

Full Length Research Paper

Combined exposure pattern of household products used by consumers

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To accurately evaluate the health risk of consumers from the combined effects of substances in multiple used household products, data on co-use and multiple-use habits and practices of consumers necessarily constitute a fundamental element of the exposure assessment process. To understand the current combined use pattern of household products, reliable combined exposure data were investigated. Eleven household product categories were selected and divided by 40 product use purposes. This approach analyzed the information of single-use, co-use, and multiple-use patterns of the 11 products at home collected from 6,397 respondents. All possible multiple combinations of products and product usage categories were analyzed. As expected, the participants used several products and product usage categories simultaneously. The data yielded important personalized combined exposure patterns that can be used in exposure assessment for hazardous substances that are used as ingredients of products. Furthermore, this study investigated the combined exposure amount of 11 products to user at home. Aggregate exposure amount per month to user was calculated to be 7479.6 g/month (six products in 1st survey) and 4056 g/month (five products in 2nd survey). This study provides valuable information on the individual use patterns and circumstances of household product use by consumers.

Key words: Web-survey, combined exposure, household products, multiple-use patterns, combined exposure amount.

INTRODUCTION

Household products are widely and regularly used by consumers; members of the general public may be exposed to hazardous chemicals by intentionally using products (for example non-professional users) that are intended to improve users' living and sanitary conditions. The public may also be exposed to "unintentional use" when they are present when others use such products for household cleaning and personal care (Nielsen et al., 2002; ECHA, 2013). Therefore, consumers of household products are exposed to several kinds of substances on a daily basis (Wolkoff

and Nielsen, 2017). Public interest in and awareness of the health impacts of exposure to multiple chemicals continues to grow as more information is gathered from several sources including personal care and household products (U.S.EPA, 2007). In the United States, organizations such as the Environmental Protection Agency (EPA) and the Agency for Toxic Substances and Disease Registry (ATSDR) have developed documents that support the development of aggregate risk assessment (ATSDR, 2002; U.S.EPA, 2002, 2003).

The EPA defined the general concepts and and

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identified specific elements of and approaches for considerations for aggregate risk assessment implementing aggregate risk assessments (U.S.EPA, 2002, 2003). Aggregate risk assessment is an analysis, characterization, and possible quantification of the combined risks to health or the environment from multiple chemicals or stressors. The exposure assessment to chemicals from several resources including household products is suspected to be the cause and the initial goal of the investigation into the identification of health effects (U.S.EPA, 2003, 2007). To conduct an exposure assessment for using household products, it is necessary to gain information on aggregate exposure (for example frequency of aggregate use and information about the circumstances of usage) (Van Engelen et al., 2007). Several studies on exposure information associated with household products were conducted. A European household product database for domestic use of 15 products was established to provide information that would enable exposure and risk assessment of the chemicals included in common household products (Dimitroulopoulou et al., 2015a; Dimitroulopoulou et al., 2015b; Trantallidi et al., 2015). In the USA, the study of use of products and exposure-related behaviors project provided data on usage patterns for many household products (Bennett et al., 2010). Exposure patterns may vary by country (Biesterbos et al., 2013; Park et al., 2015; Garcia-Hidalgo et al., 2017; Park et al., 2017). A national database of aggregate exposure information for household products is essential to conduct aggregate exposure and risk assessments.

In Korea, disinfectants were used in humidifier water tanks in order to prevent the growth and spread of germs, molds, and/or algae. The inhalation of aerosolized water from a humidifier that contained disinfectants led to serious lung issues that resulted in 200 deaths and 700 injuries, including children (Park et al., 2013). This tragedy heightened public attention and raised concerns. In 2013, the Korean government enacted regulations on substances in a variety of household products that may adversely affect health in an effort to promote the safe use of these products [The Korean Registration, Evaluation, Authorization and Restriction of Chemicals (K-REACH)] (Lee et al., 2012). Household products that fall under these regulations are required to be assessed for exposure and risk in order to evaluate the health and environmental hazards associated with their use.

The purpose of this present study was to develop a database on aggregate exposures for 11 product categories and 40 products usage to consumers. The exposure information data determined in this study will be useful in establishing more improved safety guidelines for household products.

METHODOLOGY

This study analyzed the co-use and multiple-use pattern of 11 household products collected from survey study of 6,397 respondents that carried was out over two years (2016–2017) in 15 metropolitan areas and provinces including rural areas in

Korea (Kim et al., 2019). The previous study investigated a national exposure factor database to be used in exposure assessment and risk assessment of household products to human health. This database includes the following information that is necessary for exposure assessments of household products: frequency of use, duration of use, amount of use, and emission amount of use per application. Reliable exposure factors derived from our previous study were established in notification by the National Institute of Environmental Research NIER (KNLIC, 2017; NIER, No. 2017-55); thus, because exposure factors differ by country, Korean exposure factors were specified in the law. Based on surveyed data, in this study, the co-use and multiple-use were analyzed.

