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ESTIMATED FLUORINATED COMPOUNDS EXPOSURE FROM WATERPROOF EYE COSMETICS USE IN WOMEN OF REPRODUCTIVE AGE

Nadia Zerlinda[1], Fitratul Ilahi[2], Husna Yetti[3], Eka Nofita[4], Kemala Sayuti[5], Ilmiawati[6]

[1]Medical Department in Faculty of Medicine Andalas University, Padang, Indonesia
[2]Department of Ophthalmology in Faculty of Medicine Andalas University, Padang, Indonesia
[3]Department of Public Health Sciences in Faculty of Medicine Andalas University, Padang, Indonesia
[4]Department of Parasitology in Faculty of Medicine Andalas University, Padang, Indonesia
[5]Department of Ophthalmology in Faculty of Medicine Andalas University, Padang, Indonesia
[6]Division of Environmental Toxicology, Department of Pharmacology and Therapeutics in Faculty of Medicine Andalas University, Padang, Indonesia
*Corresponding author: zerlinda46@gmail.com

ABSTRACT

Waterproof eye cosmetic are currently trending because they are a great choice for consumers who want to get long-lasting products. Research on fluorinated compounds has found high levels of fluorine in products advertised as 'wear-resistant' or 'long-lasting. Exposure to PFAS is found to cause immune suppression, liver disease, cancer, decreased fertility and low birth weight. This study aimed to determine the exposure to fluorinated compounds through the use of waterproof eye cosmetics in women of childbearing age. This study was conducted from October to December 2023. The study sample amounted to 334 women consisting of 101 high school students, 127 college students, and 106 bank employees spread across the provinces of West Sumatra, Riau, and West Java, data were obtained by filling out a 73-items research questionnaire. The results showed that the frequency of use of waterproof eye cosmetics in the last 6 months was different for each respondent group. 90% of the respondents used mascara. Silicones compounds, acrylates, and color additives were the most common compounds found in the ingredients of the waterproof eye cosmetics used by the respondents. The highest estimated systemic exposure dose of per and polyfluoroalkyl substances (PFAS) compounds was found in high school student respondents with an average of 0,22 x 10^{-7} kg/BW/day followed by bank employees (0,15 x 10^{-7}kg/BW/day) and collage student (0,14 x 10^{-7} kg/BW/day. It can be concluded that the rate of use of waterproof eye cosmetics is high in women of reproductive and high school students have a greater potential to be exposed to fluorinated compounds.

Keywords: Women of reproductive age, waterproof eye cosmetics, PFAS

I. INTRODUCTION

Millions of consumers use personal care products and cosmetics on a daily basis. A national survey of >2,300 US women reported that the average adult woman uses about 12 personal care products per day and more than a quarter of women use ≥ 15 products per day (Taylor et al., 2018). Revenues in the eye cosmetics market reached US$428 million in 2020. Data from the Campaign for Safe Cosmetics (CSC) states that of the 10,500 chemicals used in personal care products, only 11 percent have been assessed for safety. Fluorinated compounds, also known as *per- and polyfluoroalkyl substances*

(PFAS), are organic chemicals containing alkyl groups in which all or most of the hydrogen atoms have been replaced with flour. The identity of PFAS is considered confidential business information and its by-products are not declared on the product composition.

Research conducted on fluorinated compounds in cosmetics in North America states that per- and polyfluoroalkyl substances (PFAS) that are considered harmful are not transparently stated in the product composition, but are only described by their common names, such as methicone and acrylate (Whitehead et al., 2021). Exposure to PFAS is shown to increase the risk of various health effects, such as immune suppression including decreased effectiveness of thyroid function vaccines, liver disease, cancer, decreased fertility and low birth weight (Abrahamsson, et al., 2022). PFAS are used in cosmetic products because they are surfactants that make makeup more durable and weather resistant. Research into fluorinated compounds found high levels of fluorine in products commonly advertised as "wear-resistant" to water and oil or "long-lasting". The cosmetic categories that had the highest percentage of high-fluorine products were foundation (63%), eye products (58%), mascara (47%), and lip products (55%) (Whitehead et al., 2021). PFAS compounds are also referred to as forever chemicals due to their very high persistence in the environment, therefore bioaccumulation of PFAS is also a concern for women of reproductive age because it will also be able to impact women's fertility.

