Identification of Microplastics and Non-Microplastics Released from Masks under Environmental Conditions

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Abstract. Single-use plastic masks had been widely used in the background of COVID-19, which became the potential source of microplastics. This study focused on the release and characterization of microplastics and non-plastic microparticles from single-use surgical masks (SMs) under simulated environmental conditions. In this work, we found that most microplastics were released from SMs under UV exposure (120.00 ± 17.44 items/mask). Mechanical abrasion (76.00 ± 22.63 items/mask) and high temperature exposure (68.00 ± 0.00 items/mask) could also significantly promote the release of microplastics contrasted to the control groups (37.33 ± 8.33 items/mask). The main polymer types of microplastics were PP and PET. In addition, the total particles were released from masks as the order of mechanical abrasion (17.42 ± 2.25 × 10^3 items/mask) > UV exposure (5.12 ± 1.62 × 10^3 items/mask) > high temperature exposure (4.57 ± 3.47 × 10^3 items/mask) > control groups (2.83 ± 1.46 × 10^3 items/mask). Among them, there were varied and complex non-microplastics particles (22 kinds total) detected in the experiments. This study provides help to better understand the potential risk of microplastics and different component types of non-plastic microparticles released from masks under simulated environmental conditions.

1. Introduction

Since the COVID-19 outbreak, the demand for personal protective equipment (PPE) has surged. In June 2020, China produced 200 million face masks a day, a 20-fold increase compared to early February 2020 [1]. COVID-19 could lead to more than 129 billion consumption globally per month with calculation [2]. Discarded plastic masks could enter the environment through various processes and become the sources of microplastics that burden the current microplastic pollution [3, 4]. Many studies have explored the characteristics of the microplastic released from masks in water bodies. However, the research on microplastics released from masks in terrestrial environmental conditions (without water) is still unclear and needs further study. Additionally, the non-plastic microparticles released from masks in environmental conditions are also worthy of research, providing reliable data for better assessing the hazards of discarded masks.

In this study, surgical masks (SMs) were selected to explore the microplastics and potentially hazardous particles released from SMs under four environmental conditions. Micro-Raman was used to identify the abundance, component, and size characteristics of microplastics. Additionally, the non-microplastics were also analysed. This work enriched the reliable data of microplastic and non-microplastic pollution produced from masks under various environmental conditions.

2. Materials and Method

2.1 Sample preparation

Surgical masks (SMs, Likang, China) were selected for this experiment. ATR-FTIR (FT-IR, Nicolet 6700, USA) was applied to confirm the surface chemical characteristics of SMs. The SMs were added into the 250 mL glass containers and incubated for 7 days in the dark by wrapping the container with aluminium foil (control groups). For each sample add one mask. Also, SMs were incubated under UV exposure, mechanical abrasion, and high temperature exposure. In brief, SMs were placed under ultraviolet lamps (5 × 40 W, 340 nm) to simulate UV exposure [5], 20 g clean quartz sand (after washing, sonication, and drying) was added into SMs and shaked (180 r/min) to simulate mechanical abrasion, SMs were placed at 50 °C to simulated the high temperature exposure. The blank samples were processed under the same conditions as the processed samples, and each group processed 3 parallel samples and 3 blank samples.

2.2 Particle extraction

After exposure, the SMs were removed from containers and rinsed 3 times with ultrapure water. The flushing

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fluid was then vacuum-filtered with a 0.45 μm water-based filter membrane (Heaion, China). The filter membrane was transferred to a glass slide with a stainless-steel tweezer and analysed after natural drying.

2.3 Particle analysis

The filter membrane was analysed by confocal microscope Raman spectrometer (Thermo Scientific, DXR2xi with OMNICxi software, USA). In brief, the stage was moved to find particles under bright field condition with 10× objective lens multiples. The total particles were quantification through automated particle selection of the Raman imaging microscope in a randomly selected quarter [6]. The particle recognition function was enabled to select the particles on the filter, and manually correct the selection of particles. The detection parameter settings were: 7.0 mW laser power, 100 ms exposure time, 20 scans, and 1.0 image pixel size. The spectra of the samples were searched in the instrument databases and the polymer type was identified based on the similarity to the spectra of standards. When the matching degree reaches ≥ 70% [7, 8], the compound type can be confirmed. After the collection, the test results were obtained, and the information on microplastics and non-microplastics was recorded.

2.4 Quality assurance and quality control

A separate super-clean laboratory was used in the experiments and operators were equipped with lab coats and latex gloves during the experiments. All containers used in the experiments were rinsed 3 times with ultrapure water and dried upside down on the oven before use. During the vacuum filtration process, the beaker and the suction filtration device were rinsed with ultrapure water 3 times or more to reduce the loss of particles. The glassware was observed with LED lights until no particles were observed by the naked eye. The container is sealed with aluminium foil when experiments were paused.

