



# Inhalation exposure factors from the use of household products in South Korea



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## ARTICLE INFO

### Keywords:

Inhalable household products  
Exposure factors  
Exposure amount  
Exposure assessment  
Risk assessment

## ABSTRACT

Exposure assessment, a fundamental element of the risk assessment process, is the estimation of what consumers may be exposed to by using household products. Reliable exposure factors were investigated to understand the pattern of household products usage. Six household product categories were selected and divided by application types. Two surveys were carried out and 6397 participants completed the web-based questionnaires, and laboratory evaluations were also conducted to measure the actual level of exposure (g/use). We focused more on inhalation exposure from products (and/or their application types) that affect indoor air such as diffusible types. To estimate actual exposure amounts, the time spent to apply the products was investigated from the beginning to end of the product use. For spraying type products, the consumer could be exposed to the maximum amount of used product while using the triggering action and pressing the button on the aerosol spray product, and during cleaning, adhesion, and coating target, consumer could be exposed continuously. For diffuser type products, exposure duration was the time for which consumers were exposed to the diffused product. The exposure amount for trigger and aerosol spray type products were measured using the time taken to trigger or spray the product and the mass generated from the same. This study provides valuable information on the individual exposure factors that may be useful to conduct accurate exposure assessments and to manage household products.

## 1. Introduction

Household products are widely and regularly used by consumers, and members of the general public may be exposed to hazardous chemicals by using products that are intended to improve living and sanitary conditions for non-professional users. Household products have substantially improved daily living conditions (Nilsen et al., 2002; Rusin et al., 1998). However, there is a growing concern that people are inevitably exposed to several chemicals acting as active ingredients, solvents, preservatives, and additives in household products (Glegg and Richards, 2007; Weschler, 2009). Previous studies have reported that chemicals in household products may induce adverse health effects such as skin rashes, allergies, eye irritation, and respiratory irritation (Wolkoff et al., 1998). It has been postulated that air in the indoor environment may have health effects on people who spend most of the day indoors (Scherriff et al., 2005). Indoor air contains numerous substances emitted from several household products (Arey et al., 1991; Wolkoff and Nielsen, 2017), therefore exposing consumers to these substances on a daily basis. In Korea, there are disinfectants in the water tanks in humidifiers to prevent the growth and spread of germs,

molds, and/or algae. Inhalation of aerosolized water to indoor air that contained disinfectants (e.g., polyhexamethylene guanidine phosphate and oligo [2-(2-ethoxy)ethoxyethyl guanidinium chloride]) from a humidifier led to serious lung injuries, resulting in 52 deaths and 122 injuries (Lee et al., 2012; Park et al., 2014). According to Korean the Ministry of Environment (KMOE), approximately 200 deaths and 700 injuries occurred as results of this potential exposure (Korean Ministry of Environment (KMOE), 2017) as of January 13, 2017. This tragedy attracted public attention and raised concern.

To conduct exposure assessments for household product use, information on exposure factors (e.g., frequency of use, amount used per application, and circumstances of usage) are necessary (Van Engelen et al., 2007). Several studies on exposure factors associated with household products were have been but as exposure factors may vary by country (Biesterbos et al., 2013; Garcia-Hidalgo et al., 2017; Park et al., 2015; Park et al., 2017), a localized database of exposure factors for household products is essential to conduct exposure and risk assessments. For example, a European database of the use of 15 household products was set up to assist the exposure and risk assessment of the chemicals contained in these products meant for domestic use

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<https://doi.org/10.1016/j.fct.2018.11.053>

Received 3 September 2018; Received in revised form 22 November 2018; Accepted 23 November 2018

Available online 25 December 2018

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(Dimitroulopoulou et al., 2015a, 2015b; Trantallidi et al., 2015). Usage patterns were also studied for many household products used in the USA (Bennett et al., 2010). Furthermore, since 2015 the KMOE has established safety guidelines regarding several household products (Korean National Law Information Center (Korean National Law Information Center (KNLIC), 2016), including cleaners, adhesives, polishing and coating products, and others, that were designated “risk-concerned products” (Korean National Law Information Center (KNLIC), 2015) and has been enforcing regulation regarding these. The National Institute of Environmental Research (NIER) has also conducted a study to develop an exposure factor database for the household products.

The purpose of this study was to develop a national representative database on exposure factors for Korean household products. Information on exposure factors for six product categories and several application types, i.e., frequency of use, amount used per application, and amount of product used, were investigated. Reliable exposure factors derived from this study were established in notification by NIER (NIER; KNLIC, 2017). These exposure information data determined in this study will be useful in establishing improved safety guidelines for household products, conducting accurate assessments of consumer exposure and better assessing risk to human health. This comprehensive study provides exposure data to be used in safety assessments of household products in the Korean market.

## 2. Materials and methods

### 2.1. Study population

To obtain data on the exposure of consumer to household products, four factors were investigated: 1) frequency of products use based on habits, 2) duration of products use, 3) amounts of products used per application, and 4) estimates of actual exposure amounts and the inhalation exposure fraction. To ensure that the study population was representative of actual consumer use of the products studied, we randomly selected 6397 participants from 15 metropolitan areas and provinces including rural areas in Korea. Additionally, the gender of the respondents was balanced, and the age groups selected were quota sampling methods were used to there was an equal distribution of age groups were selected using. Six products in the major “risk concern” category, which had the potential to cause inhalation exposure, major risk-concern products i.e., cleaners, polishing and coating products, adhesives, air fresheners, deodorants, and inkjet/toner home printer, were selected frequent products in Korea. Target household products were established by KMOE as “risk concerned products” for residential consumers (KNLIC, 2017-153).

### 2.2. Web survey

In this study, we carried out two surveys over two years (2016–2017). The first involved a cleaner, an adhesive, a polishing and coating product, a synthetic detergent, a fabric softener, and a bleaching agent used by 3397 participants; the second involved an air freshener, a deodorant, an ironing auxiliary, an algae remover, and a home printer used by 3000 participant. A total of 6397 participants completed the questionnaires, which were administered by a Korean survey company. The survey questionnaires, which were used to estimate the exposure factors of the household products, were divided as follows: ① information on product purchase and use: list of target products used; volume of products used (ml, L, g, kg); product purchasing/using habits, to calculate the frequency of use; qualitative descriptions of product use habits, ② estimation of quantitative exposure time to products: actual product use time, and time spent around the products during use, ③ calculation of quantitative amount of household products used, and ④ demographic data: respondents’ ages, average time spent indoors (working days and holidays separated), occupation

(e.g., employed, unemployed, student, housewife), house type (e.g., single, detached, apartment, efficiency apartment), and average house size (SI 1, SI 2). An e-mail was sent to potential participants, and if they agreed to take the survey a web link was sent to them. Each web survey collected current information on the exposure factors for six product categories and different questions were used for the specific application types. For the trigger sprays, the number of squeezes (triggering tasks) per application was determined; for aerosol sprays, the spraying time (time for which the button on the product is pressed) per application was noted. For liquids, the amount of product used was estimated based on a common 50 mL liquor glass (Park et al., 2015) and for wipe type tissues, the number of sheets used per application was determined. For home printers, the printing time and quantity of A4 size sheets printed were calculated.

### 2.3. Amount of product use

The survey questionnaire included questions on the amount of each product that was used (Table A1), including amount of use per product application (if measured using a 50 ml glass cup (for liquid/powder products), pieces used per application (wipe tissue products), number of triggering/squeezing actions (trigger type product), spraying time (time spent pressing a button (aerosol spray type product)), amount of time spent around an open product (diffusible product, laboratory evaluation), and printing time (home printers). Experiments were conducted to estimate an accurate amount of use per application. The products studied were purchased online and from supermarkets based on sales ranking at big Korean markets. The mass generated (g/sec) or amounts of products used (g/use) were estimated by type of application. We used a report from the Netherland’ National Institute for Public Health and the Environment (RIVM) (Delmaar and Bremmer., 2010) to estimate the mass generated with spray products (trigger and aerosol types). In the report, the mass generation rate was determined by squeezing the product trigger 10 times for about 6 s (trigger type) or spraying the product for 10 s (aerosol spray type); the weight of the product was measured before and after use (Delmaar and Bremmer., 2010). In this study, mass generation by trigger type sprays was determined by squeezing the product 10 times and the measuring spray time; for aerosol type sprays, the method used in the RIVM report was employed. For liquid products, the amount of product used was a straightforward measurement using a 50 mL liquor glass. For tissue type products, the amount of product used were determined as difference before and after the use of the product.

