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Non-Metallic and Metallic Toxicant Exposures from Personal Care Products in Indonesian Male and Female Medical Students

Alby Dwinanda Putra,[1] Elmatris Syamsir,[2] Yulistini Yulistini,[3] Fathiyyatul Khaira,[4] Ennesta Asri,[5] Cimi Ilmiawati[6]

[1]Undergraduate Programme of Medicine, Faculty of Medicine, Universitas Andalas, Padang, Indonesia
[2]Department of Biochemistry, Undergraduate Programme of Biomedical Science, Faculty of Medicine, Universitas Andalas, Padang, Indonesia
[3]Department of Medical Education, Undergraduate Programme of Medicine, Faculty of Medicine, Universitas Andalas, Padang, Indonesia
[4]Department of Nutritional Science, Undergraduate Programme of Medicine, Faculty of Medicine, Universitas Andalas, Padang, Indonesia
[5]Department of Dermatovenereology, Undergaduate Programme of Medicine, Faculty of Medicine, Universitas Andalas, Padang, Indonesia
[6]Division of Environmental Toxicology, Department of Pharmacology and Therapeutics, Undergraduate Programme of Medicine, Faculty of Medicine, Universitas Andalas, Padang, Indonesia

Abstract

Students can gain various benefits from their daily personal care products. However, the chemicals contained in these products may have adverse health effects. Regardless the inspection performed by regulatory agencies on these products, the products circulating in the market may still contain toxicants thus may jeopardize their safety for use. This study evaluated toxicant ingredients contained in personal care products used by male and female college students. This study was conducted from September to December 2022 on 23 male and 46 female college students of the Faculty of Medicine, Universitas Andalas, Indonesia. Data were collected using a 69-items validated questionnaire. Results were then presented as a distribution of products used categorized by body areas and potentially toxic metallic and non-metallic ingredients identified from their labels. Female college students used at least 10 personal care products, with a median of 19 products. Male students used at least four products and a median of eight products. Investigation on the label of skin, hair, eye, dental and oral, lips, and nail personal care products demonstrated the presence of metallic and non-metallic toxicants. Five metallic toxicants (aluminum, titanium, zinc, copper, and chromium) and 15 non-metallic toxicants (triclosan, talc, fragrance, parabens, butylated hydroxyanisole, butylated hydroxytoluene, diethanolamine, triethanolamine, butylene glycol, propylene glycol, polyethylene glycol, phthalates, benzophenone-3, acetone, and fluoride) were identified. Thus, numerous toxicants are present in marketed personal care products, and females are exposed more than males to these toxicants. Consumers need to be more critical in their choice of personal care products.

Keywords: Cosmetics, chromium, fluoride, survey and questionnaires, triclosan

Introduction

Personal care products are essential for college students for their inherent properties in cleaning, beautifying, increasing attractiveness, or changing appearance when applied to the skin, hair, lips, nails, teeth, and mouth.[1] Personal care products include shampoo, body soap, conditioner, cosmetics, toothpaste, mouthwash, lotion, cream, hair oil, hair tonic, hair dye, deodorant or antiperspirant, body scrub, sunscreen, nail polish, nail hardener, nail polish remover, etc.[2–4] Research on female students in South Carolina, United States, concluded that they use at least one personal care product, with an average of eight products daily.[2]

Consumers often only focus on product benefits and ignore the details of the ingredients listed on the packaging of personal care products, even though it is not uncommon for personal care products to contain endocrine-disrupting chemicals (EDCs) such as phthalates,

Corresponding Author:
Cimi Ilmiawati,
Faculty of Medicine Universitas Andalas, Padang, Indonesia
Email: ilmiawati@med.unand.ac.id/
dr.ilmiawati@gmail.com

parabens, triclosan, benzophenone-3 (BP-3), bisphenols, etc., which can interfere with the average production, secretion and transportation of hormones throughout the body.[2] The development of personal care product industry has increased in recent years. Manufacturers often add chemicals to increase the effectiveness of a product's function by adding chemicals. Most consumers consider these products safe, but an estimated 10% of the 10,500 chemicals in personal care products have yet to be evaluated for safety.[4] In personal care products circulating in the market, both those that have been or have not been recognized by the Indonesian regulatory agency on drugs and food safety (*Badan Pengawas Obat dan Makanan* (BPOM)), still contain non-metallic toxicants (hydroquinone, fragrance, phthalates, parabens, butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT), diethanolamine (DEA), triethanolamine (TEA), polyethylene glycol (PEG), propylene glycol (PG), butylene glycol (BG), benzophenone-3 (BP-3), oxybenzone, triclosan, acetone, poly- and perfluoroalkyl substances (PFAS), fluoride, and talc/talcum powder) and metallic toxicants (aluminum (Al), cadmium (Cd), lead (Pb), titanium (Ti), chromium (Cr), zinc (Zn), and copper (Cu)).[5]

