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ASSESSING THE RELATIVE IMPORTANCE OF MUCOSAL EXPOSURE AND INHALATION EXPOSURE TO AIRBORNE PARTICLES

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ABSTRACT

Particles deposited on mucosa or penetrating into lower airway are two exposure routes. Quantifying administered dose of these two routes gives us idea for future advanced individual protection. Here, we report an in-vitro method to assess the administered doses of eyes, lips, and lower airway. A CT-scanning and 3D-printing based human replica is developed, and exposed in front of the 0.6-5μm monodispersed fluorescent particles. At small size particles (<2.5μm), the administered dose intensity of penetrating into lower airway inhalation (~59.41×10^{-2} g/g, 0.6μm) is higher than that of eyes and lips (~5.97×10^{-2} g/g, 0.6μm). Conversely, the administered dose intensity of lower airway inhalation (~9.39×10^{-2} g/g) becomes higher than that of eyes and lips (~6.24×10^{-2}) g/g at 5.0μm particles. This work provides us an effective and economical way to assess exposure risks of particulate contaminants.

Keywords: Human replica; Micro-sized particles; Monodisperse; Fluorescence; Experiment

1 INTRODUCTION

Exposure to micron-sized particles cause serious adverse health issues, which receive numerous attentions. Generally, there are two exposure routes for particles. One is mucosal deposition (e.g. eyes and lips), the other is penetrating into lower airway. Scientists have done a lot of researches about the relationship between these two particulate exposure routes and health effects. Epidemiological studies report the particulate-caused diseases based on inference of associations between exposure and response variables (Weis, et al. 2005). Animal models or *in vitro* cells have long proved the toxicology of particle dose and associated adverse health effects, i.e. dose-response effect (Lock, et al. 2018). However, lacking of quantitative dose contributes to the greatest uncertainties to such studies. Individual protection strategies for indoor particulate contaminants need more accurate dosage assessment. Exploring human replica remains one of the big challenges until now. Previous studies that employed anatomically correct model mainly focus on thermal comfort or inhalation exposure (Lizal, et al. 2012). Empirical work based on partial or full body replicas are hardly reported.

Here, we propose a new method to quantify the administered dose on facial mucosa and penetrating into lower airway. Individual human replica is developed with geometrical details' face and airway based on CT-scanning and 3D-printing. Relative importance of mucosal exposure and lower airway exposure to 0.6-5.0 μm monodispersed particles are finally achieved.

2 METHODOLOGY

Real human geometric data is abtained from computed tomography scan of a healthy Chinese male. The in-vitro human replica is developed by 3D-printing. It includes face, oropharynx, trachea, the first 5-generation bronchi and the lung void. Through conncenting with a pump, it inhales steadily with 11±1 L/min flow rate by mouth.

The replica exposed to 0.6-5 μm monodispersed florescent particles generated by VOAG 3450® (TSI, U.S.A.). The size distribution is monitored by APS 3321® (TSI, U.S.A.). Administered doses on eyes

and lips are measured by cumulative deposition mass. The dose of lower airway is calculated by particles penetrating from the first 5-generation bronchi into lung void. SKC BioSampler® was used for collecting the suspended fluorescent particles in the lung void, while preset foils were used to sample the particles deposited on the surface of the lung void and face mucosa. Administered dose is calculated by fluorescent intensity-mass curves normalized by Fluoro Max-4® (HORIBA, Japan).