### 2.4. Data analysis

All statistical analyses were conducted using R version 3.3.2 (R Foundation for Statistical Computing, Vienna, Austria). Frequency tables were constructed to assess the usage rate of the products (use/time). The frequency and duration of use were calculated using data from the web survey. The amount used per application (g/use) was calculated by multiplying quantitative use patterns data obtained from the web survey (e.g., spraying time, number amount of products used) by the mass generated (g/sec) or amount of product used (g/use) in the laboratory evaluation. The consumption per day (g/time) was calculated by multiplying the frequency of product use (time/use) by the amount of product used per application (g/use).

## 3. Results

### 3.1. Target products and demographics

A market survey was conducted to the “risk concern products” established by KMOE were common in the Korean market. Based on the results, we created categories based on six major “risk concern products” including cleaners, adhesives, and home printers. The product

**Table 1**  
List of studied inhalable household products and application types.

Products	Usage	Application type	Products	Usage	Application type	Products	Usage	Application type	
Cleaner	For toilet & bathroom	Trigger	Polishing and coating product	For furniture	Trigger	Deodorant	For indoor air	Trigger	
		Trigger foam		For leather	Aerosol spray		Aerosol spray	Gel & others	
		Aerosol spray			Liquid			Gel & others	
	For home glass cleaning	Solid & powder			Tissue		For clothes closet		
		Trigger		For shoes	Aerosol spray		For refrigerator	Gel & others	
	For vehicle glass cleaning	Trigger					For toilet	Trigger	
					Liquid			Gel & others	
	For vehicle inside cleaning	Trigger			Solid		For air-conditioner	Trigger	
	For cleaning kitchen	Liquid			Tissue		For vehicle	Aerosol spray	
		Trigger & trigger foam		For water-repellent of fabric	Trigger			Trigger	
		Liquid			Aerosol spray			Aerosol spray	
	For cleaning/removing mold & moss	Powder			Trigger			Trigger to heater	
		Tissue		For water-repellent of glass	Aerosol spray			Spray to heater	
		Trigger foam			Liquid			Fumigation	
	For floor cleaning	Gel			Trigger		Toner in printer	For home (black)	Toner cartridge
				For polishing & coating vehicle				For home (color)	
	For carpet cleaning	Liquid			Aerosol spray			For home (black)	Toner cartridge
			Trigger	Air freshener	For freshening indoor air	Trigger	Ink in printer	For home (color)	
For cleaning air-conditioner	Aerosol spray						For home (color)		
For cleaning washing machine	Liquid						Refill (black)	Liquid ink	
		Powder					Refill (color)	Liquid ink	
For removing sticker	Aerosol spray								
		Liquid			Plaster				
					Automatic trigger				
For cleaning drainpipe	Trigger								
					Candle				
For cleaning metal	Aerosol spray			Fumigation					
Adhesive	For multi-purpose	Aerosol spray		For freshening vehicle air	Trigger				
		Liquid			Aerosol spray				
		Instant adhesive liquid			Liquid diffuser				
	For double eyelid	Tube gel				Gel diffuser			
		Liquid				Ventilation diffuser			
	For eyebrow extension	Liquid						Decorative diffuser	
For eyelashes	Liquid								
For nails	Liquid		Deodorant	For fabric	Trigger				
For wig	Gel				Aerosol spray				
		Liquid		For shoes	Trigger				

groups were divided by intended use (i.e., the purpose of product) e.g., toilet/bathroom and glass cleaners, all-purpose adhesives, and fabric deodorants. These products were also divided to groups by application type, including aerosol and trigger type sprays; liquids; liquid diffusers; and candles, powder, gel, gel diffuser, toner cartilage, and other solids (Table 1). In total, 6397 participants completed the survey and 53.2% (n = 1805) of those who responded to the first, and 53.3% (n = 1600) of those who answered the second, were females. In the former, 497 of 3397 respondents noted that they had children under the age of 5; 77.3% of all respondents had one child. In the second survey, 25.2%, 63.4%, and 11.4% of respondents were young (15–34 years old), middle-aged (35–49 years old), or older (> 50 years old), respectively. Most male respondents were middle-aged (67.6%), and younger and older men made up 17.9% and 14.5% of the group, respectively. Among females, the younger and older groups made up 32.4% and 8.3% of the respondents, respectively, while the middle-aged group was again the largest (59.3%; data not shown). In this study, to estimate product-induced exposure time via indoor air, we surveyed exposure durations in

consumer homes and vehicles per day. The exposure durations in the home per day were 37.5% (below 10 h/day), 24.3% (10–12 h/day), and 20.0% (over 14 h/day). Additionally, 53.0% and 30.1% of the respondents were in vehicles for 1 h/day or 1–2 h/day (Table 2).

### 3.2. Prevalence of use

The prevalence of product use was defined as the numbers of users who reported using the household products studied in the last two years. The survey respondents were using several products of varying application types in each product category and regularly used products in nearly all the categories studied (Table 3). Among cleaners, liquid and solid/powder type products for toilets and bathrooms, trigger type products for cleaning glass in the home, powder type products for cleaning kitchens, and liquid type products for cleaning drainpipes were used by more than 16% of respondents (500 cases/3000 respondents); there were the highest such rates. The use rate of liquid and instant type adhesives in multi-purpose products were comparatively

**Table 2**  
Demographics of the studied population.

1 <sup>st</sup> survey (n = 3397)			2 <sup>nd</sup> survey (n = 3000)					
Variables	No.	%	Variables	No.	%			
Surveyed products	cleaners, adhesive, polishing/ coating products		Surveyed products	air-freshener, deodorant, home printer				
Male	1592	46.8	Male	1400	46.7			
Female	1805	53.2	Female	1600	53.3			
Occupation	Regular worker	1084	31.9	Occupation (workers, students)	2496	83.2		
	Shop owner	214	6.3	No occupation (including housewife)	504	16.8		
	Student	268	7.9	Age of survey subjects	Young (15–34 years)	756	25.2	
	Housewife	340	10.0		Middle-aged (35–49 years)	1902	63.4	
	No occupation	262	7.7		Older (> 50years)	342	11.4	
No. of family members	1	370	10.9	No. of family members	1	249	8.3	
	2	499	14.7		2	459	15.3	
	3	992	29.2		3	870	29.0	
	4	1230	36.2		4	1131	37.7	
	5	255	7.5		5	234	7.8	
	> 6	51	1.5		> 6	60	2.0	
No. of children under 5 years of family members (n = 497)	1	2626	77.3	Ventilation time in home	Summer	< 5hr	1083	36.1
	2	669	19.7			5–10hr	480	16.0
	3	88	2.6			10–20hr	594	19.8
	4	14	0.4			> 20hr	840	28.0
No. of rooms in surveyed houses	1	323	9.5		Winter	< 1hr	1191	39.7
	2	693	20.4			1 ~ 2hr	1014	33.8
	3	1953	57.5			2 ~ 3hr	369	12.3
	4	360	10.6			> 3hr	426	14.2
	5	51	1.5	Exposure duration in home per day		< 10hr	1125	37.5
	> 6	17	0.5			10–12hr	729	24.3
Type of building of residence	Single-family house	479	14.1			12–14hr	546	18.2
	Multi-family house	713	21.0			> 14hr	600	20.0
	Apartment	2123	62.5	Exposure duration in vehicle per day		< 1hr	1590	53.0
	Residential complex	51	1.5			1 ~ 2hr	903	30.1
	Other types	31	0.9			2 ~ 3hr	249	8.3
						> 3hr	258	8.6
				Exposure duration outside per day (occupation or school)		< 8hr	984	32.8
						8–10hr	1053	35.1
						> 10hr	960	32.0

higher than the other application types. Among coating agents, solid type products for shoes had the highest use rates. Liquid type air fresheners for indoor air and trigger type deodorants for fabric had high use rates of 36% (1081 cases/3000 respondents) and 74% (2213 cases/3000 respondents), respectively; otherwise, 30% and 32% of respondents used candle type air fresheners and gel type deodorants for closets. Inkjet cartridges were more commonly used than toner cartridges in home printers (Table 3).

