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Review

Consumption and exposure to finished cosmetic products: A systematic review

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ABSTRACT

According to the European Regulation (EC) No. 1223/2009, cosmetic products should be safe for human health when used under normal or foreseeable conditions of use. To perform a safety evaluation, consumption data of finished cosmetic product are necessary to assess the corresponding consumer's exposure.

The aim of this review was to highlight consumption (percentage of users, frequency of use, amount used, number of products daily used, types of products co-used …) and exposure data to cosmetic products available in the literature. A systematic approach was used following the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analyses) guidelines. Literature search was performed in February 2018 using Pubmed and Scopus databases. The following information was collected for the 82 publications included in this review: type of study, characteristics of the population (number, age, sex, region of origin), period of data collection, types of products studied, method(s) of data collection, consumption and/or exposure parameters obtained. Because of the high number of quantitative results obtained in the different studies, these data are not presented here. Readers interested in one or more studies are invited to consult the results available in the original publication (s). This work could be very useful for safety assessors or other persons working in the risk assessment field.

1. Introduction

Cosmetic products are defined in the European Regulation (EC) No. 1223/2009 as “any substance or mixture intended to be placed in contact with the external parts of the human body (epidermis, hair system, nails, lips and external genital organs) or with the teeth and the mucous membranes of the oral cavity with a view exclusively or mainly to cleaning them, perfuming them, changing their appearance, protecting them, keeping them in good condition or correcting body odours” (EU, 2009). Cosmetic products, also called personal care products, are part of everyday life of consumers of all ages in most regions of the world. Their use is driven mainly by the interest in hygiene, personal appearance, or feeling of well-being (Williams et al., 2016). An online survey conducted by Cosmetics Europe in 2017 on 4116 consumers across 10 European Union Member States has shown that cosmetic products were “important or very important in daily lives” for 71% of interviewed people and that products used “improved their quality of life” for 72% of them (Cosmetics Europe, 2017). A finished cosmetic product can be considered as the result of a combination of ingredients. The European regulation No. 1223/2009 specifies that a cosmetic product should be safe for human health when used under normal or foreseeable conditions of use (EU, 2009). To perform a safety evaluation, consumption data of finished cosmetic product (frequency of use, amount per use, amount per day) are necessary to assess the corresponding consumer's exposure (SCCS, 2015). The exposure (mg/kg bw/day) can be determined by dividing the daily consumption of a finished product by the body weight of the studied population. Exposure data to the finished product are essential for determining the systemic exposure dose (SED) for each ingredient found in the finished product. This SED value is used for the calculation of the margin of safety (MoS) which represents the ratio between a No Observable Adverse Effect Level (NOAEL) and a SED value (SCCS, 2015).

Initially, two large consumption and exposure studies were carried out in the 2000s. The first one, conducted in a European adult population, aimed to provide consumption and exposure data for 12 types of cosmetic products commonly applied by consumers (Hall et al., 2007, 2011; McNamara et al., 2007). These European data have been currently reported in the Scientific Committee on Consumer Safety (SCCS) notes of guidance (SCCS, 2015). The second one provided consumption data for 12 types of products largely used by US adult women (Loretz

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et al., 2006, 2005, 2008). These American and European data are presented in the US Environmental Protection Agency (US EPA) exposure factors handbooks (US EPA, 2011). However, there was a lack of published consumption/exposure data i) for many types of products available in the market and commonly used by the population such as baby wipes, hair dye, sunscreen or depilatory products; ii) for many subpopulations not taken into account in these two large studies, such as babies under 3 years old, children, adolescents or pregnant women; iii) for Asian, South American or African people who represent billions of consumers whose consumption of cosmetics may be different from Europeans or Americans.

Recent studies conducted in 2010s have investigated the consumption and the exposure of various populations (in terms of country, of origin, of age or sex) to many cosmetic product types for which there was no data available in the literature. These recent consumption studies could be large in scale (i.e. important in term of number of participants in the sample and/or in term of number of products investigated) or small in scale (i.e. focused on few product types and/or focused on a specific subpopulation). Furthermore, many epidemiological studies conducted in 2010s provided additional cosmetic consumption data. In fact, these studies aimed to evaluate the association between cosmetic products or cosmetic ingredients consumption and adverse events observed in a population. Epidemiological studies were generally conducted on hundreds or even thousands of people and could be an interesting additional source of information on cosmetic's usage patterns. All of these new data are valuable for safety assessors.

In Europe, a safety assessment is based on the safety of the ingredients found into each cosmetic product (EU, 2009). The daily co-use of cosmetics and consequently the aggregate exposure to ingredients found in these different products is not taken into account in the guidelines of the SCCS, except for preservatives for which an aggregate daily consumption value was defined (SCCS, 2015). However, most of cosmetic products, such as shower gel, deodorant, toothpaste, hand soap, perfume, face cream, mascara, lipstick or wipes, are used on a daily basis. A survey conducted among more than 2300 people in the United States showed that, on average, adult women used 12 products per day and on the other hand, adult men used 6 products daily (EWG, 2004). Another study recently conducted on 7131 French people showed that, on average, adult women daily used 16 products, adult men daily used 8 products and 6 products were daily used by parents for their baby aged 0–3 (Ficheux et al., 2015). Therefore, aggregate exposure models for ingredients found in cosmetic products were developed in the last few years, such as Probabilistic Aggregate Consumer Exposure Model (PACEM) (Dudzina et al., 2015; Ezendam et al., 2018; Nijkamp et al., 2015) or Creme RIFM models (Comiskey et al., 2015; Safford et al., 2015). The co-use of cosmetic products and thus, the aggregate exposure to their ingredients (contained in it) is a very important point for safety assessment, and generated consumption data deserve to be mentioned.

The aim of this review was to highlight consumption (percentage of users, frequency of use, amount used, number of products daily used, types of products co-used …) and exposure data to cosmetic products available in the literature. This review was conducted using a systematic approach. The following information was collected for all publications included in this review: type of study, characteristics of the population (number, age, sex, region of origin), period of data collection, types of products studied, method(s) of data collection, consumption and/or exposure parameters obtained. Because of the high number of quantitative results obtained in the different studies, these data are not presented here (thousands of data available). Readers interested in one or more studies are invited to consult the results available in the original publication(s). This work could be very useful for safety assessors or other persons working in the risk assessment field.

2. Methods

This systematic review followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analyses) guidelines for reporting systematic reviews (Liberati et al., 2009; Moher et al., 2009).

2.1. Databases and research equation

Studies containing human consumption and/or human exposure data to one or several cosmetic products were identified via electronic database. Literature search was performed in February 2018 using Pubmed and Scopus databases. The PubMed Advanced Search Builder was used to write the following equation: (((((((((“cosmetic product”) OR ″cosmetic products”) OR cosmetic) OR cosmetics) OR ″cosmetic care product”) OR ″cosmetic care products”) OR ″personal care product”) OR ″personal care products")) AND (((((((((consumption) OR ″usage pattern”) OR ″usage patterns”) OR ″use pattern”) OR ″use patterns”) OR ″use-pattern") OR ″use-patterns")) OR ((((((exposure) OR ″aggregate exposure”) OR ″skin exposure”) OR ″dermal exposure”) OR ″inhalation exposure”) OR ″probabilistic exposure")). The research on PubMed was done on title and on abstract. The query string was used in Scopus to write the same equation. The research was performed on title, abstract and keywords. As the consumption habits of cosmetic products evolve over time, we chose not to take into account the few studies published before 2000. The data generated could be very far from current consumption habits. All articles published between January 2000 and February 2018 were taken into account.

2.2. Selection of studies for review(Fig. 1)

All summaries identified through database searching were read: 3479 references in PubMed and 7071 references in Scopus. Original articles reporting data on human consumption (percentage of users, frequency of use, amount of product used, number of products used daily, number of products co-used etc …) and/or on the human exposure to cosmetic products were considered for the next step. No restriction was performed on the country of origin, on the population studied or on the written language. All the publications which did not generated human consumption data were excluded as well as publications that reported and/or used previously published consumption data. Consumption data reported only on the last 24 or 48 h in some epidemiological studies were excluded. At this stage, only studies that were clearly not appropriate for inclusion were excluded. If certain criteria for inclusion couldn't be ascertained from title or abstract, the study was kept for full-text screening. Conference posters were considered whenever available, but conference abstracts alone were excluded since the information was not sufficient (quantitative data not fully presented in poster abstracts). Conference posters related to published articles were excluded to avoid overlap. Finally, the screening step was independently assessed for the two databases(Fig. 1).

107 publications in PubMed and 134 publications in Scopus were selected on title and abstract in the screening step. After exclusion of duplicates, 134 publications were retained for full-text reading (all publications in PubMed database were found in Scopus database). Inclusion and exclusion criteria were the same that in the screening step: articles reporting data on human consumption (percentage of users, frequency of use, amount of product used, number of products used daily, number of products co-used …) and/or on human exposure to cosmetic products were considered. All the publications which did not generated human consumption data were excluded as well as publications that reported and/or used previously published consumption data. Consumption data reported only on the last 24 or 48 h in some epidemiological studies were excluded.

