FARMACIA, 2023, Vol. 71, 5

*https://doi.org/10.31925/farmacia.2023.5.7*

**ORIGINAL ARTICLE**

# MERCURY EXPOSURE IN COSMETICS AND HUMAN HEALTH RISK

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*Manuscript received: August 2023*

### Abstract

Nowadays cosmetics are part of daily routine. In addition to food and drinking water, cosmetic products also contain mercury in small amounts. Our goal was to evaluate the concentrations of mercury in various brands of cosmetic products and to demonstrate that the daily application of cosmetics raises the risk of mercury accumulation in the body. The most purchased cosmetic products were identified based on the three-months sales reports of ten pharmacies and five specialized cosmetics stores from Poland, regardless of the brand or name of the product. The first six categories of best-selling cosmetic products were selected, and the first seven most requested products were selected from each category. The concentrations of mercury in 42 cosmetic product samples were analysed by 254 Advanced Mercury Analyzer. The obtained values of mercury are within the limits allowed by the European Union, with different values depending on the brand, the type of cosmetics, or the country of manufacture. Even if the amount of mercury found in the best-selling cosmetic products is below the limit allowed by law, it is not immediately eliminated, but accumulates with each amount of cosmetic product used, and after a certain period side effects might occur. Cressey's formula was used to estimate mercury exposure from topical products, which indicated a potential dermal absorption equal to 0.2474 ng mercury/kg body weight/day with an estimated mercury accumulation over a year of approximately 480 ng mercury/kg body weight/year.

### Rezumat

La ora actuală cosmeticele fac parte din rutina zilnică. Împreună cu alimentele și apa de băut, cosmeticele conțin mercur în cantități mici. Scopul studiului nostru a fost să determinăm concentrațiile de mercur din produsele cosmetice ale diferitelor branduri și să demonstrăm că aplicarea zilnică a produselor cosmetice crește riscul acumulării de mercur în organism. Cele mai achiziționate produse cosmetice au fost identificate pe baza rapoartelor de vânzări pe trei luni din zece farmacii și cinci magazine specializate de cosmetice din Polonia, indiferent de marca sau denumirea produsului. Au fost selectate primele șase categorii de produse cosmetice cele mai vândute, iar din fiecare categorie s-au selectat primele șapte produse cele mai solicitate. Concentrațiile de mercur din cele 42 de produse cosmetice au fost determinate cu analizorul *Advanced Mercury Analyzer 254*. Valorile mercurului din produsele analizate se încadrează în limitele permise de Uniunea Europeană, valorile fiind diferite în funcție de brand, tipul de cosmetice sau țara de fabricație. Deși, cantitatea de mercur găsită în cele mai bine vândute produse cosmetice este sub limita admisă de lege, această cantitate nu se elimină imediat ci se acumulează cu fiecare cantitate de produs cosmetic utilizată și după o anumită perioadă se poate ajunge la efecte adverse. Pentru a evalua expunerea la mercurul din produsele topice a fost utilizată formula lui Cressey, care a evidențiat o potențială absorbție dermică egală cu 0.2474 ng mercur/kg greutate corporală/zi, estimând o acumulare de aproximativ 480 ng mercur/kg greutate corporală/an.

**Keywords**: mercury, cosmetics, health risk, atomic absorption

### Introduction

The term cosmetics refers to products that adorn and scent the human body without altering the function and structure of the skin [1-4]. The ingredients of cosmetic products have always been carefully analysed and the regulation agencies annually add limitations for the use of various ingredients [5-15].