Toxicants in personal care products indirectly have a tangible impact on the body and the surrounding environment. A previous study in the United States (US) showed that oxybenzone in sunscreen is not as effective against ultraviolet-A (UVA) exposure as avobenzone, titanium dioxide, or zinc oxide, even though these chemicals are associated with Hirschsprung's disease.[6] A 2021 Turkish study, which examined the aluminum metal found in personal care products, showed that aluminum is not related to breast tumors, but aluminum does increase the risk of developing Alzheimer's disease.[7]

Several previous studies, in general, examined the female sex who used personal care products more often.[2–4] This study aimed to compare the potential for exposure to the male and female sexes because the need for body care products is very important for male and female students. However, only a few students are aware of the dangers of the chemicals contained, and some are highly toxic.[4] Students of the medical education study program at the Faculty of Medicine, Universitas Andalas, especially senior-year students who have studied general toxicology and dermatology courses, must be more aware and concerned about the potential for toxic exposure from various sources. Therefore, it is interesting to assess the potential for senior students' exposure to toxicants from personal care products.

Methods

This study consecutively recruited 69 senior-year medical students (23 males and 46 females) at the Faculty of Medicine Universitas Andalas, Padang, West Sumatera, Indonesia. The minimal number of subjects was obtained by employing the Lemeshow formula. All subjects had taken dermatology and general toxicology courses, which may serve as background knowledge in choosing personal care products.

Personal care products in this study were products that are used to clean, prevent, treat, protect, beautify, increase attractiveness, change appearance, and for fragrance used by the students. To collect information on the types of personal care products used by the medical students within the last six months, in this study used a modified and translated

Table 1 Personal Care Products Used Based on Areas by Medical Students by Sex in the Last Six Months

Areas	Number of Products					
	Male			Female		
	Min	Max	Median	Min	Max	Median
Skin	2	10	6	5	20	11
Hair	1	3	1	1	6	3.5
Dental and oral	1	2	1	1	2	1
Lip	0	1	0	1	5	2
Nail	0	0	0	0	2	0
All areas	4	14	8	10	32	19

questionnaire from The Sister Study (https://sisterstudy.niehs.nih.gov/english/images/docs/PersonalCare-v3-508.pdf).[8] The questionnaire consisted of 69 items and was translated into Indonesian language before validated by content expert panels consisting of a pharmaco-toxicologist, a dermatologist, and a public health toxicologist. The reliability test of the questionnaire showed Cronbach's alpha value of 0.923. After obtaining approval from the institutional review board (No.951/UN.16.2/KEP-FK/2022), the study questionnaire was distributed online via a Google form (bit.ly/QuestionnairePCP) from September to December 2022.

All respondents opted to consent at the start of the questionnaire before responding to the questions regarding personal care product usage. Responses were collected and processed by classifying personal care products based on brands and variants. Each product's composition was recorded based on the product's ingredients label. Toxic ingredients were identified and classified as non-metallic and metallic toxicants. Toxicants were identified based on available scientific evidence of their unfavorable effects on animal and human health. Data were counted and presented as descriptive statistics and percentages (using MS Excel®) according to sex and frequency of the toxicant product.

Results

Personal care products often contain toxicants that may interfere with users' health in various ways over the short or long term. Excessive use of personal care products will increase a person's potential for exposure to toxic substances. Recently, the use of personal care products is

Table 2 Types of Toxicants in Skin Care Products Used by Medical Students

Product	Toxicant					
	Non-metallic	f	%	Metallic	f	%
Body soap (n=49)	Fragrance	49	100	Ti	10	20.4
	BHT	16	32.7	Zn	2	4.1
	PEG	14	28.6			
	PG	9	18.4			
	Paraben	8	16.3			
	BG	5	10.2			
	Talc	2	4.1			
	DEA	2	4.1			
	TEA	1	2			
	Triclosan	1	2			
	BP-3	1	2			
Perfume/ cologne (n=55)	Fragrance	54	98.2			
	PEG	17	30.9			
	BHT	10	18.2			
	PG	10	18.2			
Deodorant/antiperspirant (n= 37)	Fragrance	33	89.2	Al	33	89.2
	BHT	9	24.3	Ti	1	2.7
	PEG	9	24.3	Zn	1	2.7
	PG	8	21.6			
	BG	6	16.2			
	Paraben	4	10.8			
	Triclosan	4	10.8			
	Talc	1	2.7			

