ORIGINAL ARTICLE

Determination of lead and cadmium concentration in cosmetic products in the Saudi market

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Abstract

This study was undertaken to determine the cadmium and lead concentrations in low-price cosmetic products in the Saudi market. An analytical test was performed for 13 cosmetic products (five lipsticks, five foundations, and three eyeliners) using a flame atomic absorption spectrophotometer. The lead and cadmium heavy metals were determined as trace minerals in all 13 samples. The mean value for each metal in the three different products was as follows: 0.019532 (lipstick group), 0.020842 (foundation group), 0.026237 (eyeliner group) ppm for cadmium, and 0.032744 (lipstick group), 0.046466 (foundation group), 0.041903 (eyeliner group) ppm for lead. The results also indicated that the lead concentration was higher than cadmium in all samples under investigation. Moreover, the results indicated that the levels of cadmium and lead are affected by the company of the cosmetic products. Also, the results indicated that the cadmium and lead levels were within the allowable FDA values. Regular monitoring of the presence of heavy metals in cosmetic products should be continuously undertaken as these metals are reported to show harmful effects on the human body even in very small amounts.

Keywords Heavy metals · Lead · Cadmium · Atomic absorption spectroscopy · Cosmetic products

1 Introduction

The worldwide usage of skin care products is increasing rapidly, driven by the growing awareness of the necessity of a daily skincare routine for beautification [1]. Cosmetics is one important type of skin care product used in contact with different parts of the human body (nails, eyes, lips, etc.) for multiple purposes (perfuming, changing appearance, etc.). The cosmetics are presented in several forms, each with a specific beautifying purpose, such as eyeliner and eyeshadow to color the eyelid, lipstick, and lip gloss to color the lips, and nail polish to color the fingernails and toenails [20]. Cosmetics contain several ingredients, including water, surfactants, oils, and heavy metals [12].

Heavy metals are products whose density is five times greater than that of water and they include antimony, arsenic, bismuth, cadmium, cerium, chromium, cobalt, copper, gallium, gold, iron, lead, manganese, mercury, nickel, platinum, silver, tellurium, tin, uranium, vanadium, and zinc [8]. Heavy metals are essential trace minerals that are important for good health; however, a high level of these compounds is reported to cause harmful effects on the human body [11]. For instance, a high level of cadmium is reported to cause an inhibition of DNA mismatch in addition to dermatological irritation [22]. A mercury compound is reported to cause an allergic reaction, skin irritation, and adverse effects on the nervous system [14]. Lead is considered the second most toxic metal after arsenic causing cardiovascular, kidney, central nervous system, and fertility problems [15]. Although zinc is essential for regulating vital body activities, high concentration is toxic to the cells causing several lung problems [16].

The presence of heavy metals in our daily cosmetic products, and their harmful effects, has drawn the attention of researchers and clinicians to analyze cosmetic products [21]. This was to determine the presence of heavy metals in

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cosmetic products and to find adverse effects of contamination with those compounds [11].

Numerous studies have been done to determine the heavy metal level in cosmetic products [5, 10, 19, 23]. Different types of cosmetic products (creams, shampoo, soap, lipstick, etc.), different companies, and different countries were investigated. Ali Sani et al. revealed that in a total of 30 samples of three different types of cosmetic products commonly used in Nigeria, manganese, cadmium, lead, chromium, nickel, and copper were found in all samples with different concentrations [23]. Moreover, a study was done in Saudi Arabia to determine the concentration of cobalt and lead in different cosmetic products. The study found that in all samples, cobalt concentration was higher than the acceptable level while lead concentration was within the range [3].

Cosmetic product usage was increasing rapidly in Saudi Arabia and as these products were found to contain chemical compounds such as heavy metals, it is a considerable health issue to be studied. This study aimed to determine the concentration of heavy metals in low-price cosmetic products, as these might have lower regulations. Thirteen different types of cosmetic products from Saudi Arabian markets were collected to determine the lead and cadmium concentration in all products under investigation. These heavy metals are among the most toxic heavy metals in cosmetic products.

2 Materials and method

2.1 Reagents and materials

Analytical grade nitric acid (Sigma Aldrich), Analytical grade per-chloric acid (Sigma Aldrich), lead (Pb), and cadmium (Cd) standards for AAS were obtained from Sigma-Aldrich. Double distilled water.

2.2 Sample collection

Thirteen low-price cosmetics were collected from local Saudi Arabian markets. Five samples of lipsticks (L1-L5), five foundation products (F1-F5), and three eyeliners (E1-E3) (samples are presented in Table 1). All samples were then transferred to the lab for further estimation of heavy metal analysis.

