Comparative Analysis of the Heavy Metals Content in Selected Colored Cosmetic Products at Saudi Market

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INTRODUCTION

The high content levels of heavy metals in cosmetics have significant implications as these metals can penetrate the skin and be systemically absorbed. Excessive exposure to metals that impure some cosmetic products can lead to accumulation in the body and dysfunctions in vital organs. Most of the countries have banned the excessive use of metals as an active ingredient in cosmetic products and have provided permissible limits that should not be exceeded; however, metal impurities indeed still occur. The adsorption of heavy metals to the skin may increase due to the frequent use of cosmetics, unintentional swallowing of lipstick, or sweating skin covered with cosmetics.

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Therefore, this study aims to determine the heavy metal concentrations present in various cosmetic products that were selected from different brands (qualities) and available in the Saudi Market, also to analyze and compare the determined HM values relative to the reported permissible levels according to European Union (EU), World Health Organization (WHO), Canada, Germany, United States Food and Drug Administration (USFDA), and Saudi Food and Drug Administration (SFDA) Standards [summarized in Table 1].

MATERIALS AND METHODS

The method followed in this project is shown in Figure 1.

Sample collection
Thirty-five colored cosmetic samples were selected from local stores in the city of Riyadh, KSA, that were imported and locally manufactured. The samples prices were ranging from SAR 1.00 to SRA 250 per container. The samples were classified according to the price: lower class (SAR 1–SAR 35), middle class (SAR 36–SAR 85), and higher class (SAR 96–SAR 250).

Chemicals and reagents
For the sample preparation, we utilized analytical grade nitric acid (65%, Sigma Aldrich) and perchloric acid (70%–72%, Sigma Aldrich) and the mixture was prepared in a 4:1 ratio of nitric acid and perchloric acid using a hot plate inside fuming hood. To ensure dryness, the temperature was slowly increasing for 2–3 h due to exothermic nature of the oily compounds that would burn with a flame. The procedure was repeated until the evolution of white fumes suggesting the end of the digestion process and dryness. After that, solutions were allowed to cool and filtered into a calibrated flask (100 mL) using Whatman no. 42 and diluted up to the mark.

Samples preparation and analysis
The glasswares utilized were washed three times with DDD and rinsed with 5% HNO₃ solution before use for the analysis [Figure 2]. The samples were kept at 130°C for 30 min, then it raised to 200°C for 30 min, then the temperature of the muffle furnace was raised at 600°C for 6 h. After cooling, the samples were digested in aqua regia solution on a hotplate. The samples were filtered through Whatman filter paper No. 42 and transferred to a volumetric flask (100 mL) and completed up to the mark with deionized water, as shown in Figure 2. All the samples were analyzed by inductively coupled plasma–optical emission spectrometry (Perkin Elmer-Optima 7300DV). The method for the analysis of heavy metals has been optimized for a suitable analysis. The parameters were set as power, 1550 W; plasma gas, 15 L/min; auxiliary gas, 0.2 L/min; nebulizer, 0.8 L/min; and sampling rate, 0.3 mL/min. Results were analyzed for statistical significance, which is shown in tabulated form as mean ± standard deviation, and ND indicating “not detectable.”

Standard metal solutions
For each heavy metal, the calibration standards were prepared from the certified standard metals stock solution (1000 ppm-manufactured under ISO 9001 Quality Assurance System-Perkin Elmer) using a range from 0.5 to 10 ppm and prepared in double-distilled water (DDD).

Statistical analysis
The data were analyzed using Prism statistical package software, version 9 (GraphPad Software, Inc., San Diego, CA) and experiments were conducted in triplicate. Values were summarized in table format and represented as mean ± standard error of mean with ND as not detectable.

