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Analysis of Cosmetics Polluted with some Heavy Metals in Diwaniyah City, Iraq

Abtisam Jasim Abbas

Environment Department, Science College, AL-Qadisiyah University, AL-Qadisiyah, Iraq

Corresponding author's E-mail: abtisam.jasim@qu.edu.iq

Abstract

Polluted cosmetics with heavy metals have become a serious issue; consequently, researching this topic has become interesting. This study aims to determine the heavy metal content in 20 cosmetic products distributed across 4 groups (face powder, foundation, lipstick, and kohl), each group consisting of 5 types of imported products in Diwaniyah City, Iraq. An analytical test was performed for three heavy metals in cosmetic products, including lead (Pb), cadmium (Cd), and mercury (Hg), using a flame atomic absorption spectrophotometer. The overall mean concentration for each heavy metal was analyzed in the four different products as follows: 6.1620 (powder set), 5.3082 (foundation set), 9.9404 (lipstick set), and 3257.6521 (kohl set) ppm for lead; and 0.6724 (powder set), 8.2575 (foundation set), 4.2045 (lipstick set), and 4.4349 (kohl set) ppm for cadmium. Mercury was not detected in any of the four groups, except for two kohl samples (kh4 and kh5) with levels of 0.55 ± 0.01 and 0.84 ± 0.01 mg/kg, respectively, and a mean of 0.2791 ppb. The findings exhibited a wide range of heavy metal concentrations in the analyzed samples. They indicated that lead and cadmium levels within each class under investigation were relatively higher, with Pb > Cd > Hg. Also, emphasize that the spurious nature of cosmetics cannot be ignored because there is no safe limit for cosmetics in Iraq. Finally, the findings highlight the need for stricter regulatory oversight, enhanced manufacturing practices, and heightened consumer awareness to ensure the safety of cosmetic products.

Key Words: Heavy metals, Cosmetics, Lead, Contamination, Mercury, Cadmium.

1. Introduction

For many thousands of years, humans have used various cosmetic products to enhance their external form or to add beauty agents to their appearance (1,2). Owing to the immediate contact between cosmetic products and human skin, toxic elements accumulate, and then cosmetics will be a source of HMs in the body after a long time has passed (3). HMs, "which are five times denser than water", are found in all environmental spheres, such as soil, water, and air (4); they can also be found in cosmetic ingredients such as dyes (5). Several HMs are risky to human health, especially Hg, Pb, and Cd (6,7). Furthermore, when Pb, Cd, and Hg are all together, the synergistic effect among them may lead to mental dysfunction (8,9).

Worries about the broad use of cosmetics are primarily related to Pb, Cd, and Hg (10,11). Several compounds, such as water, oil, surfactant, and sometimes heavy metals, may be present in cosmetics

(12). Primarily, with the loss of strict standards, HMs may be purposefully added to cosmetics for stability and coloring; they may also contaminate products via water, raw substances, or manufacturing tools (13-16). Similarly, metallic tools used in cosmetics manufacturing may leach HMs such as Pb, Cd, Cr, etc. as impurities and then contaminate cosmetics themselves (17).

Environmental concerns are another issue with cosmetics (18). Cosmetics applied for a long time may negatively affect human health as well as effect on the aesthetic of the environment (19). For instant, high levels of dangerous Pb are found in cosmetics such as lipstick, as several studies have indicated (13,20). Lead, a neurotoxic agent, is categorized as a potential carcinogen for man (Set B2) according to the "International Agency for Research on Cancer" (IARC), which follows the World Health Organization (WHO), as well as Cd, which is an element that can cause kidney destruction and has been identified by the IARC as a carcinogenic agent to humans (set1) (21).

Also, Hg, which is absorbed by the skin and can lead to adverse effects on human health, is found in cosmetics like foundation or whitening creams and can accumulate in body organs, mainly the brain, liver, and kidneys (22-25). Cosmetics manufacturers employed Hg owing to its role in lightening skin degrees (26,27) which prevents the development of melanin, "the dye that controls skin and hair color", therefore, it is utilized in whitening products (28,29). Thus, persistent skin exposure to Hg may harm human vital organs (30).

Eventually, the use of cosmetics is facing rapid growth globally. These products may have toxic chemical compounds such as HMs, as mentioned above, which can have led to major health harms that require rapid investigation. Consequently, supporting the idea of cosmetovigilance and running initiatives to increase awareness of cosmetic goods can help diminish adverse outcomes (31). So, this study aims to detect and determine the concentrations of HMs in both low and mid-priced cosmetics in Diwaniyah City, where these products are often not subject to strict regulations. Twenty different types of cosmetics were collected from Iraqi markets, specifically in the city of Diwaniyah in central Iraq, to determine the levels of Pb, Cd, and Hg in the products under study, where these heavy metals are among the most toxic elements in cosmetics.

2. Experiential Part

2.1. Materials and Reagents

For atomic absorption spectroscopy analysis, three standard heavy metals were purchased from Merck KGaA chemicals, Certipur®, Germany: lead (Pb), cadmium (Cd), and mercury (Hg), as well as nitric acid AR (HNO_3), ALPHA Chemika, India, and perchloric acid ($HClO_4$) 70%, which was purchased from HIMEDIA, India. Also, ultrapure water (DI) was used for the preparation of heavy metal solutions in this study.

2.2. Sample Collection

Twenty different cosmetics were purchased from local markets in Al-Diwaniyah City, Iraq. Each group of cosmetics (face powder, foundation, lipstick, and kohl) includes five types of each one named (Pw_1-Pw_5), (Fo_1-Fo_5), (Lp_1-Lp_5), and (Kh_1-Kh_5), respectively. All cosmetic samples were moved to the laboratory and kept under the same conditions as in the store to discover the presence of the heavy metals.