2.3 Sample preparations

The protocol of sample preparation was adapted from [2]. One gram was taken from each sample and transferred to a beaker. A quantity of 5 mL of a mixture of concentrated acids was then added to each sample to be digested for two to three hours on a hot plate. The mixture of concentrated acids was comprised of nitric acid (HNO_3) and per-chloric

Table 1 Levels of Cadmium and Lead in collected cosmetic samples from the Saudi market

Sample ID	The concentration of Cd (ppm)	The concentration of Pb (ppm)
L1	0.01	0.02
L2	0.01	0.02
L3	0.02	0.04
L4	0.02	0.04
L5	0.02	0.02
F1	0.02	0.03
F2	0.02	0.02
F3	0.02	0.05
F4	0.01	0.05
F5	0.02	0.05
E1	0.02	0.01
E2	0.02	0.06
E3	0.02	0.04

L lipstick, *F* foundation, *E* eyeliner, *Cd* cadmium, *Pb* lead, *ppm* parts per million

acid ($HClO_4$) in a ratio of 3:1 of each acid, respectively. An amount of three mL of acid mixtures was added continuously till the formation of a white sample. The digested samples were then dissolved in 10 mL of triple-distilled water and were then filtered using Whatman No. 1 filter paper to get a clear solution. The resulting clear solution was finally subjected to a metal quantification analysis.

2.4 Instrumentation

The quantification of cadmium and lead levels was performed via atomic absorption spectroscopy (AAS) using the iCE 3000 Series Atomic Absorption Spectrometer by ThermoScientific. The experiment was conducted in a chemistry lab.

2.5 Statistical analysis

This study was analyzed using Graph Pad Prism Version 9. Simple descriptive statistics were used to define the characteristics of the study variables through the form of counts and percentages for the categorical and nominal variables, while continuous variables are presented by mean and standard deviations. A statistical comparison was carried out to compare the variances among the groups. An ordinary one-way ANOVA test was used to compare the significant differences between the three groups (such as the differences in cadmium concentration between the three groups of cosmetics (lipstick, foundation, and eyeliner). The comparison identified the variances as having a significant difference when the P value was < 0.05 and there was no significant difference when the P value was > 0.05. An unpaired *t*-test was

used to identify the variances between the two groups (such as the differences between the cadmium concentrations in all samples and the allowable FDA values). A comparison was identified if the variances had a significant difference when the P value was < 0.05 and there was no significant difference when the P value was > 0.05.

