

Supplementary Information

Quantitative Assessment of Inhalation Exposure and Deposited Dose of Aerosol from Nanotechnology-Based Consumer Sprays

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Supplementary Material, Table 1. Numerical data of PM inhalation exposure (Figure 3 in the article)

	Mean (SD), ng/kg bw/application				
	PM 0.1-0.014	PM 1-0.1	PM 2.5-1	PM 10-2.5	PM 20-10
Silver Nanospray	5.10E-03 (2.19E-03)	4.86E-01 (1.38E-01)	2.68E-01 (5.45E-01)	0 (1.43E+00)	0 (1.27E+00)
Silver Spray	5.78E-03 (4.96E-03)	4.40E-01 (2.49E-01)	5.67E-02 (5.58E-01)	0 (1.44E+00)	0 (1.27E+00)
Hair Nanospray	1.86E-02 (2.67E-03)	1.80E+01 (6.10E+00)	1.26E+02 (3.19E+01)	5.21E+02 (1.43E+02)	9.62E-01 (1.66E+00)
Hair Spray	1.08E-02 (1.93E-03)	2.71E+01 (2.92E+00)	2.05E+02 (2.48E+01)	1.19E+03 (2.62E+02)	2.58E+01 (1.21E+01)
Skin Hydrating Nanomist	2.91E-02 (7.71E-03)	5.27E+00 (3.24E+00)	5.26E+01 (3.95E+01)	3.72E+02 (2.45E+02)	1.49E+01 (8.59E+00)
Skin Hydrating Mist	5.77E-03 (3.17E-04)	6.94E-01 (1.59E-01)	1.96E+01 (2.97E+00)	2.24E+02 (4.56E+01)	0 (1.38E+00)
Facial Nanospray	6.85E-03 (4.56E-03)	5.23E+00 (2.10E+00)	7.77E+01 (2.57E+01)	3.26E+02 (1.06E+02)	0 (1.28E+00)
Facial Spray	4.61E-03 (2.68E-03)	4.20E+00 (3.66E-01)	1.03E+02 (9.60E+00)	6.47E+02 (8.58E+01)	0 (1.29E+00)
Disinfectant Nanospray	2.31E-03 (1.27E-03)	2.88E-01 (4.03E-01)	4.66E+00 (3.94E+00)	1.26E+01 (1.08E+01)	0 (1.27E+00)
Disinfectant Spray	4.99E-02 (2.26E-02)	3.12E+01 (7.85E+00)	3.39E+02 (7.83E+01)	7.06E+02 (1.17E+02)	0 (1.35E+00)

Supplementary Material, Table 2. Numerical data of PM deposited dose (Figure 4 in the article)

	Mean (SD), ng/kg bw/application			
	HA	TB	AL	Total
Silver Nanospray	1.65E-01 (1.79E+00)	1.85E-02 (6.91E-02)	7.46E-02 (1.12E-01)	2.59E-01 (1.79E+00)
Silver Spray	5.86E-02 (1.79E+00)	8.12E-03 (6.95E-02)	4.52E-02 (1.14E-01)	1.12E-01 (1.80E+00)
Hair Nanospray	5.19E+02 (1.26E+02)	2.91E+01 (6.49E+00)	4.87E+01 (9.61E+00)	5.97E+02 (1.27E+02)
Hair Spray	1.17E+03 (2.29E+02)	6.27E+01 (1.16E+01)	1.01E+02 (1.63E+01)	1.33E+03 (2.30E+02)
Skin Hydrating Nanomist	3.65E+02 (2.15E+02)	1.90E+01 (1.09E+01)	2.98E+01 (1.57E+01)	4.14E+02 (2.16E+02)
Skin Hydrating Mist	2.05E+02 (3.99E+01)	1.08E+01 (2.01E+00)	1.61E+01 (2.81E+00)	2.32E+02 (4.00E+01)
Facial Nanospray	3.23E+02 (9.34E+01)	1.81E+01 (4.81E+00)	2.99E+01 (7.20E+00)	3.71E+02 (9.38E+01)
Facial Spray	6.16E+02 (7.51E+01)	3.34E+01 (3.80E+00)	5.25E+01 (5.38E+00)	7.02E+02 (7.54E+01)
Disinfectant Nanospray	1.33E+01 (9.68E+00)	7.78E-01 (5.09E-01)	1.37E+00 (8.17E-01)	1.55E+01 (9.73E+00)
Disinfectant Spray	7.85E+02 (1.09E+02)	4.73E+01 (6.32E+00)	8.72E+01 (1.20E+01)	9.20E+02 (1.10E+02)

Supplementary Material, Table 3. Numerical data of PM deposited dose (Figure 5 in the article)