2.3. Digestion of Samples

One gram of each sample was weighed using a precision balance. 20 mL of concentrated nitric acid (HNO_3) was added, and the sample was heated to burn the organic matter and produce red fumes. After the red fumes stopped, 10 mL of perchloric acid ($HClO_4$) was added, and digestion continued until white fumes appeared. The digested samples were allowed to cool, and then 25 mL of DI water was added. The samples' mixture was filtered via a 0.2-µm Whatman filter paper and then transferred to a 100 mL volumetric flask. The volume was brought up to 100 mL with deionized water. Analysis for each sample was then performed using an atomic absorption spectrometer (AAS) (32).

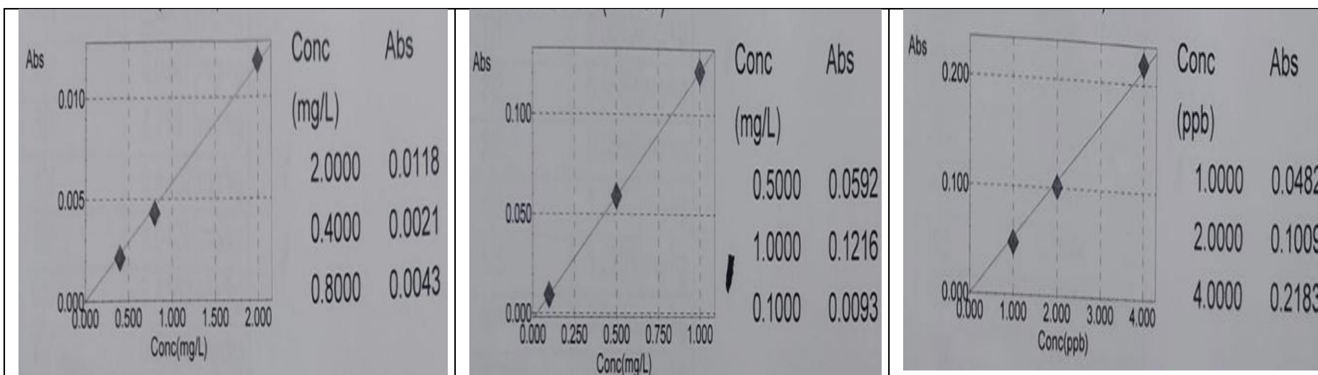
2.4. Flame-Atomic Absorption Spectrometry (F-AAS) Analysis

The lead, cadmium, and mercury amounts in cosmetic samples were measured via flame atomic absorption spectrometry (AA-7000; Version 1.01; S/N A30784800070), provided with an auto-sampler and deuterium light. In addition, a mercury vaporizer unit (MVU) was used. "(MVU) The accessory's primary function is to convert the Hg present in the sample from its liquid or complex state into an atomic Hg vapor after processing so the device can read it accurately" (33). Each test was performed in three replicates, and concentrations are presented as mean values (mg/kg). The operation settings for the AAS investigation are illustrated in **Table 1**.

Table 1. Operation settings lamp for the testing of Pb, Cd, and Hg in powder, foundation, lipstick, and kohl products.

Heavy Metal	Wavelength	Slit Width (nm)	Lamp Current Low (mA)	Lamp Mode	Flame Type
Lead (Pb)	283.3	0.7	10	BGC-D2	Air-C_2H_2
Cadmium (Cd)	228.8	0.7	8	BGC-D2	Air-C_2H_2
Mercury (Hg)	253.7	0.7	4	BGC-D2	None

The standard series for the three tested HMs (Pb, Cd, and Hg) was depicted in **Figure 1**, below:



Standard series for Pb 0.4000, 0.8000, and 2.000 ppm	Standard series for Cd 0.1000, 0.5000, and 1.000 ppm	Standard series for Hg 1.000, 2.000, and 4.000 ppb

Figure 1. illustrates the calibration curves for the HMs (Pb, Cd, and Hg)

2.5. Statistical analysis

One-sample t-tests on the triplicate data were run to check heavy metal levels. Sample averages were compared against the highest calibration standards. These test limits (μ_0) were 2.000 ppm for Pb and 1.000 ppm for Cd, with significance at $P < 0.001$, using this formula: $t = (\bar{X} - \mu_0) / (s / \sqrt{n})$, (34). Where, $\bar{X}$ is the sample mean, s is the standard deviation, and $n = 3$.

3. Results and Discussion

The current results refer to the existence of different levels of HMs (Pb, Cd, and Hg) in cosmetics under investigation, summarized in **Table 2**, which demonstrate a significant difference in HMs content among varied cosmetic types. The concentration of studied HM was tested in 20 cosmetic items, distributed across 4 categories: face powder, foundation, lipstick, and kohl. The results demonstrate that the levels of lead in face powder, foundation, lipstick, and kohl ranged between 3.22 ± 0.44 and 9.03 ± 0.10; 0.61 ± 0.10 and 12.08 ± 0.16; 3.62 ± 0.10 and 16.22 ± 0.20; and 0.61 ± 0.10 and 8770.09 ± 94.84 mg/kg, respectively. The cadmium levels for the above groups were 0.05 ± 0.00 and 1.26 ± 0.09; 0.85 ± 0.09 and 29.62 ± 0.63; 1.48 ± 0.01 and 11.91 ± 0.05; and 1.82 ± 0.01 and 7.48 ± 0.01 mg/kg, respectively.