3 Results

3.1 Heavy metal measurements

The results of the concentration measurements of lead and cadmium in 13 different types of cosmetics (five lipstick samples (L), five foundation samples (F), and three eyeliner samples (E)) are presented in Fig. 1 and Table 1. The results illustrate that a narrow range of cadmium concentrations was detected in the samples under investigation, indicated by the close values of the metal within the samples. However, the lead samples showed a wider range of concentration values within the samples in comparison to the cadmium samples. Figure 2 illustrates the
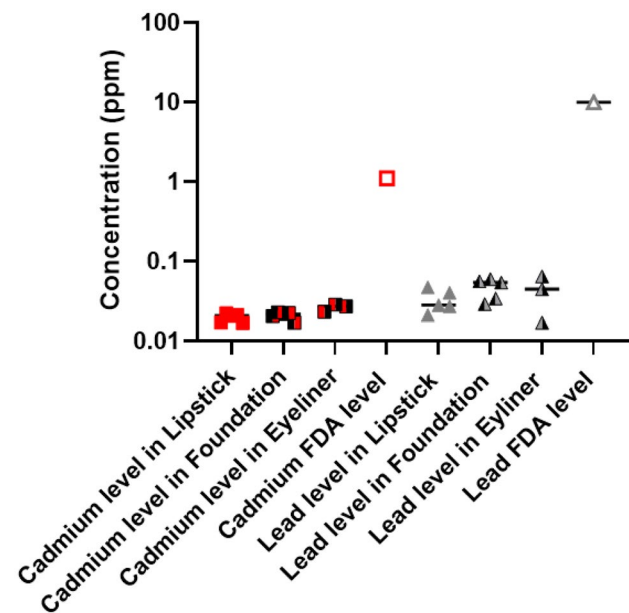
Fig. 1 Cadmium and Lead concentration measurements. The concentration of cadmium and lead in each cosmetic product is detailed in Table 1. Red data points indicate the cadmium concentration, closed-square symbols represent the cadmium concentration in the samples (fully closed symbol for lipstick, right-red-sided symbol for foundation, and left-red-sided symbol for eyeliner), and the open-square symbols represent the Literature FDA value for cadmium in cosmetics. Grey data points indicate the lead concentration, closed-triangle symbols represent the lead concentration in the samples (fully closed symbol for lipstick, right-grey-sided symbol for foundation, and left-grey-sided for eyeliner), and the open-triangle symbols represent the Literature FDA value for lead in cosmetic
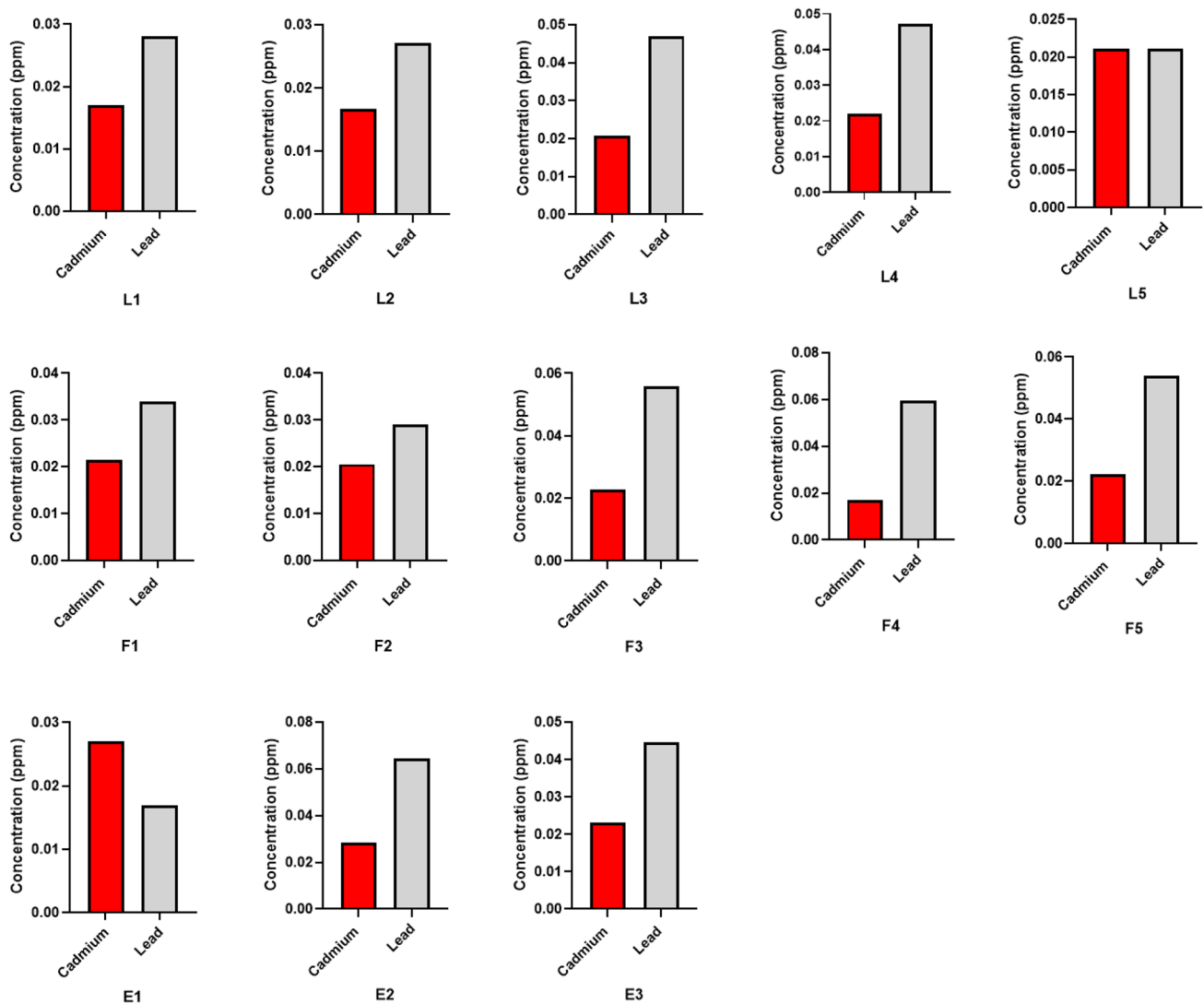
concentration of cadmium alongside the concentration of lead in each sample of the cosmetics under investigation. The graph shows that, in all samples, the concentration of cadmium was always lower than the concentration of lead, except for sample L5, where the concentration of both metals was almost the same. The results also indicate that the cosmetics company affects the concentration of cadmium and lead in each sample (Fig. 2). For comparison, available literature showing the allowable FDA levels of cadmium and lead in cosmetics are also illustrated in Fig. 1 (O, Al-Dayel, et al., 2018; Al-Saleh et al., 2009; US FDA).

3.2 Comparisons between cadmium concentrations in each sample

Figure 3 illustrates the concentration of cadmium in five lipstick samples (Fig. 3A), five foundation samples (Fig. 3B), three eyeliner samples (Fig. 3C), and all cosmetics samples under investigation (Fig. 3D). The results show that the cadmium concentration value in all cosmetic groups is close, except for F4 in the foundation group and E3 in the eyeliner group. The results also show that the highest concentrations of cadmium were in L4 for the lipstick group, with a concentration value of 0.02 ppm; F3 for the foundation group, with a concentration value of 0.02 ppm; and E2 for the eyeliner group, with a concentration value of 0.02 ppm. On the other hand, the lowest values of cadmium were in L2 for the lipstick group, with a concentration value of 0.01 ppm; F4 for the foundation group, with a value of 0.01 ppm; and E3 for the eyeliner group, with a value of 0.02 ppm.

