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Research Article

Toxic metals in facial cosmetics: Chemical Analysis Lead and Cadmium in lipstick, foundation creams sold at Aden market, Yemen

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Abstract

Cosmetics increase exterior appearance attractiveness; however, they may constitute a risk to users owing to hazardous chemical compositions. The study aimed to analyze the levels of lead (Pb) and cadmium (Cd) in lipsticks and foundation creams sold at Aden markets, Yemen. The samples of the study included ten (10) samples (6 foundation creams and 4 lipsticks) and they were analyzed for lead and cadmium content using Inductive Coupled Plasma-Optical Emission Spectrometer (ICP-OES). The concentration range of Pb and Cd were from 0.575 ppm to 234.750 ppm, 0.000 ppm to 0.108 ppm, respectively, in foundation creams. 0.000 ppm to 331.750 ppm, 0.000 ppm to 0.083 ppm, respectively in lipsticks. The majority of Pb and Cd contents were within the European Union (EU) and Food and Drug Administration (FDA) limits, except two samples: Dermacol Cream and Super Stay Matte INK lipstick. Their lead content exceeded the allowed limits. Long-term exposure to these chemicals can pose substantial health risks, notably skin cancer. To maintain human safety, cosmetic items should be monitored on a constant basis, notably for adulteration.

1. Introduction

Cosmetics have been used since the Sumerian and Pharaonic civilizations and continue to be popular today. They have been around since the dawn of human civilization, initially used to improve and enhance the skin's appearance. Recently, however, cosmetics have sometimes become an obsession for some consumers, leading to increased demand. "A cosmetic is any substance intended to be applied to external body parts example hair, nails, lips, and face or to internal parts as teeth " [1]. Cosmetics contain both organic and inorganic materials, including hydrophilic and hydrophobic substances. The use of mineral pigments in coloured cosmetics can introduce heavy metals contaminants such as Cu, Ni, Cu, Pb, Cd, and Cr making them an unavoidable component of the final [2]. These cosmetics can be classified into several categories based on their intended usage and application [3]. The facial cosmetic products such as lipstick[4], foundation creams and lipstick (used to Colour the lips) represent one of the most used cosmetics where as many lipsticks have been reported to contain heavy metals such as Pb, As and Co [5]. Foundation creams are applied in relatively large quantities to the face distribution Colour pigments evenly and reducing shine [6,7]. Some metals tend to get accumulate in the stratum corneum, potentially causing allergic reactions, while others can diffuse through sweat, tears, and sebum [8]. These metals may penetrate the skin via appendages or trans cellular and intracellular pathways, eventually reaching the human bloodstream. Therefore, daily application of many cosmetic products may result in increasing exposure of heavy metals to human body. Exposure to heavy metals can cause innumerous health problems including skin allergies, severe redness, swelling/skin ulcers, cellular death, DNA damage, neurotoxicity, oxidative stress, memory loss, reproductive failure and carcinogenic health effects [9-14]. A similar study was conducted in Yemen to analyze heavy metals as Hg, Ti, Cd, and Pb in skin whitening creams. The

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results revealed the presence of these metals at concentrations that may a risk to consumer health [15, 16]. In China, Korea, and the European Union. The use of lead as part of cosmetic compositions is prohibited [17]. Lead is one of the toxic metals for humans, and when they reach into contact with vital organs, they may cause hepatotoxicity, neurotoxicity, and nephrotoxicity [18]. Cadmium is considered a toxic metal that can have serious health effects upon exposure high levels of Cd exposure have been linked to kidney dysfunction, obstructive pulmonary disease and lung cancer [19]. Despite the increasing global demand for cosmetics their safety remains a concern for researchers driving them to establish safe regulatory levels, even when the presence of toxic metals is unintentional [20,21]. Certain heavy metals can accumulate in the body, posing health risks [22]. Therefore, regulatory authorities set permissible limits to ensure product and consumer safety [23- 25]. The aim of the study is to evaluate the safety of common lipstick, and foundation cream widely used across various groups in society. Also, the study aimed to assist concerned traders in importing cosmetic products according to the international specifications and standard. This was achieved by analyzing the concentration of some toxic metals (lead, cadmium) in lipsticks and foundation creams using ICP-OES.