II. METHODS

This study was an online survey assessing the usage of waterproof cosmetics among women of reproductive age. The survey was conducted using the modified The Sister Study Personal Care Questionnaire to focus on the usage of waterproof cosmetics within the last six months. We surveyed 334 total participants from three targeted populations of women of reproductive age ranging from 15 to 49 years old, which were high school students, college students, and bank employees. The survey was conducted between October to December 2023. Data analysis in the form of univariate descriptive analysis of variables of frequency of use, proportion of users, product composition. Bivariate analysis was conducted to see differences in systemic exposure estimates (SED) of per and polyfluoroalkyl substances (PFAS) compounds between respondent subgroups using the Kruskal-Wallis test.

III. RESULTS AND DISCUSSION

Results

This study used consecutive sampling technique and obtained a sample of 334 respondents consisting of 101 high school students, 127 female students, and 106 bank employees. Respondents who use waterproof eye cosmetics consist of high school students (n=67, 66.3%), female college students (n=106, 83.4%), and bank

employees (n=83, 78.3%) with a total of (n=256, 76.6%) respondents.

Characteristics of Women of Reproductive Age Who Use Waterproof Eye Cosmetics

Eye cosmetics are now widely used by women from all walks of life and social classes. However, there are still many who do not know the dangers of chemicals, especially toxicants, from the products they use. Therefore, researchers find out more about the characteristics of waterproof eye cosmetics users whose results are contained in table 1:

Table 1. Characteristics of women of reproductive age

Characteristics	Student (n=67)	Collage student (n=106)	Bank employee (n=83)
		Mean ± SD	
Age (years)	17,1 ± 0,8	20,9 ± 1,1	31,3 ± 7,9
Body weight (kg)	49,8 ± 9,1	54,7 ± 10,7	59,6 ± 10,3
Body height (cm)	156,9 ± 5,1	158,2 ± 5,5	160,6 ± 4,3
Residence		n (%)	
West Sumatera	57 (85,1)	83 (78,3)	57 (68,7)
Riau	9 (13,4)	13 (12,3)	18 (21,7)
West Java	1 (1,5)	10 (9,4)	8 (9,6)
Pregnancy history		n (%)	
Never been	67 (100)	106 (100)	43 (51,8)
Been pregnant	-	-	2 (2,4)
Being pregnant	-	-	38 (45,8)

Based on table 1, the use of waterproof eye cosmetics is more prevalent among female students compared to students and bank employees.

Usage Frequency of Waterproof Eye Cosmetics in Women of Reproductive Age

To find out the pattern of use of waterproof eye cosmetics in women of childbearing age, data on the frequency of use of waterproof eye cosmetics products in the last 6 months is needed

