were present |
| SH32 | Pakistan | brown | irregular | walnut shells |
| SH33 | United Arab Emirates | red, blue | granular | polyethylene |
| SH34 | Pakistan | yellow | irregular | polyethylene |
| SH35 | India | brown | irregular | walnut shells |
| SH36 | India | blue, white | irregular | polyethylene |
| SH37 | India | blue | spherical | polyethylene |
| SH38 | France | colorless | irregular | polyethylene |
| SH39 | India | white | spherical | hydroxylated silica gel |
| SH40 | Pakistan | - | - | no solid particles were present |
| SH41 | Pakistan | blue, yellow | irregular | polyethylene |
| SH42 | India | red | irregular | polyethylene, microcrystalline cellulose |
| SH43 | India | brown | granular | ethylene acrylate co-polymer |
| SH44 | Pakistan | brown | irregular | polyethylene |
| SH45 | Pakistan | - | - | no solid particles were present |
| SH46 | Thailand | blue | irregular | polyethylene |
| SH47 | United Arab Emirates | red | irregular | polyethylene |
| SH48 | Pakistan | brown, blue | irregular | polyethylene |
| SH49 | India | - | - | no solid particles were present |
| SH50 | India | red, blue | irregular | polyethylene |
| SH51 | China | white | irregular | polyethylene |
| SH52 | Pakistan | red | irregular | polyethylene |
| SH53 | India | - | - | no solid particles were present |
| SH54 | USA | brown | irregular | polyethylene, microcrystalline cellulose |
| SH55 | India | blue | irregular | ethylene acrylate co-polymer |
| SH56 | Thailand | white | Irregular | polyethylene |

**Continued**

| | | | | |
|---|---|---|---|---|
| SH57 | India | - | - | no solid particles were present |
| SH58 | United Arab Emirates | red | irregular | polyethylene |
| SH59 | Pakistan | red, blue | irregular | polyethylene, microcrystalline cellulose |
| SH60 | Thailand | brown | irregular | walnut shells |
| SH61 | India | - | - | no solid particles were present |
| SH62 | China | golden | irregular | walnut shells |
| SH63 | India | colorless | irregular | polyethylene, microcrystalline cellulose |
| SH64 | Thailand | blue | irregular | polyethylene |
| SH65 | China | red | irregular | walnut shells |
| SH66 | Thailand | brown | Irregular | walnut shells |
| SH67 | United Arab Emirates | golden | irregular | polyethylene, microcrystalline cellulose |
| SH68 | Pakistan | brown | irregular | walnut shells |
| SH69 | India | blue | irregular | polyethylene |
| SH70 | USA | brown | spherical, granular | polyethylene, microcrystalline cellulose |
| SH71 | Thailand | red, blue | irregular | walnut shells |
| SH72 | China | red | irregular | walnut shells |
| SH73 | France | red | spherical, granular | microcrystalline cellulose, polyethylene |
| SH74 | Pakistan | blue | irregular | polyethylene |
| SH75 | France | white | irregular | microcrystalline cellulose, polyethylene |
| SH76 | India | red, blue | spherical, granular | polyethylene |
| SH77 | Pakistan | brown | irregular | hydroxylated silica gel |
| SH78 | China | golden | irregular | walnut shells |
| SH79 | USA | red, blue | spherical, granular | microcrystalline cellulose, polyethylene |
| SH80 | Thailand | red | irregular | walnut shells |
| SH81 | United Arab Emirates | white | irregular | polyethylene |
| SH82 | India | - | - | no solid particles were present |
| SH83 | Pakistan | brown | irregular | walnut shells |
| SH84 | China | colorless | irregular | polyethylene |
| SH85 | Thailand | blue, white | spherical, granular | polyethylene |
| SH86 | France | red | irregular | ethylene acrylate co-polymer |
| SH87 | France | red, blue | irregular | polyethylene |
| SH88 | India | white | irregular | microcrystalline cellulose |
| SH89 | Thailand | golden | irregular | walnut shells |
| SH90 | China | white | irregular | microcrystalline cellulose |
| SH91 | Pakistan | blue | spherical, granular | microcrystalline cellulose |
| SH92 | China | white | irregular | polyethylene |
| SH93 | India | red | irregular | walnut shells |

**Continued**

| | | | | |
|---|---|---|---|---|
| SH94 | Pakistan | brown | irregular | walnut shells |
| SH95 | Pakistan | colorless | irregular | polyethylene |
| SH96 | Pakistan | blue | spherical, granular | polyethylene |
| SH97 | Pakistan | - | - | no solid particles were present |
| SH98 | China | brown | irregular | walnut shells |
| SH99 | Thailand | white | irregular | microcrystalline cellulose |
| SH100 | India | brown | irregular | hydroxylated silica gel |
| SH101 | China | red | irregular | polyethylene |
| SH102 | Thailand | Blue | irregular | polyethylene |
| SH103 | India | Colorless | irregular | microcrystalline cellulose |

Figure 3 shows a typical example of an IR spectrum depicting polythene. The spectrum was obtained from the solids of product SH-12. The characteristic absorptions are 2915, 2847, 1472, 1465, 730, 717 cm$^{-1}$. A peak at around 2915 cm$^{-1}$ corresponds to the asymmetric stretching of C-H bonds in $CH_2$ groups, the peak around 2847 cm$^{-1}$ corresponds to the symmetric stretching of C-H bonds in $CH_2$ groups, the two peaks at 1472 cm$^{-1}$ and 1465 cm$^{-1}$ correspond to the bending deformation of the polymer backbone, the peaks at 730 cm$^{-1}$ and 720 cm-1 correspond to the rocking deformation of the $CH_2$ groups [39].

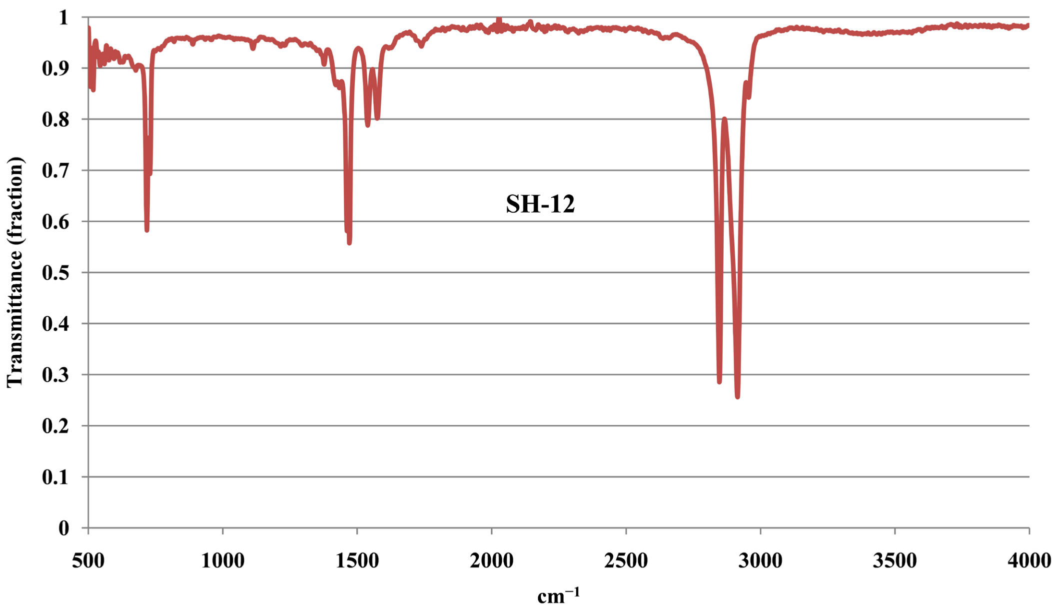



Figure 3. FT-IR spectrum of polythene containing microbead of product SH-12.

Ferret diameter size range (μm) graphs of the microbeads collected from 76 products are listed below, in Table 2 and in Figure S1 (Suppl. Data) for products SH-2 to SH-103. The size distribution graphs were plotted to compare and analyze the size range of microbeads existing in the 76 products. The filter paper used in the filtration process gives a size limit of about 12 μm for microbeads that could be retained in this experiment. The average size of 3 samples was used to plot the distribution graphs for each product on an excel sheet by using the pivot graph option. To facilitate a comparison of the microbead size distribution of different products, the start and end values for the presentation of the distribution were fixed at 1 and 350 μm, respectively, with a difference of 50 μm per bin for all 76 products.

The distribution pattern of 76 products revealed that 29 products (SH-2, SH-3, SH-4, SH-7, SH-10, SH-12, SH-16, SH-20, SH-32, SH-42, SH-60, SH-69, SH-70, SH-71, SH-73, SH-85, SH-86, SH-87, SH-90, SH-91, SH-93, SH-94, SH-95, SH-96, SH-98, SH-99, SH-100, SH-101 and SH-103) have a non-uniform size distribution, 4 products (SH-11, SH-43, SH-76 and SH-92) have a left-skewed size distribution, 43 products (SH-6, SH-9, SH-29, SH-33, SH-34, SH-35, SH-36, SH-37, SH-38, SH-39, SH-41, SH-44, SH-46, SH-47, SH-48, SH-50, SH-51, SH-52, SH-54, SH-55, SH-56, SH-58, SH-59, SH-62, SH-63, SH-64, SH-65, SH-66, SH-67, SH-68, SH-72, SH-74, SH-75, SH-77, SH-78, SH-79, SH-80, SH-81, SH-83, SH-84, SH-88, SH-89 and SH-102) have a right-skewed size distribution.

In this study, the microbead size range of 46 samples was represented by the size bin 1 μm - 50 μm. The smallest size bead, however was found to be 12.7 μm. This can also be seen as the lower size range of MPs that could still be retained in the filter paper. The upper size range of 2 samples was represented by the size bin ending at 300 μm, and in 2 samples were beads with a size slightly over 300 μm. Overall, the majority of the analyzed cosmetic products were found to have the majority of their beads with a diameter size ranging from 12.7 μm to 200 μm.

**Table 2.** Size, quantity and ash contents of the MBs collected from the 76 personal care products (facial scrubs) that contained solid content, purchased from different markets and shopping malls of Punjab, Pakistan.

| Sample | Size range of the microbeads (μm) | Average size of microbeads (μm) | Microbeads weight in g per 10 g of product | Weight (%) of ash obtained from the particles |
|---|---|---|---|---|
| SH2 | 53.6 - 201.3 | 78.7 ± 19.6 | 0.301 ± 0.019 | 3.1 |
| SH3 | 76.2 - 256.4 | 89.3 ± 15.9 | 0.210 ± 0.031 | 4.9 |
| SH5 | 65.7 - 234.5 | 76.4 ± 17.1 | 0.310 ± 0.032 | 0.9 |
| SH6 | 101.6 - 298.7 | 115.3 ± 20.4 | 0.192 ± 0.045 | 4.3 |
| SH7 | 98.9 - 167.8 | 101.3 ± 29.7 | 0.261 ± 0.032 | 6.9 |
| SH9 | 132.3 - 224.9 | 160.6 ± 13.9 | 0.265 ± 0.035 | 8.4 |
| SH10 | 87.1 - 206.4 | 95.8 ± 11.6 | 0.124 ± 0.044 | 32.6 |
| SH11 | 57.0 - 110.9 | 78.3 ± 23.9 | 0.217 ± 0.044 | 4.9 |
| SH12 | 25.2 - 196.8 | 95.3 ± 19.3 | 0.253 ± 0.043 | 34.1 |
| SH16 | 145.7 - 263.9 | 168.3 ± 25.3 | 0.264 ± 0.023 | 0.39 |
| SH20 | 98.6 - 153.9 | 115.4 ± 17.4 | 0.123 ± 0.024 | <5.0 |
| SH29 | 54.4 - 198.5 | 69.3 ± 12.4 | 0.272 ± 0.027 | 2.9 |
| SH32 | 98.2 - 156.9 | 115.9 ± 18.4 | 0.213 ± 0.026 | 3.7 |

