

ISOLATION, QUANTIFICATION, CHARACTERIZATION, AND RISK INTAKE OF MICROPLASTICS FROM RINSE-OFF SHAMPOO

Maria Raluca BUCUR (POPA)^{1,2}, Cristiana RADULESCU^{1,3,4,*},
Raluca Maria STIRBESCU⁵, Andreea Laura BANICA^{1,5}, Ioan Alin
BUCURICA⁵

This study aims to investigate the unintentionally released microplastics in rinse-off cosmetic products and the potential risk to human health. In this regard, a total of eight samples of branded rinse-off shampoo were collected based on the consumer habits survey, considering the recipient categories, i.e., children and adults. Microplastics found in these samples exhibited significant heterogeneity, not only in their chemical composition (types of polymers) but also in their quantity, color, size, and shape (whether they are fragments or fibers). This diversity makes it challenging to assess the potential risks to human health, especially considering different recipient categories, such as children and adults.

Keywords: shampoo; microplastic; quantification; optical microscopy; micro-FTIR; health risk

1. Introduction

The cosmetics industry is known for its high frequency of product launches, even with mass-produced items that are manufactured continuously or in batches. However, this industry also relies heavily on thousands of synthetic chemicals found in various cosmetic products, ranging from lipsticks to lotions, shampoos, and creams [1-3]. The categories of hair care products include: (i) hair washing and coloring products, such as shampoos (e.g., anti-dandruff, antiseborrheic, and those

¹ Doctoral School of Chemical Engineering and Biotechnology, National University of Science and Technology POLITEHNICA of Bucharest, Romania

² Research and Expertise Center for Natural Resources and Environment, Valahia University of Targoviste, Romania, e-mail: raluca maria.bucur@gmail.com.

³ Faculty of Sciences and Arts, Valahia University of Targoviste, Romania, e-mail: cristiana.radulescu@valahia.ro.

⁴ Academy of Romanian Scientists, Bucharest, Romania.

⁵ Institute of Multidisciplinary Research for Science and Technology, Valahia University of Targoviste, Romania, e-mail: stirbescu.raluca@icstm.ro; banica.andreea@icstm.ro; alin_bucurica@icstm.ro.

*Correspondence: cristiana.radulescu@valahia.ro.

with various extracts), colored shampoos, and hair dyes; (ii) volumizing and texturizing products, including hairspray and hair styling lotions.

Shampoo is the most widely used cosmetic product because people desire shiny, silky hair after every wash. However, since hair comes in various textures, a wide range of options is necessary to meet diverse needs. When selecting a quality shampoo, it is essential to consider hair type, such as normal, oily, fine, colored, healthy, or colored and damaged. Consumers often prioritize improving hair and scalp health, eliminating dandruff, and ensuring adequate hydration for colored hair when choosing a shampoo. Types of shampoo include normal, dry, medicinal, treatment, and colored varieties. Personalized care is the best way to achieve desired results, so it's important to make an informed decision when selecting a shampoo.

At the beginning of 2024, the European Union sent a series of alerts to its member countries, including Romania, regarding several branded shampoos. These alerts were issued due to the detection of 2-(4-tert-butylbenzyl) propionaldehyde (BMHCA), also known as Lyril, in these products. This substance has been banned in cosmetic products within the European Union since August 2021 because of its potential to cause allergic reactions [3]. The number of alerts regarding cosmetic hair washing products is on the rise, primarily due to the chemical compounds in their formulations. Additionally, there are concerns about potential contaminants, such as microplastics, which often come from the packaging materials [4]. When these containers are opened, they release numerous micro- and nanoplastics that can end up in the product and ultimately on hair. In some cases, if there are existing scalp lesions, such as those caused by topical dermatitis, these particles may even enter the bloodstream directly. This situation highlights an uncontrolled exposure of individuals to these widely used cosmetic products, affecting people of all age groups, from newborns to the elderly [5-7]. These findings can be compared to a study that revealed a high concentration of microplastics in the human body and that it is released into open bottled water [8]. In this respect, Zuccarello et al. [8] reported that children can consume over 3 million microparticles per kilogram of body weight per day from bottled water alone. Furthermore, the study estimates that adults are exposed (ingestion, inhalation, and topical or systemic contact) to approximately one million microparticles per kilogram of body weight per day [8]. A meta-analysis on microparticle concentrations in various foods, including water and milk, found that the suggested exposure dose for humans is around 0.10 to 5.0 grams per week [9]. Additionally, research by Zhang et al. [10] indicates an excretion rate of 0.03 to 677 milligrams of polyethylene terephthalate microparticles per week. The toxic effects of microplastics can vary based on their physical characteristics, such as size, shape, and length, as well as their chemical composition (i.e., additives and polymers). The potential risks and synergistic toxicity linked to exposure to microplastics can lead to disorders in the circulatory,

neuronal, and metabolic systems, posing a significant threat to human health [3, 11, 12].

Taking into consideration these things, this research aims to investigate the presence of potential microplastics in rinse-off shampoo from several branded products collected from Romanian markets. In this regard, two analytical techniques (optical microscopy and micro-Fourier transform infrared spectroscopy) were used to quantify and characterize potential microplastics in terms of morphological and chemical properties. One of the main challenges was identifying a suitable method to isolate microplastics from shampoo samples. Additionally, the study aimed to assess the potential health risks associated with exposure to microplastics, focusing on products designed for both children and adults, and making distinctions between those designed for women and men.

2. Materials and Methods

2.1. Materials and reagents

The laboratory glassware used for the investigations carried out in the present study was thoroughly cleaned with distilled water and washing acid (2% nitric acid), which was sterilized in a Venticell[®] forced convection oven (BMT Medical Technology) at 100°C for 48 hours. The isolation method was adopted according to the microplastic isolation protocol developed and patented by Radulescu et al. (2025b). The high-purity reagents used in this investigation were sodium dodecyl sulfate ($\leq 98.5\%$) and sodium hydroxide (Merck, KGaA, Darmstadt, Germany). Sample filtration was performed using a three-position stainless steel filtration system equipped with a vacuum pump, which had a flow rate of 18 L/min. In addition, VWR[®] Grade 413 filter paper with a porosity of 12–15 μm was used for filtration.