Study population and surveys

To analyze the co-use and multiple-use combination of household products, the results from two web surveys were used. The first survey involved six products: a cleaner, an adhesive, a polishing and coating product, a synthetic detergent, a fabric softener, and a bleaching agent used by 3,397 participants. The second survey involved an air freshener, a deodorant, an ironing auxiliary, an algae remover, and a home printer used by 3,000 participants. Each web survey collected current information on the use pattern for eleven product categories through the survey questions (Table A1 and A2).

Studied household product categories

Among the product categories established by the Korean Ministry of the Environment (KMOE) as risk-concerned products for residential consumers (KNLIC, 2017; KMOE, No. 2017-153), 11 household products were selected in this study (Table A1). Usage information of the product categories studied was collected from a market survey conducted to elucidate which products are commonly used in the Korean market. Based on the results of the survey, 40 usages (purpose of product) of 11 product categories were divided (12 usages for cleaners, three usages for adhesives, eight usages for polishing and coating products, one usage for synthetic detergent, one usage for fabric softener, one usage for bleaching agent, two usages for air freshener, eight usages for deodorant, one usage for ironing auxiliaries, two usages for algae remover, and one usage for home printers). The products that were studied and their usage categories were classified according to the following: products representative of those used on a daily basis by adult male and/or female consumers, products accounting for a major part of exposure from household products, and adequate available data such as exposure factors (frequency of use, duration of use, and amount of use) on product use and typical consumer habits. The household products included in this study were commonly used by adults, and so participants were at least 19 years of age. The list of products and categories of product use are shown in Table 1.

Co-use and multiple-use patterns of products

Exposure of consumers to household products by co-use and multiple-use products is likely described as combined exposure by consumers of multiple ingredients in products. This study used data on combined exposure of consumers to multiple household products through product use. These data were investigated to determine the aggregate consumer risk assessment. To evaluate co-use and multiple-use patterns of products and products usage categories, the responses to the questionnaire were divided into single use of one product, co-use of two products, and multiple-use of several products. *Co-use* was defined as regular use of two products (or two product uses), and *multiple-use* was defined as regular use of more than two products (from using three or more products). In the first survey, the responses for six products (cleaner, adhesive, polishing and coating product, synthetic

Table 1. List of studied household products.

Categories	Usages of products
Cleaner (CLP)	For toilet and bathroom (TB), For cleaning glass (CG), For cleaning kitchen (CK), For cleaning mold and moss (CM), For cleaning floor of building (CF), For cleaning carpet (CC), For cleaning air-conditioner (CA), For cleaning washing machine (CW), For removing sticker (RS), For cleaning drainpipe (CD), For cleaning metal products (CP), For cleaning vehicle inside and outside (CV)
Adhesive (ADP)	For multiple-purpose (MP), For double eyelid and eyebrow extension and eyelashes (DE), For nails (N)
Polishing and coating product (PCP)	For polishing furniture (PF), For polishing shoes (PS), For water-repellent of fabric (WR), For multiple-purpose water-repellent (MW), For water-repellent of vehicle glass (WV), For polishing car inside (PC), For polishing car outside (PO), For wheel and tire of vehicle (WT)
Synthetic detergent (laundry detergent. SDP)	For laundry fabric (LF)
Fabric softener (FSP)	For fabric (F)
Bleaching agent (BAP)	For fabric and shoes (FS)
Air-freshener (AFP)	For indoor air (IA), For vehicle air (VA)
Deodorant (DEP)	For fabric (FA), For shoes (FS), For indoor air (FI), For vehicle air (FV), For clothes closet (FC), For refrigerator (FR), For toilet (FT), For air-conditioner (AC)
Ironing auxiliary (IAP)	For fabric (FF)
Algae remover (ARP)	For fish tank (FT), For stone article (SA)
Toner and ink cartridge in printer (TIP)	For home printer (HP)

detergent, fabric softener, and bleaching agent) by 3,397 respondents were analyzed. In the second survey, the responses for five products (air freshener, deodorant, ironing auxiliary, algae remover, and home printer) by 3,000 respondents were analyzed.

Calculating the combined exposure amount

Considering the worst-case scenario, the combined used amount of products by respondents that used multiple products was calculated as the exposed amount to products. Exposure factor values for each household product (single use by consumers) were used to calculate the aggregate exposure amount, based on the usages and their application types. Reference reliable exposure factors of Korean consumers were already established by the NIER (KNLIC, 2017(NIER, No. 2017-55); Kim et al, 2019). Reference exposure factors for household products consists of the frequency of use, the duration of use, and the amounts of use per application divided by usages and their application types. Korean exposure factors are specified by law, and exposure scenarios for household products based on several exposure routes are also specified, with different countries exhibiting different exposure factors. On the basis of these exposure factors, the amount of exposure to studied products per month was calculated. As a result of market survey, eleven products were categorized to several usages (purpose of product) and furthermore, each usage of products was divided to their application types.