	Mean (SD), ng/kg bw/application			
	HA	TB	AL	Total
Silver Nanospray	63.98 (691.95)	7.16 (26.73)	28.86 (43.33)	100.00 (693.81)
Silver Spray	52.37 (1601.07)	7.25 (62.11)	40.39 (102.14)	100.00 (1605.54)
Hair Nanospray	86.97 (21.16)	4.87 (1.09)	8.16 (1.61)	100.00 (21.25)
Hair Spray	87.75 (17.19)	4.70 (0.87)	7.55 (1.22)	100.00 (17.25)
Skin Hydrating Nanomist	88.21 (51.89)	4.59 (2.64)	7.19 (3.80)	100.00 (52.09)
Skin Hydrating Mist	88.40 (17.20)	4.64 (0.87)	6.95 (1.21)	100.00 (17.27)
Facial Nanospray	87.09 (25.14)	4.86 (1.30)	8.05 (1.94)	100.00 (25.25)
Facial Spray	87.77 (10.70)	4.75 (0.54)	7.48 (0.77)	100.00 (10.74)
Disinfectant Nanospray	86.15 (62.54)	5.03 (3.29)	8.83 (5.27)	100.00 (62.85)
Disinfectant Spray	85.37 (11.85)	5.15 (0.69)	9.48 (1.30)	100.00 (11.95)

Supplementary Methods

Inhaled dose

The inhaled dose was determined from the following equation (Nazarenko et al. 2012):

$$ID = f_{nano} \cdot C_{inh} \cdot Q_{inh} \cdot T_{contact} / BW \quad (1),$$

Where:

ID – inhaled aerosol dose per exposure event (in this study – a 1 minute long consumer spray application), ng/kg bw/application;

C_{inh} – aerosol mass concentration in inhaled air, ng/L;

Q_{inh} – inhalation flow rate corresponding to a given gender/activity scenario, L/min;

$T_{contact}$ – duration of an exposure event, min;

BW – body weight of a hypothetical exposed person, kg;

f_{nano} – mass fraction of nanomaterial(s) in the inhaled aerosol.

Deposited dose

The deposited dose was determined from the following equation (Nazarenko et al. 2012):

$$DD_i = \sum_{d_p} DF_i(d_p) ID(d_p) \quad (2),$$

Where:

i stands for head airways, tracheobronchial region, alveolar region, or the entire respiratory system;

DD_i – deposited dose in i , ng/kg bw/application;

DF_i – deposition fraction of inhaled aerosol for i ;

ID – inhaled aerosol dose during an exposure event, ng/kg bw/application;

d_p – midpoint aerosol particle size of a given aerosol measurement size channel of SMPS/APS.

DF_i were calculated using the equations developed by Hinds (1999) to fit the ICRP (International Commission on Radiological Protection 1994) model for monodisperse spheres of standard density at standard conditions, modified to exclude IF because sampling through the mannequin head was assumed to account for it:

$$DF_{HA}(d_p) = \left(\frac{1}{1 + \exp(6.84 + 1.183 \ln d_p)} + \frac{1}{1 + \exp(0.924 - 1.885 \ln d_p)} \right) \quad (3),$$

$$DF_{TB}(d_p) = \frac{\left(\frac{0.00352}{d_p}\right) \left[\exp(-0.234(\ln d_p + 3.40)^2) + 63.9 \exp(-0.819(\ln d_p - 1.61)^2) \right]}{1 - 0.5 \left(1 - \frac{1}{1 + 0.00076d_p^{2.8}} \right)} \quad (4),$$

$$DF_{AL}(d_p) = \frac{\left(\frac{0.0155}{d_p}\right) \left[\exp(-0.416(\ln d_p + 2.84)^2) + 19.11 \exp(-0.482(\ln d_p - 1.362)^2) \right]}{1 - 0.5 \left(1 - \frac{1}{1 + 0.00076d_p^{2.8}} \right)} \quad (5),$$

$$DF_T(d_p) = \left(0.0587 + \frac{0.911}{1 + \exp(4.77 + 1.485 \ln d_p)} + \frac{0.943}{1 + \exp(0.508 - 2.58 \ln d_p)} \right) \quad (6),$$

Where:

DF_{HA} – deposition fraction of inhaled aerosol in the head airways;

DF_{TB} – deposition fraction of inhaled aerosol in the tracheobronchial region;

DF_{AL} – deposition fraction of inhaled aerosol in the alveolar region;

DF_T – total deposition fraction of inhaled aerosol, equal to the sum of DF_{HA} , DF_{TB} and DF_{AL} .

References

- Hinds WC. 1999. Aerosol technology: properties, behavior, and measurement of airborne particles. 2, illustrated ed. New York, NY: John Wiley & Sons, Inc.
- International Commission on Radiological Protection. 1994. Human Respiratory Tract Model for Radiological Protection. ICRP Publication 66. Ann ICRP 24(1-3).
- Nazarenko Y, Zhen H, Han T, Liou P, Mainelis G. 2012. Nanomaterial inhalation exposure from nanotechnology-based cosmetic powders: a quantitative assessment. J Nanopart Res 14(11): 1-14.