3.3 Comparisons between lead concentrations in each sample

Figure 4 illustrates the concentration of lead in five lipstick samples (Fig. 4A), five foundation samples (Fig. 4B), three eyeliner samples (Fig. 4C), and all cosmetics samples under investigation (Fig. 4D). The results show that the lead concentration value in all cosmetic groups is variable with a wide range of variabilities. The results also show that the highest concentrations of lead were in L3 for the lipstick group, with a concentration value of 0.04 ppm; F4 for the foundation group, with a concentration value of 0.05 ppm; and E2 for the eyeliner group, with a concentration value of 0.02 ppm. On the other hand, the lowest values of lead were in L5 for the lipstick group, with a concentration value of 0.02 ppm; F2 for the foundation group, with a value of 0.02 ppm; and E1 for the eyeliner group, with a value of 0.01 ppm.
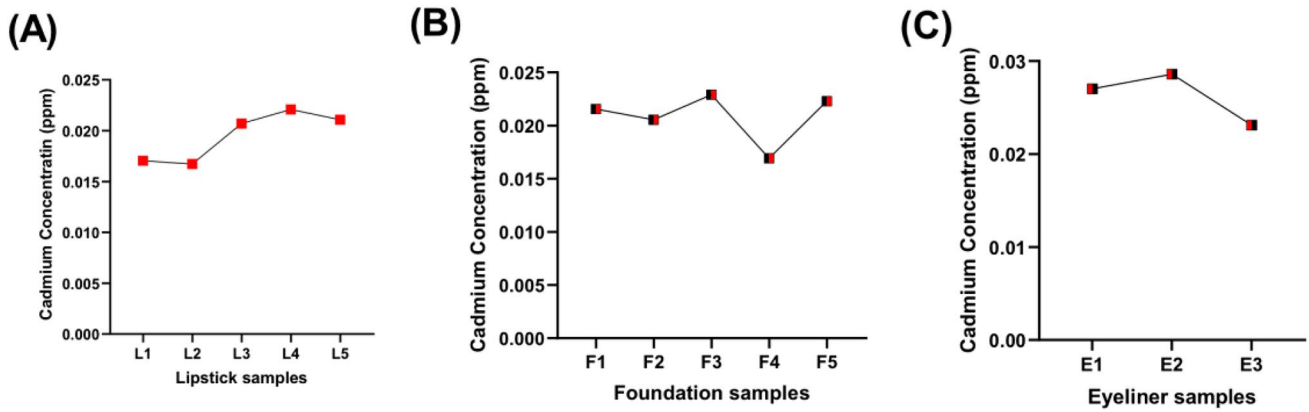
Fig. 2 Comparison between cadmium and lead concentration in each sample. The Y-axis is the concentration of cadmium and lead in each sample. The X-axis is the name of each sample (L=lipstick, F=foundation, E=eyeliner). The Red histogram bar represents the cadmium concentration, while the grey histogram bar represents the lead concentration in each sample

## 3.4 Comparisons between cadmium and lead concentrations in all samples

Figure 5 illustrates the concentration of cadmium and lead in all cosmetic samples (Fig. 5A and 5B, respectively). The results show that the concentration of cadmium is lower than the concentration of lead in almost all samples, as the highest concentration of cadmium was 0.02 ppm while, for lead, the highest concentration was 0.06 ppm. Taking each metal separately, the results show that the highest concentration of cadmium when comparing all groups under investigation (lipstick, foundation, and eyeliner) belonged to E2 in the eyeliner group, while the lowest cadmium concentration belonged to F4 in the foundation group. The results also show that the eyeliner group from different companies has the highest concentration of cadmium among all samples. The cadmium content in each sample was in the following decreasing order: E2 > E1 > E3 > F3 > F5 > L4 > F1 > L5 > L3 > F2 > L1 > F4 > L2. However, the lead concentration values illustrate that the highest value in all groups under investigation (lipstick, foundation, and eyeliner) belonged to E2 in the eyeliner group, while the lowest lead concentration belonged to E1 in the eyeliner group. The lead content in each sample was in the following decreasing order: E2 > F4 > F3 > F5 > L4 > E3 > L3 > F1 > F2 > L1 > L2 > L5 > E1. The results also showed that the eyeliner sample (E2) has the highest concentration of both cadmium and lead metals among all samples.