Table 1: Heavy metals analysis according to the European Union, World Health Organization, Canada, Germany, United States Food and Drug Administration, and Saudi Food and Drug Administration Standards

| International standards (PPM) | Cd | Co | Cr | Cu | Fe | Ni | Pb | Zn | AS |
|-------------------------------|----|----|----|----|----|----|----|----|----|
| EU[4]                         | P  | P  | P  | ND | ND | P  | P  | 10000 P |
| WHO[5–7]*                     | 1  | ND | ND | ND | ND | 0.2| ND | 0.01|
| Canada[8]                     | 3  | ND | ND | ND | ND | 10 | ND | 3  |
| Germany[9,10]                 | 0.1| ND | ND | ND | ND | 10 | 2  | ND | 0.5|
| USFDA[11]                     | ND | ND | 50 | ND | ND | 10 | ND | 3  |
| SFDA[12]                      | 3  | P  | P  | P  | P  | 10 | 10000 P |

*For food additives. P: Prohibited, ND: Not determined, PPM: Part per millions, EU: European Union, WHO: World Health Organization, USFDA: United States food and drug administration, SFDA: Saudi Food and Drug Administration, Cd: Cadmium, Co: Cobalt, Cr: Chromium, Cu: Copper, Fe: Iron, Ni: Nickel, Pb: Lead, Zn: Zinc, AS: Arsenic

Content mg / kg = \( \frac{\text{concentration mg L}^{-1} \times \text{Volume mL}}{\text{sample weight G}} \)

Figure 1: Study design
RESULTS AND DISCUSSION

Heavy metals analysis

The heavy metal contents for the selected metals which are Cd, Co, Cr, Cu, Fe, Ni, Pb, Zn, and As were measured and compared between cosmetics classes. The results are summarized in Tables 2 and 3 and Figure 3 and discussed in the below sections.

Cadmium (Cd)

Cd has been used as natural color in cosmetics; however, it may possess serious risks to human health such as kidney stones, pneumonitis, and loss of bone density. Our results showed that all the samples tested were free of Cd, which fit the limits of all international standards.

Cobalt (Co)

Co could have some benefits for humans, as it is considered to be a part of Vitamin B12. However, high exposure to Co has serious adverse health effects, including asthma, skin allergies, and dermatitis. Our results demonstrated that the content of cobalt in all the examined cosmetics was <3 PPM.

Chromium (Cr)

Exposure to cosmetics containing significant amounts of chromium may increase the risk of developing skin redness, swelling, allergy, and ulcer. All samples tested were below the USFDA limit.

Copper (Cu)

Chronic and sustained exposure to copper can results in liver and kidney damage, anemia, and immune toxicity. Green hair discoloration is also a well-known effect of excessive exposure to copper. There are no significant

![Figure 2](image)

**Figure 2:** Samples preparations: (a) Addition of HNO3 and H2O2, (b) application of heat, (c) samples filtration, and (d) samples are wetted

![As Level](image)

![Cd Level](image)

![Co Level](image)

![Cr Level](image)

![Cu Level](image)

![Fe Level](image)

![Zn Level](image)

![Pb Level](image)

![Ni Level](image)

**Figure 3:** Heavy Metal contents of Cd, Co, Cr, Cu, Fe, Ni, Pb, Zn, and As in Three Different Cosmetic categories products. Where, CL: Canadian limit, SFDA: Saudi FDA limit, WHO: World Health Organization limit, EUL: European limit, GL: German limit, USL: US limit
Table 2: Heavy metals analysis obtained values from inductively coupled plasma mass spectrometer in part per millions