RESULTS

This approach investigated the available data for the aggregate exposure assessment. Combined exposure of multiple ingredients in household products by the

multiple-use pattern of consumers was analyzed. This information might be useful in conducting aggregate exposure assessments to consumers and aggregate risk assessment to human health.

Surveys and single-use prevalence of products

On the basis of the market survey results to elucidate the household products and products usage categories that are commonly used, the 11 product categories mentioned above were divided into several uses: for example use toilet and bathroom and for home glass cleaning in cleaner, all-purpose use in adhesive, and use on fabric in deodorant (Table 1). Overall, 6,397 participants completed the use-pattern web surveys, of which 53.2% (n=1805) in the first survey and 53.3% (n=1,600) in the second survey were females (Table A1). The prevalence of product use was defined as the number of users who reported the use of studied household products in the two years prior to the study. The surveyed respondents had more than one product among each product groups at home and regularly used nearly all of the studied products groups as a high ratio (Tables 2 and 3).

In the 1st survey, the percentages of respondents using products (a single use) were 75.3% (2559 respondents/3397 participants, cleaner), 42.1% (adhesive), 40.1% (polishing and coating products), 65.1% (synthetic detergent), 68.4% (fabric softener), and 30.2% (bleaching agent) (Table 2). In the second

Table 2. Prevalence of respondents using products aggregately (1st survey).

No. of users (n=3397)	CLP	ADP	PCP	SDP	FSP	BAP
CLP	2559 ^a					
ADP	1252 (co-users: CLP, ADP) ^b	1431 ^a				
PCP	1205 (co-users: CLP, PCP) ^b					
	705 (multiple-users: CLP, ADP, PCP) ^c	760 (co-users: ADP, PCP) ^b	1362 ^a			
SDP	1843 (co-users: CLP, SDP) ^b	1071 (co-users: ADP, SDP) ^b				
	556 (multiple-users: CLP, ADP, PCP, SDP) ^c	589 (multiple-users: ADP, PCP, SDP) ^c	977 (co-users: PCP, SDP) ^b	2212 ^a		
FSP	1927 (co-users: CLP, FSP) ^b	1101 (co-users: ADP, FSP) ^b	1032 (co-users: PCP, FSP) ^b			
	495 (multiple-users: CLP, ADP, PCP, SDP, FSP) ^c	522 (multiple-users: ADP, PCP, SDP, FSP) ^c	847 (multiple-users: PCP, SDP, FSP) ^c	1847 (co-users: SDP, FSP) ^b	2325 ^a	
BAP	928 (co-users: CLP, BAP) ^b	606 (co-users: ADP, BAP) ^b	592 (co-users: PCP, BAP) ^b	820 (co-users: SDP, BAP) ^b		
	309 (multiple-users: CLP, ADP, PCP, SDP, FSP, BAP) ^c	320 (multiple-users: ADP, PCP, SDP, FSP, BAP) ^c	455 (multiple-users: PCP, SDP, FSP, BAP) ^c	748 (multiple-users: SDP, FSP, BAP) ^c	887 (co-users: FSP, BAP) ^b	1025 ^a

CLP, cleaner; ADP, adhesive; PCP, polishing and coating product; SDP, synthetic detergent; FSP, fabric softener; BAP, bleaching agent.

^a numbers of respondents using single product, ^b numbers of respondents using two products, ^c numbers of respondents using multiple products.

Table 3. Prevalence of respondents using products aggregately (2nd survey).

No. of users (n=3000)	AFP	DEP	IAP	ARP	TIP
AFP	2197 ^a				
DEP	1586 (co-users: AFP, DEP) ^b	2071 ^a			
IAP	281 (co-users: AFP, IAP) ^b				
	230 (multiple-users: AFP, DEP, IAP) ^c	277 (co-users: DEP, IAP) ^b	347 ^a		
ARP	484 (co-users: AFP, ARP) ^b	462 (co-users: DEP, ARP) ^b			
	97 (multiple-users: AFP, DEP, IAP, ARP) ^c	112 (multiple-users: DEP, IAP, ARP) ^c	122 (co-users: IAP, ARP) ^b	567 ^a	
TIP	1574 (co-users: AFP, TIP) ^b	1430 (co-users: DEP, TIP) ^b	281 (co-users: IAP, TIP) ^b		
	96 (multiple-users: AFP, DEP, IAP, ARP, TIP) ^c	107 (multiple-users: DEP, IAP, ARP, TIP) ^c	116 (multiple-users: IAP, ARP, TIP) ^c	445 (co-users: ARP, TIP) ^b	2030 ^a

AFP, air-freshener; DEP, deodorant; IAP, ironing auxiliary; ARP, algae remover; TIP, toner and ink cartridge in printer. ^a numbers of respondents using single product, ^b numbers of respondents using two products, ^c numbers of respondents using multiple products.

survey, the percentages of respondents using products (a single use) were 73.2 (2,559 respondents/3,397 participants), 69.0, 11.6, 18.9, and 67.7% for air freshener, deodorant, ironing auxiliary, algae remover, and home printer (Table 3). Among the product categories studied, bleaching agent, ironing auxiliary, and algae remover showed relatively low use rates among less than 40% of respondents. In contrast, cleaner, synthetic detergent, fabric softener, air freshener, deodorant, and home printer exhibited comparatively high use rates, involving more than 60% of respondents for each. The product showing the highest use rate was cleaner (Tables 2 and 3). Gender variations (male and female) for single-use pattern of studied products in the first and second surveys were presented in Tables 5 and 6. In the case of cleaner, adhesive, synthetic detergent, fabric softener, bleaching agent, air freshener, and deodorant, females showed higher use rate than males (the rate of single use).