### 3.3. Frequency of use

The frequency of use varied based on the product and its purpose. The mean and range of the frequency of product use (50percentile–75percentile) of the use of the products are presented in Table 4. Cleaners, adhesives, and polishing and coating products were used on a monthly basis. For cleaners, most products were used more than once a month, with a mean frequency of use of 1.12–9.50 times per month. Cleaners meant for air-conditioners and washing machines, to remove stickers, and to clear drainpipes were used less than once a month. Cleaners for air-conditioner were typically used before and after seasons in which air-conditioners were operated; the mean frequency of use was 0.55 times per month. The mean frequencies of use for adhesives ranged from 0.31 to 8.2 times per month, and among air fresheners, trigger and aerosol spray type products for indoor and vehicle air were used more frequently than cleaners, adhesives, and polishing and coating products. As the ingredients in fragrances volatilize slowly from different varieties of diffusion type products (such as liquid, gel, and other types of diffusers), we investigated the use

frequency of such products based on the number of times per day that they were open. Liquid diffuser type air fresheners for indoor air were open for 16.75 h/day, on average, but products open for 24 h/day were in the 50percentile–75percentile. This result shows that most diffuser type air freshener users presume that the products would be open for 24 h a day. The mean number of candles used was 0.74 ea/month; trigger and aerosol type deodorants for fabric were used 0.45 times/day and 0.59 times/day, respectively; and toner and inkjet cartridges (black and color) usage was about 2/year.

### 3.4. Duration of use and exposure time by products

To estimate the total amount of actual exposure to products and conduct the exposure assessment, we investigated the time spent applying the products (i.e., the duration of a single application). Respondents were asked how long they took to use the product, from the beginning to end, in one application. The time spent to use the cleaner, adhesive, and polishing and coating product was estimated as the time taken for a series of tasks involving the use of each product; this time was assumed to be similar to the exposure time for users. For trigger type cleaning products for toilets and bathrooms, the mean time taken per use was 23.8 min and there were on average 8.3 triggering actions per use. According to this result, we could estimate that users spent 23.8 min per cleaning task with these products, and used 8.3 triggering actions in this time. The usage of air fresheners and deodorants were different from that of cleaners, adhesives, and polishing and coating product as the former do not require a timed task. We estimated that the time for which users are exposed to these products is

**Table 3**  
Prevalence of use for studied household products.

Products	Cleaner (n = 3397)	Adhesive (n = 3397)	Polishing and coating product (n = 3397)	Air freshener (n = 3000)	Deodorant (n = 3000)	Toner/ink in home printer (n = 3000)
Application types & No. of user						
For toilet & bathroom	405	For multi-purpose	For furniture	For freshening indoors air	For fabric	Toner (black)
Trigger	405	Aerosol spray	Trigger	Trigger	Trigger	2213
Trigger foam	387	Liquid	Aerosol spray	Aerosol spray	Aerosol spray	357
Aerosol spray	48	Tube gel	For leather	Liquid diffuser	For shoes	Toner (color)
Liquid	548	Instant adhesive	Trigger	Gel diffuser	Trigger	Ink (black)
Solid/Powder	692	For double eyelid	Liquid	Plaster	259	739
For home glass cleaning	169	Liquid	Tissue	Automatic trigger	159	734
Trigger	817	For eyebrow extension	For shoes	Candle	For indoors air	Ink (color)
For vehicle glass cleaning	19	Liquid	Aerosol spray	Fumigation	Trigger	118
Trigger	385	For eyelashes	Liquid	For freshening vehicle air	Aerosol spray	357
For vehicle inside cleaning	244	Liquid	Solid	Trigger	Gel & others	155
Trigger	101	For nails	Tissue	Aerosol spray	Gel & others	968
Liquid	440	Liquid	For water-repellent of fabric	For freshening vehicle air	For refrigerator	Refill ink (black)
For cleaning kitchen	359	Gel	Trigger	Gel diffuser	For toilet	Refill ink (color)
Trigger/trigger foam	673	For wig	For water-repellent of glass	Ventilation diffuser	Trigger	275
Liquid	200	Liquid	Trigger	Decorative diffuser	Gel & others	363
Powder	495	For removing mold & moss	Aerosol spray	215	Gel & others	592
Tissue	382	Trigger	Liquid	For air-conditioner	Trigger	88
For removing mold & moss	231	Liquid	For polishing/coating vehicle glass	Trigger	Aerosol spray	304
Trigger foam	60	For floor cleaning	Trigger	For vehicle air	For vehicle air	211
Gel	231	Liquid	Aerosol spray	Trigger	Trigger	140
Liquid	60	For carpet cleaning	For vehicle inside	Aerosol spray	Aerosol spray	55
For cleaning air-conditioner	206	Trigger	Liquid	Spray to heater	Spray to heater	176
Liquid	171	For cleaning washing machine	Tissue	Fumigation	Fumigation	316
Powder	382	Liquid	For vehicle outside	222		
For removing sticker	141	Liquid	Trigger	48		
Aerosol spray	510	Solid	Liquid	174		
For cleaning drainpipe	79	Tissue	For wheel & tire of vehicle	32		
Liquid	81	Trigger	Trigger	208		
For cleaning metal		Aerosol spray	Aerosol spray	124		
Trigger						
Aerosol spray						