| Sample number | Sample weight (g) | Obtained value from instruments (l) | (l) X 100 | Cd | Co | Cr | Cu | Fe | Ni | Pb | Zn | AS |
|--------------|------------------|------------------------------------|-----------|----|----|----|----|----|----|----|----|----|
| 1            | 1.1935           | 0.001                              | 0.1       | 0.1| 2.9| 197.3| 1.8| 900.4| 105.0| 0.3 | 3.5 | 2.3 |
| 2            | 1.392            | ND                                 | ND        | 0.1| 4.7| 79.3| 0.7| 1357.5| 2.5 | 93.8 | 0.8 |
| 3            | 1.392            | ND                                 | ND        | 0.0| 3.6| 23.0| 1.4| 10822.6| 1.4 | 81.9 | 0.7 |
| 4            | 1.20265          | 0.002                              | 0.2       | 0.2| 2.1| 29.8| 2.7| 1380.2| 72.1| 1.5 | 39.2 | 1.6 |
| 5            | 1.1183           | ND                                 | ND        | 0.3| 32.0| 3.0| 1484.3| 4.5 | 1.9 | 8.8 | 0.1 |
| 6            | 1.2335           | ND                                 | ND        | 0.0| 2.0| 1.2| 103.0| 1.8 | 0.2 | 3.8 | ND  |
| 7            | 0.295            | ND                                 | ND        | 0.3| 14.9| 40.3| 482.4| 10.5| 3.7 | 25.8 | ND  |
| 8            | 1.1              | ND                                 | ND        | 0.3| 0.7| 194.7| 0.5 | 46.6 | ND  |
| 9            | 1.49             | 0.019                              | 1.9       | 1.3| ND | 0.4| 1.4| 57.4| 0.3 | 7.0 | 1.5 | ND  |
| 10           | 1                | ND                                 | ND        | 0.4| 5.3| 9.9| 4310.0| 7.8 | 1.5 | 30.2 | 0.8 |
| 11           | 1.036            | ND                                 | ND        | 0.3| 3.0| 24.0| 4879.3| 1.3 | 1.9 | 451.1 | 0.4 |
| 12           | 1.0953           | ND                                 | ND        | 1.1| 11.0| 14.4| 30505.1| 3.2 | 1.4 | 42.1 | 0.4 |
| 13           | 1.3605           | ND                                 | ND        | 0.4| 19.1| 1.7| 9873.4| 9.8 | 0.6 | 4.0 | 1.9 |
| 14           | 1.0521           | ND                                 | ND        | 0.3| 20.8| 3.6| 868.4| 11.2| 3.3 | 398.4 | 0.1 |
| 15           | 1.8771           | ND                                 | ND        | 0.1| 10.1| 8.2| 1036.9| 1.5 | 0.4 | 195.1 | 0.1 |
| 16           | 1.125            | ND                                 | ND        | 0.3| 4.4| 11.9| 3944.0| 1.7 | 2.0 | 148.7 | 0.1 |
| 17           | 1.0013           | ND                                 | ND        | 0.1| 5.0| 9.4| 173.4| 2.0 | 0.8 | 29.2 | 0.1 |
| 18           | 0.6066           | ND                                 | ND        | 9.2| 140.1| 16.2| 96564.0| 43.5| 1.5 | 92.2 | 0.3 |
| 19           | 1.2486           | 0.001                              | 0.1       | 0.1| 0.2| 9.4| 21.7| 3396.8| 3.2 | 0.2 | 92.2 | 0.4 |
| 20           | 1.3375           | ND                                 | ND        | 0.1| 19.8| 6.8| 4650.3| 4.6 | 0.4 | 21.5 | 0.4 |
| 21           | 1.5278           | ND                                 | ND        | 0.3| 6.1| 25.7| 1116.8| 2.9 | 2.0 | 89.0 | 1.9 |
| 22           | 1.3482           | ND                                 | ND        | 0.1| 6.1| 18.6| 448.3| 3.3 | 0.8 | 72.2 | 1.1 |
| 24           | 1                | ND                                 | ND        | 0.2| 5.4| 12.2| 2039.0| 3.3 | 1.3 | 14.4 | 0.5 |
| 25           | 1.0924           | ND                                 | ND        | 0.7| 5.0| 19.2| 41785.6| 3.1 | 0.5 | 7166.2 | 0.4 |
| 26           | 0.9616           | ND                                 | ND        | 0.1| 13.3| 40.6| 345.6| 2.7 | 2.2 | 190.2 | 1.9 |
| 27           | 1.0713           | ND                                 | ND        | 0.2| 2.5| 3.1| 2730.0| 1.7 | 1.1 | 10.5 | 0.1 |
| 28           | 0.9811           | ND                                 | ND        | 0.4| 18.7| 4.5| 9281.7| 5.1 | 2.7 | 94.5 | 0.3 |
| 29           | 1.2              | ND                                 | ND        | 0.1| 7.8| 1.1| 5366.0| 2.7 | 0.1 | 3.6 | ND  |
| 30           | 0.96             | ND                                 | ND        | 0.6| 38.8| 9.9| 5931.1| 3.0 | 0.2 | 32.1 | ND  |
| 31           | 0.7              | ND                                 | ND        | 0.1| 3.3| 11.6| 82.3| 1.7 | 0.1 | 32.1 | ND  |
| 32           | 1.1              | ND                                 | ND        | 0.4| 2.5| 6.8| 66.8| 1.1 | 0.1 | 49.3 | ND  |
| 33           | 1.2              | ND                                 | ND        | 0.1| 6.7| 17.5| 110.3| 1.3 | 0.1 | 9.8 | ND  |
| 34           | 1.043            | ND                                 | ND        | 0.1| 10.5| 6.5| 218.1| 3.1 | 0.6 | 116.9| ND  |
| 35           | 1.26             | ND                                 | ND        | 0.4| 12.7| 6.4| 6221.6| 2.7 | 0.1 | 7.1 | ND  |