Co-use pattern of products

The co-use rates of two studied products were analyzed. Co-use of products that contain the same ingredients results in aggregate exposure to those ingredients. Therefore, it is necessary to understand the key patterns of current use of different household product categories to calculate the aggregate exposure (Garcia-Hidalgo et al., 2017). Co-use analysis of 11 product categories was performed for all 6,397 respondents. In Table 2, all possible co-use and multiple-use combinations of product categories introduced in the first survey are presented. Among users of cleaner (2,559 respondents), the percentages of co-use were as follows: cleaner and adhesive co-users (48.9%), cleaner and polishing and coating products co-users, (47.1%), cleaner and synthetic detergent co-users (72.0%), cleaner and fabric softener co-users (75.3%), and cleaner and bleaching agent co-users (36.3%). Table 3 shows all possible co-use and multiple-use combinations of product categories in the second survey. The percentages of co-use among users of air freshener (2,197 respondents) were as follows: air freshener and deodorant co-users (72.1%), air freshener and ironing auxiliary (12.8%), air freshener and algae remover (22.0%), and air freshener and home printer (71.6%). Gender variations (male and female) in co-use patterns of the products studied in the first and second surveys are presented in Tables 5 and 6. The co-use rate was somewhat complicated between females and males. Studied products that showed high single-use rates also showed high concurrent co-use rates.

Multiple-use pattern of products

The multiple-use rate of products varied according to products and the purpose for use. Tables 2 and 3 show the combination and the rate of multiple-use (six products in the first survey, and five products in the

second survey). These results addressed the combination exposure of multiple products and multiple ingredients to consumers. The multiple-use pattern by users might be helpful in carrying out a general approach for combined exposure- and risk-assessment of multiple ingredients that could be adapted to the needs of users. Gender variations for multiple-use patterns of studied products in the first and second surveys were also presented in Table 5 and Table 6. In case of cleaner use among female users, the multiple-use rate of cleaner, synthetic detergent, and fabric softener was the highest at 50.8%. Also, multiple users of all six products in the first survey showed a rate of 8.7% (Table 5). In the case of air freshener use among female users, the multiple-use rate of air freshener, deodorant, and home printer was the highest at 39.2% (Table 6).

Combined exposure amount of products

The multiple used amounts of respondents to household products at home were investigated. Table 4 presents amounts each product used divided by usages (purpose of product) from single use at home by respondents. Table 4 shows the products categories, their usages, and their application types. In order to calculate the use amount of household products from single use by respondents, we summed up the use amount (g/use) of all application types of each product divided by usages. After then, the use amounts per month were calculated (g/month). The mean use amount per use and per month differed among products (Table 4). The mean use amount of cleaner products was found to be 3614.4 g/month (Table 5). The aggregate amount of cleaner, adhesive, polishing and coating product, synthetic detergent, fabric softener, and bleaching agent was calculated as 7479.6 g/month (Table 5). Tables 5 and Table 6 summarized the combined aggregate use amount of six products (target products in 1st survey) and five products (target products in 2nd survey). In order to study exposure assessment, exposed amount to user could be calculated with values of used amount of products by user. The information of aggregate exposure amount used by users might be helpful in carrying out the approach for aggregate exposure assessment study.

Co-use pattern of products divided by usage

In Tables 7 and 8, the single-use and co-use prevalence of products divided by uses were analyzed as the numbers of respondents who did respond to the use of single- and two-product usages. According to the survey results, there were 40 usages of the studied 11 product categories mainly in the Korean market. Respondents retained several usages' products from each product category. A cleaner had 12 main usages: for toilet and bathroom, cleaning glass, cleaning the kitchen, cleaning mold and moss, cleaning the floor of a building, and others. Also, deodorants with eight kinds

Table 4. The worst-case calculated used and exposed amount of products by single use.