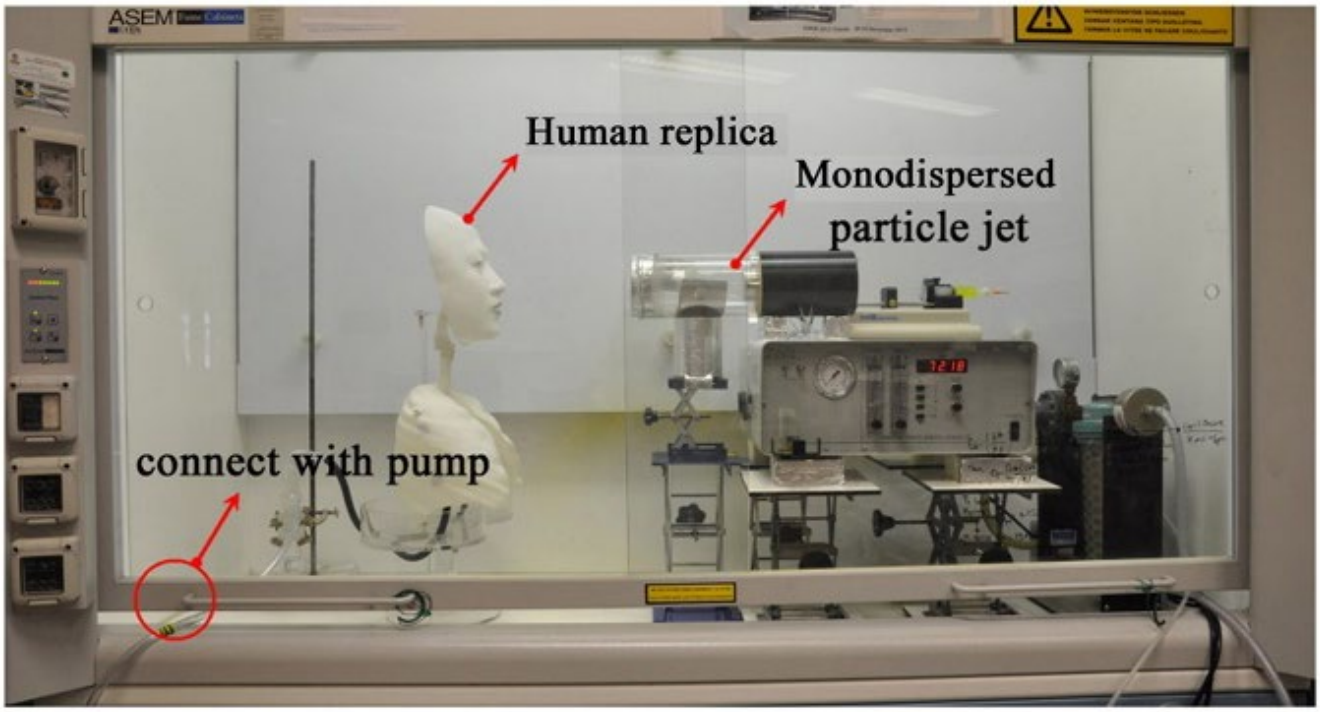

Fig. 1 Experimental set-up

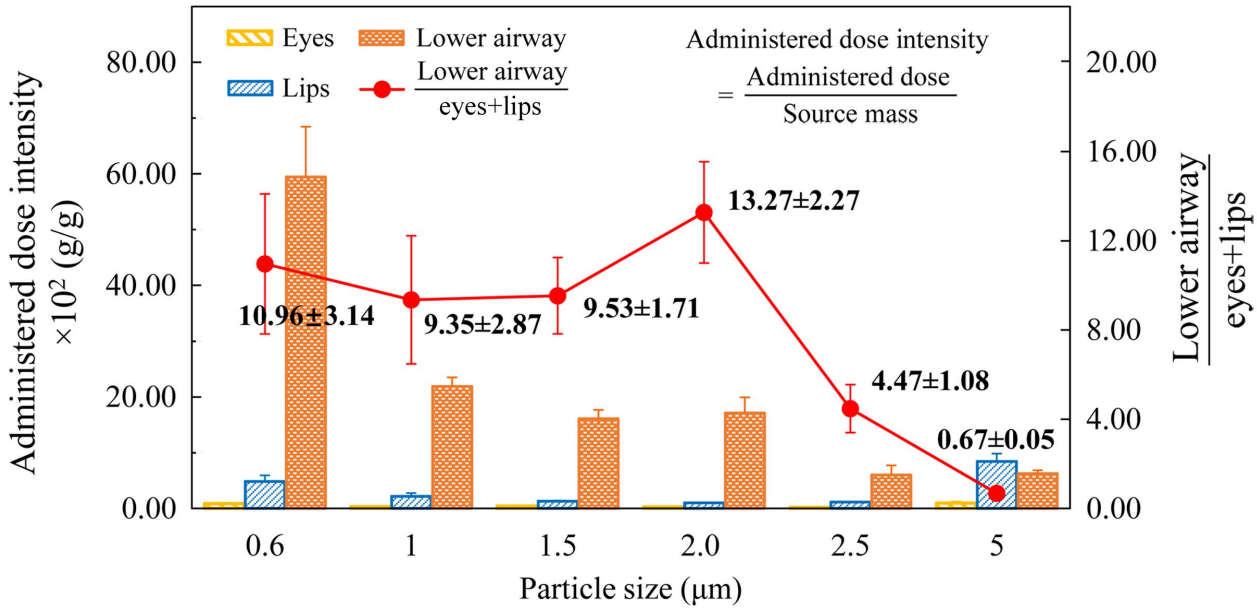

Fig. 2 Administered dose intensity of mucosal deposition and lower airway inhalation

3 RESULTS & DISCUSSION

As shown in Figure 2, the administered dose intensity of mucosa (eyes and lips) range from $(5.69\pm1.27)\times10^{-2}$-$(1.29\pm0.10)\times10^{-2}$ g/g when the particle size is small (0.6-2.0 μm). Almost 10 times larger than that of lower airway. With particle size increasing, this ratio significantly drops. Especially for 5.0 μm particles, the administered dose intensity of mucosa is $(9.39\pm1.27)\times10^{-2}$ g/g, which is even lower than that of lower airway. Furthermore, lips contribute over 90% of mucosal deposition. The results demonstrate that lower airway exposure becomes dominated in short-distance exposure when the particle size is small (less than 2.5 μm). But for large-size particles (>5.0 μm), facial mucosa, especially the lips, takes more risk than lower airway. Our results also reveal that the cutoff size, 5.0 μm, which differs the coarse and fine aerosols, might be inaccurate at least for assessing exposure risks for individuals.

4 CONCLUSIONS

In this work, we develope a human replica for accessing administered dose on facial mucosa and lower airway. The results based on our experimental bench imply that lower airway exposure is dominated for particle size less than 2.5 μm. But mucosal exposure plays an important role for 5.0 μm particles. Although the human replica still has unneglectable differences with real-life-conditions, the existing workbench inspires a new method to conveniently access administered dose in-vitro.

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REFERENCES

Lizal, Frantisek, et al. (2012) Development of a realistic human airway model. J. Engineering in Medicine 226:197-207.

Lock, Jaclyn Y, et al. (2018) Mucus models to evaluate the diffusion of drugs and particles. Adv. Drug Deliver. Rev. 2018: 34-49.

Weis, Brenda K, et al. (2005) Personalized Exposure Assessment: Promising Approaches for Human Environmental Health Research. Environ. Health Persp. 113:840-848.