Particles and fragments in unused disposable face masks: A microscopic analysis
Scholkmann F1,2
1Research Office for Complex Physical and Biological Systems, 8006 Zurich, Switzerland
2University Hospital Zurich, University of Zurich, 8091 Zurich, Switzerland

Abstract
Introduction: In the context of the COVID-19 pandemic, many governments mandated the wearing of face masks by law. New research shows that these masks contain and release microplastics.

Methods: In the present work, five samples of surgical masks were examined microscopically for the presence of particles and fragments. The masks were purchased from two of the largest supermarket chains in Switzerland.

Results: Particles and fragments were found on the fibre surfaces in the inner layer of all face masks examined. The size of these objects varied in the range of about 2–40 µm, with dark spots and particles on the fibres having a smaller diameter than the more transparent fragments.

Conclusion: In this work, it was shown that particles and fragments in the micrometer range can be found on the inside of commercially available surgical face masks purchased in supermarkets in Switzerland. The health significance of the presence of particles and fragments in the micrometer range as demonstrated by the current investigation of surgical face masks needs to be further investigated.

Key words: COVID-19, Fragments, Microplastics, Particles, Surgical face masks
to human health from exposure to microplastics is increasingly becoming the focus of research and consumer protection.\textsuperscript{26-31} Recently, a study with electron microscopy found that there are fibres, fragments and particles in the nanometre and micrometer range present on the surface of fibres from the inner facing of medical face masks, most likely nano- and microplastics.\textsuperscript{32} The authors highlighted that currently the potential health hazard from inhaling these nano- and microplastics when wearing medical (surgical) face masks during the current COVID-19 pandemic has drawn very little attention, unfortunately. In another study, spherical- and fibre-like microplastics mostly in the 20–100 µm range were detected in the air filtered by a surgical face mask.\textsuperscript{33} While the authors demonstrated the possibility of microplastic inhalation when wearing a face mask, they also showed that wearing a face mask reduces exposure to particulate matter pollution, especially in cities with high air pollution like Wuhan, China, where the study was conducted. While nano- and microplastics seem to be the main source of particulate matter released from face masks, trace metals and metalloids in disposable face masks have also been reported recently.\textsuperscript{34} In this study, in exhausted material from a surgical face mask, the presence of copper, zinc, antimony and lead has been proven.

The present study aimed to perform microscopic analyses of surgical face masks available for purchase from the two largest supermarket chains in Switzerland. The objective was to detect and characterize possible particles and fragments present in these face masks.

**Methods**

One package each of all the three-layered surgical face masks available was purchased at two supermarkets in Zurich. The supermarkets were branches of the two largest supermarket chains in Switzerland (Coop and Migros). Masks from five different manufacturers were thus purchased (Table 1).

Each mask package was carefully opened, the first top mask removed and discarded, and the second mask used for further analysis. All steps were performed at a cleaned workstation with disposable gloves. The mask was removed from the package with tweezers and placed under the microscope. Two light microscopes were used for the analysis (Eclipse E200, Nikon Inc., Tokyo, Japan, with DynoEde AM7025X 5 MP CMOS camera, Dino-Lite, Naarden, Netherlands; Axiolab 5 with Axiocam 208 color 8.3 MP CMOS camera, Carl Zeiss, Oberkochen, Germany).

The inside layers of the masks were examined microscopically using 200 x magnification for the presence of particles and fragments on or between the mask fibres. In addition, a 2 x 2 cm area on the inside of each mask was systematically examined by counting all particles and fragments and measuring their diameter.

**Results**

Particles and fragments were found on the fibre surfaces in the inner layer of all face masks examined. The size of these objects varied in the range of about 2–40 µm, with dark spots and particles on the fibres having a smaller diameter than the more transparent fragments. Figure 1 shows examples of the objects found in all the masks studied. The distribution of the diameters of the objects is depicted in Figure 2.

In masks #1, #2 and #3, dark spots/particles were found on the fibres (Fig. 1A, 1B, 1E). Mask #1 exhibited two distinct dark spots/particles with different size distributions (2 ± 1 µm and 6 ± 3 µm). The size of the dark spots/particles on fibres was 10 ± 3 µm in mask #2 and 9 ± 3 µm in mask #3. In mask #2, a large single dark object with a length of about 100 µm and a diameter of about 25 µm was found (Fig. 1F).