2. Materials and methods:

2.1. Materials

The acids used to digest the samples in this study were pure and imported from an accredited and specialized international company, (BDH-England). These include perchloric acid ($HClO_4$) at a concentration of 60-62% and nitric acid (HNO_3) at a concentration of 69%. Deionized water was used for cleaning all the glassware and plastic utensils used in the analysis. Additionally, deionized water was utilized to prepare sample and dilution standard solutions.

2.2. Instrumentation

The study utilized an Inductively Coupled Plasma – Optical Emission Spectrometer (ICP-OES) model AViO™220 Max, PerkinElmer, U.S.A.) To analyze the concentrations of Pb and Cd in cosmetics samples (lipsticks, foundation creams).

2.3. Metal ions complexes

In this study, ten random samples of two types of facial cosmetics, namely lipsticks and foundation creams, were collected from local markets in Aden Governorate during October 2023. Four samples of lipstick and six samples of liquid foundation cream in different colors were collected after ensuring that after verifying validity. These samples are among the most widely used types in the market by various classes of women in society. Figure 1 shows the lipsticks and foundation creams collected from Aden markets. Most of them are manufactured by Chinese companies and meet local demand. It is worth noting that the studied samples are packed in containers made of aluminum, glass or plastic in various shapes. They are classified and coded as recorded in Table 1.

2.4. Preparation and digestion of samples

These samples (lipsticks and foundation creams) were digested using a mixture of concentrated acids consisting of nitric acid and perchloric acid in a 3:1 ratio according to the procedure specified by [26]. 1.0 gram of each sample was weighed into a 150 ml Pyrex glass beaker using a sensitive electric balance. 5 mL of the concentrated acids mixture nitric acid (HNO3) and perchloric acid (HClO4) at a 3:1 ratio was added. The sample was heated slowly for 2-3 hours on a hot plate. To complete the digestion process another 3 ml of the acid mixture was added and then heated for 40-50 minutes to complete the digestion. 10 ml of deionized water was added to the digested sample. The samples were then filtered using Whitman filter paper (number 1) transferred into a 25 mL volumetric flask, and diluted with deionized water. The solution is transferred into polyethylene containers and placed in the refrigerator until the toxic metals concentrations were determined by ICP-OES.

2.5. Standard Solutions

The Inductive Coupled Plasma- Optical Emission Spectrometer (ICP-OES) device was calibrated by purchasing standard solutions for lead and cadmium at a concentration, 1000 µg/mL from a MERCK (Germany) company. According to Mhemeed (2020), a series of concentrations was prepared from the stock standard solution (Pb, Cd) by performing a dilution process, as follows: 2.5, 5, and 7.5 ppm. The standard deviation (SD) and slope were calculated and the values of the limit of detection (LOD) and limit of Quantification (LOQ) were found to be 0.000079 and 0.00024 ppm, 0.0000068 and 0.000020 ppm, respectively.

Figure (1): shows a picture sample collected

Table (1) List of Facial Cosmetic Samples Collected from Cosmetic Markets in Aden

Code	Brands	Container Type	Colour	Origin	Exp. Date
P_5	BTS (11)	Plastic	Red Blood	China	3/2025
P_3	Classics Matte Lips (03)	Plastic	Brown	China	9/2026
P_7	Lora (11)	Plastic	Dark Brown	China	03/2027
P_6	Super Stay Matte INK (02)	Plastic	Light Pink	China	03/2025
F_1	Rial Beauty (05)	Plastic	Brown	China	02/2027
F_2	Lareen Spotless (101)	Plastic	Light Brown	China	8/2027
F_3	Tailaimei BB(101)	Plastic	White	China	05/2025
F_4	Snial Hold Moring (103)	Glass	Light Brown	China	12/2024
F_5	Note (01)	Glass	White	Turkey	05/2025
F_6	Dermacol (209)	Aluminium Tube	Light Brown	EU	08/2027

2.6. Statistical Analysis

The data were analysed using the Statistical Package for the Social Sciences (SPSS)Version 28. Descriptive statistical parameters such as mean and standard deviation (SD) were used to describe the heavy metals concentration in the study samples. Analysis of Variance (ANOVA) was used to determine if there are significant differences between the mean of heavy metals concentrations in the study samples at a significance level of $P \leq 0.05$. The Least Significant Difference (L.S.D) test was used to determine differences between means

3. Results and Discussions

3.1. Calibration curves

Calibration curves from 2.5 to 7.5 ppm are shown in figure 2. These calibration curve for both Pb and Cd indicate fine linearity with R^2 =0.999 and figure 3 supplies spectra of Pb and Cd at 5 ppm standard solution.