**Table 4**  
Frequency of use by studied household products.

Products	Usage	Application types	Frequency of use (use/month)		Products	Usage	Application types	Frequency of use (use/day or month) or products opening time (hr/day) <sup>a</sup> or number of used products (ea/month or year) <sup>b</sup>	
			Mean	S.D.				Mean	S.D.
Cleaner	Toilet & bathroom	Trigger	3.31 (2.0–4.0)	3.91	Air freshener	Freshening indoors air	Trigger	0.75 (use/day)	1.89
		Trigger foam	3.57 (2.0–4.0)	4.96			Aerosol spray	0.84 (use/day)	2.96
	Home glass	Aerosol spray	2.89 (2.0–4.0)	2.65			Liquid diffuser	16.76 (hr/day) <sup>a</sup>	9.81
		Liquid	3.47 (2.0–4.0)	4.82			Gel diffuser	17.05 (hr/day) <sup>a</sup>	9.55
		Solid/powder	7.82 (2.0–4.0)	18.81			Plaster	17.49 (hr/day) <sup>a</sup>	9.64
	Trigger	5.39 (2.0–4.0)	16.56			Automatic trigger	3.15 (No./day) <sup>c</sup>	2.05	
Vehicle glass	Vehicle inside	Trigger	3.64 (2.0–4.0)	9.17			Candle	0.74 (ea/month) <sup>b</sup>	0.64
		Trigger	1.63 (1.0–2.0)	2.04			Fumigation	0.72 (ea/month) <sup>b</sup>	1.00
	Kitchen	Liquid	1.12 (1.0–1.0)	1.31		Freshening vehicle air	Trigger	5.51 (use/day)	4.08
		Trigger/trigger foam	7.67 (4.0–8.0)	13.03			Aerosol spray	5.73 (use/day)	5.40
Cleaning/removing mold & moss	Floor cleaning	Liquid	9.36 (4.0–12.0)	10.63			Liquid diffuser	15.34 (hr/day) <sup>a</sup>	10.34
		Powder	9.50 (4.0–8.0)	17.08			Gel diffuser	14.87 (hr/day) <sup>a</sup>	10.48
	Carpet cleaning	Tissue	9.16 (4.0–12.0)	10.14			Ventilation diffuser	13.55 (hr/day) <sup>a</sup>	10.74
		Trigger foam	3.87 (2.0–4.0)	7.74			Decorative diffuser	13.97 (hr/day) <sup>a</sup>	10.49
	Washing machine	Gel	3.12 (1.0–3.0)	7.10	Deodorant	Fabric	Trigger	0.45 (use/day)	0.76
		Trigger	3.93 (2.0–4.0)	6.86			Aerosol spray	0.59 (use/day)	0.29
	Removing sticker	Trigger	4.33 (2.0–4.0)	7.91		Shoes	Trigger	0.53 (use/day)	1.09
		Liquid	0.55 (0.17–0.5)	0.78		Indoors air	Aerosol spray	0.39 (use/day)	0.65
	Drainpipe	Liquid	0.69 (0.33–1.0)	0.78			Trigger	0.65 (use/day)	1.16
		Powder	0.54 (0.33–1.0)	0.58			Aerosol spray	0.63 (use/day)	1.23
Metal	Aerosol spray	0.58 (0.33–1.0)	0.71		Clothes closet	Gel & others	1.40 (ea/month) <sup>b</sup>	2.38	
	Liquid	0.47 (0.33–1.0)	0.37		Refrigerator	Gel & others	1.17 (ea/month) <sup>b</sup>	2.09	
Adhesive	Multi-purpose	Trigger	1.19 (1.0–2.0)	0.85	Toilet	Trigger	1.19 (ea/month) <sup>b</sup>	2.19	
		Aerosol spray	0.86 (0.5–1.0)	0.88			Gel & others	1.36 (ea/month) <sup>b</sup>	2.19
	Double eyelid extension	Liquid	0.38 (0.25–0.5)	0.33	Air-conditioner	Trigger	15.93 (use/month)	34.78	
		Instant adhesive	0.94 (0.33–1.0)	1.22			Gel & others	1.36 (ea/month) <sup>b</sup>	2.19
	Eyebrow extension	Tube gel	0.61 (0.33–1.0)	0.72	Vehicle air	Trigger	0.38 (use/month)	0.42	
Liquid		8.20 (4.0–12.0)	11.48			Aerosol spray	0.36 (use/month)	0.38	
Polishing and coating products	Eyelashes	Liquid	0.31 (0.25–0.46)	0.21			Trigger to heater	5.67 (use/month)	6.67
		Liquid	6.36 (1.0–8.0)	10.78			Spray to heater	0.36 (use/month)	0.24
	Nails	Liquid	2.52 (1.0–4.0)	2.89	Toner/ink in home	Fumigation	Spray to heater	0.21 (ea/month) <sup>b</sup>	0.25
		Gel	2.30 (1.0–4.0)	2.74			Black	2.55 (ea/year) <sup>b</sup>	0.09
	Wig	Liquid	5.91 (2.0–6.0)	8.55			Color	2.47 (ea/year) <sup>b</sup>	1.71
		Trigger	4.24 (1.0–3.0)	15.33			Black	2.41 (ea/year) <sup>b</sup>	1.68
	Furniture	Aerosol spray	1.81 (1.0–2.0)	2.13		Ink	Color	2.29 (ea/year) <sup>b</sup>	1.64
		Trigger	3.76 (1.0–2.0)	9.85		Refill ink	Black	2.11 (ea/year) <sup>b</sup>	1.51
	Leather	Liquid	2.96 (0.92–3.75)	7.48			Color	2.08 (ea/year) <sup>b</sup>	1.49
		Tissue	2.97 (1.0–4.0)	4.00					
Shoes	Aerosol spray	4.59 (1.0–4.0)	6.05						
	Liquid	6.21 (4.0–8.0)	8.42						
Water-repellent of fabric	Solid	4.15 (2.0–4.0)	5.67						
	Tissue	5.09 (0.67–4.0)	8.76						
Trigger	Trigger	1.51 (1.0–2.0)	1.26						
	Aerosol spray	1.60 (1.0–2.0)	1.46						
	Trigger	2.08 (1.0–4.0)	2.53						

(Continued on next page)

Table 4 (continued)

Products	Usage	Application types	Frequency of use (use/month)		Products	Usage	Application types	Frequency of use (use/day or month) or products opening time (hr/day) <sup>a</sup> or number of used products (ea/month or year) <sup>b</sup>	
			Mean (50th – 75th)	S.D.				Mean	S.D.
Water-repellent of glass	Polishing/coating	Aerosol spray	1.96 (0.67–2.0)	2.89	Trigger	Liquid	Aerosol spray	1.37(1.0–2.0)	1.00
		Liquid	1.36 (1.0–2.0)	1.35					
Vehicle glass	Vehicle inside	Aerosol spray	0.79 (1.0–1.0)	0.65	Trigger	Liquid	Aerosol spray	1.20 (1.0–2.0)	1.14
		Liquid	0.92 (0.42–1.0)	1.14					
Vehicle outside	Trigger	Tissue	1.25 (1.0–2.0)	1.09	Trigger	Liquid	Tissue	1.86 (1.0–2.0)	2.03
		Liquid	0.84 (1.0–1.0)	0.72					
Wheel & tire of vehicle	Trigger	Solid	1.06 (1.0–1.0)	1.09	Trigger	Tissue	Aerosol spray	2.36 (3.0–4.0)	1.66
		Liquid	1.60 (1.0–2.0)	2.01					
		Aerosol spray	1.08 (1.0–1.0)	1.13					

<sup>a</sup> Products opening time per day (products diffusing into indoors).

<sup>b</sup> Number of used products.

<sup>c</sup> Number of auto-injected to indoors/day.

the exposure duration in the place where the product was used, once it had been applied. When candles, liquid diffusers, gel type products, and other similar products were used, the respondents were asked to report, per month, the frequency at which the products were replaced after they were used up. Some deodorants had a longer application period than other products, so respondents were asked how many times these products were used per month. For home printers, respondents were asked how often they replaced the toner or ink cartridges and refilled ink after using up printer cartridges. Table 5 shows the durations of use for the products studied based on application per single use.

### 3.5. Exposure duration and amount of products used

To calculate the actual amount of consumer exposure to trigger and aerosol spray type products, per use, we investigated the time spent operating the trigger in the former and the time spent pressing the button on the aerosol spray product. Additionally, for diffusible type products, the exposure to the opened products (h/day) was investigated. For home printers, the time spent printing per day was estimated. Table 6 shows the number of triggering actions and spraying times reported by respondents. We purchased the studied trigger type products to measure the time taken for the triggering action. For diffuser type products, we compared the difference in the weight of the product before and after use at room temperature (Table 6). In case of trigger and aerosol spray type cleaners, adhesives, polishing and coating products, and deodorants, consumers could be exposed to the maximum amount of product while operating the trigger action and pressing the button (on the aerosol spray products); furthermore, the consumer could face continuous exposure to the product used while performing the tasks that it is used for. In contrast, for diffusion type air fresheners and deodorants, exposure duration is the total time the consumers are exposed to the diffused product. In trigger type cleaners for toilets and bathrooms, the mean duration of the usage time was 23.8 min/use (Table 5), of which the mean time for triggering actions was 3.7 s/use (8.3 triggering actions) and mean time spent on the cleaning task was 20.1 s/use (Table 6). For air fresheners and deodorants that had a pattern of remaining in the area where they were applied, the exposure duration to product in liquid diffusers was the longest.

### 3.6. Exposure to inhalable products sprayed indoors

We measured the mass generated (g/sec) for triggering and spraying products after they were applied according to the difference in the weight of the products before and after use. To calculate the exposure amount (g/use), the following simple equation was used:

$$\text{Exposure amount (g/use)} = [\text{time of triggering or spraying (sec/use)}] \cdot [\text{mass generation (g/sec)}]$$

Table 7 shows mass generation of products (g/sec) divided by application types and exposure amount of these products (g/use). Consumers were exposed to relatively high amounts of aerosol spray type cleaners for toilets and bathrooms, trigger and aerosol spray type coating agents for leather/shoes, and aerosol spray type coating agents for vehicle glass. For diffusible type air fresheners and deodorants, such as gel or liquid diffuser and scented candles, this value was measured as emissions in g/h (Table 8). Scented candles showed a relatively high emission amount of 4.6 g/h. The exposure from diffusible type products was calculated by the following equation:

$$\text{Exposure amount (g/use)} = [\text{time of exposure (exposure duration around the place of products use or duration of use products, time/use)}] \cdot [\text{emission amount (g/time)}]$$

In the case of home printers, the total weights of toner powder and the ink in cartridge were measured; however, residual toner powder and ink (or volatile ingredients) emitted into indoor air should also be measured because toners and inks are used for printing on paper. In this study, we could not measure these amounts and concentrations in