Fragments of a rather transparent color attached to fibres were detected in all mask samples (Fig. 1C, 1D, 1G-L) with a typical size of 15–20 µm (mask #1: 15 ± 6 µm, mask #2: 20 ± 10 µm, mask #3: 15 ± 6 µm, mask #4: 18 ± 9 µm and mask #5: 13 ± 9 µm).
Figure 1: Optical microscopic images of particles and fragments on fibres of surgical face masks. A–C: mask #1, D: mask #4, E–G: mask #2, H–I: mask #4, J: mask #3, K–L: mask #5.
Figure 2: Size distributions of particles and fragments were detected in a randomly chosen 2 x 2 cm area of the inner layer of the five types of surgical face masks investigated. \( d \): diameter.
Table 1: Masks purchased at Swiss supermarkets and analyzed in the present study. OL: outer layer, IL: inner layer.

<table>
<thead>
<tr>
<th>Mask ID</th>
<th>Product name</th>
<th>Color</th>
<th>Size</th>
<th>LOT</th>
<th>Manufacturer</th>
<th>Purchased from</th>
</tr>
</thead>
<tbody>
<tr>
<td>#5</td>
<td>Medical surgical face mask</td>
<td>OL: blue</td>
<td>Adult</td>
<td>20200909</td>
<td>Suzhou ZOEY Medical Devices Co., Ltd., China</td>
<td>Migros, Zurich, Switzerland</td>
</tr>
<tr>
<td>#4</td>
<td>Wero Swiss Protect Small Size</td>
<td>OL: green</td>
<td>Child</td>
<td>485223</td>
<td>Wernli AG, Switzerland</td>
<td>Migros, Zurich, Switzerland</td>
</tr>
<tr>
<td>#3</td>
<td>Face Mask</td>
<td>OL: blue</td>
<td>Adult</td>
<td>11112020</td>
<td>Sunsmed protective products Ltd., China</td>
<td>Migros, Zurich, Switzerland</td>
</tr>
<tr>
<td>#2</td>
<td>Medi-Inn Mundschutz</td>
<td>OL: blue</td>
<td>Adult</td>
<td>E2017468</td>
<td>BODY Products relax Pharma und Kosmetik GmbH, Germany</td>
<td>Migros, Zurich, Switzerland</td>
</tr>
<tr>
<td>#1</td>
<td>PM Plus Medical Einweg-Hygienemaske</td>
<td>OL: blue</td>
<td>Adult</td>
<td>30092575</td>
<td>Foshan Nanhai Plus Medical Co., Ltd., China</td>
<td>Coop, Zurich, Switzerland</td>
</tr>
</tbody>
</table>

Discussion

In this work, it was shown that particles and fragments in the micrometer range can be found on the inside of commercially available surgical face masks purchased in supermarkets in Switzerland. In general, two classes of objects were found: dark smaller dots/particles on the fibres and larger, more transparent fragments also on the fibres.

These results are in line with the findings of Han & He and Li et al. who also found particles and fragments in this size range in face masks. The particles and fragments detected in the current work are probably microplastics, although metallic objects are also possible as Bussan et al. detected them, at least as far as the dark (i.e. opaque) objects are concerned.

The presence of microplastics or impurities in the form of particles and fragments in the nanometre and micrometer range is currently not considered in the quality standards for face masks. As Han & He point out, neither the ASTM standards (F1862, F2100, F2299), the NIOSH regulation (42 CFR 83) nor the ISO standards (ISO 22609, 16900) and Chinese standards (GB 19083, 2626; GB/T 32610, 38880; YY 0469; YY/T 0969) on masks and respirators cover the presence of these contaminants in masks. There is an apparent regulatory gap concerning this possible hazardous contamination in face masks.

The particles and fragments detected here can detach from the fibres and be inhaled. This seems to be the case especially when the masks are mechanically deformed (e.g. by folding them, putting them in a trouser pocket, and putting them on several times).

In addition to the presence of particles and fragments in masks, it has also been shown that masks can contain various chemical pollutants. For example, 12 high-risk volatile chemicals (1, 4-dichlorobenzene, toluene, xylenes (p, m, o), ethylene oxide, ethylbenzene, caprolactam, N,N-dimethylacetamide, N,N-dimethylformamide, N-methylpyrrolidone and dimethyl glutarate) were recently detected in surgical face masks. Some of these substances are considered carcinogenic.

Conclusion

The health significance of the presence of particles and fragments in the micrometer range in surgical face masks as demonstrated by the current investigation remains to be investigated. However, since inhaled microplastics can trigger pathophysiological processes, this contamination in the masks should be further investigated, and quality standards should be revised and supplemented. When masks are worn, and especially when they are worn regularly and for prolonged periods, a balance should be struck between the exposure to toxic substances caused by wearing masks and the exposure to pathophysiologically relevant substances (viruses, microorganisms, pollutants) prevented by wearing them. This should be considered especially during the current COVID-19 pandemic.

Acknowledgments: I would like to thank Rachel Scholkmann for proofreading this manuscript.