2.2. Sampling and Sample Preparation

2.2.1. Sampling

Products from the category of cleaning, care, and treatment for the scalp and hair were randomly selected from specialized stores, taking into account customer preferences, brand, cost, and best-selling products, according to a previous survey [13]. The selected samples included eight rinse-off shampoo-branded products (Table 1), indicating the target audience (men, women, and children) for each product.

Table 1.

Type, ingredients, and recipient category of the branded rinse-off shampoo		
Code	Ingredients declared by the producer on the label	Category
S ₁	Water, sodium laureth sulfate, cocamidopropyl betaine, sodium chloride, panthenol, allantoin, perfume, citrus aurantium peel oil, glycerin, glycol distearate, hydroxypropylguar hydroxypropyltrimonium chloride, laureth-4, sodium benzoate, potassium sorbate, benzoic acid, tetramethyl acetyloctahydronaphthalene, linalyl acetate, linalool, limonene, citric acid, maris sal, sodium hydroxide.	Men
S ₂	Water, sodium laureth sulfate, cocamidopropyl betaine, disodium laureth sulfosuccinate, glycerin, glycol distearate, panthenol, aloe barbadensis leaf juice powder, hydrolyzed wheat protein, heliotropin, sodium chloride, PEG-120 methyl glucose dioleate, polyquaternium-10, quaternium-80, propylene glycol, laureth-4, sodium citrate, citric acid, phenoxyethanol, sodium benzoate, sodium hydroxide, tocopherol, perfume, CI 16185	Children
S ₃	Water, sodium laureth sulfate, sodium chloride, cocamidopropyl betaine, butylene glycol, PPG-26-buteth-26, PEG-40 hydrogenated castor oil, apigenin, oleanolic acid, biotinoyl tripeptide-1, quaternium-22, polyquaternium-7, placental protein, hydrolyzed soy protein, propylene glycol, panthenol, zinc PCA, glucose, ornithine HCL, niacinamide, arginine HCL, pyridoxine HCL, glucosamine HCL, citrulline, biotin, sodium succinate, citric acid, parfum, sodium benzoate, potassium sorbate, chlorphenesin, phenoxyethanol, sorbic acid, linalool, limonene.	Woman
S ₄	Water, sodium laureth sulfate, cocamide DEA, cocamidopropyl betaine, panthenol, polyquaternium-7, glycol distearate, cocamide MEA, menthol, sodium chloride, parfum, citric acid, sodium benzoate, tetrasodium EDTA, sodium hydroxide, limonene, alpha-isomethyl ionone, linalool.	Men
S ₅	Water, cocamidopropyl betaine, decyl glucoside, sodium cocoyl isethionate, polyquaternium-10, coconut acid, sodium isethionate, glycerin, sodium methyl cocoyl taurate, PEG-80 sorbitan laurate, PEG-150 distearate, sodium chloride, disodium EDTA, citric acid, BHT, sodium benzoate, perfume.	Children
S ₆	Water, cocamidopropyl betaine, glycerin, sodium lauroyl methyl isethionate, coco-glucoside, sodium chloride, sodium benzoate, caprylyl/capryl glucoside, polyquaternium-10, perfume, sodium methyl isethionate, citric acid, panthenol, lauric acid, zinc laurate, trisodium ethylenediamine disuccinate, sodium laurate, denatonium benzoate.	Children
S ₇	Water, sodium laureth sulfate, sodium chloride, cocamidopropyl betaine, urtica dioica (nettle) extract, pyrus malus (apple) fruit extract, sodium benzoate, coco-glucoside, perfume, oleate glyceryl, citric acid, propylene glycol, hydroxypropyl guar hydroxypropyltrimonium chloride, ethoxydiglycol, sodium hydroxide, benzyl alcohol, potassium sorbate.	Woman
S ₈	Water, sodium laureth sulfate, sodium chloride, cocamidopropyl betaine, humulus lupulus (hops) cone extract, sodium benzoate, coco-glucoside, glyceryl oleate, citric acid, perfume, glycol distearate, laureth-4, PEG-7 glyceryl cocoate, hydrogenated castor oil, hydroxypropyl guar hydroxypropyltrimonium chloride, propylene glycol, ethoxydiglycol, hexyl cinnamal, linalool, limonene, sodium hydroxide, benzyl alcohol, potassium sorbate	Men

EDTA=ethylene-diamine-tetra-acetic acid; DEA=diethanolamine; PCA=pyrrolidone carboxylic acid; PEG=polyethylene glycols; CI 16185=amaranth, trisodium 3-hydroxy-4-[(4'-sulphonatonaphthyl)azo]naphthalene-2,7-disulphonate; HCL=ornithine hydrochloride; MEA=cocamide monoethanolamine; BHT=Butylhydroxytoluene; PPG-26-buteth-26=polyoxyethylene ether of butyl alcohol.

2.2.2. Sample preparation

The isolation protocol developed by Radulescu et al. [14, 15] involves three main steps also applied in the present research: (i) sample pretreatment; (ii) chemical digestion; (iii) filtration and isolation of microplastics from the analyzed samples. To isolate microplastics from rinse-off shampoo samples, a mixture was prepared consisting of 5 mL of sample, 1 g of sodium dodecyl sulfate, 1 g of sodium hydroxide, and 500 mL of ultrapure water. Fig. 1 illustrates the isolation of microplastics stages from rinse-off shampoo samples.