3.2. Measuring Lead Concentrations in foundation creams and Lipsticks

Mentioned that lead is highly capable of accumulating in body organs posing a serious threat to human health and life [27, 28]. Continuous exposure to this toxic element leads to harmful health effects in both the short and long term affecting, the nervous system kidneys and Cardiovascular health. Additionally, excessive lead accumulation increases the risk of chronic illnesses including cancer. Therefore, implementing protective measures to minimize lead exposure is essential for safeguarding health.

The results shown in Table 2 and Figure 4 indicated that lead levels in the studied samples. Through result analysis lead concentrations ranged from 0.575 to 234.750 ppm for foundation cream samples and from 0.000 to 331.750 ppm for lipstick samples. Based on the F-test, a significance level of ($P<0.05$) was observed indicating statistically significant differences between the foundation cream samples and the mean lead concentrations in the lipstick samples. Our results demonstrated that the highest lead concentration was recorded in the sample Super Stay Matte (331.750 ppm) followed by Dermacol (234.750 ppm). The levels of lead were exceeded the permissible limits set by FDA (20 ppm), and EU (0.5 ppm) [30, 29, 23].At the same time, the rest samples of foundation creams as well as lipsticks were within acceptable limits. The foundation cream samples exhibited the following order of lead concentration: F6> F5> F4> F3> F2> F1, while the lipstick samples followed the order: P6> P3> P5> P7.

Furthermore, significant differences (P<0.05) were observed for the lead concentrations between foundation creams and lipsticks. Elevated concentrations may be attributed to packaging materials that could have degraded due to improper storage, or to other factors such as raw materials or added pigments used as preservatives or coloring agents to enhance the product's appearance. It is also possible that lead was deliberately added as a primary ingredient in the product formulation, either for functional or aesthetic purposes, particularly in cases where the actual composition of cosmetic items is not clearly disclosed. This possibility warrants further investigation into the sources and intended use of lead in such products.

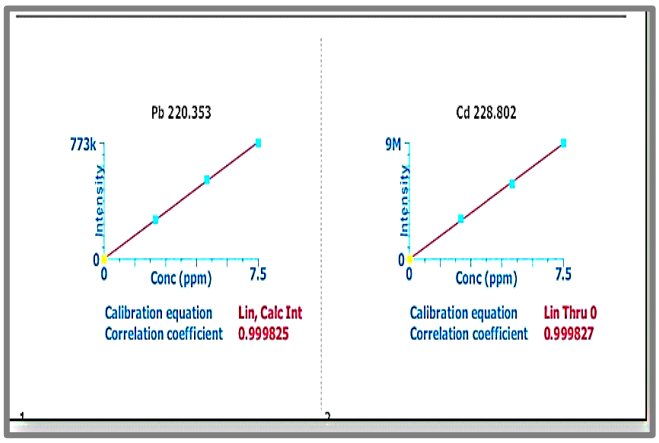

Figure (2) Calibration curve for Pb and Cd

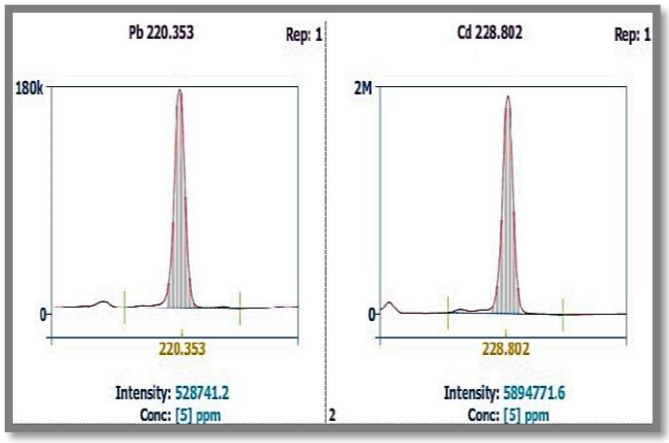

Figure (3) Spectra of Pb and Cd at 5 ppm standard solution

The mean concentration of lead in foundation cream and lipstick samples was 57.505 with a large standard deviation 121.158. Statistical analysis showed that the significance level 0.616 exceeded the adopted threshold 0.05, indicating no significant differences between the samples. Thus, the observed variations in the means are numerical rather than substantive.