Cd: Cadmium, Co: Cobalt, Cr: Chromium, Cu: Copper, Fe: Iron, Ni: Nickel, Pb: Lead, Zn: Zinc, AS: Arsenic, ND: Not determined

Table 3: Standard deviations of the cosmetics products categories

| Metal | High price | Medium price | Low price |
|-------|------------|--------------|-----------|
| Fe    | 2148±667   | 3116±1355    | 2314±861  |
| Ni    | 3.2±0.8    | 3.7±1.0      | 3.2±0.8   |
| Pb    | 0.9±0.2    | 0.7±0.2      | 1.4±0.3   |
| Zn    | 377±9.2    | 18.9±5.2     | 167.5±40.9|
| Cu    | 8.5±2.1    | 9.5±2.2      | 14.2±3.6  |
| Cr    | 13.3±3.7   | 8.1±2.3      | 9.2±1.9   |
| Co    | 0.5±0.2    | 0.3±0.1      | 0.2±0.0   |
| As    | 0.4±0.1    | 0.6±0.2      | 0.3±0.1   |
| Cd    | 0           | 0            | 0         |

(n=8-12) and SEM. SEM: Standard error of mean, Cd: Cadmium, Co: Cobalt, Cr: Chromium, Cu: Copper, Fe: Iron, Ni: Nickel, Pb: Lead, Zn: Zinc, AS: Arsenic differences in the content of Cu between various cosmetic classes, all of which contained Cu in <30 PPM, except for one low-quality product which reached 40 PPM.

Iron (Fe)
High levels of ferrous (Fe²⁺) are associated with damage to vital body organs such as the liver and kidneys. Our results showed considerable variations in the amount of iron in different cosmetic classes. All cosmetic samples did not exceed 10000 ppm.

Nickel (Ni)
One of the harmful adverse effects of nickel is allergic reactions that primarily affect skin rash at the reaction site.\(^{[9]}\)
Ni was present in most of the samples with a relatively high amount, only two samples of the high and low classes exceeded the German limit (10 PPM), while all products of medium class did not exceed that threshold.

**Lead (Pb)**
Lead has a severe toxicological profile, it affects neurological, cardiological, and renal functions, since it is widely distributed throughout the body and affects every cell.[10] All cosmetics contain lead below 4 PPM, which is consistent with the guidelines of SFDA, USFDA, and Canada. However, only one high and few low-quality products exceeded the German limit (2 PPM).

**Zinc (Zn)**
In general, zinc is not considered to be harmful; thus, there are no international regulations that restrict the amount of zinc in cosmetics. The low-quality cosmetics showed the highest content of zinc; however, all samples demonstrated <500 PPM of zinc, which is acceptable as it is within the recommended range of EU and SFDA.

**Arsenic (As)**
Oral and inhalation exposure to arsenic can cause serious internal effects such as altered myocardial depolarization and cardiac arrhythmia.[11] All the tested samples contained arsenic in an amount lower than the standards of SFDA, USFDA, and Canada. In addition, most of the low-quality cosmetics were below the German limit (0.5 PPM). The WHO recommends that arsenic should not exceed 0.01 PPM as a food additive.[12] In cosmetics, the USFDA, SFDA, and Canada have allowed a higher limit (3 PPM).

**CONCLUSIONS**
In summary, the present study was designed to determine the contents of heavy metals in selected colored cosmetic products at the Saudi Market and compare the results with the available international standards. The study findings showed that low-quality products were containing a high amount of lead, copper, iron, and zinc, while the products of the high class were containing high amount of cobalt, chromium, and arsenic. Nickel and cadmium were found to be high in all colored cosmetic classes. Together these results provide important insights into the insignificant effect of the price on the content of heavy metals in cosmetics. Even though the most analyzed samples in this study were European brands, some of the products did not appear to comply with European standards while it follows American and Canadian regulations. Therefore, it may be necessary to reconsider the limits of heavy metals impurities in cosmetics.

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**Conflicts of interest**
There are no conflicts of interest.

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