Table 2 (continued)

Product	Toxicant					
	Non-metallic	f	%	Metallic	f	%
Sunscreen (n=33)	Talc	32	97	Ti	9	27.3
	Fragrance	20	60.6	Zn	6	18.2
	PEG	18	54.5	Al	4	12.1
	BG	18	54.5			
	PG	14	42.4			
	BHT	9	27.3			
	TEA	8	24.2			
	Paraben	6	18.2			
	BP-3	1	3			
Lotion (n=42)	Fragrance	38	90.5	Ti	13	31
	Paraben	22	52.4	Al	7	16.7
	BHT	14	33.3	Zn	1	2.4
	TEA	12	28.6			
	PEG	12	28.6			
	PG	9	21.4			
	Talc	1	2.4			
Body scrub (n=24)	Fragrance	22	91.7	Ti	9	37.5
	PEG	16	66.7	Al	4	16.7
	PG	9	37.5			
	Paraben	8	33.3			
	BHT	7	29.2			
	TEA	7	29.2			
	BG	2	8.3			
	BP-3	2	8.3			
Skin whitening (n=4)	Fragrance	4	100	Ti	4	100
	BHT	2	50			
	Triclosan	1	25			
	Paraben	1	25			
	PG	1	25			
Body/foot/hand cream (n=7)	Fragrance	4	57.1	Al	1	14.3
	PG	3	42.9	Ti	1	14.3
	Paraben	2	28.6			
	BHT	1	14.3			
	TEA	1	14.3			
	PEG	1	14.3			
	BG	1	14.3			
Face wash (n=44)	Fragrance	34	77.6	Zn	4	9.1
	PEG	26	59.1	Ti	2	4.5
	BG	26	59.1	Al	1	2.3

Table 2 (continued)

Product	Toxicant					
	Non-metallic	f	%	Metallic	f	%
Face wash (n=44)	PG	18	40.9			
	Paraben	6	13.6			
	BHT	5	11.4			
	TEA	4	9.1			
	BP-3	1	2.3			
Face moisturizer (n=32)	BG	23	71.9	Cu	4	12.5
	PG	13	40.6	Ti	3	9.4
	Fragrance	12	37.5	Zn	3	9.4
	PEG	12	37.5	Al	1	3.1
	Paraben	7	21.9			
	TEA	5	15.6			
	BHA	1	3.1			
	BHT	1	3.1			
Face/makeup cleansing (n=17)	PEG	11	64.7	Zn	1	5.9
	Fragrance	10	58.8	Cu	1	5.9
	PG	8	47.1			
	Paraben	4	23.5			
	BHT	3	17.6			
	BG	3	17.6			
	TEA	1	5.9			
Face serum (n=28)	BG	18	64.3	Zn	3	10.7
	Fragrance	9	32.1			
	PEG	7	25			
	PG	7	25			
	BHT	5	17.9			
	TEA	3	10.7			
	BHA	1	3.6			
	Paraben	1	3.6			
Face cream (n=5)	Fragrance	5	100	Ti	3	60
	PEG	4	80	Al	1	20
	PG	2	40			
	BG	2	40			
	Paraben	2	40			
	BHT	2	40			
	BHA	1	20			
	TEA	1	20			
	Talc	1	20			

Table 2 (continued)

Product	Toxicant					
	Non-metallic	f	%	Metallic	f	%
Face powder (n=21)	Talc	17	81	Ti	10	47.6
	Fragrance	15	71.4	Zn	10	47.6
	BHT	5	23.8	Al	8	38.1
	Paraben	3	14.3			
	PEG	2	9.5			
	PG	2	9.5			
	TEA	1	4.8			
Blush on (n=13)	Talc	6	46.2	Al	5	38.5
	Fragrance	4	30.8	Ti	4	30.8
	Paraben	3	23.1	Zn	2	15.4
	BHT	3	23.1			
	BG	3	23.1			
	PEG	2	15.4			
	PG	2	15.4			
Foundation makeup (n=9)	PEG	7	77.8	Ti	8	88.9
	BG	3	33.3	Al	7	77.8
	Fragrance	2	22.2	Zn	3	33.3
	Talc	2	22.2			
	BHT	2	22.2			
	PG	1	11.1			
	Paraben	1	11.1			
Face toner (n=9)	BG	6	66.7			
	PG	5	55.6			
	PEG	4	44.4			
	Fragrance	3	33.3			
	Paraben	1	11.1			
	TEA	1	11.1			
Face mask (n=7)	BG	5	71.4	Al	2	28.6
	Fragrance	3	42.9	Ti	1	14.3
	PEG	2	28.6	Zn	1	14.3
	PG	1	14.3			
	Talc	1	14.3			
	Paraben	1	14.3			
Cushion (n=5)	PEG	5	100	Al	5	100
	BHT	3	60	Ti	5	100
	BG	3	60	Zn	2	40
	Fragrance	2	40			
	PG	1	20			