Table 2. Shows levels of cadmium, lead, and mercury in tested cosmetic samples

Sample Origin	Sample ID	Product Type	Cadmium (ppm) Mean ± SD	Lead (ppm) Mean ± SD	Mercury (ppb) Mean ± SD
Colombia	Pw-1	Powder	0.05 ± 0.00	5.43 ± 0.01	ND
P.R.C	Pw-2	Powder	0.56 ± 0.01	9.03 ± 0.10	ND
Turkey	Pw-3	Powder	0.58 ± 0.01	4.12 ± 0.56	ND
Turkey	Pw-4	Powder	1.26 ± 0.09	8.19 ± 0.58	ND
U.S.A	Pw-5	Powder	1.23 ± 0.01	3.22 ± 0.44	ND
Korea	Fo-1	Foundation	6.57 ± 0.02	8.11 ± 0.49	ND
Poland	Fo-2	Foundation	0.85 ± 0.09	0.61 ± 0.10	ND
China	Fo-3	Foundation	4.70 ± 0.06	2.12 ± 0.42	ND
U.K	Fo-4	Foundation	29.62 ± 0.63	12.08 ± 0.16	ND
Italy	Fo-5	Foundation	1.12 ± 0.00	2.32 ± 0.09	ND
England	Lp-1	Lipstick	2.59 ± 0.10	3.62 ± 0.10	ND
U.S.A	Lp-2	Lipstick	11.91 ± 0.05	14.36 ± 0.10	ND
Taiwan	Lp-3	Lipstick	1.48 ± 0.01	3.62 ± 0.10	ND
China	Lp-4	Lipstick	1.92 ± 0.01	16.22 ± 0.20	ND
Germany	Lp-5	Lipstick	2.62 ± 0.01	10.76 ± 0.10	ND
China	Kh-1	Kohl	4.17 ± 0.01	0.61 ± 0.10	ND
EU	Kh-2	Kohl	1.82 ± 0.01	21.09 ± 0.19	ND
India	Kh-3	Kohl	7.48 ± 0.01	9.04 ± 0.11	ND
K.S.A	Kh-4	Kohl	3.19 ± 0.01	7358.46 ± 57.57	0.55 ± 0.01
Pakistan	Kh-5	Kohl	5.41 ± 0.01	8770.09 ± 94.84	0.84 ± 0.01

-Lp (lipstick), Pw (powder), Fo (foundation), and Kh (kohl), ND: not detected, Values are Mean ± SD (n=3).

And the mean value for each metal in the four different products was as follows: 6.1620 (Powder set), 5.3082 (foundation set), 9.9404 (lipstick set), and 3257.6521 (kohl set) ppm for Pb; and 0.6724

(Powder set), 8.2575 (foundation set), 4.2045 (lipstick set), and 4.4349 (kohl set) ppm for Cd, Hg was not detected in any of the four groups, except for two kohl samples (kh4 and kh5) with a mean of 0.2791 ppb as depicted in the **Table 4**.

Table 4. Descriptive statistical test of Pb, Cd, and Hg in four cosmetic groups

Samples (5n)	Pb Mean	Pb Min- Max value	Cd Mean	Cd Min-Max value	Hg Mean	Hg Min-Max value
Powder/ pw	6.1620	2.9236 - 9.1198	0.6724	0.0510 - 1.3461	ND	ND - ND
Foundation/Po	5.3082	0.5217 - 12.2543	8.2575	0.7554 - 29.9800	ND	ND - ND
Lipstick/Lp	9.9404	3.5164 - 16.3786	4.2045	1.4727 - 11.9671	ND	ND - ND
Kohl/ Kh	3257.6521	0.5127 - 8855.4300	4.4349	1.8080 - 7.4940	0.2791	ND - 0.8457

For face powder, variants in Pb and Cd concentrations were detected, whereas Hg was not found in any of them. The samples Pw2 which record (9.03 ± 0.10 ppm) and Pw4 record (8.19 ± 0.58 ppm), especially, displayed somewhat elevated Pb levels paralleled by the residual cosmetics items, owing to dissimilarities in raw constituents or manufacturing applications among products (35). Many previous studies have reported a high level of Pb in cosmetic powder products (36-39), which agree with the current outcomes.

Foundation types displayed noticeable differences in HM content. Fo4 showed a distinctly high Cd concentration (29.62 ± 0.63 ppm) compared with the other foundation types. Also, Pb levels varied across samples, and the highest level was found also in Fo4 (12.08 ± 0.16 ppm), while Hg wasn't existing in all foundation types. Possible sources of HMs contamination in different cosmetics such as foundations and face powders can cause from mineral-based dyes or clay extracts (35).

In addition, significant variances in Pb and Cd concentrations were discovered among lipstick types. Where samples (Lp2 & Lp4) had remarkably greater Pb levels compared to other types and record (14.36 ± 0.10 and 16.22 ± 0.20 ppm) respectively, however Cd levels moderately diverged accept the sample Lp2 which record (11.91 ± 0.05 ppm). Hg wasn't present in any sample of lipstick. Consequently, the levels of Pb and Cd in Rouge extended from 3.62 ± 0.10 to 16.22 ± 0.20 mg/kg and 1.48 ± 0.01 to 11.91 ± 0.05 mg/kg, respectively, which indicate to a significant variance of HMs content of different types of lipsticks that in line with (40).

Generally, Hg was not detected in most makeup items, except for kohl, which contained trace amounts of Hg (0.55 ppb and 0.84 ppb, respectively), along with high Pb concentrations 7358.46 ± 57.57 ppm for kh4 and 8770.09 ± 94.84 ppm for kh5, whereas other kohl samples exhibited substantially lower concentrations for both Pb and Cd metals. These findings indicate that certain kohl formulations may pose a higher potential health risk. Moreover, the current result was in line with (41), who investigated heavy metals' content in cosmetics such as khol/surma, foundations, and lipstick, finding high levels of Pb, especially in kohl products, as well as highlighting the crucial demand for continuous monitoring and providing strict protocols and instructions for cosmetic safety to avoid contamination with HMs. Moreover, Pb and Cd were detected in all tested products. The kohl set showed elevated Pb concentrations, while the foundation set revealed particular sensitivity to Cd contamination. The concentration of these heavy metals is beyond the safe limit and reaches several hundred μg/g and occasionally may be several mg/g or even more than the recommended level (42), as illustrated in Table 3. The maximum allowable limits of HMs in cosmetic differ across the world. For example, Health Canada, has fixed the maximum acceptable limit for Cd in make-up by 3 mg/kg whereas in Germany as well as Italy, the recommended limit is 5 mg/kg (43,44). Table 3. illustrates the permissible limit coined by some international organizations.