Fig. 3 Comparison between cadmium concentrations in each sample. **A** Shows the concentration of cadmium in the lipstick samples, **B** Shows the concentration of cadmium in the foundation samples, and **C** Shows the concentration of cadmium in the eyeliner samples. The symbols and lines represent the concentration values of cadmium in each sample, which are shown on the Y-axis, while the X-axis shows the name of each sample. The fully closed symbol for lipstick, a right-red-sided symbol for foundation, and a left-red-sided symbol for eyeliner
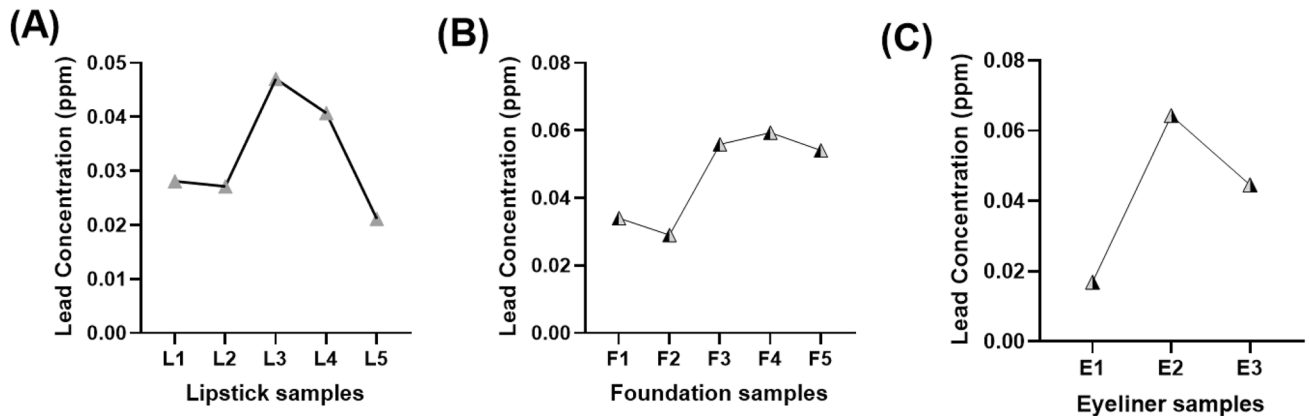
Fig. 4 Comparison between lead concentrations in each sample. **A** Shows the concentration of lead in the lipstick samples, **B** Shows the concentration of lead in the foundation samples, and **C** Shows the concentration of lead in the eyeliner samples. The symbols and lines represent the concentration value of lead in each sample, which is shown on the Y-axis, while the X-axis shows the name of each sample. The fully closed symbol for lipstick, a right-grey-sided symbol for foundation, and a left-grey-sided symbol for eyeliner

3.5 Statistical comparison

3.5.1 Statistical comparison of cadmium and lead concentration within each group

Table 2 shows the mean and median values of cadmium and lead concentrations within each group of cosmetic samples (lipstick, foundation, and eyeliner) and the mean and median concentration of each metal in all 13 cosmetic samples under investigation. In Fig. 6A–C, the concentration value of each metal in each cosmetic group is presented along with the statistical comparison of the distributions. The data shows that two out of three data sets (66.7%) were significant. The results indicate a statistically significant difference in cadmium level when comparing the three types of cosmetics,

and a statistically significant difference between cadmium and lead concentrations among all samples of the three types of cosmetics. However, the data shows no statistically significant differences in lead values among the three groups.

3.5.2 Statistical comparison between cadmium and lead concentration within each group

In Fig. 7, the concentration values of cadmium and lead in each type of cosmetic are presented along with a statistical comparison between the distributions. The data shows that three out of the four (75%) data sets are significant. The results indicate a significant difference between cadmium and lead concentrations in both the lipstick and foundation samples. Also, a significant difference was

(A)

(B)
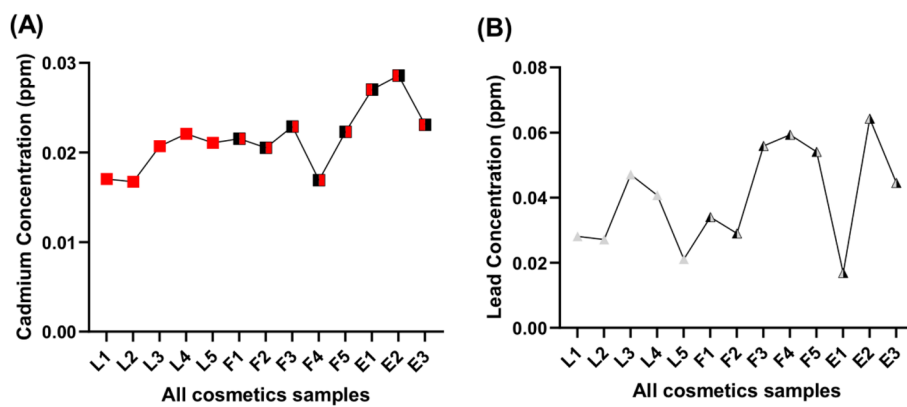
Fig. 5 Comparison between cadmium and lead concentrations in all samples. **A** Shows the concentration of cadmium in all cosmetics samples. **B** Shows the concentration of lead in all cosmetics samples. The symbols and lines represent the concentration value of cadmium and lead in each sample, which are shown on the Y-axis, while the X-axis shows the name of each sample. The cadmium values are rep-

resented as follows: Fully closed red symbol for lipstick, right-red-sided symbol for foundation, and left-red-sided symbol for eyeliner. The lead values are represented as follows: fully closed grey symbol for lipstick, right-grey-sided symbol for foundation, and left-grey-sided symbol for eyeliner

Table 2 Mean and standard deviation of cadmium and lead concentrations in the cosmetic samples