Table 2 (continued)

Product	Toxicant					
	Non-metallic	f	%	Metallic	f	%
Concealer (n=4)	BG	4	100	Al	3	75
	PEG	3	75	Ti	2	50
	BHT	2	50	Zn	2	50
	PG	1	25			
	Fragrance	1	25			
	Paraben	1	25			
Eyeliner (n=11)	PEG	8	72.7			
	PG	6	54.5			
	BG	5	45.5			
	Fragrance	1	9.1			
Eye shadow (n=6)	Talc	4	66.7	Zn	2	33.3
	Paraben	2	33.3	Al	1	16.7
	Fragrance	1	16.7	Ti	1	16.7
				Cu	1	16.7
				Cr	1	16.7
Eye serum (n=3)	Fragrance	1	33.3			
	TEA	1	33.3			
	PEG	2	66.7			
	BG	3	100			
Eye cream (n=2)	Fragrance	1	50			
	PEG	1	50			
	BG	1	50			

not only used by females but also by males. Table 1 presents the number of personal care products by area of use and the total number of benefits based on the male and female users in the last six months. The results showed that female students used at least ten personal care products, while male products used at least two in various regions in the previous six months.

Non-metallic and metallic ingredients have various functions in personal care products, but some have been shown to exert toxic effects. Table 2 describes the types of toxicants found on personal care products, classified based on the skin area application by the respondents. The result showed that in skin care products, body soap had the highest number of toxicants (11 non-metallic and two metallic toxicants), while eye cream had the lowest ones (three non-metallic toxicants). The non-metallic toxicants identified in personal care products included fragrance, BHA, BHT, PEG, PG, parabens, BG, talc, DEA, TEA, triclosan, and BP-3, while the metal toxicants identified were Zn, Al, Ti, Cu, and Cr.

Hair care products are other sources of potential toxicant exposure. Table 3 presents information on the types of toxic ingredients found in the hair care products used by the respondents. Mascara products were discovered to have the highest number of toxicants (eight non-metallic and three metallic toxicants), and hair vitamins had a single toxicant in its ingredients. The non-metallic toxicants identified were triclosan, PEG, BG, PG, talc, BHT, parabens, fragrance, DEA, and TEA, while the metal toxicants were Ti, Cr, Al, Cu, and Zn.

Dental and oral care products have the potential to be ingested by the nature of their use. Therefore, it is necessary to review the chemicals in dental and oral care products. Table 4 lists the toxic ingredients in the respondents'

Table 3 Types of Toxicants in Hair Care Products Used by Medical Students

Product	Toxicant					
	Non-metallic	f	%	Metallic	f	%
Shampoo (n=42)	Fragrance	42	100	Zn	14	33.3
	PEG	17	40.5	Ti	13	31
	PG	11	26.2			
	BG	3	7.1			
	Paraben	2	4.8			
	TEA	2	4.8			
	DEA	1	2.4			
Conditioner (n=20)	Fragrance	18	90	Zn	4	20
	PG	9	45	Cu	2	10
	PEG	4	20			
	BG	1	5			
	BHT	1	5			
	Paraben	1	5			
Hair oil (n=9)	Fragrance	7	77.8			
	PEG	3	33.3			
	PG	2	22.2			
	TEA	1	11.1			
	BHT	1	11.1			
	Paraben	1	11.1			
Hair tonic (n=9)	Fragrance	9	100	Zn	2	22.2
	PEG	8	88.9	Cu	1	11.1
	PG	6	66.7			
	BG	4	44.4			
	Paraben	2	22.2			
	Triclosan	1	11.1			
Hair vitamin (n=3)	Fragrance	3	100			
Hair perfume (n=2)	Fragrance	2	100	Zn	2	100
	Paraben	2	100			
	PEG	2	100			
	PG	2	100			
Hair mask (n=5)	Fragrance	4	80			
	PEG	3	60			
	PG	3	60			
	BG	2	40			
	Paraben	2	40			
	BHT	1	20			
	DEA	1	20			
	TEA	1	20			