After full-text reading, 68 publications were selected. The reference list of the 68 articles of interest was checked for finding other pertinent publications that may not have been found based on the general

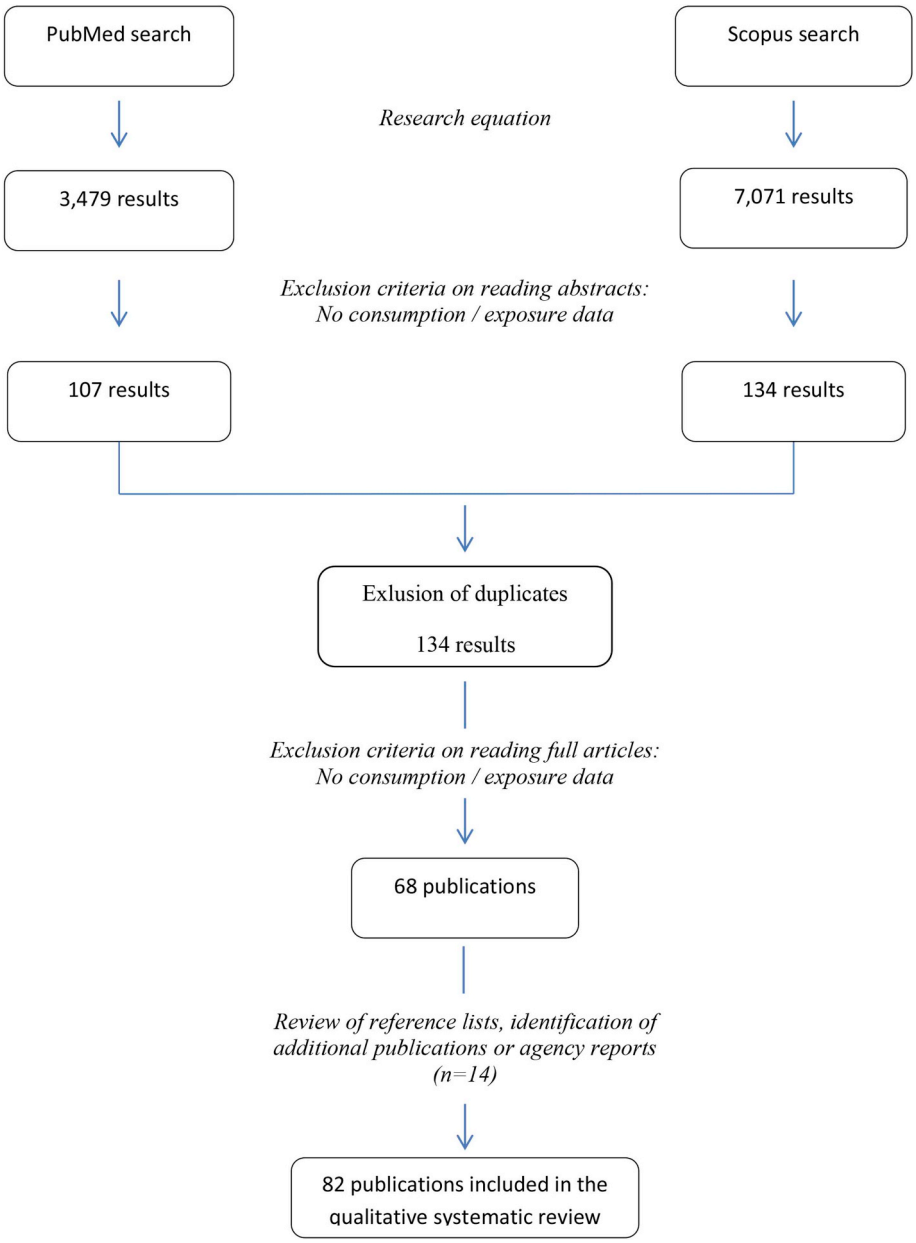

Fig. 1. Selection of studies for review.

research equation. All potentially interesting articles highlighted in the reference lists were selected or not selected for review using the same inclusion and exclusion criteria as previously described (a first selection on title and abstract, and a second selection after full-text reading). 14 additional publications were added to the review. In total, 82 publications were included in this review.

2.3. Information needed for review

The following information was extracted from the 82 publications included for review: the type of study (consumption, epidemiological, modeling …), the period of data collection, the characteristics of the interest population (country, age, sex, number …), the types of cosmetic products studied, the method(s) of data collection, the consumption and/or exposure parameters obtained.

3. Results

Studies were presented depending on their geographical region: Europe, America, Asia and Africa. When a study was conducted in different geographical regions, the description of the study was made for the region where the number of participants was the largest. In addition, reference to the study was also made for the other regions where the study was carried out. Generally, two categories of studies permitted to obtain consumption/exposure data:

- Consumption studies whose purpose was to generate new data to better assess the safety of consumers,
- Epidemiological studies whose aim was to evaluate the association between cosmetic products consumption and adverse events observed in a population,

A third category, called “aggregate exposure models”, was presented because these models can use consumption data previously

obtained (already published or not), and generate new data appropriate to their model.

In addition of the geographical origin, all studies were presented depending on the category to which they belong. A focus was performed when co-use data were generated.

3.1. Data obtained in Europe

3.1.1. Consumption studies

3.1.1.1. Presentation of the studies

3.1.1.1.1. Representative large scale studies (Table 1). A European study was carried out between 2003 and 2005 by European cosmetic manufacturers acting within the trade association The European Cosmetic and Perfumery Association (Colipa) (Hall et al., 2007, 2011; McNamara et al., 2007). The aim was to construct a European population model of consumption and exposure to cosmetic products. 12 types of products were investigated: hair styling, hand cream, liquid foundation, mouthwash, shower gel, body lotion, facial moisturizer, toothpaste, shampoo, lipstick, deodorant spray, and deodorant non-spray. Investigations were carried out in a representative panel of European adult consumers. Three databases were used. The first recorded the daily frequency of use through a postal survey consisting of a self-completion paper diary and questionnaire. In total, data from 17,561 volunteers living in Denmark, France, Germany, Great Britain and Spain were obtained (European Toiletries and Cosmetics Database, ETCD). The second database (ISC) was commissioned by Colipa to gather data on the amount used per event. The ISC study was performed in Edinburgh (Scotland) on 496 adults. Participants used their own products throughout a two-week period. Amount data was collected by weighing the subject's products at the beginning and at the end of the study. The third database, Europanel by TNS, provided data on the total quantity of cosmetic products sold in Denmark, France, Germany, Great Britain and Spain. In total, 44,100 households provided purchasing information. The Monte Carlo probabilistic method was used in calculations.

A study supported by the French National Agency of Medicine and Health Products Safety was carried out between 2013 and 2015 to assess the exposure to cosmetic products in French consumers (Bernard et al., 2018; Ficheux et al., 2014, 2015; 2016a, 2016b; 2016c; Ficheux and Roudot, 2017). Babies, children and adults were selected to form a national representative sample of the population. Pregnant women were also considered using a specific oversampling. About 150 types of products were taken into account including general hygiene, care, perfume, solar, shaving, depilatory or baby products (see Table 1 for a full list). Four studies were performed in order to collect the consumption data. The first one was a web survey on 7131 people. This survey was designed to obtain the percentage of users and the frequency of use data. The second study consisted in a 24 h-recall phone survey performed on 11,269 people which aim was to validate or to correct the frequency data previously obtained in the web survey. The third one was a face to face survey among 1078 people carried out in a laboratory in order to collect the amount per use data by weighing the tested products after one single use. The last study was a web enquiry performed on 1200 volunteers and aimed to generate missing data, such as the number of wipes used per application. In total, more than 20,000 French people were included in this study. The exposure to cosmetic products was assessed using the Monte Carlo probabilistic method.

A national survey was conducted in 2011 among a sample of 397 Swiss children, adolescents and adults. Information on the percentage of users, the frequency of use and the co-use was collected on 8 types of products (Face cream, body lotion, aftershave lotion/balm, hand cream, makeup foundation, lip care, lipstick and sunscreen) using mailed paper questionnaire (Manová et al., 2013). More recently, (2015) the same team conducted a new national survey among a larger sample of Swiss children, adolescents and adults (N = 759). Information on the percentage of users, the frequency of use, the amount of product applied per use, the co-use and the site of application was collected on 22 types of products including general hygiene, care, makeup and baby products (see Table 1 for a full list). Mailed questionnaire were used to collect consumption data (Garcia-Hidalgo et al., 2017).

Cosmetic products use patterns were assessed in an adult Netherlands population (n = 516) (Biesterbos et al., 2013). Consumption data (percentage of users, frequency of use, amount per use, amount per day, co-use and application area) were collected by digital questionnaires, and 32 types of products were considered including general hygiene, body care, hair care, shaving, sunscreen products (see Table 1 for a full list). Additional data on the circumstances of use were collected: the time of application, the location of use and the presence of ventilation.

3.1.1.1.2. Other studies (Table 1)Specific to a type of subpopulation

Babies: The consumption and the exposure of 78 French babies aged 0–23 months old to7 baby products (shampoo, shower gel, cleansing water, cleansing milk, moisturizing cream, bottom cream and wipes) were assessed in 2010–2011. Products were used at home during a 3-week period. The daily usage of each product was recorded in a diary, and the amount used was collected by weighing each product at the beginning and at the completion of the study in order to determine the total amount of product used. Discriminant analysis was performed to highlight any difference in consumption depending on age. The exposure was assessed using the Monte Carlo probabilistic method (Gomez-Berrada et al., 2017a).

Pregnant women: Consumption data were collected among 294 pregnant women living in Paris and its suburb (France). 12 cosmetic products were taken into account, including oil massage, stretch marks removal or bust care products (see Table 1 for a full list). Daily consumption was calculated using a deterministic and a probabilistic method (Bavoux et al., 2011).

A second French study was carried out in 128 French women to assess the changes in cosmetic products habits during pregnancy and risk perception. 28 common types of products were taken into account including shower gel, intimate hygiene product, shampoo, scrub, body lotion, deodorant, perfume, bronzer, face cream, and make-up products (see Table 1 for a full list). The percentage of users was presented in the publication (Marie et al., 2016).

Usage patterns (percentage of users and frequency of use) of 24 types of cosmetic products were assessed on 179 Turkish pregnant women (general hygiene and care products, but also wipes or hair bleach products). Frequency of use was assessed depending on education level, professional activity, age and skin type (Aksu Arıca et al., 2017).

Adolescents and adults: The exposure to molecules widely found in cosmetic products was assessed in a sample of 210 Flemish adolescents and in 204 adults randomly selected from the general population (The Flemish Environment and Health Study, FLEHS). Percentage of users and frequency of use were obtained from 12 cosmetic types including day or night cream, lip balm, body lotion, deodorant or perfume (see Table 1 for a full list). However, results were not presented in the publication (Den Hond et al., 2013).