3. Results and Discussions

3.1 Abundance of the total particles released from SMs

The number of particles released from SMs under mechanical abrasion condition (17.42 ± 2.25 × 10^3 items/mask) was significantly higher than UV exposure (5.12 ± 1.62 × 10^3 items/mask), high temperature exposure (4.57 ± 3.47 × 10^3 items/mask) and dark condition (2.83 ± 1.46 × 10^3 items/mask) (Figure 1B, b1). The abundance of particles released from the mechanical abrasion was an order of magnitude higher than the other three conditions. Hence, mechanical abrasion was the most important factor to promote the particles released from SMs among the four environmental conditions. This result was consistent with the particles released from masks in water condition as previous research [3, 9, 10]. In addition, UV exposure and high temperature exposure also significantly promote the release of particles from SMs, and their abundance was around 2-3 times higher than SMs in dark condition (Figure 1B, b1).

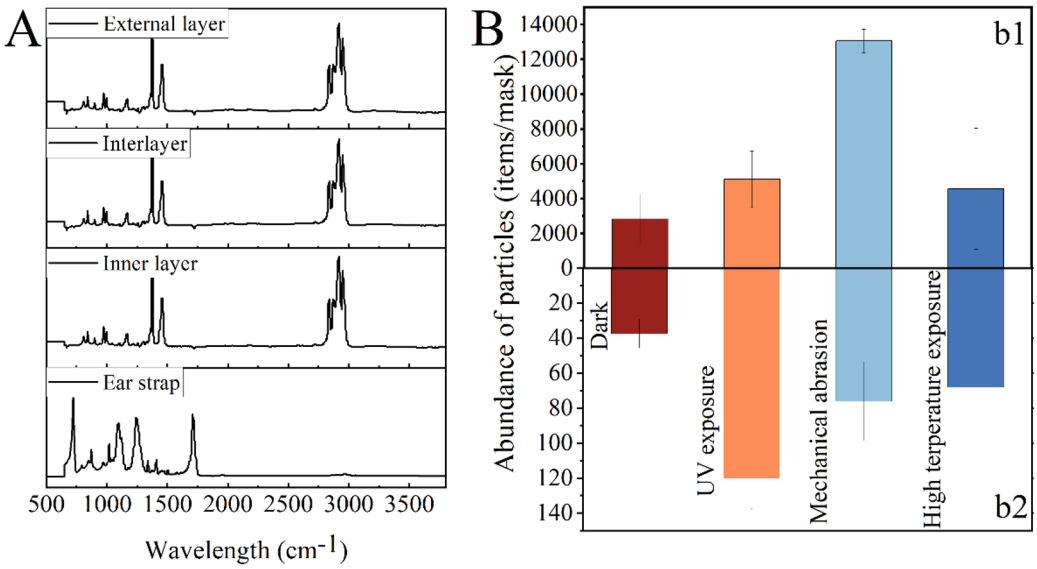

Figure 1. (A) The FTIR spectrum of the face layers (external layer, interlayer, and inner layer) and ear straps of SMs; (B) Abundance of the particles released from SMs under four environmental conditions: (b1) abundance of the total particles released from SMs and (b2) abundance of the microplastics released from SMs

3.2 Microplastics released from SMs

The abundance of microplastics released from SMs was much lower in contrast to the total particles (Figure 1B, b2). Specifically, the abundance of microplastics released from SMs followed the order: UV exposure (120.00 ± 17.44 items/mask) > mechanical abrasion (76.00 ± 22.63 items/mask) > high temperature exposure (68.00 ± 0.00 items/mask) > dark (37.33 ± 8.33

items/mask). In general, the main microplastic types released from SMs were polypropylene (PP) and polyethylene terephthalate (PET). Among the identified particles, the PP and PET microplastics accounted for 23.75 ± 4.35%, 31.75 ± 5.50%, 57.41 ± 2.62%, and 3.21 ± 0.97% under UV exposure, dark, high temperature exposure, and mechanical abrasion conditions, respectively (Figure 2A). The type of the main materials of the microplastics is consistent with the materials of SMs. PP and PET were the main components of SMs (the face layers were PP, and the ear straps were PET) as shown in Figure 1A. The size range of PP microplastics (8.3~2600 μm) was larger than PET (15.2~950.8 μm) (Figure 2B). However, the predominant size range of PP microplastics (10~300 μm; dark = 90.91 %, UV exposure = 93.88%, mechanical abrasion = 75.86%, and high temperature exposure = 90.00%) was smaller than PET microplastics (10~500 μm; dark = 77.78%, UV exposure = 80.00%, mechanical abrasion = 80.00%, high temperature exposure = 70.59%).