Table 3(continued)

Product	Toxicant					
	Non-metallic	f	%	Metallic	f	%
Hair dye (n=5)	Fragrance	5	100	Ti	4	80
	PG	5	100			
Mascara (n=13)	PEG	6	46.2	Ti	5	38.5
	BG	5	38.5	Cr	3	23.1
	PG	4	30.8	Al	2	15.4
	Talc	4	30.8			
	BHT	4	30.8			
	Paraben	3	23.1			
	Fragrance	3	23.1			
	TEA	2	15.4			
Eyelash serum (n=1)	PG	1	100	Zn	1	100
	BG	1	100			

dental and oral care products. The respondents used mouthwash (with two identified non-metallic toxicants) and toothpaste (four identified non-metallic and three metallic toxicants). The non-metallic toxicants found in these products were PEG, PG, fluoride, parabens, and triclosan. Meanwhile, the metallic toxicants were Zn, Ti, and Al. This study found fluoride in the forms of sodium fluoride and sodium monofluorophosphate.

Lip care products are straightforward to reach the digestive tract, and therefore consumers need to be aware of the safety of ingredients contained in the products. Table 5 shows the types of toxicants in classified lip care products respondents use. Lip tint was found to have the highest number of toxicants identified, and lip serum products had the least number of toxicants. Toxicants in lip care products were found in non-metallic forms such as fragrance, talc, phthalates, BG, PEG, BHT, TEA, parabens, and PG. On the other hand, metal toxicants in lip care products were Al, Ti, and Zn.

Nail care products can flake or chip away and easily enter the oral cavity when users eat with their hands. Table 6 describes the toxicants identified in nail care products used by respondents. It was found that nail polish remover was the most frequent product with toxicants identified. The non-metallic toxicants identified were fragrance, PG, BHT, and acetone. Meanwhile, the only metal toxicant was Ti in nail care products.

Discussion

This study finds that female students typically use personal care products. The main reason for women using personal care products is

Table 4 Types of Toxicants in Dental and Oral Care Products Used by Medical Students

Product	Toxicant					
	Non-metallic	f	%	Non-metallic	f	%
Toothpaste (n=21)	PEG	10	47.6	Zn	6	28.6
	PG	6	28.6	Ti	5	23.8
	Fluoride	21	100	Al	2	9.5
	Paraben	2	9.5			
Mouthwash (n=7)	PG	3	42.9	Zn	2	28.6
	Fluoride	3	42.9			

Table 5 Types of Toxicants in Lip Care Products Used by Medical Students

Product	Toxicant					
	Non-metallic	f	%	Logam	f	%
Lip balm (n=17)	BHT	11	64.7	Ti	4	23.5
	Fragrance	10	58.8	Zn	2	11.8
	Paraben	4	23.5	Al	1	5.9
	PG	3	17.6			
	BG	2	11.8			
Lip tint (n=23)	*Fragrance*	15	65.2	Ti	4	17.4
	BG	11	47.8	Al	2	8.7
	PEG	8	34.8			
	BHT	5	21.7			
	TEA	4	17.4			
	Paraben	3	13			
	PG	3	13			
Lip cream (n=18)	*Fragrance*	17	94.4	Al	14	77.8
	Talc	7	38.9	Ti	6	33.3
	Paraben	3	16.7			
	PEG	2	11.1			
	PG	2	11.1			
	BG	2	11.1			
Lipstick (n=9)	*Fragrance*	7	77.8	Al	5	55.6
	Paraben	2	22.2	Ti	5	55.6
	BHT	2	22.2			
	Talc	1	11.1			
	Phthalate	1	11.1			
Lip gloss (n=6)	*Fragrance*	3	50	Al	2	33.3
	BHT	2	33.3	Ti	2	33.3
	PEG	1	16.7			
	PG	1	16.7			
Lip mask (n=2)	*Fragrance*	1	50	Al	1	50
	BHT	1	50	Ti	1	50
				Zn	1	50
Lip serum (n=3)	*Fragrance*	2	66.7	Al	1	33.3
	BHT	1	33.3			

explained by Dodson et al.[3] that women buy or use products because of their aroma and get recommendations from their environment or female friends. According to Hart et al.[2], women are culturally pressured to improve their beauty, hence using many personal care products. This fact puts women at a much bigger risk of exposure to toxicants in these products. Some toxicants may have a long half-life and circulate in the body for a long time, eventually carrying developmental risk to their offspring when the women conceive. Research on pregnant rats exposed to personal care products containing BP-3 showed disturbances in the growth of the rat fetus.[9]

