Emission of microplastics particles during the mechanical removal of polymer materials in cosmetics industry

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Abstract—Plastics and microplastics represent an increasing threat to both the environment and human health, particularly in enclosed spaces such as beauty salons. This study presents a preliminary characterization of microplastic particles generated during the milling of various nail styling materials. Morphological analyses were carried out using optical microscopy and scanning electron microscopy (SEM), while chemical composition was determined by FTIR spectroscopy. The results revealed that the microplastic particles ranged in size from a few to several tens of micrometers and exhibited diverse morphologies. Component identification confirmed the presence of potentially irritating, allergenic, and asthma-inducing substances such as acrylates. These findings highlight the need for further investigation into inhalation exposure among beauty salon workers, as well as the necessity of emission control strategies for microplastics in such environments.

Plastic has significantly contributed to the development of nearly all areas of life, from medicine and industry to everyday consumer products. Due to its durability, light weight, and low production costs, it has become one of the most widely used materials in the modern world [1–2]. However, the same resistance to degradation that makes plastic so functional also poses a serious threat to the natural environment.

Microplastics (MPs) are small, synthetic, water-insoluble particles ranging in size from 1 µm to 5 mm [3–5]. They are widespread in the environment, having been detected in soil, water, air, and even food [3, 5–6]. An increasing number of scientific studies suggest that microplastics may have adverse effects on human health [5, 6]. Despite increasing environmental awareness and ongoing efforts to limit microplastic pollution, the problem remains highly relevant. This is largely due to the continued high production of plastic and its degradation, whether intentional or resulting from normal use [3, 4].

To reduce the presence of MPs in the environment, several measures should be considered. For example, the production of small-scale plastic items (so-called primary microplastics) should be limited, while the formation of secondary microplastics—those unintentionally generated—requires strict monitoring and analysis [1, 4, 7]. Researchers have also reported elevated concentrations of microplastics in indoor air, particularly in enclosed spaces [8]. At the same time, they highlight the limited number of studies on service locations, such as dry cleaners or beauty salons. Depending on particle size, microplastics may reach different regions of the human respiratory system: particles up to ~100 µm tend to deposit in the upper airways, those up to ~10 µm can penetrate the trachea and bronchi, while particles smaller than ~4 µm may reach the alveoli [9].

Given the insufficient knowledge on microplastic presence in service-based locations, such as beauty salons, this study aimed to initiate research in this area. As a first step, we performed a preliminary characterization of microplastic particles generated during nail milling procedures—a common activity that may contribute to inhalation exposure and affect indoor air quality. The study included an analysis of particle morphology and chemical composition. Optical microscopy was used for the initial identification and quantification of particles. A more detailed surface analysis was then performed using scanning electron microscopy (SEM) to determine the structure and dimensions of the particles. Finally, Fourier-transform infrared spectroscopy (FTIR) was used to identify the types of polymers present in the sampled microplastics.

Five types of materials commonly used in nail styling were selected for the study: top coat, hybrid nail polish, one-step polish, hybrid base, and acrylic gel. Each material was individually exposed to UV/LED light for the recommended polymerization time to harden it, and afterwards was milled using a nail drill. The resulting dust was collected into separate containers, maintaining material separation without mixing different product types. Additionally, two types of decorative glitters used in nail styling were selected for analysis. The first glitter was characterized by regular shapes resembling hexagonal prisms, while the second had irregular shapes and a wide size distribution, ranging from coarse particles easily seen without magnification to very small ones.

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These glitters were chosen due to their practical use in nail salons, where a significant portion of particles directly end up as waste (e.g., falling onto the work surface during application).

Preliminary analysis of the microplastic particle shape and size was conducted using reflected light optical microscopy. More detailed morphological analysis was performed using a scanning electron microscope (SEM, INSPECT S50) with the following parameters: HV = 10 kV, spot size = 3.5, and an ETD (Everhart-Thornley Detector) for glitter with non-uniform sizes; and HV = 5 kV, spot size = 3.0, with ETD for the remaining samples. To identify the chemical composition of selected samples, Fourier-transform infrared spectroscopy (FTIR) (Nicolet 6700/8700) was applied. All analyses were carried out at room temperature.