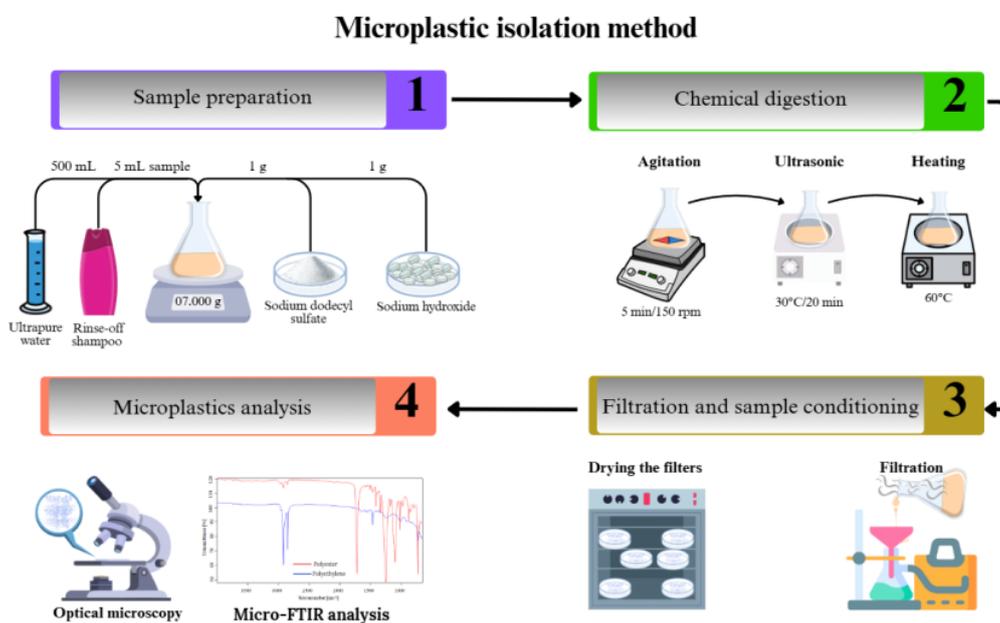


Fig. 1. Method for isolating microplastics from rinse-off shampoo samples

2.3. Methods

The initial morphological investigation, along with the quantification of microparticles isolated from shampoo samples, was performed by optical microscopy, using a Primo Star and a Stemi 2000-C optical microscope (Carl Zeiss, Jena, Germany), in both transmitted and reflected light. The final images were acquired using an AxioCam 105 digital video camera (Carl Zeiss, Jena, Germany) and Zen software (ZEN 2012, blue edition, Version 1.1.2.0).

Morphological and chemical analyses were performed by non-invasive and non-destructive micro-FTIR analysis using a Vertex 80v spectrometer (Bruker, Ettlingen, Germany) coupled with a HIPERION 2000 microscope (Hitachi, Tokyo, Japan). The spectra were primarily obtained in reflectance mode, along with some punctual acquisitions. The spectral background was recorded from a clean section of the filter. For each spectrum, 32 scans were collected, and the resulting data were

processed and identified using the OPUS v7.5 reference library (Bruker, Ettlingen, Germany).

2.4. Exposure to microplastics

The chronic daily exposure dose through dermal absorption (D_{der}) of the shampoo was calculated using Equation 1, as presented by Popa (Bucur) et al. [3].

$$D_{der} = \frac{C \cdot SA \cdot ED \cdot EF}{BW \cdot AT} \cdot CF \quad (1)$$

where: C is concentration of microplastics ($n \cdot 0.25 \text{ L}^{-1}$); SA is exposed surface area (for children $SA_{total} = 4500 \text{ cm}^2$, woman $SA_{total} = 10500 \text{ cm}^2$, and men $SA_{total} = 15700 \text{ cm}^2$); ED is duration of exposure, expressed in years (for adults $ED = 40$ years and children $ED = 14$ years); EF is exposure frequency expressed in $\text{day} \cdot \text{year}^{-1}$ ($EF = 100 \text{ day} \cdot \text{year}^{-1}$); BW is body mass expressed in kg (for children $BW = 45 \text{ kg}$, woman $BW = 60 \text{ kg}$, and men $BW = 70 \text{ kg}$); AT is the average exposure time (for children $AT = 1400$ days and adults $AT = 4000$ day); and CF is conversion factor ($CF = 1 \cdot 10^{-6}$); n is the number of microplastics identified in the sample expressed at 0.25 L .

3. Statistical Analysis

Statistical analysis is the most commonly used method for assessing sample similarities and organizing data by identifying anomalies and eliminating redundant information. To better understand the complexity of the recorded data, the IBM SPSS Statistics version 26 (SPSS Inc., Chicago, IL, USA, 2011) was used along with hierarchical cluster analysis (HCA).

4. Results and Discussion

After isolation, the microparticles present in the samples were quantified and examined morphologically using optical microscopy (Fig. 2). The quantification and color-based classification of microparticles (i.e., black, blue, red, purple, green, turquoise, and brown) were displayed in Table 2.

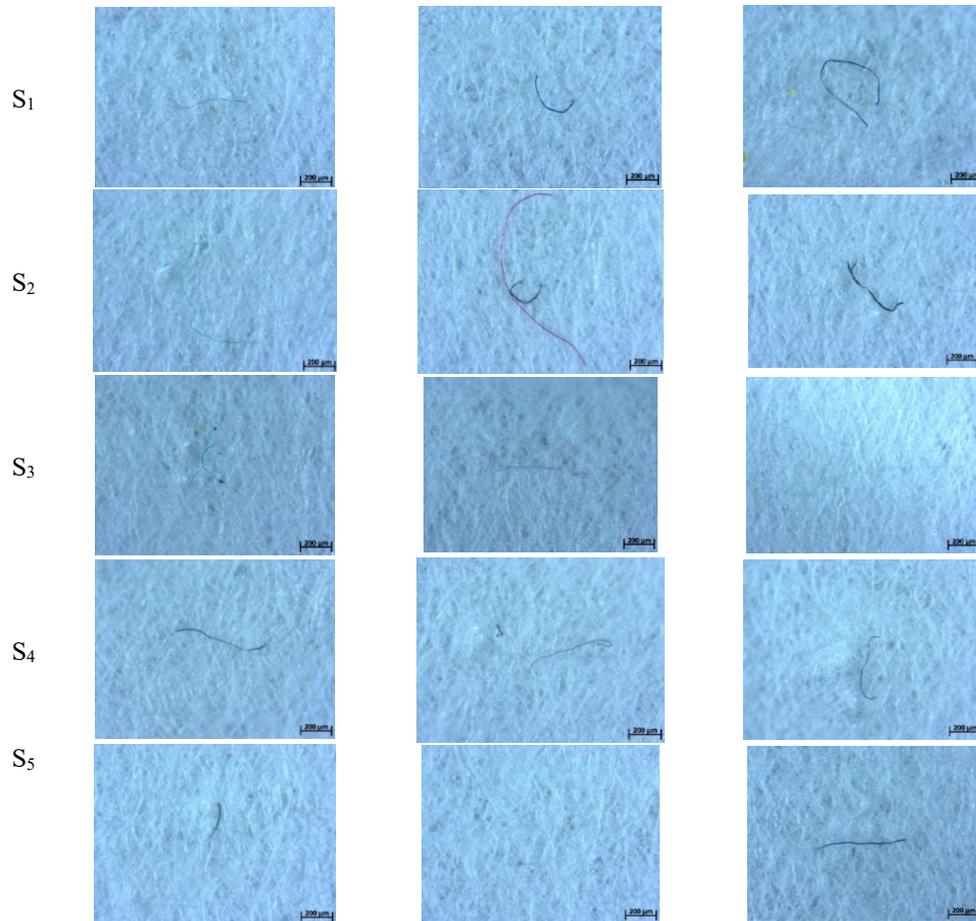
Table 2.