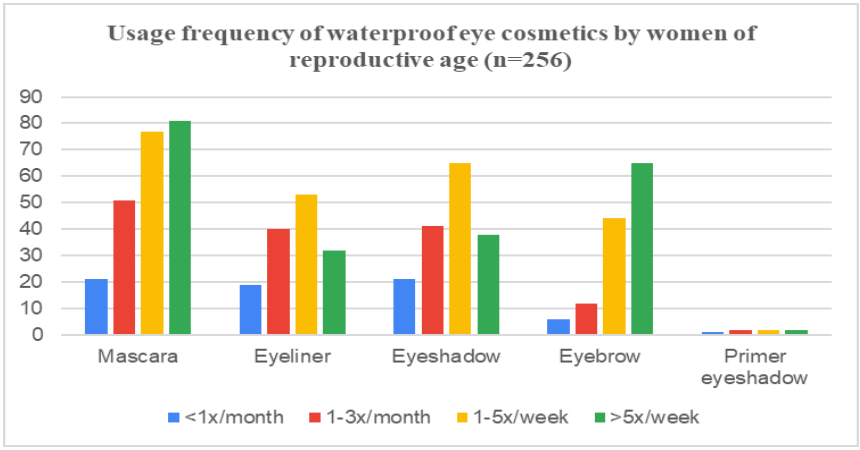

Figure 1. Usage frequency of waterproof eye cosmetics

Based on Figure 1, the frequency of use of waterproof eye cosmetics in women of reproductive age that dominates is the frequency of 1-5x/week.

Percentages of Waterproof Eye Cosmetics Use Among Women of Reproductive Age

There are several types of eye cosmetics products with different functions. Different types of eye cosmetics are also applied to different areas around the eyes. Percentages of waterproof eye cosmetics use is shown in figure 2:

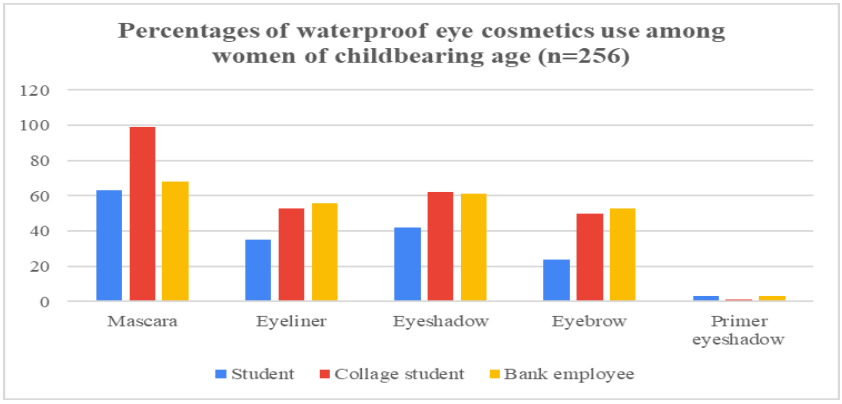

Figure 2. Percentages of waterproof eye cosmetics use

Based on figure 2, mascara is the most used eye cosmetic product by all respondents. The least used eye cosmetic product is eyeshadow primer.

Waterproof Eye Cosmetics Compositions related to fluorinated compounds

Fluorinated compounds or what we call PFAS are often used in eye cosmetic products that claim to be waterproof because PFAS have hydrophobic properties and the ability to create a film, thus improving the wearability, durability and spreadability of the product. From the 120 cosmetic brands used by the respondents, we searched for compounds suspected to be associated with PFAS present in figure 3:

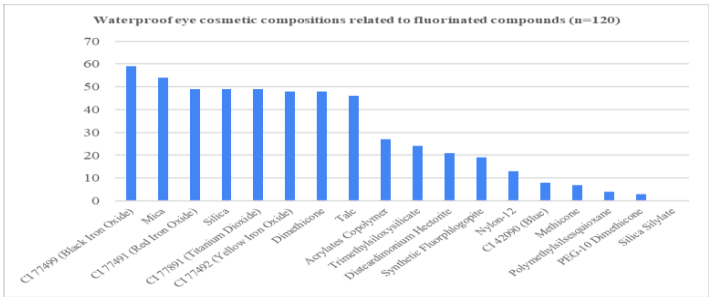

Figure 3. Waterproof eye cosmetic compositions related to fluorinates compounds

The most common compound found in waterproof eye cosmetics is coloring agent CI 77499 (black iron oxide).