**Table 5**  
Duration of use products.

Products	Usage	Application types	Duration of use (min/use)		Products	Usage	Application types	Duration of use (min/use)		
			Mean (50th - 75th)	S.D.				Mean (50th - 75th)	S.D.	
Cleaner	Toilet & bathroom	Trigger	23.8 (15.5–30.0)	25.1	Air freshener	Indoors air	Trigger	0.8 (0.5–1.0)	0.7	
		Trigger foam	21.3 (15.0–30.0)	21.7			Aerosol spray	0.7 (0.5–1.0)	0.7	
		Aerosol spray	22.4 (10.0–30.0)	27.4			Liquid diffuser	0.9 (0.3–1.0) <sup>a</sup>	1.2	
		Liquid	23.0 (15.0–30.0)	23.0			Gel diffuser	0.6 (0.1–1.0) <sup>a</sup>	0.7	
		Solid/powder	30.2 (20.0–40.0)	35.4			Plaster	0.7 (0.1–1.0) <sup>a</sup>	1.1	
	Home glass	Trigger	19.5 (10.0–30.0)	22.0		Automatic trigger	0.6 (0.5–1.0)	0.5		
		Vehicle glass	Trigger	14.5 (10.0–20.0)		15.5	Candle (min/day) <sup>b</sup>	82.7 (60.0–120.0)	85.7	
	Vehicle inside	Trigger	21.7 (15.0–30.0)	20.0		Vehicle air	Fumigation	181.7 (122–360)	152.9	
		Liquid	39.2 (30.0–60.0)	33.9			Trigger	1.2 (1.0–1.4)	1.3	
	Kitchen	Trigger/trigger foam	(10.0–22.75)	19.3		27.8	Aerosol spray	1.7 (1.0–3.0)	1.5	
			Liquid	20.0 (10.0–30.0)		24.4	Liquid diffuser	0.8 (0.3–1.0) <sup>a</sup>	0.9	
		Powder	20.9 (15.0–30.0)	23.6		Gel diffuser	0.6 (0.3–1.0) <sup>a</sup>	0.6		
		Tissue	10.5 (5.0–10.0)	12.3		Ventilation diffuser	0.7 (0.3–1.0) <sup>a</sup>	0.7		
		Cleaning/removing mold & moss	Trigger foam	30.7 (20.0–30.0)		46.0	Decorative diffuser	0.5 (0.3–1.0) <sup>a</sup>	0.4	
	Floor cleaning	Gel	42.7 (20.0–40.0)	71.1		Deodorant	Fabric	Trigger	1.2 (0.5–1.5)	1.6
		Liquid	27.1 (20.0–30.0)	24.4				Aerosol spray	1.1 (0.3–1.0)	1.6
	Carpet cleaning	Trigger	31.1 (20.2–60.0)	28.6		Shoes	Trigger	1.9 (0.5–2.0)	3.0	
	Air-conditioner	Aerosol spray	19.1 (10.0–20.3)	26.8			Aerosol spray	1.7 (0.5–2.0)	2.8	
	Washing machine	Liquid	0.9 (1.0–1.0)	0.9		Indoors air	Trigger	2.0 (1.0–2.0)	2.7	
		Powder	1.1 (1.0–1.0)	1.3			Aerosol spray	2.0 (0.5–3.0)	2.9	
	Removing sticker	Aerosol spray	13.4 (7.1–20.0)	18.7		Clothes closet	Gel & others	1.4 (0.5–1.0) <sup>a</sup>	2.3	
	Drainpipe	Liquid	32.7 (15.0–30.3)	45.7			Gel & others	1.1 (0.3–1.0) <sup>a</sup>	2.0	
	Metal	Trigger	16.5 (10.0–20.0)	20.1		Refrigerator	Gel & others	1.1 (0.3–1.0) <sup>a</sup>	2.1	
		Aerosol spray	18.9 (10.0–20.0)	27.3		Toilet	Trigger	2.8 (3.6–5.0)	3.6	
	Adhesive	Multi-purpose	Aerosol spray	19.4 (5.25–20.0)		35.5	Air-conditioner	Gel & others	1.3 (0.8–1.0) <sup>a</sup>	2.1
			Liquid	8.1 (5.0–10.0)		14.7		Trigger	4.3 (3.0–5.0)	3.9
			Instant adhesive	6.3 (3.0–5.0)		14.2		Aerosol spray	3.2 (1.0–5.0)	3.7
Double eyelid		Tube gel	9.2 (5.0–10.0)	15.4	Vehicle air	Trigger	2.6 (1.0–3.0)	3.3		
		Liquid	12.7 (5.0–10.0)	28.2		Aerosol spray	2.6 (1.0–3.0)	3.4		
Eyebrow extension		Liquid	26.0 (10.0–40.1)	29.8	Trigger to heater	2.6 (1.5–3.0)	3.1			
Eyelashes		Liquid	36.9 (5.0–20.0)	91.1	Spray to heater	2.8 (1.7–5.0)	2.8			
Nails		Liquid	36.9 (15.0–30.0)	89.9	Fumigation	18.2 (15.0–20.0) <sup>c</sup>	7.6			
		Gel	26.5 (10.0–30.0)	56.6		Black	2.5 (2.0–5.0) <sup>c</sup>	1.7		
Wig		Liquid	50.8 (15.0–46.6)	87.7	Toner/ink in home printer	Toner	Color	2.4 (2.0–5.0) <sup>c</sup>	1.6	
	Trigger	25.4 (10.0–30.0)	31.1	Ink			Black	2.4 (2.0–5.0) <sup>c</sup>	1.6	
Furniture	Aerosol spray	25.2 (17.5–30.0)	24.4		Color	2.2 (1.0–3.7) <sup>c</sup>	1.6			
	Leather	Trigger	20.5 (10.0–30.0)	19.3	Refill ink	Black	2.1 (1.0–3.0) <sup>d</sup>	1.5		
Liquid		21.1 (15.0–30.0)	22.0	Color		2.0 (1.0–3.0) <sup>d</sup>	1.4			
Tissue		18.1 (10.0–20.0)	19.5							
Shoes	Aerosol spray	7.0 (5.0–10.0)	7.4							
	Liquid	7.9 (5.0–10.0)	11.6							
Water-repellent of fabric	Solid	11.7 (10.0–10.7)	13.5							
	Tissue	12.5 (5.0–10.0)	18.7							
Water-repellent of glass	Trigger	16.2 (10.0–20.0)	20.8							
	Aerosol spray	14.3 (5.0–20.0)	19.6							
Polishing/coating vehicle glass	Trigger	29.6 (15.0–60.0)	33.5							
	Aerosol spray	23.6 (10.0–30.0)	30.1							
Vehicle inside	Liquid	37.8 (30.0–35.0)	33.4							
	Trigger	21.4 (10.0–30.0)	26.1							
Vehicle outside	Aerosol spray	19.0 (10.0–30.0)	25.5							
	Trigger	30.0 (20.0–40.3)	28.7							
Wheel & tire of vehicle	Liquid	44.0 (25.0–60.0)	58.4							
	Tissue	21.5 (10.0–20.0)	31.4							
	Trigger	31.3 (20.0–50.0)	28.7							
	Liquid	40.6 (30.0–60.0)	29.7							
Solid	45.3 (30.0–60.0)	34.0								
	Tissue	22.6 (12.5–30.0)	22.0							
Trigger	23.6 (15.0–30.0)	25.8								
	Aerosol spray	19.5 (10.0–22.5)	27.0							

<sup>a</sup> Frequency of replacement (ea/month).  
<sup>b</sup> Time of use products per day (min/day).  
<sup>c</sup> Frequency of replacement (ea/year).  
<sup>d</sup> Frequency of refill (refill/year).