Under real conditions (working in beauty salons), the dust is not homogeneous in composition; it consists of a mixture of various materials (e.g., bases, polishes, gels, top coats, glitters, and other decorations). Figure 1 shows an image (obtained using an optical microscope) of the dust generated during milling of a no-wipe top coat layer, while Fig. 2 presents an image of the dust produced after milling a hybrid polish layer. In both figures, the particles are small, on the order of several to a dozen micrometers.

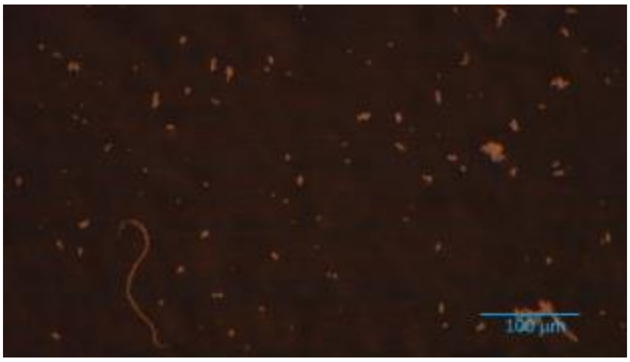

Fig. 1. Particles obtained from milling the top coat layer.

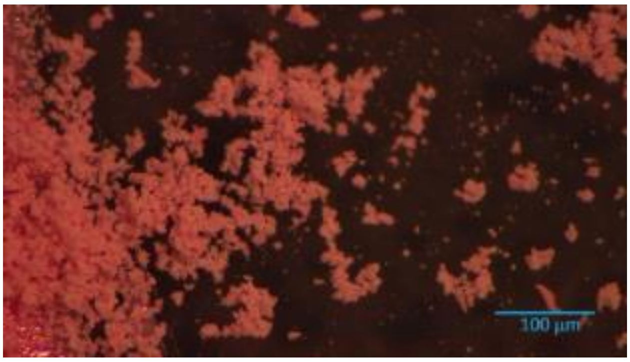

Fig. 2. Particles obtained from milling the hybrid nail polish.

To examine the surface topography in more detail, SEM microscopy was used, allowing for higher magnification. Figure 3 shows the top coat dust (as presented in Fig. 1) at magnifications of ×800 and ×6000.

SEM images of the dust revealed that the particle sizes vary, but it is clearly visible that a large portion consists of very small particles, in the order of a few micrometers. In the case of glitters (see Fig. 4 and 5), the particle sizes were also small. In the first case (Fig. 4), sizes reach up to approximately 100÷120 µm, while in the second case (Fig. 5), they vary from several to several dozen micrometers.