Mercury (Hg) is not allowed in any cosmetic product except in a trace amount of less than 1 part *per* million (ppm) and only if its presence is unavoidable under good manufacturing practice. In the current cosmetics legislation, Hg is a prohibited ingredient, even if in the past it was used as a whitening agent in soaps, face creams, or depigmentation creams [14]. Nowadays, manufacturers are not allowed to use any kind of mercury ingredients because it was demonstrated that mercury may cause skin rashes, skin discoloration and scarring, as well as a reduction in the skin's resistance to bacterial and fungal infections [12-15]. Cosmetic products containing Hg could present potentially harmful effects considering its long half-life of elimination (minimum 50 days): neurotoxicity (elemental mercury and methylmercury-MeHg), nephrotoxicity (elemental mercury and mercuric salts), teratogenicity (MeHg) and death (elemental mercury and MeHg) [16-18].

Many studies have focused on determining mercury in local cosmetics. Generally, the amount of mercury is exceeded if face whitening creams are determined. For example, in a publication regarding creams from Pakistan, the level of mercury was 324 ng/g [17], in creams from Jamaica the maximum content was 17547 ng/g [18], while in creams from China, the maximum content was 45 ng/g [19]. Mercury is generally used in whitening cosmetics because Hg salts inhibit the formation of melanin, resulting in a lighter skin tone. Several published studies showed that mercury bichloride can directly inhibit tyrosinase, which explains its mechanism of action and toxicity [20, 21].

Besides the traditional sources of mercury exposure such as industry mining, new sources of mercury exposure appeared in various cosmetics such as soaps, skin creams and whitening creams [5-11]. Cosmetics are considered one of the most important sources of heavy metals released in the human biological system and environment [8]. Following such an observation, there is a growing need to investigate the concentration of toxic metals (including mercury) in some commonly used cosmetic products. The general population knows about the risk of mercury poisoning from eating ocean fish, but the toxic potential of mercury in cosmetics is less well known.

Though in the European Union (EU) Hg-containing cosmetics are forbidden, traces of mercury through accumulation may contribute to Hg toxicity, considering the current trend to use increasing amounts of cosmetics [22]. Even with quantities of mercury less than the maximum value allowed by law, summing up the amount of all the products used *per* day, amounts of toxic exposure are reached [23-26].

The main goal of our research was to assess, by an efficient method, mercury content in the most frequently purchased cosmetics on the market and to demonstrate that a regular cosmetic or hygiene product application raises the risk of mercury accumulation in the body. Subsequently, by establishing the mercury concentration and analysing the minimum amount of application and use of these products we can find out if there is a risky exposure or not. Another objective of this study was to realize that the use of cosmetics can also be a source of mercury, even if Hg is below the allowed limit. With this warning signal, competent institutions should regulate the labelling of all cosmetics concerning the amount of mercury to which the consumer is subjected.

## Materials and Methods

*Sample collection*

Between October 2019 and December 2019, we obtained sales data from ten pharmacies and five stores specialized in cosmetics to identify the most frequently used cosmetic products in Poland. According to the sales reports of those three months, the most requested categories of cosmetic products by customers were selected regardless of the brand or name of the product. Subsequently, the first six product categories most frequently purchased in the largest quantities were chosen. The top seven most requested products were selected from each cosmetic product category. The selection criterion was not based on brand or price, but solely on the number of sold units. We, therefore, selected a total of 42 samples of cosmetics from commercial brands available as follows: face creams (n = 7), hand creams (n = 7), cleansing milk (n = 7), body lotions (n = 7), foot creams (n = 7) and tooth-paste (n = 7). The samples were coded from S1 to S42 to keep the brand names anonymous.

*Determination of mercury concentration*

Mercury concentration in cosmetic products was determined using an atomic absorption spectrometer (AMA 254, Leco, Prague, Czech Republic) at its specific wavelength of 253.65 nm. AMA is specifically designed for measuring total mercury content in various solids and liquids based on the amalgamation technique, without sample pretreatment or sample preconcentration.

The measurement of the Hg was realized in three steps. The first step was drying and then burning the 0.02 g sample in an oxygen stream for 75 seconds. The second step consists of passing the Hg vapours released from the sample through a catalytic column and then capturing them by the amalgamator for 150 seconds. The third step involves releasing Hg from the amalgamator and measuring its contents in measuring tanks at a wavelength of 253.65 nm (45 seconds) [27, 28]. Each sample was measured in triplicate and the results are presented as the average.