Quantification of microparticles in rinse-off shampoo samples							
Sample code	Color and number of microparticles						Total [microparticles $\cdot 250 \text{ mL}^{-1}$]
	Black	Blue	Red	Purple	Green	Green	
S ₁	200	200	nd*	nd*	150	nd*	550
S ₂	250	350	nd*	100	100	50	850
S ₃	100	400	nd*	50	nd*	100	650
S ₄	nd*	400	nd*	nd*	nd*	nd*	400
S ₅	nd*	50	100	nd*	100	nd*	250
S ₆	100	nd*	nd*	nd*	50	50	200

S ₇	300	150	100	nd*	200	200	950
S ₈	250	150	50	nd*	200	nd*	650

nd* - unidentified

Based on optical microscopy analysis of the eight rinse-off shampoo samples, the highest number of microplastics was found in sample S₇, which is intended for women. In the intended shampoo samples for children, the number of microplastics identified in 250 mL of product was 850 microplastics·250 mL⁻¹ (sample S₂), 250 microplastics·250 mL⁻¹ (sample S₅), and 200 microplastics·250 mL⁻¹ (sample S₆). In the case of men, sample S₈ showed the highest number of microplastics (650 microplastics·250 mL⁻¹). The most representative optical microscopy images for the samples are shown in Fig. 2.



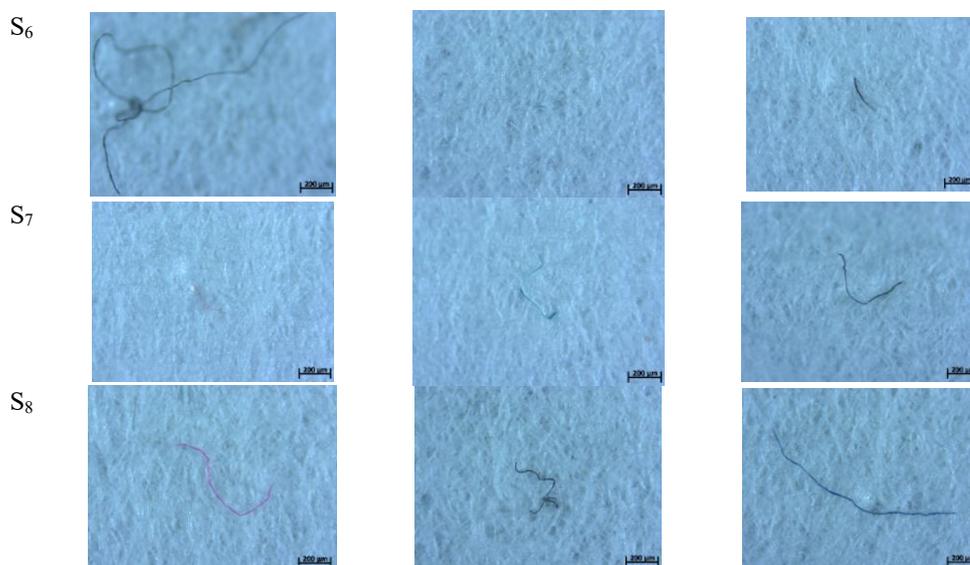
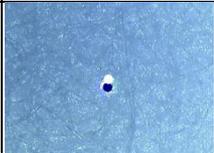
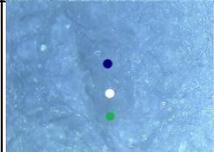


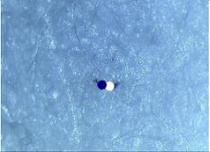
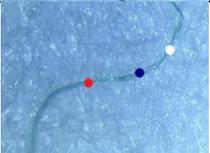
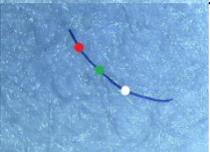
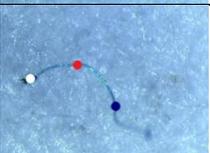
Fig. 2. Representative microparticles in rinse-off shampoo samples

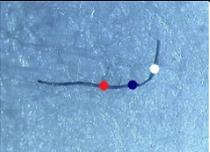
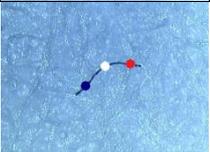
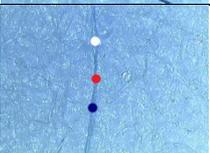
Micro-Fourier transform infrared spectroscopy (micro-FTIR) is a valuable technique for advanced morphological and chemical investigations of microparticles, especially when combined with data obtained from optical microscopy. This study successfully identified the structure of microparticles, despite the limitations of micro-FTIR transmittance mapping for detailed chemical characterization of microplastics found in rinse-off shampoos. Initial analyses at three different points revealed various fibers and fragments of differing sizes, shapes, and chemical compositions (Table 3). Additionally, the correct composition of the microparticles, whether natural, mixed, or synthetic, was determined using the spectral library in OPUS software v.7.5.