Sample	Cadmium		Lead	
	Mean (ppm)	SD	Mean (ppm)	SD
Lipstick (5 samples)	0.01	±0.00	0.03	±0.01
Foundation (5 samples)	0.02	±0.00	0.04	±0.01
Eyeliner (3 samples)	0.02	±0.00	0.04	±0.02
All cosmetics (13 samples)	0.02	±0.00	0.04	±0.01

SD standard deviation

observed between cadmium and lead when comparing the 13 data sets of the samples under investigation. However, the data shows that the values of cadmium and lead in the eyeliner group are close enough to show no significant differences between the two metals in this cosmetic type.
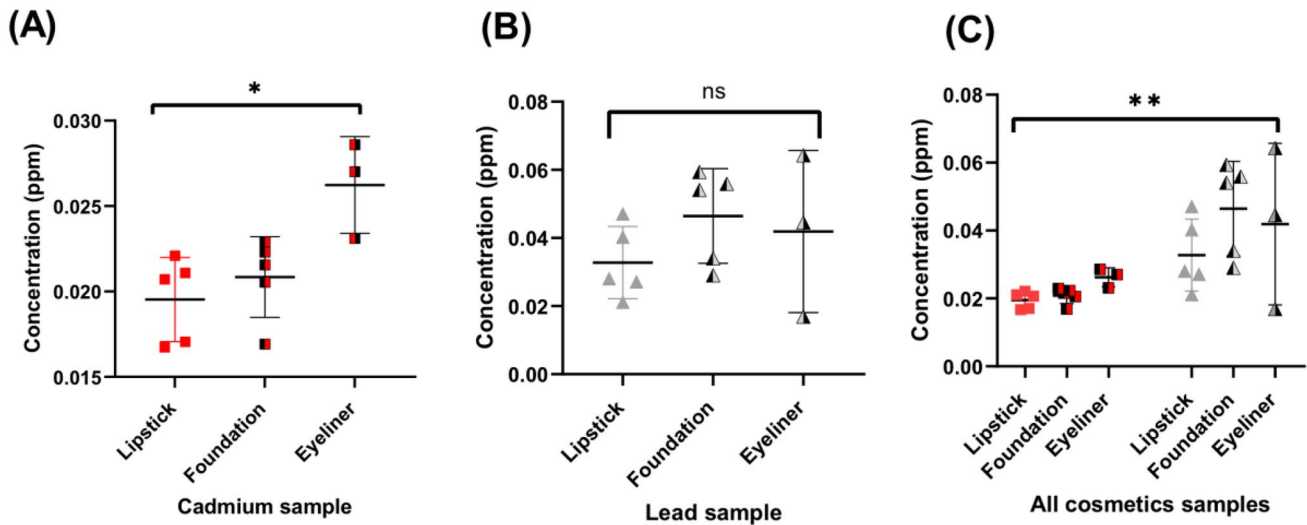
3.5.3 Statistical comparisons of cadmium and lead concentration in the samples with the allowable FDA level of each metal in cosmetics

In Fig. 8, a statistical comparison between the 13 data sets of cadmium and lead concentration with the allowable FDA values of both metals in the cosmetic samples is presented. That data shows that, in both metals, there were no significant differences between the values with a lower concentration of the heavy metals in the cosmetic samples under investigation compared with that of the FDA values.

4 Discussion

4.1 Heavy metal measurements

The concentration values of both cadmium and lead in the different types of cosmetic samples are presented in Fig. 1. The results indicate that the cadmium concentration values show a narrow range of distributions where all samples are clustered around 0.01 ppm and 0.02 ppm. This contrasts with the lead concentration values, where samples show a wider range of concentration distributions, demonstrated by the values of lead within the samples ranging from 0.01 to 0.06 ppm (Fig. 1 and Table 1). Figure 2 compares the concentration of cadmium within the samples with that of lead within the same samples. The results indicate that the cadmium concentration in almost all samples (except for sample L5) is lower than that of lead within the samples (Fig. 2). This finding was similar to a study done by Salama, who found that lead values were higher than cadmium values within cream products under investigation [22]. However, it is important to note that different skin products, different cosmetic companies, and different quality of skin products are used in this study compared to other studies. Moreover, the graphs compared the concentration values of each metal under investigation in this research to that of the allowable FDA values of the same metals within cosmetics (Fig. 1). The results showed that both metals' values were within the allowable FDA range [25]. This means that the cadmium and lead concentrations were found as trace amounts within the lower-priced cosmetic samples. This is like the Sani et al. study, where they found that a group of metals, including