Products	Usages of products	Application types	Amount of single use ^{a, b}	
			Mean, g/use	Mean, g/month ^c
CLP	TB	Trigger/trigger foam/spray foam/liquid/powder	1339.4	844.0
	CG	Trigger	19.5	87.7
	CK	Trigger foam/liquid/powder	122.13	1138.9
	CM	Trigger foam/gel	57.5	186.9
	CF	Liquid	86.4	548.0
	CC	Trigger	15.0	64.9
	CA	Trigger/spray	19.2	12.9
	CW	Liquid/powder	526.0	331.9
	RS	Spray	0.6	0.3
	CD	Liquid	518.4	243.6
	CP	Trigger/spray	35.4	35.8
CV	Trigger	8.6	119.5	
ADP	MP	Spray/tube/instant-adhesion/glue	80.3	43.6
	DE	Liquid	4.6 mg/use	34 mg/month
	N	Emulsion	8.9	20.6
PCP	PF	Trigger/spray	16.3	41.6
	PS	Liquid/emulsion/wax	12.64	53.2
	WR	Trigger/spray	19.6	17.3
	MW	Trigger/spray	22.0	43.6
	WV	Trigger/spray	46.7	40.2
	PC	Trigger/liquid	33.3	32.2
	PO	Trigger/liquid	22.6	33.5
WT	Trigger/spray	12.0	14.9	
SDP	LF	Powder/liquid/capsule/tissue	247.1	2247.9
FSP	F	Liquid/tissue	57.7	590.0
BAP	FA+FS	Trigger/liquid/powder	109.0	688.6
AFP	IA	Trigger, spray	2.4	61.9
		Liquid diffuser/gel diffuser/candle	0.1 g/h, 0.2 g/h, 4.g/h	359.3
	VA	Trigger, spray	3.5	20.3
		Liquid diffuser/gel diffuser	0.1 g/h, 0.2 g/h, 0.3 g/day	154.9
DEP	FA	Trigger	2.1	29.1
	FS	Trigger/spray	3.9	53.6
	FI	Trigger/spray/gel	0.2 g/h	36.4
	FV	Trigger/spray	4.8	849.4
	FC + FR	Gel	0.1 g/h	43.2
	FT	Trigger	1.3	20.7
AC	Trigger/spray	6.5	2.4	
IAP	FF	Trigger/spray	7.0	66.7
ARP	FT	Liquid/solid/powder	120.1	336.6
	SA	Liquid	16.9	47.8
TIP	HP	Toner/ink (weight of cartridge and ink)	-	1973.7

TB, cleaner for toilet and bathroom; CG, cleaner for glass; CK cleaner for kitchen; cleaner for mold and moss; CF, cleaner for floor of building; cleaner for carpet; cleaner for air-conditioner; CW, cleaner for washing machine; RS, cleaner for removing sticker; CD, cleaner for drainpipe; CP, cleaner for metal products; CV, cleaner for vehicle inside and outside; MP, adhesive for multiple-purpose; DE, adhesive for double eyelid and eyebrow extension and eyelashes; N, adhesive for nails; PF, polishing and coating product for furniture; PS, polishing and coating product for shoes; WR, polishing and coating product for water-repellent of fabric; MW, polishing and coating product for multiple-purpose water-repellent; WV, polishing and coating product for water-repellent of vehicle glass; PC, polishing and coating product for car inside; PO, polishing and coating product for car outside; WT, polishing and coating product for wheel and tire of vehicle; LF, synthetic detergent for fabric; F, fabric softener for fabric; FS, bleaching agent for fabric and shoes; IA, air-freshener for indoor air; VA, air-freshener for vehicle air; FA, deodorant for fabric; FS, deodorant for shoes; FI, deodorant for indoor air; FV, deodorant for vehicle air; FC, deodorant for clothes case; FR, deodorant for refrigerator; FT, deodorant for toilet; AC, deodorant for air-conditioner; FF, ironing auxiliaries for fabric; FT, algae remover for fish tank; SA, algae remover for stone article; HP, home printer. ^a experimented mean weight of products from using each product by respondents, ^b mean amount of products single-used by consumers were evaluated as KNLIC-2017 (NIER No. 2017-55) and Kim et al (2018), ^c calculated mean summed weight of products per month (30 days).

Table 5. The worst-case combined use pattern and exposed amount (1st survey).