**Continued**

| | | | | |
|---|---|---|---|---|
| SH33 | 165.1 - 203.4 | 187.3 ± 36.4 | 0.265 ± 0.036 | 0.95 |
| SH34 | 69.9 - 208.2 | 89.4 ± 23.0 | 0.213 ± 0.034 | 6.9 |
| SH35 | 72.8 - 300.6 | 98.9 ± 15.3 | 0.251 ± 0.014 | 4.6 |
| SH36 | 89.9 - 156.7 | 110.8 ± 17.4 | 0.127 ± 0.066 | 9.1 |
| SH37 | 35.8 - 199.2 | 74.7 ± 16.4 | 0.112 ± 0.026 | 3.0 |
| SH38 | 143.7 - 205.9 | 178.4 36.5 | 0.212 ± 0.026 | 13.9 |
| SH39 | 46.0 - 109.6 | 93.4 ± 23.3 | 0.321 ± 0.086 | 3.9 |
| SH41 | 98.5 - 165.9 | 142 ± 27.0 | 0.219 ± 0.058 | 5.2 |
| SH42 | 96.2 - 176.8 | 110.0 ± 15.8 | 0.193 ± 0.017 | 0.58 |
| SH43 | 53.8 - 145.9 | 74.9 ± 16.3 | 0.201 ± 0.053 | 6.2 |
| SH44 | 24.6 - 90.7 | 78.4 ± 12.4 | 0.194 ± 0.074 | 3.9 |
| SH46 | 25.8 - 154.8 | 78.3 ± 14.3 | 0.212 ± 0.035 | <6.0 |
| SH47 | 21.9 - 97.4 | 85.8 ± 12.3 | 0.192 ± 0.084 | 9.3 |
| SH48 | 16.8 - 183.6 | 98.3 ± 14.3 | 0.182 ± 0.026 | 6.5 |
| SH50 | 43.1 - 97.9 | 83.5 ± 21.1 | 0.113 ± 0.024 | 7.0 |
| SH51 | 12.9 - 165.7 | 99.4 ± 23.4 | 0.115 ± 0.075 | 3.9 |
| SH52 | 24.6 - 97.4 | 79.0 ± 17.3 | 0.132 ± 0.040 | 5.2 |
| SH54 | 32.1 - 94.6 | 76.9 ± 14.9 | 0.134 ± 0.016 | 9.1 |
| SH55 | 53.0 - 197.5 | 110.3 ± 23.9 | 0.123 ± 0.054 | 1.9 |
| SH56 | 34.6 - 87.9 | 58.3 ± 11.2 | 0.325 ± 0.028 | 3.5 |
| SH58 | 25.7 - 79.5 | 69.4 ± 17.3 | 0.371 ± 0.064 | 7.8 |
| SH59 | 25.6 - 96.7 | 75.9 ± 21.4 | 0.283 ± 0.054 | 2.8 |
| SH60 | 23.7 - 106.5 | 69.4 ± 12.1 | 0.294 ± 0.086 | 5.1 |
| SH62 | 25.1 - 98.7 | 76.3 ± 11.5 | 0.220 ± 0.013 | 7.0 |
| SH63 | 32.7 - 143.9 | 83.5 ± 31.7 | 0.193 ± 0.037 | 4.3 |
| SH64 | 12.7 - 163.9 | 73.9 ± 12.6 | 0.195 ± 0.054 | 6.0 |
| SH65 | 23.4 - 153.7 | 87.4 ± 17.3 | 0.372 ± 0.074 | 3.2 |
| SH66 | 38.9 - 90.1 | 73.9 ± 18.3 | 0.281 ± 0.065 | 4.9 |
| SH67 | 21.7 - 142.5 | 80.4 ± 11.2 | 0.197 ± 0.069 | 3.6 |
| SH68 | 21.4 - 96.6 | 76.4 ± 11.0 | 0.328 ± 0.036 | 5.1 |
| SH69 | 43.6 - 151.5 | 73.9 ± 12.3 | 0.293 ± 0.064 | 9.1 |
| SH70 | 32.5 - 206.7 | 74.9 ± 12.9 | 0.295 ± 0.076 | 1.9 |
| SH71 | 43.8 - 143.8 | 98.3 ± 17.2 | 0.192 ± 0.013 | 3.5 |
| SH72 | 22.3 - 108.9 | 68.9 ± 10.2 | 0.320 ± 0.038 | 7.8 |
| SH73 | 43.7 - 176.7 | 98.3 ± 17.3 | 0.302 ± 0.054 | 2.8 |
| SH74 | 32.4 - 98.9 | 63.7 ± 17.9 | 0.294 ± 0.028 | 5.1 |
| SH75 | 23.5 - 124.7 | 76.5 ± 18.3 | 0.294 ± 0.038 | 7.0 |

**Continued**

| | | | | |
|---|---|---|---|---|
| SH76 | 43.1 - 97.7 | 78.9 ± 11.2 | 0.232 ± 0.083 | 4.3 |
| SH77 | 23.6 - 142.7 | 87.7 ± 21.2 | 0.291 ± 0.064 | 6.0 |
| SH78 | 19.4 - 156.3 | 69.4 ± 11.0 | 0.302 ± 0.028 | 3.2 |
| SH79 | 26.4 - 197.1 | 65.5 ± 10.9 | 0.274 ± 0.097 | 4.9 |
| SH80 | 24.9 - 203.4 | 95.5 ± 10.2 | 0.329 ± 0.009 | 3.6 |
| SH81 | 29.5 - 175.3 | 98.3 ± 21.6 | 0.304 ± 0.056 | 9.1 |
| SH83 | 46.8 - 206.9 | 114.5 ± 23.9 | 0.239 ± 0.062 | 1.9 |
| SH84 | 17.8 - 153.5 | 85.4 ± 19.5 | 0.193 ± 0.024 | 3.5 |
| SH85 | 27.3 - 145.3 | 87.9 ± 11.4 | 0.172 ± 0.038 | 7.8 |
| SH86 | 34.6 - 106.8 | 79.4 ± 17.3 | 0.193 ± 0.062 | 2.8 |
| SH87 | 43.2 - 242.8 | 118.3 ± 23.1 | 0.208 ± 0.075 | 5.1 |
| SH88 | 36.0 - 94.5 | 67.3 ± 12.9 | 0.187 ± 0.056 | 7.0 |
| SH89 | 15.8 - 103.6 | 58.9 ± 9.4 | 0.231 ± 0.054 | 4.3 |
| SH90 | 37.2 - 231.2 | 132.5 ± 23.1 | 0.253 ± 0.073 | 6.0 |
| SH91 | 32.4 - 102.8 | 75.3 ± 12.2 | 0.365 ± 0.028 | 3.2 |
| SH92 | 36.0 - 94.5 | 65.8 ± 11.0 | 0.377 ± 0.064 | 4.9 |
| SH93 | 15.8 - 103.6 | 58.3 ± 8.3 | 0.299 ± 0.054 | 3.6 |
| SH94 | 37.2 - 231.2 | 101.7 ± 19.2 | 0.342 ± 0.053 | 5.1 |
| SH95 | 32.4 - 102.8 | 76.3 ± 12.9 | 0.254 ± 0.037 | 9.1 |
| SH96 | 35.3 - 147.0 | 83.6 ± 10.2 | 0.306 ± 0.054 | 1.9 |
| SH98 | 48.2 - 156.9 | 130.2 ± 23.8 | 0.377 ± 0.054 | 3.5 |
| SH99 | 48.1 - 203.4 | 136.2 ± 17.3 | 0.2908 ± 0.045 | 7.8 |
| SH100 | 39.9 - 208.2 | 116.9 ± 21.2 | 0.297 ± 0.027 | 2.8 |
| SH101 | 72.8 - 300.6 | 143.5 ± 32.8 | 0.328 ± 0.067 | 5.1 |
| SH102 | 49.9 - 156.7 | 110.6 ± 12.9 | 0.303 ± 0.044 | 7.0 |
| SH103 | 45.8 - 199.2 | 79.4 ± 19.3 | 0.295 ± 0.084 | 4.3 |

The most common colors used in the studied products of the plastic microbeads were blue (35%), red (29%) and white/colorless (25%). The rest of the products had yellow (5%), brown (2%), green (2%) and golden (2%) plastic microbeads (Suppl. **Figure S1**). Over all products with beads (Suppl. **Figure S1**), the color scheme was composed of red, blue, and colorless, equally contributing 21%, golden (6%), yellow (3%) and green (1%). The much larger share of brown is due to the use of walnut shell in the products as solid abrasive material. Interestingly, walnut shell has also been found to be dyed golden and red in some cosmetic products [21]. The predominance of the colors blue and colorless/white can be found in cosmetics from a number of other markets around the world. Often, blue microplastics make up by color the dominant share of microplastics found in the oceans [5] [40]-[42]. The large share of the color red is something that may be specific to the Pakistani market.

## 4. Discussion

Microbeads play a vital role in some cosmetics products. Their functions depend on the size, shape, and composition of the microbeads [43]. Mostly, they are used as exfoliants [34] [44] [45] in personal care and cosmetic products (PCCPs), where PCCPs can be body and facial scrubs, shower gels and toothpastes, but also other cosmetic products such as lip sticks. Oftentimes, the basic function of the microbeads is to produce a smoother skin by increasing the rate of keratinization through exfoliation [46]-[48]. The composition of abrasive material in solid form in PCCPs has changed over time, beginning with exclusively natural materials such as pumice (pumicite), diatomaceous earth, perlite and tripoli, as well as many plant derived solids, such as chick-peas, barley, almonds, and horseradish seeds, in addition to ash and salt in oral care products [49]. Although early patents for microbeads in personal care and cosmetic products began to appear in the late 1960s with the first patent to include micro-polymer content in cosmetics being awarded in 1965 [50], plastic microbeads did not find entry into rinse-off cosmetics and personal care products in a large scale until the early 1990s. Some of the advantages of plastic microbeads are their low cost, the ease of dyeing, the possibility of tailoring their size and size distribution and their relative softness so that the microbeads do not damage the skin or the enamel of teeth. In the last two decades, the most commonly used synthetic polymers found in plastic microbeads have been polyethylene (PE), polypropylene (PP), polyethylene terephthalate (PET), poly (methyl methacrylate) (PMMA), and nylon, whereas cellulose, pumice, cornmeal, apricot kernels, silica, and walnut husks have been the most common natural or biodegradable materials used in microbead formulations [51] [52].

Zitko and Hanlon [53] were one of the first researchers reporting on potential dangers of plastic microbeads in commercially available personal care products. They commented on skin cleansers that contained granulated polyethene, polypropylene and polystyrene, 40 - 200 mesh (75 - 420 μm) in size. A few years later, Gregory reported on finding solid plastic content in 3 facial scrubs and in 3 face cleansers, sold in New Zealand markets, with contents of 0.19 - 6.91 g plastic microbeads per 100 g of product [54]. Since then, the use of plastic microbeads in cosmetic products has been seen as an international problem as these tend to pollute the environment, once washed off into the wastewater.

MPs from PCCPs, including from cosmetics, often find their way directly into household drains and are transported to wastewater treatment plants (WWTPs) [55]. WWTPs cannot retain the MPs completely, and so WWTPs have been identified as one of the point sources of MP emissions [56] [57], including of plastic microbeads from cosmetics [58]-[60] to the marine environment. Also, plastic microbeads find their way into soil, especially in the case, where sewage sludge is used for agricultural purposes [61] [62]. It must be noted, however, that it is far from easy to pinpoint the source of a microplastic and thus associate a particular microplastic with a PCCP, once the microplastic is released [63] [64].