For the determination of Hg concentration in the tested cosmetics a standard curve was realized using a standard Hg solution for atomic absorption spectrometry with 1 g/L concentration (Merck, Darmstadt Germany) [29-31]. The curve has seven points from 0 to 50 ng Hg *per* sample concentration. The equation for the calibration curve was calculated automatically by the AMA based on the known Hg concentrations of standard dilutions. The manufacturer declares the limit of detection for the AMA 254 at 0.003 ng Hg *per* sample [32-34].

The accuracy of the method was checked every day before the start of the analysis and every 7 samples. The method of adding an internal standard of known concentration was used. The limit of detection (LOD) was calculated as 3.3 · σ/S, where S is the slope of the calibration curve and σ is the standard deviation (SD) of the intercept of the regression equation [35, 36]. The method highlighted an LOD of 0.038 ng/L for the sample. The relative standard deviation was < 1.5%.

*Model for assessing mercury exposure from topical products*

The dermal exposure model for mercury has been used in the assessment of exposure to cosmetic products [37, 38] considering that it has been used in other assessments of hazardous substances [39-43]. In this approach, dermal exposure is independent of contact time, and potential dermal uptake rate is expressed in mg/kg body weight/day.

$$Potential\ dermal\ uptake\ rate = \frac{Aderm\ x\ Absorbtion\ factor}{Average\ body\ weight},$$

where, $A_{derm}$ = C x T x A x B x N, $A_{derm}$ = external exposure to skin (mg/event), C = concentration in the products ($mg/cm^3$), T = thickness of the film layer on the skin (default = 0.01 cm), A = surface area of skin exposed ($cm^2$), B = bioavailability for dermal exposure (default = 1), N = number of events *per* period (events/day), Absorbtion factor = 4% [44].

*Statistical analysis*

Statistical analysis was performed using the Statistica 13.3 program (Statsoft, Tibco, Palo Alto, CA, USA). The Mann-Whitney U-test was used to show the differences in Hg content between the two groups. The differences were assumed to be statistically significant at $p < 0.05$.

## Results and Discussion

*Sample collection*

Cosmetic products were chosen from ten pharmacies and five cosmetics stores in Poland, which also had online sales, taking into account that these products are only found in pharmacies and specialized cosmetics stores. Based on the sales report of the three months, six categories of the most frequently purchased cosmetics were identified: face creams, hand creams, cleansing milk, foot creams, body lotions and toothpaste.

Of all cosmetic products sold in pharmacies, the most sold were face creams (15%), hand creams (11%), toothpaste (10%), cleansing milk (9%), body creams (8%) and foot creams (7%) explained by the fact that a pharmacist's recommendation complements the information provided by a dermatologist or dentist (Figure 1). This explanation is in agreement with other reported data which sustained that the pharmacist's role is to reinforce the information provided by dermatologists to increase patients' adherence to treatment [45-47]. Trust in the pharmacist's recommendation is often greater than the consumer's own opinion taking into account that the pharmacist is a specialist in the formulation of cosmetic products [47, 48]. The most reliable source of information regarding skin care products was the dermatologist, and consumers preferred to purchase face skin cosmetics from a pharmacy [49]. Cosmetic products recommended by dermatologists are mostly found in pharmacies and less in specialized cosmetics stores [49].