The current study found triclosan as

Table 6 Types of Toxicants in Nail Care Products Used by Medical Students

Product	Toxicant					
	Non-metallic	f	%	Metallic	f	%
Nails polish (n=6)	PG	2	33.3	Ti	1	16.7
Nail polish remover (n=4)	*Fragrance*	4	100			
	PG	1	25			
	Aseton	1	25			
Nail moisturizer (n=1)	*Fragrance*	1	100			
	BHT	1	100			

an ingredient in body soap, deodorant or antiperspirant, skin whitening, and hair tonic. Triclosan is added for its anti-bacterial and anti-fungal property. Triclosan disrupts endocrine and cardiovascular function, affects the immune response, and increases reactive oxygen species production.[10] The US Food and Drug Administration (FDA) has banned several triclosan soap products. However, the Indonesian BPOM only limits its content levels in personal care products (a maximum content of 0.3% in products other than mouthwash, 0.2% for mouthwash).[11]

Among non-metallic toxicants, talc was found in numerous products (body soap, deodorant or antiperspirant, sunscreen, lotion, foundation, face powder, blush on, eye shadow, face cream, face mask, mascara, lip cream, and lipstick). Talc is added to products to soften or smoothen the skin and reduce friction by absorbing moisture, clot prevention agents, and skin protectants. Acute toxicity of talc can manifest as dry or erosion of the skin in an experiment on rabbits. In chronic toxicity, talc can induce endobronchitis or narrowing of the airways in someone exposed to large amounts of talc in the facial area.[12]

Other non-metallic toxicants in this study, such as parabens, phthalates, and UV filters (benzophenone-3), may act as EDC. Parabens are preservative compounds in personal care products. Several studies have shown a link between parabens and the occurrence of breast, ovarian, and testicular cancer in humans.[13] Ingested, inhaled, or applied onto the skin, and phthalates can particularly affect the nervous system.[14] Research on pregnant mice exposed to BP-3 on the skin of mice with a dose similar to sunscreen resulted in stunted fetal growth. [9]

Acetone is a toxicant found in nail polish remover. Acetone can be absorbed through the digestive tract, lungs, and skin, affecting the central nervous system, digestive, respiratory, cardiovascular, and endocrine systems.[15] Fluoride is found in dental and oral care products to prevent dental caries. Mouthwashes containing fluoride are not generally recommended for children under 6 or 7 years of age because most children cannot yet spit effectively. It has a potency of 90% being ingested daily. Fluoride that enters the intestine will be absorbed quickly. Ingested fluoride, approximately 55% will be stored by children and 36% by adults; the rest of the absorbed fluoride will be excreted as urine. Children retain or keep higher levels of ingested fluoride than adults because of the large surface area provided by the growing mass of bone crystallites. Fluoride can cause systemic effects on the respiratory, cardiovascular, gastrointestinal, hematologic, hepatic, renal, and muscular or bone systems.[16]

Exposure to personal care products containing fragrances in substantial concentrations can trigger asthma-like symptoms.[17] Fragrance interaction with the olfactory receptors may induce physiological markers of stress, by enhancing the cortisol and cardiovascular stress response.[18] In addition, fragrance compounds with estrogenic properties (phthalates and parabens) can play an active role in breast cancer.[17] BHA and BHT are toxicants in personal care products. Although BHA and BHT are chemically similar, the mechanism of toxicity is different between the two. BHA toxicity can cause apoptosis because it can increase caspase-3 activity, while BHT shows a decrease in caspase-3, accompanied by an increase in dead cells.[19]

Diethanolamine, in personal care products, functions as a pH adjuster. DEA toxicity can cause ulceration, irritation, and crusting. It can even lead to ulcerative necrosis to the lower part of the dermis, which has been tested on experimental animals.[20] Triethanolamine functions as a surfactant and pH regulator in