**Table 3.** Published studies on the presence of MPs in personal care products from around the world.

| Sample type | % of products with plastic microbeads | Country/region | Reference |
|---|---|---|---|
| 4 face cleansers | 100% | New Zealand | Fendall & Sewell, 2009 [44] |
| 5 body scrubs | 100% (PE and PP) | Malaysia | Praveen *et al*., 2018 [65] |
| 5 toothpastes | 20 % | Malaysia | Praveen *et al*., 2018 [65] |
| 9 body scrubs | 100% (PE such as LDPE) | PR China | Cheung & Fok, 2017 [25] |
| 68 facial skin care products | 64.7% (63% PE) | Macao, PR China | Bashir *et al*., 2021 [68] |
| 31 body skin care products | 29% (PE) | Macao, PR China | Bashir *et al*., 2021 [68] |
| 45 cosmetic products | 100% (53.3% PE) | Macao, PR China | Bashir *et al*., 2021 [68] |
| 135 toothpastes/23 brands | 0% | PR China | Lei et el., 2017 [23] |
| 126 facial cleansers/16 brands | 7.1% | PR China | Lei et el., 2017 [23] |
| 136 shower gels/30 brands | 2.2% | PR China | Lei et el., 2017 [23] |
| 33 toothpastes | 0% | UAE/Syria | Elkashlan *et al*., 2022 [22] |
| 74 body scrubs | year 2020: 12% (PE) | UAE | Habib *et al*., 2022 [21] |
| 89 body scrubs | year 2019: 12% (PE) | UAE | Habib *et al*., 2022 [21] |
| 37 body scrubs | year 2018: 29.7% (PE) | UAE | Habib *et al*., 2020 [20] |
| 20 toothpastes | 20% | Turkey | Ustabasi & Baysal, 2019 [66] |
| 50 abrasive cosmetics | 26% | Poland | Guzik *et al*., 2023 [11] |
| 130 body scrubs | 55% | Poland | Piotrowska *et al*., 2020 [67] |
| 3 shower gels and 2 body sprays | MBs throughout, of unclear composition | Romania | Banica *et al*., 2023 [10] |
| 103 body scrubs | 45.6% (42.7% PE) | Punjab, Pakistan | this study |

Currently, the likelihood of a personal care or cosmetic product to carry plastic microbeads varies, depending on the region, where the products are being sold. In 2018, Praveena *et al.* published a study on 5 body-scrubs and 5 toothpastes, bought in Malaysia. 1 out of 5 toothpastes contained MPs in form of polythene microbeads, however, all 5 body-scrubs contained plastic microbeads made of either polythene or polypropylene [65]. In 2019, in their study of products available in Istanbul, Turkey, Ustabasi and Baysal found polythene containing MPs at contents of between 0.4 and 1 w% in 5 (20%) of the 20 toothpaste products they had analyzed [66]. In 2023, Guzik *et al.* looked at 50 abrasive cosmetic products of Polish manufacturers, and found 13 of the products to contain MPs, but none of them were made of polythene. 49 of the products contained abrasive particles of natural origin [11]. This was a considerable improvement when compared to a previous study from Poland where of 130 analyzed body scrub products, 72 (55%) contained MPs made of PE [67]. Habib *et al.* studied PPCPs in the United Arab Emirates (UAE) and found a substantial reduction of products carrying MPs, looking at the market in 2020 (12%) [20] as opposed to what the market was in 2018 (29.7%) [22].

With 45.6% of the products examined in the current study carrying plastic microbeads, the proportion of PCCPs with MPs in the Punjab region of Pakistan is significant compared to PCCPs in many other countries (**Table 3**). There was no correlation between the presence of microbeads in a product and the cost of the product. The average size of the microbeads found in the products is similar to sizes found in products sold in other regions [25] [68], with a relatively narrow size distribution, albeit at the lower side of the size ranges that have been reported elsewhere. This also holds true for the weight contribution of MPs in the products [25] [68], which ranged from 1.13 w% to 3.72 w%. Most plastic microbeads in the studied products were found to be made of PE, similar to what has been found in other studies [69] [70]. Overall, this leads to a notable plastic burden in the Pakistani wastewater, where any plastic particles not retained in treatment regimes would reach the environment. This is significant as not all areas in Pakistan are connected to adequate wastewater treatment facilities and a sizable proportion of the wastewater is channeled into natural drains [71] [72], which would impose a heavy plastic burden on the environment.

Of the 103 examined products, 77 products (74.8%) were imported from other countries. While 38% of the Pakistani products included MPs, 48% of the imported products did so (Suppl. **Figure S1**). Interestingly, 9 out of the 10 products imported from France and USA contained MPs, where both USA and France are countries which have a ban on MPs in rinse-off cosmetics in place. This is similar to what was noted to be true in UAE markets [20] [21], where MP-carrying PCCPs are imported that are manufactured by companies whose headquarters lie in regions where the use of MPs in rinse-off cosmetics is already banned.

Pakistan has issued a new directive [73] which bans the manufacture, storage, and sale of single-use plastic items, which includes single-use polythene bags. Industrial plastic wrapping is excluded from the ban. Rinse-off MP containing personal care and cosmetic products is not mentioned in the ban. Recently, the Pakistan Chemical Manufacturing Association (PCMA) [74] has developed a webpage on MPs to further the Pakistani public's awareness of issues surrounding the use of MP-containing products.

Much has been made of the fact that in order to reduce plastics emissions into the environment, especially into the marine environment [75], international efforts would be needed [76] [77]. In addition, the voluntary phase-out of MPs in personal care products by the cosmetic companies [78] in coordination with the individual governments was much heralded as a way forward. This was seen to proceed in conjunction with better technologies in regard to wastewater treatment [79], although WWTPs themselves are not specifically designed to retain plastic microbeads. These measures would show little effect in regions to which MP laden products would still be exported and which do not have an adequate wastewater treatment infrastructure. Therefore, it would be advisable that international regulations would also focus on the export of MP containing products from countries that have regulations on plastic microbeads in place and on the import of such products to regions, which have not yet implemented a ban on plastic microbead containing products. Alternatives for plastic microbeads are beads or microparticles made from crushed hazelnut, almond, pecan and especially walnut shells, from apricot and plum kernels, and from jojoba seeds, corn, oat or rice grain/meal as well as from refined wood pulp in form of microcrystalline cellulose. Purely inorganic natural alternatives are pumice, silica, and bentonites, including montmorillonite, or other clays such as talc. Furthermore, degradable, synthetic polymeric microbeads are being developed [80]-[83], and support for further research in this direction would be welcome.

## 5. Conclusions

This study analyzed 103 personal care and cosmetic products bought in markets in Punjab, Pakistan. 45.6% of the products contained MPs in their formulation, 42.7% of them PE microbeads. Comparing these numbers with studies from around the world and with data released from governmental organizations, the proportion of cosmetic products available in Pakistani markets carrying MPs is high. Especially concerning is the high proportion of MP containing products imported from countries, where a ban of plastic microbeads in rinse-off cosmetics is already in place. With 1.13 w% to 3.72 w%, the weight contribution of MPs to the individual products which contain plastic microbeads is similar to those reported for products available in other countries. As not all households in Pakistan are connected to a viable wastewater treatment facility, it is expected that significant amounts of MPs are emitted into the environment. Therefore, heightened consumer awareness, a reduction in the import of MP-containing rinse-off cosmetics, and continued research into affordable MP replacement materials would be of great value.

## Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

## References


[1] PlasticEurope 2022 (2023) Plastics—The Facts 2022. https://plasticseurope.org/wp-content/uploads/2022/10/PE-PLASTICS-THE-FACTS_V7-Tue_19-10-1.pdf

[2] Statista Research Department (2023) Global Plastic Production 1950-2021. https://www.statista.com/statistics/282732/global-production-of-plastics-since-1950/

[3] Thompson, R.C. (2006) Plastic Debris in the Marine Environment: Consequences and Solutions. *Marine Natural Conservation in Europe*, **193**, 107-115.

[4] Auta, H.S., Emenike, C.U. and Fauziah, S.H. (2017) Distribution and Importance of Microplastics in the Marine Environment: A Review of the Sources, Fate, Effects, and Potential Solutions. *Environment International*, **102**, 165-176. https://doi.org/10.1016/j.envint.2017.02.013

[5] Coyle, R., Hardiman, G. and Driscoll, K.O. (2020) Microplastics in the Marine Envi-

ronment: A Review of Their Sources, Distribution Processes, Uptake and Exchange in Ecosystems. *Case Studies in Chemical and Environmental Engineering*, **2**, Article ID: 100010. https://doi.org/10.1016/j.cscee.2020.100010

[6] Moore, C.J. (2008) Synthetic Polymers in the Marine Environment: A Rapidly Increasing, Long-Term Threat. *Environmental Research*, **108**, 131-139. https://doi.org/10.1016/j.envres.2008.07.025

[7] van Sebille, E., Wilcox, C., Lebreton, L., Maximenko, N., Hardesty, B.D., van Franeker, J.A., *et al*. (2015) A Global Inventory of Small Floating Plastic Debris. *Environmental Research Letters*, **10**, Article ID: 124006. https://doi.org/10.1088/1748-9326/10/12/124006

[8] Eriksen, M., Cowger, W., Erdle, L.M., Coffin, S., Villarrubia-Gómez, P., Moore, C.J., *et al*. (2023) A Growing Plastic Smog, Now Estimated to Be over 170 Trillion Plastic Particles Afloat in the World's Oceans—Urgent Solutions Required. *PLOS ONE*, **18**, e0281596. https://doi.org/10.1371/journal.pone.0281596

[9] Napper, I.E., Bakir, A., Rowland, S.J. and Thompson, R.C. (2015) Characterisation, Quantity and Sorptive Properties of Microplastics Extracted from Cosmetics. *Marine Pollution Bulletin*, **99**, 178-185. https://doi.org/10.1016/j.marpolbul.2015.07.029

[10] Banica, A.L., Bucur, R.M., Dulama, I.D., Bucurica, I.A., Stirbescu, R.M. and Radulescu, C. (2023) Assessment of Microplastics in Personal Care Products by Microscopic Methods and Vibrational Spectroscopy. *Science Study & Research Chemistry & Chemical Engineering, Biotechnology, Food Industry*, **24**, 155-171.

[11] Guzik, M., Czerwińska-Ledwig, O. and Piotrowska, A. (2023) Compositions of Abrasive Cosmetics from Polish Manufacturers. *Cosmetics*, **10**, Article 67. https://doi.org/10.3390/cosmetics10020067

[12] Zhou, Y., Ashokkumar, V., Amobonye, A., Bhattacharjee, G., Sirohi, R., Singh, V., *et al*. (2023) Current Research Trends on Cosmetic Microplastic Pollution and Its Impacts on the Ecosystem: A Review. *Environmental Pollution*, **320**, Article ID: 121106. https://doi.org/10.1016/j.envpol.2023.121106

[13] Mashirin, K.R. and Chitra, K.C. (2022) Microplastics—An Emerging Threat in the Indian Waterbodies. *Marine Biology Research*, **18**, 1-12. https://doi.org/10.1080/17451000.2022.2096905

[14] US Congress 2015. HR. 1321—Microbead-Free Waters Act of 2015 (Pallone, F., Sponsor).

