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Occurrence and health risks of semi-volatile organic compounds in face masks

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Face masks contribute greatly to the protection of human health in the epidemic of coronavirus disease 2019 (COVID-19). However, the extensive use of masks has brought new challenges to the environment and human health, such as vast plastic and plastic particle waste [1, 2]. As some chemicals can be involved in raw materials of the masks, such as semi-volatile organic compounds (SVOCs), the face masks could be a potential source of chemical exposure to humans, posing risks to human health. However, there are still no mandatory standards or regulation documents that impose restriction on the SVOCs in the face masks. In addition, there is still a knowledge gap on the occurrence and risks of the chemical exposure from the face masks.

In our recent study, fifty-three mask samples were collected from three different regions including China, the USA and Europe. Three categories of SVOCs, including 14 polycyclic aromatic hydrocarbons (PAHs), 4 organophosphorus flame retardants (OPFRs) and 13 UV-filters, were analyzed in the mask samples. Based on the results of quantification, daily intakes of the detected SVOCs for adults and toddler were calculated and health risks of the SVOCs exposure from the masks were assessed. Descriptions of the corresponding methods are summarized in Supplementary materials (online). The determination results of the SVOCs in the 53 mask samples were listed in Table S4 (online). Among the 31 target SVOCs, a total of 26 compounds were detected at least once, including 10 PAHs, 12 UV-filters and 4 OPFRs. The total concentrations of the SVOCs ranged from 8.83 to 9200 ng/g, with a median value of 263 ng/g. The PAHs, UV-filters and OPFRs were detected in 90.6%, 96.2% and 92.5% of the mask samples, respectively. The detection frequencies of individual compound for the OPFRs were found to be generally higher than those for the PAHs and UV-filters.

The face masks from China, Europe and the USA were compared to interpret the regional differences of the SVOCs content in the masks. Fig. 1a shows the total levels of the OPFRs, PAHs and UV-filters in the masks collected from the three regions. According to statistical analysis, there was no significant variation in the total concentrations of PAHs and OPFRs among the masks sampled from different regions (P = 0.289 and 0.590, respectively). While for the UV-filters, a significant difference was observed among the three regions (P < 0.01). The median value of the total levels of UV-filters in the masks collected from China was 68.5 ng/g, which was approximately 30–50 times lower than those from Europe and the USA. This suggests different uses for the UV-filters in the masks or raw materials among the different regions.

Twenty-eight mask samples for adults and 16 mask samples for toddler were analyzed to investigate the SVOCs content in the masks intended for different users. As can be seen from Fig. 1b, the median values of the total concentrations of the OPFRs, PAHs and UV-filters were closely matched between the adult masks and toddler masks. According to the statistical test result, the total concentrations of the OPFRs, PAHs and UV-filters showed no significant differences between the masks intended for adults and toddler (P = 0.951, 0.903 and 0.088, respectively). Similar results were also found in our previous study on phthalate content in masks intended for adults and toddler (not published), indicating the possibility that the raw materials used to make the masks intended for adults and toddler are identical.

In the present study, the differences of SVOCs content in the masks with different production standards were investigated (shown in Fig. 1c). Two typical masks from China, the KN95 mask and disposable mask, were chosen to be analyzed due to their extensive application. According to the statistical test result, the total concentrations of the OPFRs and PAHs in the two types of masks showed significant differences (P = 0.022 for OPFRs and 0.013 for PAHs). The median values of total concentrations of the OPFRs and PAHs in the KN95 masks were 224 and 57.1 ng/g, which were significantly higher than those in the disposable masks with values of 63.4 and 26.7 ng/g. While for the UV-filters content, no significant difference was observed between the two types of masks (P = 0.378). The different SVOCs content between the KN95 and disposable masks is suspected to result from a specific layer in the KN95 mask. Compared with the disposable masks, the KN95 masks usually contain a layer of tuyere cotton applied for insulation. The tuyere cotton was reported to be with elasticity and flame retardancy according to the manufacturer. In general, the PAHs are not intentionally added into the consumer products, but are existent in the raw materials commonly used as plasticizers or fillers [3]. Moreover, the OPFRs are usually applied as flame retardants [4]. Therefore more OPFRs and PAHs may be involved in the production of the KN95 masks.