Product categories	No. of respondents using single and multiple products		Combined exposed amount to products by respondents using multiple products (g/month) ^a
	Female (N = 1805, 53.2%)	Male (N = 1592, 46.8%)	
CLP	1407	1152	3614.4
CLP+ADP/CLP+PCP/CLP+SDP/C LP+FSP/CLP+BAP	733/524/1066/1097 /549	519/681/777/830/3 79	3676.6/3890.9/5862.3/4204 .4/4303
CLP+ADP+PCP/CLP+ADP+SDP	339/584/	366/392	3953.1/5924.5
CLP+ADP+FSP/CLP+ADP+BAP	591/346	403/224	4266.6/4365.2
CLP+PCP+SDP/CLP+PCP+FSP	408/416	491/526	6138.8/4480.9
CLP+PCP+BAP	276	283	4579.5
CLP+SDP+FSP/CLP+SDP+BAP	917/453	663/303	6452.3/6550.9
CLP+FSP+BAP	479	335	4893
CLP+ADP+PCP+SDP	270	286	6201
CLP+ADP+PCP+FSP	278	292	4542.6
CLP+ADP+PCP+BAP	194	182	4641.7
CLP+PCP+SDP+FSP	357	431	6728.8
CLP+PCP+SDP+BAP	234	233	6827.4
CLP+PCP+FSP+BAP	246	254	5169.5
CLP+ADP+PCP+SDP+FSP	243	252	6791
CLP+ADP+PCP+SDP+BAP	167	159	6889.6
CLP+ADP+PCP+FSP+BAP	175	166	5231.7
CLP+ADP+PCP+SDP+FSP+BAP	157	152	7479.6
ADP	825	606	62.2
ADP+PCP/ADP+SDP/ADP+FSP/ADP+BAP	356/631/647/362	404/440/455/244	338.7/2310.1/652.2/750.8
ADP+PCP+SDP/ADP+PCP+FSP	280/291	309/315	2586.6
ADP+PCP+BAP/ADP+SDP+FSP	199/522	195/379	928.7
ADP+SDP+BAP/ADP+FSP+BAP	305/324	207/220	1027.3
ADP+PCP+SDP+FSP	252	270	2900.1
ADP+PCP+SDP+BAP	169	170	2998.7
ADP+PCP+FSP+BAP	179	178	1340.8
ADP+PCP+SDP+FSP+BAP	158	162	3865.2
PCP	560	802	276.5
PCP+SDP/PCP+FSP/PCP+BAP	426/442/286	551/509/306	2524.4/866.5/965.1
PCP+SDP+FSP/PCP+SDP+BAP	373/239	474/247	3114.4/3213
PCP+FSP+BAP	255	272	1555.1
PCP+SDP+FSP+BAP	223	232	3803
SDP	1257	955	2247.9
SDP+FSP/SDP+FSP+BAP	1064/439	783/309	2837.9/6364.4
FSP	1319	1006	590.0
FSP+BAP	518	369	1278.6
BAP	599	426	688.6

CLP, cleaner; ADP, adhesive; PCP, polishing and coating product; SDP, synthetic detergent; FSP, fabric softener; BAP, bleaching agent. ^a combined exposed amount to products were calculated as sum of amounts used usages and their application types of each products.

of usages were mainly sold in the Korean market. The use rates of cleaner usage categories divided by the number of uses (a single use) in the first survey were: for toilets and bathrooms (45.7%), for cleaning glass (32.5%), for cleaning the kitchen (42.5%), for cleaning mold and moss (23.7%), for cleaning the floor of a building (6.8%), for cleaning carpets (1.8%), for cleaning air conditioners (6.1%), for cleaning washing machines (15.1%), for removing stickers (4.2%), for

cleaning drainpipes (15.0%), for cleaning metal products (4.4%), and for cleaning the inside and outside of vehicles (9.6%) (Table 7). The use rates of other product categories divided by usages in the first survey (three for adhesive, eight for polishing and coating products, one for synthetic detergent, one for fabric softener, and one for use as a bleaching agent) are shown in Table 7. Product usage categories of the second survey were two usages for air freshener, eight

Table 6. The worst-case combined use pattern and exposed amount (2nd survey).

Product categories	No. of single users and combined users		Exposed amount to products by respondents using multiple products (g/month) ^a
	Female (N = 1600, 53.3%)	Male (N = 1400, 46.7%)	
AFP	1207	990	596.4
AFP+DEP/AFP+IAP/AFP+ARP/ AFP+TIP	867/149/235/856	719/132/249/718	1631.2/663.1/980.8/2570.1
AFP+DEP+IAP/AFP+DEP+ARP	120/197	110/209	1697.9/2015.6
AFP+DEP+TIP/AFP+IAP+ARP	627/53	539/52	3604.9/1365.2
AFP+IAP+TIP/AFP+ARP+TIP	125/196	120/196	2636.8/2954.5
AFP+DEP+IAP+ARP	49	48	2082.3
AFP+DEP+IAP+TIP	103	101	3671.6
AFP+IAP+ARP+TIP	53	51	3989.3
AFP+DEP+IAP+ARP+TIP	49	47	4056
DEP	1115	956	1034.8
DEP+IAP/DEP+ARP	141/224	136/238	1101.5/1419.2
DEP+TIP/DEP+IAP+ARP	762/57	668/55	3008.5/1485.9
DEP+IAP+TIP/DEP+ARP+TIP	118/188	115/191	3075.2/3392.9
DEP+IAP+ARP+TIP	55	52	3459.6
IAP	179	168	66.7
IAP+ARP/ IAP+TIP	62/143	60/138	451.1/2040.4
IAP+ARP+TIP	59	57	2424.8
ARP	273	294	384.4
ARP+TIP	221	224	2358.1
TIP	1070	960	1973.7

AFP, air-freshener; DEP, deodorant; IAP, ironing auxiliary; ARP, algae remover; TIP, toner and ink cartilage in printer.