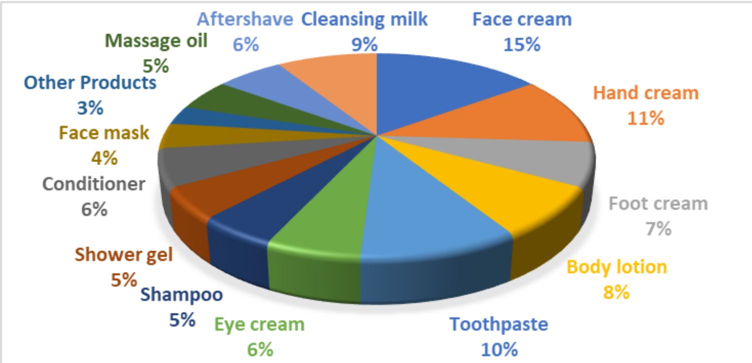


**Figure 1.**
The most purchased cosmetic products from pharmacies in Poland

Consumers purchased several product categories from cosmetic stores. Even though face or eye creams were sold in a smaller amount than in pharmacies the top six product categories sold were the same as in pharmacies (Figure 2). Certainly, the range of products in cosmetic stores is much different from that in pharmacies and for this reason, there are many more product categories [50]. The report received from specialized cosmetics stores showed that for three categories of cosmetics, the percentage of purchases is higher than in pharmacies. Hand creams accounted for 13% of total sales from cosmetic stores compared to 11% from pharmacies, foot creams accounted for 8% compared to 7% from pharmacies and body creams accounted for 10% of total sales compared to 8% from pharmacies. For eye creams, we found an extremely different percentage of sales between pharmacies *versus* cosmetic stores. Consumers purchased 6% of eye creams from pharmacies and only 2% from specialized cosmetics stores, explained by the fact that many dermatologists recommend as antiaging treatments eye creams with retinoids, cosmeceutical-type dermatological products that are mainly found in pharmacies [51].

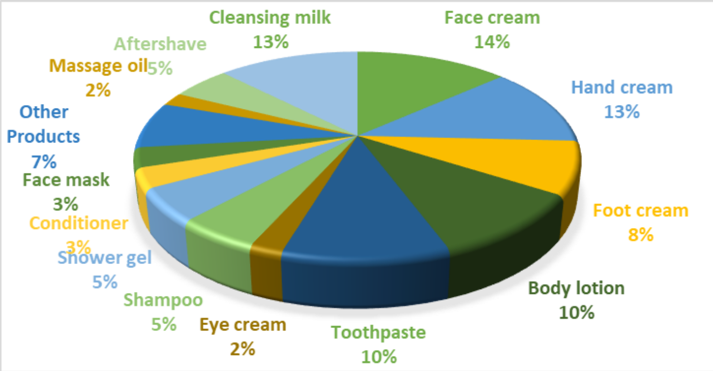


**Figure 2.**
The best-selling cosmetic products in cosmetic stores in Poland

The top seven positions were chosen as units sold from face creams, cleansing milk, hand creams, foot creams, body lotions and toothpaste. All sold products were based on market notoriety and consumer demand. Although this study was conducted in Poland, not all products originate from this country. Many companies use country identifiers as part of their international marketing strategy, and many researchers have studied how these identifiers influence consumer behaviour [49]. The globalization of markets has made the fabrication origin of products an important criterion in buyers' decisions. Of the 42 best-selling products, only 22 are made in Poland. The products had different fabrication origins: Poland (n = 22), France (n = 7), Germany (n = 6), USA (n = 2), China (n = 2), Italy (n = 1), United Kingdom (n = 1) and Latvia (n = 1) (Figure 3).

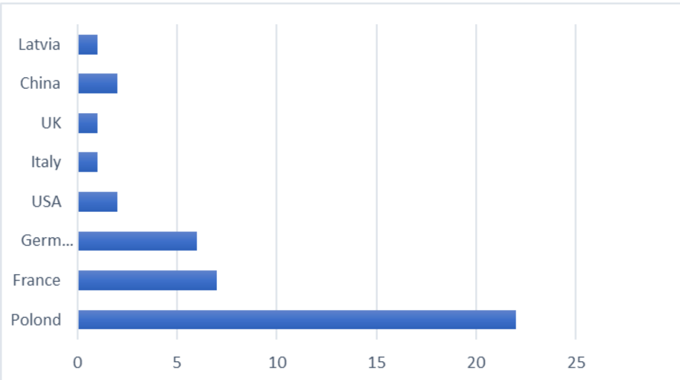


**Figure 3.**
The country of origin of the best-selling cosmetics from pharmacies or cosmetic stores in Poland

*Regression data for the standard calibration plots*

The following regression equations, Pearson's correlation coefficients and coefficient of determinations were obtained for the calibration plot (Table I).