Hairdressers: Hairdressers'usage patterns and exposure to hair dye, highlighting mixtures and shampoo were assessed in 11 salons in Brest city (France). 28 hairdressers participated in the study conducted in 2013. Information was collected by questionnaires, including the frequency of use, the characteristics of hairdressing salons (size and type of ventilation used), the occurrence of respiratory symptoms among professionals, and the use of protective equipment. Amount of product used was recorded by weighing after a single use; the duration of contact with products was recorded by direct observations. Exposure was assessed for dermal and inhalation routes by a deterministic method (Ramirez-Martinez et al., 2016).Specific to a type of cosmetic product

Sunscreen: General information on sunscreen usage patterns

Table 1
Consumption studies conducted in Europe.

Population	Sex	Age (years old)	N	Products studied	Consumption data	Additional data	Method(s) of data collection	Period of data collection	Product exposure data (mg/kg bw/day)	References
Large scale studies										
European	M and F	Adults ≥ 17	18,057	Hair styling, hand cream, liquid foundation, mouthwash, shower gel, body lotion, facial moisturizer, toothpaste, shampoo, lipstick, deodorant spray, deodorant non-spray	Amount per day	/	Postal diary and questionnaire Amount used: weighting	2004–2005	Yes	Hall et al. (2007), 2011; McNamara et al. (2007)
French	M and F	Adults ≥ 15 Pregnant women ≥ 15 Children 4–14 Babies 0-3	20,678	150 types of products including general hygiene, care, perfume, solar, shaving, depilatory or baby products[a]	Percentage of users, frequency of use, amount per use	wipes: number per use, % of transfert on skin	Web questionnaire and 24 h-recall by phone Amount used: weighting	2013–2015	Yes	Bernard et al. (2018); Ficheux et al. (2014), 2015, 2016a, 2016b, 2016c, Ficheux and Roudot, 2017
Swiss	M and F	Adults ≥ 18 Adolescents 13–17 Children 6–12 Toddlers 0-5	759	Shampoo, conditioner, shower gel, bubble bath, liquid hand soap, hand cream, body lotion, face cream, facial cleansing, cosmetic/baby wet wipes, shaving products, aftershave, perfume/eau de toilette/cologne, deodorant, toothpaste, lipstick/lip gloss/lip balm, nail polish, makeup remover, eye shadow, powder or rouge, foundation	Percentage of users, frequency of use, amount per use, amount per day, co-use	/	Postal questionnaire	2015	No	Garcia-Hidalgo et al. (2017)
Swiss	M and F	Adults ≥ 18 Adolescents 13–17 Children 0-12	397	Face cream, body lotion, aftershave lotion/balm, hand cream, makeup foundation, lip care, lipstick and sunscreen	Percentage of users, frequency of use, co-use	/	Postal questionnaire	2011	No	Manova et al. (2013)
Netherland	M and F	Adults ≥ 18	516	Deodorant, perfume/eau de toilette, shower gel, bathing foam/oil, toothpaste, shaving foam/gel/oil/soap, aftershave, shampoo, conditioner, hairspray, hair lotion/gel/foam/wax, hair dye, body lotion, hand cream, day cream, night cream, facial cleaning lotion, foundation, makeup remover, powder or rouge, eye shadow, mascara, eye pencil, eyebrow pencil, lip pencil, lipstick or gloss, lip balm, nail polish, nail polish remover, tanning products (bronzers, sunscreen and after sun)	Percentage of users, frequency of use, amount per use, amount per day, co-use, application area	Circumstances of use: time of application (morning, afternoon, evening), location of use, presence of ventilation	Digital questionnaire	2011–2012	No	Biesterbos et al. (2013)
Other studies										
French (Rennes)	M and F	Babies < 2	78	Shampoo, shower gel, cleansing water, cleansing milk, moisturizing cream, bottom cream and wipes	Frequency of use, amount per use, amount per day	/	Diary and questionnaire Amount used: weighting	2010–2011	Yes	Gomez-Berrada et al. (2017a)
French (Paris)	F	Pregnant women	294			/	NM	NM	No	Bavoux et al. (2011)

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Table 1 (*continued*)

Population	Sex	Age (years old)	N	Products studied	Consumption data	Additional data	Method(s) of data collection	Period of data collection	Product exposure data (mg/kg bw/day)	References
				Face cream, body cream/milk, body lotion, body oil, doedorant stick/roller, deodorant spray, oil massage, stretch marks removal, bust care product, sunscreen milk/cream, sunscreen spray, personal liquid gel/soap	Percentage of users, amount per day					
French	F	Pregnant women 18-44	128	Shower gel, solid soap, dermatological soap, intimate hygiene product, body scrub, body lotion or cream, deodorant (spray or non-spray), perfume, bronzers, facial cleanser, day face cream, night face cream, facial scrub, facial mask, shampoo, hair mask and hair dye, foundation, blush, mascara, eye-liner, eye pencil, eye shadow, lipstick, lip pencil, make-up remover, nail polish, nail polish remover	Percentage of users	Pregnant (n = 68)and non pregnant (n = 60) women	Questionnaire	2015	No	Marie et al. (2016)
Turkish	F	Pregnant women	179	Toothpaste, shampoo, soap, hand cream, wipes, shower gel, conditioner, moisturizing cream, eye makeup, face cream, lipstick, depilatory was, lip balm, makeup remover, fondation, mouthwash, nail polish, powder, nail polish remover, sunscreen, depilatory cream, intimate hygiene, hair spray, hair gel, tanning, hair bleach	Percentage of users, frequency of use	/	Questionnaire	2015–2016	No	Aksu Arica et al. (2017) (publication in Turkish)
Flemish	M and F	Adolescents 14-15 Adults 20-40	414	Day or night cream, lip balm, body lotion, hand cream, shampoo, hair balm, hair conditioner, make-up, bath or shower products, deodorant, perfume, eau de toilette	Percentage of users, frequency of use (data not shown in the publication)	/	Questionnaire	2008–2009	No	Den Hond et al. (2013)
French (Brest)	M and F	16–58	28	Hair dye, highlighting mixtures and shampoo	Daily frequency of use, amount per use	Characteristics of hairdressing salons, respiratory symptoms among professionals, use of protective equipment	Questionnaire, weighting (amount used) and direct observations in salons	2013	Yes	Ramirez-Martinez et al. (2016)
French (Rennes)	M and F	Adults 23–60 Children 3-13	337	Sunscreen spray	Period of use, number of use, frequency of use, amount per use, amount per day	Consumption was assessed demending on tanning intensity and sunlight intensity	Diary and questionnaire Amount used: weighting	2014	Yes	Gomez-Berrada et al. (2018a)

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Table 1 (*continued*)

Population	Sex	Age (years old)	N	Products studied	Consumption data	Additional data	Method(s) of data collection	Period of data collection	Product exposure data (mg/kg bw/day)	References
French	F	≥15	4237	Hair products: bleach, lightener, permanent dye, semi-permanent dye, temporary dye, or vegetal dye	Percentage of users, frequency of use	Place of use (at the hairdressers, at home), type of products (professional or supermarket products)	Web questionnaire	2013–2015	Yes	Bernard et al. (2016)
British, Dutch and American (US)	M and F	0–48 months	531	Baby wipes for diaper area	Frequency of use, daily lotion transfer		Diary and experimental data (lotion transfer)	2013	Yes	Dey et al. (2016)
French	M and F	Children 2-17 Adults ≥ 18	401	Toothpaste	Frequency of use, amount per use, amount per day	Teeth brushing time, additional brushing area	Diary and questionnaire Amount used: weighting	2015	Yes	Gomez-Berrada et al. (2018b)
French	F	Children 0-17 Adults ≥ 18	1923	Nail polishes (base coat, polish, top coat) and nail polish remover	Percentage of users, frequency of use, wearing time, number of coats applied, amount of product used per application, setting and drying time	Place of manicures, evaporation rates, onychophagia	Web anf face to face questionnaires Amount used and evaporation rates: weighting	2013	Yes	Ficheux et al. (2014)
French, Dutch, British, Italian and Spanish	M and F	16–70	2535	Cosmetic products containing tea tree oil: Body lotion, hand cream, face cleansing, shampoo, showering and body wash, foot deodorant spray, body deodorant spray, face cream, hand wash soap, blemish spot gel and lip balm	Daily frequency of use, amount per day	Exposure to tea tree oil ingredient	Web questionnaire	2015–2016	Yes	Rieder, 2017
French (Brest and Laval)	F	NM	117	Facial care products (scrub and mask), hair removal wax	Frequency of use, amount per use	/	Face to face questionnaires Amount used: weighting	2015	Yes	Coinet et al. (2015)
French (Rennes)	M and F	18–70	221	Shampoo, shower gel, emollient cream	Amount per use, amount per day	/	Diary and questionnaire Amount used: weighting	2014	No	Gomez-Berrada et al. (2017b)
French, Dutch, Italian, Spanish, Macedonian, Mauritian		Babies and Children 0-10	1481	Rinse-off products for hair and body (gel, oil, foam), rinse-off products for the whole body (gel, foam, cream), leave-on products for face and body (cream, lotion, balm), cleansers (cleansing water and cleansing lotion, diaper dermatitis treatment products (cream, oil spray and paste), shampoos	Amount per use, amount per day	/	Amount used: weighting	2001–2011	Yes	Gomez-Berrada et al., 2013
Mauritian, Spanish, French, Italian	M and F	Children 3-14 Adults ≥ 15	3001	Sun care products: sunscreen cream, sunscreen milk, sunscreen spray, sunscreen stick, moisturizing cream with SPF, after-sun milk	Amount per use, amount per day, amount per use per cm^2, amount per day per cm^2	/	Amount used: weighting	2006–2016	Yes	Gomez-Berrada et al. (2017c)
	M and F		2994			/		2002–2016	Yes	

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Table 1 (*continued*)

Population	Sex	Age (years old)	N	Products studied	Consumption data	Additional data	Method(s) of data collection	Period of data collection	Product exposure data (mg/kg bw/day)	References
French, Macedonian, Spanish, Dutch, Polish Portuguese, Mauritian, South African, Brazilian		Babies 0–3 Children 4-12 Adults ≥ 18		Family products: shampoo, shower gel, solid soap, cleansing lotion, emollient foam, emollient bath, cream, milk, balm, lip balm	Amount per use, amount per day		Amount used: weighting			Gomez-Berrada et al. (2017d)

M: males, F: females, N: Number of participants, NM: Not mentioned.