^acombined exposed amount to products were calculated as sum of amounts used usages and their application types of each products.

for deodorant, one for ironing auxiliaries, two for algae remover, and one for home printer. In the case of air freshener, the use rates of respondents using two usages products were 64.7 and 41.1% for use of indoor air and use of vehicle air, respectively. The single-use rates of deodorant usage categories were as follows: use of fabric (77.5%), use of shoes (15.3%), use of indoor air (18.3%), use of vehicle air (21.1%), use of clothes closet (32.3%), use of refrigerator (19.1%), use of toilet (28.5%), and usage of air conditioner (12.7%) (Table 8). In Tables 7 and 8, all possible co-use combinations of product usage categories in the two surveys are presented. Among cleaner, products for toilet and bathroom, products for cleaning home glass, and products for cleaning kitchens exhibited relatively high co-use rates among respondents. In the case of adhesive, its co-use rate for multi-purpose products was comparatively high. In case of synthetic detergent and fabric softeners, 1,847 (54.4%) of the 3,397 respondents had co-use habits involving those two products (Table 7).

DISCUSSION

Systemic evaluation of the aggregate health risks from the combined effects of multiple products and chemicals is becoming a vital component of risk-based decisions aimed at protecting consumers. The process of

assessing risk to humans of household products entails a sequence of actions relevant to human health, such as identification of hazardous substances in products, characterization of these substances, exposure assessment, and risk characterization (ECHA, 2012, 2013, 2016). The current study investigated the exposure database of single-use patterns and reliable exposure factors concerning household products (Kim et al., 2019). The current study provides data on the co-use and multiple use of 11 household products and 40 uses of 11 products. In addition, the rates of single-use, co-use, and multiple-use by respondents were analyzed. Relatively high rates of respondents used combinations of two or more products, for example, a cleaner and an adhesive or a cleaner and a synthetic detergent. The estimation of consumer exposure to household products is a fundamental element of the risk assessment process and requires quantification of the levels of exposure for consumers (non-professional users) to household products (ECHA, 2016). Such a consumer exposure assessment should normally address the intended uses of the product. An important component of current exposure and risk assessment is the consideration of aggregate and aggregate exposures. When assessing exposure and health risk to consumers, more accurate exposure assessment could be estimated by cumulated and aggregated exposures from all potential exposure routes (Sexton, 2012). The aim of this study was to create the sufficient

Table 7. Prevalence of respondents co-using products divided by usages (1st survey).

Products and usages	CLP (No. of users)												ADP			PCP					SDP	FSP	BAP				
	TB	CG	CK	CM	CF	CC	CA	CW	RS	CD	CP	CV	MP	DE	N	PE	PS	WR	MW	WV	PC	PO	WT	LF	F	FS	
CLP	TB	1551																									
	CG	697	1104																								
	CK	927	640	1443																							
	CM	523	394	509	806																						
	CF	175	122	144	108	231																					
	CC	32	31	33	36	25	60																				
	CA	142	126	135	90	31	7	206																			
	CW	340	215	338	211	50	8	78	512																		
	RS	90	85	89	54	14	3	32	45	141																	
	CD	332	229	332	184	56	9	56	146	44	510																
CP	112	107	108	76	28	8	23	32	15	42	151																
CV	217	221	219	149	57	16	59	69	31	64	51	326															
ADP	MP	748	564	702	379	122	25	126	219	88	242	105	181	1201													
	DE	185	160	188	135	49	16	25	61	16	42	42	60	158	315												
	N	112	87	110	79	35	11	23	44	13	33	29	43	84	61	184											
PCP	PF	189	150	156	115	51	19	45	66	24	55	49	81	139	59	35	240										
	PS	506	460	499	288	97	28	101	170	62	168	81	157	460	94	60	144	852									
	WR	125	104	125	90	39	12	32	48	21	40	47	59	109	55	32	59	96	179								
	MW	95	80	85	64	21	14	27	33	12	33	39	44	81	33	25	48	68	48	130							
	WV	196	180	176	126	42	14	45	69	28	60	58	78	158	46	39	56	139	68	54	278						
	PC	165	154	143	103	43	15	40	59	30	48	51	96	137	46	38	73	127	66	58	83	233					
	PO	270	249	261	178	61	23	69	88	51	98	62	148	222	63	50	106	231	78	56	126	128	404				
WT	203	193	197	142	53	20	62	71	31	75	71	116	176	60	46	84	167	72	58	105	101	151	304				
SDP	LF	1218	835	1154	625	176	34	159	398	109	406	125	245	932	222	133	184	644	140	98	224	174	306	233	2212		
FSP	F	1258	888	1195	638	187	40	172	421	116	425	122	252	957	227	129	194	659	149	98	236	184	327	235	1847	2325	
BAP	FS	692	487	628	375	121	28	99	232	67	208	86	161	528	139	90	143	414	109	78	158	126	214	163	820	887	1025

exposure information for implementing aggregate exposure and health risk assessment of household products. This study analyzed the current multiple-use patterns of household products by surveying via the web over 6,000 consumers in Korea. This study of aggregate exposure information for household products suggests potential health risk concerns

among adult consumers and unintentionally exposed children. This information includes the combined multiple-use pattern, which is needed for aggregate exposure assessments of household products. Co-use and multiple-use patterns of household products by consumers are to the aggregate multiple exposures of products and of multiple ingredients in products.