**Table 6**  
Use amount and exposure duration of inhalable products during use.

Products	Usage	Application types	Variables	Mean (75th)	S.D.	Products	Usage	Application types	Variables	Mean (75th)	S.D.
Cleaner	Toilet, bathroom/Home glass/Vehicle glass, inside/ Mold & moss	Trigger/trigger foam	No. of triggering (no./use)	8.3 (10.0)	7.9	Air freshener	Vehicle air	Trigger	No. of triggering (no./use)	4.4 (5.0)	3.9
			Time of triggering (sec/use)	3.7 (4.5)	3.5				Time of triggering (sec/use)	2.3 (2.6)	2.0
		Aerosol spray	Time of spraying (sec/use)	10.4 (10.0)	10.5				Staying time (min/use) <sup>a</sup>	61.0 (75)	57.5
	Kitchen/Carpet/Metal	Trigger/trigger foam	No. of triggering (no./use)	5.8 (5.2)	6.1			Aerosol spray	Time of spraying (sec/use)	2.3 (3.0)	2.3
			Time of triggering (sec/use)	2.5 (3.5)	2.7				Exposure time (min/use) <sup>b</sup>	65.3 (90)	66.3
	Air-conditioner	Aerosol spray	Time of spraying (sec/use)	11.7 (10.0)	17.1			Diffuser	Exposure time (hr/day) <sup>c</sup>	1.9 (3.0)	0.8
	Remove sticker	Aerosol spray	Time of spraying (sec/use)	5.2 (5.0)	6.7			Gel	Exposure time (hr/day) <sup>c</sup>	1.8 (3.0)	0.8
	Metal	Aerosol spray	Time of spraying (sec/use)	7.0 (5.0)	9.3			Ventilation	Exposure time (hr/day) <sup>c</sup>	1.9 (3.0)	0.8
	Multi-purpose	Aerosol spray	Time of spraying (sec/use)	6.7 (9.2)	6.8			Decorative	Exposure time (hr/day) <sup>c</sup>	1.9 (3.0)	0.8
Adhesive	Furniture	Trigger	No. of triggering (no./use)	6.9 (10.0)	8.2	Deodorant	Fabric	Trigger	No. of triggering (no./use)	4.5 (5.0)	3.9
Polishing and coating product	Leather	Trigger	Time of triggering (sec/use)	3.1 (4.5)	3.7				Time of triggering (sec/use)	2.6 (2.8)	2.2
		Aerosol spray	Time of spraying (sec/use)	6.8 (6.5)	7.1			Aerosol spray	Time of spraying (sec/use)	1.5 (2.0)	1.9
	Shoes	Trigger	No. of triggering (no./use)	7.1 (10.0)	7.4		Shoes	Trigger	No. of triggering (no./use)	3.8 (5.0)	2.6
			Time of triggering (sec/use)	11.9 (15.0)	12.7				Time of triggering (sec/use)	2.1 (2.8)	1.5
	Water-repellent of fabric	Aerosol spray	Time of spraying (sec/use)	7.3 (10.0)	6.8			Aerosol spray	Time of spraying (sec/use)	2.2 (2.6)	2.5
		Trigger	No. of triggering (no./use)	4.9 (5.0)	4.3		Indoors air	Trigger	No. of triggering (no./use)	4.7 (5.0)	3.9
			Time of triggering (sec/use)	2.1 (2.1)	1.8				Time of triggering (sec/use)	2.8 (3.0)	2.3
	Water-repellent of glass	Aerosol spray	Time of spraying (sec/use)	7.9 (7.0)	8.3				Exposure time (min/use) <sup>b</sup>	138 (180)	18.4
		Trigger	No. of triggering (no./use)	4.3 (5.0)	3.3			Aerosol spray	Time of spraying (sec/use)	1.9 (2.5)	2.0
			Time of triggering (sec/use)	1.8 (2.1)	1.4				Exposure time (min/use) <sup>b</sup>	130 (180)	17.6
	Polishing/coating vehicle glass	Aerosol spray	Time of spraying (sec/use)	5.2 (5.0)	2.7			Gel & others	Exposure time (hr/day) <sup>c</sup>	6.0 (9.0)	3.3
		Trigger	No. of triggering (no./use)	7.2 (10.0)	6.7		Toilet	Trigger	No. of triggering (no./use)	4.3 (5.0)	3.4
			Time of triggering (sec/use)	3.6 (5.0)	3.3				Time of triggering (sec/use)	2.3 (2.7)	1.8
		Aerosol spray	Time of spraying (sec/use)	7.8 (10.0)	8.3				Exposure time (min/use) <sup>b</sup>	15.7 (20)	24.7
	Vehicle inside	Trigger	No. of triggering (no./use)	9.7 (14.2)	10.0		Air-conditioner	Trigger	No. of triggering (no./use)	4.7 (6.2)	3.4
			Time of triggering (sec/use)	18.6 (34.8)	24.6				Time of triggering (sec/use)	2.7 (3.6)	1.9

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Table 6 (continued)

Products	Usage	Application types	Variables	Mean (75th)	S.D.	Products	Usage	Application types	Variables	Mean (75th)	S.D.
	Vehicle outside	Trigger	No. of triggering (no./use)	16.7 (30.0)	18.9			Aerosol spray	Time of spraying (sec/use)	2.0 (3.0)	2.2
			Time of triggering (sec/use)	7.5 (13.5)	8.5		Vehicle air	Trigger	No. of triggering (no./use)	6.1 (7.0)	6.7
	Wheel & tire of vehicle	Trigger	No. of triggering (no./use)	8.4 (10.0)	9.2				Time of triggering (sec/use)	3.6 (4.2)	4.0
			Time of triggering (sec/use)	1.7 (2.0)	1.9				Exposure time (min/use) <sup>a</sup>	57.3 (70)	75.0
		Aerosol spray	Time of spraying (sec/use)	6.2 (7.0)	4.4			Aerosol spray	Time of spraying (sec/use)	2.4 (2.5)	2.9
Air fres-her	Indoors air	Trigger	No. of triggering (no./use)	5.1 (6.0)	4.6				Exposure time (min/use) <sup>b</sup>	64.1 (81)	82.7
			Time of triggering (sec/use)	2.1 (3.0)	2.1			Trigger to heater	No. of triggering (no./use)	4.5 (5.0)	3.8
			Exposure time (min/use) <sup>a</sup>	84.0 (120)	11.9				Time of triggering (sec/use)	1.9 (2.5)	1.9
		Aerosol spray	Time of spraying (sec/use)	2.1 (3.0)	2.1				Exposure time (min/use) <sup>a</sup>	73.5 (80)	10.8
			Exposure time (min/use) <sup>b</sup>	86.0 (120)	13.3			Spray to heater	Time of spraying (sec/use)	1.9 (2.5)	1.9
		Liquid diffuser	Exposure time (hr/day) <sup>c</sup>	6.8 (12.0)	4.3				Exposure time (min/use) <sup>b</sup>	72.6 (90)	11.1
		Gel diffuser	Exposure time (hr/day) <sup>c</sup>	5.6 (12.0)	4.6			Toner cartridge	Printing time (min/day)	2.5 (5.0)	1.7
		Plaster	Exposure time (hr/day) <sup>c</sup>	5.9 (10.0)	4.4	Toner/ink in home printer	Toner (black)		Printing quantity <sup>d</sup>	8.9 (10)	9.2
		Automatic trigger	Exposure time (hr/day) <sup>c</sup>	4.3 (5.0)	5.3		Toner (color)		Printing time (min/day)	2.4 (5.0)	1.6
		Candle	Exposure time (hr/day) <sup>c</sup>	2.2 (3.0)	2.1		Ink (black)		Printing quantity <sup>d</sup>	9.4 (10)	9.0
		Fumigation	Exposure time (hr/day) <sup>c</sup>	2.9 (5.0)	2.3		Ink (color)		Printing time (min/day)	9.1 (10)	9.5
								Inkjet cartridge	Printing time (min/day)	2.2 (5.0)	1.6
									Printing quantity <sup>d</sup>	8.3 (10)	8.8

<sup>a</sup> Exposure time after triggering (min/use).  
<sup>b</sup> Exposure time after spraying (min/use).  
<sup>c</sup> Exposure time around the products (hr/day).  
<sup>d</sup> Printing quantity (A4 sheets printed per day).