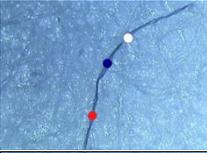
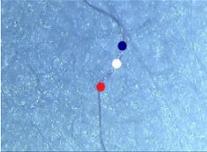
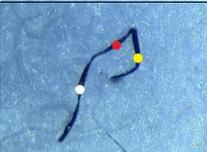
Table 3.

Data in terms of chemical and morphological properties of microplastics in shampoo samples

Sample code	Shape	Image	Composition of microplastics						Size (LxW)
			PU ¹	PS ²	PMMA ³	PA ⁴	Cotton	Cellulose Acetate	
S _{1.1}	Fragment irregular		nd*	nd*	11	6	70	13	77.78x68.91
S _{1.2}	Fragment angular		nd*	nd*	11	6	70	13	573.44x209.79

Sample code	Shape	Image	Composition of microplastics						Size (LxW)
			PU ¹	PS ²	PMMA ³	PA ⁴	Cotton	Cellulose Acetate	
S _{1.3}	Fragment angular		nd*	nd*	nd*	25	65	10	339.88x250.55
S _{1.4}	Fragment irregular		nd*	nd*	nd*	15	64	21	112.93x163.78
S _{1.5}	Fiber		nd*	nd*	11	6	70	13	>803.28
S _{1.6}	Fiber		5	nd*	nd*	nd*	95	nd*	>1116.54
S _{2.1}	Fragment regular		nd*	nd*	nd*	25	65	10	121.63x90.68
S _{2.2}	Fiber		2	nd*	nd*	16	33	49	516.12
S _{3.1}	Fiber		nd*	nd*	11	6	70	13	473.37
S _{3.2}	Fiber		8	nd*	nd*	nd*	92	nd*	756.41

Sample code	Shape	Image	Composition of microplastics						Size (LxW)
			PU ¹	PS ²	PMMA ³	PA ⁴	Cotton	Cellulose Acetate	
S _{3.3}	Fiber		nd*	nd*	nd*	40	60	nd*	>1166.78
S _{4.1}	Fragment irregular		8	nd*	nd*	nd*	92	nd*	195.42
S _{4.2}	Fiber		nd*	nd*	nd*	15	64	21	688.95
S _{5.1}	Fragment irregular		nd*	32	nd*	nd*	68	nd*	587.17
S _{7.1}	Fiber		nd*	nd*	nd*	40	60	nd*	338.91
S _{7.2}	Fiber		nd*	nd*	nd*	40	60	nd*	511.22
S _{7.3}	Fiber		nd*	nd*	nd*	40	60	nd*	1258.94
S _{7.4}	Fiber		nd*	nd*	nd*	100	nd	nd*	>698.98

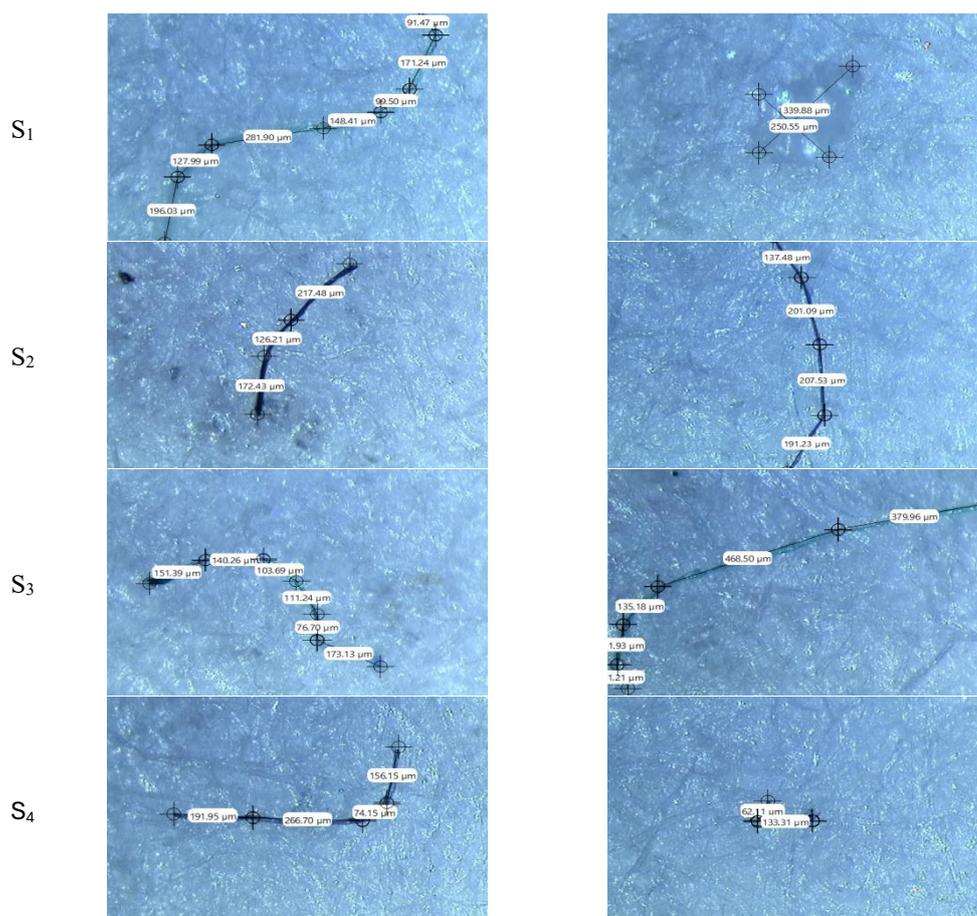
Sample code	Shape	Image	Composition of microplastics						Size (LxW)
			PU ¹	PS ²	PMMA ³	PA ⁴	Cotton	Cellulose Acetate	
S _{7.5}	Fiber		nd*	nd*	nd*	100	nd	nd*	>889.44
S _{7.6}	Fiber		nd*	nd*	nd*	40	60	nd*	>829.53
S _{7.7}	Fiber		nd*	nd*	nd*	40	60	nd*	>1069.51
S _{7.8}	Fragment angular		nd*	nd*	nd*	40	60	nd*	126.01
S _{8.1}	Fiber		nd*	nd*	nd*	40	60	nd*	739.30
S _{8.2}	Fiber		nd*	nd*	nd*	25	65	10	921.08
S _{8.3}	Fiber		nd*	nd*	nd*	2	47	51	503.48

¹PU – Polyurethane; ²PS – Polyester; ³PMMA – Poly(methyl methacrylate); ⁴PA – Polyamide; nd*–no date.