[15] McDevitt, J.P., Criddle, C.S., Morse, M., Hale, R.C., Bott, C.B. and Rochman, C.M. (2017) Addressing the Issue of Microplastics in the Wake of the Microbead-Free Waters Act—A New Standard Can Facilitate Improved Policy. *Environmental Science & Technology*, **51**, 6611-6617. https://doi.org/10.1021/acs.est.6b05812

[16] ECHA (2023) Microplastics. https://echa.europa.eu/hot-topics/microplastics

[17] European Commission (2023) Comitology Register. https://ec.europa.eu/transparency/comitology-register/screen/home

[18] Environment.gov.au (2018) Voluntary Industry Phase-Out of Solid Plastic Mcrobeads from 'Rinse-Off' Personal Care, Cosmetic and Cleaning Products. https://accord.asn.au/sustainability/beadrecede/#:~:text=The%20Australian%20cosmetics%2C%20personal%20care%20and%20cleaning%20products,coordinated%20by%20Accord%20Australasia%20through%20the%20BeadRecede%20campaign

[19] O'Farell, K. and Harvey, F. (2020) An Assessment of the Presence of Microbeads in Rinse-Off Personal Care, Cosmetic and Cleaning Products Currently Available within the Australian Retail Market. Project Report, Commissioned by the Depart-

ment of Agriculture, Water and Environment. https://www.dcceew.gov.au/sites/default/files/documents/microbeads-rinse-products-survey-report.pdf

[20] Habib, R.Z., Salim Abdoon, M.M., Al Meqbaali, R.M., Ghebremedhin, F., Elkashlan, M., Kittaneh, W.F., *et al*. (2020) Analysis of Microbeads in Cosmetic Products in the United Arab Emirates. *Environmental Pollution*, **258**, Article ID: 113831. https://doi.org/10.1016/j.envpol.2019.113831

[21] Habib, R.Z., Aldhanhani, J.A.K., Ali, A.H., Ghebremedhin, F., Elkashlan, M., Mesfun, M., *et al*. (2022) Trends of Microplastic Abundance in Personal Care Products in the United Arab Emirates over the Period of 3 Years (2018-2020). *Environmental Science and Pollution Research*, **29**, 89614-89624. https://doi.org/10.1007/s11356-022-21773-y

[22] Elkashlan, M., Poulose, V., Habib, R.Z., Karabala, O., Aldhanhani, A., Shakir, M., *et al*. (2022) Analysis of the Solid Contents of Toothpastes Available in UAE (United Arab Emirates) Markets. *Journal of Environmental Protection*, **13**, 539-556. https://doi.org/10.4236/jep.2022.137034

[23] Lei, K., Qiao, F., Liu, Q., Wei, Z., Qi, H., Cui, S., *et al*. (2017) Microplastics Releasing from Personal Care and Cosmetic Products in China. *Marine Pollution Bulletin*, **123**, 122-126. https://doi.org/10.1016/j.marpolbul.2017.09.016

[24] Cheung, P.K. and Fok, L. (2016) Evidence of Microbeads from Personal Care Product Contaminating the Sea. *Marine Pollution Bulletin*, **109**, 582-585. https://doi.org/10.1016/j.marpolbul.2016.05.046

[25] Cheung, P.K. and Fok, L. (2017) Characterisation of Plastic Microbeads in Facial Scrubs and Their Estimated Emissions in Mainland China. *Water Research*, **122**, 53-61. https://doi.org/10.1016/j.watres.2017.05.053

[26] Madhumitha, C.T., Karmegam, N., Biruntha, M., Arun, A., Al Kheraif, A.A., Kim, W., *et al*. (2022) Extraction, Identification, and Environmental Risk Assessment of Microplastics in Commercial Toothpaste. *Chemosphere*, **296**, Article ID: 133976. https://doi.org/10.1016/j.chemosphere.2022.133976

[27] Ahmed, Q., Ali, Q.M., Bat, L., Oztekin, A., Memon, S. and Baloch, A. (2021) Preliminary Study on Abundance of Microplastic in Sediments and Water Samples along the Coast of Pakistan (Sindh and Balochistan)-Northern Arabian Sea. *Turkish Journal of Fisheries and Aquatic Sciences*, **22**, TRJFAS19998. https://doi.org/10.4194/trjfas19998

[28] Akhter, N. and Panhwar, S.K. (2022) Baseline Study of Microplastics in the Gastrointestinal Tract of Commercial Species Inhabiting in the Coastal Waters of Karachi, Sindh, Pakistan. *Frontiers in Marine Science*, **9**, Article 855386. https://doi.org/10.3389/fmars.2022.855386

[29] Arshad, N., Alam, M.M., Su'ud, M.B.M., Imran, S., Siddiqui, T., Saleem, K., *et al*. (2023) Microplastic Contamination from Surface Waters and Commercially Valuable Fishes of Karachi Coast, Pakistan. *Regional Studies in Marine Science*, **62**, Article ID: 102955. https://doi.org/10.1016/j.rsma.2023.102955

[30] Bilal, M., Ul Hassan, H., Siddique, M., Khan, W., Gabol, K., Ullah, I., *et al*. (2022) Microplastics in the Surface Water and Gastrointestinal Tract of Salmo Trutta from the Mahodand Lake, Kalam Swat in Pakistan. *Toxics*, **11**, Article 3. https://doi.org/10.3390/toxics11010003

[31] Nousheen, R., Hashmi, I., Rittschof, D. and Capper, A. (2022) Comprehensive Analysis of Spatial Distribution of Microplastics in Rawal Lake, Pakistan Using Trawl Net and Sieve Sampling Methods. *Chemosphere*, **308**, Article ID: 136111.

https://doi.org/10.1016/j.chemosphere.2022.136111

[32] Irfan, T., Khalid, S., Taneez, M. and Hashmi, M.Z. (2020) Plastic Driven Pollution in Pakistan: The First Evidence of Environmental Exposure to Microplastic in Sediments and Water of Rawal Lake. *Environmental Science and Pollution Research*, **27**, 15083-15092. https://doi.org/10.1007/s11356-020-07833-1

[33] Carbery, M., O'Connor, W. and Palanisami, T. (2018) Trophic Transfer of Microplastics and Mixed Contaminants in the Marine Food Web and Implications for Human Health. *Environment International*, **115**, 400-409. https://doi.org/10.1016/j.envint.2018.03.007

[34] Rochman, C.M., Tahir, A., Williams, S.L., Baxa, D.V., Lam, R., Miller, J.T., *et al*. (2015) Anthropogenic Debris in Seafood: Plastic Debris and Fibers from Textiles in Fish and Bivalves Sold for Human Consumption. *Scientific Reports*, **5**, Article No. 14340. https://doi.org/10.1038/srep14340

[35] Tagg, A.S., Harrison, J.P., Ju-Nam, Y., Sapp, M., Bradley, E.L., Sinclair, C.J., *et al*. (2017) Fenton's Reagent for the Rapid and Efficient Isolation of Microplastics from Wastewater. *Chemical Communications*, **53**, 372-375. https://doi.org/10.1039/c6cc08798a

[36] Schneider, C.A., Rasband, W.S. and Eliceiri, K.W. (2012) NIH Image to ImageJ: 25 Years of Image Analysis. *Nature Methods*, **9**, 671-675. https://doi.org/10.1038/nmeth.2089

[37] Schindelin, J., Arganda-Carreras, I., Frise, E., Kaynig, V., Longair, M., Pietzsch, T., *et al*. (2012) Fiji: An Open-Source Platform for Biological-Image Analysis. *Nature Methods*, **9**, 676-682. https://doi.org/10.1038/nmeth.2019

[38] Santagapita, P.R., Mazzobre, M.F. and Buera, M.d.P. (2012) Invertase Stability in Alginate Beads: Effect of Trehalose and Chitosan Inclusion and of Drying Methods. *Food Research International*, **47**, 321-330. https://doi.org/10.1016/j.foodres.2011.07.042

[39] Gulmine, J.V., Janissek, P.R., Heise, H.M. and Akcelrud, L. (2002) Polyethylene Characterization by FTIR. *Polymer Testing*, **21**, 557-563. https://doi.org/10.1016/s0142-9418(01)00124-6

[40] Martin, J., Lusher, A., Thompson, R.C. and Morley, A. (2017) The Deposition and Accumulation of Microplastics in Marine Sediments and Bottom Water from the Irish Continental Shelf. *Scientific Reports*, **7**, Article No. 10772. https://doi.org/10.1038/s41598-017-11079-2

[41] Courtene-Jones, W., Quinn, B., Gary, S.F., Mogg, A.O.M. and Narayanaswamy, B.E. (2017) Microplastic Pollution Identified in Deep-Sea Water and Ingested by Benthic Invertebrates in the Rockall Trough, North Atlantic Ocean. *Environmental Pollution*, **231**, 271-280. https://doi.org/10.1016/j.envpol.2017.08.026

[42] Lusher, A.L., Burke, A., O'Connor, I. and Officer, R. (2014) Microplastic Pollution in the Northeast Atlantic Ocean: Validated and Opportunistic Sampling. *Marine Pollution Bulletin*, **88**, 325-333. https://doi.org/10.1016/j.marpolbul.2014.08.023

[43] Becker, L.C., Bergfeld, W.F., Belsito, D.V., Hill, R.A., Klaassen, C.D., Liebler, D.C., *et al*. (2014) Safety Assessment of Modified Terephthalate Polymers as Used in Cosmetics. *International Journal of Toxicology*, **33**, 36S-47S. https://doi.org/10.1177/1091581814537001

[44] Fendall, L.S. and Sewell, M.A. (2009) Contributing to Marine Pollution by Washing Your Face: Microplastics in Facial Cleansers. *Marine Pollution Bulletin*, **58**, 1225-1228. https://doi.org/10.1016/j.marpolbul.2009.04.025

[45] Leslie, H. (2014) Review of Microplastics in Cosmetics. Report R14/29. IVM Institute

for Environmental Studies, Amsterdam.

[46] Kawaguchi, H. (2000) Functional Polymer Microspheres. *Progress in Polymer Science*, **25**, 1171-1210. https://doi.org/10.1016/s0079-6700(00)00024-1

[47] Decker, A. and Graber E.M. (2012) Over-the-Counter Acne Treatments: A Review. *Journal of Clinical and Aesthetic Dermatology*, **5**, 32-40.

[48] Draelos, Z.D. (2005) Reexamining Methods of Facial Cleansing. *Cosmetic Dermatology*, **18**, 173-175.

[49] McMullen, R.L. and Dell'Acqua, G. (2023) History of Natural Ingredients in Cosmetics. *Cosmetics*, **10**, Article 71. https://doi.org/10.3390/cosmetics10030071

[50] Blaustein, M. (Phillips Petroleum Co) (1965) US Pat. 3,196,079 Polyethylene Containing Cosmetic Powders.

[51] Rinaudo, M. (2006) Chitin and Chitosan: Properties and Applications. *Progress in Polymer Science*, **31**, 603-632. https://doi.org/10.1016/j.progpolymsci.2006.06.001

[52] Robles, M.C. (2016) Plastic Not Fantastic: Industry Responds to US Microbeads Ban. Euromonitor International Blog. http://blog.euromonitor.com/2016/10/plastic-not-fantastic-industry-responds-to-us-microbeads-ban.html

[53] Zitko, V. and Hanlon, M. (1991) Another Source of Pollution by Plastics: Skin Cleaners with Plastic Scrubbers. *Marine Pollution Bulletin*, **22**, 41-42. https://doi.org/10.1016/0025-326x(91)90444-w

[54] Gregory, M.R. (1996) Plastic 'Scrubbers' in Hand Cleansers: A Further (and Minor) Source for Marine Pollution Identified. *Marine Pollution Bulletin*, **32**, 867-871. https://doi.org/10.1016/s0025-326x(96)00047-1

[55] Murphy, F., Ewins, C., Carbonnier, F., and Quinn, B. (2016) Wastewater Treatment Works (WwTW) as a Source of Microplastics in the Aquatic Environment. *Environmental Science & Technology*, **50**, 5800-5808.