Fig. 6 Statistical comparisons among cosmetic samples. **A** The statistical comparison of cadmium concentration between the three groups of cosmetic samples. **B** The statistical comparison of lead concentration between the three groups of cosmetic samples. **C** The statistical comparison between cadmium and lead concentration in each cosmetic group. The full-red square represents the cadmium lipstick sample, the full-grey triangle represents the lead lipstick sample, the right-red-sided square symbol represents the cadmium foundation sample, the right-grey-sided triangle symbol represents the lead foundation sample, the left-red-sided square symbol represents the cadmium eyeliner sample, and the left-grey-sided triangle sample represents the lead eyeliner sample. An ordinary one-way ANOVA test was used to compare the variance among the three groups. The P value was used to determine significant differences; no significant differences if the p-value > 0.05 (ns), $*P < 0.05$, $**P < 0.01$
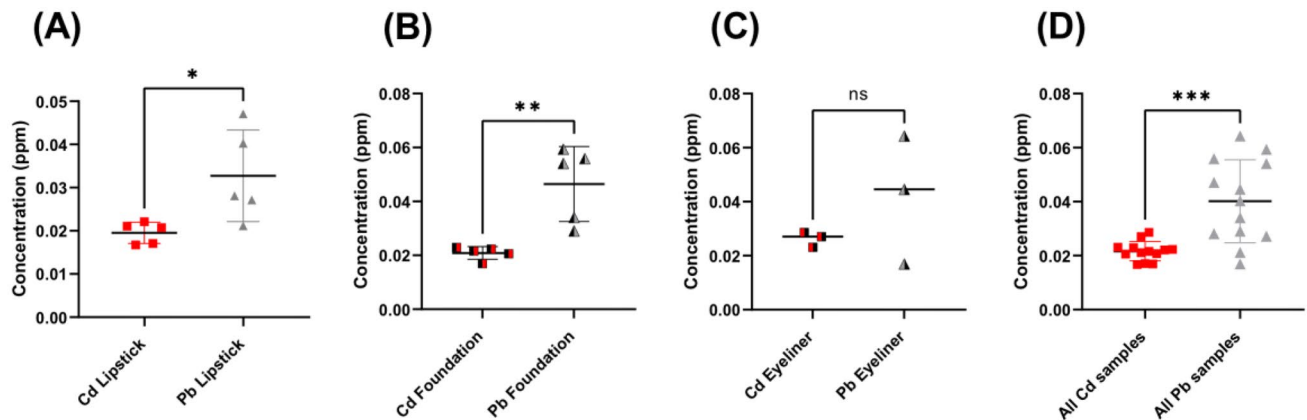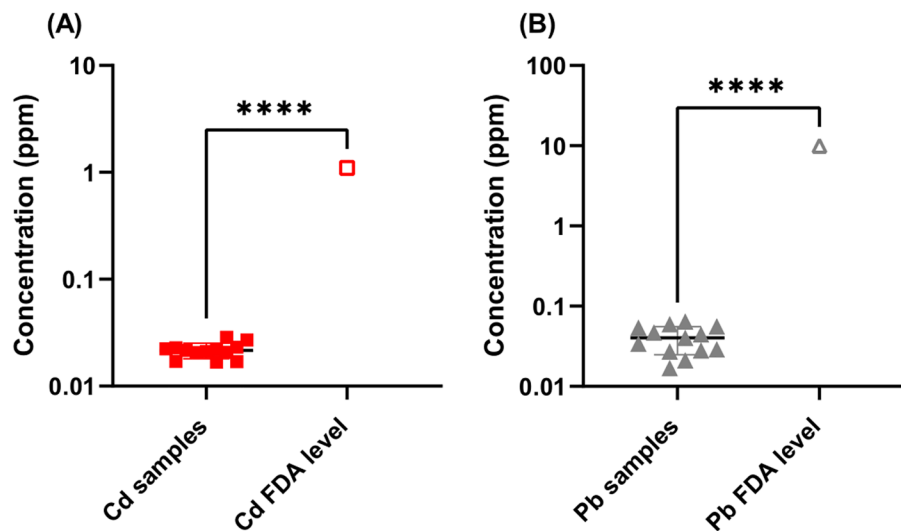

Fig. 7 Statistical comparisons among cosmetic samples. **A**, **B**, **C** Statistical comparison between cadmium and lead concentrations in lipstick sample, foundation sample, and eyeliners ample, respectively. **D** Statistical comparison between cadmium and lead concentrations in all cosmetic samples. Each symbol in the graph represents a specific metal and a specific sample (the key for each symbol was determined in Fig. 6). An unpaired t-test was used to compare the variances between the two groups. The P value was used to determine significant differences; no significant differences if the p-value > 0.05 (ns), $*P < 0.05$, $**P < 0.01$, $***P < 0.001$

nickel, manganese, cadmium, and chromium, were found to be lower in low-priced products compared to the values of the same metals in high-priced products [23]. Also, a study done in Saudi Arabia on different cosmetic products such as skin lightening and foundation, found that lead concentration in all samples was within the allowable level of the FDA values [3].