Table (3): Arithmetic Means, Standard Deviations (SD) and Significance Levels for Lead (Pb) Concentrations in Foundation cream and Lipstick

Samples		Mean ± SD	Significance Level
Foundation samples		Lead (ppm)	
Beauty Rial (05)	F_1	0.575 ± 0.000	
Lareen Spotless (101)	F_2	1.025 ± 0.000	
Tailaimei BB(101)	F_3	2.025 ± 0.000	
Snail Hold Moring (103)	F_4	2.125 ± 0.000	
Note (0.1)	F_5	2.350 ± 0.000	
Dermacol (209)	F_6	234.750 ± 0.000	
The Overall Arithmetic Mean		40.475 ± 89.406	**0.000**
Lipstick samples			
Classics Matte Lips	P_3	0.450 ± 0.000	
BTS	P_5	0.000 ± 0.000	
Super Stay Matte INK	P_6	331.750 ± 0.000	
Lora	P_7	0.000 ± 0.000	
The overall Arithmetic Mean		83.050 ± 149.972	**0.000**
The Overall Arithmetic Mean in Foundation and Lipstick		57.505 ± 121.158	**0.616**
FDA		**20 ppm**	
EU		**0.5 ppm**	

ppm: part per million

While comparing the highest lead concentration recorded in our study with previous research results it was noted that the lead level in our study was lower than that reported by Samali *et al* [31]. Their analysis of lead in lipsticks revealed a maximum concentration of 47927 ppm.

Nevertheless, our results partially aligned with the results of Jacob's and Ebhota's study on lead content in lipsticks in Nigeria, where most samples in their research exhibited low lead levels, except for 1 sample that recorded a concentration of 72.12µg/g (72.12ppm) [32]. Conversely, our results differed from studies conducted by Al-Qutob *et al*., and Arshad *et al*., which reported lower lead concentrations in analyzed lipstick and foundation cream samples during their research in Palestine and Pakistan [33, 34]. Our study underscores the necessity of exercising caution by increasing awareness of the risks associated with the presence of lead in facial cosmetics, even in small quantities. After numerous studies have confirmed the harmful effects of lead on human health [35, 36], our study, along with other research has reported the presence of toxic metals in cosmetics [5, 31, 37].

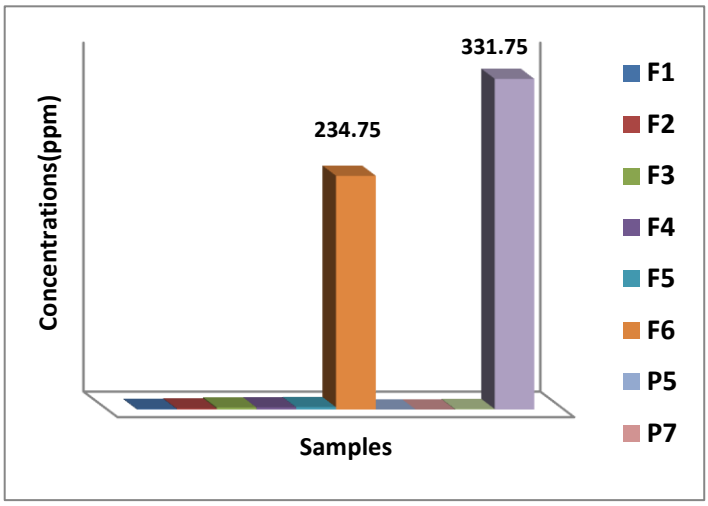

Figure (4): Concentrations (ppm) of lead in study samples

3.2. Measuring cadmium concentrations in foundation creams and Lipsticks

Cadmium is used in cosmetics as a colorful pigment due to its ability to add distinctive and bright colors to the products. However, it is a toxic metal that can negatively impact human health. Its risks are particularly concerning in products like lipstick, as accidental ingestion may lead to harmful effects on health [38,39].