Multiple exposures by several product categories could address the combined exposure to multiple chemicals. Because of the unidentified fatal lung disease caused by chemical disinfectants used in household humidifiers in Korea, KMOE and NIER conducted human risk assessment studies to assess levels of hazardous ingredients in consumer products.

Table 8. Prevalence of respondents co-using products divided by usages (2nd survey).

No. of users	AFP		DEP				IAP			ARP		TIP			
	IA	VA	FA	FS	FI	FV	FC	FR	FT	AC	FF	FT	SA	HP	
AFP	IA	1942													
	VA	978	1233												
	FA	1571	978	2326											
	FS	329	250	433	459										
	FI	432	324	509	198	548									
DEP	FV	447	429	547	178	244	633								
	FC	706	493	815	219	253	310	968							
	FR	420	286	496	143	172	184	282	573						
	FT	624	425	745	212	249	319	392	252	855					
	AC	271	208	318	96	128	166	169	107	199	380				
IAP	FF	262	181	284	108	103	121	154	99	137	62	347			
ARP	FT	260	201	268	97	108	102	146	83	142	67	86	246		
	SA	313	229	352	104	125	136	187	105	187	72	101	152	321	
TIP	HP	1402	935	1602	351	429	473	713	390	607	279	281	246	321	2030

The KMOE has established safe guidelines for consumer products and is regulating ingredients in consumer products strongly (KNLIC, 2017; KMOE, No. 2017-153). However, aggregate exposure evaluations of chemicals used in household products have remained a grey area in chemical management in Korea. According to numerous international organizations, such as the EPA and WHO, aggregate risk assessments are intended to answer difficult and formerly unaddressed questions regarding combined risk burdens and disproportionate health impacts. Also, such assessments tend to be more theoretically complex, methodologically complicated, and challenging than traditional single-chemical assessments (U.S.EPA, 2003, 2007). At present, KMOE and NIER pay a great deal of attention as they conduct aggregate health risk assessment studies to assess combined chemicals from possible routes. Therefore, as a further study, we are investigating the combined exposure and health risk assessment study to primary and secondary users.

Conclusion

This study provides valuable information on the individual use patterns and circumstances of household products used by Korean adult consumers. A database might be helpful to conduct aggregate exposure assessment for ingredients that are components of household products.

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CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Appendix A Table A1. Demographics of the surveyed population and survey questions in the questionnaire.

Surveyed populations	1 st survey	n=3397 (male 4592, female 1805) Cleaners, adhesive, polishing/coating product, synthetic detergent, fabric softener, bleaching agent
	2 nd survey	n=3000 (male 1400, female 1600) Air-freshener, deodorant, ironing auxiliary, algae remover, toner and ink cartridge for home printer
Questions in the questionnaire	Socio-demographic questions	Age, gender, region, number of people living in the household, occupation, average exposure duration in the house
	Information of used products	What kinds of products, usages (purpose of use), and application types of products are used?
	Frequency of use	How often?
	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)
	Amount of use	Amount of use per product application (single use and multiple use)

Table A2. The example of survey questions for exposure pattern.

Question 1. Have you ever used for last 1year cleaners for toilet and bathroom?

① yes (to q1-1)

products examples



q1-1) what kinds of cleaners have you used? choose every products (can choose multiple products)

spray type spray type (trigger spray type (aerosol trigger) foam) spray type (aerosol trigger)



liquid type



solid type



powder type



Table A2. Cont.

q1-2) what was products name you used? size, volume of products, write detail.

application types of products	products name (manufacturing company)
① spray type (trigger)	
② spray type (trigger foam)	
③ spray type (aerosol spray)	
④ liquid type	
⑤ solid type	
⑥ powder type	

q1-3) [use frequency] how often have you used?

factors	application types of products	times	use frequency
use frequency	spray type (trigger)	①week ②1month ③6months ④1year	() times
	spray type (trigger foam)	①week ②1month ③6months ④1year	() times
	spray type (aerosol spray)	①week ②1month ③6months ④1year	() times
	liquid type	①week ②1month ③6months ④1year	() times
	solid type	①week ②1month ③6months ④1year	() times
	powder type	①week ②1month ③6months ④1year	() times

q1-4) [time of use] time of use : mean exposure time from products, chemicals of products when you used products through inhalation and dermal contact

Questions	Application types	Factors
Mean time for using products per one time? (including task time, total time for finishing clean bathroom and(or) toilet after use cleaners)	spray type (trigger)	() hr,() min, () sec
	spray type (trigger foam)	() hr,() min, () sec
	spray type (aerosol spray)	() hr,() min, () sec
	liquid type	() hr,() min, () sec
	solid type	() hr,() min, () sec
	powder type	() hr,() min, () sec