Estimated of Systemic Exposure Dose (SED) to Fluorinated Compounds through the Use of Waterproof Eye Cosmetics in Women of Reproductive Age

The Systemic Exposure Dose (SED) of a cosmetic ingredient is estimated by taking into account the amount of finished cosmetic product applied per day, the concentration of the substance in the finished cosmetic product, the skin absorption of the particular substance and the average human body weight value. The exposure assessment is conducted in accordance with the principles of the Scientific Committee for Consumer Safety (SCCS) safety assessment guidelines for chemicals in cosmetic products.

Table 2. Estimation of Systemic Exposure Dose (SED) of per and polyfluoroalkyl substances (PFAS) in Mascara Products with 2% DAP

SED (A x C x DAp)	Student	Collage student	Bank employee
	n=33	n=66	n=59
	DAp 2%		
Mean	**0,22 x 10^{-7}**	0,14 x 10^{-7}	0,15 x 10^{-7}
Median	0,15 x 10^{-7}	0,13 x 10^{-7}	0,12 x 10^{-7}
IQR	0,16 x 10^{-7}	0,04 x 10^{-7}	0,04 x 10^{-7}
Min	0,09 x 10^{-7}	0,07 x 10^{-7}	0,07 x 10^{-7}
Max	0,57 x 10^{-7}	0,40 x 10^{-7}	0,45 x 10^{-7}

A = Estimated amount of exposure to cosmetic products per kilogram of body weight and

frequency of product application per day (mg/kgBB/day)
C = Concentration of fluorinated compounds in cosmetic products (%)
DAp = Dermal absorption expressed as a percentage of the amount of the fluorinated compound absorbed (%)

Based on table 2, the average result of SED calculation with 2% skin absorption on student respondents is 0.22 x 10^{-7} with the highest average. The average calculation of SED on collage respondents is the lowest with 0.14 x 10^{-7}.

Table 3. Estimation of Systemic Exposure Dose (SED) of per and polyfluoroalkyl substances (PFAS) in Mascara Products with 70% DAP

SED (A x C x DAp)	Pelajar n=33	Mahasiswi n=66	Pegawai Bank n=59
	DAp 70%		
Mean	**7,55 x 10^{-7}**	4,99 x 10^{-7}	5,30 x 10^{-7}
Median	5,20 x 10^{-7}	4,59 x 10^{-7}	4,26 x 10^{-7}
IQR	5,48 x 10^{-7}	1,26 x 10^{-7}	1,28 x 10^{-7}
Minimal	3,08 x 10^{-7}	2,60 x 10^{-7}	2,54 x 10^{-7}
Maksimal	20,06 x 10^{-6}	14,04 x 10^{-6}	15,60 x 10^{-6}

A = Estimated amount of exposure to cosmetic products per kilogram of body weight and frequency of product application per day (mg/kgBB/day)
C = Concentration of fluorinated compounds in cosmetic products (%)
DAp = Dermal absorption expressed as a percentage of the amount of the fluorinated compound absorbed (%)

Based on table 3, the results of the average SED calculation with 70% skin absorption on student respondents with the highest value of 7.55 x 10-7 and the average SED calculation on collage respondents is the lowest with 4.99 x 10-7.

Differences in Systemic Exposure Dose Estimates of per- and polyfluoroalkyl substances between Respondent Subgroups

Differences in the results of estimating the systemic exposure dose of per and polyfluoroalkyl substances (PFAS) compounds in mascara products between subgroups of respondents were analyzed using the Kruskal Wallis test. Kruskal Wallis test was used because the data was not normally distributed (Sig. <0.05) after normality test. Kruskal Wallis test results are said to be meaningful if the Asymp.Sig value <0.05.

Table 4. Difference in Estimated Systemic Exposure Dose (dermal absorption 2%) between Respondent Subgroups

Participant	n	Median	p value*
Student	33	5,20 x 10^{-7}	**<0,001**
Collage student	66	4,59 x 10^{-7}	

Bank employee	59	$4{,}26 \times 10^{-7}$

*Kruskal-Wallis test

Based on table 4, the Asymp. Sig value obtained in the estimation of systemic exposure dose with 2% dermal absorption between respondent subgroups after the Kruskal Wallis test was <0.001. This result shows that there is a statistically significant difference between the three groups of respondents tested.