**Table I**
Regression data for the analysis of the standard solutions

| Metal | Mercury |
|---|---|
| Regression equation | $y = 0.077x + 0.0158$ |
| Coefficient of determination ($R^2$) | 0.9993 |
| Pearson's correlation coefficient (r) | 0.999 |

*Mercury content in the tested cosmetics*

The values of mercury in the analysed cosmetic products are within the limits allowed by the EU except for one sample in the toothpaste category, which was labelled as a "bio" product (Table II).

In the six categories of examined products, similar levels of mercury exist in each of them with little deviation from the mean (Table II). The exception to this rule is represented by the body cream group and, to a larger extent, the toothpaste group. In the body cream group, the average concentration of mercury was 2.942 ng/g with a standard deviation of 2.672

ng/g. The high variance in this category is due to one product with 8.7815 ng/g of mercury. In the toothpaste group, the average value of tested products was 26.607 ng/g of mercury insignificant due to the standard deviation of 51.070 ng/g. This high variance in values is due to one product that had a tested value of mercury of 141.596 ng/g. In addition to this product, high concentrations of mercury (19.293 ng/g) were found for another cosmetic product. Both products were labelled as bioproducts but did not have the EU's designated logo.

**Table II**

Hg concentration in the tested cosmetic products

| Sample name | Type of cosmetic products | mean*±SD* of Hg (ng/g) | Mean/SD of Hg (ng/g) | Sample name | Type of cosmetic products | mean*±SD* of Hg (ng/g) | Mean/SD of Hg (ng/g) |
|---|---|---|---|---|---|---|---|
| **S1** | Face cream | 1.1902 ± 0.002 | 1.6862/0.730 | **S22** | Foot cream | 1.0869 ± 0.10 | 1.0393/0.474 |
| **S2** | | 1.2110 ± 0.01 | | **S23** | | 0.7679 ± 0.02 | |
| **S3** | | 2.9780 ± 0.01 | | **S24** | | 0.5462 ± 0.01 | |
| **S4** | | 0.9721 ± 0.05 | | **S25** | | 1.7375 ± 0.04 | |
| **S5** | | 2.3753 ± 0.08 | | **S26** | | 1.6468 ± 0.05 | |
| **S6** | | 1.6684 ± 0.07 | | **S27** | | 0.7578 ± 0.08 | |
| **S7** | | 1.4088 ± 0.01 | | **S28** | | 0.7321 ± 0.02 | |
| **S8** | Hand cream | 0.9861 ± 0.01 | 1.3976/0.643 | **S29** | Cleansing milk | 1.0550 ± 0.05 | 1.0069/0.500 |
| **S9** | | 0.7405 ± 0.01 | | **S30** | | 0.7017 ± 0.03 | |
| **S10** | | 0.8820 ± 0.02 | | **S31** | | 0.9606 ± 0.01 | |
| **S11** | | 1.1589 ± 0.03 | | **S32** | | 0.8857 ± 0.03 | |
| **S12** | | 2.3665 ± 0.01 | | **S33** | | 2.0880 ± 0.02 | |
| **S13** | | 2.1828 ± 0.01 | | **S34** | | 0.7259 ± 0.005 | |
| **S14** | | 1.4602 ± 0.04 | | **S35** | | 0.6319 ± 0.01 | |
| **S15** | Toothpaste | 9.5086 ± 0.03 | 26.6472/51.070 | **S36** | Body cream | 3.2610 ± 0.03 | 2.9420/2.672 |
| **S16** | | 8.4566 ± 0.08 | | **S37** | | 1.0690 ± 0.02 | |
| **S17** | | 0.3638 ± 0.04 | | **S38** | | 1.8661 ± 0.01 | |
| **S18** | | 19.2939 ± 0.05 | | **S39** | | 8.7815 ± 0.09 | |
| **S19** | | 5.7988 ± 0.01 | | **S40** | | 1.4185 ± 0.01 | |
| **S20** | | 141.596 ± 0.02 | | **S41** | | 1.7484 ± 0.07 | |
| **S21** | | 1.5124 ± 0.01 | | **S42** | | 2.4499 ± 0.04 | |