[a] Hair cleanser (liquid shampoo, solid shampoo, dry shampoo, baby shampoo), styling (lacquer (aerosol), gel, foam, wax, spray (pump), care (conditioner, lotion, serum, oil, mask, dye, henna dye, hair bleach, highlights, permanent straightening, permanent wave) products. Face cleanser (solid soap, liquid soap, soap-free gel cleanser, milk, lotion/micellar water, wipes, exfoliating scrub), care (moisturizer cream, night cream, anti-aging cream, eye contour, serum, lip balm, talc, skin lightening product, hair bleach, mask, clay mask, neck cream, strip), makeup (eye shadow, eye liner, eye pencil, mascara, concealer, prime face, foam foundation, compact powder foundation, loose powder foundation, cream foundation, imperfection corrector, blush, lipstick, lip pen), makeup remover (lotion, milk, oil, foam, wipes, remover pads), oral care (toothpaste, whitening toothpaste, gum protection toothpaste, fluoride toothpaste, child toothpaste, multi-care toothpaste, mouthwash) products. Body cleanser (solid soap, shower gel, baby shower gel, 2 in 1 hair and body, milk, foam bath, wipes, intimate hygiene liquid cleanser, intimate hygiene wipes, exfoliating scrub), care (moisturizing milk, moisturizing cream, moisturizing oil, bust cream, heavy legs cream/gel, slimming cream/gel, anti-stretch mark cream, nipple cream/oil, skin. lightening product, hair bleach, deodorant (aerosol, roll-on, stick, cream, Alun stone), fragrance (perfume, Eau de toilette, Eau de toilette for baby, Eau de Cologne), massage (balm, oil, cream), hands (moisturizer cream, anti-spot cream, anti-perspirant cream, wipes, talc), feet (moisturizer cream, anti-perspirant, exfoliating scrub, talc), bottom (lotion, milk, wipes, cream/balm, liniment), sunscreen (cream, aerosol, spray (pump), milk, oil, foam), after sun (cream, milk, oil), tanning (spray (pump), milk, oil), shaving (gel, foam, cream, soap, shower gel), after shaving (lotion, cream, oil, talc), depilatory (depilatory cream, wax, strips), after depilatory (cream, gel, lotion), nail polish (base coat, polish, top coat) and remover products.

(percentage of users, Sun Protection Factor, galenic form and application area) was collected via a web-based questionnaire on 567 French families. The consumption (period of use, number of use, frequency of use, amount per use and amount per day) and the exposure of 95 French families (337 adults and children) to a SPF 50 sunscreen spray product during the 2014 summer holidays were studied. The daily usage of sunscreen spray was recorded in a diary and the amount used was collected by weighing at the beginning and at the completion of the study in order to determine the total amount of product used. The exposure was assessed using the Monte Carlo probabilistic method (Gomez-Berrada et al., 2018a).

Hair dye: Hair dye products'usage patterns and exposure were assessed on 4237 French adult women using three national web surveys (2013–2015). Information about the place of use (at the hairdressers, at home), the type of products (professional or supermarket products) or the line of products (hair bleach, lightener, permanent dye, semi-permanent dye, temporary dye, or vegetal dye) was collected. Percentage of users and frequency of use were calculated. The exposure was assessed using the Monte Carlo probabilistic method (Bernard et al., 2016).

Baby wipes on diaper area: A probabilistic exposure model to assess the transfer of a lotion from wipes to babies'diaper skin was developed. A diary study was conducted in 2013 to determine the number of wipes used per day, on 531 children up to 48 months of age, from United Kington, Germany and United States. The lotion transfer was measured (Dey et al., 2016).

Toothpaste: Consumption (frequency of use, amount per use and amount per day) and exposure to toothpaste were assessed in 2015 in 104 French families over a 3-week period. In total, data were collected on 206 adults and 195 children aged 2–17. The daily usage of toothpaste was recorded in a diary and the amount used was collected by weighing at the beginning and at the completion of the study in order to determine the total amount of product used. The exposure was assessed using the Monte Carlo probabilistic method. The influence of toothbrush kind (manual or electric) on consumption was evaluated (Gomez-Berrada et al., 2018b).

Nail polish: The consumption of nail polishes (base coat, polish, top coat) and nail polish remover was assessed in French adult and children in 2013 (n = 1813). Percentage of users, frequency of use, wearing time, number of coats applied and place of manicures were obtained by a national web questionnaire survey. Real applications were carried out with 110 volunteers to collect data on the amount of product used per application by weighing, setting and drying time. Exposure was assessed for cutaneous, inhalation and oral routes (Ficheux et al., 2014).Specific to a type of ingredient

Products containing tea tree oil: Consumption data were collected on online-panels of users of products containing tea tree oil. 2535 users from France, Germany, Great Britain, Italy and Spain were included in the study. Consumption and exposure data were obtained on 11 product types such as face cleansing, foot deodorant spray or hand wash soap. Daily frequency of use, amount per use (estimated using photographs) and exposure were available for all the products and for the tea tree oil ingredient (Rieder, 2017).Specific to a location

Beauty salon: Consumption and exposure to French consumers to cosmetic products in beauty salons was assessed. The study was carried out among 117 women in 3 beauty salons (2 in Brest and 1 in Laval cities) in 2015. Frequencies of use data were obtained by questionnaires, amount per use data were collected by weighing the products and exposure was assessed by a Monte Carlo probabilistic method. Facial care products (scrub and mask) and hair removal wax were studied. Additional consumption and exposure data were obtained for beauty professionals (not presented in the poster) (Coinet et al., 2015).Specific to a container

The consumption of shampoo, shower gel and emollient cream contained in a tube with a flip top cap and in a bottle with a pump was assessed on a panel of 221 French adults over a 3-week period.

Table 2
Epidemiological studies conducted in Europe.

Population	Sex	Age (years old)	N	Products studied	Consumption data	Additional data	Method(s) of data collection	Period of data collection	Name of the study	References
Swedish	M and F	Adolescents 16	3115	Hair dye	Percentage of users	/	Questionnaire	2010–2012	Swedish abbreviation for Children, Allergy, Milieu, Stockholm, Epidemiology (BAMSE)	Lagrelius et al. (2017)
French	F	Pregnant women 29 (mean)	219	Hair spray, colouring shmpoo	Percentage of users	Mother were asked on lifestyle during the first trimester of pregnancy	Questionnaire	2011–2014	/	Haraux et al., 2017
Norwegian	F	Adults 41-76	114	Body lotion, hand cream, face cream, sunscreen, perfume	Percentage of users, frequency of use	/	Questionnaire	2003–2011	The Norwegian Women and Cancer study (NOWAC)	Aniansson et al. (2016)
Czech	M and F	Adults 18-65	201	Face cream, face and eye makeup, perfume and cologne, face lotion, lipstick, hand cream, body creas, sun cream, deodorant and antiperspirant, soap, shampoo, hair spray, hair gel, nail polish, toothpaste	Frequency of use (data not shown in the publication)	/	Questionnaire	Not mentioned	FANTOM	Müllerová et al., 2016

M: males, F: females, N: Number of participants, NM: Not mentioned.

Participants were asked to record in a diary the daily usage of each product and the corresponding amount used was collected by weighing at the beginning and at the completion of the study in order to determine the total amount of product used (Gomez-Berrada et al., 2017b).Specific to a protocol type

Some consumption and probabilistic exposure data were obtained from clinical safety studies aimed to assess the cutaneous tolerance and efficacy of cosmetic products over a 7–28-day period. The frequencies of use, close to real life conditions of use, were defined by the protocol of the study. The amount of product used per application depended on the usage patterns specific to each participant. Products were weighed at the beginning and at the completion of the study in order to determine the total amount of product used.

Data on cosmetic products dedicated to babies and children were obtained from 48 clinical studies (2001–2011) mostly conducted in Europe (Spain, France, Italy, Germany and Macedonia). 4 studies were conducted in Mauritius. Usage patterns and exposure were studied on 1481 babies and children aged 0–10 years for 6 categories of products: rinse-off products for hair and body, rinse-off products for the whole body, leave-on products for face and body, cleansers, diaper dermatitis treatment products and shampoos (Gomez-Berrada, 2013).

Data on sun care products were obtained from 75 clinical safety studies conducted on 3001 children (3–14 years old) and adults between 2006 and 2016 in Mauritius, Spain, France and Italy. 6 types of products were studied: sunscreen cream, sunscreen milk, sunscreen spray, sunscreen stick, moisturizing cream with SPF and after-sun milk (Gomez-Berrada et al., 2017c).

Consumption and exposure to family products were obtained from 87 clinical studies conducted in Europe (France, Macedonia, Spain, Germany, Poland and Portugal). 2994 babies (0–3 years old), children (4–12 years old) and adults were involved between 2002 and 2016.10 types of products were assessed, such as shampoo, shower gel, solid soap or cleansing lotion (see Table 1 for a full list) (Gomez-Berrada et al., 2017d).

3.1.1.1.3. Additional consumption data. The RIVM Cosmetic Fact Sheet document provided consumption default values for 35 categories of cosmetic products, including general hygiene, care, makeup, sun care or baby care products (Bremmer et al., 2006).

The Danish EPA provided data on liquid hand soap amount per use on adults in the workplace (Larsen and Andersen, 2006).

Another study performed in 30 households in Delf, (Netherlands) assessed hairsprays frequency of use and amount per use (Weegels and van Veen, 2001).

3.1.1.1.4. Focus on co-use data. Co-use patterns of cosmetic products were assessed on a Swiss children, adolescents and adults population (Garcia-Hidalgo et al., 2017; Manová et al., 2013).

The number of products and the number of products daily used per subject were assessed on a French population (babies, children, adults and pregnant women) (Ficheux et al., 2015) (See section 3.1.1.1.1 for the description of the studies).