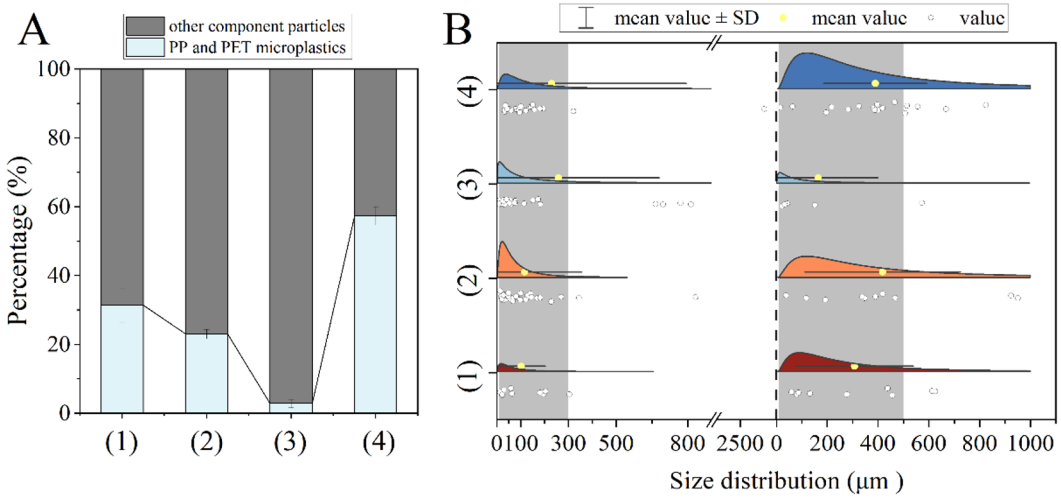

Figure 2. (A) The percentage of PP and PET microplastics of the determined particles and (B) Size distribution of PP and PET microplastics released from SMs under environmental conditions.
Note: (1), (2), (3), and (4) represent dark, UV exposure, mechanical abrasion, and high temperature exposure conditions, respectively.

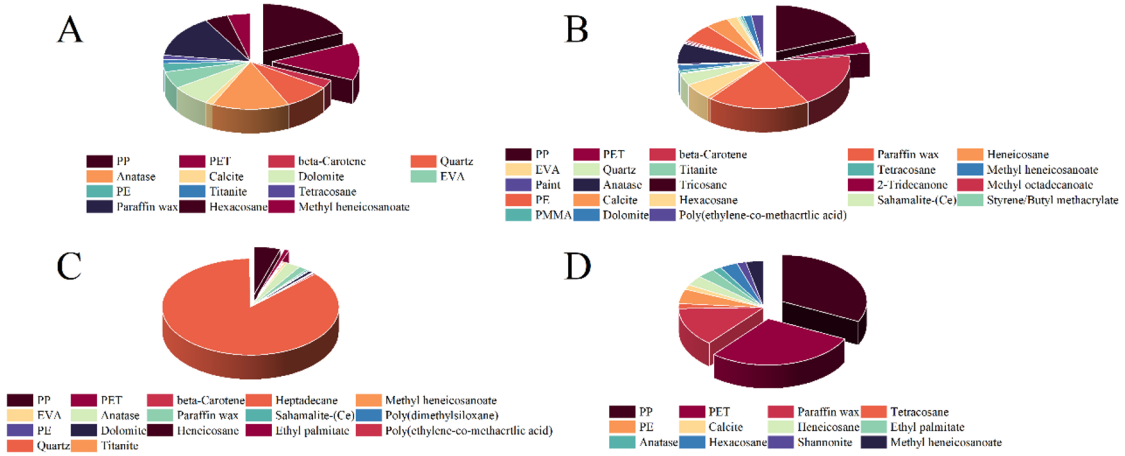

Figure 3. Component of particles released from SMs in the four environmental conditions. (A) dark; (B) UV exposure; (C) mechanical abrasion and (D) high temperature exposure

3.3 Non-microplastics released from SMs

Non-microplastic particles released from SMs accounted for the majority of the total particles (96.28 ± 3.14%-99.33 ± 0.32%), as well as predominant in the determined particles (37.04 ± 0.00%-94.25 ± 1.58%, Figure 3) released from SMs under four environmental conditions. As shown in Figure 3, the identified components of non-microplastics were complex. Anatase, methyl heneicosanoate, and paraffin wax were all detected in four environmental conditions. β-carotene, quartz, dolomite, and titanite were found in dark, UV exposure, and mechanical abrasion groups. Among these, quartz has also been found in previous research [9]. Calcite, hexacosane, and tetracosane particles jointly released under dark, UV exposure, and high temperature exposure conditions. Heneicosane particles were found in UV exposure, mechanical abrasion, and high temperature exposure groups. Ethyl palmitate particles were found in mechanical abrasion and high temperature exposure conditions. Poly(ethylene-co-methacrylic acid) and sahamalite-(Ce) were released after UV exposure and mechanical abrasion. Moreover, the components of non-microplastics varied under four environmental

conditions. Specifically: (1) 2-tridecanone, methyl octadecenoate, paint, styrene/butyl methacrylate, and tricosane were only detected in UV exposure condition, (2) shannonite particles were only detected in high temperature exposure condition, and (3) heptadecane and poly(dimethylsiloxane) were separately released under mechanical abrasion condition.

4. Conclusion

In this work, the characteristic of microplastics and the specific component types of non-microplastics released from SMs were investigated. Most total particles were released from SMs after mechanical abrasion condition, and most microplastics were released after UV exposure condition. PP and PET were predominant microplastic types from SMs, and PP microplastics had a wider size range in contrast to PET microplastics. Varied non-microplastics were released from SMs and accounted for the vast majority of the total particles. Further measurements of nanoplastics released from SMs are important to study the source of environmental micro/nanoplastics. This will promote the assessment and pollution control for environmental plastics.

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