Limit of mercury accepted in cosmetics products in Europe, 1 ppm; *SD = standard deviation; *Mean = average of three measurements

Although the amount of mercury measured in each cosmetic product was well within the approved EU level, we want to determine how much total mercury exposure comes from cosmetic products compared to other known sources of mercury.

Many studies have shown the amount of cosmetic products we use daily for both women and men. Of all the publications, Ficheux *et al.* [52, 53] mentioned the most precisely, by cosmetics category, the amount of cosmetic product applied to the body, and regarding the consumption of toothpaste Creeth *et al*. [54] detailed most specifically the average amount used by an adult *per* day. The estimated quantity of applied mercury is obtained by multiplying the daily amount of cosmetics used (from Ficheux`s and Creeth`s estimation) and the mean amount of mercury found in every category of cosmetic product (Table III).

**Table III**

The potential risk to which consumers are exposed through the daily application of cosmetics

| Type of cosmetic products | Ficheux`s and Creeth`s estimation of the daily amount of cosmetics used (g/day) | Mean Hg quantity in cosmetics of our study (ng/g) | Estimated quantity of applied mercury (ng/day) |
|---|---|---|---|
| **Face creams** | 6.4 | 1.6862 | 10.695 |
| **Body creams** | 30.5 | 2.9420 | 89.731 |
| **Hand creams** | 0.4 | 1.3976 | 0.558 |
| **Foot creams** | 0.2 | 1.0393 | 0.208 |
| **Toothpaste** | 0.8 | 26.6472 | 21.285 |
| **Cleansing milk** | 4.1 | 1.0069 | 4.188 |

*Model for assessing mercury exposure from topical products*

Of all the formulas presented in the literature that assess mercury exposure from topical products we used the one proposed in Cressey's report [37]. The formula is applicable for dermal exposure to adult and healthy persons without any damage to the skin. In this formula, $A_{derm}$ represents the external exposure of Hg to the skin namely the amount of Hg in cosmetic products daily administered [52-54]. For surface area we used the data presented in Table IV and for the number of events we used the results from Ficheux *et al*. [52]. Little information is available on the dermal absorption of mercury from skin products. An *in vitro* study found that almost 4% of the mercury was absorbed from an emulsion product when applied topically [44]. Applying this 4% absorption factor to the amount of $A_{derm}$ results in 468.08 ng Hg absorbed into the body daily through the use of all cosmetic product categories in the study.

Considering that the average body weight of an adult is 70 kg, we can calculate the value for the potential dermal uptake, which is equal to 0.2474 ng Hg/kg body weight (0.002474 mg Hg/kg b.w.). Knowing the value of daily exposure and Hg's half-life, a minimum 50 days [55], we calculate the accumulation of Hg over the course of one year, resulting in 33780 ng Hg/year or around 480 ng Hg/kg body weight/year.