[56] Habib, R.Z., Thiemann, T. and Al Kendi, R. (2020) Microplastics and Wastewater Treatment Plants—A Review. *Journal of Water Resource and Protection*, **12**, 1-35. https://doi.org/10.4236/jwarp.2020.121001

[57] Lv, X., Dong, Q., Zuo, Z., Liu, Y., Huang, X. and Wu, W. (2019) Microplastics in a Municipal Wastewater Treatment Plant: Fate, Dynamic Distribution, Removal Efficiencies, and Control Strategies. *Journal of Cleaner Production*, **225**, 579-586. https://doi.org/10.1016/j.jclepro.2019.03.321

[58] Kalčíková, G., Alič, B., Skalar, T., Bundschuh, M. and Gotvajn, A.Ž. (2017) Wastewater Treatment Plant Effluents as Source of Cosmetic Polyethylene Microbeads to Freshwater. *Chemosphere*, **188**, 25-31. https://doi.org/10.1016/j.chemosphere.2017.08.131

[59] Ding, N., An, D., Yin, X. and Sun, Y. (2020) Detection and Evaluation of Microbeads and Other Microplastics in Wastewater Treatment Plant Samples. *Environmental Science and Pollution Research*, **27**, 15878-15887. https://doi.org/10.1007/s11356-020-08127-2

[60] Mason, S.A., Garneau, D., Sutton, R., Chu, Y., Ehmann, K., Barnes, J., *et al.* (2016) Microplastic Pollution Is Widely Detected in US Municipal Wastewater Treatment Plant Effluent. *Environmental Pollution*, **218**, 1045-1054. https://doi.org/10.1016/j.envpol.2016.08.056

[61] de Souza Machado, A.A., Kloas, W., Zarfl, C., Hempel, S. and Rillig, M.C. (2018) Microplastics as an Emerging Threat to Terrestrial Ecosystems. *Global Change Biology*, **24**, 1405-1416. https://doi.org/10.1111/gcb.14020

[62] Nizzetto, L., Futter, M. and Langaas, S. (2016) Are Agricultural Soils Dumps for Mi-

croplastics of Urban Origin? *Environmental Science & Technology*, **50**, 10777-10779. https://doi.org/10.1021/acs.est.6b04140

[63] Gong, J. and Xie, P. (2020) Research Progress in Sources, Analytical Methods, Eco-Environmental Effects, and Control Measures of Microplastics. *Chemosphere*, **254**, Article ID: 126790. https://doi.org/10.1016/j.chemosphere.2020.126790

[64] Sui, Q., Zhang, L., Xia, B., Chen, B., Sun, X., Zhu, L., *et al*. (2020) Spatiotemporal Distribution, Source Identification and Inventory of Microplastics in Surface Sediments from Sanggou Bay, China. *Science of the Total Environment*, **723**, Article ID: 138064. https://doi.org/10.1016/j.scitotenv.2020.138064

[65] Praveena, S.M., Shaifuddin, S.N.M. and Akizuki, S. (2018) Exploration of Microplastics from Personal Care and Cosmetic Products and Its Estimated Emissions to Marine Environment: An Evidence from Malaysia. *Marine Pollution Bulletin*, **136**, 135-140. https://doi.org/10.1016/j.marpolbul.2018.09.012

[66] Ustabasi, G.S. and Baysal, A. (2019) Occurrence and Risk Assessment of Microplastics from Various Toothpastes. *Environmental Monitoring and Assessment*, **191**, Article No. 438. https://doi.org/10.1007/s10661-019-7574-1

[67] Piotrowska, A., Czerwińska-Ledwig, O., Serdiuk, M., Serdiuk, K. and Pilch, W. (2020) Composition of Scrub-Type Cosmetics from the Perspective of Product Ecology and Microplastic Content. *Toxicology and Environmental Health Sciences*, **12**, 75-81. https://doi.org/10.1007/s13530-020-00051-9

[68] Bashir, S.M., Kimiko, S., Mak, C., Fang, J.K. and Gonçalves, D. (2021) Personal Care and Cosmetic Products as a Potential Source of Environmental Contamination by Microplastics in a Densely Populated Asian City. *Frontiers in Marine Science*, **8**, Article 683482. https://doi.org/10.3389/fmars.2021.683482

[69] Sun, Q., Ren, S. and Ni, H. (2020) Incidence of Microplastics in Personal Care Products: An Appreciable Part of Plastic Pollution. *Science of the Total Environment*, **742**, Article ID: 140218. https://doi.org/10.1016/j.scitotenv.2020.140218

[70] Gouin, T., Avalos, J., Brunning, I., Brzuska, K., de Graaf, J., Kaumanns, J., Koning, T., Meyberg, M., Rettinger, K., Schlatter, H., Thomas, J., van Welie, R. and Wolf, T. (2015) Use of Microplastic Beads in Cosmetic Products in Europe and Their Estimated Emissions to the North Sea Environment. *SOFW-Journal*, **141**, 40-46.

[71] Marfani, W.B., Vohra, L.I., Sahito, A.M. and Nadeem, A. (2022) Wastewater Surveillance in Pakistan: Preventing Future Epidemics. *Annals of Medicine & Surgery*, **81**, Article ID: 104495. https://doi.org/10.1016/j.amsu.2022.104495

[72] Ashfaq, M., Li, Y., Rehman, M.S.U., Zubair, M., Mustafa, G., Nazar, M.F., *et al*. (2019) Occurrence, Spatial Variation and Risk Assessment of Pharmaceuticals and Personal Care Products in Urban Wastewater, Canal Surface Water, and Their Sediments: A Case Study of Lahore, Pakistan. *Science of the Total Environment*, **688**, 653-663. https://doi.org/10.1016/j.scitotenv.2019.06.285

[73] Ministry of Climate Change & Environmental Coordination (2023) Single Use Plastics (Prohibition) Regulations. The Gazette of Pakistan, Islamabad, June 2023. https://www.mocc.gov.pk/SiteImage/Misc/files/1418(23)%20Ex_%20Gaz-II%20(Climate).pdf

[74] Pakistan Chemical Manufacturing Association (PCMA) (2025) Microplastics in Pakistan. https://pcma.org.pk/microplastics-in-pakistan-2/

[75] Jambeck, J.R., Geyer, R., Wilcox, C., Siegler, T.R., Perryman, M., Andrady, A., *et al*. (2015) Plastic Waste Inputs from Land into the Ocean. *Science*, **347**, 768-771. https://doi.org/10.1126/science.1260352

[76] Xanthos, D. and Walker, T.R. (2017) International Policies to Reduce Plastic Marine

Pollution from Single-Use Plastics (Plastic Bags and Microbeads): A Review. *Marine Pollution Bulletin*, **118**, 17-26. https://doi.org/10.1016/j.marpolbul.2017.02.048

[77] Raubenheimer, K. and McIlgorm, A. (2017) Is the Montreal Protocol a Model That Can Help Solve the Global Marine Plastic Debris Problem? *Marine Policy*, **81**, 322-329. https://doi.org/10.1016/j.marpol.2017.04.014

[78] Borrelle, S.B., Rochman, C.M., Liboiron, M., Bond, A.L., Lusher, A., Bradshaw, H., *et al*. (2017) Why We Need an International Agreement on Marine Plastic Pollution. *Proceedings of the National Academy of Sciences of the United States of America*, **114**, 9994-9997. https://doi.org/10.1073/pnas.1714450114

[79] Dauvergne, P. and Lister, J. (2012) Big Brand Sustainability: Governance Prospects and Environmental Limits. *Global Environmental Change*, **22**, 36-45. https://doi.org/10.1016/j.gloenvcha.2011.10.007

[80] Chang, M. (2015) Reducing Microplastics from Facial Exfoliating Cleansers in Wastewater through Treatment versus Consumer Product Decisions. *Marine Pollution Bulletin*, **101**, 330-333. https://doi.org/10.1016/j.marpolbul.2015.10.074

[81] Callaghan, C., Scott, J.L., Edler, K.J. and Mattia, D. (2022) Continuous Production of Cellulose Microbeads by Rotary Jet Atomization. *Journal of Colloid and Interface Science*, **627**, 1003-1010. https://doi.org/10.1016/j.jcis.2022.07.120

[82] Gan, H., Okada, T., Kimura, S., Kasuya, K. and Iwata, T. (2023) Manufacture, Physical Properties, and Degradation of Biodegradable Polyester Microbeads. *Polymer Degradation and Stability*, **208**, Article ID: 110239. https://doi.org/10.1016/j.polymdegradstab.2022.110239

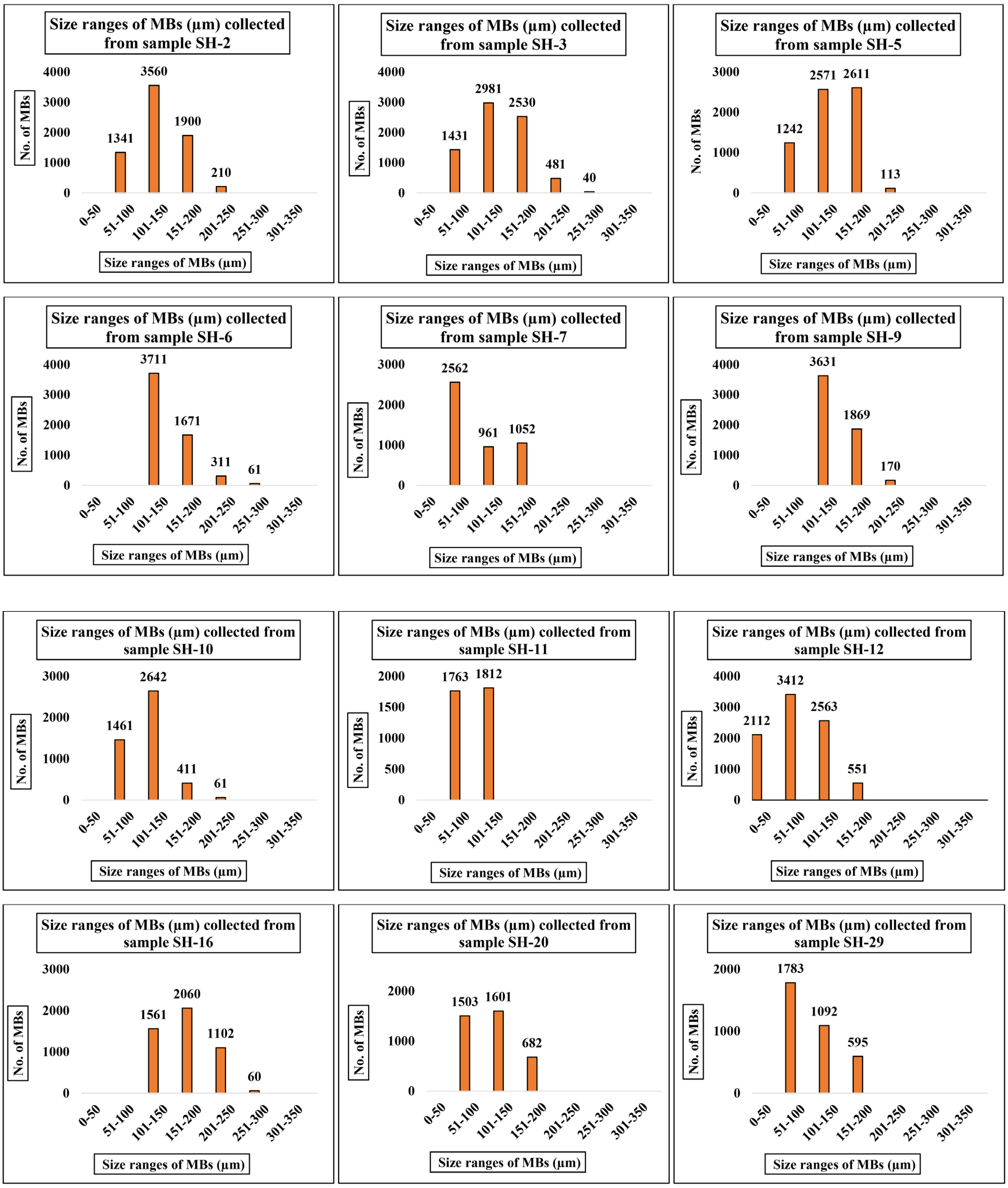
[83] Selvasudha, N., Goswami, R., Tamil Mani Subi, M., Rajesh, S., Kishore, K. and Vasanthi, H.R. (2023) Seaweeds Derived Ulvan and Alginate Polysaccharides Encapsulated Microbeads-Alternate for Plastic Microbeads in Exfoliating Cosmetic Products. *Carbohydrate Polymer Technologies and Applications*, **6**, Article ID: 100342. https://doi.org/10.1016/j.carpta.2023.100342