4.2 Comparisons of cadmium and lead within samples

Figures 3, 4, and 5 show the different concentrations of each metal within each sample. The results indicate different concentration values of cadmium and lead within each sample. The results also indicate that the product company affects the concentrations of both metals within the samples, where

Fig. 8 Statistical comparisons of cadmium and lead concentration in the samples with the allowable FDA level of each metal in cosmetics. **A** Comparing cadmium concentration in the test samples with the FDA level of cadmium in cosmetics. **B** Comparing lead concentration in the test samples with the FDA level of lead in cosmetics. The Red-closed square symbol represents samples, while the open represents the FDA value; the Grey-closed triangle symbol represents the lead samples, while the open represents the FDA level. An unpaired t-test was used to compare the variances between each two groups. The P value was used to determine the significant differences, ****$P < 0.001$

some samples show a high concentration of metal compared to a low concentration of the same metal within the same product type. For example, lead is indicated in a concentration value of 0.06 ppm in the eyeliner sample (E2), which is also the highest concentration of lead in all 13 samples (Fig. 4). On the other hand, the eyeliner sample (E1) shows a lead concentration value of 0.01 ppm, which is also the lowest value of lead within the 13 types of samples (Fig. 4). However, the E2 sample shows the highest concentration of both cadmium and lead in all samples under investigation (Figs. 3 and 5). This is similar to the study by Ullah et al., where the lead concentration values were found to be different between lipstick cosmetic samples from different market sites [24]. This finding is also similar to the study by Salama, who found different concentration values of lead and cadmium between different companies of soap products [22]. Moreover, a study was done to determine cadmium concentration in 30 different types of lotions and found that cadmium concentration differed from brand to brand [9]. This confirms that each company (market site) uses a different concentration of heavy metals in their products.

4.3 Statistical comparison.

Table 2 together with Figs. 6, 7, and 8 shows the statistical comparison between the cadmium content in each sample, the lead content in each sample, and the lead and cadmium contents within the samples together with a comparison to the acceptable FDA levels of each metal. The results indicate seven out of nine significant variances between the concentration values, while two out of nine results show no significant differences. The two non-significant variances were found in the lead content between the three groups of samples and in the lead and cadmium content in the eyeliner group (Figs. 6 and 7). The non-significant effect of the lead content might refer to the wide range of metal concentration distribution within the samples (Fig. 6). On the other hand, the non-significant effect between lead and cadmium content in the eyeliner sample might refer to the small size number of comparisons: three samples in the eyeliner group compared to five samples in each of the lipstick and foundation groups.

Health Canada reported that the allowable levels of heavy metals will vary according to the population of interest (children, for example, are more susceptible to heavy metal toxicity due to the hand-to-mouth activities), site of product's application (lips or hands), and the amount of product use [13, 14]. In this respect, the FDA provided acceptable levels of each heavy metal used in cosmetics products and any sample exceeding those levels will be non-acceptable. The allowable FDA level for metals used in this study was 1.1 to 2.7 ppm for cadmium [17] and not more than 10 ppm for lead [4]. In our study, all 13 samples showed a significant difference in cadmium and lead content in comparison to the acceptable FDA level for each metal (Fig. 8). This significant difference was able to show that all the samples were within the acceptable level of each metal within low-price cosmetics. Although some

metals, such as cobalt and copper, are important trace minerals for the human body, others, such as cadmium and lead, are toxic to human beings [22]. In this study, each product type and company showed different levels of each metal within the samples. Although cadmium and lead levels were found to be within the acceptable FDA values, some studies reported that, in all types of cosmetics, any amount of cadmium is prohibited as it can cause irritant dermatitis when there is significant dermal exposure [10, 13]. Also, exposure to a low level of lead (the second toxic metal after arsenic) was reported to cause behavioral abnormalities, learning impairments, and hearing problems. Heavy metals in cosmetics are controversial due to their toxic effect on the human body that comes from biological accumulation after long usage of cosmetic products [6].

Since the amount of lead and cadmium in this study and other studies [22, 24] was found to be affected by the product type and the product company, industrialists would have to check the raw material before they are introduced into the final products for the exact determination of the heavy metal amounts.

5 Conclusion

In this study, thirteen different low-price cosmetic products from different companies were analyzed to detect the presence of cadmium and lead. Humans are exposed to those two types of metals daily, as they are present in different skin care products, including cosmetics. The results showed that, in all thirteen samples, both metals were detected as trace minerals with a mean value of (0.02) for cadmium and (0.04) for lead. The results were also able to determine the concentration of each metal within the product sample and they found them to be within the acceptable FDA range. However, a continuous assessment of the presence of heavy metals in different skin products should be carried out as even a small amount may cause harmful effects to users.

Author contributions AMA: Formal analysis; investigation; methodology; provided research material; review and editing. MM: Data curation; formal analysis; methodology provided research material; review and editing. AS: investigation; methodology; analysis and interpretation of samples; review and editing. BEA: Formal analysis; data analysis; written initial and final draft of article; review and editing. AA: Provided research material; methodology; data curation; review and editing. SA: Provided research material; methodology; data curation; review and editing. GA: provided research material; methodology; data curation; review and editing. OW: Provided research material; methodology; data curation; review and editing. AA: Provided research material; methodology; data curation; review and editing. All authors have critically reviewed and approved the final draft and are responsible for the content and similarity index of the manuscript.

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