In the case of fragments, the shape of the fragments, i.e., their uneven, angular, and elongated shape, was revealed according to their chemical composition. Micro-FTIR mapping produced a high-quality identification of the polymer structure. In addition to those mentioned above, the size of the Microplastics was determined by micro-FTIR (Fig. 3).

Interestingly, the morphology of microplastics varies significantly within a single shampoo sample (Table 3), resulting in a diverse range of microplastics rather than a uniform collection. Additionally, the size distribution among the microplastics was notably different. Most of the shampoo samples contain complex organic matrices (Table 1), which interfere with the polymer spectrum, and this can be a real issue.

Micro-FTIR mapping of the microplastics extracted from the shampoo samples helps resolve the identification challenge. The analysis revealed that microplastics mainly exist as a mixture (Table 3) consisting of natural materials (i.e., cotton) and synthetic polymers, such as polyurethane, polyester, poly(methyl methacrylate), and polyamide. A polyacrylate compound was identified in the matrices of three samples (Table 3). This compound is commonly used in hair products as a smoothing and conditioning agent, suggesting that it may be the primary reason for its presence in these samples. On the other hand, polyamide (PA) was found in thirteen microplastics, mainly in mixtures, while only two of these were 100% composition (Table 3).



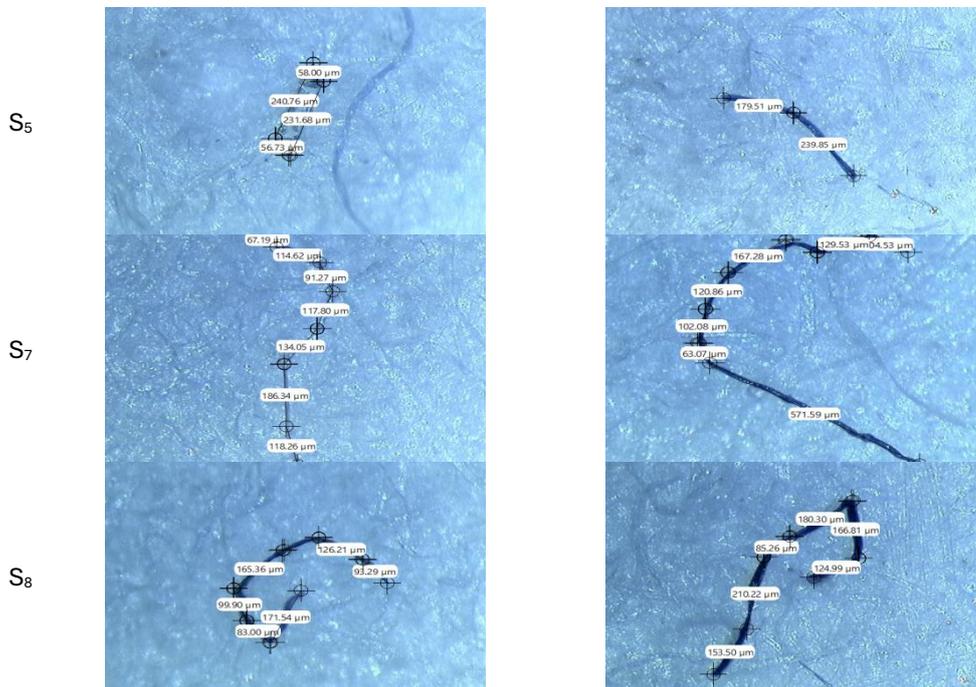


Fig. 3. Sequence for measuring microplastics in rinse-off shampoo samples

Initially, optical microscopy allowed for the quantification of numerous microparticles, both natural and synthetic. However, the micro-FTIR technique provided the capability to specifically identify synthetic microparticles, even when they were mixed with natural particles that were at least an order of magnitude more abundant. It can be concluded that utilizing both optical microscopy and micro-FTIR techniques can provide more reliable results and ensure accurate identification and characterization of the filtered samples in physical and chemical terms.

The total chronic microplastic exposure dose by absorption (D_{der}) for rinse-off shampoo samples was calculated based on Equation (1), both for children and adults (Table 1).

Table 4.

Total chronic exposure dose to microplastics through absorption for rinse-off soap samples

Code	D_{der}	Category
S ₁	1.08E ⁻⁶	Men
S ₂	3.59E ⁻⁵	Children
S ₃	5.38E ⁻⁵	Woman
S ₄	4.20E ⁻⁵	Men
S ₅	1.12E ⁻⁶	Children
S ₇	1.96E ⁻⁴	Woman
S ₈	9.80E ⁻³	Men

In another study by Bucur (Popa) et al. (2025), the total chronic exposure dose through the three routes (ingestion, inhalation, and absorption) was calculated for samples of liquid soap, micellar water, and micellar cleansing oil. When considering the most used cosmetic products, such as liquid soap and rinse-off shampoo, it's clear that the total chronic exposure dose to microplastics increases significantly with both the frequency of use and the number of different products included in daily care, cleaning, and beauty routines.

The analysis of the distribution of microplastics according to colors and recipient category (i.e., men, women, or children) of the rinse-off soap samples allows the identification of links between samples. Hierarchical clustering (Fig. 4) methods facilitate the grouping of samples according to the similarity of the microplastic profile, providing an overview of the variations between the investigated categories.