Based on the results presented in Table 3 and Figure 5, cadmium levels in the analyzed samples ranged from0.000 to 0.108 ppm in foundation cream samples, while in lipstick samples the levels varied between 0.000 and 0.083 ppm. Statistically significant differences were found between the lipstick samples (P<0.05). For lipstick samples the results indicated that 25% revealed the presence of cadmium with only 1 sample labeled P6 showing a mean cadmium concentration of 0.083 ppm. While cadmium was not detected in the remaining 75% of the samples.

As for foundation cream samples, cadmium was detected in 50% of the samples, with the highest mean concentration observed in sample F3 at 0.108 ppm. The absence of detectable cadmium in most samples may be attributed to manufactures precautions in avoiding its use due to potential risk to consumers. Additionally, the possibility of chemical reactions occurring during the production process could influence the stability of this metal, leading to its absence in the analysis. Through quantitative analysis of cadmium concentrations in lipstick and foundation cream samples, it was found that cadmium levels are within the permissible limits according to EU (5 ppm) and FDA (20 ppm) standards [22,40,41]. Cadmium is ranked as the seventh most toxic metal according to the ATSDR, due to its continuous bio accumulative nature [42].

These standards are shown in Table 3: EU, FDA and since cadmium is ranked as the most toxic heavy metal, it accumulates within the human body throughout life once absorbed due to its persistent and bio accumulative nature. Asra's *et al*., in their study [43], revealed that the mean cadmium concentrations found in lipstick samples ranged between 0.1220 and 0.2287 mg/kg (0.2287mg/kg). Comparing these means to our current study, it is evident that the cadmium levels in our study are significantly lower than those observed by Asra's *et al*. Nevertheless, both studies agree that cadmium concentrations in lipstick remain within safe levels.

The overall mean cadmium concentration in the foundation cream and lipstick samples was 0.033, with standard deviation of 0.044. Statistical analysis showed that a significance level of 0.502 exceeded the established significance level 0.05, confirming the absence of significant differences in cadmium concentrations between the samples, and that the numerical differences remained limited and insignificant.

In contrast, our result differs from those reported by Feizi's *et al*., [44], as his samples of lipstick showed high cadmium content, with means ranging between 0 and 51.11mg/kg (51.11ppm). Despite this discrepancy, a comparison of [45] results with ours highlights a similarity, as lipstick and foundation cream samples did not contain cadmium, indicating that these samples are free from this harmful metal. Cadmium is a chemical element that can be toxic and detrimental to health when there is continuous exposure. We can highlight our findings by comparing the overall mean lead and cadmium concentration in of lipstick and foundation cream samples.

Table (3): arithmetic means, standard deviations and significance levels for cadmium (cd) concentrations in foundation cream and lipstick

Samples		Cd (ppm) ± SD	Significance Level
Foundation samples			
Beauty Rial (05)	F_1	0.000 ± 0.000	
Lareen Spotless (101)	F_2	0.058 ± 0.014	
Tailaimei BB (101)	F_3	0.108 ± 0.014	
Snail Hold Moring (103)	F_4	0.000 ± 0.000	
Note (0.1)	F_5	0.083 ± 0.014	
Dermacol (209)	F_6	0.000 ± 0.000	
The overall arithmetic mean		0.042 ± 0.046	**0.000**
Lipstick samples			
Classics Matte Lips	P_3	0.000 ± 0.000	
BTS	P_5	0.000 ± 0.000	
Super Stay Matte INK	P_6	0.083 ± 0.014	
Lora	P_7	0.000 ± 0.000	
The overall arithmetic mean		0.021 ± 0.038	**0.000**
The overall arithmetic mean in foundation & lipstick		0.033 ± 0.044	**0.502**
Maximum Permissible Limits	EU	**5 ppm**	
	FDA	**0.3 ppm**	

ppm: part per million

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The mean lead concentration in foundation cream samples was 40.475 ppm, while the mean lead concentration in lipstick samples 83.050 ppm, both values significantly exceeded the mean cadmium concentrations of 0.042 ppm and 0.021 ppm, respectively. Considering that our study analyzed two metals, lead and cadmium, in samples of lipstick and foundation cream, it was essential to compare their overall mean concentration. Based on the overall mean concentrations of both metals (lead, cadmium) in the study samples, it is clear that there are no statistically significant differences in their mean concentration, as the calculated significance levels were P>0.05, exceeding the threshold significance assumed in this study.