skin cosmetics and hair conditioner. However, TEA may cause skin irritation and, if ingested, can affect the kidneys, liver, erythrocytes, and nervous system.[21] This toxicant is found in almost all personal care products. For its function, PEG has the role of a surfactant, emulsifier, cleansing agent, humectant, and skin conditioner.[22] PEG exposure leads to toxicity mainly via the oral route. PEG's target organ is generally the kidney. If PEG enters the systemic circulation, acidosis is expected due to PEG acid metabolites.[23] Propylene glycol is a solvent used in personal care products as a skin conditioning agent, viscosity-reducing agent, solvent, and one of the ingredients for fragrance in cosmetic products. However, prolonged and high dose exposure can cause toxicity. Propylene glycol is not irritating to the skin but has the potential to induce an inflammatory response when mixed with methylisothiazolinone. Methylisothiazolinone is a heterocyclic organic compound that has long been used in personal care products.[24] Butylene glycol has characteristics as a solvent and viscous liquid and has antimicrobial properties. However, in a study in Japan, there were cases of increased allergies due to BG.[25]

In this study, several metallic toxicants were identified in personal care products used by our respondents. The most frequently found metal toxicant was Ti. Titanium in the form of nanoparticles has the potential to be inhaled and accumulate in the lungs. Besides that, it can be spread throughout the body through the lung barrier.[26] Another toxicant is Al. Aluminum is a buffering agent, corrosion inhibitor, pH regulator, and agent to prevent accumulation. Aluminum can also treat hyperhidrosis, therefore often used in deodorant/antiperspirant products. However, it is thought that the frequent use of Al-containing antiperspirants may play a role in cases of breast cysts because cases of breast cysts often occur on the outer upper part of the breast adjacent to the axilla, by obstructing secretory ducts. [7] Another metallic toxicant is Zn, which has UV protective, anti-acne, anti-inflammatory, anti-bacterial, and anti-odour properties. However, Zn in the form of ZnO compounds has toxic properties because it can enter the blood-brain barrier, which may lead to neurotoxicity and affects brain physiology.[27]

Copper is another toxic metal found in this study. Copper correlates with headaches, migraines, mental depression, and even autism due to Cu accumulation in the hair.[28] Chromium is a metal toxicant that is used as a coloring agent. Chromium is one of the most common allergens found in cosmetics.[5]

The USFDA last updated the lax regulation regarding ingredients in personal care products in 1938, despite the proven detrimental effects of EDC exposure from personal care products.[29] Similarly, in Indonesia, BPOM, as a regulatory body, has not banned related ingredients that are proven to be harmful, only limiting the concentration of ingredients in these products.[11] Consumers need to build awareness of the potential toxic effect of various ingredients in personal care products on chronic exposure. Combined exposure to multiple toxicants may further complicate the long-term safety of personal care products. There should be advocacy to protect consumer safety and to push the industry to provide safer alternatives.

This study has limitations inherent to the survey method used to collect the data, which accuracy relied heavily on the respondents. The identification of potential toxicants relied solely on the written ingredients on the products' label. The list of products in the questionnaire might not be exhaustive, therefore any other products used by the respondents were possibly unaccounted for.

It is concluded that numerous non-metallic and metallic toxicants in personal care products are used by college students, where females are exposed more than male users. As an implication of this study, it is recommended that while waiting for regulatory bodies to amend industry practices that favor consumer safety, consumers need to be more critical in choosing personal care products.

References

1. Cosmetics Overview [Internet]. US Food and Drug Administration. 2021 [cited 2022 May 19]. Available from: https://www.fda.gov/industry/regulated-products/cosmetics-overview#cosmetic.
2. Hart LB, Walker J, Beckingham B, Shelley A, Alten Flagg M, Wischusen K, et al. A characterization of personal care product use among undergraduate female college students in South Carolina, USA. J Expo Sci Environ Epidemiol. 2020;30(1):97–106.
3. Dodson RE, Cardona B, Zota AR, Robinson Flint J, Navarro S, Shamasunder B. Personal care product use among diverse women in California: Taking Stock Study. J Expo Sci Environ Epidemiol. 2021;31(3):487–502.
4. Chan LM, Chalupka SM, Barrett R. Female