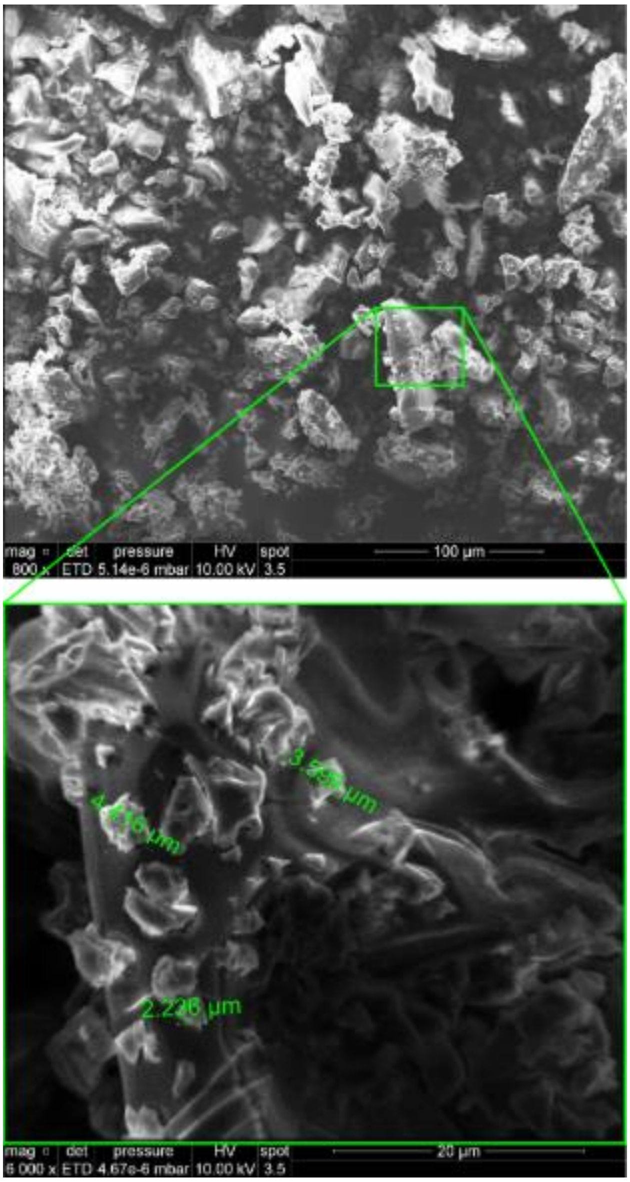

Fig. 3. SEM images of hybrid top coat particles.

Fig. 4. SEM images of the hybrid powder with a hexagonal prism shape.

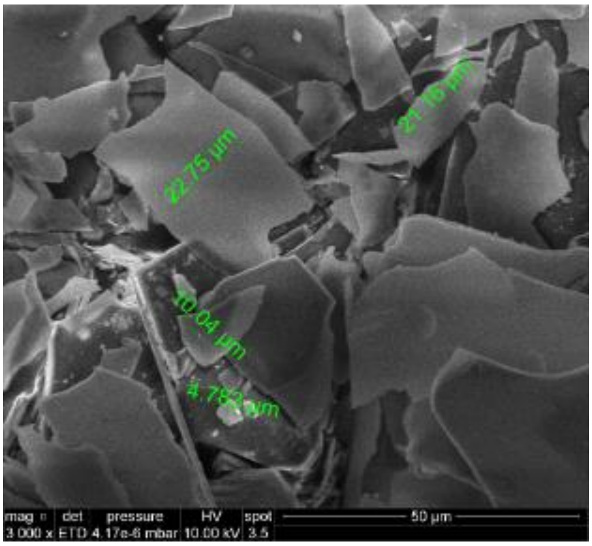

Fig. 5. SEM images of hybrid powder with irregular shape.

FTIR spectral analysis of five dust samples derived from various nail styling products revealed several common features. In all samples, intense bands were present in the 2950÷2850 cm^{-1} range, corresponding to the stretching vibrations of C–H bonds in methyl (CH_3) and methylene (CH_2) groups. This indicates the presence of aliphatic chains, typical for acrylic and methacrylate polymers. A characteristic feature in all spectra was also a strong band in the 1720÷1735 cm^{-1} range, corresponding to the stretching vibrations of ester C=O bonds. This is a clear signal of the presence of acrylic esters, the main component of most products used in hybrid and gel manicures. Another common trait was the presence of signals in the 1250÷1000 cm^{-1} range, assignable to C–O–C and C–O bond vibrations, typical for ester structures and crosslinked polymer networks. The presence of these bands confirms the use of synthetic acrylic resins, which form the basis of polishes, bases, and top coats alike. All spectra also exhibited bands in the 1450÷1370 cm^{-1} range, corresponding to deformation vibrations of CH_2 and CH_3 groups, confirming the presence of aliphatic structures in the analyzed materials. In summary, despite differences between the products (polish, top coat, base, acrylic gel), all analyzed powders share common chemical features, including aliphatic hydrocarbon chains, ester bonds, and crosslinked C–O–C networks, indicating a common origin from the group of synthetic acrylate polymers prone to fragmentation and the formation of microplastic particles.

In conclusions, the results of this study indicate that microplastic generated during the milling of materials used in nail styling could cause a potential health risk to workers in beauty salons. Due to the small size of the particles, inhalation may lead to their penetration into various parts of the respiratory system, including the alveoli in the lungs [9]. Additionally, chemical composition analysis revealed the presence of compounds with irritant, allergenic, and asthma-like effects, such as acrylates and pigments. These findings highlight the necessity of implementing effective methods to reduce microplastic emissions in such work environments and the use of personal protective equipment. They also emphasize the need for continued research on the health effects of long-term exposure to microplastics in indoor settings, especially in service industry workplaces.

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