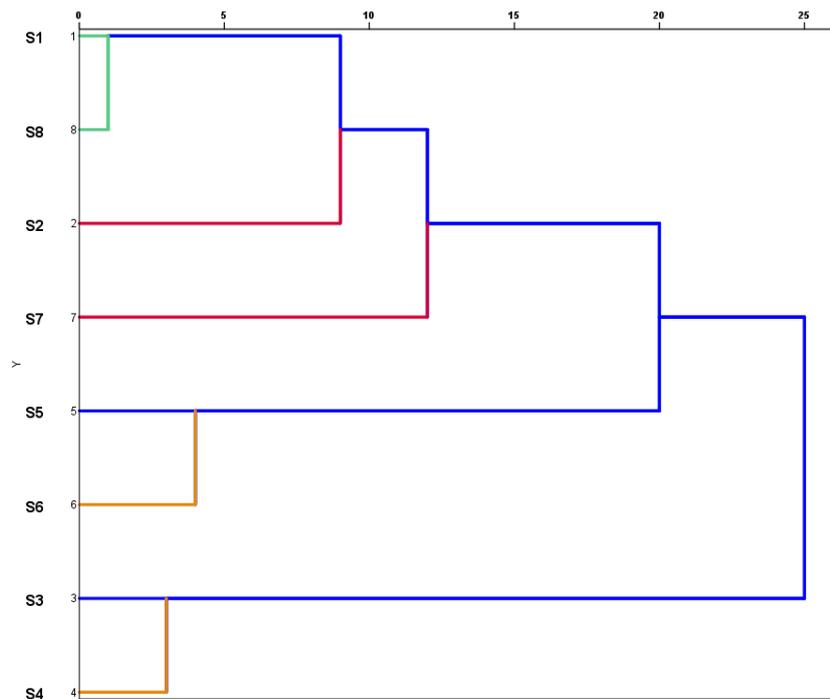


Fig. 4. Hierarchical analysis of rinse-off shampoo samples of sample similarity according to microplastic colors and recipient category.

The obtained dendrogram grouped the eight samples into three major clusters, reflecting the similarities and differences between the identified chromatic patterns and the demographic groups of the samples depending on their destination. Overall, the results indicate the existence of three major patterns of microplastic exposure: (i) a mixed group with high loading and chromatic diversity, (ii) a child-

specific cluster with moderate levels and the appearance of red, and *(iii)* a distinct blue-dominated cluster, independent of gender. These findings highlight that although there are common factors of microplastic exposure, certain subgroups show particular characteristics that may reflect differences in contamination sources or exposure patterns.

The micro-FTIR technique has allowed the identification of plastic types by recognizing the characteristic spectra of different polymers. However, the large number of samples and their chemical diversity can make it difficult to directly interpret the raw data. To highlight the similarity relationships between samples, statistical classification methods, such as hierarchical clustering analysis, are used. This organizes the samples based on compositional similarity and generates a dendrogram, where the branches illustrate the degree of chemical proximity or differentiation between the samples (Fig. 5).

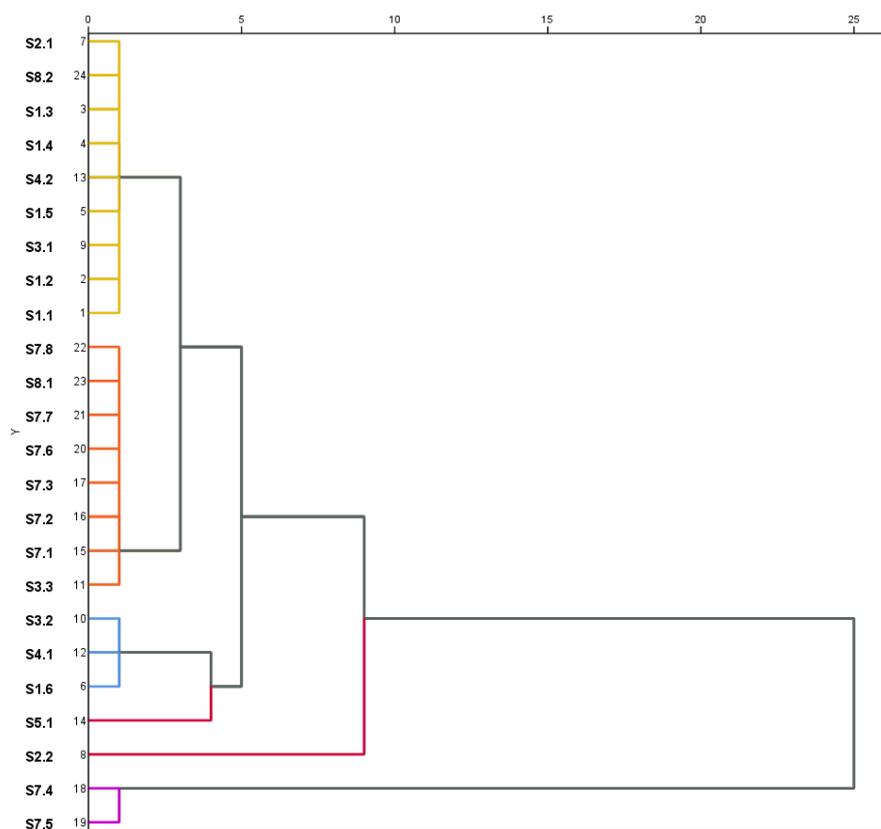


Fig. 5. Hierarchical analysis of rinse-off shampoo samples according to the chemical composition of microplastics

Hierarchical analysis of microplastic samples identified by micro-FTIR grouped fragments and fibers into six clusters. The yellow cluster grouped nine

fibers and fragments identified in rinse-off shampoo samples with a predominant composition of cotton and cellulose acetate and variations in composition for PA and PMMA. A second dominant cluster was formed by eight fibers and fragments, where the grouped microplastics had PA and cotton in their composition. Samples with 100% PA (S_{7.4} and S_{7.5}) appear separate, which is normal, due to their chemical composition compared to the rest of the samples.

5. Conclusions

Regarding the novelty of this research, it can be mentioned that in the field of cosmetics, there is a lack of information that is also reflected in the lacunar legislation at the international level regarding the quantification, characterization, and risk associated with the presence of these microplastics that can enter the human body directly through topical application (dermal contact).