The Kantar Worldpanel Usage Toiletries and Cosmetics Database contains habits and practices data for subjects from the United States and Europe. This database was used to highlight the top 20 co-use combinations of product types in adult for the US and EU regions combined (Comiskey et al., 2015, 2017).

3.1.2. Epidemiological studies (Table 2)

The associations between skin exposures and skin symptoms in relation to contact allergy were assessed in a longitudinal cohort of Swedish adolescents (BAMSE cohort). Among information contained in the publication, the percentage of hair dye users collected by a questionnaire on 3115 adolescents girls and boys aged 16 is available (Lagrelius et al., 2017).

A case-control study was conducted in 16 French maternity between 2011 and 2014. Cases were defined as male newborns with hypospadias and controls were male newborns without hypospadias. Mother's

lifestyle (household, environmental and occupational exposure) over the first trimester of pregnancy was assessed by questionnaires (n = 219). The percentage of mothers who used hair cosmetic products (hairspray and colouring shampoo) during pregnancy was collected (Haraux et al., 2017).

The Norwegian Women and Cancer study (NOWAC), a cross-sectional study conducted on 114,202 Norwegian adult women, aimed to assess the application of skin care products (body lotion, hand cream and face cream) between heavy-users and non-users and to compare life style characteristics (smoking history, drinking alcohol …). The percentage of users and the frequency of use parameters were presented in the publication. Additional data on sunscreen and perfume uses were also described (Aniansson et al., 2016).

A large epidemiological study focused on the potential link between obesity, its metabolic co-morbidities and the exposure to endocrine disrupting chemicals. In this context, the use of cosmetic products was assessed in a cohort of 201 Czech non-obese healthy adults (men and women). Use frequency was collected for many cosmetic product types, including face cream, makeup, perfume, deodorants or hair spray (see Table 2 for a full list). However, results were not presented in the publication (Müllerová et al., 2016).

3.2. Data obtained in America

3.2.1. Consumption studies

3.2.1.1. Presentation of studies

3.2.1.1.1. Representative large scale study (Table 3). Usage patterns and consumption of cosmetic products was studied on US adult women between 2000 and 2005.360 consumers aged 19–65 who regularly used the products of interest were recruited at ten different geographical locations within the US. Adult women were provided with test products and recorded detailed daily usage information in a diary over a 2-week-period. Products were weighed at the beginning and at the completion of the study in order to determine the total amount of product used. Products were lipstick, body lotion, face cream, hairspray, spray perfume, liquid foundation, shampoo, body wash, solid antiperspirant, facial cleanser, hair conditioner and eye shadow. Consumption parameters were obtained using probabilistic methods. Distributions of use patterns, including percentage of users, frequency of use and amount used (per use and per day) were derived. These studies were conducted by cosmetic companies and their associations (Loretz et al., 2006, 2005, 2008).

Both publications mentioned below are part of the SUPERB project (Study of Use of Products and Exposure-Related Behaviors) that focused on behaviors influencing exposure to environmental chemicals in the home environment (Hertz-Picciotto et al., 2010). Information on cosmetic usage patterns were collected by phone interviews between 2006 and 2009 in 604 California households (453 households with children and 151 households with an older adult) randomly sampled. 30 types of cosmetic products were studied, such as general hygiene, skincare, makeup or hair products (see Table 3 for a full list). Percentage of users and frequency of use were collected in children and in adults. Only results collected over the first year were presented in the publication (Wu et al., 2010). Passive sampling methods were used to assess the consumption of cosmetic products in 47 Californian households: 30 household consisted of families with young children and 17 households consisted of families with elderly people. The types of products found in households and the amount used over a 1-week period, obtained by weighing, were reported. 17 categories of products were taken into account including shampoo, facial moisturizer, hair styling products, fragrance or sun block (see Table 3 for a full list). Results were presented for the whole household (Bennett et al., 2012; Hertz-Picciotto et al., 2010).

3.2.1.1.2. Other studies (Table 3)Specific to a type of subpopulation

Pregnant women: The use of cosmetic products was assessed in a cohort of 80 pregnant women in Ottawa (2009–2011). Information was collected six times during pregnancy and the post-partum period. 16 categories of cosmetic products were taken into account including general hygiene, baby, hair styling and makeup products (See Table 3 for a full list). General consumption parameters were obtained within a 24 h or a 48 h period. However, scarce data such as the total number of cosmetic product applications per day, the number of products daily used, or the co-use combinations of products were generated (Lang et al., 2016).

Adolescents: Usage patterns (percentage of users and frequency of use) were assessed among 357 US adolescents aged 11–18 in middle- and high school. 10 categories of products were studied including hygiene, body and facial products (See Table 3 for the list of product types). Furthermore, the relation between the use of cosmetic products and the degree of media influence was evaluated (Yoo and Kim, 2010).

Cosmetologists: An online survey was performed to gather information on respiratory issues related to work in cosmetologists, esthetician and manicurists in Minnesota. 2058 people participated in this survey conducted in 2011. Data about work history, respiratory symptoms, health and safety training and product usage were collected. Percentage of users data were generated for curling/wave, straightener, colouring and bleach hair products (Norlien et al., 2017).Specific to a type of product

Baby wipes: The baby wipes lotion transfer to premature and term neonatal babies'skin was studied in 121 hospitalized infants aged 24–42 weeks (Newborn Intensive Care Unit of Cincinnati Children's Hospital Medical center, USA). The number of wipes used per day in diaper area data was also described, and exposure was assessed (Hossain et al., 2015).

A probabilistic exposure model for lotion transfer to diapered skin of babies was developed. European and American consumption data were taken into account (see section 3.1.1.1.2 for more details) (Dey et al., 2016).

Sunscreen and mouthwash: Data from the National Health and Nutrition Examination Survey (NHANES) questionnaire was used to examine associations between the use of sunscreen and mouthwash, and urinary concentrations of phthalate metabolites and phenols in a nationally representative cohort of 3529 American adults from the US (2009–2012). The percentage of users is mentioned in the publication (Ferguson et al., 2017).

Tanning products: The use of artificial tanning products was assessed in 448 adults aged 18–30 in Boston (USA) during summer 2004. Percentage of users was presented for sunless tanning lotions and spray tans (Brooks et al., 2006).

The percentage of sunless tanning product types (lotion, cream and spray) was studied in 2007 on 181 adult women users of tanning products in Boston (Mahoney, 2012).

The percentage of sunless tanning product was also assessed in a cohort of 415 adult women in Atlanta (Sahn, 2012) and in a cohort of 1600 adolescents (M and F) (Cokkinides et al., 2010).

Toothpaste: A clinical study assessed the consumption of toothpaste in 90 children aged 2–12 (Miamiville, USA). Toothpaste ingestion and amount used per application were calculated (Strittholt et al., 2016). The duration of consumption of toothpaste in the household and the number of brushing per day was measured in 688 Brazilian households in 2009. Mothers answered the questionnaire for the whole family (Colussi et al., 2011).Specific to a protocol type

Clinical safety studies aimed to assess the cutaneous tolerance and efficacy of cosmetic products were used to obtain consumption and exposure data on sun care products and babies/children products. Brazilian participants were included in studied populations (see section 3.1.1.1.2 for the description of study) (Gomez-Berrada et al., 2017d).Behavior in a Brazilian population

The consumption behavior among 101 Brazilian adults was studied in 2015. The publication focused on the buying motivations, but some consumption data such as the type of products used was collected (Infante, 2016).

Table 3
Consumption studies conducted in America.

Population	Sex	Age (years old)	N	Products studied	Consumption data	Additional data	Method(s) of data collection	Period of data collection	Product exposure data (mg/kg bw/day)	References
Large scale study										
USA	F	Adults 19-65	360	Lipstick, body lotion, face cream, hairspray, spray perfume, liquid foundation, shampoo, body wash, solid antiperspirant, facial cleanser, hair conditioner, eye shadow	Percentage of users, number of applications per day, number of application per body area, amount per use, amount per day	/	Diary Amount used: weighting	2000–2005	No	Loretz et al. (2005), 2006, 2008
California	M and F	NM	453 households with children; 151 households with an older adult	Shampoo, hair conditioner, bath gel, body lotion, hand lotion, deodorant, liquid soap (antibacterial and not antibacterial), waterless hand sanitizer, facial cleanser, facial moisturizer, mask/deep cleanser, anti-aging or overnight cream, lip balm/lipstick, sunscreen, hair dye, hair perm, hair spray, hair mousse, foundation, mascara, nail polish, fragrance, aftershave	Percentage of users, frequency of use,	Preferences in selecting products	Phone interview	2006–2009	No	Wu et al. (2010)
California	M and F	NM	30 households with children; 17 households with an older adult	shampoo/conditioner, liquid soap, antibacterial soap, hand sanitizer, hand and body lotion, facial moisturizer, body wash, hair styling products, nail polish, foundation, make-up, aftershave, fragrance, sun block, bubble bath, baby shampoo, baby bath, baby lotion	Amount used in 1 week	/	Weighing	NM	No	Bennett et al. (2012)
Other studies										
Canadian (Ottawa)	F	Pregnant women 32.4 (mean)	80	baby lotions, soaps and other baby products, general makeup, lip products, eye makeup, hairstyling products, nail polish and remover, fragrance, deodorant/antiperspirant, body lotion, cream, oil, face lotion and cream, body soap, facial soap, cleanser and wash, toothpaste and mouthwash, hand soap, sanitizers, shampoo, conditioner	Percentage of users, frequency of use, number of products daily used, co-use, number of applications within a 24 h period	Consumption parameters were asked across all trimesters of pregnancy and into postpartum period	Diary	2009–2011	No	Lang et al. (2016)
USA	M and F	Adolescents 11-18	357	Shampoo and/or conditioner, hairstyling gel/hairspray, hair dye, body products (body wash, lotion), facial products (facial soap, moisturizer), perfume, acne treatment products, hygiene proucts (deodorant, toothpaste), cosmetics, nail products	Percentage of users, frequency of use	Relation between consumption habits and the degree of media influence	Questionnaire	NM	No	Yoo and Kim (2010)
USA (Minnesota)	M and F	Adults > 15	2058	Hair products: curling/wave, straightener, colouring, bleache products	Percentage of users		Questionnaire (web survey)	2011	No	Norlien et al. (2017)