**Table 7**  
Mass generation and worst-case exposure amount of inhalable products via spraying indoors.

Products	Usage	Application types	Mass generation (g/sec)		exposure amount (g/use) <sup>a</sup>	
			Mean (50th - 75th)	S.D.	Mean	
Cleaner	Toilet & bathroom	Trigger & trigger foam	2.3 (2.2–2.6)	0.5	8.5	
		Aerosol spray	4.7 (5.5–5.2)	0.8	48.8	
	Home glass/Vehicle glass/Vehicle inside	Trigger	2.2 (2.0–2.1)	0.7	8.1	
		Trigger & trigger foam	2.3 (2.2–2.6)	0.5	5.7 & 8.5	
	Carpet cleaning	Trigger	2.5 (2.5–2.8)	0.5	6.2	
	Air-conditioner	Aerosol spray	0.6 (0.3–0.7)	0.7	7.0	
	Removing sticker	Aerosol spray	0.1 (0.1–0.16)	0.08	0.5	
	Metal	Aerosol spray	2.6 (2.2–2.9)	0.8	18.2	
	Adhesive	Multi-purpose	Aerosol spray	1.0 (1.0–1.3)	0.4	6.7
		Polishing and coating product	Furniture	Trigger & aerosol spray	1.6 (1.6–1.9)	0.9
	Leather/Shoes		Trigger & aerosol spray	1.9 (1.9–2.1)	0.1	22.6 & 13.8
	Water-repellent of fabric	Water-repellent of fabric	Trigger & aerosol spray	1.1 (1.0–1.2)	0.3	2.3 & 8.6
			Trigger	2.3 (2.3–2.5)	0.5	4.1
		Water-repellent of glass	Aerosol spray	3.3 (3.3–3.7)	0.5	17.1
Trigger			2.2 (2.1–2.4)	0.5	7.9	
Polishing/coating vehicle glass		Aerosol spray	5.1 (5.2–5.7)	0.6	39.7	
		Trigger	1.2 (1.1–1.7)	0.1	22.3	
Vehicle inside		Trigger	1.9 (1.7–2.3)	0.8	14.2	
		Trigger	2.0 (2.1–2.1)	0.7	3.4	
Air freshener		Indoors air	Aerosol spray	1.9 (1.8–2.1)	0.8	11.7
			Trigger & aerosol spray	1.1 (1.3–1.4)	0.3	2.3
Deodorant	Shoes	Trigger	0.3 (0.2–0.2)	0.2	0.6	
		Aerosol spray	1.1 (1.3–1.4)	0.3	2.5	
Fabric	Indoors air	Trigger	0.8 (0.5–1.2)	0.6	2.0	
		Aerosol spray	0.8 (0.5–1.2)	0.6	1.6	
	Toilet	Aerosol spray	0.9 (0.8–0.9)	0.4	1.9	
		Trigger	0.5 (0.6–0.7)	0.2	1.4	
	Air-conditioner	Aerosol spray	1.1 (0.4–1.4)	0.5	2.0	
		Trigger	0.5 (0.6–0.7)	0.2	1.1	
	Vehicle air	Trigger	1.0 (0.9–1.0)	0.05	2.7	
		Aerosol spray	1.8 (1.7–1.9)	0.5	3.6	
	Spray to heater	Trigger	0.5 (0.6–0.7)	0.2	1.8	
		Aerosol spray	1.1 (0.4–1.4)	0.5	2.6	
	Spray to heater	Trigger to heater	1.0 (0.9–1.0)	0.05	1.9	
		Spray to heater	1.8 (1.7–1.9)	0.5	3.4	

<sup>a</sup> Worst-case exposure amount (g/use): exposure amount (g/use) = time of spraying (g/sec) x amount of use (sec/use).

indoor air. Other applications of the products studied were measured in g/use. The amounts used per application differed among products and application types.

#### 4. Discussion

The aim of this study was to create a national exposure factor database for use in exposure and risk assessments of household products in terms of human health. This database includes the frequency, duration, amount, and emissions per application, which is needed for exposure assessments. To accurately estimate consumer exposure to spraying type products, in particular, we investigated the time taken for triggering actions, spraying, and exposure to diffusible products after use. The risk assessment process entails a sequence of actions relevant to human health, such as identifying and characterizing hazardous substances in products, measuring exposure assessment, and characterizing risk (European Chemicals Agency (ECHA), 2013). Exposure assessments are estimates of the concentration of a product that humans may be exposed to in their environments.

##### 4.1. Target products

In 2013, the Korean government adopted regulations to promote the safe use of a range of household products, as these contained chemicals that could adverse health effects in humans (Lee et al., 2012). After that, the KMOE established safe guidelines for certain “risk-concerned products” used by consumers (Korean National Law Information Center (KNLIC), 2016). These products included cleaning products, polishing

and coating products, air fresheners, adhesives, deodorants, and home printers. Our previous studies were a human health risk assessment for consumer exposure to the ingredients in deodorants and air-fresheners according to tier 1 (screening) and tier 2 (detailed) assessment processes (Kim et al., 2018a, 2018b). In this study, we investigated the exposure of consumers (non-professional users) to six household products that had a high potential for risk if inhaled.

##### 4.2. Study population

In previous studies that investigated exposure factors for household and personal care products, actual users of the household products were considered when recruiting respondents (Dimitroulopoulou et al., 2015a; Park et al., 2015, 2017). In this study, the studied household products were commonly used by adults; therefore, the individuals included were 19 years and older. To obtain a sufficient number of respondents who used each product, data from a total of 6397 respondents were included in this study. One study found that as sample sizes increased, the exposure factors for the majority of the household products become closer to those of the parent population, and a sample size of more than 50–100 were recommended for each product tested. Based on these guidelines, we enrolled the recommended number respondents in our study to accurately represent all of the household products.

##### 4.3. Web survey

Methods for data collection using web surveys have been well

**Table 8**  
Emission amount of products via emission indoors & use amount of other products.

Products	Usage	Application types	Amount of use (g/use) or emission amount (g/hr or g/day or g/month)		
			Mean (50th - 75th)	S.D.	
Air freshener	Indoors air	Liquid diffuser	0.1 g/hr (0.1–0.17)	0.1	
		Gel diffuser	0.2 g/hr (0.1–0.2)	0.2	
		Candle	4.6 g/hr (4.1–4.8)	2.5	
	Vehicle air	Liquid diffuser	0.1 g/hr (0.1–0.17)	0.1	
		Gel diffuser	0.2 g/hr (0.1–0.2)	0.2	
Deodorant	Indoors air	Ventilation diffuser	0.3 g/day (0.1–0.6)	0.4	
		Gel & others	0.2 g/hr (0.1–0.2)	0.2	
	Refrigerator	Gel & others	0.06 g/hr (0.06–0.07)	0.02	
Toner/ink in home printer	Toner (black)	Toner cartridge (toner weight)	706.0 g/month (383.3–958.3)	656.1	
	Toner (color)	Toner cartridge (toner weight)	704.3 g/month (383.3–958.3)	668.5	
	Ink (black)	Inkjet cartridge (ink weight)	63.7 g/month (50.0–125.0)	42.7	
	Ink (color)	Inkjet cartridge (ink weight)	31.9 g/month (25.8–64.6)	21.6	
Cleaner	Toilet & bathroom	Liquid	84.2 g/use (57.8–115.6)	85.9	
		Powder	77.4 g/use (53.3–106.6)	63.5	
	Vehicle inside	Liquid	94.2 g/use (78.0–104.0)	88.5	
		Kitchen	Liquid	56.1 g/use (57.8–57.8)	38.9
	Powder		58.7 g/use (53.3–53.3)	45.4	
	Tissue		3.0 sheet/use (2.5–3.0)	2.3	
	mold & moss	Gel	47.5 g/use (32.6–70.0)	43.0	
		Washing machine	Liquid	319.6 g/use (250.0–500.0)	152.7
			Powder	206.4 g/use (100–400)	177.3
	Adhesive	Drainpipe	Liquid	518.4 g/use (500.0–666.6)	372.3
Multi-purpose		Instant adhesive	0.16 g/use (0.11–0.19)	0.06	
		Tube gel	0.5 g/use (0.5–0.6)	0.4	
Double eyelid		Liquid	2.3 mg/use (2.4–2.4)	0.9	
Eyelashes		Liquid	2.3 mg/use (2.4–3.6)	1.0	
Nails		Liquid	8.9 g/use (8.2–9.2)	6.9	
Wig		Liquid	0.1 g/use (0.08–0.12)	0.04	
Polishing and coating product		Furniture	Tissue	3.8 sheet/use (3.0–5.0)	4.0
		Leather	Liquid	44.9 g/use (46.5–46.5)	24.1
			Tissue	3.7 sheet/use (3.0–5.0)	2.8
	Shoes	Liquid	0.3 g/use (0.2–0.4)	0.5	
Solid		12.2 g/use (8.0–20.0)	11.3		
	Vehicle outside	Liquid	8.3 g/use (7.7–10.3)	6.3	