Micro-FTIR spectroscopy combined with optical microscopy can provide the detailed qualitative and quantitative characterization of microplastics. In the authors' insight, it is important to monitor the structural features of microplastics, as these may significantly influence their properties. Additionally, it can be concluded that morphology plays a more critical role in determining the environmental impact than the type of polymer chain. This study revealed evidence regarding the type and morphology of microplastics, even within a single product.

Cluster analysis revealed three main patterns of exposure to microplastics. The first group includes a mix of men, women, and children with high levels of exposure and a diverse range of colors. The second group is specific to children and is characterized by lower levels of exposure. The third group is defined by a dominance of blue particles, regardless of gender.

Modeling the morphology of microplastics is essential for assessing the potential health risks they pose to humans in terms of common cosmetic products. Given the complex organic composition of shampoo (as shown in Table 1), as well as the variety of organic and inorganic compounds and microorganisms that can affect stored products, especially after the container has been opened and under specific environmental conditions, there are increasing concerns. Dermal exposure to microplastics in cosmetics poses significant health risks, necessitating strict global legislation in the field of the cosmetics industry.

REFERENCES

- [1] *L. Banica, R. M. Bucur (Popa), I. D. Dulama, I. A. Bucurica, R. M. Stirbescu, C. Radulescu*, Assessment of microplastics in personal care products by microscopic methods and

- vibrational spectroscopy, Chemistry and Chemical Engineering, Biotechnology, Food Industry, Vol. **24**, Iss. 2, 2023.
- [2] *A. L. Banica, C. Radulescu, I. D. Dulama, I. A. Bucurica, R. M. Stirbescu, S. G. Stanescu*, Microplastic debris in yogurt: occurrence, characterization, and implications for human health, Journal of Science and Arts, Vol. **24**, Iss. 1, 2024.
- [3] *R. M. Bucur (Popa), C. Radulescu, I. D. Dulama, R. M. Stirbescu, I. A. Bucurica, A. L. Banica, S. G. Stanescu*, Potential Health Risk of Microplastic Exposures from Skin-Cleansing Products, Toxics, Vol. **13**, Iss. 5, 2025.
- [4] *M.E. Meeka, A. Boobisb, I. Cotec, V. Dellarcod, G. Fotakise, S. Munnf, J. Seedg, C. Vickersh*, New developments in the evolution and application of the WHO/IPCS framework on mode of action/species concordance Analysis, J Appl Toxicol. Vol. **34**, Iss. 1, 2014. DOI:10.1002/jat.2949
- [5] *I.E., Napper, A. Bakir, S.J. Rowland, R.C. Thompson*, Characterisation, quantity and sorptive properties of microplastics extracted from cosmetics, Mar. Pollut. Bull., Vol. **99**, 2015. DOI: [10.1016/j.marpolbul.2015.07.029](https://doi.org/10.1016/j.marpolbul.2015.07.029).
- [6] *N. Loprieno*, Guidelines for safety evaluation of cosmetic ingredients in the EC countries. Food Chem Toxicol., Vol. **30**, Iss. 9, 1992. DOI: [10.1016/0278-6915\(92\)90084-x](https://doi.org/10.1016/0278-6915(92)90084-x).
- [7] *C. Guerranti, T. Martellini, G. Perra, C. Scopetani, A. Cincinelli*, Microplastics in cosmetics : environmental issues and needs for global bans. Environ. Toxicol. Pharmacol., Vol. **68**, 2019. DOI: [10.1016/j.etap.2019.03.007](https://doi.org/10.1016/j.etap.2019.03.007).
- [8] *P. Zuccarello, M. Ferrante, A. Cristaldi, C. Copat, A. Grasso, D. Sangregorio, M. Fiore, G. O. Conti*, Exposure to microplastics (<10 µm) associated to plastic bottles mineral water consumption: The first quantitative study, Water Research, Vol. **157**, 2019. DOI: [10.1016/j.watres.2019.03.091](https://doi.org/10.1016/j.watres.2019.03.091)
- [9] *K. Senathirajah, S. Attwood, G. Bhagwat, M. Carbery, S. Wilson, T. Palanisami*, Estimation of the mass of microplastics ingested—A pivotal first step towards human health risk assessment, Journal of Hazardous Materials, Vol. **404**, 2021. DOI: [10.1016/j.jhazmat.2020.124004](https://doi.org/10.1016/j.jhazmat.2020.124004)
- [10] *J. Zhang, L. Wang, K. Kannan*, Polyethylene terephthalate and polycarbonate microplastics in pet food and Feces from the United States, Environmental Science and Technology, Vol. **53**, Iss. 20, 2019.
- [11] *Z. Wang, N. Li, Y. Ding, N. Li, M. Su, C. Zhang, Y. Li, Q. Wang, C. Sha, B. Xia, J. Cheng, G. Jiang*, Microplastics and human health: Exposure pathways, toxicity mechanisms, and future research challenges, Journal of Environmental Chemical Engineering, Vol. **13**, Iss. 5, 2025.
- [12] *D. Baecelo, Y. Pico, A. H. Alfarhan*, Microplastics: Detection in human samples, cell line studies, and health impacts, Environmental Toxicology and Pharmacology, Vol. **101**, 2023. DOI: [10.1016/j.etap.2023.104204](https://doi.org/10.1016/j.etap.2023.104204).
- [13] *R. M. Bucur (Popa), S. G. Stanescu, C. Radulescu, A. L. Banica, R. M. Stirbescu*, Consumer Habits and Practices for Cosmetics: A Statistical Approach, Journal of Science and Arts, Vol. **25**, Iss. 2, 2025.
- [14] *C. Radulescu, I. D. Dulama, A. L. Banica, I. A. Bucurica, R. M. Stirbescu, L. M. Gorghiu*, Fast Method of Isolating Microplastics from Milk, Yoghurt, Sour Cream and. Butter. Patent Application RO137927A0, 26 September 2023.

- [15] *C. Radulescu, I. D. Dulama, A. L. Banica, I. A. Bucurica, R. M. Stirbescu, L. M. Gorghiu*, Rapid Method for Isolation of Microplastics from Milk, Yogurt, Sour Cream, and Butter. Patent Application No. PCT/RO2024/000010, 15 April 2024.