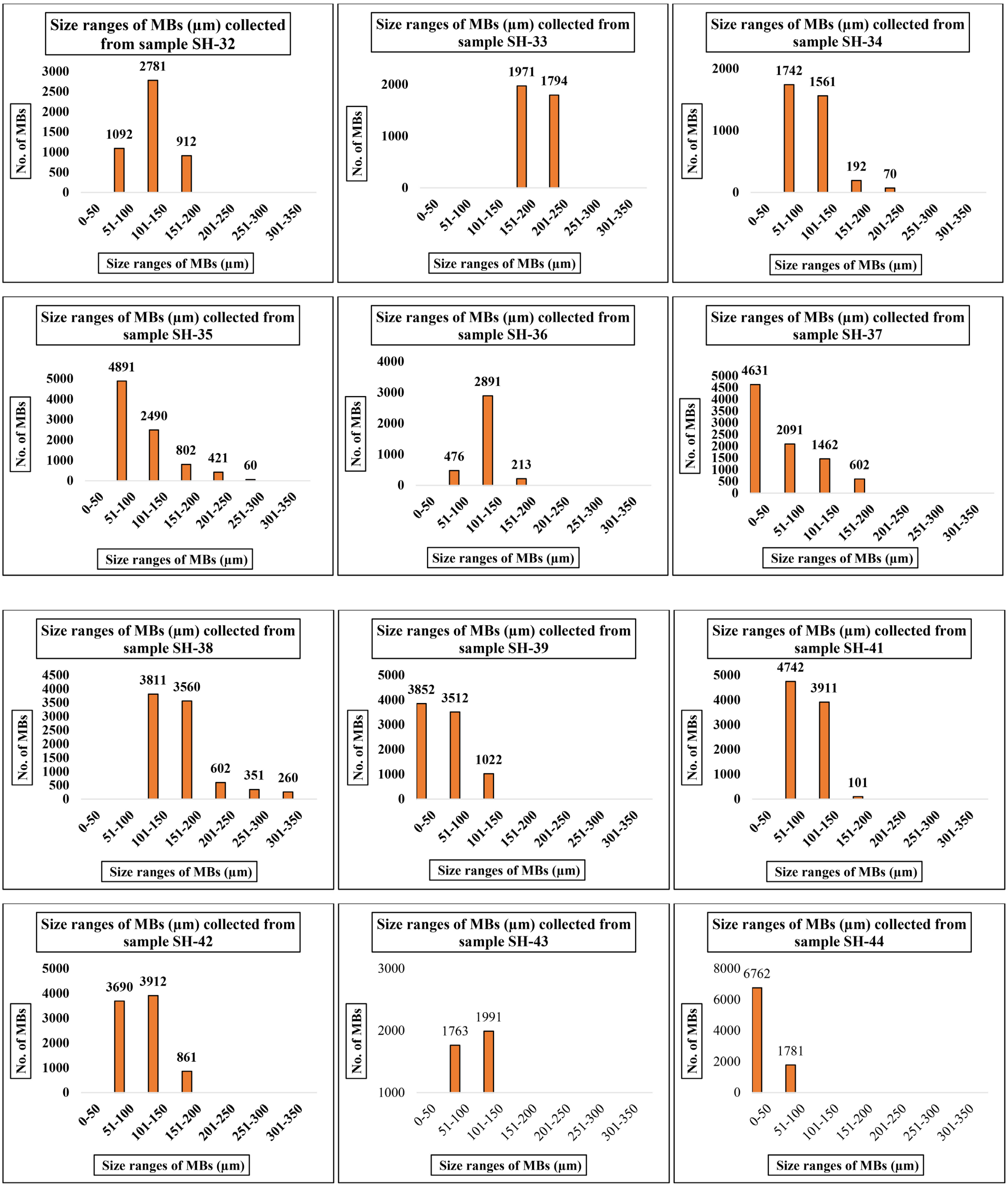
## Supplementary Data

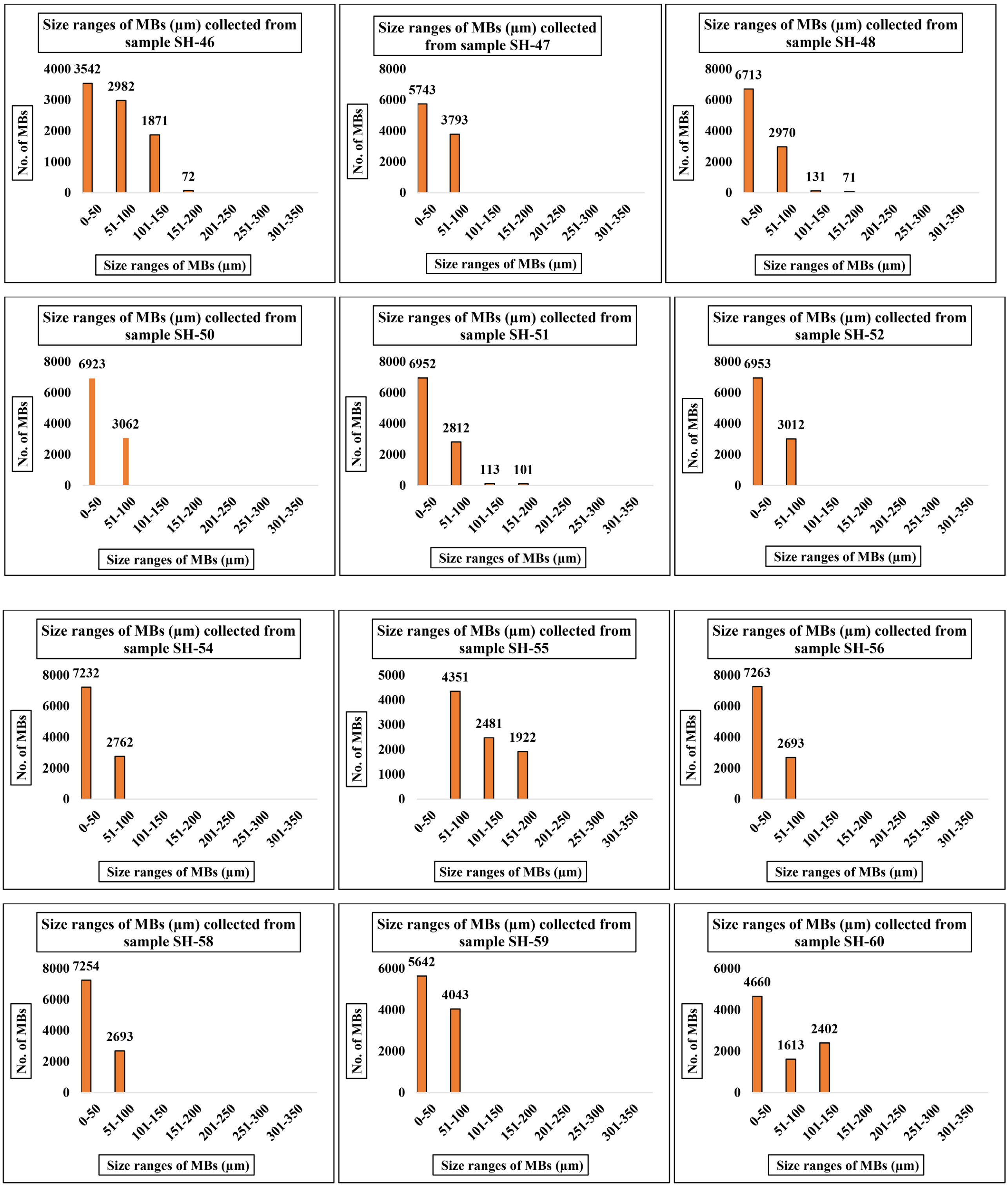
Size distribution graph of microbead containing products (**Figure S1**) pp. 2-14

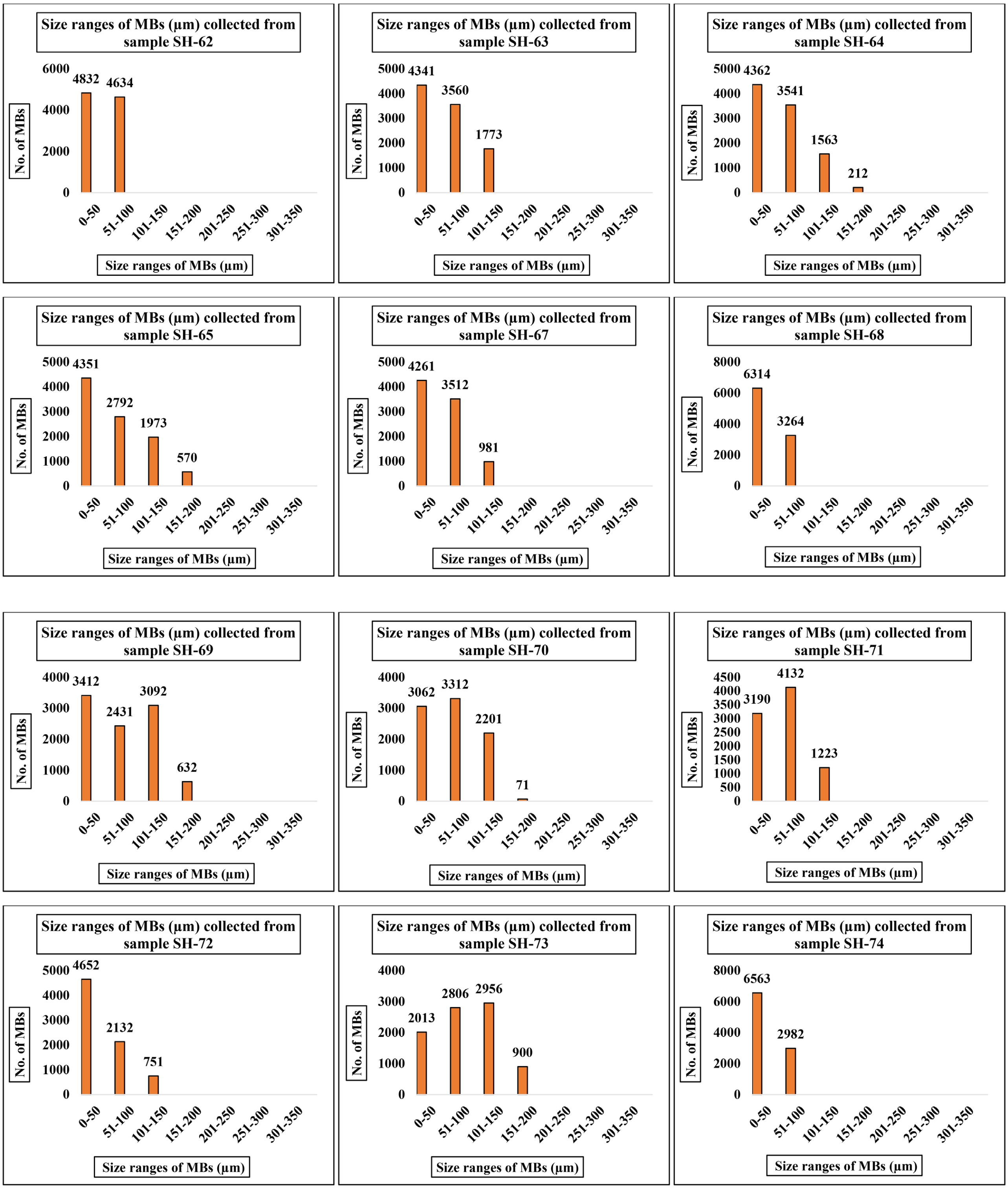
Categorization of the products according to color of the microbeads (**Figure S2**) p. 15

Categorization of the analyzed products by country as to their composition (no microbeads, plastic microbeads and non-plastic microbeads) (**Figure S3**) pp. 16-18