(*continued on next page*)

Table 3 (*continued*)

Population	Sex	Age (years old)	N	Products studied	Consumption data	Additional data	Method(s) of data collection	Period of data collection	Product exposure data (mg/kg bw/day)	References
USA (Cincinnati)	M and F	Babies 24–42 weeks	121	Baby wipes	Lotion transfert measurement, number of wipes per day	Hospitalized infants	Experimental data (lotion transfer) and standard practice (diaper change)	NM	Yes	Hossain et al. (2015)
USA	M and F	Adults	3529	Mouthwash and sunscreen	Percentage of users	/	Questionnaire	2009–2012		Ferguson et al. (2017)
USA (Boston)	M and F	Adults 18-30	448	Sunless tanning lotions and spray tans	Percentage of users		Questionnaire	2004	No	Brooks et al. (2006)
USA (Boston)	F	Adults 18-40	181 users of tanning products	Sunless Tanning products: lotions, creams, and salon-administered sprays	Percentage of users	/	Face to face interview	2007		Mahoney, 2012
USA	M and F	Adolescents 11-18	1,6	Sunless Tanning products	Percentage of users	/	Phone interview	2004		Cokkinides et al. (2010)
USA (Miamiville)	M and F	Children 2-12	90	Toothpaste	Amount ingested, amount per use		Experimental data, weighting	NM	No	Strittholt et al. (2016)
Brazilian	F	NM	688 households	Toothpaste	Duration of consumption of a tube of toothpaste in the household, number of brushing teeth per day	Mothers answered the questionnaire for the whole family	Face to face interview	2009		Colussi et al. (2011) (publication in Brazilian)
Brazilian	M and F	Adults 18-35	101	Soap, toothpaste, hair products (anti hair loss topical lotion, styling spray, mousse, mascara, dry shampoo, shampoo, conditioner), skin products (Perfume, facial moisturizer, body moisturizer, astringent lotion, products for acne, makeup, makeup remover, anti-aging cream, thermal water, anti-spot cream), sunscreen, lip balm	Percentage of users	/	Questionnaire	2015	No	Infante, 2016

M: males, F: females, N: Number of participants, NM: Not mentioned.

3.2.1.1.3. Focus on co-use data. The Kantar Worldpanel Usage Toiletries and Cosmetics Database was used to highlight the top 20 co-use combinations of cosmetic product types in adult for the US and EU regions combined (Comiskey et al., 2015, 2017).

Co-use and non-use data were generated on 3297 adult women for 9 cosmetic products to refine an aggregate exposure model (internal P&G consumer study) (Cowan-Ellsberry and Robison, 2009).

The number of cosmetic products used in the last 24 h was evaluated in a cohort of 337 adult women with a young child. Results showed that 25% of women reported using 9 or more product types (Parlett et al., 2013).

The use of cosmetic products was assessed in a cohort of 80 pregnant women in Ottawa (2009–2011). General consumption parameters were obtained within a 24 h or a 48 h-period and information on the number of products daily used or the co-use combinations of products were generated (see section 3.2.1.1.2 for more details) (Lang et al., 2016).

3.2.2. Epidemiological studies (Table 4)

3.2.2.1. Studies conducted in the US. The link between cosmetic products use during pregnancy and the risk of testicular germ cell tumors (TGCT) in sons was assessed in 1089 American women between 2002 and 2005. Mothers of both cases (sons with TGCT) and controls (sons without TGCT) were asked to report on the use and on the frequency of use during their pregnancy and breastfeeding for 9 product types including hair dye, hair perm/relaxer, sunscreen and nail polish (see Table 4 for a full list). Consumption data were also available depending on women skin color. However, authors mentioned that women were asked to remember events from 1960 to 1980, so their answers could be very approximate (Ghazarian et al., 2018).

The association between childhood hair product use and early age at menarche and the association between childhood and adult hair product use and adult mammographic breast density were assessed in two urban women cohorts (n = 248) between 2001 and 2008.6 types of hair products were taken into account: oil, lotion, leave-in conditioner, root stimulator, perm/relaxer and dye. Percentages of users are presented in the publication (James-Todd et al., 2011; McDonald et al., 2018).

The association between cosmetic products use and exogenous hormone use (oral contraceptive and hormone therapy use) was studied in 47,019 adult women from the NIEHS Sister Study (2003–2009). Consumption data (percentage of users and frequency of use) were obtained for 48 types of cosmetic products. Morover, the association between cosmetic product use and two common estrogenic medications was examined. However, consumption results were not presented in the publication (Taylor et al., 2017).

The association between the use of hair product (dye, relaxer/straightener) and breast cancer was studied in a case-control study conducted among 4285 adult women between 2002 and 2008. The percentage of users, the frequency of use, the usual shade and application used (home-kit or salon) and the total duration of use were collected and results were presented depending on origin (African or white American women) (Llanos et al., 2017).

3.2.2.2. Study conducted in Brazil. The link between maternal use of hair dye and hair straightening products during pregnancy and leukemia in children was assessed in a multicenter case-control study carried out in 13 Brazilian states between 1999 and 2007.650 adult women were included in this study. Percentage of use parameter was asked over all trimesters of pregnancy as well as breastfeeding period (Couto et al., 2013).

3.3. Data obtained in Asia

3.3.1. Consumption studies

3.3.1.1. Presentation of studies (Table 5)

3.3.1.1.1. Representative large scale study. A study was conducted during summer 2012 on a sample of 3333 Korean women and men aged 15 and older. Participants were randomly selected from 15 metropolitan areas and provinces. Face-to-face interviews using a questionnaire about percentage of users, frequency of use, amount per use and time spent using each product were performed. 5 cosmetic products, face cleanser, toothpaste, shampoo, hair conditioner and body wash were taken into account. Consumption data were generated using a deterministic method. Circumstances of use (place of use, volume of place and ventilation) and reliability of questionnaire data were also investigated. This study was supported by Korea Ministry of Environment (Park et al., 2015).

3.3.1.1.2. Other studiesSpecific to a type of subpopulation

Babies: The consumption and the exposure to baby products were assessed among 336 babies under the age of 36 months living in Seoul and Pusan (Korea). 7 product types were taken into account: leave-on face cream, leave-on body cream, oil-type leave-on lotions, sunscreen, liquid type cleanser, shampoo and wet wipes. Parents used their own products at home for a 14-day period. Frequency of use was daily recorded in a diary; amount of product was obtained by weighing. Enquiries were performed in summer and in winter; and a comparison of consumption and exposure values between seasons was assessed (Lee et al., 2017).

Adult women: The consumption of cosmetic products was assessed in a population of Japanese adult women living in Tokyo (n = 600). Volunteers were asked to use their own products as usual for at least a 2-week period and to report each use in a diary. Amount data were collected by weighing each product at the beginning and at the end of the study. 17 types of cosmetics were studied such as lotion, emulsion, facial mask pack, sunscreen or makeup (see Table 5 for a full list). Surveys were carried out during summer and winter for skincare products, and a comparison of consumption values obtained for each season was performed. Data for the other product types were collected only during summer. Comparisons of hand use and cotton use for lotion and emulsion products were also presented (Yamaguchi et al., 2017).

Aggregate risk assessment to 11 phthalate esters was assessed in Chinese adult women. A questionnaire survey conducted in 2013 in Shanghai on 103 adult women (20–55 years old) allowed to collect frequency of use data. About 20 types of products were studied, including shampoo, perfume, skin toner or makeup (see Table 5 for a full list). Amount data were obtained from literature (Bao et al., 2015).

Risk assessments to four phthalates (DEHP, DEP, DBP and BBP) found in perfume, deodorant, nail polish and hair product were performed. In this case, a questionnaire was designed to obtain frequency and volume of products used by 150 adult women (20–73 years old) living in Suwon (Korea) (Koo and Lee, 2004).

The prevalence of cosmetic product-related contact dermatitis was studied among 360 adult women from two geographical areas of Israel (coastal and mountain). Face-to-face interviews were carried out at pharmacies and beauty salons. Cosmetic products consumption habits were collected (data not shown in the publication) (Trattner et al., 2009).

Elementary school students: Cosmetic products of interest and makeup behaviors were assessed in 300 elementary school students from a private school in Seoul (Korea). Data were collected by questionnaire in 2012. Measured variables were beauty involvement, interest in beauty product, beauty behavior and cosmetic consumers behavior. However, no consumption results are presented in the publication (Barng, 2017).

3.3.2. Epidemiological studies

No epidemiological study performed in Asia was found.

3.4. Data obtained in Africa

3.4.1. Consumption studies

Clinical safety studies aimed to assess the cutaneous tolerance and efficacy of cosmetic products allowed to obtain consumption and

Table 4
Epidemiological studies conducted in America.

Population	Sex	Age (years old)	N	Products studied	Consumption data	Additional data	Method(s) of data collection	Period of data collection	Name of the study	References
USA	F	Pregnant and/or breastfeeding women 24 (mean)	1089	perfume, hairspray, nail polish, hair dye, perm/ relaxer, face lotion, body lotion, deodorant/ antiperspirant, sunscreen	Percentage of users, frequency of use, number of products used among the 9 proposed	/	Questionnaire	2002–2005	US Servicemen's Testicular Tumor Environmental and Endocrine Determinants (STEED)	Ghazarian et al. (2018)
USA (New York)	F	Adults 40-60	248	Hair products: oil, lotion, leave-in conditioner, root stimulator, perm/relaxer, dye	Percentage of users	Consumption during childhood (before age of 13) and adulthood (since age 20)	Phone interview	2001–2006 and 2007–2008		James-Todd et al. (2011); McDonald et al. (2018)
USA	F	Adults 35-74	47,019	48 product types. Complet list in the supplementary material (not found)	Frequency of use (data not shown in the publication)	/	Questionnaire	2003–2009	The Sister study	Taylor et al. (2017)
USA (New York city and ten countries in New Jersey)	F	Adults 20-75	4285	Hair dye and relaxer/ straightener	Percentage users, frequency of use, total duration (years) of use, typical application used (home-kit or salon) and typical shade used	/	Questionnaire	2002–2008	The Women's Circle of Health Study (WCHS)	Llanos et al. (2017)
Brazilian	F	Pregnant women > 19	650	hair dye, hair straightening	Percentage of users	Consumption parameters were asked across all trimesters of pregnancy and into breastfeeding period	Face to face interview	1999–2007	Multi-Institutional Study of Infant Leukemia	Couto et al. (2013)

M: males, F: females, N: Number of participants, NM: Not mentioned.

exposure data on sun care, family and babies/children products. Mauritian and South African participants were included in the studied populations (see section 3.1.1.1.2 for the description of studies) (Gomez-Berrada, 2013; Gomez-Berrada et al., 2017d, 2017c).