**Table IV**

Values used to calculate $A_{derm}$

| Type of cosmetics products | Surface area* | Number of daily uses | $A_{derm}$ |
|---|---|---|---|
| **Face creams** | 733 $cm^2$ | 2.91 | 468.08 ng Hg |
| **Cleansing milk** | 733 $cm^2$ | 1.91 | |
| **Hand creams** | 326 $cm^2$ | 0.88 | |
| **Foot creams** | 326 cm | 0.5 | |
| **Body creams** | 15241 $cm^2$ | 0.7 | |
| **Toothpaste** | 200 $cm^2$ | 2 | |

*Surface on which the daily amount of cosmetic product is applied deducted from the standard surface of on adult (16300 $cm^2$)

A level of over 100 ng/mL of mercury in blood is considered to be capable of producing noticeable side effects such as poor muscle coordination, tingling and numbness sensations and is considered to be the threshold for mercury poisoning [55]. Our calculations estimate that cosmetic products could only account for 0.48 ng Hg/mL blood which is less than 0.5% of the level capable of exerting side effects. This value of 0.48 ng Hg/mL blood is the approximate value after the accumulation of mercury in the body concerning the total blood volume. However, we should be aware of the exposure of this heavy metal. Every day both women and men are exposed to mercury, not only from cosmetic products, but also from the environment or food. This amount of 0.48 ng Hg/mL blood may seem small, but if added to the amount of mercury present in food or the environment it can cause serious side effects.

If we compare these cosmetic products according to the average quantity of daily use, we discover that we are more exposed to 3242 ng of mercury in 30 days. Within 30 days of use, mercury cannot be eliminated and accumulates in the body. When frequently used cosmetics, the Hg alarm level of 5000 ng is reached in 56 days. This is the alert level for this heavy metal, and while side effects do not develop until the level of 20000 ng is reached the 2% intake that cosmetics are responsible for could represent the "tip of the iceberg" in an already saturated and sensitive mercury metabolism, especially in people with a diet rich in marine fish and meat.

*Further considerations and study limitations*

After thorough research of all cosmetic labels, we identified all the INCI ingredients. Unfortunately, no statistical analysis was conducted because the proprietary formulations did not list the quantity either in absolute values or in percentages for the ingredients. The only ingredient shared among the analysed products was olive oil, which was found in all six face cream products.

A comparative analysis would provide better insight into which cosmetic product accounts for the greatest accumulation of Hg in the human body, but cosmetic products taken individually do not significantly influence the amount of Hg in the human body, only all of them together can significantly increase the risk of accumulation. As such, except for the determination of the average concentration of Hg for each cosmetic product category, we did not perform further calculations for each individual cosmetic product, as the total amount would be insignificant. Also, considering the $A_{derm}$ formula, we established that every cosmetic product accounts for Hg accumulation directly proportionally with its Hg concentration.

Although at first sight, toothpaste is not classified as a cosmetic product, it was included in this paper due to the high frequency purchase and usage, occupying the second position according to pharmacies and specialized cosmetics stores sales reports (Figure 1). While the above-mentioned formula, regarding dermal absorption does not apply to the toothpaste category products, one study found that the absorption of an aqueous solution was higher for oral mucosa compared with dermal absorption [56]. As such, for this article, the Hg absorption from toothpaste is approximate.

## Conclusions

Our study highlights the most used cosmetic products that are purchased from pharmacies or specialized cosmetics stores in Poland for which the amount of mercury was checked. It was demonstrated that the same top categories of products were sold both in pharmacies and in specialty stores. The most purchased cosmetic products were: face creams, hand creams, foot creams, cleansing milk, body creams and toothpaste. The amount of mercury found in the 42 samples of commercial cosmetics from Poland is below the limit allowed by EU law, yet it is not immediately eliminated but accumulates with each amount of cosmetic product used. The alarm level of 5000 ng of Hg is reached in 56 days when cosmetic products are frequently used, but we must take into account that we are not exposed to mercury only from cosmetic products. Through this study, we want to trigger an alarm for the competent institutions to set a lower limit than the current one for the amount of mercury in cosmetic products and to regulate the labelling of all cosmetics with regard to the amount of mercury to which the consumer is subjected.

**Conflict of interest**

The authors declare no conflict of interest.

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