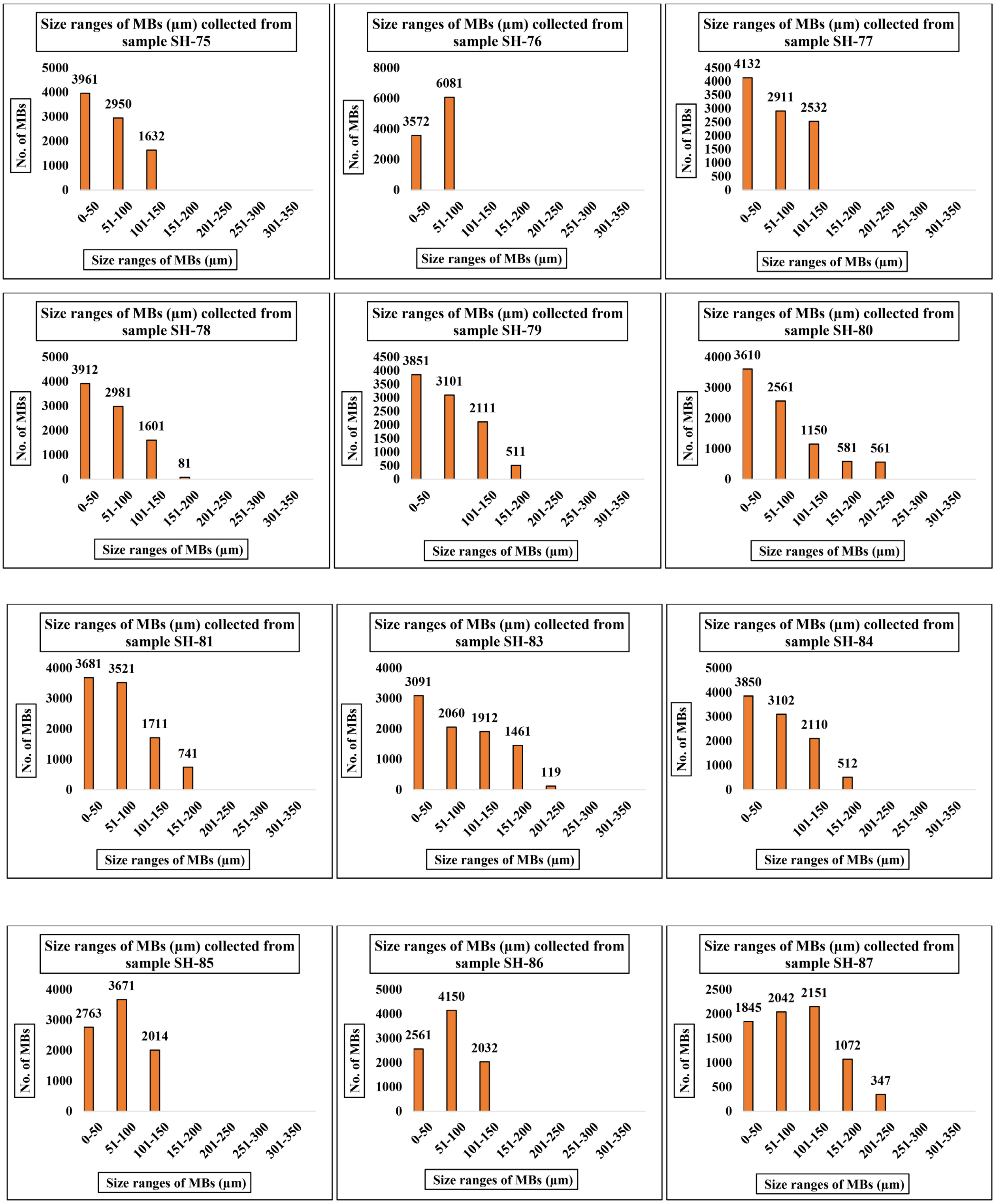


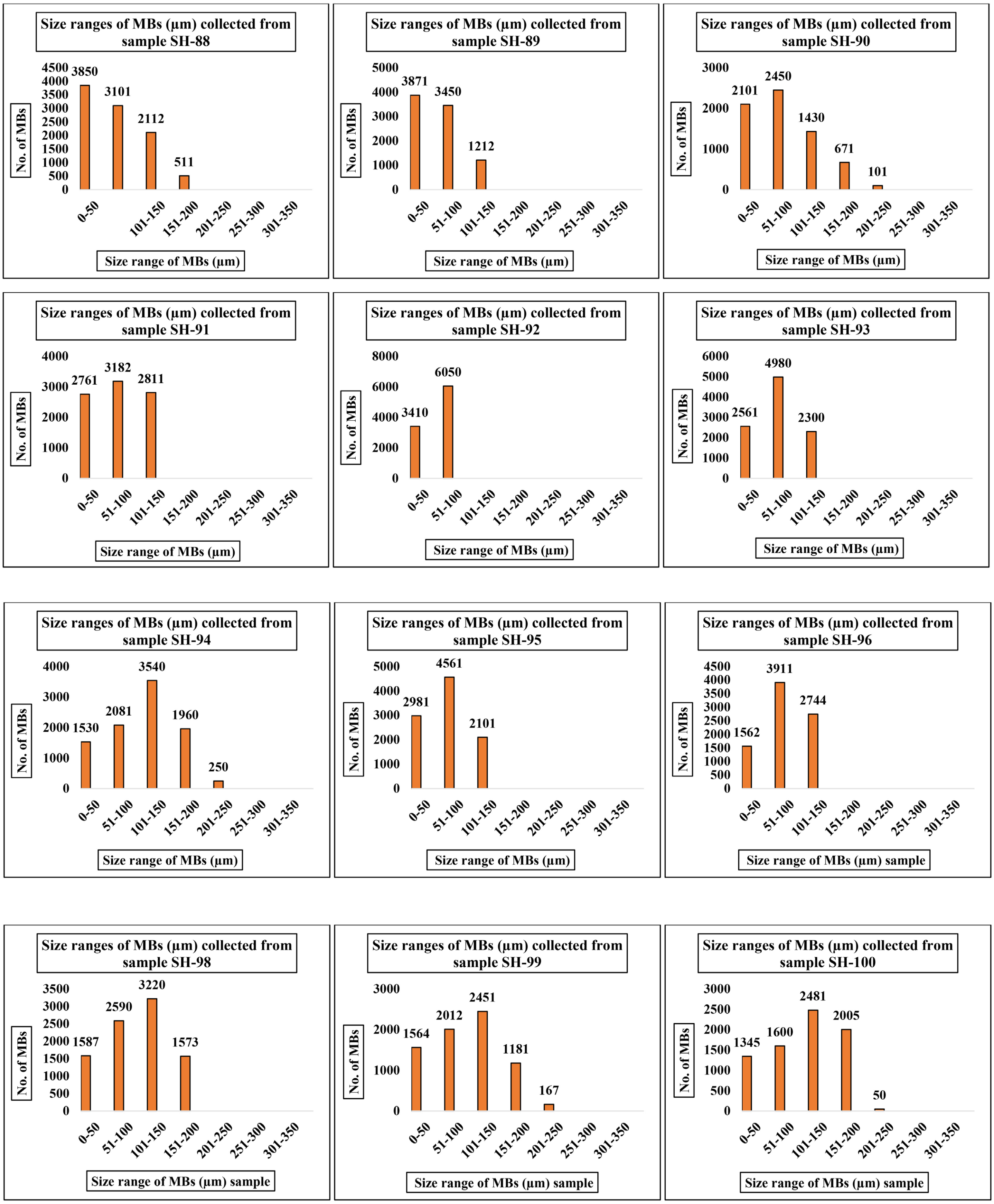

Size ranges of MBs (µm) collected from sample SH-32
No. of MBs
3000
2500
2000
1500
1000
500
0
1092
2781
912
0-50
51-100
101-150
151-200
201-250
251-300
301-350
Size ranges of MBs (µm)
Size ranges of MBs (µm) collected from sample SH-33
No. of MBs
2000
1000
0
1971
1794
Size ranges of MBs (µm)
Size ranges of MBs (µm) collected from sample SH-34
No. of MBs
2000
1000
0
1742
1561
192
70
Size ranges of MBs (µm)
Size ranges of MBs (µm) collected from sample SH-35
No. of MBs
5000
4000
3000
2000
1000
0
4891
2490
802
421
60
Size ranges of MBs (µm)
Size ranges of MBs (µm) collected from sample SH-36
No. of MBs
4000
3000
2000
1000
0
476
2891
213
Size ranges of MBs (µm)
Size ranges of MBs (µm) collected from sample SH-37
No. of MBs
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
4631
2091
1462
602
Size ranges of MBs (µm)
Size ranges of MBs (µm) collected from sample SH-38
No. of MBs
4500
4000
3500
3000
2500
2000
1500
1000
500
0
3811
3560
602
351
260
Size ranges of MBs (µm)
Size ranges of MBs (µm) collected from sample SH-39
No. of MBs
5000
4000
3000
2000
1000
0
3852
3512
1022
Size ranges of MBs (µm)
Size ranges of MBs (µm) collected from sample SH-41
No. of MBs
5000
4000
3000
2000
1000
0
4742
3911
101
Size ranges of MBs (µm)
Size ranges of MBs (µm) collected from sample SH-42
No. of MBs
5000
4000
3000
2000
1000
0
3690
3912
861
Size ranges of MBs (µm)
Size ranges of MBs (µm) collected from sample SH-43
No. of MBs
3000
2000
1000
1763
1991
Size ranges of MBs (µm)
Size ranges of MBs (µm) collected from sample SH-44
No. of MBs
8000
6000
4000
2000
0
6762
1781
Size ranges of MBs (µm)

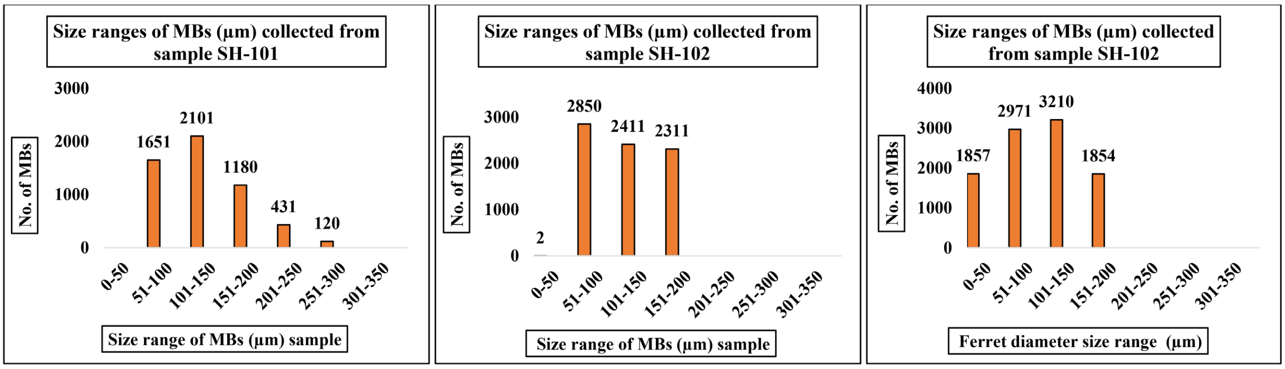

Size ranges of MBs (μm) collected from sample SH-46
No. of MBs
4000 3542
2982
1871
72
Size ranges of MBs (μm)
Size ranges of MBs (μm) collected from sample SH-47
5743
3793
Size ranges of MBs (μm) collected from sample SH-48
6713
2970
131
71
Size ranges of MBs (μm) collected from sample SH-50
6923
3062
Size ranges of MBs (μm) collected from sample SH-51
6952
2812
113
101
Size ranges of MBs (μm) collected from sample SH-52
6953
3012
Size ranges of MBs (μm) collected from sample SH-54
7232
2762
Size ranges of MBs (μm) collected from sample SH-55
4351
2481
1922
Size ranges of MBs (μm) collected from sample SH-56
7263
2693
Size ranges of MBs (μm) collected from sample SH-58
7254
2693
Size ranges of MBs (μm) collected from sample SH-59
5642
4043
Size ranges of MBs (μm) collected from sample SH-60
4660
1613
2402
0-50
51-100
101-150
151-200
201-250
251-300
301-350



Size ranges of MBs (µm) collected from sample SH-62
No. of MBs
6000
4000
2000
0
4832
4634
0-50
51-100
101-150
151-200
201-250
251-300
301-350
Size ranges of MBs (µm)
Size ranges of MBs (µm) collected from sample SH-63
No. of MBs
5000
4000
3000
2000
1000
0
4341
3560
1773
Size ranges of MBs (µm)
Size ranges of MBs (µm) collected from sample SH-64
No. of MBs
4362
3541
1563
212
Size ranges of MBs (µm)
Size ranges of MBs (µm) collected from sample SH-65
No. of MBs
4351
2792
1973
570
Size ranges of MBs (µm)
Size ranges of MBs (µm) collected from sample SH-67
No. of MBs
4261
3512
981
Size ranges of MBs (µm)
Size ranges of MBs (µm) collected from sample SH-68
No. of MBs
8000
6000
4000
2000
0
6314
3264
Size ranges of MBs (µm)
Size ranges of MBs (µm) collected from sample SH-69
No. of MBs
4000
3000
2000
1000
0
3412
2431
3092
632
Size ranges of MBs (µm)
Size ranges of MBs (µm) collected from sample SH-70
No. of MBs
3062
3312
2201
71
Size ranges of MBs (µm)
Size ranges of MBs (µm) collected from sample SH-71
No. of MBs
4500
4000
3500
3000
2500
2000
1500
1000
500
0
3190
4132
1223
Size ranges of MBs (µm)
Size ranges of MBs (µm) collected from sample SH-72
No. of MBs
4652
2132
751
Size ranges of MBs (µm)
Size ranges of MBs (µm) collected from sample SH-73
No. of MBs
2013
2806
2956
900
Size ranges of MBs (µm)
Size ranges of MBs (µm) collected from sample SH-74
No. of MBs
6563
2982
Size ranges of MBs (µm)