3.4.2. Epidemiological study (Table 6)

A cross-sectional study conducted in Jigjiga (Ethiopia) on 600 adults of both sexes assessed the use of cosmetic products and the occurrence of adverse events related to their use (allergic reactions, acne …). 9 types of products were taken into account: deodorant, face powder, lipstick, hair cosmetics, toothpaste, eye makeup, skin colorant, nail polish and soap. Information on the percentage of users, the frequency of use and the number of products daily used were available (Bilal et al., 2017).

3.5. Consumption data used in aggregate exposure models

RIVM and Dutch consumption databases: The aggregate exposure to methyl-, ethyl-, propyl- and butyl-paraben was assessed in children aged 0–3 years. 17 types of products were studied: baby oil, baby powder, massage oil, ear cleaner, anti-cradle cap product, sunscreen, after sun, hair lotion, 2 in 1 shampoo, body lotion, shower bath/soap, bath oil, liquid soap, toothpaste, baby wipes and babysalve. Authors applied a deterministic (tier 1) and a person-oriented probabilistic approach (tier 2) for exposure calculations. In tier 1 step, ConsExpo consumption default values were used (Bremmer et al., 2006). In tier 2 step, consumption data (frequency of use and amount per use) were generated from a small pilot study performed with an online questionnaire on Dutch parents of 28 children aged 0–3 (Gosens et al., 2014).

Swiss and Dutch consumption database: Manová et al. (2015) assessed the aggregate exposure to ethylhexyl methoxycinnamate. 9 types of products were included in the model: face cream, body lotion, aftershave lotion/balm, hand cream, makeup foundation, lip care, lipstick, and sunscreen. Consumption data were previously obtained by the authors: frequency of use data were derived from a Swiss adult and child population (Manová et al., 2013) and amount per use data were obtained from an adult Dutch population (Biesterbos et al., 2015).

Dutch consumption database: The aggregate exposure to diethyl phthalate, decamethyl-cyclopentasiloxane, geraniol or methylisothiazolinone in cosmetic products were assessed using a Dutch adults consumption database previously described in section 3.1.1.1.1 (Biesterbos et al., 2013). The data were used to develop and to validate a person-oriented exposure model: the Probabilistic Aggregate Consumer Exposure Model (PACEM) (Delmaar et al., 2015; Dudzina et al., 2015; Ezendam et al., 2018; Nijkamp et al., 2015).

European and North American consumption databases: A model was developed to estimate the aggregate exposure to fragrance ingredients in cosmetic products: the Creme RIFM aggregate exposure model. Consumption data were obtained from the Kantar Worldpanel Usage Toiletries and Cosmetics Database which is usually used for marketing research purposes. This database contains habits and practices data on subjects from The United States and Europe. Data from 36,446 subjects aged at least 18 were taken into account, including frequency of use or application sites. Amount per use data were previously collected by Colipa (now Cosmetics Europe) for European adult consumers (Hall et al., 2007, 2011) and by CTFA (now the Personal Care Products Council) for US American adult consumers (Loretz et al., 2006, 2005, 2008) (see section 3.1.1.1.1 and 3.2.1.1.1 for the description of European and American studies, respectively). 19 types of products representing seven product categories (body lotion, deodorant, oral care, styling, hydro-alcoholics, shower and moisturizers) were used in the model (Comiskey et al., 2015; Safford et al., 2015). This model was recently expanded to 8 new fragrance ingredients (Safford et al., 2017).

A probabilistic aggregate exposure model was developed to estimate consumer exposure from 5 rinse-off cosmetic products containing zinc pyrithione: shampoo, shower gel, bar soap, liquid hand soap and cleanser (Tozer et al., 2015). Frequency of use and co-use data were obtained from two web surveys conducted by Procter and Gamble on an sample of 4262 US American adult representative of the US population using the National health and nutrition examination survey (NHANES) demographic information. Amount per use data were previously obtained by Colipa (now Cosmetics Europe) in a European adult sample (Hall et al., 2007, 2011) (see section 3.1.1.1.1 for more details).

French consumption database: The aggregate exposure to phenoxyethanol and parabens were assessed using a French consumption database (Ficheux et al., 2015, 2016a). Consumption data were obtained from 2838 adult women and 9 types of products were included in the model: day cream, night cream, cleansing milk, eye contour gel, toothpaste, body milk, slimming gel, body oil and intimate hygiene product. A probabilistic approach was used (Morsch et al., 2015).

4. Discussion

4.1. General point on data available in literature

82 references were included in this review, and most of them were published in 2010s. Most of the studies, called in this review “consumption studies”, were conducted to assess the cosmetic products usage patterns in a population and, in half of the cases, to assess the corresponding exposure. Studies classified as epidemiological studies were conducted to evaluate the association between cosmetic products or cosmetic ingredients consumption and adverse events. They provide additional information on cosmetic product's consumption. Most of the data available were recently generated, on different subpopulations, in different countries, on many types of products, and co-use data were obtained.

4.1.1. Data obtained in different subpopulations

In 2000s, consumption data were available only on European adults (Hall et al., 2007, 2011) and on American women (Loretz et al., 2006, 2005, 2008); consumer exposure was assessed only in the European studies. No data specific to population at risk such as babies, children, adolescents or pregnant women were available. A study conducted at the beginning of 2010 on French pregnant women showed that exposure values obtained in pregnant women were higher than exposure values obtained in the general European adult population for many types of products. The authors emphasized that differences may exist between some particular subpopulations (Bavoux et al., 2011). Studies conducted in different subpopulations then multiplied, and large differences in consumption and/or exposure were highlighted depending on age or sex. Consumption/exposure data were provided on products used for babies/children, such as cleansing products, moisturizing products, Eau de toilette, wipes, but also products for the nappy area or sunscreen products (Dey et al., 2016; Ficheux et al., 2015, 2016a; 2016b; Garcia-Hidalgo et al., 2017; Gomez-Berrada, 2013; Gomez-Berrada et al., 2017a, 2017d; 2017c, 2018a; Hossain et al., 2015; Lee et al., 2017; Manová et al., 2013). Consumption and exposure data were also generated on adolescents (Bernard et al., 2018; Cokkinides et al., 2010; Den Hond et al., 2013; Ficheux et al., 2015, 2016a; 2016c; Garcia-Hidalgo et al., 2017; Gomez-Berrada et al., 2017c; Lagrelius et al., 2017; Manová et al., 2013) and on pregnant women (Couto et al., 2013; Ficheux et al., 2015; Ghazarian et al., 2018; Haraux et al., 2017; Lang et al., 2016; Marie et al., 2016). These data are very important for safety assessment. In fact, young people could be more susceptible to the effects of chemical exposure than adults because of a greater surface area to weight ratio, a higher metabolic rate and immature organ systems (Becker et al., 2010). Adolescents are of particular concern because they are in a period of accelerated development such as the maturation of the reproductive systems or a rapid bone growth (EWG, 2008). Pregnant women are an important subpopulation because of the potential health impact of their exposure on the fetus, for which

Table 5
Consumption studies conducted in Asia.

Population	Sex	Age (years old)	N	Products studied	Consumption data	Additional data	Method(s) of data collection	Period of data collection	Product exposure data (mg/kg bw/day)	References
Large scale study										
Korean	M and F	Adults ≥ 15	3333	Face cleanser, toothpaste, shampoo, hair conditioner, body wash	Percentage of users, frequency of use, amount per use, time spent using product	Circumstances of use: place of use, volume of place and ventilation	Face-to-face questionnaire	2012	No	Park et al. (2015)
Other studies										
Korean (Seoul and Pusan)	M and F	Babies 0–36 months	336	Baby products: leave-on face cream, leave-on body cream, oil-type leave-on lotions, sunscreen, liquid type cleanser, shampoo, wet wipes	Frequency of use, amount per use, amount per day	Lotion transfert ratio measurement from wipes to baby skin	Diary Amount used: weighting	2016	Yes	Lee et al. (2017)
Japanese (Tokyo)	F	Adults 18-74	600	Lotion, emulsion, cream, essence, makeup base, sunscreen, facial mask pack, powder foundation, liquid foundation, eyeliner, eyeshadow, eyebrow, mascara, lipstick, lip gloss, cleansing foam, makeup-remover	Percentage of users, frequency of use, amount per use, amount per day	Comparison of hand use and cotton use (lotion and emulsion)	Diary Amount used: weighting	2014–2015	No	Yamaguchi et al. (2017)
Chinese (Shanghai)	F	Adults 20-55	103	Perfume, shampoo, hair conditioner, hair gel, face cream/lotion, body lotion, skin toner, eye cream, sunscreen, face cleaner, body wash, makeup remover, hand cream, lip balm, hand soap, foundation, lipstick, eye shadow, mascara, eyebrown pencil, nail polish and remover	Frequency of use		Questionnaire	2013	No, but ingredient exposure assessment	Bao et al. (2015)
Korea (Suwon)	F	Adults 20-73	150	Perfume, deodorant, nail polish and hair product	Frequency of use, volume per use		Questionnaire	NM	No, but ingredient exposure assessment	Koo and Lee (2004)
Israel	F	Adults 15-89	360	NM	NM		Face-to-face questionnaire	NM	No	Trattner et al. (2009)
Korea (Seoul)	M and F	Elementary school students	300	NM	NM		Questionnaire	2012	No	Barng (2017)

M: males, F: females, N: Number of participants, NM: Not mentioned.