Table 3. Shows the global standard rules of the maximum HMs content (mg/Kg) for Pb, Cd, and Hg.

Sample	Available standards	Pb (ppm)	Cd (ppm)	Hg (ppm)	Reference
Cosmetics	*USFDA	20	3	1	(45,46,41)
	**WHO	2	1	3	
	Canada	10	3	1	
	Germany	0.5	0.1	0.1	

*USFDA "United States Food and Drug Administration", **WHO "World Health Organization".

3.1. Comparison of Cd level in each product

Figure 2.a shows the trend in Cd concentration within the 4 make-up items sets by a line chart. The outcomes display that the Cd concentration in the powder set (pw) is comparatively low and steady (averaging 0.74 ppm), whereas the foundation sets (Fo) show noteworthy variability owing to a sharp peak in sample Fo4. The highest Cd concentration was recorded in Fo4 (29.62 ppm), followed by Lp2 (11.91 ppm). These values considerably surpass the reference limit of 1 ppm, which is frequently cited in safety rules (47-49). In the make-up products manufacturing, Cd is seldom added to cosmetics as an intentional constituent; alternatively, industrial impurities like Cd may occur from mineral dyes or pigments, for instance, FeO2, ZnO, mica, etc. (50).

3.2. Comparing Pb level in Each Sample

Figure 2. b describes the trend in Pb levels in cosmetics using a logarithmic line diagram, accounting for outliers. The kohl (Kh) items show a sharp increasing trend, with levels considerably greater than those of the other cosmetics sets. The highest levels were recorded in Kh5 (8770.09 ppm) and Kh4 (7358.46 ppm). This indicates that kohl products probably have galena (Pb S_2) as a key component, posing a serious risk of Pb toxicity (51,52). Amongst typical cosmetics, Lp4 revealed the maximum level at (16.22 ppm), surpassing the FDA guideline limit of (10 ppm) (53,54).

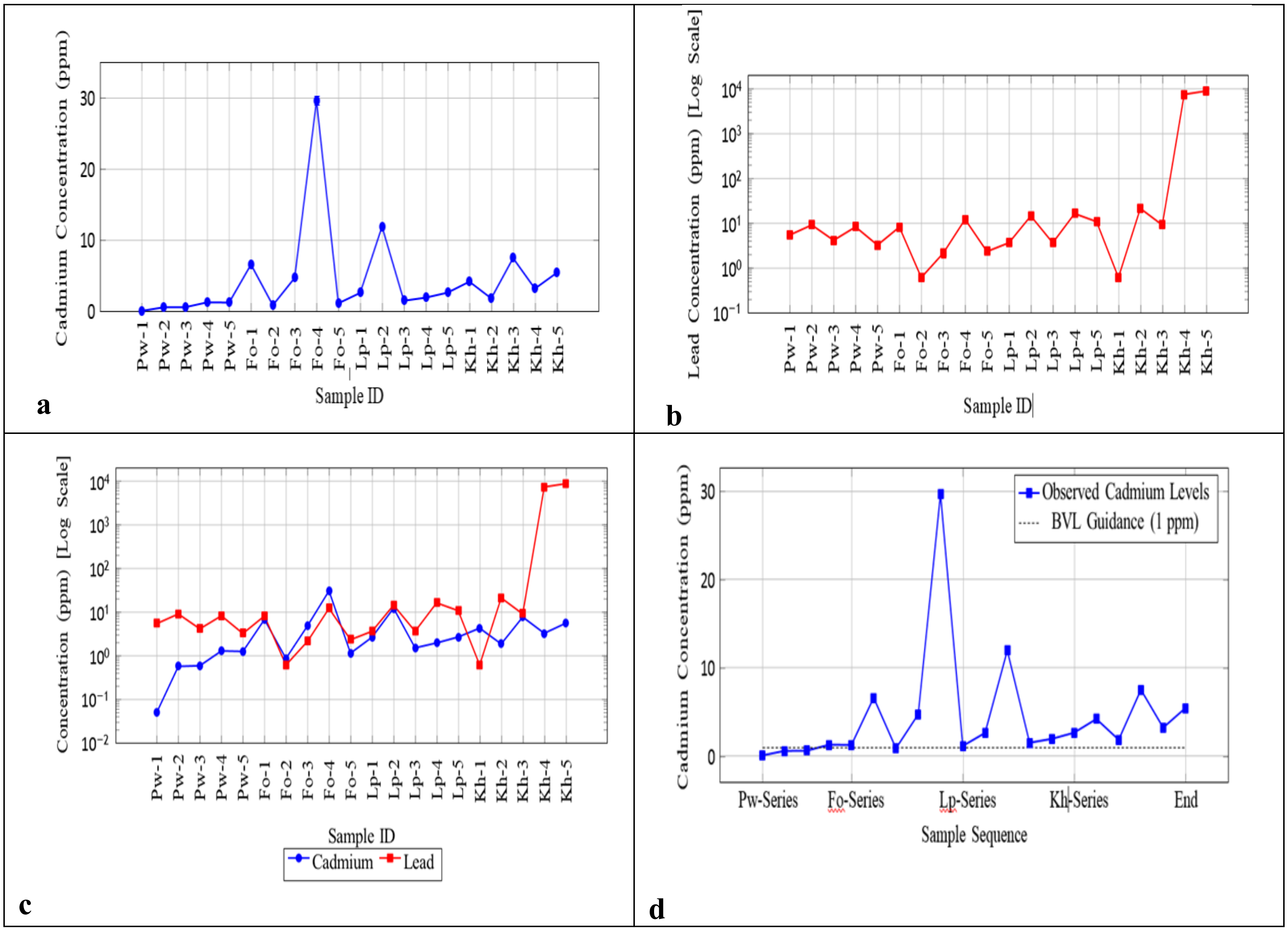
3.3. Comparison between Cd and Pb Concentrations in all cosmetic

The Comparison of the two metals (Pb and Cd) shows that kohl (Kh) is the key source of Pb exposure, whereas foundation (Fo) and lipstick (Lp) are the key sources of Cd exposure, which is agree with (55), who report that high levels of Cd have been recorded in lipsticks and foundation and also found high concentrations of Pb and other metals in foundations owing to the use of dyes and fillers in cosmetic formulations as a type of contamination and filler features. As illustrated in **Figure 2. c**, the Pb and Cd concentration curves differ significantly. However, Pb levels are uppermost in the kohl group, and Cd levels peak in the foundation set. Sample Fo4 is a distinguished point of meeting where both curves rise sharply, demonstrating binary contamination.