established. Online questionnaires have been demonstrated to be an inexpensive, convenient, and quick data collection method (Walker, 2013). Considering these advantages, several researchers have used web surveys to collect data on exposure factors for consumer products (Ficheux et al., 2015, 2016; Park et al., 2015, 2017). For the web survey used in this study, respondents had to declare the frequency, duration, and amount of product used per application of household products, given several options (SI 1, SI2). However, web surveys have their limitations. A lack of understanding regarding the questions posed might impact the quality of the data; in person surveys might yield data of better quality (Heerwegh and Loosveldt, 2008; Holbrook et al., 2003). However, due to the magnitude of the number of respondents enrolled, it was difficult to conduct in person surveys. Additionally, since respondents were adults, it was assumed that they were able to correctly record the frequency and concentration of the product used per application.

#### 4.4. Frequency of use and duration of use

Estimating human exposure to household products is a fundamental element of the risk assessment process that requires quantifying the levels to which consumers (non-professional users) are exposed to household products. The consumer exposure assessment should normally address the intended uses of the product. To quantify the such consumer exposure, pattern of use information should be investigated. This information is used to develop exposure scenarios that are then evaluated to derive quantitative exposure estimates. The essential pattern of use information required to derive exposure scenarios include ①

the physical state of the product, ② where and how the product will be used (method of application), ③ who would use the product (primary exposure), ④ tasks, frequency, and duration for each stage of use, and ⑤ other data. The frequency and duration of a task are major determinants influencing levels of exposure, and the use rates and frequencies for household products differ by country and type of household products (European Chemicals Agency (ECHA), 2013). To understand the pattern of household product use by Korean consumers, this study investigated the frequency and exposure amount per use, including time exposed to products. Additionally, we accurately evaluated the exposure time and amount of product consumers were exposed to, considering the characteristics of each product and these application types in our analysis. We found that the use rate of some studied products in Korea was lower than that reported for the Switzerland, the Germany, the French, and the Italy (Table A2). This study result showed the differences in the use pattern (frequency, duration, and amount of use) between countries (Garcia-Hidalgo et al., 2017). This study results analyzed for further exposure- and risk-assessment study. For comparison of use pattern between countries, more detailed further data analysis was required.

#### 4.5. Amount of product used and exposure amount

Main exposure of consumers to household products is related to the task performed and the overall exposure scenario. The scenario consists of a series of tasks involved in the application of the product. Consumer exposure to household products occurs through any or all of two potential exposure routes: inhalation and dermal contact. In this study, we

estimated exposure time and amount for inhalable application type products by considering the characteristics of the application type such as aerosol sprays and diffusers in terms of indoor air. Inhalation exposure is usually derived from the airborne concentration in the zone in which the exposed consumer breathes (European Chemicals Agency (ECHA), 2013). The use pattern for studied products may also have seasonal differences. This study did not take potential seasonal variation in product use into account; therefore, the frequency or amount of product used might have been affected by the study period. In addition, a web-based questionnaire was used to survey 3000 participants; hence, understanding the questions asked might have affected the data collected. To estimate exposure to toner and ink from home printers, volatile substances and residual toner powder released into the indoor environment from the printer after the printing task is completed should be measured. In many investigations, several volatile organic compounds (particularly benzene, toluene, xylenes, and styrene) and carbonyls (formaldehyde and acetaldehyde) were designated the most sensitive indicators of indoor pollution (Hodgson et al., 2000; Katsoyiannis et al., 2008; Wilke et al., 2004). The actual concentrations of substances in indoors air that come from consumer products should be analyzed according to the amount of substances emitted from the products (Wolkoff and Nielsen, 2017). An understanding of the actual amount of such substances present in indoor air, based on emission from the products studied, is needed to further evaluate and refine estimations of consumer exposure to household products.

## 5. Conclusion

This study investigated a fundamental approach to assess human exposure to six household products used in daily life. The process of assessing exposure to household products requires determining the

patterns of use (exposure factors), identifying the exposure population (non-professional users), establishing exposure pathways (inhalation and dermal exposure), and quantifying potential product (or chemical) intake. This study determined the recent exposure factors using a web survey of over 6000 consumers in Korea. The result showed that the same product can have different exposure factors depending on the method of application. Therefore, the type of application must be considered when exposure assessments are conducted. The exposure factors in this study can be used to manage or control chemical substances in household products and conduct accurate exposure assessments. Reliable exposure factors used in this study, including frequency of use, amount of use per application, and duration of use, were established in a notification by the NIER (NIER, 2017–55); thus, because exposure factors differ by country, Korean exposure factors were specified in the law. This comprehensive study suggests for how to conduct exposure assessments of household products in the Korean market. Additionally, advances in emission analysis of substances from household products will certainly improve the quality of exposure estimates in health risk assessments.

## Conflicts of interest

The authors declare they have no conflict of interests.

## Acknowledgment

This work was supported by a grant from the National Institute of Environment Research (NIER), funded by the Korean Ministry of Environment (KME) of the Republic of Korea (NIER-2016-01-01-122 & NIER-2017-01-01-012).

## Appendix B. Supplementary data

Supplementary data related to this article can be found at <https://doi.org/10.1016/j.fct.2018.11.053>.

## Appendix A

Table A1  
Survey questions regarding product use in the questionnaire.

Category	Question
Socio-demographic questions	Age, gender, region, number of people living in the household, number of children living in the household, occupation, education level, type of dwelling and number of rooms in the house, average exposure duration in the house,
Products information	What kinds of products, usages (purpose of use), and application types of products are used?
Frequency of use	How often (per day, month, year)
Duration of use	Time from the beginning to end of the products use including task time (such as washing task/coating task/air freshening task and others) Total time of triggering/spraying (aerosol spray type product) Total time of open product and stay around the product (diffusible type product) printing time (home printer)
Amount of use	Amount of use per product application (single use), if it was measured using a 50 ml glass cup (liquid/powder type product) How many pieces were used per product application (wipe tissue type product) Number of triggering/squeezing (trigger type product) - > Amount of spent use during the number of triggering/squeezing (laboratory evaluation) The time of pressing button on the aerosol spray products (aerosol spray type product) - > Amount of spent use during the time of pressing button on the aerosol spray products (laboratory evaluation) Amount of spent use during the time of open product and stay around the product (diffusible type product, laboratory evaluation) Amount of spent use of toner/cartridge during printing time (home printer, laboratory evaluation)

Table A2  
Summary of the reported rates and frequencies of products use.

Products	Use rate (%) <sup>a</sup>					
		Current study (n = 3397)	The Switzerland (n = 600)	The German (n = 450)	The French (n = 150)	The Italian (n = 100)
Kitchen cleaner spray	Trigger/trigger foam: 13.0	58.3		57.5	56.6	70.9
Toilet cleaner	Trigger: 12.0	85.0		86.8	84.2	67.0
Bathroom cleaner liquid	Trigger foam: 11.4	51.8		44.7	61.8	56.3

(continued on next page)

Table A2 (continued)

Products	Use rate (%) <sup>a</sup>				
	Current study (n = 3397)	The Switzerland (n = 600)	The German (n = 450)	The French (n = 150)	The Italian (n = 100)
Bathroom cleaner spray	Spray: 1.4 Liquid: 16.1 Others: 20.4	43.9	47.8	38.2	34.0
Floor cleaner	6.8	52.7	46.6	59.2	64.1
Carpet cleaner	1.8	12.5	13.7	15.1	8.7
Glass cleaner	11.3	71.3	65.6	75.7	74.8

<sup>a</sup>Garcia-Hidalgo et al. (2017).

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