Table 6
Epidemiological study conducted in Africa.

Population	Sex	Age (years old)	Number of people	Products studied	Consumption parameters studied	Additional data	Method(s) of data collection	Data collection period	Name of the study	Reference
Ethiopian (Jigiga)	M and F	≥ 18	600	deodorant, face powder, lipstick, hair cosmetics, toothpaste, eye makeup, skin colorant, nail polish, soap	Percentage of users, frequency of use, number of products used per day	Information about traditional herbal cosmetics are available	Questionnaire	2014	/	Bilal et al. (2017)

M: males, F: females, N: Number of participants.

exposure may inflict life-long adverse health effects (Tefre de Renzy-Martin et al., 2014). Data specific to a professional use were also generated, such as hairdressers (Ramirez-Martinez et al., 2016). All data obtained for various subpopulations are essential to protect all consumer profiles.

4.1.2. Data obtained in different countries

As previously mentioned, two large databases on European and American populations were initially available in the literature. Many consumption but also epidemiological studies have been recently conducted in various European countries such as France, Switzerland, Netherland, Belgium, Sweden, Norway and Czech Republic (Tables 1 and 2). In America, other consumption and epidemiological studies were conducted in several cities in the US, but also in Canada and Brazil (Tables 3 and 4). Consumption studies have been recently conducted on Asian, Korean, Japanese and Chinese populations (Table 5). One epidemiological study reported usage patterns of cosmetic products in an Ethiopian population (Table 6). All these studies carried out in various regions of the world are important because differences in usage patterns of cosmetic products can be observed. For example, there are many differences between European, American and Japanese data. The amount of skin care products used per application by adult women was lower in the Japanese sample and the types of products used were different. Authors concluded that these differences could be explained by disparities in cosmetic customs as well as regional and climatic differences (Yamaguchi et al., 2017). In an epidemiological study conducted in African adults living in Ethiopia (Bilal et al., 2017), the percentage of cosmetic products users was much lower than those reported from Netherland, Swiss or French national studies (Biesterbos et al., 2013; Ficheux et al., 2015; Manová et al., 2013); and the number of products daily used was lower than values reported in a French population (Ficheux et al., 2015). All these data obtained are likely to be of great benefit for a safety assessor wanting to put a cosmetic product on the market in a particular region of the world.

4.1.3. Data obtained for many types of products

The two large European and American databases available in the 2000s covered about ten product types commonly applied by consumers. Recent studies were performed on a large number of product types. About 150 types of products were investigated in a national French study (Ficheux and Roudot, 2017). The usage patterns of cosmetic products was assessed in a Netherlands population for 32 types of products (Biesterbos et al., 2013), and in a Swiss population for 22 types of products (Garcia-Hidalgo et al., 2017). The changes in cosmetic products habits during pregnancy and risk perception were assessed in French women, for which 28 common types of products were investigated (Marie et al., 2016). Frequency of use data were collected in a Chinese population, with 22 types of products taken into account (Bao et al., 2015). These studies have shown differences in consumption/exposure values obtained for cosmetic products in a same line such as hair styling products (lacquer, gel, foam, wax or spray) (Ficheux et al., 2016c) or makeup remover products (milk, lotion or wipes) (Bernard et al., 2018). Other studies focused on one type of product, and provided many consumption information, such as studies focused on baby wipes (Dey et al., 2016), hair dye (Bernard et al., 2016), toothpaste (Colussi et al., 2011; Strittholt et al., 2016), nail polish (Ficheux et al., 2014) or sunscreen products (Gomez-Berrada et al., 2018a). For example, usage patterns of sunscreen products during summer holidays such as usual sun protection factor, usual galenic form or usual application area were collected, (Gomez-Berrada et al., 2018a). All these refined data are an important point for safety assessment.

4.1.4. Co-use data

Co-use patterns were assessed on Swiss (Garcia-Hidalgo et al., 2017; Manová et al., 2013), French (Ficheux et al., 2015), American people from the US and European people (Comiskey et al., 2015, 2017),

American people from the US (Cowan-Ellsberry and Robison, 2009; Parlett et al., 2013) and Canadian (Lang et al., 2016). As an example, on the 22 types of products investigated, Swiss adult women regularly used on average 13 cosmetic products versus 9 for adult men. Children (0–17 years old) used on average 11 products for girls and 7 for boys (Garcia-Hidalgo et al., 2017). The number of cosmetic products daily used was evaluated in a cohort of adult women with a young child. Among the 13 types of products studied, 25% of women reported using nine or more product types in the last 24 h (Parlett et al., 2013). A study carried out on French people showed that, among 141 types of products studied, 18 cosmetics were used daily by adult pregnant women, 16 by adult non-pregnant women, 8 by adult men, 7 for girls, 5 for boys and 6 for babies under 3 years old (mean values) (Ficheux et al., 2015). Co-use information is important for public health reasons because consumers use several cosmetic products a day, and consequently are potentially exposed many times a day to the same ingredient such as preservatives or perfume. Aggregate exposure models for ingredients found in cosmetic products, such as Probabilistic Aggregate Consumer Exposure Model (PACEM) (Dudzina et al., 2015; Manová et al., 2015; Nijkamp et al., 2015) or Creme RIFM models (Comiskey et al., 2015; Safford et al., 2015), are of great interest, and are part of the future of cosmetic safety assessment.

4.2. Point on methods in data collection

As it was described above, differences in age, sex or geographical region induce differences in term of consumption and exposure values for the same type of cosmetic product. Important methodological points could also explain the differences of values observed between studies, such as the representativeness of the sampling to a population or the methodology of data collection. These important points deserved to be developed.

4.2.1. Representativeness of the sampling

Most of consumption and epidemiological studies have been conducted with a representative sampling approach, such as randomed sampling, stratified sampling, systematic sampling, quota sampling or convenience sampling (Tyrer and Heyman, 2016). For example in consumption studies, population could be randomly selected (Biesterbos et al., 2013; Garcia-Hidalgo et al., 2017; Park et al., 2015), sampled according to quota method (Ficheux and Roudot, 2017; Lee et al., 2017; Rieder et al., 2017) or sampled by convenience (Bao et al., 2015). In epidemiological studies, systematic sampling (Taylor et al., 2017) or randomly sampling were used (Aniansson et al., 2016). Sampling plans are of great importance, because qualitative and quantitative data obtained can be extrapolated to an entire population (Levy and Lemeshow, 2013). Some consumption studies were also conducted without sampling plan, for example on a panel of consumers (Cowan-Ellsberry and Robison, 2009; Gomez-Berrada, 2013; Gomez-Berrada et al., 2017a, 2018a; Strittholt et al., 2016) or on subjects recruited on demographics or on consumption parameters (Yamaguchi et al., 2017). These subjects could have a different consumption behavior from the general population's one. In this case, the data obtained could be extrapolated to a specific population, but not always to the whole population.

4.2.2. Methods in data collection

Epidemiological studies permitted to obtain consumption data, especially percentage of users and frequency data (Tables 2 and 4). These data were obtained by questionnaires (self-administered, face to face or phone questionnaires). In consumption studies, frequency data were obtained by questionnaires or by diaries. In questionnaires, frequency scales were proposed depending on the type of products studied (Garcia-Hidalgo et al., 2017; Infante, 2016; Manová et al., 2015; Park et al., 2015). In diaries, each usage of cosmetic product was noted for a given period of use (2 or 3 weeks in general) (Gomez-Berrada et al., 2017a, 2018a; Hall et al., 2007, 2011; Loretz et al., 2006, 2005, 2008). The use of a diary could refine frequency data obtained in frequency scales if diaries are diligently completed during the required period. In a national French consumption study, frequency of use data obtained by questionnaire was refined using a 24-h recall by phone (Ficheux and Roudot, 2017). In consumption studies, amount data could be obtained by weigting or by estimation. In some studies, amount consumed could be obtained by weighing the product before and after a given period of use at home (Gomez-Berrada et al., 2017a, 2017b; 2018a; Hall et al., 2007, 2011; Loretz et al., 2006, 2005; 2008; Strittholt et al., 2016; Yamaguchi et al., 2017) or after a single use of the product at the laboratory (Ficheux et al., 2016a) or at the workplace (Coinet et al., 2015; Ramirez-Martinez et al., 2016). Amount per use data could also be estimated by photographs (Biesterbos et al., 2015; Garcia-Hidalgo et al., 2017) or by circle pads (Park et al., 2015). These methodologic choices could result in systematic bias of extreme values which could be for example conditioned by the minimum and the maximum amount of product presented by the photographs/circle cards. Moreover, the inter-individual variability would not be taken into account at its fair value. In Park et al. (2015) study, a comparison between the amount of toothpaste estimated by circle cards and the measured amount of this product consumed at home showed that the amount of toothpaste estimated by circle pads was lower than the measured amount. As it was demonstrated in Park et al. (2015) study), it would be preferable to focus on the amount data obtained by weighing in order to evaluate more precisely the consumption of cosmetic products.

5. Conclusion

This systematic review provides, for the first time, a state of art on consumption and exposure data of finished cosmetic product available in literature. Before the year 2000, very few studies were devoted to the consumption of cosmetics. In 2000s, only two large consumption databases on adult consumers were available. From a decade, consumption studies are increasingly numerous, and data were generated on various subpopulations (babies, children, adolescents, adults, pregnant women), on various geographical regions (Europe, North America but also Asia or South America) and on various types of products. Epidemiological studies bring additional consumption data obtained on large cohorts. Co-use data were generated, and aggregate exposure models were developed. All these data show the willingness of scientists to improve the safety assessment of cosmetic products. The challenge is now probably rather to begin sorting these data in order to choose the most appropriate data for safety assessment. A particular attention should be given to aggregate exposure models which are the future of cosmetic safety assessment.

Transparency document

Transparency document related to this article can be found online at doi:10.1016/j.fct.2018.11.060.

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