Pb was usually used in cosmetics, for instance, rouges, eyeliners, kohl or kajal, etc., along with the U.S. Food and Drug Administration, which fixed a maximum limit of 10-20 ppm for Pb as a colorant in cosmetics (56), current results found that Pb levels near to the levels established by the FDA, except in kohl samples (kh4 and kh5) and foundation (Fo4) that achieved many folds, which indicates a real risk for human health. Also, (57), who found that Pb level in traditional kohl samples whether paste or powder have surpassed that permissible levels.

3.4. Analysis of Cd Contamination Trends

Unlike Pb, which displayed highly abnormal values in the kohl set, Cd contamination was more noticeable in the foundation (Fo) and lipstick (Lp) sets. Figure 2.d, illustrates the Cd levels in the dataset. The trend line represents a baseline impurity level of nearly 1-2 ppm for most cosmetics, which relates to the unavoidable tiny quantities of impurities in mineral soil dyes and pigments (58). Nevertheless, some unexpected spikes disorder this baseline. The Fo4 Sample (foundation) recorded an average concentration of 29.62 ppm, a value approximately 30 times higher than the permissible limit of 1 ppm proposed by the German Federal Office for Consumer Protection and Food Safety (47). Likewise, sample Lp2 (lipstick) reached 11.91 ppm, which is in line with (59), who stated that the mean Cd level in cosmetic was highest in lipstick, eye pencil (kohl), cream, and powder, and the maximum Cd level was in the lipstick which records up to 403 µg/g that is surpass the Germany limits (5 µg/g) and Canada limits (3 µg/g) for Cd pollution in cosmetics. Also, (60) notice that the level of Cd in the experienced lipsticks extended from 4.08 to 60.20 µg/g. These abnormal values indicate the use of specific batches of highly contaminated dyes-likely yellow, red, or orange dyes derived from cadmium sulfide or cadmium selenide, which are sometimes used illegally to enhance color vibrancy (61).



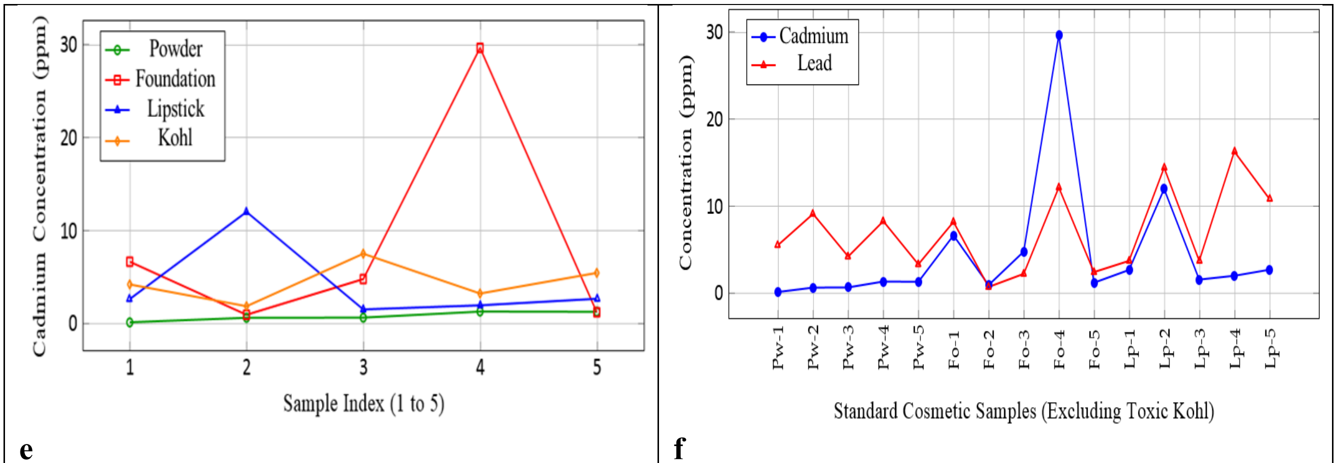


Figure 2. a) Line plot of Cd concentrations in the 4 cosmetic sets, **b)** Line plot of Pb levels across the 4 cosmetic sets, **c)** Comparative line plot of Cd and Pb levels, **d)** Line plot of Cd levels (the particular spikes in the foundation (Fo-series) and lipstick (Lp-series) regions, paradoxically with the stable low levels in powders(Pw), **e)** Comparative line plot presenting intra-group variability. The constancy of the green line (Pw) difference sharply with the instability of the red one (Fo), **f)** Comparative line plot of Pb vs. Cd, the dual spike at Fo4 versus the single Pb spike at Lp4, representing varied contamination sources.

3.5. Intra-group Variation Comparisons

To elucidate the consistency of industrial quality in all cosmetics categories, **Figure 2.e** shows a comparative line plot, where each line represents the Cd behavior across a particular product set within the 5 subgroup samples. This graph highlights a crucial finding: powders (Pw) show a straight line, indicating consistent and high-purity manufacturing. In contrast, foundations (Fo) and lipsticks (Lp) display wavy and fluctuating lines. This fluctuation proposes poor quality control, as one item (Fo4) may be highly toxic while another item of the same category (Fo2) is relatively safe. The high Cd content in Fo4 and Lp2 specifically indicates that liquid and wax foundations may be using lower-quality mineral fillers compared to loose powders (62).