college student awareness of exposures to environmental toxins in personal care products and their effect on preconception health. Work Heal Saf. 2015;63(2):64–70.
5. Borowska S, Brzóska MM. Metals in cosmetics: Implications for human health. Journal of Applied Toxicology. 2015;35(6):551–72.
6. DiNardo JC, Downs CA. Dermatological and environmental toxicological impact of the sunscreen ingredient oxybenzone/ benzophenone-3. J Cosmet Dermatol. 2017; 17(1):15–9.
7. Sanajou S, *Şahin* G, Baydar T. Aluminium in cosmetics and personal care products. J Appl Toxicol. 2021;41(11):1704–18.
8. The Sister Study [Internet]. [cited 2022 Apr 25]. Available from: https://sisterstudy.niehs.nih.gov/English/about.html.
9. Santamaria CG, Meyer N, Schumacher A, Zenclussen ML, Teglia CM, Culzoni MJ, et al. Dermal exposure to the UV filter benzophenone-3 during early pregnancy affects fetal growth and sex ratio of the progeny in mice. Arch Toxicol. 2020;94(8):2847–59.
10. Weatherly LM, Gosse JA. Triclosan exposure, transformation, and human health effects. J Toxicol Environ Heal - Part B. 2017;20(8):447–69.
11. BPOM. Peraturan Nomor 23 tahun 2019 tentang persyaratan teknis bahan kosmetika, 2019. Available from: https://notifkos.pom.go.id/upload/informasi/20220805164646.pdf.
12. Fiume MM, Boyer I, Bergfeld WF, Belsito DV, Hill RA, Klaassen CD, et al. Safety assessment of talc as used in cosmetics. 2015;34:66–129.
13. Panico A, Serio F, Bagordo F, Grassi T, Idolo A, de Giorgi M, et al. Skin safety and health prevention: An overview of chemicals in cosmetic products. J Prev Med Hyg. 2019;60(1):E50–7.
14. Radke EG, Braun JM, Nachman RM, Cooper GS. Phthalate exposure and neurodevelopment: A systematic review and meta-analysis of human epidemiological evidence. Environ Int. 2020;137:1–20.
15. Umeh C, Gupta R. Acetone Ingestion Resulting in Cardiac Arrest and Death. Cureus. 2021;13(10):1–5
16. O'Mullane DM, Baez RJ, Jones S, Lennon MA, Petersen PE, Rugg-Gunn AJ, et al. Fluoride and oral health. Community Dent Health. 2016;33(2):69–99.
17. Patel S. Fragrance compounds: The wolves in sheep's clothings. Med Hypotheses. 2017;102:106–11.
18. Pützer A & Wolf OT. Effects of the odorant Hedione on the human stress response. Stress. 2021;24(6):1069–74.
19. Mizobuchi M, Ishidoh K, Kamemura N. A comparison of cell death mechanisms of antioxidants, butylated hydroxyanisole and butylated hydroxytoluene. Drug Chem Toxicol. 2022;45(4):1899–906.
20. Fiume MM, Heldreth B, Bergfeld WF, Belsito D v., Hill RA, Klaassen CD, et al. Safety assessment of diethanolamine and its salts as used in cosmetics. Int J Toxicol. 2017;36:89–110.
21. Fiume MM, Heldreth B, Bergfeld WF, Belsito D v., Hill RA, Klaassen CD, et al. Safety assessment of triethanolamine and triethanolamine-containing ingredients as used in cosmetics. Int J Toxicol. 2013;32(Suppl 1):S59S–83.
22. Jang HJ, Shin CY, Kim KB. Safety evaluation of polyethylene glycol (PEG) compounds for cosmetic use. Toxicol Res. 2015;31(2):105–36.
23. Webster R, Elliott V, Park BK, Walker D, Hankin M, Taupin P. PEG and PEG conjugates toxicity: towards an understanding of the toxicity of PEG and its relevance to PEGylated biologicals. PEGylated Protein Drugs Basic Sci Clin Appl. 2009;127–46.
24. Park J, Lee H, Park K. Mixture toxicity of methylisothiazolinone and propylene glycol at a maximum concentration for personal care products. Toxicol Res. 2018;34(4):355–61.
25. Blomberg M, Johansen JD. Allergic contact dermatitis due to butylene glycol in cosmetics. Contact Dermatitis. 2020;83(3):242–3.
26. Dréno B, Alexis A, Chuberre B, Marinovich M. Safety of titanium dioxide nanoparticles in cosmetics. J Eur Acad Dermatology Venereol. 2019;33(7):34–46.
27. Singh S. Zinc oxide nanoparticles impacts: cytotoxicity, genotoxicity, developmental toxicity, and neurotoxicity. Toxicol Mech Methods. 2019;29(4):300–11.
28. Anant JK, Inchulkar SR, Bhagat S. An Overview of Copper Toxicity Relevance to Public Health. Eur J Pharm Med Res. 2018;5(11):232–7.
29. Roeder A. Harmful, untested chemicals rife in personal care products. HARVARD TH CHAN School of Public Health [Internet]. 2014; Available from: https://www.hsph.harvard.edu/news/features/harmful-chemicals-in-personal-care-products/.