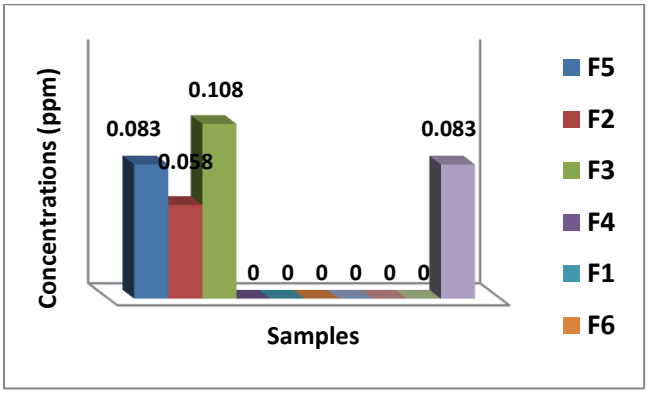

Figure (5): Shows the Mean Cadmium Concentrations (ppm) in Study Samples

Conclusion

The investigation of lead and cadmium levels in lipstick and foundation cream offered in Aden marketplaces revealed that the majority of samples met international standards, with statistically significant variances between them. The findings show that lead and cadmium are not key constituents in these cosmetics, but are present as impurities, most likely owing to manufacturing techniques, raw material utilization, or pigment addition. The elevated concentration of lead in the two samples is likely attributable to its presence as impurities in the raw material or its introduction during manufacturing processes. Inadequate storage conditions facilitate the corrosion of these impurities from the packaging into the product, making poor packaging and storage a contributing factor to increased lead migration and higher concentrations in the samples. Based on these findings, the study proposes doing extensive research on a large scale, including a varied variety of cosmetic items, as well as assessing additional dangerous metals, to assure consumer health and improve safety standards.

Disclosure

The authors declare the conflicts of interest in their work.

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بحث علمي

المعادن السامة في مستحضرات تجميل الوجه: التحليل الكيميائي للرصاص و الكادميوم في أحمر الشفاه، كريمات الأساس المباعة في سوق عدن, اليمن

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الملخص

تزيد مستحضرات التجميل من جاذبية المظهر الخارجي ؛ ومع ذلك، قد تشكل خطرًا على المستخدمين بسبب تركيباتها الكيميائية الخطرة. هدفت الدراسة إلى تحليل مستويات الرصاص(Pb) و الكادميوم (Cd) في أحمر الشفاه وكريمات الأساس المباعة في أسواق عدن، اليمن. شملت عينات الدراسة عشر (10) عينات (6 كريمات أساس و 4 أحمر شفاه)، وتم تحليلها للكشف عن محتواها من الرصاص و الكادميوم باستخدام مطياف الانبعاث الضوئي بالبلازما المقترنة حثيًا (ICP-OES). تراوح تركيز الرصاص و الكادميوم في كريمات الاساس بين 0.575 جزء في المليون و 234,750 جزء في المليون وبين 0.000 جزء في المليون و 0.108 جزء في المليون على التوالي. أما في أحمر الشفاه, فتراوح تركيز الرصاص بين 0.000 جزء في المليون و 331,750 جزء في المليون وبين0.000 جزء في المليون و 0.083 جزء في المليون على التوالي. كانت معظم محتويات الرصاص و الكادميوم ضمن الحدود المسموح بها من قبل الاتحاد الأوروبي و هيئة الغذاء و الدواء الأمريكية باستثناء عينتين: كريم (Dermacol) و أحمر شفاه (Super Stay Matte INK). حيث تجاوز محتوى الرصاص فيهما الحدود المسموح بها. قد يُشكل التعرض طويل الأمد لهذه المواد الكيميائية مخاطر صحية جسيمة، و لاسيما سرطان الجلد. للحفاظ على سلامة الإنسان، يجب مراقبة مستحضرات التجميل بشكل مستمر, ولا سيما للكشف عن أي غش.

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