3.6. Comparative Variance of Pb and Cd Concentrations

Lastly, the relationship between Pb and Cd was analyzed to determine whether the contamination was related (i.e., caused by a single source of contamination). **Figure 2.f** shows the concentrations of both metals in untreated lipstick samples (to avoid axis deviation). The graph shows a clear discrepancy, in the sample Fo4, both the Pb and Cd lines rise sharply simultaneously, indicating a highly contaminated raw material source affecting both indicators. Nevertheless, in sample Lp4, the Pb line rises significantly which is constituent with (63), who stated that Pb levels in numerous lipstick products near or surpassed the FDA edge of 10 mg/kg, representing possible neurotoxic illness, while the Cd line remains stable. This separation suggests that the Pb contamination of the lipstick is likely due to specific colorants such as, Red 7, Red 34, or different additives that do not contain Cd impurities (64).

4. Conclusions

In this study, 20 cosmetics, including face powder, foundations, lipsticks, and kohl, were examined to detect the HMs' contamination with three hazardous metals (lead, cadmium, and mercury). Spiked cosmetics products were investigated via Flame - AAS. Mercury levels determined by the vaporizer unit (MVU). The results demonstrate a high level of Pb and Cd content of face powder, foundation, lipstick, and Kohl products. Mercury was not detected in any of the four groups, except for two kohl samples (kh4 and kh5) with levels of 0.55 ± 0.01 and 0.84 ± 0.01 mg/kg, respectively. The highest level of Pb was found in kohl samples and the order of Pb levels in all samples was kohl > lip sticks > powder > foundation. Where, the maximum level of Cd was found in foundation types and the order of Cd in all products was foundation > lipsticks > kohl > powder. In conclusion, people should be aware of what they apply to their faces, as the skin can absorb these substances and eventually allow them to enter the bloodstream, leading to serious illness issues. Furthermore, authorities should monitor and check all types of imported cosmetics, especially those that are illegally imported. Finally, mitigation of HM concentration should be achieved through reliable, safe raw material sets and a suitable manufacturing process. Unfortunately, there was no scientific data on the real content of the HMs, primarily the unsafe ones, on each container leaflet or label.

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References

1- Brown, V. J. (2013). Metals in lip products-a cause for concern?. Environmental health perspectives, 121(6), a196.

2- McMullen, R. L., & Dell'Acqua, G. (2023). History of natural ingredients in cosmetics. Cosmetics, 10(3), 71.

3- Saadatzadeh, A., Afzalan, S., Zadehdabagh, R., Tishezan, L., Najafi, N., Seyedtabib, M., & Noori, S. M. A. (2019). Determination of heavy metals (lead, cadmium, arsenic, and mercury) in authorized and unauthorized cosmetics. Cutaneous and ocular toxicology, 38(3), 207-211.

4- Duruibe, J. O., Ogwuegbu, M. O. C., & Egwurugwu, J. N. (2007). Heavy metal pollution and human biotoxic effects. International Journal of physical sciences, 2(5), 112-118.

5- Lim, D. S., Roh, T. H., Kim, M. K., Kwon, Y. C., Choi, S. M., Kwack, S. J., ... & Lee, B. M. (2018). Non-cancer, cancer, and dermal sensitization risk assessment of heavy metals in cosmetics. Journal of Toxicology and Environmental Health, Part A, 81(11), 432-452.

6- Ullah, A. A., Maksud, M. A., Khan, S. R., Lutfa, L. N., & Quraishi, S. B. (2017a). Dietary intake of heavy metals from eight highly consumed species of cultured fish and possible human health risk implications in Bangladesh. Toxicology reports, 4, 574-579.

7- Kicińska, A., & Wysowska, E. (2021). Health risk related to the presence of metals in drinking water from different types of sources. Water and Environment Journal, 35(1), 27-40.

8- Fu, Z., Xu, X., Cao, L., Xiang, Q., Gao, Q., Duan, H., ... & Yang, X. (2024). Single and joint exposure of Pb, Cd, Hg, Se, Cu, and Zn were associated with cognitive function of older adults. Scientific Reports, 14(1), 28567.

9- Du, G., Ouyang, L., Yang, S., Li, Q., Li, J., Zhuang, X., ... & Fan, G. (2026). Cognitive behavioral dysregulation induced by low-level lead, cadmium, and mercury co-exposure is linked to AMPA receptor-associated with E/I imbalance. Ecotoxicology and Environmental Safety, 313, 119988.

10- Cao, H., Chen, J., Zhang, J., Zhang, H., Qiao, L., & Men, Y. (2010). Heavy metals in rice and garden vegetables and their potential health risks to inhabitants in the vicinity of an industrial zone in Jiangsu, China. Journal of environmental sciences, 22(11), 1792-1799.

11- Mohiuddin, A. K. (2019). Heavy metals in cosmetics: the notorious daredevils and burning health issues. Am. J. Biomed. Sci. Res, 4(5), 333-337.

12- Halla, N., Fernandes, I. P., Heleno, S. A., Costa, P., Boucherit-Otmani, Z., Boucherit, K., ... & Barreiro, M. F. (2018). Cosmetics preservation: a review on present strategies. Molecules, 23(7), 1571. https://doi.org/10.3390/molecules23071571.

13- Kaličanin, B., & Velimirović, D. (2016). A study of the possible harmful effects of cosmetic beauty products on human health. Biological trace element research, 170(2), 476-484.

14- Ababneh, F. A., & Al-Momani, I. F. (2018). Assessments of toxic heavy metals contamination in cosmetic products. Environmental Forensics, 19(2), 134-142.

15- Munir, A., Hayyat, M. U., Shahzad, L., Sharif, F., Farhan, M., & Ghafoor, G. Z. (2020). Assessment of heavy metals concentrations in commercially available lipsticks in Pakistan. Environmental forensics, 21(3-4), 259-266.