IV. DISCUSSION

The results showed that female collage students were the respondents who used waterproof eye cosmetics the most compared to students and bank employees with a total of 106 people. Research by Husain, Kakul (2018) in Saudi Arabia found high rates of cosmetic use in female collage students. Statistical analysis shows that 69.8% of female students use cosmetics every day and 23.6% of students use cosmetics two to three times a day. Female students receive more information about cosmetics due to the increasing popularity of cosmetics on the internet and social media platforms, this also increases the consumption level of female students. Female students are a very large group and have good purchasing power so that the female student market is a very large market. Based on age, the results show that the average age of student cosmetic users is 17 years old. Research by Husain, Kakul (2018) found 16 years old is the average age of a woman using cosmetics for the first time. The Renfrew Center Foundation (2007), conducted a survey of 1,292 women aged 18 and over and found 44% of women experienced "negative feelings" when they did not wear makeup, 16% responded that they felt unattractive, 14% reported that they felt insecure, and 14% admitted that they felt naked or as if something was missing without makeup".

In female respondents, the highest frequency of use of waterproof eye cosmetics was "1-5 times per week". The results of this study support research conducted by Husain, Kakul (2018) on 106 female students in Saudi Arabia and show 68.8% of female students use cosmetics every day. Research conducted by N. Najmee et al (2022) found as many as 58.8% of 165 female students from several universities in Malaysia used eye cosmetics more than three times per week. The results of the study found that the use of waterproof eye cosmetics on bank employees is included in the frequent category, this is because all bank employees, especially female employees, have a high intensity to interact with customers so that they are required to look attractive.

The results showed that mascara is the most widely used eye cosmetic product by student respondents, female collage students, and bank employees. The results of this study are in line with research conducted by N. Najmee et al (2022) on female students at Malaysian universities where it was found that of the several types of eye cosmetics studied, mascara was the most widely used product with 77%. The results of this

study support research conducted on female students at the University of New Hampshire, where mascara is the most popular word that respondents remember after hearing the word make up. This shows that mascara is considered important to a college student's make up collection. In contrast to research conducted on high school students in the Philippines, the use of eyeliner was found to be more than the use of mascara.

The results showed that the coloring agent CI 77499 (black iron oxide) was the most common substance found from the 120 eye cosmetic brands studied. Whitehead et al (2021) on cosmetics in North America shows that additional coloring agents are associated with inorganic fluoride. CI 77499 is a black iron oxide containing iron and oxygen and is used in cosmetics as a coloring agent, has long-lasting properties, and usually does not need to be reapplied once applied. The results showed that the results of the SED calculation with 2% and 70% skin absorption obtained the highest average in student respondents and the average SED calculation in female respondents was the lowest. According to SCCS, SED is estimated by taking into account the frequency of product application per day, the concentration of substances in cosmetic products, skin absorption and the average value of human body weight. In this study, it was found that the results of PFAS SED calculations for mascara products showed higher numbers in student respondents. This is influenced by several factors, namely daily frequency and body weight. Student respondents have more daily frequency than female students and bank employees. For body weight, students have the smallest average body weight, so it can be concluded that the smaller the body weight, the greater the SED calculation number. This is certainly a concern, especially for student respondents who have started using cosmetics daily. The average age of students who use eye cosmetics is 17 years old, this age is relatively young and will make the time PFAS accumulates in the body longer.

V. CONCLUSION

It can be concluded that students are the most potential group of women of reproductive age to be exposed to fluorinated compounds. This is obtained from the calculation of SED using the formula and also looking at the age of students who are still relatively young so that the possibility of exposure to fluorinated compounds is getting longer throughout their lives. For this reason, it is necessary to educate students about the risk of PFAS exposure.

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