Size ranges of MBs (µm) collected from sample SH-75
No. of MBs
3961
2950
1632
Size ranges of MBs (µm) collected from sample SH-76
3572
6081
Size ranges of MBs (µm) collected from sample SH-77
4132
2911
2532
Size ranges of MBs (µm) collected from sample SH-78
3912
2981
1601
81
Size ranges of MBs (µm) collected from sample SH-79
3851
3101
2111
511
Size ranges of MBs (µm) collected from sample SH-80
3610
2561
1150
581
561
Size ranges of MBs (µm) collected from sample SH-81
3681
3521
1711
741
Size ranges of MBs (µm) collected from sample SH-83
3091
2060
1912
1461
119
Size ranges of MBs (µm) collected from sample SH-84
3850
3102
2110
512
Size ranges of MBs (µm) collected from sample SH-85
2763
3671
2014
Size ranges of MBs (µm) collected from sample SH-86
2561
4150
2032
Size ranges of MBs (µm) collected from sample SH-87
1845
2042
2151
1072
347
0-50
51-100
101-150
151-200
201-250
251-300
301-350
Size ranges of MBs (µm)


Size ranges of MBs (µm) collected from sample SH-88
No. of MBs
4500 4000 3500 3000 2500 2000 1500 1000 500 0
3850 3101 2112 511
0-50 101-150 151-200 201-250 251-300 301-350
Size range of MBs (µm)
Size ranges of MBs (µm) collected from sample SH-89
No. of MBs
5000 4000 3000 2000 1000 0
3871 3450 1212
0-50 51-100 101-150 151-200 201-250 251-300 301-350
Size range of MBs (µm)
Size ranges of MBs (µm) collected from sample SH-90
No. of MBs
3000 2000 1000 0
2101 2450 1430 671 101
0-50 51-100 101-150 151-200 201-250 251-300 301-350
Size range of MBs (µm)
Size ranges of MBs (µm) collected from sample SH-91
No. of MBs
4000 3000 2000 1000 0
2761 3182 2811
0-50 51-100 101-150 151-200 201-250 251-300 301-350
Size range of MBs (µm)
Size ranges of MBs (µm) collected from sample SH-92
No. of MBs
8000 6000 4000 2000 0
3410 6050
0-50 51-100 101-150 151-200 201-250 251-300 301-350
Size range of MBs (µm)
Size ranges of MBs (µm) collected from sample SH-93
No. of MBs
6000 5000 4000 3000 2000 1000 0
2561 4980 2300
0-50 51-100 101-150 151-200 201-250 251-300 301-350
Size range of MBs (µm)
Size ranges of MBs (µm) collected from sample SH-94
No. of MBs
4000 3000 2000 1000 0
1530 2081 3540 1960 250
0-50 51-100 101-150 151-200 201-250 251-300 301-350
Size range of MBs (µm)
Size ranges of MBs (µm) collected from sample SH-95
No. of MBs
5000 4000 3000 2000 1000 0
2981 4561 2101
0-50 51-100 101-150 151-200 201-250 251-300 301-350
Size range of MBs (µm)
Size ranges of MBs (µm) collected from sample SH-96
No. of MBs
4500 4000 3500 3000 2500 2000 1500 1000 500 0
1562 3911 2744
0-50 51-100 101-150 151-200 201-250 251-300 301-350
Size range of MBs (µm) sample
Size ranges of MBs (µm) collected from sample SH-98
No. of MBs
3500 3000 2500 2000 1500 1000 500 0
1587 2590 3220 1573
0-50 51-100 101-150 151-200 201-250 251-300 301-350
Size range of MBs (µm) sample
Size ranges of MBs (µm) collected from sample SH-99
No. of MBs
3000 2000 1000 0
1564 2012 2451 1181 167
0-50 51-100 101-150 151-200 201-250 251-300 301-350
Size range of MBs (µm) sample
Size ranges of MBs (µm) collected from sample SH-100
No. of MBs
3000 2500 2000 1500 1000 500 0
1345 1600 2481 2005 50
0-50 51-100 101-150 151-200 201-250 251-300 301-350
Size range of MBs (µm) sample




**Figures S1.** Size distribution graph of microbead containing products.

**Figure S2.** Categorization of the products according to color of the microbeads.

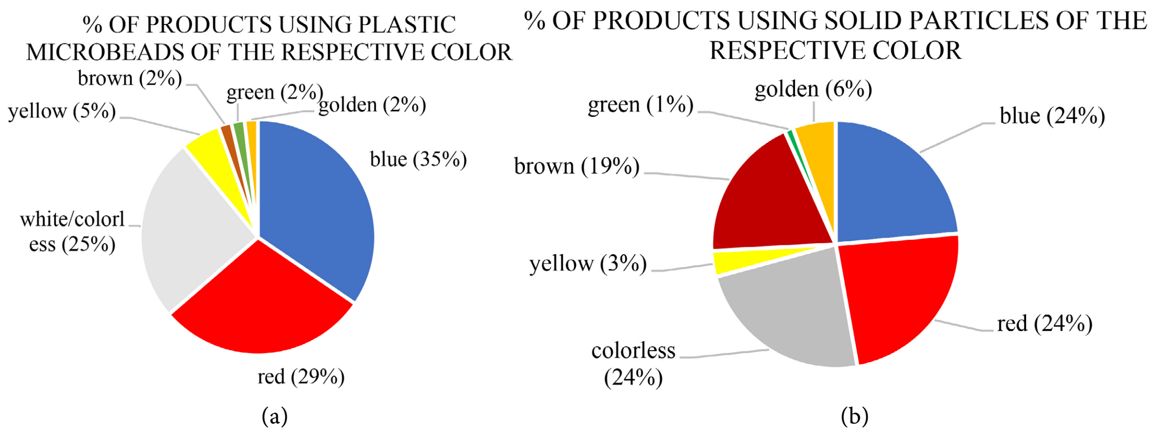
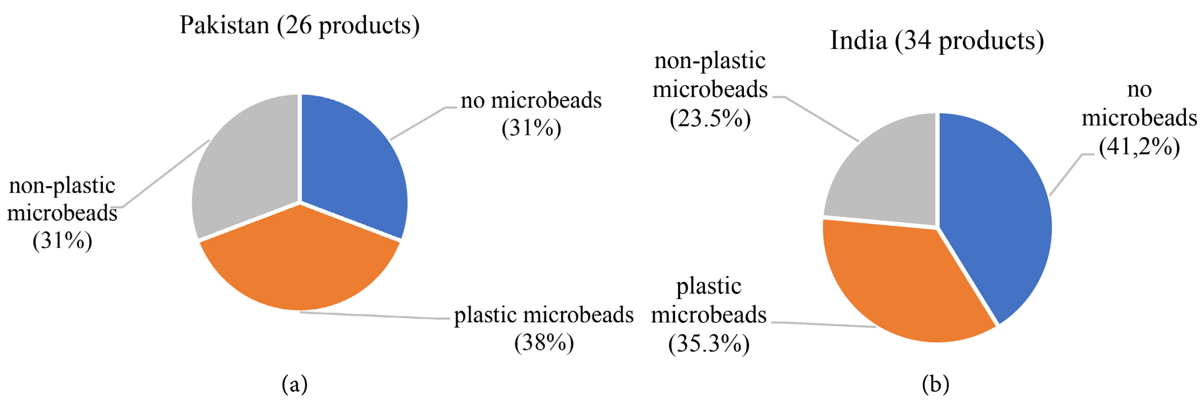



**Figure S2.** (a) Colors of the plastic microbeads in the examined products, (b) Colors of microbeads (plastic and non-plastic) in the examined products.

**Figure S3.** Categorization of the analyzed products by country as to their composition (no microbeads, plastic microbeads and non-plastic microbeads).



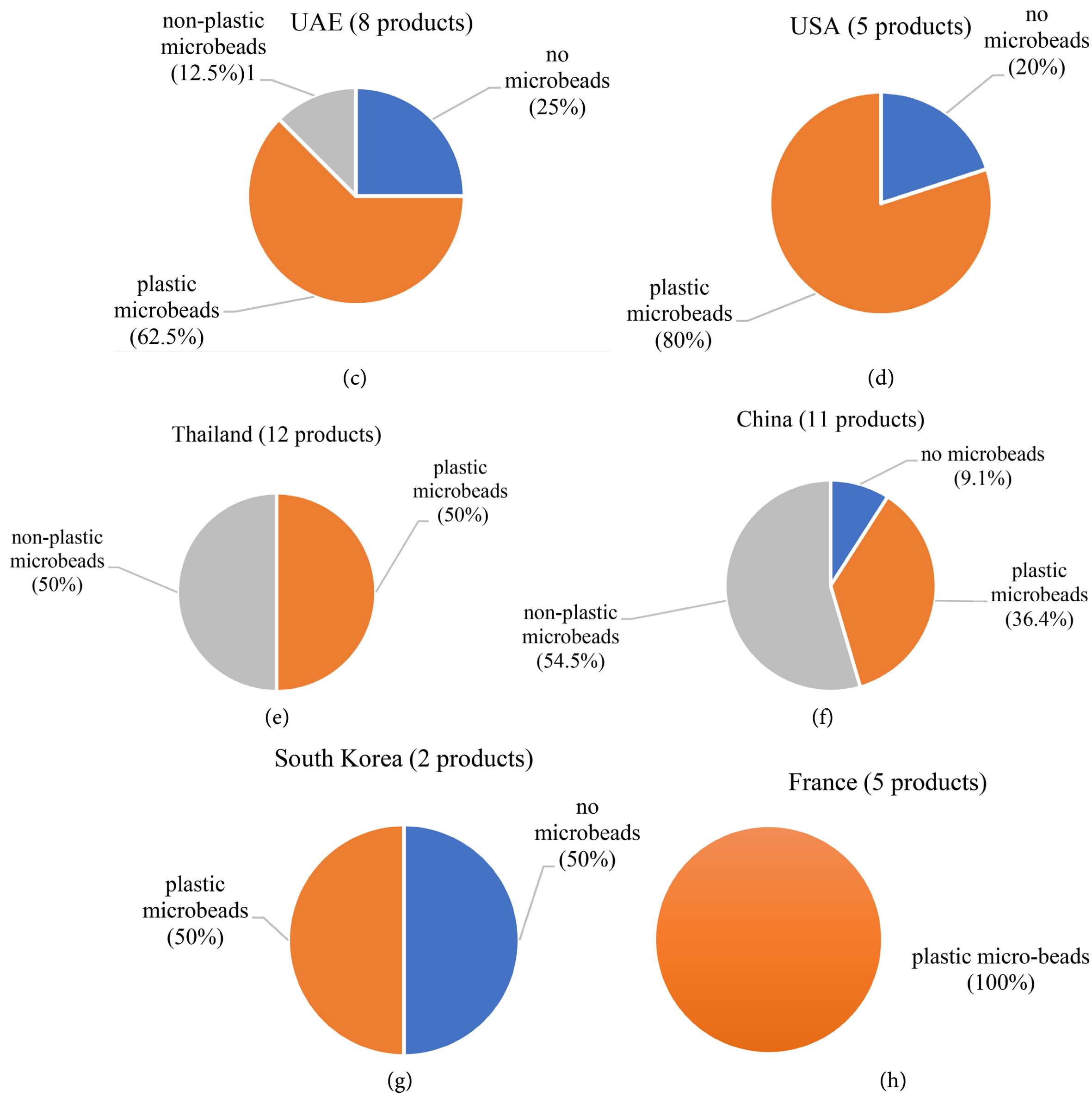



**Figure S3.** (a) Composition of products stemming from Pakistan, (b) Composition of products imported from India, (c) Composition of products imported from the United Arab Emirates, (d) Composition of products imported from the United States of America, (e) Composition of products imported from Thailand, (f) Composition of products imported from PR China, (g) Composition of products imported from South Korea, (h) Composition of products imported from France.