16- Abdulkareem, E. A., Abdulsattar, J. O., & Abdulsattar, B. O. (2022). Iron (II) determination in lipstick samples using spectrophotometric and microfluidic paper-based analytical device (μPADs) platform via complexation reaction with iron chelator 1, 10-phenanthroline: A comparative study. Baghdad Science Journal, 19(2), 0355-0355.

17- Usman, U. L., Danhauwa, S. A., Sajad, S., & Banerjee, S. (2021, June). Assessment of heavy metal in some commonly used cosmetic product and associated health risk in Nigeria: threat to public health. In Macromolecular Symposia (Vol. 397, No. 1, p. 2100161).

18- Bilal, M., Mehmood, S., & Iqbal, H. M. (2020). The beast of beauty: environmental and health concerns of toxic components in cosmetics. Cosmetics, 7(1), 13.

19- Wirtu, Y. D. (2024). A review of environmental and health effects of synthetic cosmetics. Frontiers in Environmental Science, 12, 1402893.

20- Łodyga-Chruścińska, E., Sykuła, A., & Więdłocha, M. (2018). Hidden metals in several brands of lipstick and face powder present on polish market. Cosmetics, 5(4), 57.

21- Kim, T. H., Kim, J. H., Le Kim, M. D., Suh, W. D., Kim, J. E., Yeon, H. J., ... & Jo, G. H. (2020). Exposure assessment and safe intake guidelines for heavy metals in consumed fishery products in the Republic of Korea. Environmental Science and Pollution Research, 27(26), 33042-33051.

22- Alam, M. F., Akhter, M., Mazumder, B., Ferdous, A., Hossain, M. D., Dafader, N. C., ... & Atique Ullah, A. K. M. (2019). Assessment of some heavy metals in selected cosmetics commonly used in Bangladesh and human health risk. Journal of Analytical Science and Technology, 10(1), 1-8.

23- Arshad, H., Mehmood, M. Z., Shah, M. H., & Abbasi, A. M. (2020). Evaluation of heavy metals in cosmetic products and their health risk assessment. Saudi pharmaceutical journal, 28(7), 779-790.

24- Qudus, H. I., Purwadi, P., Holilah, I., & Hadi, S. (2021). Analysis of mercury in skin lightening cream by microwave plasma atomic emission spectroscopy (MP-AES). Molecules, 26(11), 3130.

25- Bastiansz, A., Ewald, J., Saldaña, V. R., Santa-Rios, A., & Basu, N. (2022). A systematic review of mercury exposures from skin-lightening products. Environmental health perspectives, 130(11), 116002.

26- Ramli, F. F. (2021). Clinical management of chronic mercury intoxication secondary to skin lightening products: A proposed algorithm. Bosnian Journal of Basic Medical Sciences, 21(3), 261.

27- Bamidele, O. D., Kayode, B. A., Eniayewu, O. I., Adegbola, A. J., Olatoye, R. S., Njinga, N. S., ... & Bakare-Odunola, M. T. (2023). Quality assessment of hydroquinone, mercury, and arsenic in skin-lightening cosmetics marketed in Ilorin, Nigeria. Scientific Reports, 13(1), 20992.

28- Agrawal, S. S., & Sharma, P. (2017). Current status of mercury level in skin whitening creams. Current Medicine Research and Practice, 7(2), 47-50.

29- Juliano, C. C. (2022). Spreading of dangerous skin-lightening products as a result of colourism: a review. Applied Sciences, 12(6), 3177.

30- Balali-Mood, M., Naseri, K., Tahergorabi, Z., Khazdair, M. R., & Sadeghi, M. (2021). Toxic mechanisms of five heavy metals: mercury, lead, chromium, cadmium, and arsenic. Frontiers in pharmacology, 12, 643972.

31- Bilal, A. I., Tilahun, Z., Osman, E. D., Mulugeta, A., Shekabdulahi, M., & Berhe, D. F. (2017). Cosmetics use-related adverse events and determinants among Jigjiga town residents, Eastern Ethiopia. Dermatology and therapy, 7(1), 143-153.

32- Adepoju-Bello, A. A., Oguntibeju, O. O., Adebisi, R. A., Okpala, N., & Coker, H. A. (2012). Evaluation of the concentration of toxic metals in cosmetic products in Nigeria.

33- Ohga, K., Kurauchi, Y., & Yanase, H. (1987). Adsorption of Cu2+ or Hg2+ ion on resins prepared by crosslinking metal-complexed chitosans. Bulletin of the Chemical Society of Japan, 60(1), 444-446.

34- Moore, D. S., McCabe, G. P., & Craig, B. A. (2009). Introduction to the Practice of Statistics (Vol. 4, p. 641). New York: WH Freeman.

35- Ahmed, M., Ahmad, M., Sohail, A., Sanaullah, M., Saeed, A., Qamar, S., ... & Khalid, K. (2024). Multivariate statistical analysis of cosmetics due to potentially toxic/heavy metal (loid) contamination: Source identification for sustainability and human health risk assessment. Sustainability, 16(14), 6127.

36- Al-Qutob, M. A., Alatrash, H. M., & Abol-Ola, S. (2013). Determination of different heavy metals concentrations in cosmetics purchased from the Palestinian markets by ICP/MS.

37- Iwegbue, C. M., Bassey, F. I., Obi, G., Tesi, G. O., & Martincigh, B. S. (2016). Concentrations and exposure risks of some metals in facial cosmetics in Nigeria. Toxicology reports, 3, 464-472.

38- Issa, S. Y. I., Maguid, R. A., & Al Mazroua, M. K. (2016). Determination of toxic contents and metals in different cosmetic products in the Arabian market. Journal of Environmental and Analytical Toxicology, 6(3), 120-125.

39- Eticha, T., Getachew, H., Kahsay, G., & Gebretsadik, H. (2018). Metals contamination in face powders and their associated health risks to the users in mekelle, Ethiopia. J. Environ. & Anal. Toxicol, 8(01), 2161-0525.

40- Zakaria, A., & Ho, Y. B. (2015). Heavy metals contamination in lipsticks and their associated health risks to lipstick consumers. Regulatory toxicology and pharmacology, 73(1), 191-195.