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Daily exposure dosages (EXPs) of the SVOCs from the masks were estimated using the models reported in previous studies [5,6], and the results were listed in Table S5 (online). The total EXPs of the SVOCs from the masks ranged from 0.09 to 94.2 ng/kg bw/d (bw, bodyweight). The UV-filters contributed most significantly to the SVOCs exposure accounting for 40.0% (mean value), followed by OPFRs and PAHs contributing 37.6% and 22.4%, respectively. Moreover, the median values of the EXPs for the OPFRs, PAHs and UV-filters from the 53 face masks were 0.63, 0.98 and 0.99 ng/kg bw/d, respectively. These EXP levels were clearly lower than those from personal care products and house dust (reported up to μg/kg bw/d) [7,8]. The EXPs of the three types of SVOCs from the masks intended for toddler were significantly higher than those for adults (P < 0.05). Similar results were also found in our former work on the phthalate exposure from the masks (not published). In addition, no significant difference was observed among the levels of the individual type of SVOCs in the masks intended for adults and toddler (P > 0.05).

The noncancerous risks of the SVOCs exposure from the masks were assessed by the cumulative noncancerous risks (CNRs) [9], and the values were listed in Table S6 (online). When the CNR values were <1, the SVOCs intakes from the masks appeared to be accessible [10]. As can be seen from Fig. 1d, the CNRs of the SVOCs from the 53 masks ranged from 2.3 × 10⁻¹⁰ to 1.1 × 10⁻⁶, with a median value of 4.9 × 10⁻⁹, indicating the risks of the SVOCs in all the masks were within the safe value for the noncancerous risks. As for the carcinogenic risks, the cumulative carcinogenic risks (CCRs) were calculated and exhibited in Fig. 1d and Table S6 (online). The CCR within 1 × 10⁻⁶ was regarded as an acceptable limit [9]. The CCRs of the SVOCs exposure from the masks were in the range of 5.3 × 10⁻⁴–2.3 × 10⁻⁴. The CCRs for 39 masks exceeded the safe level for the carcinogenic risks, which accounted for 73.6% of the whole mask samples. The CCRs for all the European and American masks were higher than the limit, while the 14 masks obtained from China were shown to be relatively safe in terms of the carcinogenic risk. This may be caused by the different SVOCs content in the masks collected from different regions, however, the samples from Europe and the USA were very limited and the difference of carcinogenic risks among different regions should be further studied. In addition, the carcinogenic risks for the SVOCs exposure from the masks were much more severe than those for the phthalate exposure investigated in our former study (data have not been published). In the present study, although some compounds were detected with low detection frequencies, they can still pose risks to human health for the specific masks. Therefore, the CNRs and CCRs were investigated to present a whole scene of the risks of the SVOCs from each brand of the masks. As a result, the potential carcinogenic effects of the SVOCs from the masks should be concerned.

In summary, the occurrence and health risks of the SVOCs exposure from the face masks were explored in the present study. The PAHs, UV-filters and OPFRs were all detected in more than 90% of the mask samples. Among the 31 target SVOCs, a total of 26 compounds were detected with total concentrations ranging from 8.83 to 9200 ng/g. Statistical analysis indicated that the total concentrations of the PAHs and OPFRs showed no significant difference among the masks collected from different regions, while the UV-filters content exhibited regional difference. The daily exposure dosages of the SVOCs from the masks intended for toddler were significantly higher than those for adults. According to the results of risk assessment, the SVOCs exposure from 73.6% of the masks could pose potential carcinogenic risks to humans. Due to the limited number of the targets investigated in the present study, the risks of the SVOCs posed by the masks may be underestimated. Therefore, a further study should be conducted in the future to screen the SVOCs which are detrimental to human beings. To
conclude, it is demonstrated in this study that the face mask can be a potential source of SVOCs exposure to humans, which gives rise to a need to manage the additives in the masks in the future.

Conflict of interest

The authors declare that they have no conflict of interest.

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Appendix A. Supplementary materials

Supplementary materials to this article can be found online at https://doi.org/10.1016/j.scib.2021.04.009.

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