41- Bashir, H., Ibrahim, A. B., Ullah, H., Anwar, S., Rehman, T. U., Gul, Z., ... & Habib, M. A. (2025). Heavy metal in cosmetics and its risk to future generation in remote area of Azad Jammu and Kashmir Trarkhel District Sudhnoti. Scientific Reports, 15(1), 43847.

42- Ullah, H., Aslam, S., Mustafa, G., Waseem, A., de Freitas Marques, M. B., Gul, Z., ... & Ibrahim, M. (2024). Potential toxicity of heavy metals in cosmetics: fake or fact: a review. International Journal of Environmental Analytical Chemistry, 104(20), 8878-8909.

43- Health Canada. (2012). Guidance on heavy metal impurities in cosmetics. Health Canada-Santé Canada.

44- Marinovich, M., Boraso, M. S., Testai, E., & Galli, C. L. (2014). Metals in cosmetics: An a posteriori safety evaluation. Regulatory Toxicology and Pharmacology, 69(3), 416-424.

45- Ullah, H., Noreen, S., Rehman, A., Waseem, A., Zubair, S., Adnan, M., & Ahmad, I. (2017b). Comparative study of heavy metals content in cosmetic products of different countries marketed in Khyber Pakhtunkhwa, Pakistan. Arabian Journal of Chemistry, 10(1), 10-18.

46- Sharma, A., Kulshrestha, S., Goel, A., & Singh, S. V. (2021). An insight into chemicals toxicity in cosmetics and their Health-Related perceptions. Annals of the Romanian Society for Cell Biology, 25(3), 1773-1794.

47- Federal Office of Consumer Protection and Food Safety (BVL). Heavy metals in cosmetics. Journal of Consumer Protection and Food Safety, 5(1):123–125, 2010.

48- Balwierz, R., Biernat, P., Jasińska-Balwierz, A., Siodłak, D., Kusakiewicz-Dawid, A., Kurek-Górecka, A., ... & Ochędzan-Siodłak, W. (2023). Potential carcinogens in makeup cosmetics. International journal of environmental research and public health, 20(6), 4780.

49- Serb, A. F., Georgescu, M., Onulov, R., Novaconi, C. R., Sisu, E., Bolocan, A., & Sandu, R. E. (2024). Mass-spectrometry-based research of cosmetic ingredients. Molecules, 29(6), 1336.

50- Shah, P., Gandhi, J., Kansara, Y., Barve, K., & Gupta, S. (2021). Leveraging nanotechnology in cosmeceuticals: Formulation, characterisation, regulatory status and toxicity. In Nanocarriers: drug delivery system: an evidence based approach (pp. 411-456). Singapore: Springer Singapore.

51- Daar, E., Alsubaie, A., Almugren, K. S., Barnes, S., Alanazi, A., Alyahyawi, A., ... & Bradley, D. A. (2017). X-ray fluorescence analysis of Pb, Fe and Zn in kohl. Results in physics, 7, 3590-3595.

52- Filella, M., Martignier, A., & Turner, A. (2020). Kohl containing lead (and other toxic elements) is widely available in Europe. Environmental research, 187, 109658.

53- US Food and Drug Administration, & US Food and Drug Administration. (2016). Limiting lead in lipstick and other cosmetics. Retrieved March, 12, 2017.

54- de Figueiredo, D. (2019). Risk Assessment of Heavy Metals in Lipsticks (Master's thesis, Universidade de Lisboa (Portugal)).

55- Ligate, F. J., & Ntarisa, A. V. (2026). A review of heavy metals research in Tanzania (2000–2024). Discover Environment, 4(1), 210.

56- Naqvi, S. A. R., Idrees, F., Sherazi, T. A., Hassan, S. U., & Ishfaq, N. (2022). Toxicology associated with heavy metals found in cosmetics. Journal of the Chilean Chemical Society, 67(3), 5615-5622.

57- Sharif, A. A., Ahmed, S. E., Uhaydah, M. M., Ammar, I. A., & Abdalsamed, I. A. (2025). Estimation of heavy metals (Pb, Cd, Zn) in raw, commercial and traditional Eye-khol samples sold in Libya. Libyan Journal of Medical and Applied Sciences, 158-166.

58- Jităreanu, A., Trifan, A., Caba, I. C., Mârțu, I., & Agoroaei, L. (2025). An overview of heavy metals in cosmetic products and their toxicological impact. Applied Sciences, 15(24), 12883.

59- Ghaderpoori, M., Kamarehie, B., Jafari, A., Alinejad, A. A., Hashempour, Y., Saghi, M. H., ... & Ferrante, M. (2020). Health risk assessment of heavy metals in cosmetic products sold in Iran: the Monte Carlo simulation. Environmental Science and Pollution Research, 27(7), 7588-7595.

60- Nourmoradi, H., Foroghi, M., Farhadkhani, M., & Vahid Dastjerdi, M. (2013). Assessment of lead and cadmium levels in frequently used cosmetic products in Iran. Journal of environmental and public health, 2013(1), 962727.

61- Sainio, E. L., Jolanki, R., Hakala, E., & Kanerva, L. (2000). Metals and arsenic in eye shadows. Contact dermatitis, 42(1), 5-10.

62- Gyamfi, O., Aboko, J., Ankapong, E., Marfo, J. T., Awuah-Boateng, N. Y., Sarpong, K., & Dartey, E. (2024). A systematic review of heavy metals contamination in cosmetics. Cutaneous and oCular toxiCology, 43(1), 5-12.

63- Saah, S. A., Boadi, N. O., Sakyi, P. O., & Smith, E. Q. (2024). Human health risks of lead, cadmium, and other heavy metals in lipsticks. Heliyon, 10(23).

64- Piccinini, P., Pakalin, S., Contor, L., Bianchi, I., & Senaldi, C. (2016). Safety of tattoos and permanent make-up: Final report. EUR27947, 10.